Macraes Phase 4 Project

Air Quality Assessment

Prepared for: OceanaGold (New Zealand Limited)

Prepared by: Tonkin & Taylor Ltd

Job Number: 1101342 v0

Date: Aug 2026

Document control and review

Title: Macraes Phase 4 Project - Air Quality Assessment					
Date	**Version**	**Description**	**Prepared by**	**Reviewed by**	**Authorised by**
Aug 2026	Rev 0	Final	R Chilton	J Simpson	J Simpson

Table of contents

Executive summary **i**

1 Introduction **1**
1.1 Overview 1
1.2 Background 1

2 Description of site and activities **3**
2.1 Site location and description 3
2.2 Activity description 5
2.2.1 Overview of mining activities 5
2.2.2 Processing Plant 7

3 Resource consent requirements **10**

4 Nature of discharges **12**
4.1 Overview 12
4.2 Dust from mining activities 12
4.2.1 Sources of dust 12
4.2.2 Potential nuisance effects of dust 14
4.2.3 Potential health effects of dust 14
4.3 Processing Plant stack discharges 14
4.3.1 Overview 14
4.3.2 Sulphur dioxide 15
4.3.3 Mercury 16
4.3.4 Trace metals 16
4.4 Site combustion emissions 17

5 Environmental setting **18**
5.1 Receiving environment 18
5.2 Sensitive receptors 18
5.3 Meteorology and topography 22
5.3.1 Topography 22
5.3.2 Wind 22
5.3.3 Rainfall 25
5.4 Air quality monitoring 27
5.5 Airshed 27

6 Review of monitoring data **28**
6.1 Overview 28
6.2 Total suspended particulate 28
6.3 Dust deposition monitoring 33

7 Mitigation measures **37**
7.1 Dust control for mining activities 37
7.2 Processing Plant 38
7.3 Routine checks 39

8 Assessment of effects – mining activities **40**
8.1 Introduction 40
8.2 Assessment methodology 40
8.2.1 Overview 40
8.2.2 Screening assessment 40
8.2.3 FIDOL assessment 41
8.2.4 Source-receptor-pathway (IAQM) methodology 41

8.3 Complaints 47
8.4 Assessment 47
8.4.1 Screening assessment 47
8.4.2 Source-pathway-receptor assessment 50
8.5 FIDOL 53
8.6 Human health impacts 54
8.6.1 Introduction 54
8.6.2 Fine particulate PM_{10} and $PM_{2.5}$ 54
8.6.3 Respirable crystalline silica 57
8.6.4 Arsenic 59
8.7 Cumulative effects 61
8.8 Recommended monitoring 61
8.9 Conclusions 62
9 Assessment of effects – stack emissions 63
9.1 Assessment method 63
9.1.1 Assessment approach 63
9.1.2 Dispersion modelling 63
9.1.3 Meteorological modelling 64
9.2 Assessment criteria 65
9.3 Model results 66
9.3.1 Sulphur dioxide 66
9.3.2 Mercury 68
9.3.3 Trace metals 72
9.4 Recommended monitoring 75
9.5 Conclusions 76
10 Alternatives 77
11 Conclusions 78
12 References 80
13 Applicability 81

Appendix A K2 stack emission testing reports
Appendix B Deposition monitoring data
Appendix C Air Quality Management Plan
Appendix D CALPUFF configuration
Appendix E CALMET and WRF configuration
Appendix F WRF data wind roses
Appendix G Proposed air discharge permit conditions

Executive summary

OceanaGold (New Zealand) Limited (OGNZL) currently undertakes open pit and underground gold mining operations at the Macraes Operation located at Golden Point Road, Macraes Flat, East Otago. As part of its ongoing operations, OGNZL continually reviews the remaining life of the Macraes Operation in light of updated knowledge of the gold resource and the economics of mining.

Reflecting recent exploration success and optimisation work, together with higher gold prices, the Macraes Phase Four Project (MP4 or 'the Project') seeks to extend the life of mining at the Macraes Operation until at least 2039. The Project, which will enable ongoing gold production at a rate of approximately 130,000 ounces per annum, is identified as a Listed Project in Schedule 2 of the Fast-track Approvals Act 2024 ("**FTAA**") as a project providing significant national or regional benefits.

To support the development of the substantive application for the Project, OGNZL has engaged Tonkin & Taylor Ltd (T+T) to provide an assessment of the Project's effects on air quality and, to the extent required, identify any necessary management and operation measures to address any such effects.

The Project is made up of a number of proposed key activities, including: open pit mining extensions at Golden Bar, Coronation, Coronation North, and Innes Mills; underground mine expansion through further development of the Golden Point Underground mine; tailings management, including construction of the Frasers Tailings Storage Facility (FTSF) Stage 3 to accommodate an additional 153 million tonnes of tailings; waste rock management; water management infrastructure; and mine closure and rehabilitation activities. The Project also includes the continued operation of the Processing Plant, which processes ore through a pressure oxidation (POX) circuit to produce gold doré.

The proposed rate of mineral extraction associated with the Project will exceed the permitted activity thresholds under Rule 16.3.5.3 of the Regional Plan: Air for Otago (Air Plan). Accordingly, resource consent to authorise the discharges to air associated with the Project is required as a discretionary activity.

The main discharge to air from the existing and proposed mining operations is dust (or particulate matter) from mining activities, including from the handling and transport of waste rock and ore. The most significant potential source of dust arises from the movement of vehicles along unpaved haul routes during dry weather. Other sources include drilling, blasting, excavation, loading, wind erosion of exposed surfaces, and ore crushing and screening.

Discharges to air also occur from the Processing Plant via a number of stacks. The main discharge source is the POX plant stack, which discharges sulphur dioxide (SO_2), mercury, and trace metals. Other, smaller emission sources include the carbon regeneration kiln stacks, the barring furnace stack, the retort oven, and fume hoods above the electrowinning cells.

Site combustion emissions from the operation of vehicles and machinery are also a source of minor discharges to air. Given the rural setting of the site and the low number of vehicles relative to urban environments, combustion emissions are not considered to require further assessment.

Macraes Flat is situated on an elevated plateau at approximately 500 m above sea level, within a rural upland landscape of fluvially dissected rolling hills. Macraes Village is located approximately 1.2 km west of the Project and includes residential, school, and recreational land uses. Rural residential dwellings are also located around the various Project sub-areas.

Sensitive receptors identified in the surrounding environment include high-sensitivity residential receptors at Macraes Village; the Macraes Moonlight School (high sensitivity during school hours); the Coronation Hall and cricket pavilion (medium- to high-sensitivity recreational land uses); and the

Golden Point Historic Reserve, which is characterised as having a moderate sensitivity to air quality effects given its context as a historical mining location within a wider operational mining site.

The Project is not located within, or near, any airshed gazetted under the National Environmental Standards for Air Quality Regulations 2004 and is therefore within the remainder of the Otago region airshed, which is not a polluted airshed.

Rainfall at the mine site averages approximately 700 mm/year, with winter months generally being drier. Analysis of local wind data shows stronger winds tending from the east during daytime hours. The combination of topographic shielding and prevailing wind patterns means there is a low to very low frequency of strong, dry winds directed from the mine towards sensitive receptor locations.

OGNZL currently undertakes air quality monitoring as part of its existing resource consents, including dust deposition monitoring at 16 sites and total suspended particulate (TSP) monitoring at the village site. An analysis of dust deposition rate data for the period 2015–2024 demonstrates generally good compliance with consent limits. Given the explanation of recorded exceedances, it is considered that mining activities have complied with the dust deposition consent limits over the monitoring period.

Analysis of the TSP monitoring has identified that the instrument used is significantly affected by elevated relative humidity, resulting in the vast majority of recorded high concentrations being linked to humidity rather than actual dust events. This is a common occurrence with some instruments of the type used (a nephelometer). Notwithstanding this issue, the instrument is capable of detecting 'real' dust events during dry weather when the relative humidity is lower and when the potential for dust generation is greatest. In this regard, it is noted that no such dust events have been recorded to date.

It is recommended that existing dust deposition monitoring at 16 sites and meteorological monitoring at the mine site and village stations continue for all existing monitoring locations as part of the Project. It is further recommended that TSP monitoring at the village site be replaced with continuous PM_{10} monitoring using a reference standard instrument, in order to avoid the instrumental issues that have occurred with the existing nephelometer and to provide a more direct comparison against health-based air quality criteria. It is also recommended that a suitable nephelometer instrument set up to measure PM_{10} be established on OGNZL land near to the closest sensitive receptor, in order to provide an early warning of increasing dust levels.

A range of dust control measures is currently implemented at the site in accordance with the existing dust management plan (OGNZL 2024), which has been updated to be an air quality management plan (AQMP) to reflect the scope of MP4. These measures are proposed to be implemented for the Project. The principal control measure for dust from mining activities is water suppression applied to haul roads and working areas.

For the Processing Plant, the key air emission control measure is the wet scrubber that treats POX autoclave off-gases. A retort oven is used to control mercury emissions associated with the drying of cathodes from the electrowinning process, and a fabric filter baghouse controls particulate emissions from the barring furnace. Overall, the control measures in place are considered appropriate for the continued management of dust from mining and processing activities.

A qualitative assessment of dust effects from mining activities has been undertaken using the Ministry for the Environment (MfE) FIDOL framework and the source-pathway-receptor methodology recommended by the UK Institute of Air Quality Management (IAQM). The assessment has been informed by site-specific meteorology and topography, historical air quality monitoring data, complaints records, and consideration of sensitive receptor locations in the surrounding environment.

An initial screening assessment has been undertaken using the EPA Victoria recommended separation distances for 'mining of other minerals' (250 m) and 'quarry with blasting' (500 m from the blast area boundary). The screening assessment shows that there are no sensitive receptors within these recommended separation distances, such that a detailed assessment would generally not be required. Notwithstanding this, a detailed source-pathway-receptor assessment using the IAQM methodology has been undertaken for each sub-area.

The IAQM assessment concludes that the potential for off-site dust effects at sensitive human receptors is negligible, provided the dust control measures set out in the AQMP are employed. Residual source emissions from haul road traffic and material handling activities are large, reflecting the scale of mining activities. However, the substantial separation distances to sensitive receptors, which all exceed 600 m with most exceeding 1 km, combined with the very low to low frequency of strong, dry winds directed towards those locations, result in a negligible dust impact risk and a negligible magnitude of effect at all sensitive receptor locations.

The FIDOL assessment, informed by the IAQM results, the historical monitoring data, and complaint records, confirms that offensive or objectionable dust effects at sensitive receptor locations are unlikely to occur.

Concentrations of PM_{10}, $PM_{2.5}$, and respirable crystalline silica (RCS) at all sensitive receptor locations are concluded to be negligible. This assessment is informed by monitoring data from comparable quarrying operations (the Yaldhurst study), which demonstrates that beyond approximately 250 m the change in PM_{10} concentrations due to quarrying activities is negligible. All sensitive receptors are located considerably further than 250 m from Project activities, and there are few periods when those receptors are downwind of strong, dry winds. This finding is further supported by historic monitoring of respirable quartz undertaken at the Macraes Operation in 1999 and 2000, which indicated concentrations well below the relevant guideline.

The potential for exposure to arsenic-containing PM_{10} from the tailings storage facilities (TSFs) has been assessed using the FIDOL framework and is concluded to be negligible. This finding is based on the low potential for dust generation from tailings surfaces, the substantial separation distances between the TSFs and sensitive receptor locations, and the low frequency with which strong, dry winds transport material from the TSFs towards sensitive receptors. As a further line of evidence, even at significantly overstated PM_{10} concentrations, the arsenic content of TSF dust would need to be approximately three times higher than actual measured levels for ambient arsenic concentrations to approach the MfE ambient air quality guideline (AAQG) for arsenic.

Cumulative dust effects from existing OGNZL mining activities and from non-mining sources (principally agricultural activities) are concluded to be negligible and will not materially alter the above conclusions.

Dispersion modelling has been used to predict ground level concentrations (GLCs) of sulphur dioxide, mercury, and trace metals at sensitive receptor locations resulting from Processing Plant stack emissions. Predicted ambient concentrations have been compared with health-based air quality assessment criteria. The model results demonstrate that predicted concentrations of all contaminants at all sensitive receptor locations are well within all relevant assessment criteria. In the case of sulphur dioxide, predicted concentrations are less than 1% of the corresponding assessment criteria. Predicted mercury and trace metal concentrations at the most impacted sensitive receptor locations are similarly very low relative to the applicable OEHHA reference exposure levels and MfE guidelines, with several trace metal species modelled at or below laboratory limits of detection.

Stack emission data underpinning the dispersion modelling are derived from a limited number of testing rounds. Notwithstanding this, the very low predicted GLCs at the most impacted sensitive receptor locations provide a considerable margin of compliance relative to all applicable assessment

criteria. On the basis of the assessment findings, it is concluded that the Processing Plant stack discharges are not expected to give rise to adverse effects on human health at any sensitive receptor location. It is recommended that periodic stack emission testing of the POX plant stack be undertaken once every three years, testing for particulate matter, sulphur dioxide, and metals, to confirm that emissions remain consistent with the data underpinning this assessment. It is also recommended that a consent emission limit for nickel be set for the POX plant stack, based on the dispersion modelling results.

Given the findings of this assessment, it is concluded that the Project can be undertaken in a manner that appropriately manages and minimises discharges to air to ensure that adverse effects on sensitive receptors and the surrounding environment will be negligible. These conclusions are contingent on the continued implementation of the dust mitigation measures currently applied at the site. Proposed resource consent conditions relating to discharges to air are provided in **Appendix G**.

1 Introduction

1.1 Overview

OceanaGold (New Zealand) Limited (**OGNZL**) currently undertakes open pit and underground gold mining operations at the Macraes Operation located at Golden Point Road, Macraes Flat, East Otago. As part of its ongoing operations, OGNZL continually reviews the remaining life of the Macraes Operation in light of updated knowledge of the gold resource and the economics of mining.

Reflecting recent exploration success and optimisation work, together with higher gold prices, the Macraes Phase Four Project (**MP4** or '**the Project'**) seeks to extend the life of mining at the Macraes Operation until at least 2039. The Project, which will enable ongoing gold production at a rate of approximately 130,000 ounces per annum, is identified as a Listed Project in Schedule 2 of the Fast-track Approvals Act 2024 ("**FTAA**") as a project providing significant national or regional benefits.

To support the development of the substantive application for the Project, OGNZL has engaged **Tonkin & Taylor Ltd (T+T)** to provide an assessment of the Project's effects on **air quality** and, to the extent required, identify any necessary management and operation measures to address any such effects.

The purpose of this report is to describe the activities associated with the Project that have the potential to result in discharges to air, and to provide a technical assessment of their actual and potential effects. The assessment includes consideration of both direct and cumulative impacts.

In particular, the report:

- Describes the Project and its associated activities with potential to generate airborne contaminants.
- Characterises the environmental context, including sensitive human receptors, local meteorology, and topography, as well as background air quality conditions.
- Identifies the resource consent requirements under applicable legislation for discharges to air from the Project.
- Assesses the potential effects of the Project's air discharges, including:
  - Dust and nuisance effects; and
  - Potential human health effects.
- Outlines the mitigation and monitoring measures proposed to avoid or minimise adverse effects.
- Considers alternative methods for managing or reducing air discharges.
- Presents conclusions regarding the significance of potential air quality effects and the Project's overall consistency with relevant planning objectives and policies.

This scope covers the Project in its entirety, associated infrastructure, and relevant operational activities over the proposed life of the Project. It also considers the cumulative air quality effects of MP4 in conjunction with other authorised mining activities and integration of existing or already authorised activities into the MP4 air discharge permit.

1.2 Background

The different components of the Project are summarised below in Table 1.1

Table 1.1. These Project elements are described in further detail in Section 2.2.

Table 1.1: Project components

Component	Area
Open pits and underground mine extensions	Innes Mills (Stages 11 – 13) including Southern Pit TSF and MTI tailings relocation
	Coronation (Stages 6-8)
	Coronation North (Stage 6)
	Golden Bar (Stages 2-3)
	Golden Point Underground extension
Waste Rock Stacks	Frasers West Waste Rock Stack height raise
	Trimbells Waste Rock Stack height raise and extension
	Coronation North Backfill height raise
	Coronation Backfill
	Coronation North Waste Rock Stack height raise
	Innes Mills Backfill
	Southern Pit Backfill
	Golden Point Backfill
	Golden Bar Waste Rock Stack Extension
Tailings storage facilities and return water	Frasers Tailings Storage Facility Stage 3
Processing Plant	The capacity of the Processing Plant will be maintained at approximately 6.5 Mtpa
Other infrastructure/activities (including vegetation clearance and earthworks)	Macraes Road realignment (Stages 1 and 2)
	Camp Creek and Coal Creek dams
	Open Pit Workshop relocation
	Tailings and Return water relocation
	Internal site electricity supply upgrades and distribution line relocations
	Water quality mitigation options – toe drains/silt ponds
	Continuation of existing site wastewater discharges
	Topsoil, ore and brown rock stockpiles
	Murphys Ecological Enhancement Area

2 Description of site and activities

2.1 Site location and description

OGNZL owns and operates the Macraes Operation at Macraes Flat, approximately 30 km northwest of Palmerston in the Otago Region. The Macraes Operation is the largest gold mine in New Zealand and, since commissioning in 1990, has produced more than 6 million ounces of gold.

Macraes Flat is situated on an elevated plateau at approximately 500 m above sea level. The plateau is flanked by the Taieri Ridge to the northwest, Shag Valley and Horse Range to the east, and the coastal hills and extinct volcanic cones of Palmerston and Waikouaiti to the southeast. Macraes Road provides access to Macraes Flat and the Macraes Operation, connecting to State Highway 85 to the east and State Highway 87 (SH87, the Middlemarch–Hyde Road) to the west.

The environment within and surrounding the Macraes Operation has been shaped by historic and current mining activities. Figure 2.1 shows the arrangement of the major mine features at the Macraes Operation. In summary, the current components of the Macraes Operation include:

- Numerous open pits (both operational and non-operational);
- Two underground mines (Frasers, now closed, and Golden Point, which is actively mined);
- Waste rock stacks at various stages of operation and rehabilitation;
- A network of haul roads and general mine service tracks;
- A Processing Plant;
- Five tailings storage facilities (three inactive, one active but nearing capacity, and one under construction and currently receiving tailings);
- An extensive network of water management infrastructure, including diversion drains, silt ponds, sumps, pit lakes, and freshwater storage reservoirs;
- Two consented but not yet constructed water storage reservoirs (Camp Creek Dam and Coal Creek Dam); and
- Associated infrastructure supporting ongoing operations, including district roads, powerlines, workshops, offices, and associated water and amenity facilities.

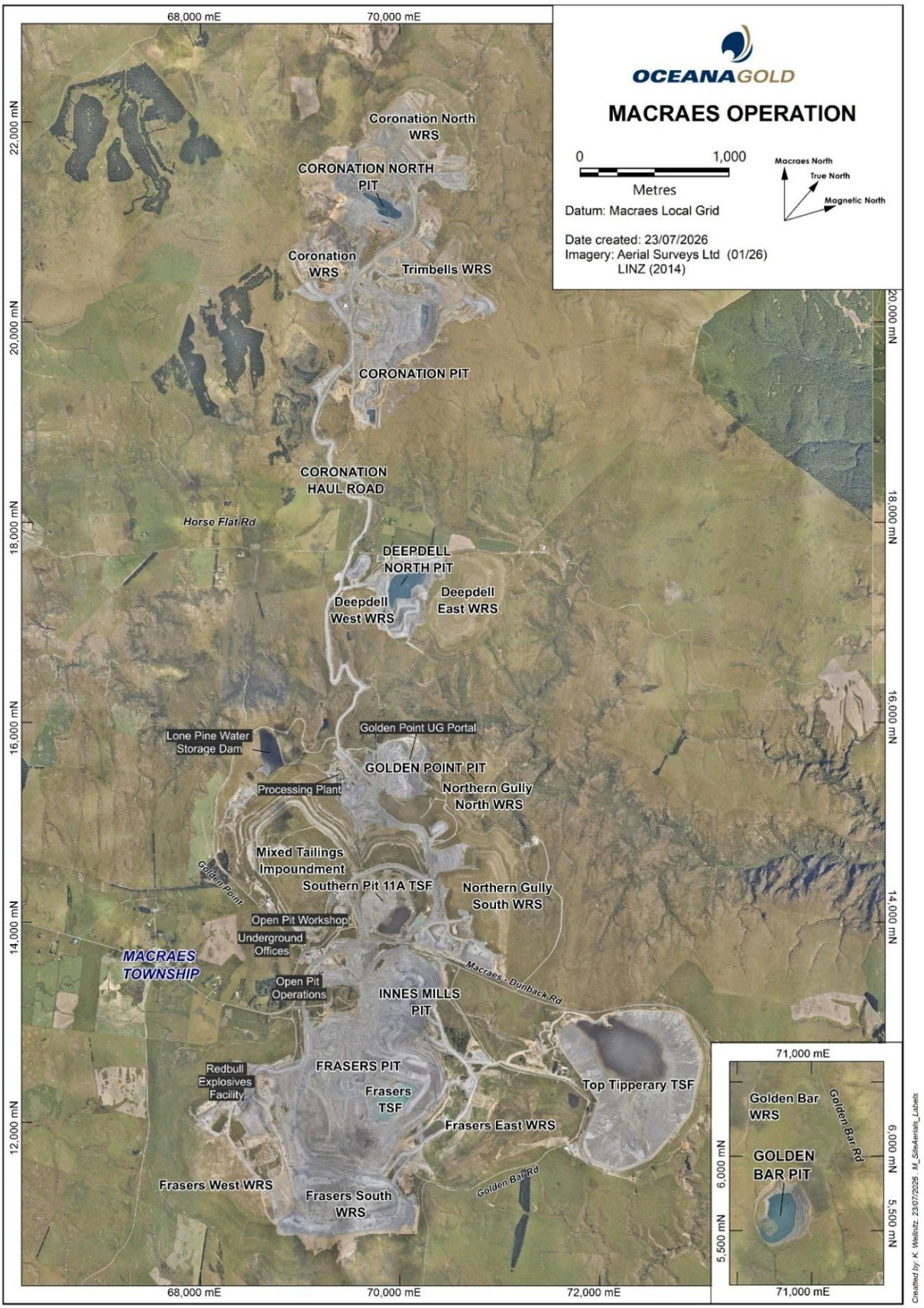


Figure 2.1: Existing site layout.

2.2 Activity description

2.2.1 Overview of mining activities

A detailed description of the Project is provided in Section A.05 of the substantive application, with the exception of details regarding the Processing Plant. Accordingly, only a high-level summary of the Project is provided here, along with a more detailed description of the Processing Plant.

The Project is made up of the following proposed key activities:

- **Open pit mining extensions** at Coronation, Coronation North, Innes Mills, and Golden Bar.
- **Underground mine expansion** through further development of the Golden Point Underground mine.
- **Tailings management**, including:
  - Construction of the Frasers Tailings Storage Facility (FTSF) Stage 3 to accommodate a total tailings storage of up to 153 Mt; and
  - Hydraulic mining and relocation of tailings from the Mixed Tailings Impoundment (MTI), Southern Pit Option 10 TSF (SP10), and Southern Pit Option 11A TSF (SP11) to FTSF.
- **Waste rock management**, including increased storage capacity within open pits and at existing waste rock stacks at Coronation, Coronation North, Innes Mills, Golden Bar, Golden Point, and Frasers.
- **Water management infrastructure and operations**, including:
  - Construction of the already consented Camp Creek and Coal Creek water storage dams;
  - Construction, operation and maintenance of a Water Treatment Plant; and
  - Ongoing operation and maintenance of the Mine Water Management System.
- **Infrastructure and roading works**, including realignment of Macraes Road in two stages and relocation of the Open Pit Mining Workshop.
- **Ecological enhancements**, including establishment of**:**
  - Murphys Ecological Enhancement Area (MEEA) near Murphys Creek, including predator fencing, access tracks, and site facilities;
  - Mt Highlay restoration area;
  - Cranky Jims Link shrubland enhancement area;
  - Murphys Link tussock protection area; and
  - Additional compensation measures for residual ecological impacts.
- **Mine closure and rehabilitation activities**, including rehabilitation of mining landforms, creation of pit lakes, dry capping of tailings storage facilities, and revegetation in accordance with closure objectives.

An overview of the proposed activities which make up the Project is shown in Figure 2.2 below.

In addition to the above components of the Project, resource consent is being sought for continuation of air discharges from other parts of the mine (for which existing resource consents expire in 2032). This includes the continued operation of the Processing Plant as part of the Project. The Processing Plant is not described in detail in Section A.05 of the substantive application, due to its discharges being limited to air contaminants. Consequently, it is described in detail in Section 2.2.2 of this report.

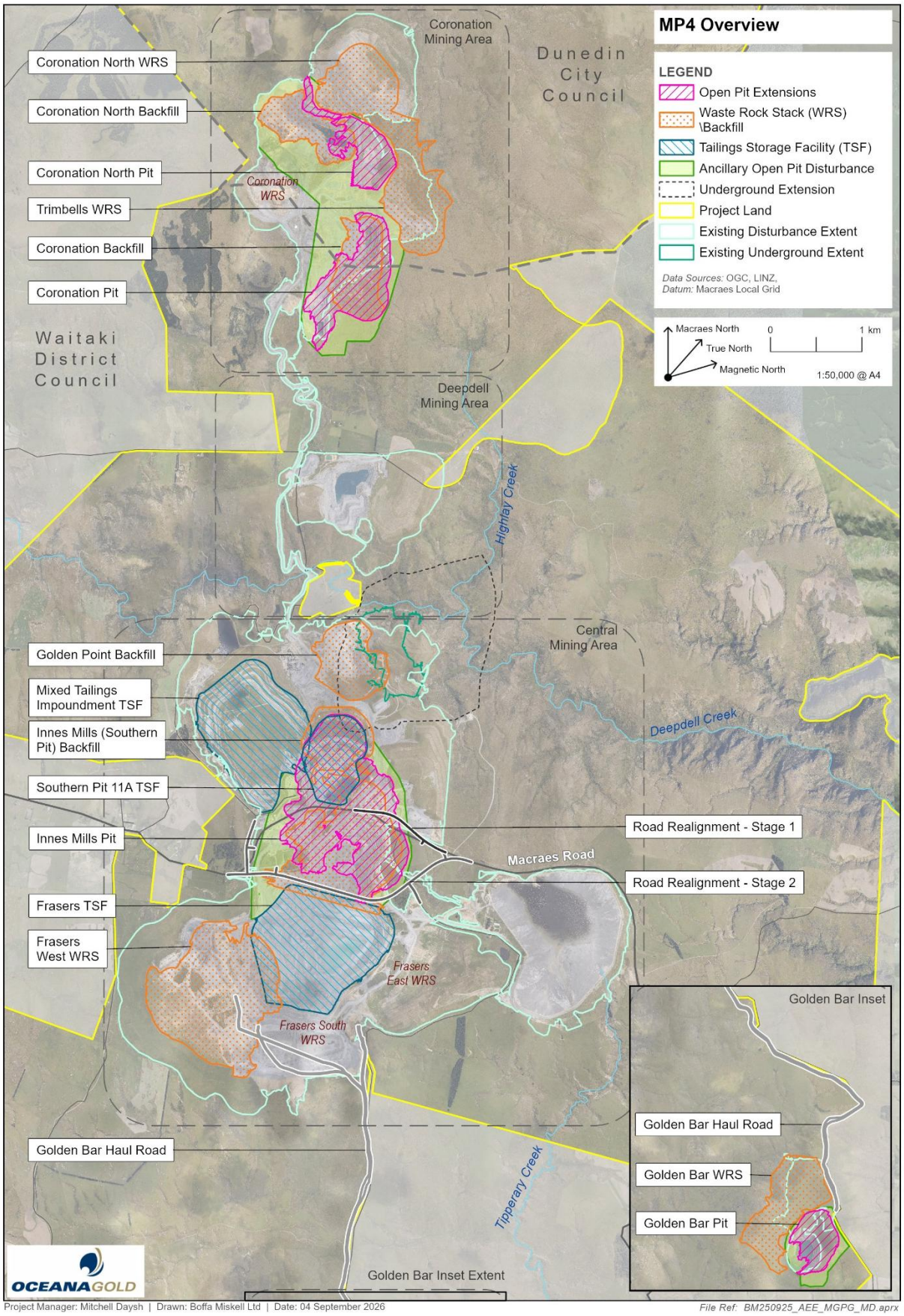


Figure 2.2: MP4 Project overview plan.

2.2.2 Processing Plant

2.2.2.1 Overview

Gold present in the Macraes ore is generally only visible when viewed under a microscope. The Macraes ore predominantly contains sulphide minerals to which the gold is bound. To extract the gold, the sulphide ore is treated through a series of stages that includes crushing, grinding, flotation, pressure oxidation (POX), Carbon-in-Leach (CIL) elution, electrowinning and smelting. Tailings streams from flotation and detoxified CIL are discharged to the tailings storage facility (TSF), with decanted water recovered and recycled to the Processing Plant.

Potential air emission sources are associated primarily with crushing and materials handling, the POX autoclave off-gas (via the vent scrubber and stack), and smaller exhaust points from carbon regeneration, electrowinning ventilation, and smelting.

The different stages of the process are described in the following sub-sections.

The location of the Processing Plant is presented on Figure 8.2.

2.2.2.2 Crushing

Crushing is the first stage of processing, which reduces the size of the run-of-mine (ROM) ore from 900 mm down to less than 125 mm. ROM ore is tipped across a static grizzly screen (a heavy-duty screen that separates very large rocks) into crusher bins, after which jaw crushers are used to reduce the size of the ore. A separate crushing circuit is used for the ore from the underground mining operation. The static grizzly and jaw crushers can be a source of localised dust emissions.

2.2.2.3 Grinding and classification

The crushed ore is conveyed to the grinding circuit. The grinding circuit is a wet process (generating no dust) and is used to reduce the crushed ore into a finely ground slurry, with a particle size of about 120 microns. The grinding circuit comprises two SAG (Semi-Autogenous Grinding) mills and two ball mills. The SAG mills perform the primary grinding of the crushed ore and the ball mills conduct the secondary grinding. Steel balls are added to the mills to aid the grinding process. Any oversized particles discharging from the grinding mills are redirected for further crushing and recycled to the SAG mills. After grinding, the slurry passes through hydro-cyclones to separate coarse and fine particles. The coarse particles are split into two streams where one stream is recycled to the secondary mills for further grinding and the other stream is diverted to the flash flotation circuit to recover fast floating sulphide minerals.

2.2.2.4 Flotation circuit

The flotation circuit is used to separate the ground gold-bearing sulphide minerals from the non-valuable portion of the ore (gangue). Flotation chemicals are added to coat the surface of the gold-bearing sulphide minerals to be water-repellent (hydrophobic). Air is then introduced into the flotation cells through the slurry. This results in the hydrophobic sulphide minerals containing the gold particles sticking to the air bubbles and rising to the top of the cells as froth that is skimmed off. The froth is referred to as ‘rougher concentrate’. The rougher concentrate is cleaned in successive stages to increase its gold and sulphur content. This cleaned concentrate is referred to as the ‘flotation concentrate’.

The flotation concentrate is reground in a regrind mill to a particle size of about 15 microns, with limestone added to control acidity levels prior to the pressure oxidation process. The flotation concentrate is then thickened in a ‘concentrate thickener’ to remove excess water. The thickened concentrate is then transferred into concentrate tanks to be treated in the pressure oxidation (POX)

circuit. Flotation tailings containing the gangue are directed to the mixed tails tank and discharged to the tailings storage facility.

2.2.2.5 Pressure Oxidation (POX) circuit

The purpose of the pressure oxidation process is to oxidise the strong chemical bonds between the sulphide minerals and the gold particles in the thickened flotation concentrate. This separates the gold particles from the sulphide minerals. The oxidation process is achieved by introducing pure oxygen gas under high pressure (3,140 kPa) and high temperature (225°C) in the sealed pressure oxidation vessel called the autoclave.

The resulting oxidised slurry is then discharged into a flash vessel, where the slurry pressure is safely released and reaches atmospheric pressure instantly. The gases released in the flash vessel are cleaned in a vent scrubber before being discharged via a stack. This is the plant's main air emission point.

The oxidised slurry is then washed, cooled and thickened in two-stage, counter-current-decantation (CCD) thickeners in preparation for the next stage of processing: Carbon-In-Leach. Acidic solution from the CCD thickeners is discharged into the mixed tailings tank.

The descaling of the autoclave vessel during routine maintenance can be a localised, infrequent source of dust emissions.

2.2.2.6 Carbon-in-Leach (CIL)

The purpose of the Carbon-in-Leach (CIL) circuit is to dissolve and separate the gold from the waste minerals present in the oxidised slurry. This is achieved with the aid of low-pressure oxygen gas, sodium cyanide reagent and slaked lime injected into the leach tanks. The gold in solution is then adsorbed onto the porous surface of activated carbon.

Fresh activated carbon is introduced into the CIL circuit via the last CIL tank and moves up the train of the CIL tanks to the first CIL tank in a counter-current direction to the flow of CIL slurry.

The slurry pH is monitored and maintained at the recommended levels to minimise generation of hydrogen cyanide gas. The CIL tailings, containing a mixture of cyanide residue and waste minerals from the oxidised ore, are treated in the INCO cyanide destruction unit, which uses sulphur dioxide and air to convert residual cyanide into much less harmful cyanide compounds before combining with the flotation and CCD tailings in the tailings hopper for disposal.

2.2.2.7 Elution Process

The activated carbon, after being loaded with the dissolved gold, is screened and cleaned, then discharged into a pressure vessel called the elution column. The carbon is then treated in the elution column at high temperature (125°C) and high pressure (200 kPa) with nitric acid, sodium cyanide and caustic to wash impurities off the carbon surface and dissolve the fine gold concentrated particles adsorbed on the carbon into highly concentrated soluble gold called 'pregnant solution'. The stripped or barren carbon is thermally reactivated in a carbon regeneration kiln at high temperature (>700°C), which burns off impurities accumulated in the porous cavities of the activated carbon so it can be reused. Each of the three carbon regeneration kilns has a small exhaust stack.

2.2.2.8 Electrowinning Circuit

The pregnant solution is pumped into the electrowinning cells, which are bathtub-like and contain anodes and cathodes. Stainless steel wire mesh is used as the anode and mild steel wool wrapped around the frame as the cathode. The anode frames are made of poly plastic and placed in the cells near the cathode frames. When the cells are electrified, the cathode produces a negative charge and

the anode frame produces a positive charge. The soluble gold particles have a positive electric charge and deposit onto the steel wool of the cathode frames while the non-gold impurities (with negative electric charges) deposit onto the anode frames. Any fumes from these cells are captured under a fume hood and discharged via small stacks.

Once the steel wool is loaded with the gold particles, it is removed and dried in a retort oven overnight.

2.2.2.9 Smelting Process

The dried gold-loaded steel wool and smelting reagents (flux) are added to the electric smelting furnace to improve the purity and quality of the gold doré[1]. The electric furnace is operated at high temperatures (1,100–1,200 °C) to smelt and produce gold bars of about 95% purity. The remaining iron slag is recycled back into the process to extract any gold trapped in the slag during the smelting process. Furnace off-gas is extracted and vented through a small stack.

2.2.2.10 Tailings and water management

Detoxified CIL tails, CCD wash water tailings and flotation tails are combined in the mixed tails hopper and pumped to the TSF. Water from the TSF is pumped to the Turkey's Nest and recycled back to the Processing Plant via gravity flow. Recycled water from the tailings storage facility (TSF) is used in the crushing, grinding and flotation circuits while pressure oxidation, CIL, elution, electrowinning and mixing of chemical reagents at the Processing Plant use fresh water sourced from the Taieri River that is stored in a freshwater catchment called the Lone Pine Water Storage Dam. Further information on the stack discharges associated with the Processing Plant is presented in Section 4.3.

[1] The Macraes Mine produces 'dore' which is an alloy of mostly gold with some silver and copper.

3 Resource consent requirements

The Regional Plan: Air for Otago (Air Plan) sets out rules for activities that require resource consent to discharge contaminants into air. The plan was last updated on 30 September 2023 as part of Plan Change 3 that sought to update the plan to reflect the requirements of the National Environmental Standards for Greenhouse Gas Emissions from Industrial Process Heat.

Rule 16.3.5.3 provides for discharges to air from mineral extraction and processing as a permitted activity, provided the following conditions are met.

> *The discharge of contaminants into air from:*
>
> *(1) The extraction of minerals from the surface or from an open pit at a rate less than 20,000 cubic metres per month and 100,000 cubic metres per year; or*
>
> *(2) The crushing and screening of minerals at a rate less than 200 tonnes an hour; or*
>
> *(3) The drying or heating of minerals from single activities or a combination of activities on one site with equipment that has a heat generation capacity of less than 500 kW; or*
>
> *(4) The making of refractory, bricks or ceramic products at a rate less than 200 kg/hr of products;*
>
> *is a permitted activity, providing:*
>
> *(a) The mineral extraction, crushing and screening activities are located in Air Zone 3; and*
>
> *(b) In the case of equipment installed after 28 February 1998, any chimney complies with Schedule 6 ("Determination of Chimney Heights"); and*
>
> *(c) Any discharge of smoke, odour or particulate matter is not noxious, dangerous, offensive or objectionable at or beyond the boundary of the property.*

The rate of mineral extraction associated with the Project would significantly exceed the permitted activity thresholds of 20,000 cubic metres per month and 100,000 cubic metres per year of clause (1). Similarly, the rate of ore crushing associated with the Processing Plant will significantly exceed the rate of 200 tonnes per hour of clause (2). Finally, the Processing Plant will result in the heating of minerals with equipment with a heat generating capacity of more than the 500 kW threshold limit of clause (3).

Where discharges do not meet the conditions of permitted activity Rule 16.3.5.3, resource consent is required as a discretionary activity under Rule 16.3.14.1, which provides for activities that are not expressly provided for by the other rules of the Air Plan.

Given the above, the proposed new mining areas and continued use of existing mining areas associated with the Project will require resource consent for discharge of contaminants to air as a discretionary activity under Rule 16.3.14.1. Furthermore, the ongoing discharges to air from the continued operation of the Processing Plant will also require a replacement resource consent (i.e. "renewal" of the existing consent) under Rule 16.3.14.1.

Rule 16.3.15.1 to Rule 16.3.15.5 relate to activities discharging fine particulate matter less than 10 microns (µm) in diameter (PM_{10}). As discussed later in Section 4, mining activities will give rise to the discharge of PM_{10}. Of these rules, only Rule 16.3.15.5 is relevant as the discharge will take place after 31 August 2013, and the discharge will not occur into an airshed where the air quality standard for PM_{10} is already breached. Rule 16.3.15.5 states the following:

Except as provided for by the permitted activity rules in this Plan or prohibited by Rules 16.3.1.1, 16.3.3.1, 16.3.12.1 and 16.3.15.1, the discharge of PM_{10} to air in an airshed after 31 August 2013; is a discretionary activity, providing:

(a) The concentration of PM_{10} in the airshed does not breach its ambient air quality standard; or

(b) The granting of the resource consent is not likely, at any time, to cause the concentration of PM_{10} in an airshed to breach its ambient air quality standard.

The assessment presented later in this report demonstrates that the concentration of PM_{10} arising from mining activities is expected to comply with the requirements of clauses (a) and (b). Accordingly, the discharge of PM_{10} from mining activities for the Project is a discretionary activity under Rule 16.3.15.5.

4 Nature of discharges

4.1 Overview

The main discharge to air from the existing and proposed mining operations is dust (or particulate matter) from the mining activities, including from the handling and transport of waste rock and ore.

Discharges to air also occur from the Processing Plant, which processes the ore to produce gold doré.

Air discharge permits currently held by OGNZL for the Macraes Operation are summarised in Table 4.1. The proposed MP4 air discharge permit will replace all existing air discharge permits at the site with the exception of:

- 2006.689 which will be surrendered; and
- RM20.024.12 which will remain until its expiry in 2027.

Table 4.1: Existing air discharge permits currently held by OGNZL

Air discharge permit number	Details
Discharge Permit 96785.V5	To discharge contaminants from **mining operations and post-mining rehabilitation** to air in the vicinity of Macraes Flat (all of the mine site except features associated with Macraes Phase III and Coronation).
Discharge Permit 2006.689	To discharge contaminants to air for the purpose of **ventilating Frasers Underground Mine**.
Discharge Permit 2007.511	To discharge contaminants to air for the purpose of **carrying out mining activities** and post mining rehabilitation (**Golden Bar Pit, Rock Stack, Silt Ponds and Infrastructure**).
Discharge Permit RM10.351.52.V4	To discharge contaminants from mining operations and **post mining rehabilitation to air for the purpose of undertaking mining operations (Macraes Phase III expansion and Frasers West).**
Discharge Permit RM12.378.15	To discharge contaminants from **mining operations** and post-mining rehabilitation to air for the purpose of undertaking mining operations (**Coronation Waste Rock Stack, Coronation Pit and associated haul roads, utility areas and stockpiles**).
Discharge Permit RM16.138.19.V2	To discharge contaminants from **mining operations** and post-mining rehabilitation to air for the purpose of undertaking mining operations (**Coronation North**).
Discharge Permit RM20.024.12	To discharge contaminants from **mining operations** and post-mining rehabilitation to air for the purpose of undertaking mining operations (**Deepdell North Stage III).**
Discharge Permit RM20.130.01.V1	To discharge contaminants to air for the purpose of **ventilating the Golden Point Underground Mine** (Golden Point Underground Mine – Macraes).

4.2 Dust from mining activities

4.2.1 Sources of dust

The most significant potential source of dust associated with mining activity arises from the movement of vehicles along unpaved haul routes during dry weather. This occurs due to the action of the vehicle wheels suspending dust. Dust from vehicle movements can occur irrespective of wind speed but depends on the moisture content and proportion of fine material in the haul road, as well as the number of wheels, weight and speed of vehicles. The second largest source of dust for mining

activities is typically from the crushing and processing of materials, where water suppression or wet processes are not used.

During dry weather, dust discharges can arise from the excavation and cartage of topsoil, as well as from the excavation of overburden and waste rock, which may involve blasting, and the cartage of this material.

Other lesser sources of dust from the mining activities include the following:

- Drilling of blast holes and grade control holes for the collection of samples. Dust is controlled by rubber skirts at the drill hole collar and using water misting; and a dust collection system that collects dust from around the drill hole collar and deposits it in a heap beside the drill rig.
- Blasting of rock and ore to loosen it for extraction produces some fugitive dust, albeit for short periods of time and relatively infrequently.
- Excavation from the mine working face.
- Loading of trucks from the loader where an excessive drop height is used.
- Trucks and loaders operating on stockpile areas.
- Wind erosion of dusty material from bare exposed areas on dry days.
- Entrainment of dusty material from exposed surfaces during strong and dry wind events. This includes topsoil and overburden stockpiles prior to the establishment of a vegetation cover, and the ROM stockpile.
- Uncovered conveyor transfer points.
- Processing of the ore where dry processes take place, such as crushing and screening.

The key factors that influence the amount of dust from the above sources are as follows:

- Moisture content of the material – Moisture binds particles together and prevents dust from being generated through surface wind erosion or disturbances such as vehicle movement. Consequently, the application of water is a key measure for controlling dust emissions from mining operations, which is discussed further in Section 7.1.
- Particle size distribution of the material – Fine particles are more easily entrained in wind or lifted via mechanical disturbance.
- Surface wind speed – The generation of dust emissions through wind erosion of exposed surfaces and the propagation of suspended dust generally increase with wind speed. Dust pick-up by wind typically becomes significant at hourly average wind speeds of greater than 7 metres per second (m/s) (AQMA 2000), and shows increased surface pick-up with wind speeds greater than 10 m/s (Watson et al., 2000). Propagation of dust suspended in air through mechanical disturbance towards downwind locations may occur at lower wind speeds.
- The area of the exposed surface – The greater the area of exposed surface, the larger the potential for dust generation will be during strong wind events. Stabilisation of surfaces, which includes installation of wind breaks and progressive rehabilitation activities, significantly decreases the potential for generation of dust by binding surface particles and reducing surface wind speeds.

4.2.2 Potential nuisance effects of dust

The main effects of dust emissions relate to nuisance effects and property soiling. These effects include impacts on amenity, visibility and impacts on structures, such as abrasion.

Effects on plant life can occur, but this is typically only an issue where there are very high dust deposition rates and in the immediate vicinity of a source. Such effects are not expected to occur with the Project and are not considered further.

4.2.3 Potential health effects of dust

Adverse health effects from quarry dust exposure relate to the fine fraction of particles in dust emissions. This includes the particles smaller than 10 microns in diameter (PM_{10}) and especially those that are smaller than 2.5 microns ($PM_{2.5}$) – although $PM_{2.5}$ particles are largely associated with combustion processes. The comparative size of PM_{10} and $PM_{2.5}$ particles to a grain of sand is illustrated in Figure 4.1. The effects of high PM_{10} and $PM_{2.5}$ exposure relate to aggravation of existing respiratory and cardiovascular disease, and can lead to restricted activity days, hospitalisation and increased mortality.

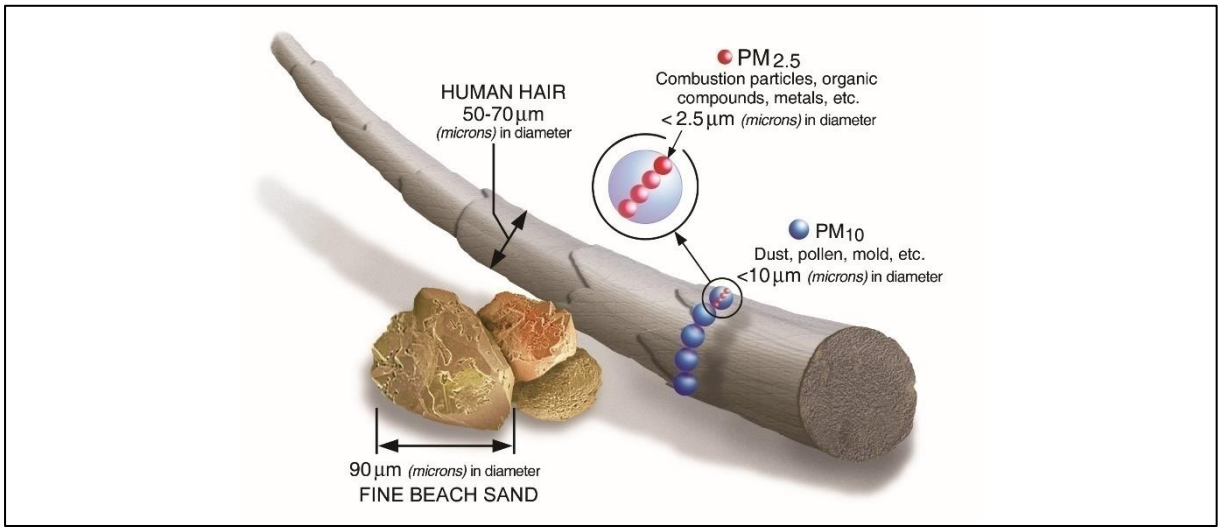


Figure 4.1: Size comparison of particles (source: USEPA).

Crystalline silica is a naturally occurring component in rock. Therefore, dust generated from natural rock sources, such as dust from mines and quarries, will include a component of crystalline silica. In terms of health effects, we are most interested in exposure to fine (respirable) dust containing crystalline silica (respirable crystalline silica or RCS)[2].

4.3 Processing Plant stack discharges

4.3.1 Overview

Stack emission testing has been undertaken on the POX plant stack and other stacks associated with the Processing Plant. The POX plant stack was most recently tested by K2 Environmental Limited (K2) in 2010 and 2022, whilst the smaller stacks were tested in 2010 and 2016. Copies of the testing reports are provided in Appendix A. The main emissions associated with the POX plant are sulphur dioxide, acid mist and trace metals (including mercury). Emissions of acid mist and particulate matter (as Total Suspended Particulate) in the POX stack have also been measured. The emission rates of

[2] RCS is principally on occupational hazard and therefore is defined as crystalline silica particles less than 4 micron in diameter (PM4) to align with occupational health and safety monitoring techniques.

these contaminants are very low and therefore have not been included in the dispersion modelling.[3] The main contaminant of interest in the emissions associated with other process stacks is mercury.

Other emission sources and associated stacks at the Processing Plant include:

- The Barring furnace stack.
- Fume hood collection above the electrowinning cells:
  - Electrowinning 1 (EWIN1).
  - Electrowinning 2 (EWIN2).
  - Electrowinning 3 (EWIN3).
- Carbon regeneration kiln 1 stack.
- Carbon regeneration kiln 2 stack.
- Carbon regeneration kiln 3 stack.
- The retort oven.

Stack discharge parameters used for the dispersion modelling assessment (see Section 9) are presented below in Table 4.2.

Table 4.2: Stack discharge parameters

Stack	Stack height (m)	Stack diameter (m)	Stack exit velocity (m/s)	Stack exit temperature (K)
POX plant	23.0	0.78	3.6	362.15
Barring furnace	12.6	0.30	36.0	323.15
EWIN 1	13.3	0.37	12.0	298.15
EWIN 2	13.1	0.37	9.5	289.15
EWIN 3	14.0	0.37	19.0	294.15
Carbon regen 1	16.3	0.50	13.0	298.15
Carbon regen 2	18.5	0.50	13.0	290.15
Carbon regen 3	17.2	0.50	4.7	523.15
Retort oven	14.9	0.16	1.7	295.15

The data presented in Table 4.2 are based on a limited amount of stack testing data (two rounds of testing) as the current resource consent conditions do not require routine stack testing.

As noted above, emissions from the POX plant stack were tested by K2 in 2010 and 2022. The 2010 test results have not been used in this assessment, as the POX plant operating conditions at that time were significantly different from those in 2022. Based on discussions with OGNZL, the operating conditions during the 2022 testing are most closely aligned with those expected for MP4, and the 2022 results are therefore considered representative of MP4 emissions. Notwithstanding this, further stack testing has been commissioned.

4.3.2 Sulphur dioxide

SO_2 is of interest with respect to potential human health effects because it is a potent respiratory irritant when inhaled in sufficient quantities. Asthmatics are particularly susceptible.

[3] Conservatively assuming all TSP is present as PM_{10}, worst case modelled concentrations would be less than 1% of the ambient air quality standard.

SO_2 emission rates measured for the POX Plant are summarised in Table 4.3.

Table 4.3: SO_2 emission rates

Stack	Emission rate (kg/hour)
POX plant	0.075

4.3.3 Mercury

Short-term exposure to mercury at elevated concentrations can irritate and damage the lungs, causing cough, chest tightness/pain, and shortness of breath; severe cases can progress to chemical pneumonitis and pulmonary oedema. It can also cause a flu-like illness (fever, chills, fatigue, headache), nausea/vomiting and abdominal pain, plus neurological symptoms like dizziness, weakness, or confusion.

Long-term exposure can affect the nervous system (tremor; irritability, anxiety, insomnia; poor concentration/memory), cause tingling/numbness or coordination problems, inflame gums and mouth (gingivitis, sores, excess salivation), and injure the kidneys (protein in urine or reduced function). Very high exposures can cause respiratory failure, severe neurological toxicity, and death; pregnancy and childhood exposures carry higher risk for brain effects.

Emissions of gaseous and particulate-phase mercury have been measured from the various stacks by K2 Environmental and are summarised in Table 4.4[4]. The emission testing reports from K2 are provided in **Appendix A**.

Table 4.4: Mercury emission rates

Stack	Gaseous emission rate (kg/hour)	Particulate emission rate (kg/hour)	Testing report
POX plant	5.00×10^{-7}	8.27×10^{-5}	K2 2022
Barring furnace	9.36×10^{-6}	9.36×10^{-5}	K2 2016
EWIN 1	9.50×10^{-7}	2.02×10^{-4}	K2 2016
EWIN 2	7.56×10^{-7}	5.76×10^{-5}	K2 2011
EWIN 3	4.51×10^{-6}	1.30×10^{-4}	K2 2016
Carbon regen 1	3.24×10^{-6}	2.98×10^{-4}	K2 2011
Carbon regen 2	2.80×10^{-6}	1.50×10^{-5}	K2 2011
Carbon regen 3	3.49×10^{-7}	5.40×10^{-5}	K2 2011
Retort oven	4.26×10^{-7}	1.13×10^{-5}	K2 2016

4.3.4 Trace metals

Trace metals testing (excluding mercury, which is discussed above) has been undertaken on the POX plant stack (K2 2022) and is summarised in Table 4.5. As described above, the values from the K2 2022 report have been used in preference to those from the 2010 testing period (K2 2011); however, the emission rate for nickel from the 2010 testing period has been used as it was not measured in 2022. The trace metals included are those known to have the most stringent ambient air quality assessment criteria (see Section 9.2).

[4] The emission rates of mercury are very low and are presented in 'scientific format' for ease of reading. A mass emission rate of 5×10^{-7} kg/hour could also be expressed as 0.0000005 kg/hour.

Unlike mercury, which follows gold through the subsequent processing stages (due to its unique solubility, carbon affinity, and volatility), the other trace metals are not expected to be present in appreciable concentrations in the air discharges following the POX plant, as they are chemically bound in the solid residue. Consequently, trace metal emissions are only assessed as being discharged from the POX plant stack.

Table 4.5: Trace metal contaminant emission rates

Stack	Contaminant	Emission rate (kg/hr)	Testing report
POX plant	Arsenic (As)	$9.00 \times 10 \times 10^{-5}$	K2 2022
	Chromium (Cr)	$8.00 \times 10 \times 10^{-6}$	K2 2022
	Lead (Pb)[1]	$6.30 \times 10 \times 10^{-5}$	K2 2022
	Nickel (Ni)	$3.56 \times 10 \times 10^{-3}$	K2 2011

Note: Emission rate below the laboratory limit of detection and thus modelled at the limit of detection.

4.4 Site combustion emissions

The operation of machinery and vehicles at the mine will generate exhaust emissions containing combustion products, such as oxides of nitrogen (NOx), carbon monoxide (CO), PM_{10} and $PM_{2.5}$, and sulphur dioxide (SO_2).

The number of vehicles and machines associated with the Project is low compared to urban areas where ambient combustion contaminant levels may be elevated. The rural setting of the site means that background contaminant levels are also relatively low. This means that the cumulative effects of combustion emissions beyond the site will be very low compared to applicable air quality standards and guidelines. Accordingly, no further consideration is given in this report to combustion emissions from site equipment.

5 Environmental setting

5.1 Receiving environment

The environment within and surrounding the Project has been shaped by agriculture and both historical and current mining activities. Macraes Flat is situated on an elevated plateau at approximately 500 m above sea level. The plateau is flanked by the Taieri Ridge to the northwest, Shag Valley and Horse Range to the east, and the coastal hills and extinct volcanic cones of Palmerston and Waikouaiti to the southeast. Macraes Road provides access to Macraes Flat and the existing mine area.

Macraes Village is located approximately 1.2 km west of the Project. There are a number of sensitive land uses within the village including residential, a school and recreational space. In addition to sensitive land uses within Macraes Village, there are also other areas of sensitive land uses in the form of rural residential dwellings in the area surrounding the Project. These areas are identified and discussed further in Section 5.2.

5.2 Sensitive receptors

Sensitive receptors around the Project have been identified in line with the sensitivity ratings within the Ministry for the Environment (MfE) '*Good Practice Guide for Assessing and Managing Dust*'[5]. Residential properties have a high sensitivity to air quality effects, while rural land more generally has a low sensitivity due to the infrequent presence of people. Rural dwellings may have a lower sensitivity to dust effects compared to urban residential zones because rural properties can experience dust from rural-type activities such as stock movements, fertiliser application, cultivation etc.

The greatest concentration of residential receptors in the vicinity of the Project is the Macraes Village. OGNZL owns a number of properties within the township, while others are privately owned. In addition to the Macraes Village, rural residential dwellings are also located around the various Project sub-areas. Notwithstanding this, the residential dwellings owned by OGNZL within Macraes Village are located in between privately owned residences, including Receptor 1 which is the closest receptor to the Mine. Accordingly, the impacts at these OGNZL properties will be of a similar or lower magnitude of effect than at the privately owned receptors.

Other non-residential activities that are sensitive to air quality effects are the Macraes Moonlight School (high sensitivity during school hours), the Coronation Hall and the cricket pavilion at 16 Hyde Street. The Coronation Hall and cricket pavilion are recreational land uses, which have a medium to high sensitivity to air quality effects, but only while people are present.

The Golden Point Historic Reserve is located within the wider Mine area on land owned by the Department of Conservation. It includes historical gold mining machinery and buildings and is open to the public for recreational use, although overnight camping is not allowed. Some tourist, cultural and conservation land uses expect a high level of amenity (for example wilderness environments). However, given the site's context as a historical mining location within a wider operational mining site, and the short-term nature of people's visits, the Reserve has been characterised as having a moderate sensitivity to air quality effects.

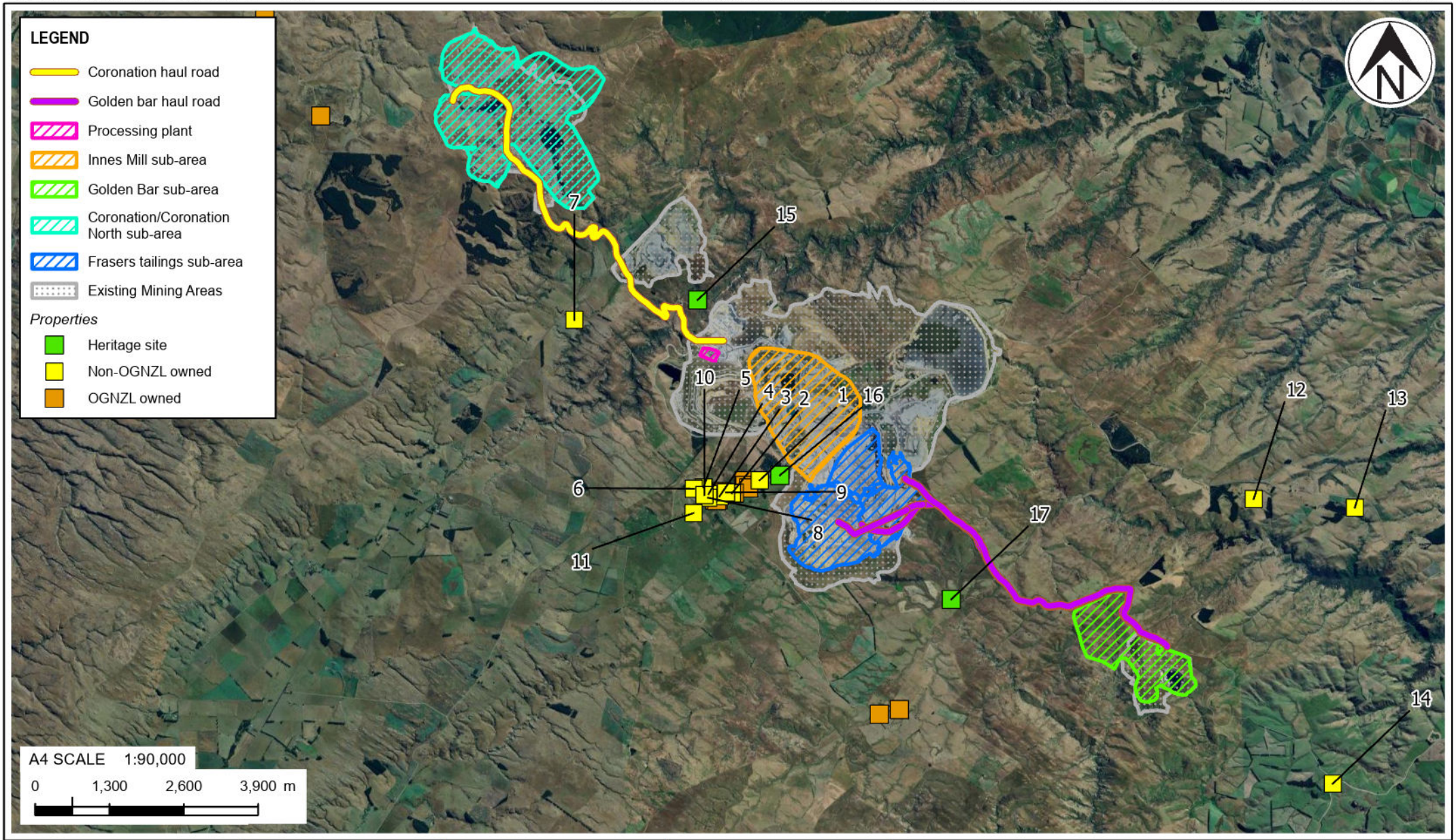
Sensitive receptors for the Project are presented below in Table 5.1 and on Figure 5.1.

[5] Ministry for the Environment (2016) ''Good practice guide for assessing and managing dust'. Available online at: https://environment.govt.nz/publications/good-practice-guide-for-assessing-and-managing-dust/

Table 5.1: Sensitive receptors

Receptor ID	Address	Receptor type	Receptor sensitivity
1	1668 Macraes Road	Residential	High
2	1726 Macraes Road	Residential	High
3	1750 Macraes Road	Recreational	Moderate–high
4	6 Hyde Street	School	High
5	16 Hyde Street	Recreational	Moderate–high
6	47 Hyde Street	Residential	High
7	406 Horse Flat Road	Residential	High
8	11 Hyde Street	Residential	High
9	2 Hill Street	Residential	High
10	15 Hyde Street	Residential	High
11	1801 Macraes Road	Residential	High
12	593 Macraes Road	Residential	High
13	659 Richie Road	Residential	High
14	800 Stoneburn Road	Residential	High
15	Golden Point Historic Reserve	Conservation / historic	Moderate
16	Gay Tan's Cottage	Historic site	Moderate
17	Murphys Flat Reserve	Historic site	Moderate

C:\Users\rich\OneDrive - Tonkin + Taylor Group Ltd\Documents\ArcGIS\Projects\Oceana Gold Macraes\SAOL GIS\Oceana Macraes\Oceana Macraes.aprx Layout: Figure 5.1 - Sensitive Receptors 2026-Aug-05 10:45 am Drawn by RICH



Tonkin+Taylor

www.tonkintaylor.co.nz

Exceptional thinking together

NOTES:
Google Satellite: Google

REVISIONS	NO.	BY
First version (14/07/26)	0	RIICH

PROJECT No.	1101342	
DESIGNED	RICH	AUG.26
DRAWN	RICH	AUG.26
CHECKED		
APPROVED	DATE	

CLIENT **OCEANAGOLD (NEW ZEALAND) LIMITED**

PROJECT **MP4 AIR QUALITY ASSESSMENT**

TITLE SENSITIVE RECEPTORS

SCALE (A4) 1:90,000 FIG No. FIGURE 5.1 REV 0

C:\Users\rich\OneDrive - Tonkin + Taylor Group Ltd\Documents\ArcGIS\Projects\Oceana Gold Macraes\SAOL GIS\Oceana Macraes\Oceana Macraes.aprx Layout: Figure 5.2 - Sensitive Receptors Village 2026-Aug-05 10:45 am Drawn by RICH

Tonkin+Taylor
www.tonkintaylor.co.nz
Exceptional thinking together

NOTES:
Google Satellite: Google

REVISIONS	NO.	BY
First version (14/07/26)	0	RICH

PROJECT No.	1101342	
DESIGNED	RICH	AUG.26
DRAWN	RICH	AUG.26
CHECKED		
APPROVED	DATE	

CLIENT **OCEANAGOLD (NEW ZEALAND) LIMITED**
PROJECT **MP4 AIR QUALITY ASSESSMENT**
TITLE SENSITIVE RECEPTORS - MACRAES VILLAGE
SCALE (A4) 1:8,000 FIG No. FIGURE 5.2 REV 0

5.3 Meteorology and topography

5.3.1 Topography

Macraes sits within a rural upland landscape of fluvially dissected rolling hills of moderate relief and with characteristic broad ridge crests, being the coastal extent of central Otago's basin and range topography. Regional landscape features include the Nenthorn Valley, Taieri Ridge and Taieri Valley. The Rock and Pillar Range lies to the south and west, the Shag Valley and Horse Range lie to the east, with the coastal hills and extinct volcanic cones of Palmerston and Waikouaiti to the south.

5.3.2 Wind

OGNZL operates the following two meteorological stations:

- The 'mine site' station (DG03), located close to the OGNZL site offices; and
- The 'village site' station (DG15), located close to the Macraes Village.

Wind roses from both of these stations are presented below in Figure 5.3. Photographs of the two stations are provided in Figure 5.4.

Wind roses graphically summarise wind speed and direction data over a period of time. The petals of the wind rose show the direction that winds come from – their length indicating the frequency of winds from that direction. The different colour bands within each petal indicate the frequency distribution of wind speeds for each direction.

The village meteorological station is located approximately 1.2 km south of the mine meteorological station. Though they are close in proximity, there are differences in the observed meteorological conditions. A review of recent Ambient Air Monitoring Reports (Beca 2024) submitted to the Otago Regional Council (ORC) has identified that the mine site station is incorrectly aligned to magnetic north, rather than true north. The wind rose for the mine site station presented in Figure 5.3 has been corrected for this. Overall, the corrected wind roses for the two meteorological stations show similar wind patterns.

Due to the close proximity of the two stations, and the identified direction issues with the mine site station, it was determined that the data for the village site would be used to inform the remainder of this assessment.

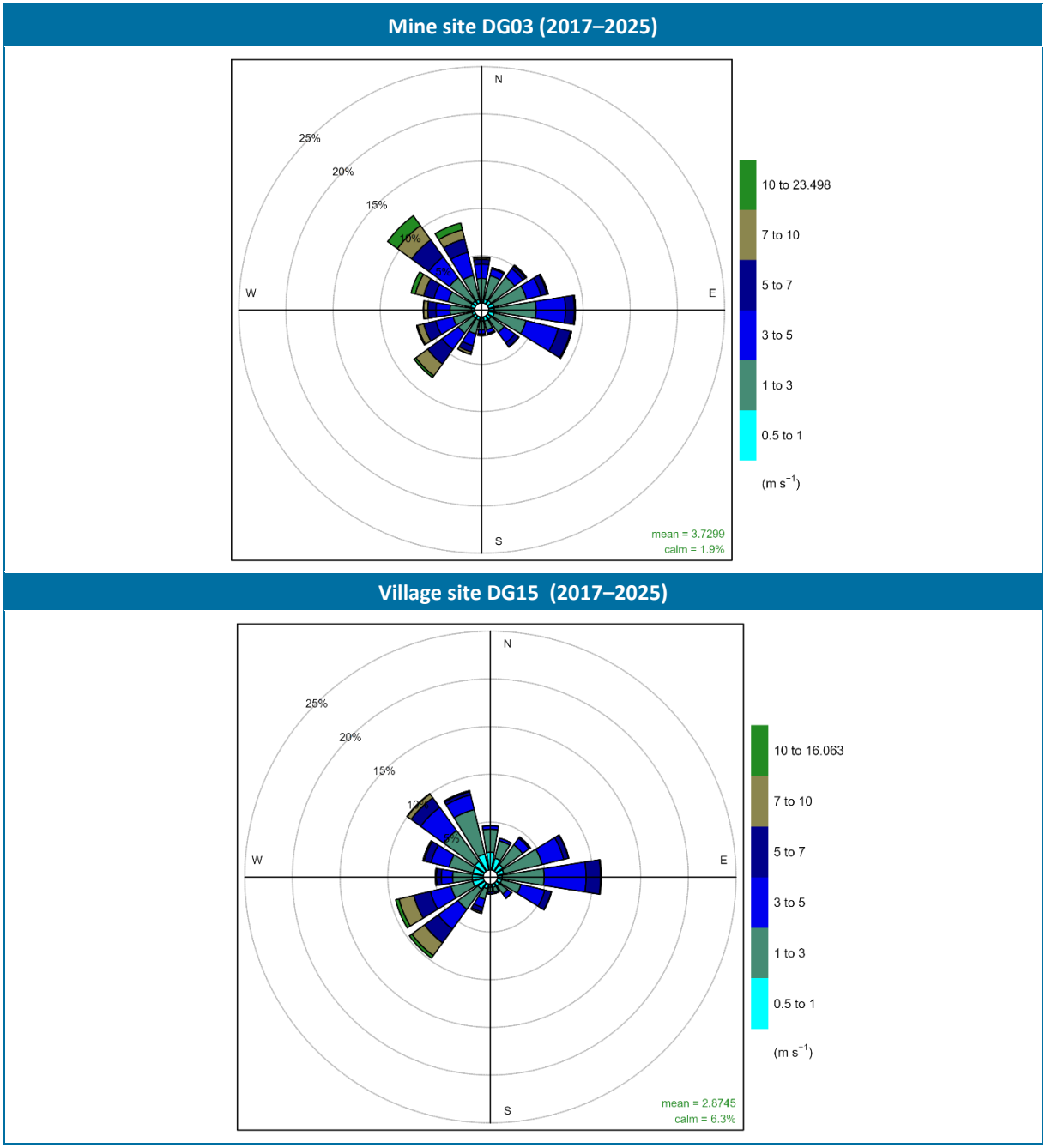


Figure 5.3: Wind roses for the Mine site and Village site meteorological stations 2017–2025 (data for the Mine Site corrected from magnetic north to true north).

Mine site (DG03)

Village site (DG15)

Figure 5.4: Photographs of the two meteorological stations.

Figure 5.5 shows wind roses by time of day for the Village site, showing the wind patterns for early morning, daytime and sunset to sunrise. From this there is a clear pattern of stronger winds during daytime hours, with winds tending more from the east.

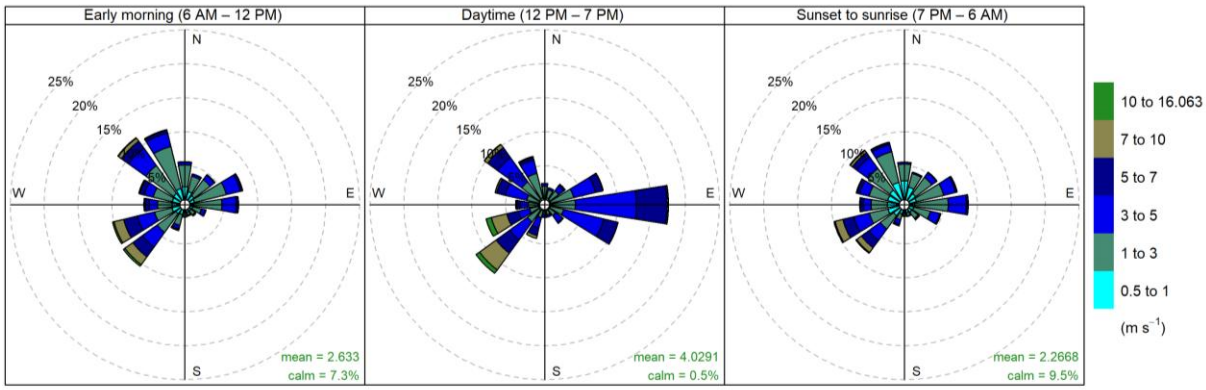


Figure 5.5: Diurnal pattern of wind roses for the Village site.

5.3.3 Rainfall

Dust generation can be suppressed on days when there is sufficient rainfall. Accordingly, it is relevant to understand the amount of rainfall a location experiences.

Rainfall measured at the Mine site (DG03) has varied in recent years between 575 mm/year and 1,047 mm/year as illustrated in Figure 5.6. On average the rainfall over this period is approximately 700 mm/year.

The variation in monthly rainfall is illustrated in Figure 5.7. This shows that winter months (with the exception of July which is likely to be an outlier due to an isolated rainfall event in 2022) are generally drier, with rainfall rates peaking in mid to late spring and then reducing through summer and autumn months.

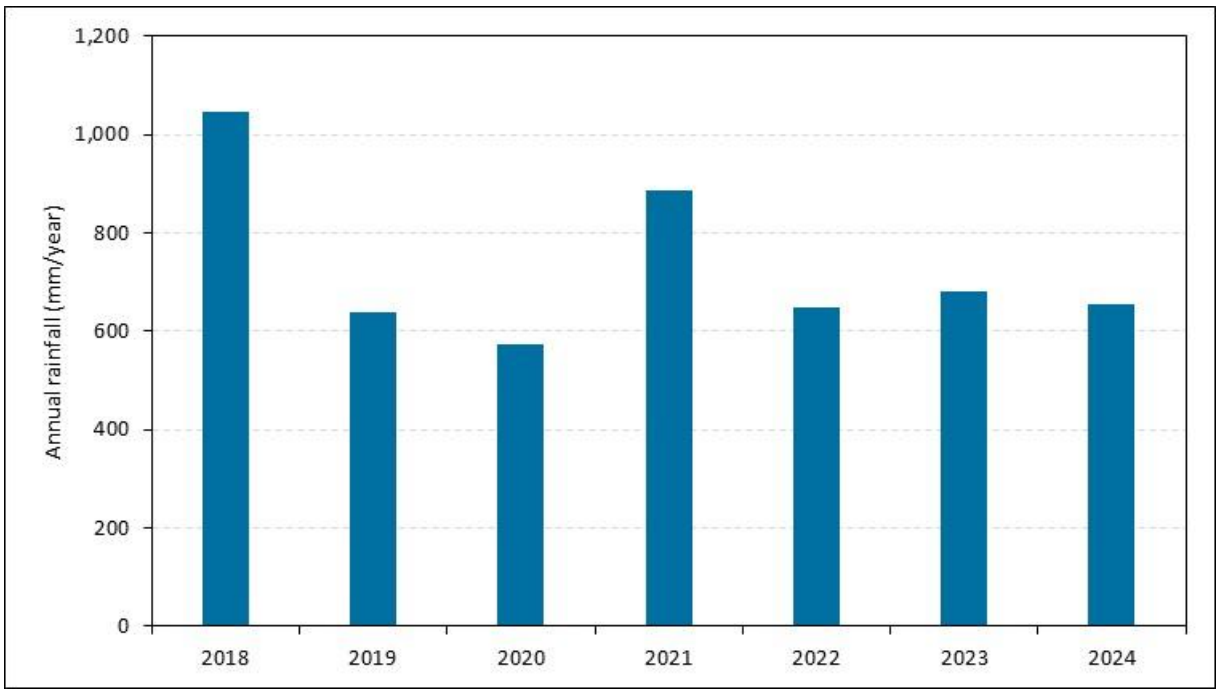


Figure 5.6: Annual rainfall as measured at DG03 between 2018 and 2024.

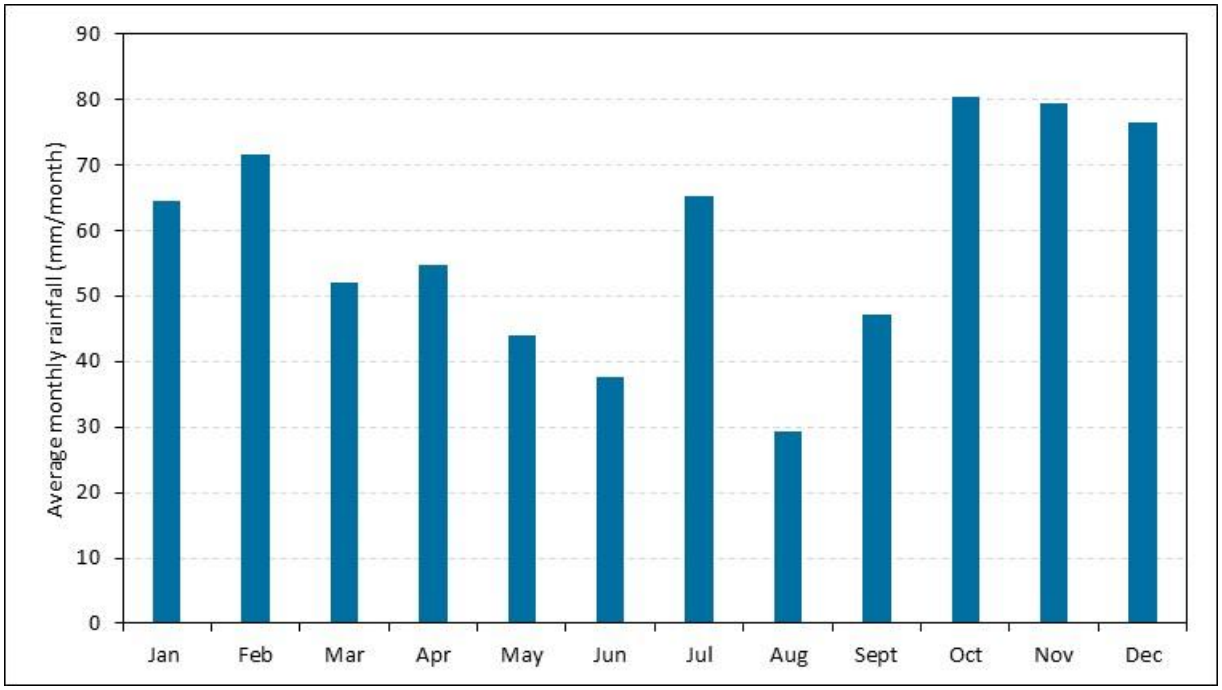


Figure 5.7: Average monthly rainfall as measured at DG03 between 2018 and 2024.

Variation in monthly ambient temperature measured at the Mine Site (DG03) is illustrated in Figure 5.8. This shows that January and December are the warmest months, reaching approximately 26.5 °C. Winters by comparison reach the lowest temperatures through June to August each year.

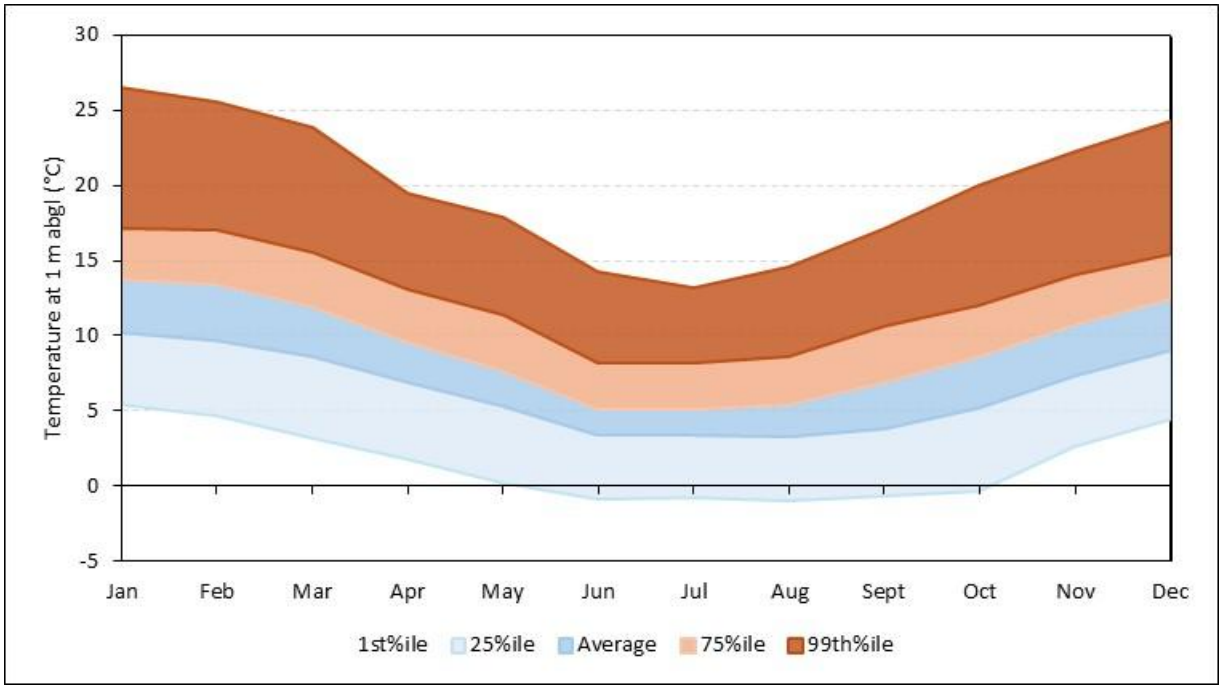


Figure 5.8: Variation in ambient temperature by month as measured at DG03 between 2018 and 2024.

5.4 Air quality monitoring

Air quality monitoring that measures dust deposition rates and total suspended particulate matter is carried out in accordance with the requirements of a number of OGNZL's resource consents for the Macraes Operation. Details of this monitoring and a summary of the data are provided in Section 6.

5.5 Airshed

The Project is not located within, or near, any airshed gazetted under the Resource Management (National Environmental Standards for Air Quality) Regulations 2004 and is therefore within the 'remainder of the Otago region' airshed. This region-wide airshed[6] is not a polluted airshed. The nearest gazetted airshed, at Palmerston, is approximately 21 km southeast of the Project area and would not be affected by Project emissions.

[6] The Otago region excluding the land covered by any gazetted airsheds.

6 Review of monitoring data

6.1 Overview

OGNZL currently undertakes multiple types of air quality and meteorological monitoring as part of its existing resource consents, including:

- Dust deposition at 16 sites.
- Total Suspended Particulate (TSP) monitoring at the village site (DG15) and at monitoring site[7] near to DG07 (Woolshed TSP).
- Meteorological monitoring at two locations (mine site and village site, see Section 5.3 for further information).

The location of the various monitoring sites is shown in Figure 6.1.

The monitoring data are analysed in the following subsections and used to support the assessment of the Project. It is proposed that this existing monitoring will be retained under the Project, albeit that the monitoring of TSP at the village site is replaced with an instrument to continuously monitor PM_{10}. The PM_{10} instrument should be an equivalent reference standard instrument, which will not be affected by relative humidity as has been the case with the existing TSP monitor. The shift to continuous monitoring of PM_{10} will still enable a real-time response to elevated dust levels when paired with appropriate trigger concentration values. It will also enable measured concentrations to be compared with applicable health-based standards and guidelines for PM_{10}.

6.2 Total suspended particulate

TSP is often used as a measure of dust concentrations suspended in the air. Where the data are recorded on a short time scale (i.e., in the order of 1 hour), it can be used to inform dust management measures enabling a proactive response to conditions before dust results in adverse nuisance effects.

The conditions of Permit RM10.351.52.V4 require the measurement of TSP at agreed locations. Historically, monitoring has been undertaken at three different locations and continues at the Village site (DG15) (see Table 6.2). The conditions include a limit on 24-hour average TSP, as well as 1-hour and 24-hour trigger concentration values. The purpose of the trigger levels is as a management tool, requiring an investigation of likely causes and an appropriate response (where the Mine is the likely source). The existing limit and trigger values relating to the DG15 monitoring site are set out in Table 6.1.

The 1-hour average trigger value was added as part of a change to consent conditions in November 2025. Accordingly, annual reports to date have not been required to consider the 1-hour average concentration trigger values.

Table 6.1: Consent concentration values for TSP monitoring

Parameter	Averaging period	Concentration	RM10.351.52.V4 Condition
Consent trigger value	1-hour average	250 µg/m³	12A.(a)
Consent trigger value	24-hour average	80 µg/m³	12A.(a)
Consent limit	24-hour average	120 µg/m³	9

[7] TSP monitoring at DG07 was not undertaken between 2024 and early 2025 due to technical issues. However, the instrument has been operating since early 2026.

The TSP trigger values in Table 6.1 are the same as the recommended values given by MfE (2016) in its 'Good Practice Guide for Assessing and Managing Dust' for locations of a moderate sensitivity to dust impacts.

Historically, the consents for the site required TSP concentrations to be measured using an instrument referred to as a 'High-volume Gravimetric Sampler'. This type of instrument is only able to measure 24-hour average concentrations, and the filters need to be manually collected and sent away for analysis. The long sampling period and delay before results are obtained mean that this type of monitoring is not helpful for proactive dust management. For this reason, the High-volume Gravimetric Sampler was replaced with an instrument referred to as a 'nephelometer' that can record concentrations in real time. Nephelometers measure light scattering resulting from particles to determine a concentration value.

In practice, nephelometer instruments are sensitive to certain meteorological conditions (particularly high humidity) giving rise to false readings. This is recognised in Condition 12A.(b) where it provides for there being no action required for OGNZL when a trigger concentration is recorded and where:

- Relative humidity is greater than 95%; and/or
- Prevailing wind is from the southeast to northwesterly (135 degrees to 315 degrees) – i.e., it is not from the direction of the Mine.

Otherwise, the trigger event is considered to be valid, and the consent holder must investigate the cause of the trigger event and, if required, implement additional dust control measures.

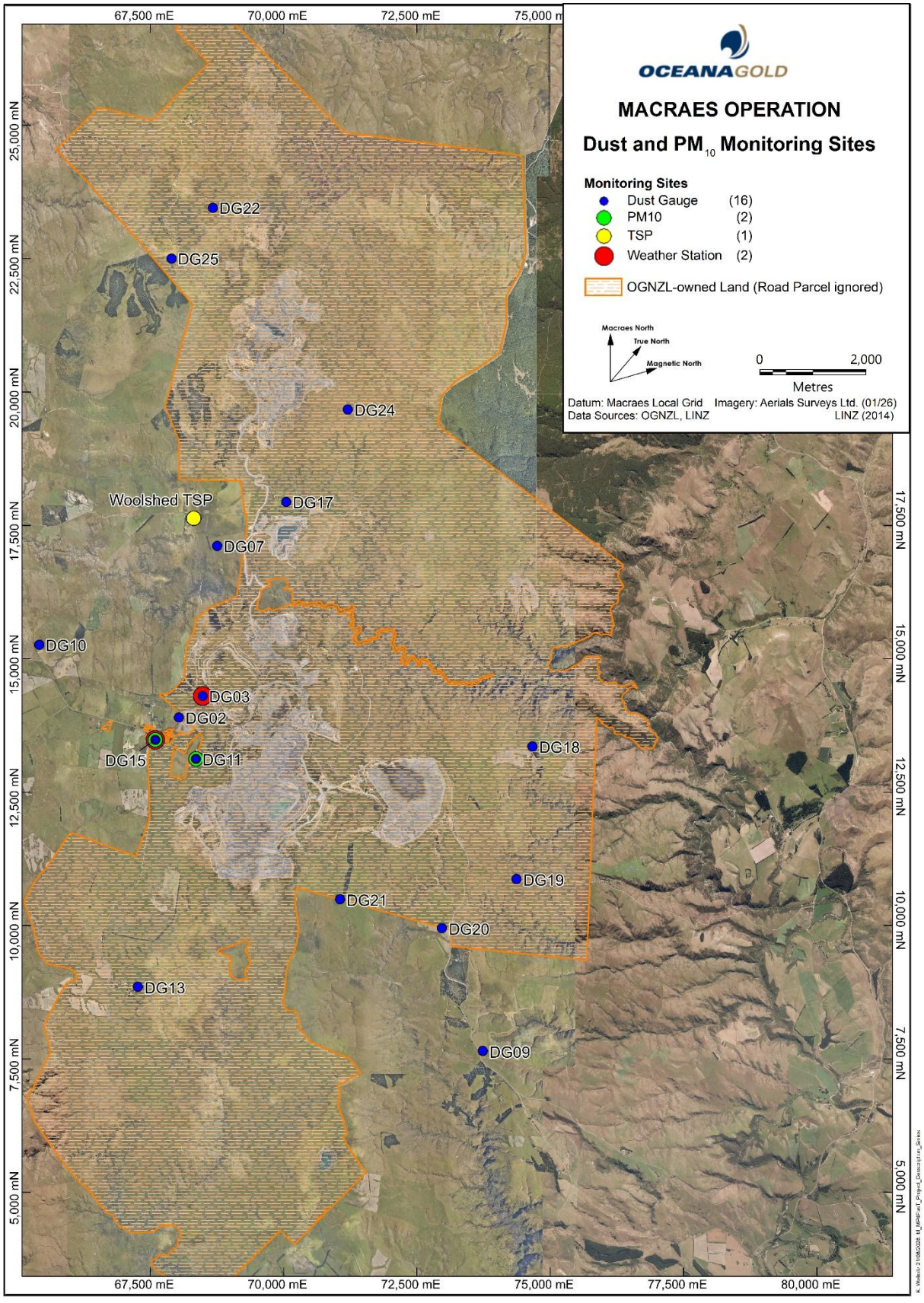


Figure 6.1: Monitoring locations.

Table 6.2: TSP monitoring sites

Site ID	Location of monitor	Notes
DG07	406 Horse Flat Road	Monitor malfunctioned in August 2023 and was reinstated in early 2026.
DG11	Across from 1688 Macraes Road	Monitoring ceased in August 2023 following agreement with ORC.
DG15	Behind 1757 Macraes Road, Macraes across from Stanley's Hotel	Monitoring ongoing and proposed to continue for PM_{10}. See Section 8.8 for full recommendations.

The results of the 24-hour average TSP concentrations are presented as a time-series graph in Figure 6.2. This graph shows a significant number of trigger events (≥ 80 µg/m³) and exceedance events (≥ 120 µg/m³). However, through analysis of the hourly data for these events, all but two dates were the result of the instrument being affected by high relative humidity (≥ 95%), meaning that those events are not real. The two dates with valid TSP measurements were as follows:

- 11 June 2021: This event recorded high hourly concentrations between 2 am and 7 am, when the relative humidity was approximately 80%. The winds were from 235°N (i.e., the monitor was downwind of the mine) and winds were relatively light (average of 2.7 m/s). The ambient temperature at this time was approximately 1 °C.
- 14 June 2021: This event recorded high hourly concentrations between 8 and 11 am, and later between 6 and 9 pm. The relative humidity over these hours was on average 56%, with winds from 290°N (downwind of the mine). Wind speeds were approximately 8 m/s.

The measured 1-hour average TSP concentrations are similarly presented as a time-series graph in Figure 6.3. It should be noted that the requirement for responding to 1-hour average TSP trigger concentrations only came into force following the most recent variation to resource consent RM10.351.52.V4 in 2025. Notwithstanding this, the framework set out in 12A.(a) of the consent provides a pragmatic basis for filtering the data based on whether the measured concentration was associated with high relative humidity (meaning it is not real) and then whether the mine was upwind of the monitor. Figure 6.3 highlights that virtually all of the 1-hour average concentrations above 250 µg/m³ occurred when the relative humidity was 95% or greater, meaning the measurements are not real – this is illustrated by the grey data points above 250 µg/m³ in the graph. Only a small number of occasions occurred when measured concentrations were above 250 µg/m³ and when relative humidity was less than 95% and the monitor was downwind of the Mine – these are denoted by orange-coloured dots in the graph. This includes 11 and 14 June 2021, which are discussed above in relation to the 24-hour average concentrations. It also includes two hours in 2025. Analysis of these two hours in 2025 is as follows:

- 6 am on 21 March 2025. This was associated with relatively high relative humidity (82%) and low wind speeds (2.6 m/s). However, the preceding hours all recorded high relative humidity in excess of 95%. Given this context, it is concluded that the instrument was most likely affected by high humidity and the resulting measured concentration was not real.
- 2 am on 7 November 2025. This was associated with high relative humidity (92%) and light winds (2 m/s). Based on this, it is concluded that the instrument was most likely affected by high humidity and the resulting measured concentration was not real.

While the 1-hour average monitoring results show that the instrument is sensitive to high humidity, the instrument is capable of detecting 'real' dust events during dry weather when the relative humidity is lower and when the potential for dust generation is greatest. In this regard, it is important to note that no such dust events have been recorded to date.

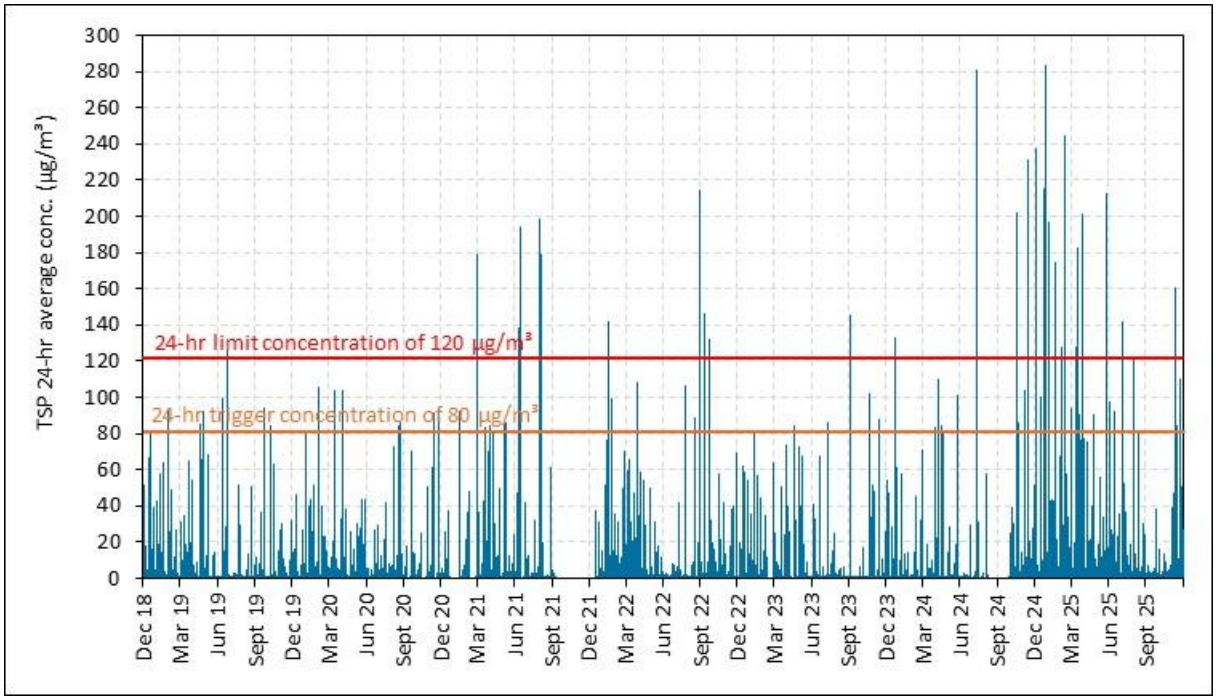


Figure 6.2: 24-hour average TSP concentrations showing trigger and limit concentrations (concentrations ≥ 80 and 120 µg/m³).

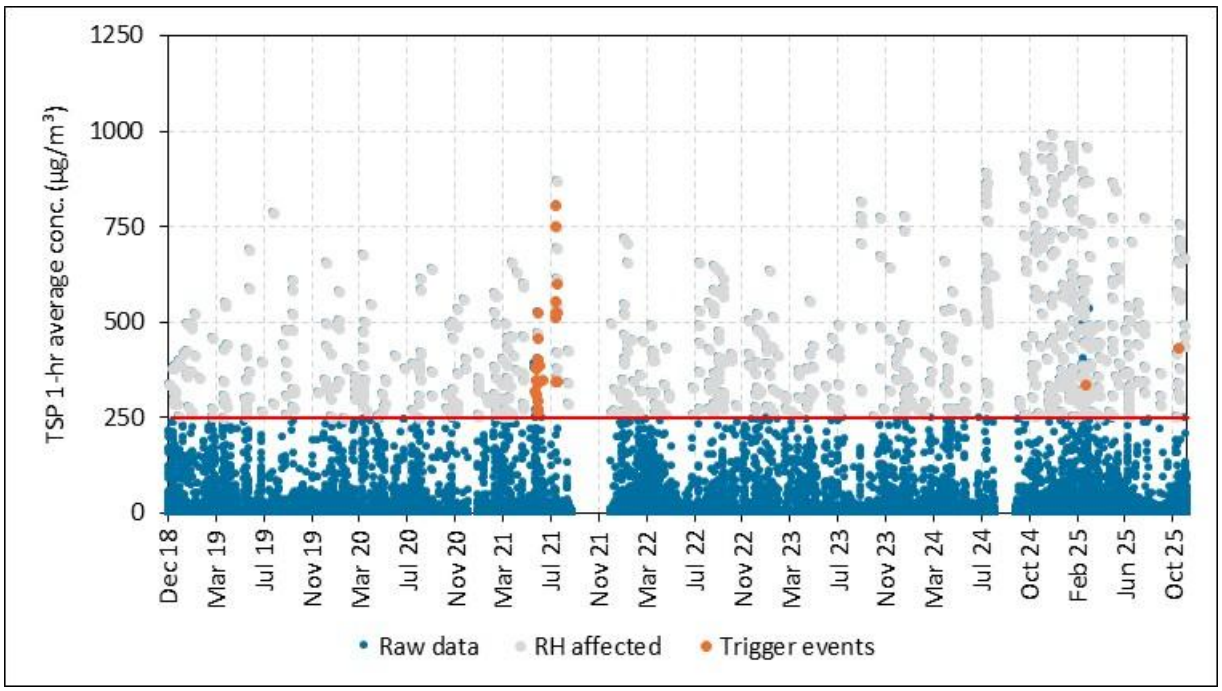


Figure 6.3: 1-hour average TSP concentrations showing trigger events (concentrations ≥ 250 µg/m³) excluding events where the relative humidity was 95% or greater and excluding winds from 135°N to 315°N. Note, the trigger requirements for 1-hour average TSP concentrations were only required by conditions of consent in November 2025.

6.3 Dust deposition monitoring

Monitoring of the rate of insoluble dust deposition is currently carried out at 16 sites. Monitoring at the majority of these sites is carried out to meet the requirements of the following resource consents:

- 96785_V5
- RM16.138.19.V2
- RM12.378.15
- RM10.351.52.V4

Dust deposition monitoring has limited value for characterising short-term dust events, which are better characterised by TSP or PM_{10} monitoring described in Section 6.2. However, it is useful for identifying long-term trends in dust management and impacts.

The monitoring results for sites that are subject to consent limits are assessed against a dust deposition limit of 3 g/m²/30 days above background. For this reason, monitoring is also carried out at background sites, not impacted by mine site emissions. At some monitoring sites, the deposition rate is allowed to be exceeded twice per calendar year.

The following monitoring sites are designated as background sites to determine background deposition rates:

- DG09
- DG10
- DG24

A number of dust monitoring sites located within the Mine site are operated by OGNZL in addition to any consent requirements and are therefore not subject to the consent conditions. These are DG03, DG13, DG18 and DG19. Table 6.3 summarises the monitoring sites and applicable consent limits.

An analysis of the dust deposition rate data for the period from 2015 to 2024 (inclusive) is provided in Appendix B. Box and whisker plots of the distribution of dust deposition rates at each site have been prepared. These show that deposition rates meet the criterion of 3 g/m²/30 days above background most of the time.

Compliance with the consent limit and the allowed number of exceedances per year is shown in Table 6.4. This shows generally good compliance, although:

- Site DG15 (the Macraes Village site) recorded 1 exceedance in each of 2017, 2020, and 2022 (i.e., one measured deposition rate greater than 3 g/m²/30 days above background in each year); and
- Site DG17 recorded 3 exceedances in 2020 (i.e., 1 exceedance more than the allowable number of 2).

Table 6.3: Dust deposition monitoring sites

Site ID	Location of monitor	Consent limit (g/m²/30-days above background)	Monitoring site type	Allowed exceedances per calendar year RM10.351.52.V4	Allowed exceedances per calendar year
Sites beyond mine boundary					
DG02	Back of Macraes	3	Compliance		
DG07	406 Horse Flat Road	3	Compliance	2	2
DG15	Behind 1757 Macraes–Road, Macraes across from Stanley's Hotel	3	Compliance		
DG20	East of Frasers East Rock Stack	3	Compliance	2	2
DG21	East of Frasers South Rock Stack	3	Compliance	2	2
DG22	North of Coronation	3	Compliance		2
DG25	North of Coronation North Pit	3	Compliance		2
DG09	Control 7 km ex H/W 85	-	Background		
DG10	Control 3.25 km ex Macraes	-	Background		
DG24	East of Coronation	-	Background		
Sites located within mine boundary					
DG03	South of Mixed Tailings Dam beside a gravel section of Golden Point Road	N/A	Additional		
DG11	Expansion drilling site, across from 1700 Macraes Road	3	Compliance	2	2
DG13	Red Bank Rd	N/A	Additional		
DG17	Horse Flat Rd	3	Compliance†		2
DG18	North of Top Tipperary Tailings Storage Facility	N/A	Additional		
DG19	East of Top Tipperary Tailings Storage Facility	N/A	Additional		

Note: N/A = not applicable due to these sites not being subject to a consent limit.
†Compliance with the deposition limit for DG17 is only required for Deepdell North (RM20.024.12)

Table 6.4: Exceedances of 3 g/m²/30 days by site and year

Site	Limit	Number exceedances allowed	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Beyond Mine Boundary – compliance monitoring site												
DG02	3											
DG07	3	2		1			1	2				
DG15	3				1			1		1		
DG20	3	2										
DG21	3	2		1								
DG22	3	2			1			2				
DG25	3	2			1	1						
Within Mine Boundary												
DG11	3	2										
DG17	3	2	1		1		1	3*	1			

Note: Values highlighted in red denote an exceedance of the consent limit for that respective site and allowable number of exceedances. * The compliance limit for DG17 only relates to RM20.024.12.

Time series plots of the dust deposition rate above background are presented in Figure 6.4 and Figure 6.5 for the sites beyond the Mine boundary and within the Mine boundary respectively. From these plots the following is noted:

- Deposition rates across a number of sites were elevated in 2016, 2017, and 2020, and to a lesser degree in 2018 and 2022.
- Since the start of 2022, there has been a downward trend in measured dust deposition rates above background for all sites.

The annual reports for 2017 and 2022 note that the recorded exceedances at DG15 (in May 2017 and in January 2022) were as a result of contamination with bird droppings and that the exceedance was unlikely to have been the result of mining activities.

With regard to the exceedance recorded in February 2020 at DG15, the annual monitoring report describes this event as coinciding with mining activities at Frasers Pit (approximately 2 km east of DG15) and Macraes–Dunback Road realignment works (approximately 1.5–3.5 km NE of DG15). However, these distances are significantly further than would be expected to influence deposited dust and were not replicated at the DG11 monitoring site; the monitoring site located west of Frasers Pit and east of DG15. The annual report also describes urea spreading as occurring in February on a paddock near to DG15 (approximately 280 m southeast). The report concluded that *"… while mining activities cannot be ruled out as a contributor to the deposited dust exceedance measured at DG15, it is very likely that other activities in the Macraes Flat township in close proximity to the monitoring site, that have not been identified and/or potentially the spreading of urea in the nearby paddock, were the main contributors to the exceedance."*

Given the above explanation of measured exceedances, it is considered that mining activities have complied with the dust deposition rate consent limits, indicating that dust emissions associated with mining activities have been appropriately controlled.

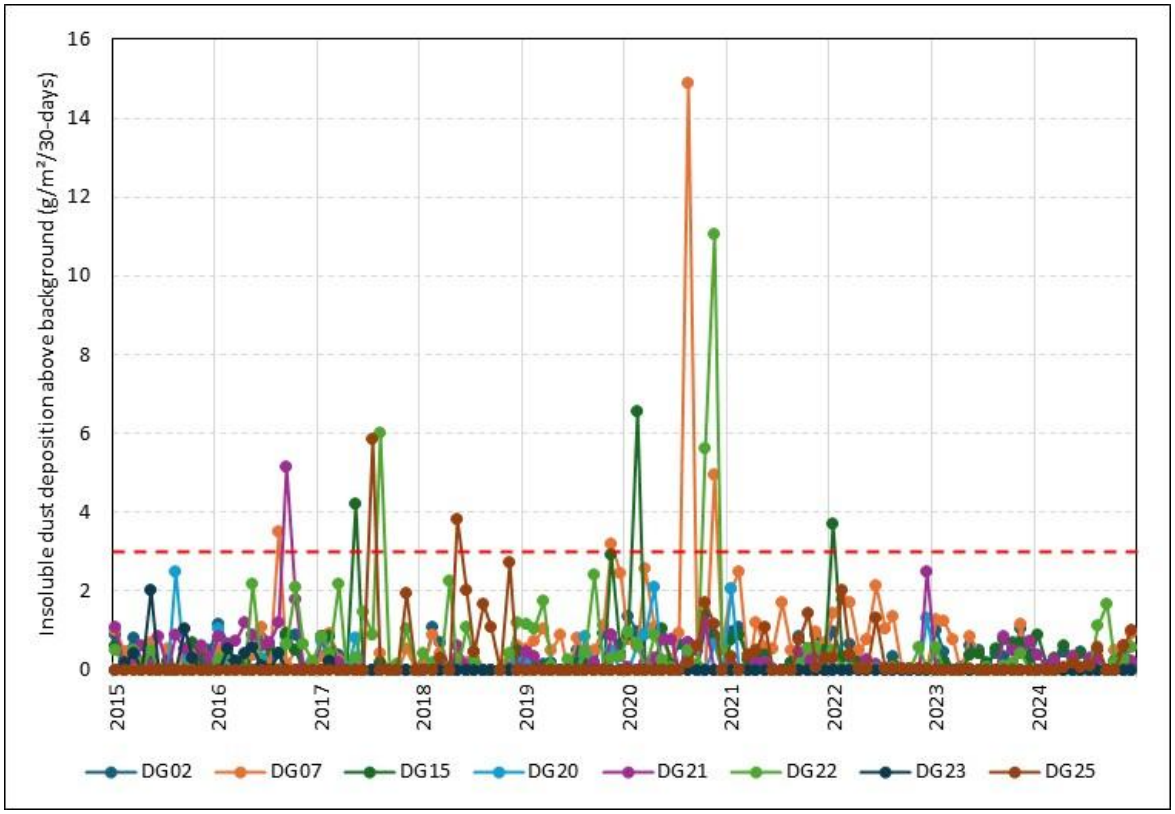


Figure 6.4: Monthly insoluble dust deposition rates above background for monitoring site locations beyond the mine boundary.

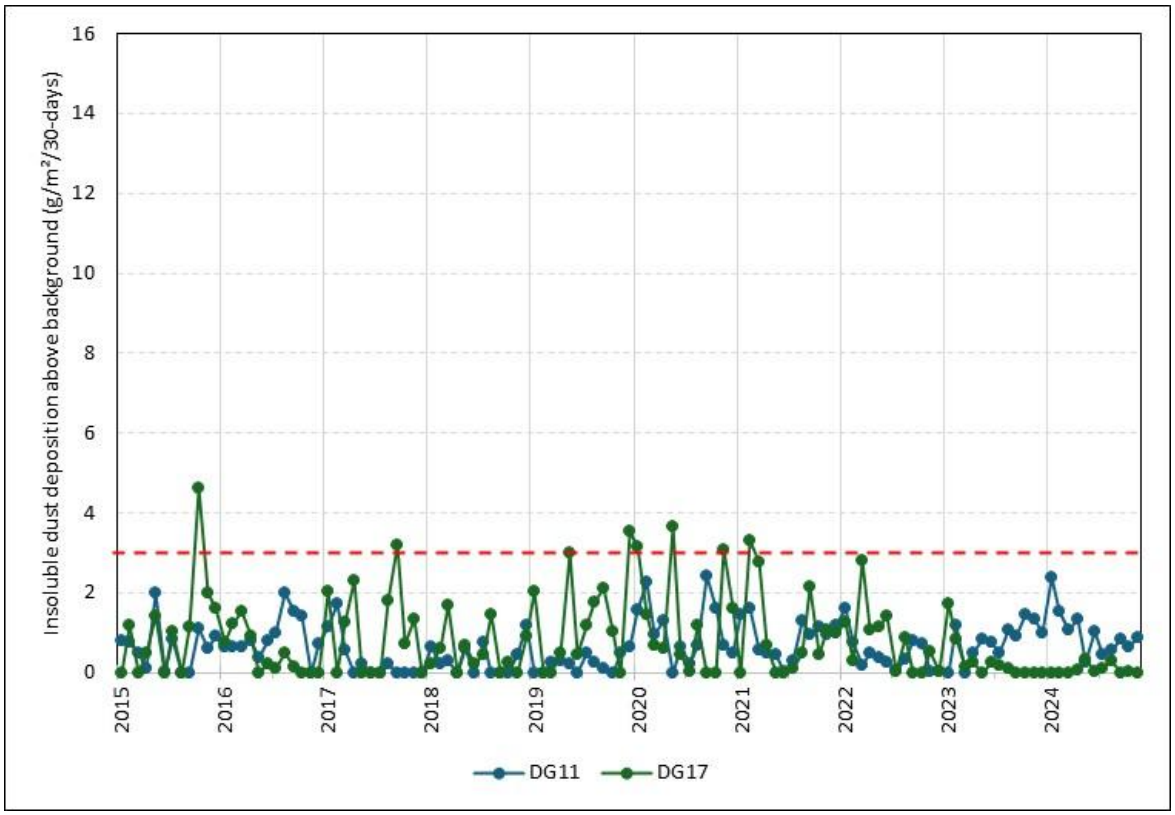


Figure 6.5: Monthly insoluble dust deposition rates above background for monitoring site locations within the mine boundary (excluding additional sites).

7 Mitigation measures

7.1 Dust control for mining activities

The following control measures are described in detail in the existing air quality management plan (AQMP – Appendix C) and implemented as necessary onsite to control and manage dust from mining activities:

Unpaved surfaces (haul roads, waste rock stacks, tailings impoundment surfaces, pits)

- Keep haul roads and exposed surfaces damp during dry conditions with water carts8 or fixed sprinklers. Monitor daily during dry conditions to ensure water cart and/or sprinkler operation is effective.
- Limit the area of exposed surfaces.
- Retain as much vegetation as possible.
- Regular haul road maintenance at the tailings impoundment, in the pit, stockpile areas and at waste rock stacks, such as repair of potholes and the laying of fresh gravel or surfacing material.
- Cover exposed fine fill materials with coarse materials where practicable.

Vehicles (light vehicles, dump trucks, other earthmoving machinery)

- Minimise traffic movements and control vehicle speeds to a maximum of 60 km/h on haul roads. During particularly dry weather when there is a risk of dust being carried towards off-site sensitive receptors, water suppression using water carts is prioritised.
- Adhere to load sizes to avoid spillages.
- Minimise travel distances through appropriate site layout and design.

Stockpiles (topsoil, brown rock, ore, waste rock)

- Limit the height and slope of stockpiles to reduce wind entrainment.
- Orientate stockpiles to maximise wind sheltering.
- Minimise drop heights from excavator and loader buckets when loading material into trucks or hoppers.
- Vegetate stockpiles of any materials that are to be left undisturbed for more than three months.
- Maximise shelter from winds as practicable.

Miscellaneous

- Revegetate exposed soil with appropriate vegetation as soon as practicable.
- Install wind fences or barricades where practicable and appropriate.
- Minimise the area of surfaces covered with fine materials.
- Remove topsoil and loose material covering rock prior to blasting.
- Schedule potentially dusty operations where possible to avoid times of the day and year when conditions are likely to be particularly dry and windy.
- Schedule blasts to consider wind conditions.

[8] The water carts used on site are much larger than standard water carts, and currently comprise a Caterpillar 773D (approx. vol 45,000 L) and a Caterpillar 785C Water Cart (approx. vol 120,000 L).

Tailings

- Tailings deposition to be sequentially moved around the dam, restricting the likelihood of windborne dust generation created by the tailings beach drying out.
- A tailings wetting system can be used to keep the tailings surface damp during periods of dry and windy conditions.
- Tailings wetting systems are to have the capacity to be operational at all times when the impoundment is not active.
- Limit traffic on the tailings surface when the impoundment is inactive to preserve the crust.
- Ensure tailings wetting system can be mobilised to other areas of the impoundment where necessary to mitigate dust generation.
- Where tailings are to be excavated (such as relocation of tailings from the MTI) using dry mining methods, pre-wetting of the material is to be carried out as necessary to maintain the tailings in a damp condition. This is to be carried out at the start of each day of excavation to minimise the likelihood of dust during excavation due to the fine particle size of tails and is to be repeated as necessary during each day of excavation. Where hydraulic mining methods are to be used, the risk of dust generation is greatly reduced. However, pre-wetting of dry areas of tailings may be required from time to time during dry weather conditions.

Rock covering

- If feasible, mitigate dust generation from the tailings beach via construction of a rock covering.
- Where there is a risk of dust generation, rock mattress construction will commence as soon as practicable after cessation of tailings deposition for impoundments constructed using upstream construction methods.

Vehicle movements over exposed surfaces are the largest source of potential dust emissions associated with mining. The main control to reduce dust generation during mining activities is the use of water suppression. Water binds particles together which prevents them from being disturbed and suspended in air by wind or vehicle movements. Water carts are operated on mine haul roads following periods where there has been no rainfall, with one typically operating in each mining area.

Overall, the dust control measures in place are considered appropriate for the continued management of dust from mining activities.

7.2 Processing Plant

The Processing Plant incorporates a number of emission control measures to minimise air discharges from the various process stages. The principal air emission sources at the processing plant, and the corresponding control measures in place, are described below.

POX plant vent scrubber

As described in Section 2.2.2.5, the pressure oxidation (POX) autoclave is used to oxidise the sulphide flotation concentrate. Following discharge of the pressurised slurry from the autoclave into the flash vessel, the gases released are passed through a vent scrubber before being discharged via the POX plant stack.

The vent scrubber is a wet scrubbing system that removes SO_2, acid mist, and particulate-phase contaminants and is the primary control measure for the POX plant.

The effectiveness of the scrubber is maintained through routine monitoring of scrubbing liquor flow rates and composition, system pressure drop, along with a planned maintenance schedule to ensure the scrubber operates at design efficiency at all times.

Crushing – grizzly screen and jaw crushers

The crushing circuit is the first ore processing stage and includes static grizzly screens and jaw crushers, which can be a source of localised fugitive dust emissions.

The following measures are implemented to minimise dust emissions from the crushing circuit:

- Water spray systems are installed at the grizzly screen and jaw crusher feed and discharge points to suppress dust at key impact and transfer locations.
- Drop heights from the ROM bin to the grizzly screen and between crushing stages are minimised to reduce dust generation from material impact.
- The ROM pad surface is kept wetted during dry conditions to suppress dust from vehicle movements and ore handling in the vicinity of the crushing circuit.
- Routine inspection and maintenance of water spray nozzles to ensure dust controls remain functional and effective.

Retort oven

Following electrowinning, the gold-laden steel wool cathodes are placed in the retort oven and dried to remove residual moisture prior to smelting. During drying, mercury that has co-deposited with the gold is driven off as vapour, upon which it is condensed and collected as liquid mercury. This process controls mercury emissions that would otherwise be discharged to air from drying of the gold-laden steel wool cathodes.

The following measures are used to minimise mercury emissions associated with the operation of the retort oven:

- Routine inspection of the retort oven is performed as part of a standard operating procedure to ensure the mercury condenser associated with the retort oven is operating correctly and that the mercury collection system is functioning as intended. Maintenance on the retort oven is undertaken on an annual basis.

Barring Furnace

The barring furnace generates furnace off-gases containing fine particulate matter and trace metal vapours. Furnace off-gas is captured by a fume extraction system and directed through a small fabric filter baghouse before being discharged via the furnace stack. The baghouse removes fine particulate matter, including trace metal-bearing particles, from the off-gas prior to atmospheric discharge. The following measures are used to minimise mercury emissions associated with the operation of the barring furnace:

- The pressure drop across the baghouse is manually monitored to warn of a bag failure.
- Routine inspection and maintenance of baghouse on an annual basis.

7.3 Routine checks

Visual monitoring of the haul roads and working areas is undertaken every 12-hour shift to assess dust suppression requirements and haul and access road conditions, including the need for grading, compacting and re-sheeting.

8 Assessment of effects – mining activities

8.1 Introduction

This section provides an assessment of the effects of dust emissions from the operation of the mining phases and ore handling activities.

8.2 Assessment methodology

8.2.1 Overview

The assessment of dust effects has followed guidance from the Ministry for the Environment (MfE, 2016a) in its *Good Practice Guide for Assessing and Managing Dust,* as well as guidance published by the UK Institute of Air Quality Management (IAQM, 2016). A qualitative assessment approach has been used in accordance with these guidance documents, noting that dispersion modelling of diffuse dust sources, such as those from mines, is not recommended by the MfE guide.

The general approach which is set out in the following sections is an initial screening evaluation to identify sensitive receptor locations where a more detailed assessment is required, followed by a more detailed assessment of those locations.

The assessment of the potential health effects associated with the fine fraction of dust (PM_{10} and $PM_{2.5}$) and the respirable fraction of crystalline silica (RCS) is assessed through a comparison of the mining activity with published monitoring data.

8.2.2 Screening assessment

An initial screening assessment has been conducted to identify receptors potentially affected by dust from the Project based on their separation distance from dust-generating activities. In the absence of New Zealand guidance, separation distance guidance published by the Environment Protection Authority Victoria (EPA Victoria) is commonly used in New Zealand. EPA Victoria released its updated separation guidelines[9] on 12 August 2024. The recommendations for separation distances for activities relevant to the Project are presented in Table 8.1. As blasting is used within the open pits to break down ore and overburden, the separation distance for quarrying with blasting has been considered where relevant, in addition to the separation distance for general mining activities.

It is important to note that these separation distances are generic and do not account for local site conditions. They are intended to be used as an initial screening assessment to identify locations where a more detailed assessment is necessary.

Table 8.1: EPA Victoria (2024) applicable separation distance guidelines

Industry/activity type	Activity/definition	Scale and description	Recommended separation distance (m)
Mine of other minerals	Crushing, screening, stockpiling and conveying of other minerals	N/A	250
Quarry	Quarrying, crushing, screening, stockpiling and conveying of rock	With blasting	500

[9] EPA Victoria. Draft separation distance guideline. Publication 1949 December 2022.

8.2.3 FIDOL assessment

Nuisance dust effects can be assessed using a structured framework that considers the frequency, duration and intensity of impacts, the offensiveness of the dust (some dusts have a greater potential for soiling, such as coal dust), and the sensitivity of the location where the impacts occur. These factors are referred to as the FIDOL[10] factors and are set out by the MfE in its '*Good Practice Guide for Assessing and Managing Dust*' (MfE, 2016a) and in Policy 7.4.3 of the Regional Plan: Air for Otago (Air Plan). The FIDOL factors are described in Table 8.2.

Table 8.2: Definition of each FIDOL factor (MfE, 2016a)

Factor	Description
Frequency:	The frequency of exposure to dust impacts experienced at a given location. This depends on both the frequency of discharges and the frequency of weather conditions that could transport a discharge towards a sensitive location.
Intensity:	The intensity of dust impacts depends on the degree to which dust sources are controlled but also the separation distance between a source and the receptor.
Duration	The duration of dust impacts depends on both the duration of the discharge and how long a sensitive location is continuously downwind of the dust source.
Offensiveness	The offensiveness of the dust relates to both the character of dust and the degree of how pleasant or unpleasant the dust is. For example, some dust types such as coal dust have a greater potential for soiling.
Location	The location factor relates to the sensitivity of the location being assessed, and is typically expressed as low, medium or high. Residential dwellings are considered to have a high sensitivity, whereas rural/pastoral land is considered to have a low sensitivity.

The FIDOL assessment is a qualitative assessment which provides consideration of the potential dust impacts on sensitive locations surrounding the mining activities. The assessment is initially informed by 'screening' for sensitive locations based on their separation distance from the dust sources, using published separation distance criteria, as identified in Section 8.4.1. Those locations within the evaluation distance criteria are then assessed in more detail using the FIDOL factors, which consider the exposure of sensitive locations to certain wind conditions and terrain features to inform the likely frequency and duration of potential impacts. This focuses on the occurrence of moderate to strong winds, as these conditions can rapidly dry surfaces and generate and carry windblown dust.

The assessment is also informed by consideration of the following:

- Review of process controls.
- Analysis of site-specific meteorology and topographical features.
- Review of historical complaints to identify public concern or specific sources of nuisance dust. While an absence of complaints does not necessarily show absence of adverse effects, it can be indicative that adverse effects are not significant and ongoing.

8.2.4 Source-receptor-pathway (IAQM) methodology

The FIDOL factors are well established and used for dust assessments in New Zealand. However, as an assessment approach, their use is reliant on expert judgement when weighing the different factors and determining the degree of effects. In practice, this means different outcomes can result from different interpretations of the combination of the factors. For this reason, the approach set

[10] Frequency, Intensity, Duration, Offensiveness, Location.

out by the UK Institute of Air Quality Management (IAQM, 2016) is increasingly being adopted for dust assessments in New Zealand. While the IAQM approach is consistent with FIDOL, it applies more clearly defined criteria than FIDOL. Therefore, although an overall professional judgement is still required, the transparency of the IAQM framework means it is less reliant on interpretation than FIDOL. The IAQM approach is discussed in the following section. The IAQM (2016) published guidance on the assessment of impacts of mineral dust emissions, which is applicable for the assessment of mining operations. The assessment methodology is based on the following:

> *"…simple distance-based screening processes to identify those minerals sites where the dust impacts are unlikely to be significant and therefore require no further assessment.*
>
> *Where more detailed assessment is required, a basic assessment framework is presented which employs the Source → Pathway → Receptor approach to evaluate the risk of dust impacts and effects."*

The results from the detailed assessment method using the IAQM approach determine the degree of potential dust effects as being 'negligible', 'slight', 'moderate' or 'substantial'. We have treated this as being commensurate with a FIDOL assessment, as the IAQM method is premised on the same considerations as the FIDOL factors, but uses an objective framework to establish the degree of potential effects.

The 'source-pathway-receptor' method described by the IAQM is schematically illustrated in Figure 8.1. The method seeks to do the following:

- Understand the scale of residual emissions from the discharge source (i.e., those remaining following the implementation of dust control measures). In the context of the FIDOL factors, this is relative to the 'intensity' and 'duration' factors influenced by source emissions.
- The pathway effectiveness of environmental factors (i.e., strong dry winds, and the distance to a receptor) that govern how residual emissions may disperse and dilute in the process of being transported towards a receptor location. In the context of the FIDOL factors, this is relative to the 'intensity', 'frequency' and 'duration' factors.
- Determine the combined dust risk, taking into account the pathway effectiveness and magnitude of residual source emissions.
- Evaluate the magnitude of impact taking account of the dust impact risk and the sensitivity of sensitive receptors. In the context of the FIDOL factors, this final step takes into account the sensitivity of the 'location' being impacted.

The categorisation and decision matrices associated with the IAQM method are set out in Table 8.3 to Table 8.9.

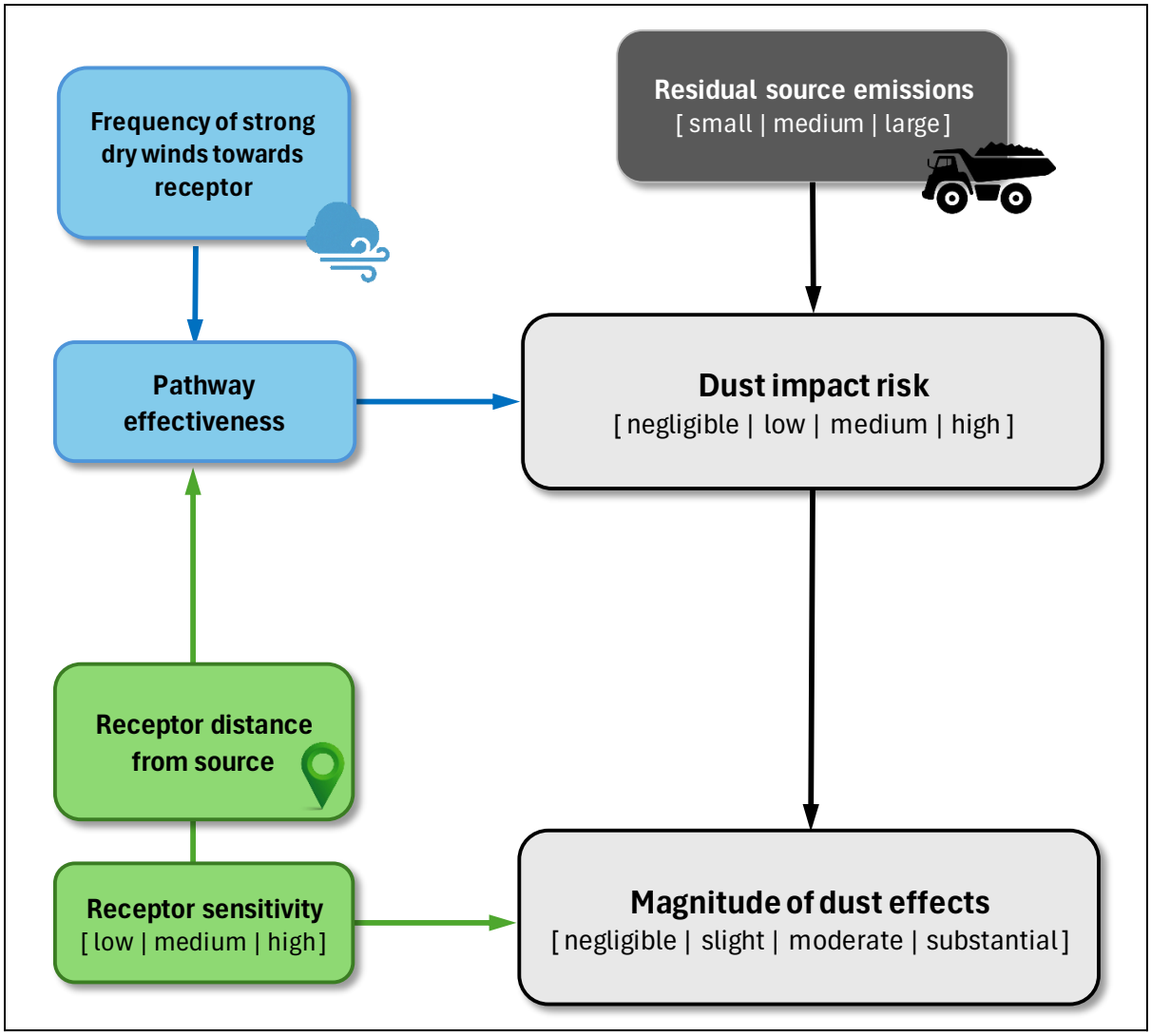


Figure 8.1: Source-pathway-receptor method for determining the magnitude of dust effect (derived by T+T from IAQM 2016).

Table 8.3: Receptor sensitivity (IAQM, 2016)

Receptor sensitivity	Example
Low	Playing fields, farmland (unless commercially sensitive horticultural), footpaths, short-term car parks and roads
Medium	Parks and places of work
High	Residential dwellings or areas, schools, community areas, places of worship

Table 8.4: Residual source emissions (adapted from IAQM 2016)

Scale of residual dust emission	Emission source activity
Small	Site Preparation and Restoration
Small	Off-site transportation
Medium	Mineral Extraction
Medium	Materials Handling
Medium	Stockpiles and Exposed Surfaces
Large	On-site transportation
Large	Mineral Processing

Table 8.5: Receptor distance source categorisation (adapted from IAQM 2016)

Distance categorisation	Distance between source and receptor
Negligible	> 1 km
Very distant	400 m – 1 km
Distant	200 m – 400 m
Intermediate	100 m – 200 m
Close	50 – 100 m
Very close	< 50 m

Table 8.6: Categorisation of exposure to strong dry winds (IAQM, 2016)

Wind exposure categorisation	Frequency of winds > 5 m/s on dry days
Very infrequent	< 1%
Infrequent	1% – 5%
Moderately frequent	5% – 12%
Frequent	12% – 20%
Very frequent	> 20%

Table 8.7: Pathway effectiveness matrix (adapted from IAQM 2016)

		Strong dry wind exposure category				
		Very infrequent (<1%)	Infrequent (1% – 5%)	Moderately frequent (5% – 12%)	Frequent (12% – 20%)	Very frequent (>20%)
Receptor distance category	Very close	Ineffective	Moderately effective	Highly effective	Highly effective	Highly effective
	Close	Ineffective	Ineffective	Moderately effective	Highly effective	Highly effective
	Intermediate	Ineffective	Ineffective	Moderately effective	Moderately effective	Highly effective
	Distant	Ineffective	Ineffective	Ineffective	Moderately effective	Moderately effective
	Very distant	Very ineffective	Very ineffective	Ineffective	Ineffective	Moderately effective
	Negligible	Very ineffective	Very ineffective	Very ineffective	Ineffective	Ineffective

Table 8.8: Dust impact risk matrix (adapted from IAQM 2016)

		Residual source emission category		
		Small	Medium	Large
Pathway effectiveness	Highly effective	Low	Medium	High
	Moderately effective	Negligible	Low	Medium
	Ineffective	Negligible	Negligible	Low
	Very ineffective	Negligible	Negligible	Negligible

Table 8.9: Magnitude of effect matrix (adapted from IAQM 2016)

		Receptor sensitivity		
		Low	Medium	High
Dust impact risk	High risk	Slight adverse effect	Moderate adverse effect	Substantial adverse effect
	Medium risk	Negligible effect	Slight adverse effect	Moderate adverse effect
	Low risk	Negligible effect	Negligible effect	Slight adverse effect
	Negligible risk	Negligible effect	Negligible effect	Negligible effect

8.3 Complaints

Complaints records can provide a general sense of community satisfaction or otherwise, noting that an absence of complaints does not necessarily mean there is an absence of community annoyance. However, an absence of complaints does indicate that dust emissions from the activity are not an ongoing substantial concern.

OGNZL provided complaints received since 2018. From these records there have been five complaints relating to dust since 2018 with two in 2018, two in 2019 and one in 2020. Four of these complaints were received from Receptor 7 – 406 Horse Flat Road. There was one complaint relating to windblown dust from the Top Tipperary Tailings Storage Facility made by a Macraes District resident who was driving past the area.

OGNZL investigations into three of these complaints indicated that there were delays in the operation of the water trucks (in one instance relating to sub-zero temperatures and risk of icing up roads). The complaints records indicate that the operation of water trucks is essential to control dust emissions from mining activities, and improvements in the management of the water trucks have led to no complaints being received in the last 6 years. The changes include an improved maintenance programme for the water carts and filling systems, and updated driver training. The remaining complaints related to dust from temporary construction work and windblown dust from a tailings storage facility during very high wind conditions.

The single complaint associated with windblown dust from the tailings storage facility occurred as a result of temporary works to dry the bed to enable a lift in the height of the tailings facility coinciding with very strong winds (approximately 70 km/h, 19 m/s). This risk has been taken into account for future temporary works designs to avoid the tailings surface drying.

8.4 Assessment

8.4.1 Screening assessment

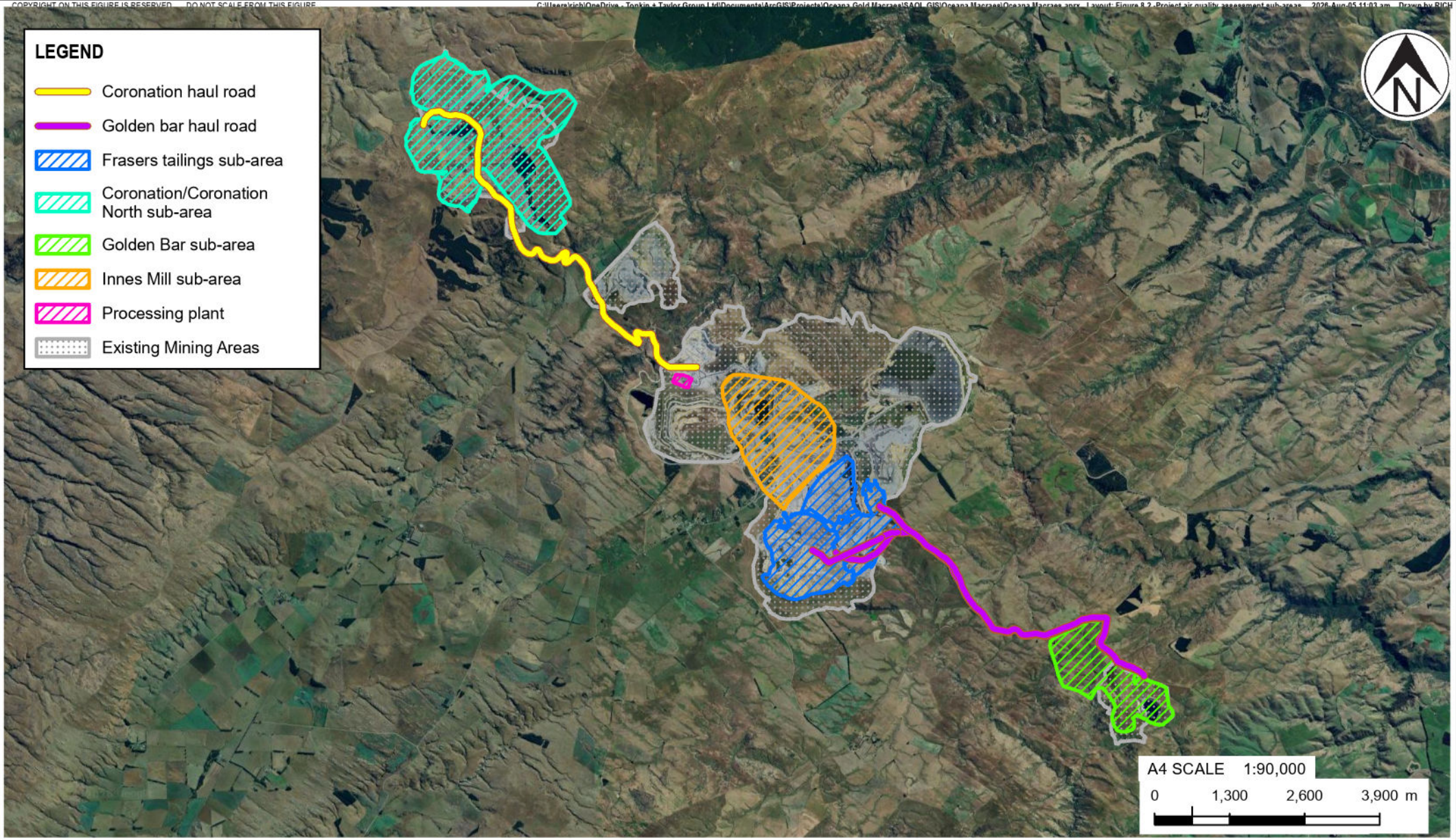
For the purpose of air quality assessment, the Project has been divided into the following air quality sub-areas due to the differing activities, scale of the proposed works, and geographical areas that they cover (refer to Figure 8.2):

- Innes Mills.
- Golden Bar.
- Coronation and Coronation North.
- Frasers tailings storage facility and waste rock stacks.
- Coronation haul road.
- Golden Bar haul road.

A screening assessment has been undertaken for each of the Project sub-areas using the EPA Victoria separation distances for ‘mining of other minerals’ (250 m) and ‘quarry with blasting’ (500 m) (from Table 8.1). These separation distances are illustrated in Figure 8.3.

The screening assessment shows that there are no sensitive receptors within these recommended separation distances and consequently a detailed assessment of potential dust effects would generally not be required. However, given the nature of the Project, a more detailed assessment has been undertaken, for completeness, using the IAQM source-pathway-receptor methodology.

C:\Users\rich\OneDrive - Tonkin + Taylor Group Ltd\Documents\ArcGIS\Projects\Oceana Gold Macraes\SAQL_GIS\Oceana Macraes\Oceana Macraes.aprx Layout: Figure 8.2 -Project air quality assessment sub-areas 2026-Aug-05 11:03 am Drawn by RICH



Tonkin+Taylor

www.tonkintaylor.co.nz

Exceptional thinking together

NOTES:	REVISIONS	NO.	BY	PROJECT No. 1101342		
Google Satellite: Google	First version (05/08/26)	0	RICH	DESIGNED	RICH	AUG.26
				DRAWN	RICH	AUG.26
				CHECKED		
				APPROVED	DATE	

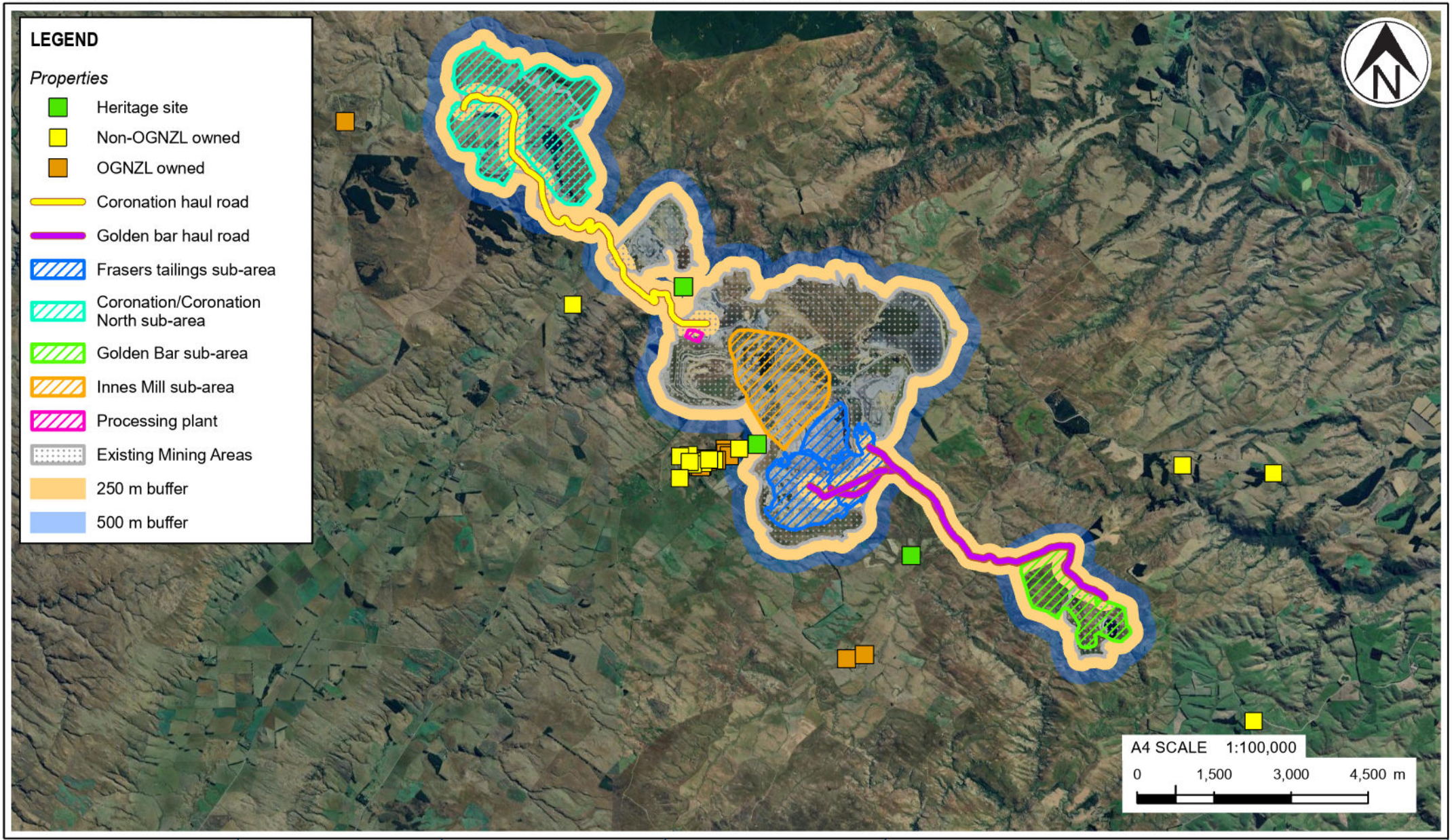
CLIENT **OCEANAGOLD (NEW ZEALAND) LIMITED**

PROJECT **MP4 AIR QUALITY ASSESSMENT**

TITLE PROJECT AIR QUALITY ASSESSMENT SUB-AREAS

SCALE (A4) 1:90,000 FIG No. FIGURE 6.1 REV 0

C:\Users\rich\OneDrive - Tonkin + Taylor Group Ltd\Documents\ArcGIS\Projects\Oceana Gold Macraes\SAOL GIS\Oceana Macraes\Oceana Macraes.aprx Layout: Figure 8.3 - Screening Evaluation 2026-Aug-05 11:07 am Drawn by RICH



Tonkin+Taylor

www.tonkintaylor.co.nz

Exceptional thinking together

NOTES:
Google Satellite: Google

REVISIONS	NO.	BY
First version (DD/MM/YY)	0	XXXX

PROJECT No.	1101342	
DESIGNED	RICH	AUG.26
DRAWN	RICH	AUG.26
CHECKED		
APPROVED		DATE

CLIENT **OCEANAGOLD (NEW ZEALAND) LIMITED**

PROJECT **MP4 AIR QUALITY ASSESSMENT**

TITLE SCREENING EVALUATION

SCALE (A4) 1:100,000 FIG No. FIGURE 8.3 REV 0

8.4.2 Source-pathway-receptor assessment

8.4.2.1 Overview

The following sections present assessments undertaken using the IAQM source-pathway-receptor approach for each of the Project sub-areas. The screening assessment identified that there are no sensitive receptors within the recommended separation distances (i.e. there are no receptors expected to be affected by dust emissions, and this more detailed assessment is only carried out for completeness). Consequently, an inclusive receptor approach has been used and receptors at distances up to 1 km from the Project sub-areas have been considered.

8.4.2.2 Innes Mills

The nearest identified sensitive receptor to the Innes Mills sub-area is Receptor 1 – 1668 Macraes Road, approximately 605 m west at the start of Macraes Village. The next nearest sensitive receptors are other residences within Macraes Village ranging from 1,150 m to 1,675 m away. Golden Point Reserve is located approximately 1,285 m north of the Innes Mills sub-area. The frequency of strong, dry winds from the sub-area towards these sensitive receptors is very low (<1% for most dwellings and up to 1.27% for the maximum receptor).

The IAQM results for Receptor 1 are summarised in Table 8.10 and Table 8.11. The resulting dust impact risk is categorised as negligible and the magnitude of effects is assessed as negligible effect when using the IAQM methodology. Given the other sensitive receptors in the Macraes Village are located further away, the same conclusion of negligible effects is reached.

Table 8.10: Sensitive receptor details for Innes Mills sub-area

Receptor ID/name	Distance between receptor and consented area	Direction from receptor to consented area	Frequency of strong, dry winds
1 - 1668 Macraes Road	605 m	354–88°N	1.27%

Table 8.11: IAQM assessment for sensitive receptors near to the Innes Mills sub-area

Receptor ID/name	Sensitivity of receptor	Receptor distance category	Strong, dry winds category	Residual dust emissions	Pathway effectiveness	Dust impact risk	Magnitude of effects
1 - 1668 Macraes Road	High	Very distant	Infrequent (1% – 5%)	Large	Very ineffective	Negligible	Negligible effect

8.4.2.3 Golden Bar pit

The nearest identified sensitive receptor to the Golden Bar pit sub-area is Receptor 9 – 593 Macraes Road, approximately 2,735 m north of the pit. The next nearest sensitive receptor is Receptor 11 – 800 Stoneburn Road located approximately 2,940 m southeast of the pit. These are substantial separation distances from the sub-area. Consequently, the potential dust effects of this sub-area are assessed as being negligible.

8.4.2.4 Golden Bar haul road

The nearest identified sensitive receptor to the Golden Bar haul road sub-area is Receptor 1, located at 1668 Macraes Road, approximately 1,535 m west of the haul road where it is shown as extending into the Frasers Pit. The next sensitive receptors are other residences within Macraes village ranging from 1,925 m to 2,590 m. These are substantial separation distances from the sub-area. Consequently, the potential dust effects of this sub-area are assessed as being negligible.

8.4.2.5 Coronation and Coronation North

The nearest identified sensitive receptor to the Coronation and Coronation North sub-area is Receptor 7, located at 406 Horse Flat Road, approximately 1,950 m south of the sub-area. The next nearest sensitive receptor is Receptor 15, Golden Point Reserve, located approximately 2,610 m southeast of the sub-area. Consequently, the potential dust effects of this sub-area are assessed as being negligible.

8.4.2.6 Coronation haul road

The nearest identified sensitive receptor to the Coronation haul road sub-area is Receptor 15, the Golden Point Reserve, approximately 315 m east. The next nearest sensitive receptor is Receptor 7, 406 Horse Flat Road, located approximately 1,120 m west of the sub-area. The frequency of strong, dry winds from the sub-area towards these sensitive receptors is moderate.

The IAQM results for Receptor 15 (Golden Point Reserve – the closest receptor) and Receptor 7 (406 Horse Flat Road – the closest high sensitivity receptor) are summarised in Table 8.12 and Table 8.13. The resulting dust impact risk for both receptors is categorised as negligible and the magnitude of effects is assessed as a negligible effect when using the IAQM methodology.

Table 8.12: Sensitive receptor details for Coronation haul road sub-area

Receptor ID	Distance between receptor and consented area	Direction from receptor to consented area	Frequency of strong, dry winds
15 - Golden Point Reserve	315 m	143–316°N	9.67%
7	1,135 m	330–100°N	2.40%

Table 8.13: IAQM assessment for sensitive receptors near to the Coronation haul road sub-area

Receptor ID/name	Sensitivity of receptor	Receptor distance category	Strong, dry winds category	Residual dust emissions	Pathway effectiveness	Dust impact risk	Magnitude of effects
15 - Golden Point Reserve	Moderate	Distant	Moderately frequent (5% – 12%)	Large	Very ineffective	Negligible	Negligible effect
7	High	Negligible	Infrequent (1% – 5%)	Large	Very ineffective	Negligible	Negligible effect

8.4.2.7 Frasers TSF and waste rock stack

The nearest identified sensitive receptor to the Frasers sub-area is Receptor 1, located at 1668 Macraes Road, approximately 670 m southwest at the start of Macraes Village. The next nearest sensitive receptors are other residences within Macraes Village ranging from 1,045 m to 1,715 m.

The IAQM results for Receptor 1 are summarised in Table 8.14 and Table 8.15. The resulting dust impact risk is categorised as negligible and the magnitude of effects is assessed as a negligible effect when using the IAQM methodology.

Table 8.14: Sensitive receptor details for Frasers sub-area

Receptor ID/name	Distance between receptor and consented area	Direction from receptor to consented area	Frequency of strong, dry winds
1 - 1668 Macraes Road	670 m	65–158°N	2.46%

Table 8.15: IAQM assessment for sensitive receptors near to the Frasers sub-area

Receptor ID/name	Sensitivity of receptor	Receptor distance category	Strong, dry winds category	Residual dust emissions	Pathway effectiveness	Dust impact risk	Magnitude of effects
1 - 1668 Macraes Road	High	Very distant	Infrequent (1% – 5%)	Large	Very ineffective	Negligible	Negligible effect

8.4.2.8 Processing Plant

In addition to the assessment of stack discharges from the Processing Plant (presented in Section 9), the potential for dust impacts from ore processing has also been considered. This is for the first stage (crushing) of the ore, as the remaining stages are wet processing methods.

The nearest identified sensitive receptor to the Processing Plant sub-area is Receptor 15, Golden Point Reserve, approximately 755 m east. The nearest residential sensitive receptor is Receptor 1, 1668 Macraes Road, located approximately 2,250 m south of the sub-area.

The IAQM results for Receptor 15 are summarised in Table 8.16 and Table 8.17. The resulting dust impact risk is categorised as negligible and the magnitude of effects is assessed as a negligible effect when using the IAQM methodology.

Table 8.16: Sensitive receptor details for Processing Plant sub-area

Receptor ID/name	Distance between receptor and consented area	Direction from receptor to consented area	Frequency of strong, dry winds
15 - Golden Point Reserve	755 m	153–174°N	<0.01%

Table 8.17: IAQM assessment for sensitive receptors near to the Processing Plant sub-area

Receptor ID/name	Sensitivity of receptor	Receptor distance category	Strong, dry winds category	Residual dust emissions	Pathway effectiveness	Dust impact risk	Magnitude of effects
15 - Golden Point Reserve	Moderate	Very distant	Very infrequent (<1%)	Large	Very ineffective	Negligible	Negligible effect

8.4.2.9 Summary

The IAQM assessments undertaken for all Project sub-areas and receptors within 1 km indicate that the potential for off-site dust effects at sensitive human receptors is negligible in all cases. The combination of substantial separation distances to the nearest receptors, very low to low frequencies of strong, dry winds towards those receptors, and the existing and proposed dust mitigation measures significantly limits the potential for nuisance or amenity effects.

For most receptors, the assessment identifies pathway effectiveness as 'very ineffective', despite residual dust emissions in some locations being categorised as large due to the nature of haul road traffic, and material movement and mineral processing. This results in dust impact risks that are all negligible. Magnitude of effects is assessed as negligible assuming that the mitigation measures described in Section 7 are implemented.

8.5 FIDOL

Table 8.18 provides a FIDOL assessment having taken into consideration the results of the IAQM assessment, complaints data and the results of the air quality monitoring presented in Section 6. Based on the findings of the FIDOL assessments and given the continued use of dust management measures and monitoring, it is concluded that offensive or objectionable dust effects associated with the Project are unlikely to occur.

Table 8.18: FIDOL assessment

Factor	Description
Frequency and **Duration**	Discharges of dust from the site occur on most dry days. However, the frequency and duration of strong dry winds blowing toward the nearest receptors is infrequent for most receptors. For those receptors where there is a moderate frequency of wind exposure (i.e., associated with the Coronation Haul Road), the separation distances are significant, offsetting exposure. This is supported by the low frequency of recorded complaints relating to dust, the low frequency of TSP trigger events and the low levels of dust deposition (mostly within consent limits). Accordingly, the frequency of exposure to dust from existing and proposed mining activities is considered to be low.
Intensity	The intensity of dust depends on the efficacy of dust mitigation measures used to control dust (described in Section 7) and the separation distance to sensitive receptors. The monitoring results for dust deposition and TSP illustrate that mitigation measures to date have been largely effective at minimising dust emissions. Furthermore, significant separation distances between existing and proposed mining activities and sensitive receptors are available. Accordingly, the intensity of exposure to dust from existing and proposed mining activities is considered to be low.

Factor	Description
Offensiveness	The nature of dust associated with mining activities (i.e., grey in colour) in this instance is not dissimilar to dust generated in the wider receiving environment. For this reason, the dust is considered to have a neutral character.
Location	The assessment has focused on the nearest receptors with a high sensitivity where persons are likely to be frequently present (i.e., residential dwellings, schools or other community facilities). Rural land by comparison has a low sensitivity to dust impacts.

8.6 Human health impacts

8.6.1 Introduction

As discussed in Section 4.2.3, potential health effects of dust are related to the fine (PM_{10}) component of dust emissions. Although it is unlikely to pose an environmental hazard, consideration has also been given to potential exposure to RCS.

It is not possible to accurately predict ground level concentrations of PM_{10} or RCS from diffuse sources (such as mining activities) for comparison with air quality standards and guidelines. Therefore, alternative techniques have been used to evaluate the potential for adverse effects from exposure to PM_{10} or RCS from the Project. In this case, monitoring undertaken around aggregate quarries in Canterbury has been used to inform the assessment of potential effects of PM_{10} and RCS from the Project. The activities at these quarries are broadly similar to the activities associated with the Project, but do not include blasting.

8.6.2 Fine particulate PM_{10} and $PM_{2.5}$

An air quality study focusing on the Yaldhurst quarries located to the west of Christchurch was carried out as a joint project for Environment Canterbury (ECan), Christchurch City Council (CCC) and the Canterbury District Health Board (CDHB) in 2018 (herein referred to as the Yaldhurst study). Mote Limited (Mote) and Emissions Impossible Limited were engaged to undertake a monitoring programme to determine exposure to fine particulate matter (PM_{10} and $PM_{2.5}$) and respirable crystalline silica (RCS) for the surrounding Yaldhurst community.

The study has provided a detailed characterisation of fine particulate matter and respirable crystalline silica concentrations in the receiving environment surrounding the Yaldhurst quarries. The Yaldhurst quarries comprised several gravel quarries with large process plants (crushing and screening) and at the time of the study covered an exposed area of approximately 220 hectares (ha). The general activities undertaken with quarrying, the mechanisms for dust generation, and the mitigation measures employed are very similar to those associated with the Project. Consequently, the Yaldhurst study provides a useful source of information that can be used to infer potential health effects associated with PM_{10} and $PM_{2.5}$ emissions associated with the Project. While the extent of the Yaldhurst quarries is smaller than the activities associated with the Project, the annual rainfall for Christchurch is about 600–650 mm per year, slightly less than the Macraes area. The results of the Yaldhurst study when considered in the context of the Project are expected to be conservative.

The Yaldhurst study measured PM_{10}, $PM_{2.5}$ and RCS surrounding the quarries at varying distances as illustrated in Figure 8.4, with details of the monitoring sites provided in Table 8.19.

Figure 8.4: Indicative location of monitoring sites (reproduced from Mote 2018). Image is aligned to true north.

Table 8.19: Main monitoring sites description (summarised from Mote 2018)

Site ID	Distance from quarries	Contaminant monitored
1	50 m (east)	PM_{10}, RCS
2	190 m (northeast)	PM_{10}, $PM_{2.5}$, RCS
3	50 m (south)	PM_{10}, $PM_{2.5}$, RCS
4 (background site)	4.8 km	PM_{10}, $PM_{2.5}$, RCS
5	80 m (southwest)	PM_{10}, RCS
6	160 m (northwest)	PM_{10}, RCS
7	250 m (southeast)	PM_{10}
8	500 m (southeast)	PM_{10}
9	650 m (southeast)	PM_{10}

Note: Sites 7, 8 and 9 were installed later in the monitoring programme.

A literature review undertaken for Environment Canterbury by Pattle Delamore Partners (PDP 2024) provided a review of the Yaldhurst study data and provided the following conclusion regarding PM_{10} impacts with distance from the quarry:

> *"The comparison of the maximum 24-hour average PM_{10} concentration measured at background and the three 160 to 250 m downwind sites suggest that beyond 250 m the change in PM_{10} concentrations due to the influence of the quarry's emissions is not distinguishable from background PM_{10} concentrations".*

IAQM provides data, summarised in Figure 8.5, for a range of mineral mining/quarrying operations (including opencast coal mining), from which a similar conclusion to that of PDP is reached. The data in that instance shows that the additional mean PM_{10} concentration beyond 300 m is negligible. Given this context and the significantly larger separation distances to sensitive receptors where persons are likely to be present for 24 hours or longer, it is concluded that potential effects of PM_{10} discharges associated with the Project are likely to be negligible.

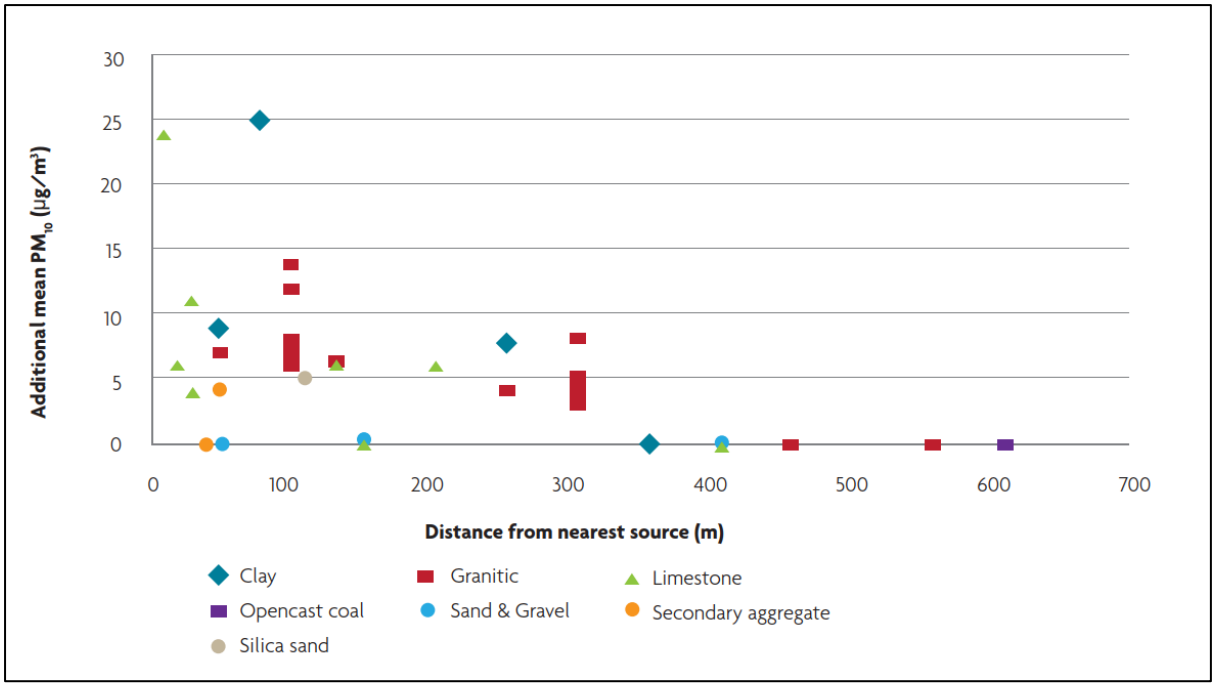


Figure 8.5: Mineral site PM_{10} increment as a function of distance from operation by mineral type (source: IAQM 2016).

With regard to the finer $PM_{2.5}$ fraction, the Yaldhurst study found concentrations were generally low with no recorded exceedances of the MfE reporting 24-hour guideline of 25 µg/m³. The study also states that "*A comparison of $PM_{2.5}$ and PM_{10} (nephelometer) data shows $PM_{2.5}$ to be a minor component of the PM_{10} concentrations measured in Yaldhurst (at sites 2 and 3) compared with background (site 4). The fine fraction $PM_{2.5}$ was 17% and 14% of PM_{10} measured at sites 2 and 3 respectively, but 24% at site 4.*" This finding is consistent with the understanding that quarry and mining operations are not expected to be a significant source of $PM_{2.5}$ emissions, noting that such emissions are predominantly associated with combustion related emission sources.

Given the findings of the Yaldhurst study and the significant separation distances to sensitive locations where persons are likely to be present for 24 hours or longer, it is concluded that potential $PM_{2.5}$ impacts will be negligible.

8.6.2.1 Historic PM_{10} and $PM_{2.5}$ monitoring

Monitoring of PM_{10} and $PM_{2.5}$ and RCS was also undertaken at four locations[11] around the mine site, including at a location representing Macraes Village, from 1999 to 2000 by the University of Otago Consulting Group (Fitzharris et al., 2000; Fitzharris et al., 2001). It was undertaken using two high-volume samplers, one fitted with a PM_{10} filter head and the other a $PM_{2.5}$ filter head and was carried out once a month at each of the sites in January, March, November and December.

Because only one 24-hour sample was collected per site per month, and monitoring was limited to the summer and late spring months when the potential for dust generation is greatest, significant caution is required when reviewing the results. Notwithstanding this, the dataset is the only site-specific measurement record of ambient PM_{10} and $PM_{2.5}$, and is summarised here to provide context.

[11] The monitoring site were referred to as Macraes, Suttons, Golden Pt and Howards.

Because the PM_{10} and $PM_{2.5}$ samples were collected using two separate high-volume samplers each with a stated precision of approximately ±20%, there are instances where the reported $PM_{2.5}$ concentration exceeds the corresponding PM_{10} concentration.

The results for the Macraes monitoring site are summarised in Table 8.20. The measured 24-hour PM_{10} and $PM_{2.5}$ concentrations are low, with all valid samples below the National Environmental Standards for Air Quality (NESAQ – MfE 2020) PM_{10} 24-hour standard of 50 µg/m³ and the proposed NESAQ $PM_{2.5}$ 24-hour standard of 25 µg/m³.

Table 8.20: Macraes Village – 24-hour average particulate matter concentrations

Month	PM_{10} (µg/m³)	$PM_{2.5}$ (µg/m³)
January 1999	3	1
February 1999	3	3
March 1999	6	2
November 1999	2	5
December 1999	6	4
January 2000	15	11
February 2000	<1	<1
March 2000	16	11
Assessment criteria	**50**	**25**

8.6.3 Respirable crystalline silica

The Yaldhurst study was the first time in New Zealand that long-term average ambient RCS concentrations had been measured at a resolution that would enable a comparison against the California Office of Environmental Health Hazard Assessment (OEHHA) guideline (3 µg/m³ expressed as an annual average) (OEHHA, 2020). T+T is not aware of any similar subsequent study that has been undertaken in New Zealand.

Concentrations of RCS averaged over the 4-month monitoring period were very low, with all but one of the sites recording individual monthly concentrations below the limit of detection (LOD) of the monitoring method (between 0.2 and 0.8 µg/m³) (Mote, 2018). Site 3, to the south of the quarries, had two monthly samples where the concentration was recorded as above the LOD (0.33 and 1.68 µg/m³). This site was located 50 m from a quarry boundary (the closest of all monitoring sites), downwind under prevailing northeast winds and away from any sensitive locations.

The monitoring was carried out for four months, but this was timed for when the potential for dust generation is greatest. RCS levels will be lower in winter and spring when ground conditions are frequently damp. From the 4-monthly average results, it was concluded that the annual average RCS concentration would almost certainly be well below the OEHHA guideline of 3 µg/m³ as an annual average, even for the location of the closest monitoring site.

The findings of this monitoring resulted in Environment Canterbury issuing a media release (22 June 2018) quoting the Canterbury Medical Officer of Health, Dr Ramon Pink, who at that time reviewed the results and provided the following statement:

> *"Overall, the results show there is no serious public health risk to Yaldhurst residents from airborne dust… Nuisance dust levels will not cause long-term health effects, but we know it can cause irritation and symptoms of concern in some people …".*

We consider that the proposed mining operations at the Project are very unlikely to give rise to annual average RCS concentrations at sensitive receptor locations that would approach the OEHHA guideline of 3 µg/m³ based on the following:

- The distance between the Yaldhurst quarries and the monitors (50 m – 190 m) is considerably closer than the nearest sensitive receptors to the proposed Project operations (> 600 m).
- There are few periods of time when sensitive receptors are downwind of strong dry winds that would lead to exposure (winds presented in IAQM assessment in Section 8.4.2).
- The study period comprised a wide range of wind conditions and used monitoring sites that surrounded the quarry zone. Consequently, the results are considered to be representative of concentrations for a wide range of wind conditions and are independent of wind direction.

8.6.3.1 Historic respirable quartz monitoring

As described in Section 8.6.2.1, monitoring of respirable quartz (a form of respirable crystalline silica) was carried out in 1999 and 2000 by the University of Otago Consulting Group (Fitzharris et al., 2000; Fitzharris et al., 2001). Concentrations were not directly measured but were estimated based on measured PM_{10} and $PM_{2.5}$ concentrations and an estimated quartz content of the rock. The reports describe a quartz content of 15%, being an estimate of the true airborne quartz fraction in the respirable size range, and a figure of 37%, being the quartz content of the native rock ("the upper limit"). The monitoring results based on measured PM_{10} concentrations and a 15% quartz content are provided in Table 8.21.

The results in Table 8.21 should not be compared against the OEHHA annual average guideline for RCS of 3 µg/m³ because of the following reasons:

- RCS was not directly measured but is inferred based on estimated quartz content.
- The OEHHA applies to a respirable fraction of particles less than 4 µm (i.e., PM_4). The monitoring used PM_{10} and $PM_{2.5}$ heads; PM_{10} overstates the respirable fraction and $PM_{2.5}$ understates it.
- The guideline is an annual average, whereas the data are single 24-hour samples collected only in the summer and late-spring months when dust is greatest. The tabulated means are therefore summer-biased and overstate a true annual average, which would include the damper autumn, winter and spring months.

Notwithstanding the above caveats, the results presented in Table 8.21 indicate low concentrations of RCS are likely to occur and support a conclusion that RCS exposure is unlikely to approach or exceed the OEHHA guideline.

Table 8.21: Macraes Village – 24-hour average respirable quartz concentrations

Month	Respirable quartz (µg/m³)*
January 1999	0.5
February 1999	0.5
March 1999	0.9
November 1999	0.3
December 1999	0.9
January 2000	2.3
February 2000	<0.2
March 2000	2.4

* values are derived from measured PM_{10} concentrations and an estimated 15% quartz content.

8.6.4 Arsenic

The tailings produced from the gold processing operations at the Macraes Operation contain naturally occurring arsenic. While arsenic in tailings does not present a risk in terms of nuisance dust effects, it is appropriate to consider whether arsenic-bearing dust from the TSFs could give rise to adverse human health effects at sensitive receptor locations.

To assess the potential impacts of arsenic-containing dust from the TSFs on the Macraes community we have used the FIDOL approach, informed by the following:

- An understanding of the likelihood for dust to be generated from a TSF and the conditions under which that would occur.
- The local wind conditions, which drive the frequency and duration of potential exposure to winds from the mine site, and more particularly the TSFs.
- An understanding of how the concentration of fine respirable dust, less than 10-micron diameter (PM_{10}), reduces with distance from a dust source in comparison with the separation distance between the TSFs and Macraes community.

Tailings are discharged to the TSFs as a wet slurry. As the slurry dries, it forms a hard surface crust that does not readily generate dust unless it is mechanically disturbed. Consequently, TSFs are not typically a significant source of dust from mining activities, particularly when compared with other key sources such as vehicle movements on unpaved haul roads. Wind entrainment of dust from TSF surfaces only occurs under strong wind conditions – typically when hourly average wind speeds exceed 5 m/s, and more frequently when winds exceed 7 m/s. The potential for dust generation from the TSFs is further minimised through the use of a tailings wetting system, comprising spigots fitted with spray nozzles that are operated to maintain the surface moisture of the TSFs during dry, windy conditions, as described in Section 7.1.

The potential for the Macraes community to be exposed to arsenic-containing dust from the TSFs depends on the frequency with which strong, dry winds transport material from the TSFs toward sensitive receptor locations. As illustrated in Figure 5.3, strong winds at the Macraes site predominantly occur from the southwest. Since the Macraes community and the nearest sensitive residential receptors are located to the southwest of the main mining areas, the community is rarely (<2% of the time) downwind of the TSFs during the strong, dry wind conditions necessary to generate and transport dust.

IAQM (2016) guidance indicates that incremental PM_{10} concentrations attributable to mineral extraction activities typically reduce to negligible levels within approximately 350 m of the source. The nearest sensitive residential receptor (Receptor 1, 1668 Macraes Road) is located approximately 1,115 m from the Mixed Tailings Impoundment (MTI), which will expose tailings as it is lowered as part of the Project – a separation distance approximately four times greater than the distance at which PM_{10} concentrations are expected to reduce to negligible levels.

A FIDOL assessment of the potential for the sensitive receptors to be exposed to PM_{10} containing arsenic derived from the TSF is provided in Table 8.22. This takes into account the frequency of wind conditions that may generate dust at the TSF[12] and blow it towards the community and the separation distance between the TSFs and the community.

The overall conclusion based on this FIDOL assessment is that there is negligible risk of exposure of the Macraes community to arsenic-containing PM_{10} derived from the TSF.

[12] Noting that dust generation is unlikely given the wet nature of the tailings and use of water for dust suppression

Table 8.22: FIDOL assessment

FIDOL factor	Assessment
Frequency and duration	The frequency and duration of dust impacts at a receptor location depends on the frequency of discharge from a source, and the frequency of wind conditions that can carry that discharge towards a receptor. In this instance, the frequency of discharge is linked to wind conditions, in that a discharge will only occur during strong dry winds. Strong winds on dry days blowing from the direction of the Mine and TSFs (i.e., winds coming from the southeast through east to northeast) towards the Macraes community are infrequent (< 2%). This is considered to be 'infrequent' using IAQM 2016 guidance.
Intensity	The intensity of dust impacts at a receptor location is a function of intensity at the point of discharge and how that concentration of dust reduces with distance from a source. The discharge of dust emissions from TSFs is usually low and only has the potential to occur during strong dry winds. The potential is further minimised through the use of dust suppression. The second factor is the distance between a source and receptor. The nearest receptor within the Macraes community is well in excess of the distance at which contribution to PM_{10} concentration can be expected to reduce to negligible levels.
Offensiveness	The key concern with regard to the offensiveness of the dust from the tailings in the context of this assessment is the content of arsenic.
Location	The assessment has focused on the location of sensitive residential dwellings as the location where a person can be present for long periods of time.

As a further line of evidence, consideration has been given to the arsenic concentration that would be required in TSF dust for ambient arsenic concentrations at sensitive receptor locations to reach the MfE Ambient Air Quality Guideline (AAQG) for arsenic of 0.0055 µg/m³ (annual average; MfE, 2002).

Based on the IAQM guidance, PM_{10} concentrations from mineral extraction activities are expected to reduce to negligible levels beyond approximately 350 m from the source. Notwithstanding this, for the purpose of this assessment, an incremental PM_{10} concentration of 1 µg/m³ has been conservatively assumed at the nearest sensitive receptor location. This assumption significantly overstates the likely exposure, given that Receptor 1 is located approximately 1,115 m from the closest TSF and that strong, dry winds directed toward the community occur less than 2% of the time.

At this assumed PM_{10} concentration, the arsenic content of TSF dust would need to be approximately 5,500 parts per million (ppm) by weight for ambient arsenic concentrations to reach the AAQG of 0.0055 µg/m³. OGNZL has provided sampling results that show the arsenic concentration of tailings sampled from near the surface of the MTI is less than 2,000 ppm – approximately one-third of the concentration that would be required to reach the AAQG under the conservatively assumed PM_{10} exposure conditions described above. Given that the assumed PM_{10} concentration itself represents a significant overestimate of actual conditions, ambient arsenic concentrations at sensitive receptor locations are expected to be well below the AAQG.

Given the above, it is concluded that the risk of sensitive receptors being exposed to arsenic-containing PM_{10} from the TSFs at concentrations approaching the AAQG for arsenic is negligible. Dust emissions from TSFs are inherently low because the tailings are deposited as a wet slurry that forms a hard crust, meaning dust is only generated under infrequent strong, dry winds and is further controlled by dust suppression techniques. Local meteorological data indicates that strong winds

blowing from the mine toward the community occur less than 2% of the time, restricting the transport pathway for any airborne particles. Finally, the nearest community receptor is located approximately 1,115 m from the closest TSF, a separation distance that far exceeds the 350 m distance where PM_{10} concentrations from mining activities typically reduce to negligible levels. Therefore, the combination of limited dust generation, infrequent transport winds, and a substantial buffer distance means that exposure of the community is highly unlikely.

8.7 Cumulative effects

The main potential for cumulative dust effects arises from existing consented mining-related dust emissions, including from the large open areas associated with existing activities. However, in all cases, the existing mining areas are by-and-large overlaid by those associated with the Project, especially for locations closest to the nearest sensitive receptor locations. Furthermore, the separation distances to the nearest sensitive receptors are large. Consequently, cumulative effects associated with existing mining activities are not expected to materially alter the conclusions reached in the above assessment.

With regard to non-mining sources of dust, this is mainly associated with existing agricultural activities, such as stock movements and fertiliser application, which will be intermittent and are unlikely to materially alter the conclusions reached in the above assessment.

Accordingly, it is concluded that cumulative effects from OGNZL existing mining activities and from non-mining sources of dust will not materially alter the conclusions reached in the above assessment.

8.8 Recommended monitoring

It is recommended that the existing dust deposition monitoring described in Section 6 and meteorological monitoring described in Section 5.3 continue for all existing monitoring sites as part of the Project. It is also recommended that the existing dust deposition trigger value of 3 g/m²/30-days above background continue to be used.

Continuous monitoring of TSP is currently carried out at site DG15 (Macraes Village). The nephelometer instrument currently used is significantly affected when there is elevated relative humidity, resulting in the vast majority of recorded high concentrations being linked to high levels of humidity. This is a common occurrence with some nephelometer instruments. Furthermore, TSP is only useful as an indicator of increasing concentrations of dust and has no recognised human health criteria. By contrast, the finer fraction of particles, PM_{10}, is often used for indicating elevated dust levels and is a criteria air pollutant for which there is an air quality standard. For these reasons, it is recommended that TSP monitoring be replaced with monitoring of PM_{10} and that a reference standard instrument be used to avoid the instrumental issues that have occurred with the existing TSP instrument. A similar regime of trigger concentration values will be used to guide site management and avoid a compliance limit exceedance.

With regard to the location of the monitoring, it is recommended that PM_{10} monitoring at Macraes Village (DG15) site replace the existing TSP monitoring in line with the above recommendations. However, it is also recommended that a suitable lower-cost nephelometer instrument set up to measure PM_{10} be established on OGNZL land near to Receptor 1 to provide an early warning regime for increasing dust levels using the same regime of trigger concentration values. The instrument at this new location will need to be capable of mitigating the effects of relative humidity that affects the current TSP monitor.

A similar trigger concentration response framework as currently applied to the TSP monitoring is proposed for PM_{10} monitoring, albeit with the following trigger level concentration values that are suitable when using PM_{10} for real-time dust monitoring purposes:

- 1-hour average concentration of 150 µg/m³, recommended by MfE (2016) for high sensitivity receptors; and
- 24-hour average concentration of 40 µg/m³ (80% of the NESAQ).

8.9 Conclusions

It is concluded that the potential for dust effects at all sensitive receptors is negligible when using both the IAQM source-pathway-receptor methodology and the FIDOL framework. This finding applies consistently across all sub-areas assessed. While residual source emissions from haul road traffic and material handling activities are large (reflecting the scale of mining activities), the substantial separation distances to sensitive receptors and the very low to low frequency of strong, dry winds directed towards those locations mean that effects are assessed as being negligible. Concentrations of PM_{10}, $PM_{2.5}$, and RCS at all sensitive receptor locations are similarly concluded to be negligible.

The FIDOL assessment, informed by an assessment using the methodology recommended by the IAQM alongside the historical monitoring data and complaint records, confirms that offensive or objectionable dust effects at sensitive receptor locations are unlikely to occur. This is consistent with the dust deposition monitoring data for the period 2015–2024, which demonstrates general compliance with consent limits, a downward trend in deposition rates above background since early 2022, and only five dust-related complaints since 2018, none of which have been received since 2020.

The above conclusions are contingent on the continued implementation of the dust mitigation measures currently applied at the site, as described in Section 7, especially water suppression to haul roads and working areas. The downward trend in measured dust deposition rates since early 2022, and the absence of complaints since 2020, are consistent with the effectiveness of the existing mitigation regime and provide confidence that the Project's actual effects will be in accordance with the findings of this assessment.

9 Assessment of effects – stack emissions

9.1 Assessment method

9.1.1 Assessment approach

Dispersion modelling using the CALPUFF dispersion modelling suite has been used to predict contaminant ground level concentrations (GLCs) resulting from particulate matter and combustion contaminant emissions from the site stacks.

Meteorological input data for use in dispersion modelling were predicted using the CALMET model (latest version 6.5.0), as described further in Section 9.1.3.

9.1.2 Dispersion modelling

Dispersion modelling has been undertaken using the most recent version of the CALPUFF air dispersion model (latest version 7.2.1), which is widely used in New Zealand for such assessments. The model was configured to predict the impact of emissions described in Section 4.3, as discussed further in Section 9.3.

The CALPUFF model was configured to predict GLCs for a number of discrete receptor locations representing locations of particular interest (refer to Section 5.2) for the assessment, as well as three grids of evenly spaced receptors at increasing resolution. The 'nested receptor' grid approach provides a high level of detail close to the site where the magnitude and spatial variation in impacts are typically greatest, with decreasing resolution in grid spacing further afield. This allows for a significant reduction in model computation time. The extents and resolution of the three nested receptor grids are as follows:

- 1,800 m by 750 m at a 50 m resolution.
- 4,500 m by 4,250 m at a 250 m resolution.
- 19 km by 14 km at a 500 m resolution.

The location of the discrete receptors and nested receptor grids is shown in Figure 9.1.

Nearby buildings and structures can affect the dispersion of a plume from a stack, causing it to be brought to the ground rapidly – this is known as 'building downwash'. To account for this, the PRIME building downwash algorithm within the CALPUFF model is used to simulate this effect. The PRIME building downwash algorithm is the recommended option for dispersion modelling.[13]

In accordance with recommended good practice (MfE, 2004), the maximum predicted one-hour average results are the 99.9th percentile of the yearly model predictions.

The CALPUFF configuration is presented at Appendix C.

[13] Ministry for the Environment (2004) 'Good practice guide for atmospheric dispersion modelling'. Available online: https://environment.govt.nz/publications/good-practice-guide-for-atmospheric-dispersion-modelling/

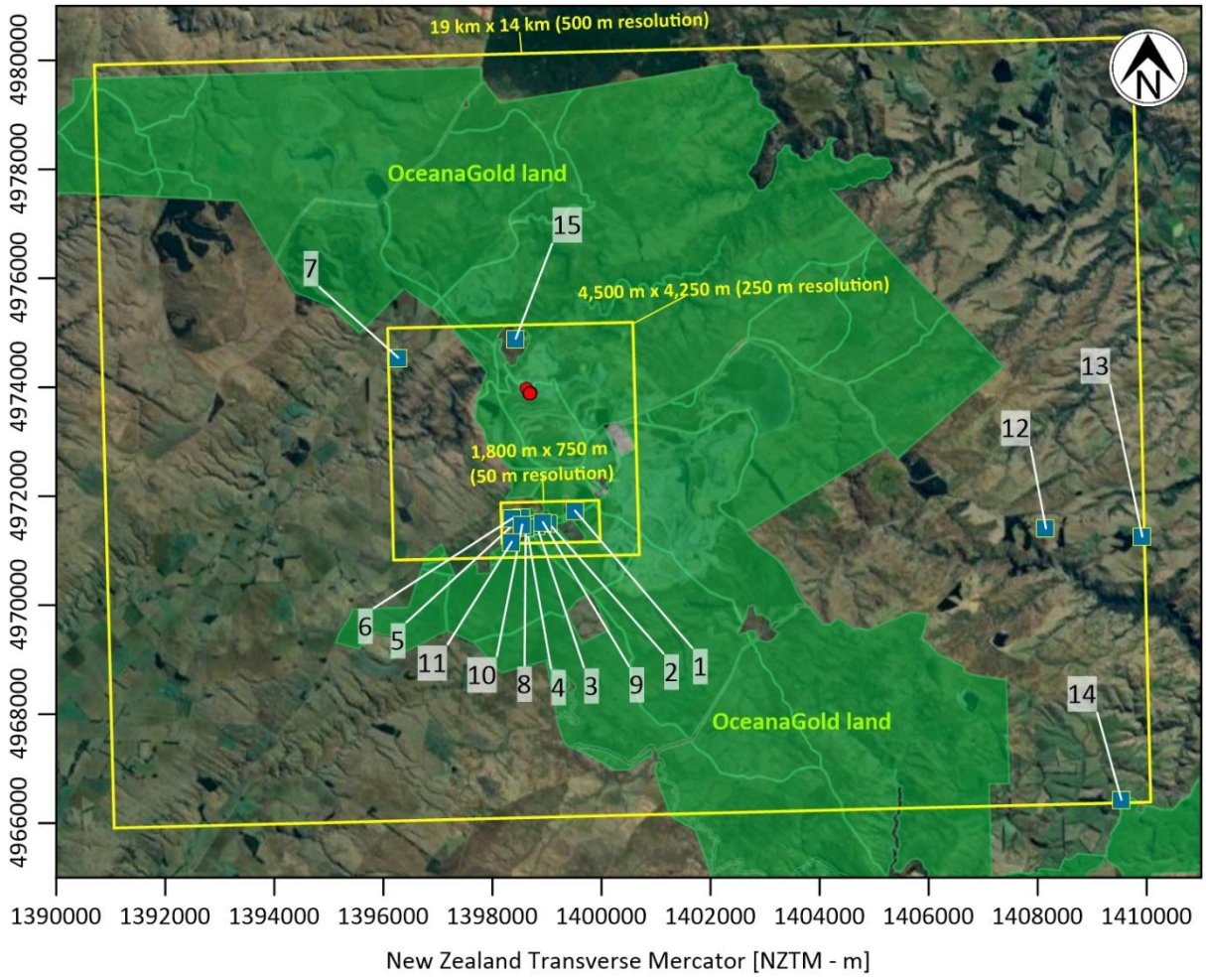


Figure 9.1: Discrete receptor locations and nested receptor grids used in the CALPUFF model. OGNZL land shown in green.

9.1.3 Meteorological modelling

Meteorological information is one of the key inputs for dispersion modelling. Meteorological inputs to the CALPUFF model are generated using the CALMET model (latest version 6.5.0). The CALMET model generates hourly, three-dimensional fields of meteorological parameters that are used by CALPUFF.

The CALMET dataset used for this assessment was developed for the processing site. It was configured to use inputs from a combination of surface-based meteorological observations and outputs from the Weather Research and Forecasting (WRF) model. WRF provides the surface conditions for locations not directly covered by surface monitoring observations, as well as upper-air information needed to initialise the three-dimensional fields within the CALMET model. Hourly surface-based meteorological observations were included from the Macraes Village meteorological site.

The CALMET model covers an area that is 19 km by 14 km centred on the processing site and extending up from the surface to the atmospheric boundary layer. It has been run at a horizontal grid resolution of 125 m, which is considered sufficiently high to capture variations in the meteorology caused by terrain and land use, in particular the significant terrain features associated with the existing mining pits.

Details of the WRF and CALMET configuration are provided in Appendix E.

CALMET was run for a two-year period covering 2022–2023 in accordance with MfE good practice guidance[14]. The choice of these two recent years was based on:

- A review of available data for the Village site meteorological station (at DG15); and
- A review of the Southern Oscillation Index (SOI) for the last 10 years, which indicates that 2022 exhibited La Niña while 2023 exhibited El Niño conditions. This ensures that the dataset comprises a wide range of meteorological conditions for the location of the Mine.

9.2 Assessment criteria

Predicted ambient contaminant concentrations have been compared with health-based air quality assessment criteria to assess the potential for adverse effects on human health.

MfE (2016) recommends that the following criteria for assessing the effects on air quality should be selected, in the following order of priority:

- National Environmental Standards for Air Quality (NESAQ).
- National Ambient Air Quality Guidelines (AAQG).
- Regional objectives – ORC has established 'Otago Goal Levels' (OGL) to help improve air quality management of airsheds, rather than specifically for the management of individual sources. The OGLs are identified in the RPAO (2008). Although not strictly intended as assessment criteria, they have been included for completeness.
- World Health Organisation (WHO) Air Quality Guidelines (WHO, 2021).
- California reference exposure levels (acute and chronic) and US EPA inhalation reference concentrations and unit risk factors (chronic) (Office of Environmental Health Hazard Assessment (OEHHA) 2016).

The relevant assessment criteria are summarised in Table 9.1.

The WHO released an update to its global air quality guidelines in September 2021. This update includes revision of WHO's previous guideline values for fine particulate matter (PM_{10} and $PM_{2.5}$), SO_2, NO_2 and CO.

The updated WHO guidelines were based on recent evidence on health effects and were published to provide recommendations for informing the development of air quality management policy. As noted in the guideline document, the guidelines "*are not legally binding standards; however, they do provide WHO Member States with an evidence-informed tool that they can use to inform legislation and policy.*"

The WHO guidelines have not been adopted in New Zealand to date in either the NESAQ or the MfE AAQG. Nonetheless, the WHO 2021 guidelines are acknowledged in this assessment and discussed in Section 9.3. The WHO 2021 guidelines are presented below in Table 9.2.

[14] Ministry for the Environment (2016) 'Good practice guide for assessing discharges to air from industry'. Available online: https://environment.govt.nz/assets/publications/good-practice-guide-industry.pdf

Table 9.1: Assessment criteria

Contaminant	Standard / guideline source	Averaging period	Concentration (µg/m³)	Allowable annual exceedances
Sulphur dioxide (SO_2)	NESAQ	1-hour	350	9
	NESAQ	1-hour	570	-
	AAQG	24-hour	120	-
	RPAO	1-hour	350	-
	RPAO	1-hour	230	-
Mercury (Hg)	OEHHA	1-hour	0.6	-
	OEHHA	8-hour	0.06	
	AAQG OEHHA	Annual	0.33 0.03	-
Arsenic (As)	OEHHA	1-hour	0.20	-
	OEHHA	8-hour	0.015	-
	AAQG	Annual	0.0055	-
Lead (Pb)	AAQG	3-month moving average	0.2	-
Nickel (Ni)	OEHHA	Acute (1-hour)	0.2	-
	OEHHA	8-hour	0.06	-
	OEHHA	Annual	0.014	-
Chromium (trivalent) (Cr)	OEHHA	1-hour (Acute)	0.48	-
	OEHHA	8-hour	0.12	-
	OEHHA	Annual	0.06	-

Table 9.2: WHO 2021 guideline criteria

Contaminant	Time average	Concentration (µg/m³)	Allowable annual exceedances
SO_2	10-minute	500	-
	24-hour	40	3–4

9.3 Model results

9.3.1 Sulphur dioxide

The predicted SO_2 concentrations resulting from the POX plant are summarised in Table 9.3. The predicted model results are less than 1% of the corresponding assessment criteria. When evaluated against the Otago Goal Levels and WHO guidelines, the predicted concentrations are still negligible.

Contour plots of the 1-hour and 24-hour average model results are provided in Figure 9.2 and Figure 9.3.

Table 9.3: Summary of predicted SO_2 concentrations

Prediction	Predicted SO_2 concentration (µg/m³)	
	Peak 1-hour average	Peak 24-hour average
Predicted concentration at most impacted receptor	0.4	0.053
Receptor location	Mine boundary	R2
Percentage of guideline	0.07%	0.04%
Assessment criteria	**350/570 NESAQ**	**120 AAQG**

Note: Assumes background concentrations of SO_2 are negligible, which is reasonable given there are no other notable sources of SO_2 in the receiving environment.

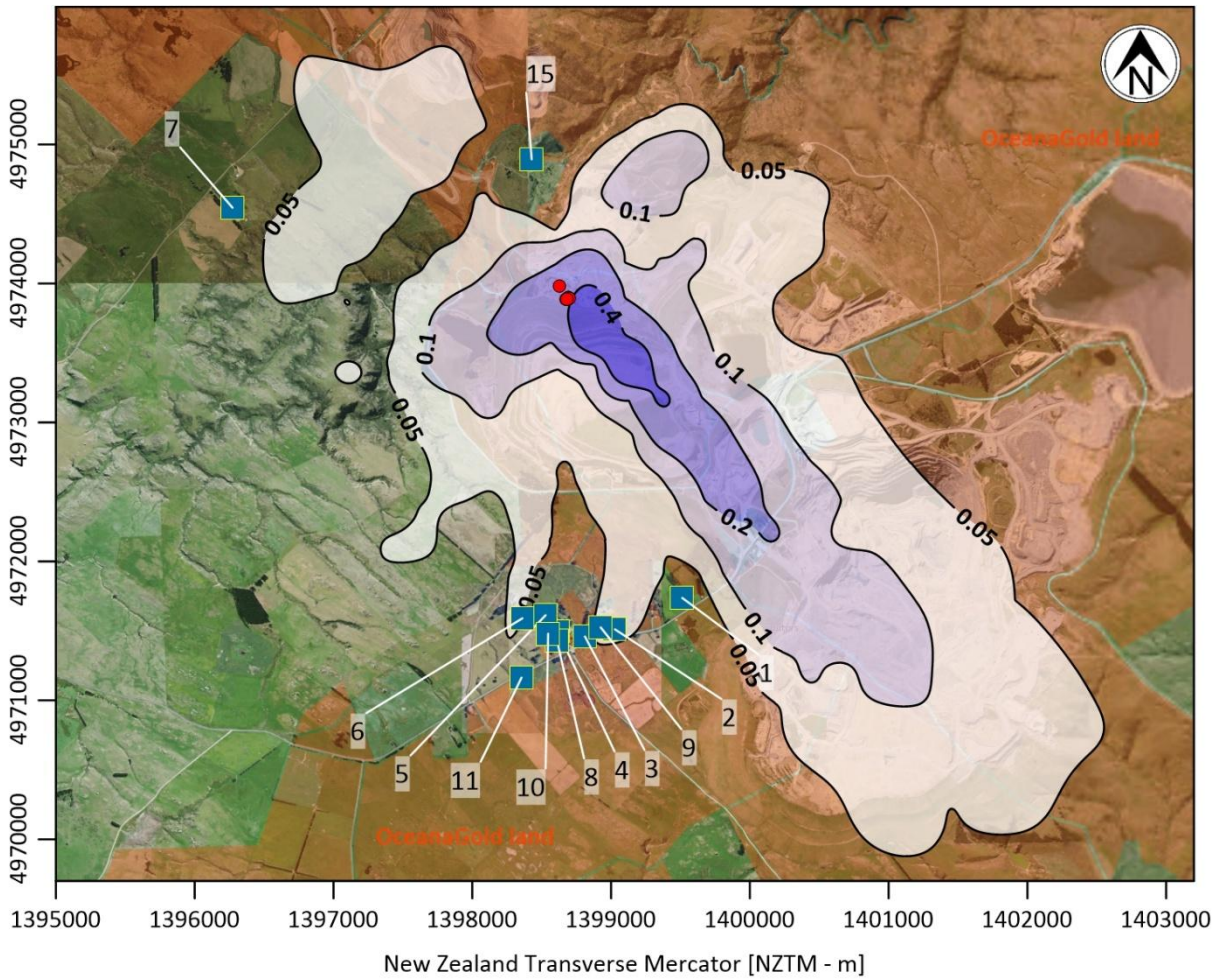


Figure 9.2: Predicted 24-hour average SO_2 concentrations (µg/m³). Blue squares denote sensitive receptors. Orange shaded area denotes OGNZL land.

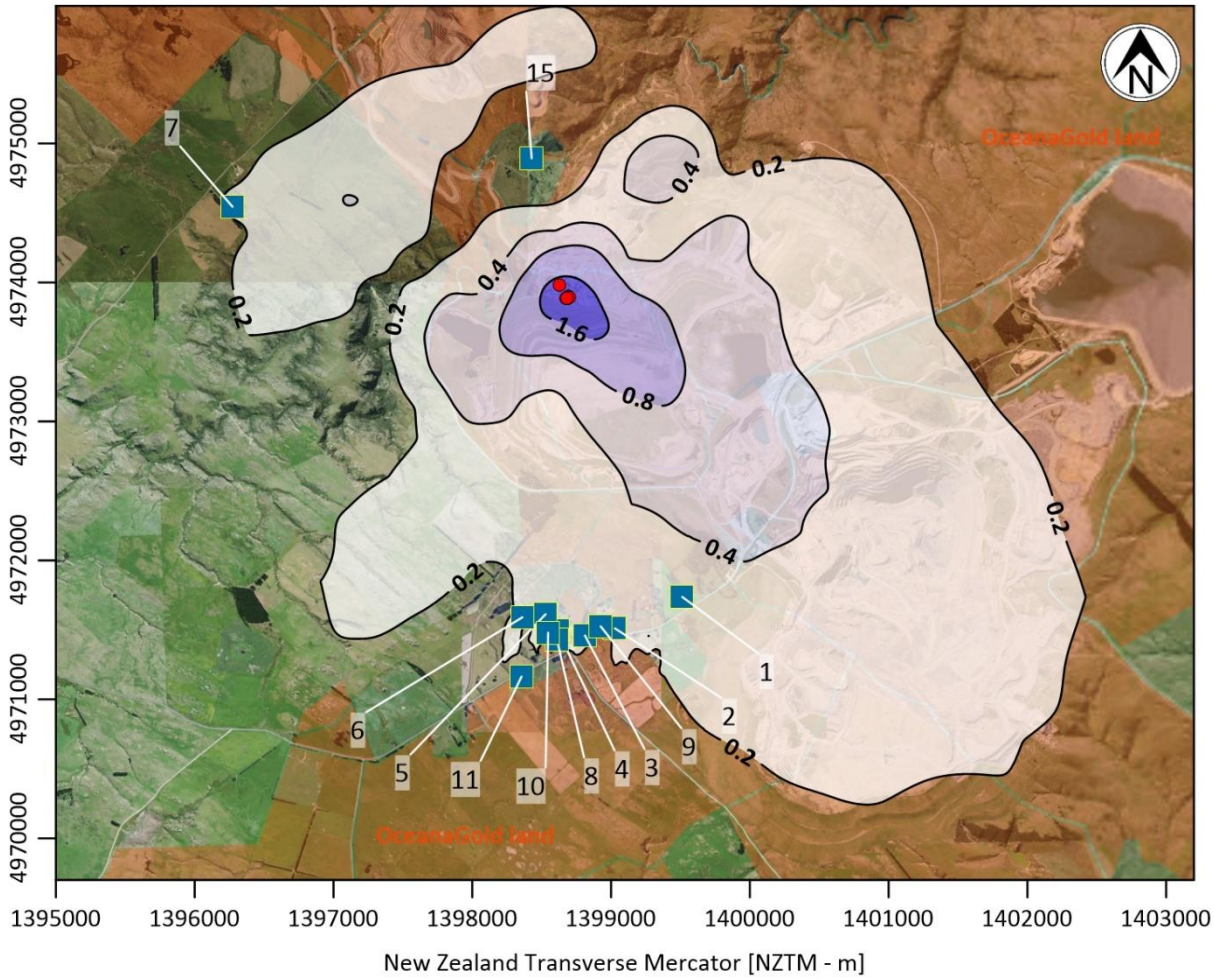


Figure 9.3: Predicted 1-hour (modelled 99.9th percentile) average SO_2 concentrations (µg/m³). Blue squares denote sensitive receptors. Orange shaded area denotes OGNZL land.

9.3.2 Mercury

The model results for predicted offsite mercury concentrations (a combination of both gaseous and particulate phase) resulting from the POX plant and other Processing Plant stacks are summarised in Table 9.4 for the predicted peak 1-hour average, 8-hour average and annual average. In all cases the results are well within the corresponding assessment criteria for mercury.

Contour plots showing the predicted 1-hour, 8-hour and annual average concentrations are provided in Figure 9.4, Figure 9.5 and Figure 9.6 respectively.

Table 9.4: Summary of predicted Hg concentrations

Metal	Prediction	Predicted concentration (µg/m³)		
		Peak 1-hour average	Peak 8-hour average	Annual average
Hg	Predicted concentration at most impacted receptor	0.008	0.002	6.80×10^{-5}
	Receptor location	Mine boundary	R9	R1
	Percentage of guideline	1.3%	3.6%	0.02% 0.23%
	Assessment criteria	**0.6** **OEHHA**	**0.06** **OEHHA**	**0.33** **AAQG** **0.03** **OEHHA**

Note: Assumes background concentrations of Hg are negligible, which is reasonable given there are no other notable sources of Hg in the receiving environment.

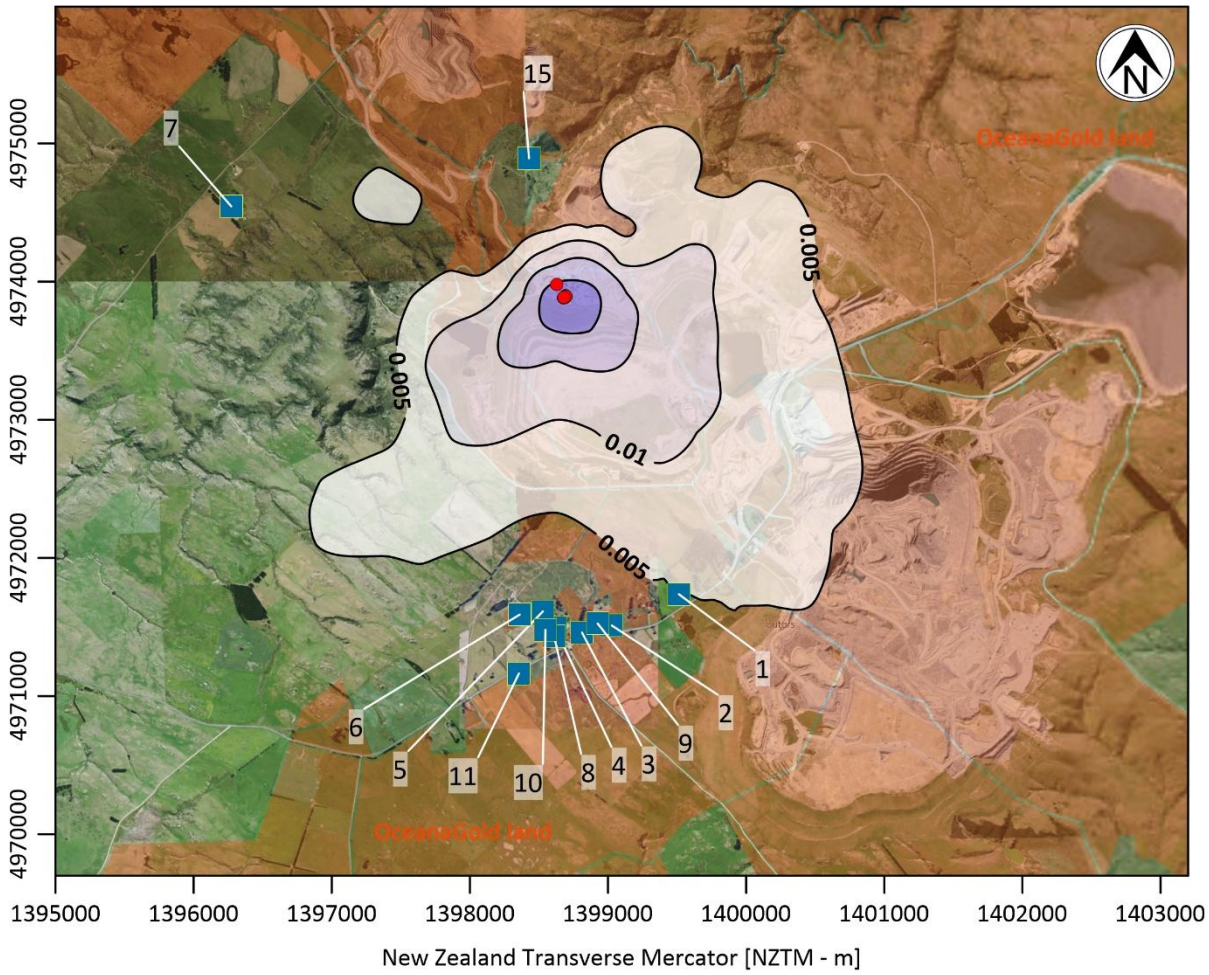


Figure 9.4: Predicted 1-hour (99.9th percentile modelled) average mercury concentrations (µg/m³). Blue squares denote sensitive receptors. Orange shaded area denotes OGNZL land.

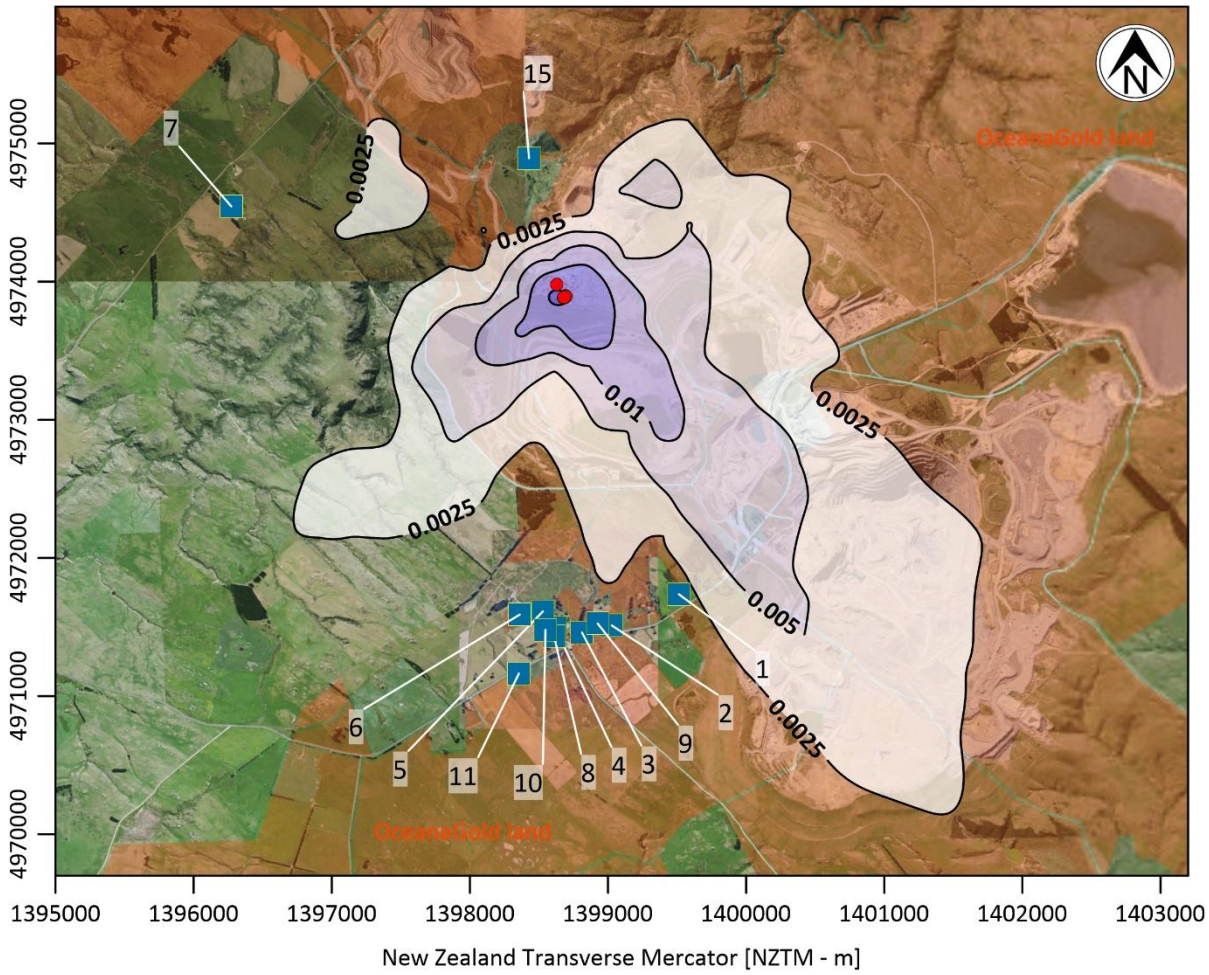


Figure 9.5: Predicted 8-hour average mercury concentrations (µg/m³). Blue squares denote sensitive receptors. Orange shaded area denotes OGNZL land.

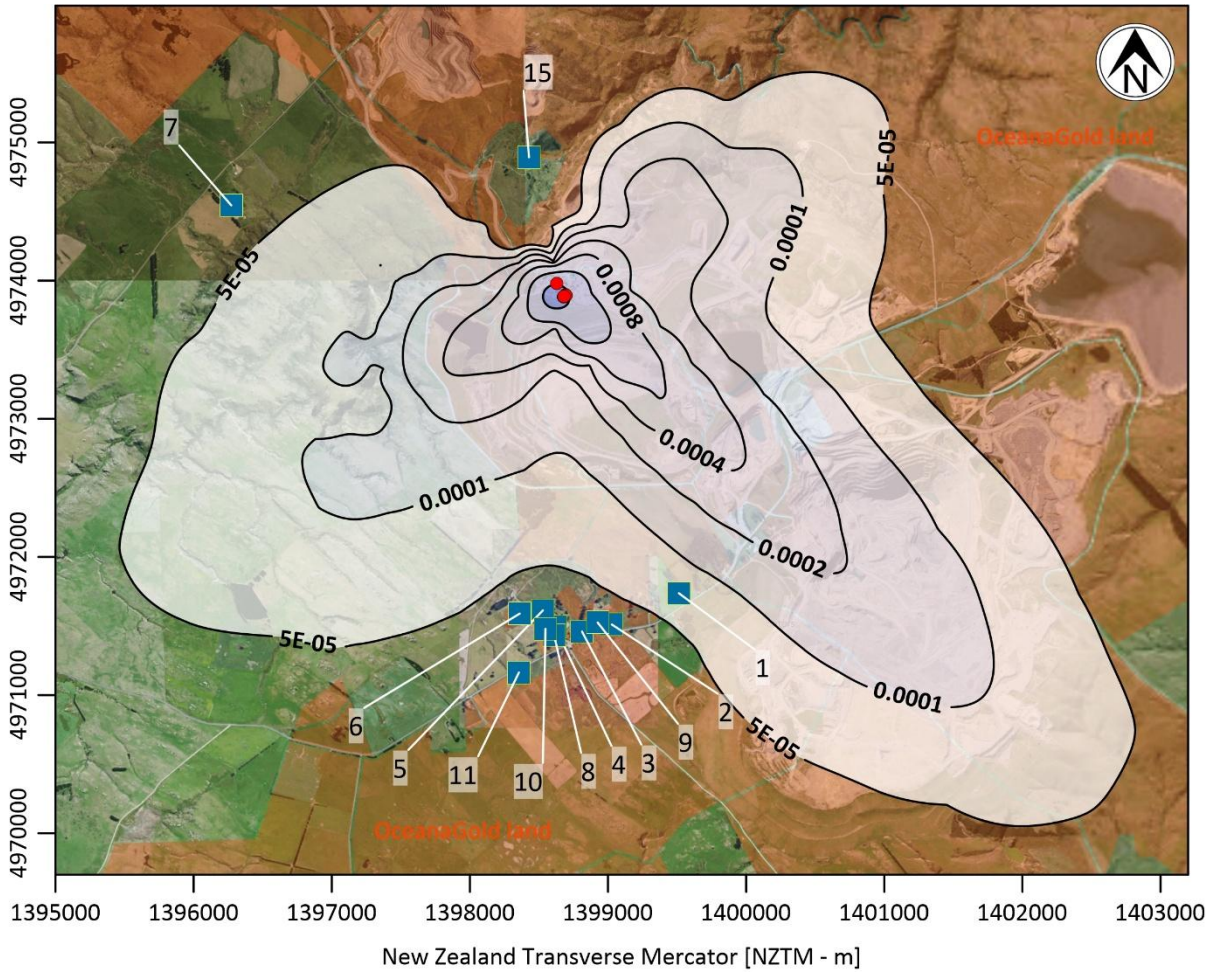


Figure 9.6: Predicted annual average mercury concentrations (µg/m³). Blue squares denote sensitive receptors. Orange shaded area denotes OGNZL land.

9.3.3 Trace metals

The model results for predicted offsite trace metal concentrations resulting from the POX plant are summarised in Table 9.5 for the predicted peak 1-hour average, 8-hour average and annual average. In all cases the results are well within the corresponding assessment criteria for all trace metals. Example contour plots for nickel concentrations for each time-averaging period are provided in Figure 9.7, Figure 9.8 and Figure 9.9 respectively; the same spatial distribution in concentrations will occur for the other trace metals.

Table 9.5: Summary of predicted trace metal concentrations

Metal	Prediction	Predicted concentration (µg/m³)		
		Peak 1-hour average*	Peak 8-hour average	Annual average
Ni	Predicted concentration at most impacted receptor	0.02	0.0076	0.00013
	Receptor location	Mine boundary	R2	R7
	Percentage of guideline	10%	13%	0.9%
	Assessment criteria	**0.2 OEHHA**	**0.06 OEHHA**	**0.014 OEHHA**
Cr	Predicted concentration at most impacted receptor	0.00005	0.000017	2.96×10^{-7}
	Receptor location	Mine boundary	R2	R7
	Percentage of guideline	0.1%	0.01%	<0.001%
	Assessment criteria	**0.48 OEHHA**	**0.12 OEHHA**	**0.06 OEHHA 0.11 AAQG**
Pb	Predicted concentration at most impacted receptor	N/A		2.33×10^{-6}
	Receptor location			R7
	Percentage of guideline			<0.001%
	Assessment criteria	N/A	N/A	**0.2 AAQG**
As	Predicted concentration at most impacted receptor	5.10×10^{-4}	1.92×10^{-4}	3.33×10^{-6}
	Receptor location	Mine boundary	R2	R7
	Percentage of guideline	0.30%	1.30%	0.06%
	Assessment criteria	**0.20 OEHHA**	**0.015 OEHHA**	**0.0055 AAQG**

Note: Assumes background concentrations of trace metals are negligible, which is reasonable given there are no other notable sources in the receiving environment.
* Peak 1-hour average concentrations are derived from modelled 99.9th percentile concentrations as per MfE guidance (2004).

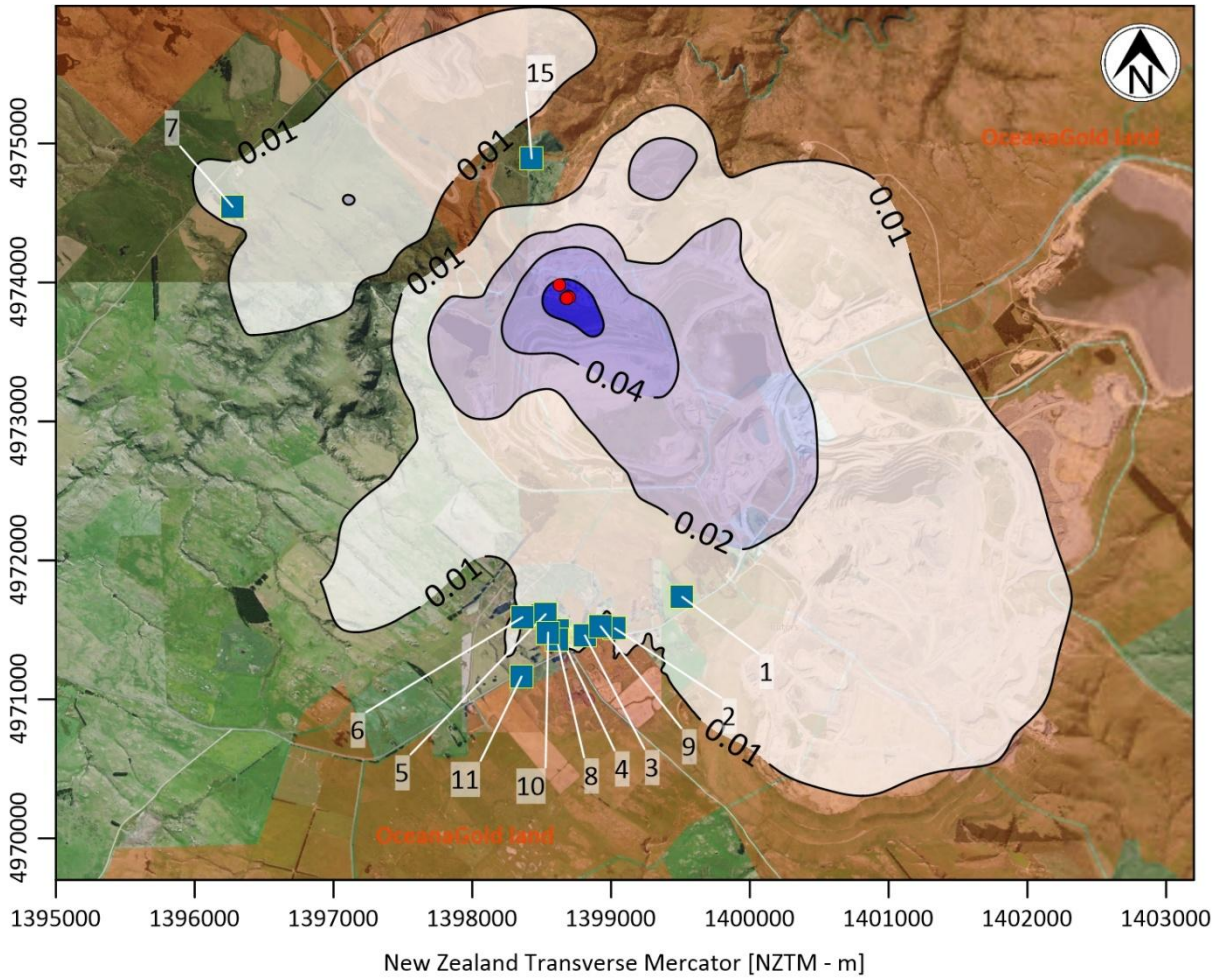


Figure 9.7: Predicted 1-hour maximum (modelled 99.9th percentile) nickel concentrations (µg/m³). Blue squares denote sensitive receptors. Orange shaded area denotes OGNZL land.

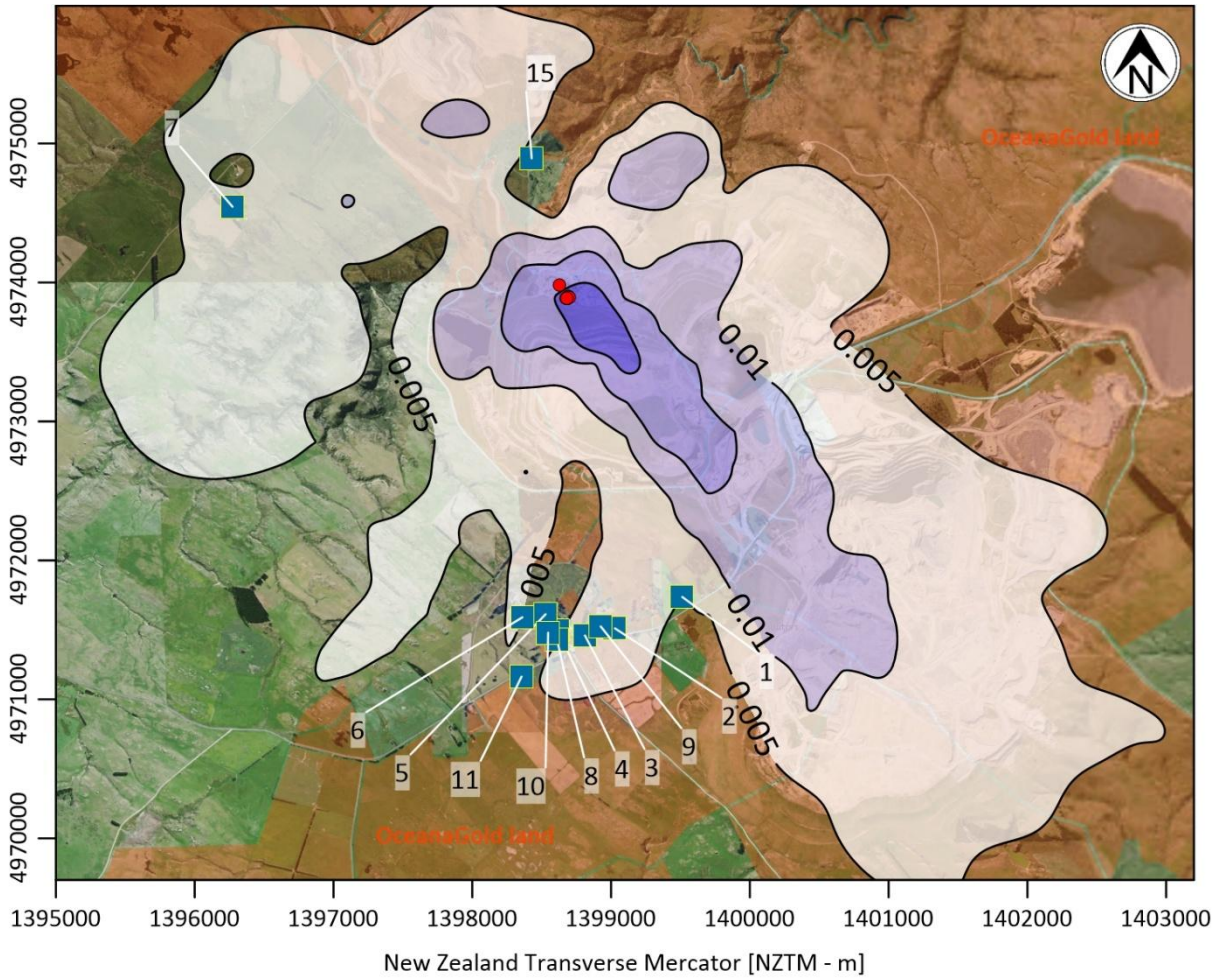


Figure 9.8: Predicted 8-hour average nickel concentrations (µg/m³). Blue squares denote sensitive receptors. Orange shaded area denotes OGNZL land.

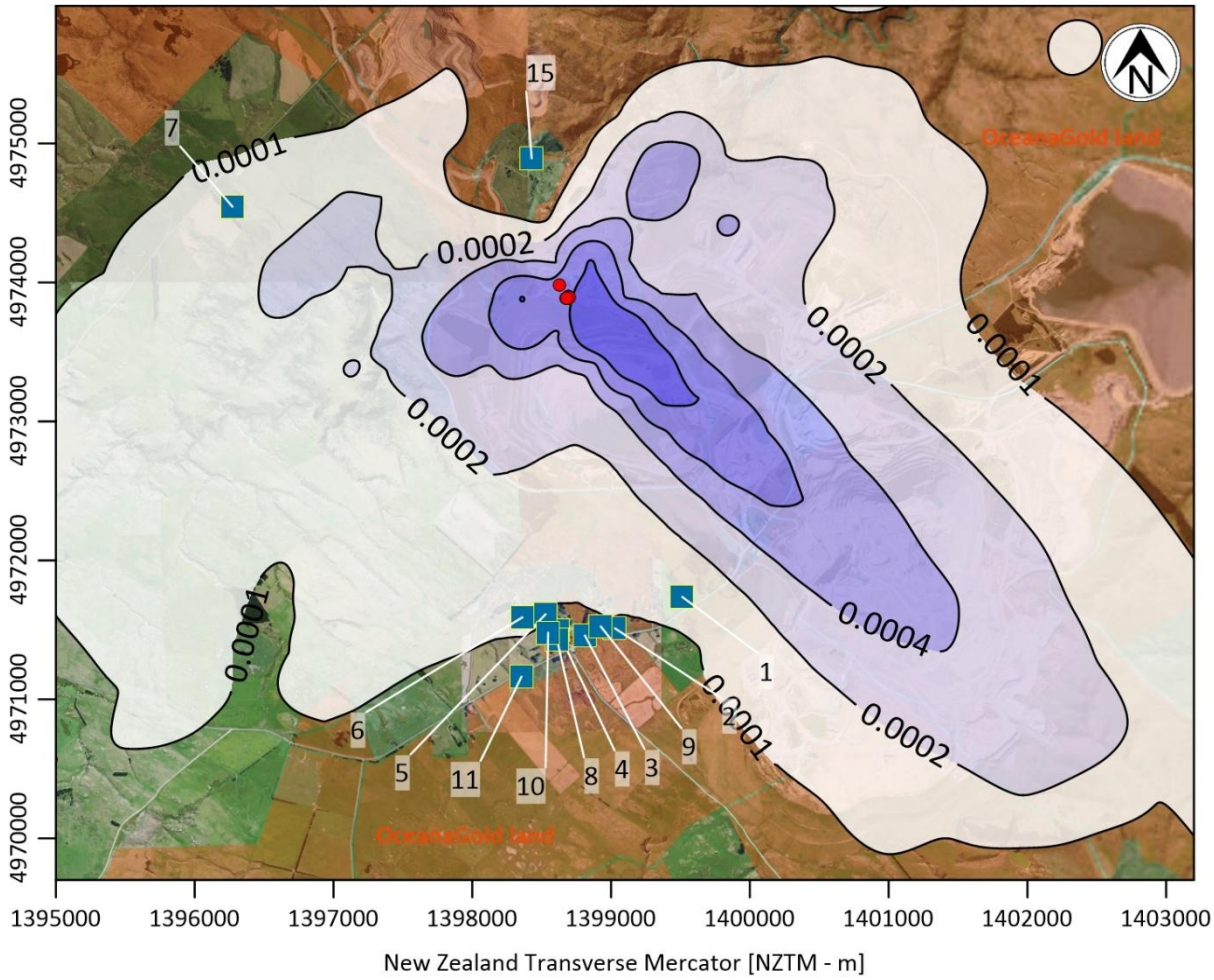


Figure 9.9: Predicted annual average nickel concentrations (µg/m³). Blue squares denote sensitive receptors. Orange shaded area denotes OGNZL land.

9.4 Recommended monitoring

Stack emission testing for industrial discharge stacks is typically required to be undertaken on a routine basis to confirm emission rates are within those assessed. Testing is typically carried out on an annual basis or less frequently where predicted impacts are low. Historically this has not been required for the Processing Plant discharge sources.

It is recommended that stack emission testing of the main discharge source, the POX plant stack, be carried out once every three years, testing for particulate matter, sulphur dioxide and metals. This recommendation is based on the low level of predicted impacts and is also due to the small dataset of existing testing data that has been used to inform this assessment. Monitoring of the other discharge stacks is not recommended due to the small scale of the discharge sources and very low predicted impacts associated with those sources.

It is recommended that a consent emission limit for nickel be set for the POX plant stack, based on the dispersion modelling results (refer to Section 9.3.3). Nickel is the only trace metal for which a limit is considered necessary, as its predicted 8-hour average concentration was 13% of the assessment criteria, whereas all other trace metals were less than 2% of their respective assessment criteria.

It is acknowledged that only a small body of stack emission test results is currently available from which to derive an emission rate for nickel. On this basis, a conservative emission limit has been

calculated as the emission rate that would result in a concentration of 30% of the assessment criteria at the most impacted off-site receptor. This equates to a nickel emission rate limit of 0.0084 kg/hr.

9.5 Conclusions

Dispersion modelling has been undertaken to predict ground level concentrations of sulphur dioxide, mercury, and trace metals at sensitive receptor locations resulting from the Processing Plant stack emissions. The modelling has been informed by a two-year meteorological dataset (2022–2023) configured using the CALMET model with site-specific meteorological data, taking into account both La Niña and El Niño conditions when selecting the model years. This ensures the assessment encompasses a representative range of meteorological variability and is representative of site conditions.

The model results demonstrate that predicted concentrations of all contaminants at all sensitive receptor locations are well within the relevant assessment criteria, including the NESAQ, MfE ambient air quality guidelines, and WHO 2021 guidelines. In the case of sulphur dioxide, predicted concentrations are less than 1% of the corresponding assessment criteria. Predicted mercury and trace metal concentrations at the most impacted sensitive receptor locations are similarly very low relative to the applicable OEHHA reference exposure levels and MfE guidelines, with several trace metal species modelled at or below laboratory limits of detection.

It is acknowledged that the stack emission data underpinning the dispersion modelling are derived from a limited number of testing rounds, with the modelling principally based on the K2 2022 test results. This reflects the current resource consent conditions not requiring routine stack testing. Notwithstanding this, any issues regarding the paucity of stack testing data are substantially offset by the very low predicted ground level concentrations at the most impacted sensitive receptor locations, which provide a considerable margin of compliance relative to all applicable assessment criteria. On the basis of the assessment findings, it is concluded that the Processing Plant stack discharges are not expected to give rise to adverse effects on human health at any sensitive receptor location.

Notwithstanding the low predicted concentrations, it is recommended that periodic stack testing of the POX plant stack be undertaken to confirm that emissions remain consistent with the data underpinning this assessment and to build a more robust long-term emissions dataset to support future assessments.

10 Alternatives

Section 105 of the RMA requires that, when considering a discharge permit application, regard must be had to the nature of the discharge and the sensitivity of the receiving environment to adverse effects, the applicant's reasons for the proposed choice, and any possible alternative methods of discharge, including discharge into any other receiving environment.

Existing and proposed mining operations at Macraes are constrained by the nature and distribution of the gold-bearing ore resource. Therefore, relocation of the Project or discharge of mining-related air contaminants into an alternative receiving environment is not a practicable option. The complete elimination of airborne discharges from open pit mining is not technically feasible. Underground mining is already a component of the Project through the Golden Point Underground mine; however, the scale, geometry and economics of the ore resource necessitate open pit mining methods for the majority of Project operations. As demonstrated by the assessments in Sections 8 and 9, the receiving environment is of low to moderate sensitivity with respect to these discharges given the substantial separation distances to sensitive receptors, and predicted effects at locations where there is high sensitivity are assessed as being negligible in all cases.

In terms of alternative methods of managing dust discharges, the mitigation measures described in Section 7 – principally water suppression, vehicle speed controls, progressive rehabilitation of exposed surfaces, and tailings management measures – represent the best practicable option for dust management at this location. For the Processing Plant, the wet scrubber treating POX plant off-gas provides effective control of stack emissions, and no technically or economically feasible alternative treatment technologies have been identified that would materially reduce emissions beyond those already achieved. In respect of mercury emissions specifically, the use of a retort oven to dry gold-loaded cathodes represents a deliberate design choice to capture and contain mercury vapour and is consistent with best practicable options for minimising mercury emissions from gold processing operations.

11 Conclusions

This air quality assessment has been prepared to support OGNZL's application for MP4 under the FTAA. The assessment evaluates the actual and potential effects of air discharges from the proposed mining activities alongside continuation of existing mining activities including operation of the Processing Plant. This includes consideration of direct and cumulative impacts.

The assessment has considered discharges to air from mining operations (primarily dust from vehicle movements, material handling, and exposed surfaces) and from the Processing Plant (stack emissions of sulphur dioxide, mercury, and trace metals). The evaluation has been informed by site-specific meteorology and topography, historical air quality monitoring data, complaints records, and consideration of sensitive receptor locations in the surrounding environment.

A qualitative assessment of dust effects from mining activities has been undertaken using both the Ministry for the Environment (MfE) FIDOL framework and UK IAQM guidance for assessing air quality effects associated with mineral extraction activities. The assessment concludes that the potential for dust effects at all sensitive receptors is negligible. While residual source emissions from haul road traffic and material handling activities have the potential to be large (reflecting the scale of mining activities), the substantial separation distances to sensitive receptors (all exceeding 600 m, with most exceeding 1 km) and the very low to low frequency of strong, dry winds directed towards those locations mean that effects are assessed as being negligible.

Historical monitoring data supports the above conclusion regarding dust effects, demonstrating general compliance with consent limits for dust deposition, a downward trend in deposition rates above background since early 2022, and low frequency of total suspended particulate (TSP) trigger events. Complaints records show only five dust-related complaints since 2018, with none received since 2020, consistent with effective implementation of dust mitigation measures.

Concentrations of PM_{10}, $PM_{2.5}$, and RCS at all sensitive receptor locations are concluded to be negligible. This assessment is informed by monitoring data from comparable quarrying operations (the Yaldhurst study) and consideration of substantial separation distances, which significantly exceed the distances at which incremental PM_{10} concentrations from mineral extraction activities typically reduce to negligible levels. This conclusion is further supported by historic monitoring of respirable quartz undertaken at the Macraes Operation in 1999 and 2000, which indicated concentrations well below the relevant guideline.

The potential for exposure to arsenic-containing PM_{10} from tailings storage facilities has been assessed using the FIDOL framework and is concluded to be negligible. This finding is based on the low potential for dust generation from tailings surfaces. Furthermore, even at significantly overstated PM_{10} exposure levels, the arsenic content of TSF dust would need to be approximately three times higher than actual levels to approach the MfE ambient air quality guideline.

Dispersion modelling has been undertaken to predict ground level concentrations of sulphur dioxide, mercury, and trace metals at sensitive receptor locations resulting from Processing Plant stack emissions. The modelling has been informed by a two-year meteorological dataset (2022–2023) configured using site-specific data.

The model results demonstrate that predicted concentrations of all contaminants at all sensitive receptor locations are well within the relevant assessment criteria, including the National Environmental Standards for Air Quality (NESAQ), the MfE ambient air quality guidelines, and WHO (2021) guidelines. Predicted sulphur dioxide concentrations are less than 1% of the corresponding assessment criteria. Predicted mercury and trace metal concentrations at the most impacted sensitive receptor locations are similarly very low relative to assessment criteria. On this basis, it is concluded that the Processing Plant stack discharges are not expected to give rise to adverse effects on human health at any sensitive receptor location.

These conclusions are contingent on the continued implementation of the dust mitigation measures currently applied at the site, including water suppression to haul roads and working areas, vehicle speed controls, progressive rehabilitation of exposed surfaces, and tailings management measures.

It is recommended that existing dust deposition and meteorological monitoring continue, with TSP monitoring at the village site replaced with continuous PM_{10} monitoring using a reference standard instrument. It is further recommended that a suitable nephelometer instrument set up to measure PM_{10} be established on OGNZL land near to the closest sensitive receptor (Receptor 1) in order to provide an early warning of increasing dust levels. For the Processing Plant, periodic stack testing of the POX plant stack is recommended to confirm emissions remain consistent with the data underpinning this assessment. It is also recommended that a consent emission limit for nickel be set for the POX plant stack, based on the dispersion modelling results.

Given the findings of this assessment, it is concluded that the Project can be undertaken in a manner that appropriately manages and minimises discharges to air to ensure that adverse effects on sensitive receptors and the surrounding environment will be negligible.

Proposed resource consent conditions relating to discharges to air are provided in Appendix G.

12 References

Beca, 2024. Oceana Macraes – Ambient Air Monitoring Report for 2023. Report prepared by Beca Limited for OceanaGold New Zealand Limited.

Fitzharris, Bowden, and Jackson, 2000. Atmospheric dustfall at Macraes, Otago 1999. University of Otago Consulting Group, Dunedin.

Fitzharris, Bowden, and Jackson, 2001. Atmospheric dustfall at Macraes, Otago 2000. University of Otago Consulting Group, Dunedin.

IAQM, 2016. Guidance on the assessment of mineral dust impacts for planning. Institute of Air Quality Management, United Kingdom.

K2, 2010. OceanaGold – Macraes Plant: Emission assessment of POX autoclave. Report prepared by K2 Environmental Limited for OceanaGold Limited. Job Number: L019.

K2, 2011. OceanaGold – Macraes Gold Mine Production Facility. Report prepared by K2 Environmental Limited for OceanaGold Limited. Job Number: M221 - DRAFT.

K2, 2016. OceanaGold, Macraes Flat, Otago: Emission Assessment of Production Plant. Report prepared by K2 Environmental Limited for OceanaGold Limited. Job Number: R1178.

K2, 2022. Stack emission assessment: OceanaGold Macraes. Report prepared by K2 Environmental Limited for OceanaGold Limited. Job Number: X0263.

MfE, 2002. Ambient Air Quality Guidelines. Ministry for the Environment. ME Number 438.

MfE, 2004. Good Practice Guide for Atmospheric Dispersion Modelling. Publication number ME 522. Ministry for the Environment. June 2004.

MfE, 2016a. Good Practice Guide for Assessing and Managing Dust. Ministry for the Environment. Publication number: ME 1277.

MfE, 2020. Proposed amendments to the National Environmental Standards for Air Quality – Consultation Document. Ministry for the Environment. Publication ME 1478.

Mote, 2018. Yaldhurst Air Quality Monitoring – Summary Report: 22 December – 21 April 2018. Report prepared for Environment Canterbury by Mote Limited.

OEHHA, 2020. Acute, 8-hour and chronic reference exposure levels. Office of Environmental Health Hazard Assessment as of June 2016, California. https://oehha.ca.gov/air/general-info/oehha-acute-8-hour-and-chronic-reference-exposure-level-rel-summary.

WHO, 2021. WHO global air quality guidelines: particulate matter ($PM_{2.5}$ and PM_{10}), ozone, nitrogen dioxide, sulphur dioxide and carbon monoxide. ISBN 978-92-4-003422-8. World Health Organization.

13 Applicability

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

This document has been produced for New Zealand consenting purposes only. Information contained herein must not be relied on for investment purposes.

We understand and agree that our client will submit this report as part of an application under the Fast-track Approvals Act 2024 and that an Expert Panel as the consenting authority will use this report for the purpose of assessing that application. We understand and agree that this report will be used by the Expert Panel in undertaking its regulatory functions.

Tonkin & Taylor Ltd
Environmental and Engineering Consultants

Report prepared by:

[redacted]

Richard Chilton
Technical Director - Air Quality

Authorised for Tonkin & Taylor Ltd by:

[redacted]

Jenny Simpson
Project Director

RICH

\\ttgroup.local\corporate\christchurch\tt projects\1101342\issueddocuments\1101342_macraesgold_aqia_rev0.docx

Appendix A K2 stack emission testing reports

South Island – Head Office	North Island Office
PO Box 28147, Beckenham, Unit 24, 105 Bamford Street, Woolston, Christchurch Tel: 03 384 8966 Fax: 03 384 8960 Mobile: [redacted] Email: [redacted]	Unit 23, 203 Kirkbride Road, Manukau, Auckland Tel: 09 275 1261 Fax: 09 275 1263 Mobile [redacted] Email: [redacted]

Oceana Gold – Macraes Plant

Emission Assessment of POx Autoclave

March/April 2010

Key Technical Personnel

Stuart Keer-Keer _____

Sample Team and Authors

Frank MacDonald
Nick Heatley
Joshua Probert
Lance Constable
Stuart Keer-Keer

Job Number: L019
Issue: 2
Report Date: 31 May 2010

TABLE OF CONTENTS

1 INTRODUCTION 1

1.1 Summary of Results 1

1.2 Deviation from Methods 1

1.3 Purpose of Sampling 1

1.4 Sampling Performed 2

1.5 Moisture Content 3

2 SAMPLING DETAIL AND RESULTS 3

2.1 Process Description 3

2.2 Sample Point Information 4

2.3 Results 5

2.3.1 Flow Measurements 5
2.3.2 Stack Gas Conditions 6
2.3.3 Trace Metal Results 7
2.3.4 Particulate Results 16
2.3.5 H_2SO_4/SO_2 Results 16

APPENDIX A: SAMPLING CONCEPTS EXPLAINED 17

A.1 Visual assessment of filters 18

A.2 Why measure Carbon dioxide and water concentrations? 18

A.3 What are velocity and flow rate? 18

A.4 Concentration vs. Mass Discharge 18

A.5 What is isokinicity? 19

A.6 How is isokinicity determined? 19

A.7 What are the velocity checks? 19

A.8 Why are numerous points and planes sampled? 19

A.9 Why are there numerous moisture and Carbon dioxide results? 19

APPENDIX B: SAMPLING METHODS 20

B.1 USEPA Method 5: Determination of Particulate Emissions from Stationary Sources 21

B.2 USEPA Method 8: Determination of Sulphuric Acid Mist and Sulphur Dioxide Emissions from Stationary Sources (Isokinetic) 22

B.3 USEPA Method 29: Determination of Metal Emissions from Stationary Sources 23

APPENDIX C: RAW DATA 25

C.1 Raw Data for Oceana Gold Macraes Gold Mine- Macraes Mix. 26

C.2 Raw Data for Oceana Gold- Macraes Mix Trace Metals 29

C.3 Raw Data for Oceana Gold Macraes Goldmine- Macraes Mix Method 8 38

C.4 Raw Data for Oceana Gold Macraes Goldmine- Reefton Mix..... 43

C.5 Raw Data for Oceana Gold- Macraes Gold Mine- Reefton Mix Trace Metals 47

C.6 Raw Data for Oceana Gold Macraes Gold Mine- Reefton Mix Method 8..... 56

INDEX OF TABLES AND FIGURES

Table 1 Summary of Results..... 1
Table 2 Flow Rates from POx Autoclave Stack 5
Table 3 Stack Gas Conditions..... 6
Graph 1 Average Velocity across POx Autoclave Duct 6
Table 4 Macraes Mix Test 1..... 7
Table 5 Macraes Mix Test 2..... 8
Table 6 Macraes Mix Test 3..... 9
Table 7 Average Macraes Mix Results..... 10
Table 8 Reefton Mix Test 1..... 11
Table 9 Reefton Mix Test 2..... 12
Table 10 Reefton Mix Test 3..... 13
Table 11 Average Reefton Mix Results..... 14
Table 12 Field Blank Results..... 15
Table 13 Total Suspended Particulate Results..... 16
Table 14 H_2SO_4 and SO_2 Emissions..... 16
Figure 1 Sampling Train for Measuring Particulate – Out of Stack..... 21
Figure 2 Sampling Train for H_2SO_4/SO_2 22
Figure 3 Trace metals Sampling Train..... 24

1 INTRODUCTION

1.1 Summary of Results

Table 1 Summary of Results

Analyte	Macraes Mix		Reefton Mix	
	Concentration[1]	Mass Emissions (kg/hr)	Concentration[1]	Mass Emissions (kg/hr)
Total Suspended Particulate	1600	3.8	2700	2.6
H_2SO_4	7700	18	9700	9.9
SO_2	1100	2.5	790	0.77
Total Metals[2]	140		330	

1.2 Deviation from Methods

Acid Mist sampling method is ideally used on dry stacks. The stacks were 80-90% moisture. Extra impingers were used to capture the high amount of moisture present.

It is likely that the H_2SO_4 results will be elevated as some of the sulphur dioxide will be trapped in the moisture present in the first impingers.

1.3 Purpose of Sampling

Sampling was performed on the POx autoclave stack, to determine if the concentration and mass emissions coming from the stack are at evaluated levels.

1 mg/m^3, 1 atm, 0^oC, dry

2 Including detection limit

1.4 Sampling Performed

On the 9th, 10th, 15th of March and the 7th of April 2010, sampling was carried out at Oceana Gold - Macraes Goldmine, Otago.

Samples were collected from the POx Autoclave discharge to determine the concentration and mass emission of trace metals, total suspended particulate, sulphur trioxide (as H_2SO_4) and sulphur dioxide present in the gases released to the atmosphere.

The following trace metals were sampled for:-

- Antimony
- Arsenic
- Barium
- Beryllium
- Cadmium
- Chromium
- Cobalt
- Copper
- Lead
- Manganese
- Mercury
- Nickel
- Phosphorus
- Selenium
- Silver
- Tellurium
- Thallium
- Zinc

Other parameters measured were:-

- Carbon dioxide (CO_2)
- Oxygen (O_2)
- Stack temperature
- Stack flow
- Stack gas moisture

The analysis for H_2SO_4 and SO_2 was carried out at the K2 Environmental Laboratory.

Trace metal analysis was subcontracted.

K2 Environmental Ltd. is accredited for the following methods used in this report:-

- Total Suspended Particulate (USEPA Method[3] 5)
- Determination of Acid Mist and SO_2 (USEPA Method 8)
- Determination of Trace Metals (USEPA Method 29)
- Sampling Location (USEPA Method 1)
- Measurement of Velocity (USEPA Method 2)
- Molecular Weight (USEPA Method 3)
- Moisture Determination (USEPA Method 4)

[3] USEPA: United States Environmental Protection Agency

1.5 Moisture Content

Sampling trains were modified to include an extra impinger and drop out bottle to collect the moisture.

The moisture content in the stack is greater than 90 percent. Isokinetic sampling was unsustainable at 7-10 L/min because of the high vacuum. This was overcome by using a smaller nozzle size and sampling at around 2-4 L/min. This enabled a sample to be gathered for 15-20mins.

2 SAMPLING DETAIL AND RESULTS

2.1 Process Description

Gold is mined within quartz deposits. Gold-rich ore is transported to the processing area where grinding/milling takes place.

The ore is then subjected to an acidification process in order to remove carbonates. This is achieved using sulphuric acid. The autoclave process involves high pressure oxidation of the gold ore.

Parameters which are monitored:-

- temperature,
- fineness of the gold ore,
- pH level,
- total retention time.

After autoclaving the slurry is cooled in flash towers and tube heat exchangers. It is then sent to the neutralization circuit.

In the neutralization circuit. Gold binds itself to the activated carbon where cyanidation begins. The activated carbon is then sent through to the carbon strip circuit where the following happens:-

1. Elution or stripping of the carbon.
2. Carbon regeneration.
3. Gold production by electro-winning or cementation from the elate solution.

The final process involves the refining of the gold.

2.2 Sample Point Information

Location and description

The sampling position is located approximately 2 stack diameters downstream from a flow disturbance and approximately 1 stack diameters upstream from a flow disturbance.

1.070 Meter diameter circular duct.

Sample Date and Times

Macraes Mix

Sample		Date	Start	Finish
Trace Metals	1	9-3-2010	15:35	15:45
	2	7-4-2010	11:15	11:30
	3		13:12	13:27
H_2SO_4/ SO_2	1	9-3-2010	16:00	16:15
	2	7-4-2010	09:50	10:10
	3		13:57	14:12

Reefton Mix

Sample		Date	Start	Finish
Trace Metals	1	10-3-2010	16:00	16:15
	2	15-3-2010	13:17	13:32
	3		15:56	16:11
H_2SO_4/ SO_2	1	10-3-2010	16:30	16:45
	2	15-3-2010	12:09	12:24
	3		15:18	15:31

Sample Point Requirements

USEPA Method 1 requires 12 points are sampled on 2 traverses (total of 24 points). Sampling was performed at one point on one traverse. This was due to the challenging stack conditions and the location of the sample ports. Flows were measured as per USPEA Method 1.

2.3 Results

A brief description of the sampling procedures used during the programme is given in Appendix B. A copy of the calculation spreadsheets are included in Appendix C.

2.3.1 Flow Measurements

Table 2 Flow Rates from POx Autoclave Stack

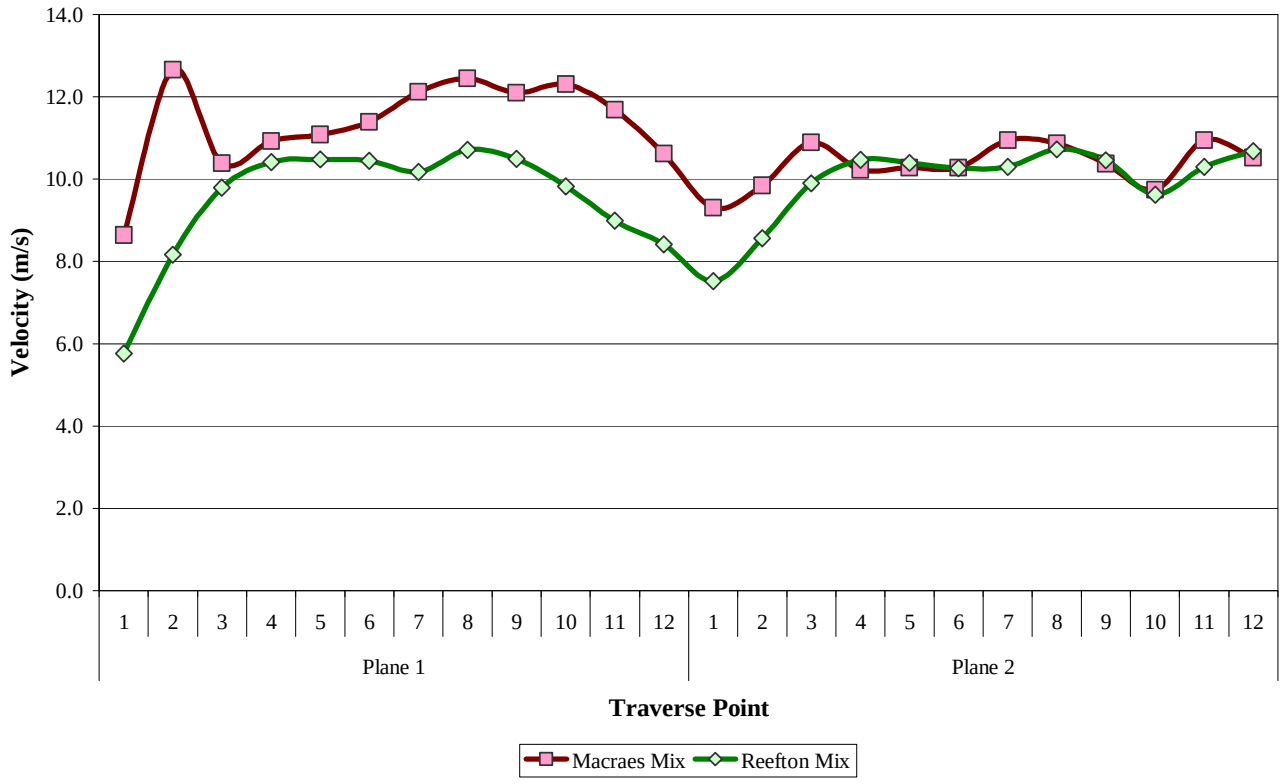
Sample		Velocity (m/s)	Flow Rate (m^3/s, 0°C, 1atm, dry)
Macraes Mix	**1**	11	0.67
	2	11	0.64
	Average	11	0.66
Reefton Mix	**1**	10	0.28
	2	10	0.28
	3	8.6	0.23
	Average	10	0.28

2.3.2 Stack Gas Conditions

Table 3 Stack Gas Conditions

Sample		Trace Metals			H_2SO_4/ SO_2		
		Temp (^oC)	Moisture (%)	Isokinicity (%)	Temp (^oC)	Moisture (%)	Isokinicity (%)
Macraes Mix	1	99	96	144	99	92	77
	2	99	91	89	99	90	100
	3	99	85	61	99	91	127
	Average	**99**	**91**	**98**	**99**	**91**	**101**
Reefton Mix	1	97	94	97	97	95	137
	2	99	96	124	99	95	89
	3	98	97	100	98	97	159
	Average	**98**	**96**	**107**	**98**	**95**	**128**

Graph 1 Average Velocity across POx Autoclave Duct



2.3.3 Trace Metal Results

The results obtained from trace metal sampling are shown in Tables 4 to 11.

Table 4 Macraes Mix Test 1

Analyte	Concentration (µg/m^3, dry, 0 °C,1 Atm,)					
	Gas and Particulate Fractions				Total Metals	
	Particulate		Gaseous		Excluding DL	Including DL
	Detection Limit	Result	Detection Limit	Result		
Antimony (Sb)	3.1	1100	12	89	1200	1200
Arsenic (As)	13	41000	50	4300	46000	46000
Barium (Ba)	13	460	50	150	610	610
Beryllium (Be)	13	<13	50	<50	<62	<62
Cadmium (Cd)	3.1	8.4	12	24	32	32
Chromium (Cr)	13	490	50	220	710	710
Cobalt (Co)	6.3	420	25	71	490	490
Copper (Cu)	13	2100	50	85	2200	2200
Lead (Pb)	3.1	530	12	180	710	710
Manganese (Mn)	6.3	980	25	<25	980	980
Mercury (Hg)	1.3	<1.3	5.0	1500	1500	1500
Nickel (Ni)	13	660	50	570	1200	1200
Phosphorus (P)	630	940	2500	<2500	940	3400
Selenium (Se)	13	230	50	890	1100	1100
Silver (Ag)	13	<13	50	<50	<62	<62
Tellurium (Te)	3.1	<3.1	12	13	13	16
Thallium (Tl)	3.1	<3.1	12	13	13	16
Zinc (Zn)	19	3500	74	2900	6400	6400

Table 5 Macraes Mix Test 2

Analyte	Concentration (µg/m^3, dry, 0 °C,1 Atm,)					
	Gas and Particulate Fractions				Total Metals	
	Particulate		Gaseous		Excluding DL	Including DL
	Detection Limit	Result	Detection Limit	Result		
Antimony (Sb)	1.8	520	8.1	63	580	580
Arsenic (As)	7.4	17000	32	14000	31000	31000
Barium (Ba)	7.4	240	32	140	380	380
Beryllium (Be)	7.4	<7.4	32	<32	<40	<40
Cadmium (Cd)	1.8	<1.8	8.1	12	12	13
Chromium (Cr)	7.4	310	32	180	490	490
Cobalt (Co)	3.7	220	16	330	560	560
Copper (Cu)	7.4	890	32	1100	2000	2000
Lead (Pb)	1.8	390	8.1	210	590	600
Manganese (Mn)	3.7	670	16	6600	7300	7300
Mercury (Hg)	0.74	25	2.4	860	890	890
Nickel (Ni)	7.4	330	32	1100	1400	1400
Phosphorus (P)	370	380	1600	140000	140000	140000
Selenium (Se)	7.4	87	32	670	760	760
Silver (Ag)	7.4	<7.4	32	<32	<40	<40
Tellurium (Te)	7.4	<7.4	32	<32	<40	<40
Thallium (Tl)	1.8	<1.8	8.1	<8.1	<9.9	<9.9
Zinc (Zn)	11	1400	48	2700	4000	4000

Table 6 Macraes Mix Test 3

Analyte	Concentration (µg/m^3, dry, 0 °C,1 Atm,)					
	Gas and Particulate Fractions				Total Metals	
	Particulate		Gaseous		Excluding DL	Including DL
	Detection Limit	Result	Detection Limit	Result		
Antimony (Sb)	1.7	110	6.0	48	160	160
Arsenic (As)	6.7	8100	24	11000	19000	19000
Barium (Ba)	6.7	120	24	71	130	130
Beryllium (Be)	6.7	<6.7	24	<24	<31	<31
Cadmium (Cd)	1.7	<1.7	6.0	6.5	6.5	8.2
Chromium (Cr)	6.7	81	24	110	190	190
Cobalt (Co)	3.3	94	12	150	250	250
Copper (Cu)	6.7	400	24	470	870	870
Lead (Pb)	1.7	110	6.0	140	250	250
Manganese (Mn)	3.3	320	12	2600	2900	2900
Mercury (Hg)	0.67	13	2.4	220	230	230
Nickel (Ni)	6.7	160	24	1700	1800	1800
Phosphorus (P)	330	620	1200	150000	150000	150000
Selenium (Se)	6.7	37	24	340	370	370
Silver (Ag)	6.7	<6.7	24	<24	<31	<31
Tellurium (Te)	6.7	<6.7	24	<24	<31	<31
Thallium (Tl)	1.7	<1.7	6.0	<6.0	<7.7	<7.7
Zinc (Zn)	1.0	320	36	1800	2100	2100

Table 7 Average Macraes Mix Results

Analyte	Excluding Detection Limits	Including Detection Limit
	Concentration (µg/m^3, dry, 0 °C,1 Atm,)	
Antimony (Sb)	630	630
Arsenic (As)	32000	32000
Barium (Ba)	370	370
Beryllium (Be)	44	44
Cadmium (Cd)	16	18
Chromium (Cr)	460	460
Cobalt (Co)	430	430
Copper (Cu)	1700	1700
Lead (Pb)	530	520
Manganese (Mn)	3700	3700
Mercury (Hg)	880	880
Nickel (Ni)	1500	1500
Phosphorus (P)	99000	99000
Selenium (Se)	750	750
Silver (Ag)	<44	<44
Tellurium (Te)	44	44
Thallium (Tl)	10	11
Zinc (Zn)	4200	4200

Table 8 Reefton Mix Test 1

Analyte	Concentration (µg/m^3, dry, 0 °C,1 Atm,)					
	Gas and Particulate Fractions				Total Metals	
	Particulate		Gaseous		Excluding DL	Including DL
	Detection Limit	Result	Detection Limit	Result		
Antimony (Sb)	1.9	6300	9	140	6500	6500
Arsenic (As)	7.5	23000	36	8800	32000	32000
Barium (Ba)	3.7	46	36	99	150	150
Beryllium (Be)	7.5	<7.5	36	<36	<44	<44
Cadmium (Cd)	1.9	<1.9	9.0	<9.0	<11	<11
Chromium (Cr)	7.5	110	36	74	180	180
Cobalt (Co)	3.7	63	18	820	880	880
Copper (Cu)	3.7	490	36	440	920	920
Lead (Pb)	1.9	550	9.0	230	770	770
Manganese (Mn)	3.7	76	18	1000	1100	1100
Mercury (Hg)	0.75	6.4	3.6	84	90	90
Nickel (Ni)	7.5	280	36	950	1200	1200
Phosphorus (P)	370	<370	1800	26000	26000	27000
Selenium (Se)	7.5	48	36	42	89	89
Silver (Ag)	7.5	<7.5	36	<36	<44	<44
Tellurium (Te)	7.5	<7.5	36	<36	<44	<44
Thallium (Tl)	1.9	<1.9	9.0	<9.0	<11	<11
Zinc (Zn)	11	220	54	1200	1400	1400

Table 9 Reefton Mix Test 2

Analyte	Concentration (µg/m^3, dry, 0 °C,1 Atm,)					
	Gas and Particulate Fractions				Total Metals	
	Particulate		Gaseous		Excluding DL	Including DL
	Detection Limit	Result	Detection Limit	Result		
Antimony (Sb)	3.1	58000	7.7	120	58000	58000
Arsenic (As)	12	71000	31	35000	110000	110000
Barium (Ba)	12	210	31	32	240	240
Beryllium (Be)	12	<12	31	<31	<43	<43
Cadmium (Cd)	3.1	<3.1	7.7	10	10	13
Chromium (Cr)	12	150	31	220	370	370
Cobalt (Co)	6.2	220	15	980	1200	1200
Copper (Cu)	12	1300	31	2700	4000	4000
Lead (Pb)	3.1	6200	7.7	490	6700	6700
Manganese (Mn)	6.2	410	15	1200	1600	1600
Mercury (Hg)	1.2	5.9	10	45	51	51
Nickel (Ni)	12	530	31	1700	2200	2200
Phosphorus (P)	620	620	1500	120000	120000	120000
Selenium (Se)	12	380	31	<31	380	410
Silver (Ag)	12	<12	31	<31	<43	<43
Tellurium (Te)	12	<12	31	<31	<43	<43
Thallium (Tl)	3.1	<3.1	7.7	<7.7	<11	<11
Zinc (Zn)	18	680	46	1900	2600	2600

Table 10 Reefton Mix Test 3

Analyte	Concentration (µg/m^3, dry, 0 °C,1 Atm,)					
	Gas and Particulate Fractions				Total Metals	
	Particulate		Gaseous		Excluding DL	Including DL
	Detection Limit	Result	Detection Limit	Result		
Antimony (Sb)	4.3	58000	25	460	58000	58000
Arsenic (As)	17	89000	100	110000	200000	200000
Barium (Ba)	17	140	100	260	410	410
Beryllium (Be)	17	<17	100	<100	<120	<120
Cadmium (Cd)	4.3	<4.3	25	25	25	29
Chromium (Cr)	17	150	100	430	580	580
Cobalt (Co)	8.6	220	50	1600	1800	1800
Copper (Cu)	17	1300	100	7000	8300	8300
Lead (Pb)	4.3	5200	25	1700	6900	6900
Manganese (Mn)	8.6	71	50	3100	3100	3100
Mercury (Hg)	1.7	<2.2	10	39	41	41
Nickel (Ni)	17	510	100	4100	4600	4600
Phosphorus (P)	860	15000	5000	300000	320000	320000
Selenium (Se)	17	790	100	<100	790	790
Silver (Ag)	17	<17	<100	<100	<120	<120
Tellurium (Te)	17	42	100	<100	42	140
Thallium (Tl)	4.3	<4.3	25	<25	<29	<29
Zinc (Zn)	26	<26	150	6700	6700	6700

Table 11 Average Reefton Mix Results

Analyte	Excluding Detection Limits	Including Detection Limit
	Concentration (µg/m^3, dry, 0 °C,1 Atm,)	
Antimony (Sb)	41000	41000
Arsenic (As)	110000	110000
Barium (Ba)	260	260
Beryllium (Be)	68	68
Cadmium (Cd)	15	18
Chromium (Cr)	380	380
Cobalt (Co)	1300	1300
Copper (Cu)	4400	4400
Lead (Pb)	4800	4800
Manganese (Mn)	1900	1900
Mercury (Hg)	61	61
Nickel (Ni)	2700	2700
Phosphorus (P)	160000	160000
Selenium (Se)	420	460
Silver (Ag)	<68	<68
Tellurium (Te)	43	76
Thallium (Tl)	<17	<17
Zinc (Zn)	3600	3600

Table 12 Field Blank Results

Analyte	Concentration (µg/m^3, dry, 0 °C,1 Atm,)					
	Gas and Particulate Fractions				Total Metals	
	Particulate		Gaseous		Excluding DL	Including DL
	Detection Limit	Result	Detection Limit	Result		
Antimony (Sb)	2.1	3.1	8.2	22	25	35
Arsenic (As)	8.3	13	33	5800	5800	5800
Barium (Ba)	8.3	13	33	<33	13	45
Beryllium (Be)	8.3	13	33	<33	13	45
Cadmium (Cd)	2.1	3.1	8.2	<8.2	3.1	11
Chromium (Cr)	8.3	13	33	94	110	150
Cobalt (Co)	4.1	6.3	16	<16	6.3	23
Copper (Cu)	8.3	13	33	100	120	160
Lead (Pb)	2.1	13	8.2	34	37	47
Manganese (Mn)	4.1	6.3	16	2100	2100	2100
Mercury (Hg)	0.83	1.3	3.3	<3.3	1.3	4.5
Nickel (Ni)	8.3	13	33	440	450	490
Phosphorus (P)	410	630	1600	200000	200000	200000
Selenium (Se)	8.3	13	33	<33	13	45
Silver (Ag)	8.3	13	33	<33	13	45
Tellurium (Te)	10	<10	44	<44	7.5	52
Thallium (Tl)	2.1	3.1	8.2	<8.2	3.1	11
Zinc (Zn)	12	19	49	<49	19	68

2.3.4 Particulate Results

Table 13 Total Suspended Particulate Results

Sample		Mass (mg)	Concentration (mg/m^3, 1 atm, 0^oC, dry)	Mass Emission (kg/hr)
Macraes Mix	**1**	69	2700	6.4
	2	61	1400	3.4
	3	32	700	1.6
	Average		1600	3.8
Reefton Mix	**1**	110	1700	1.7
	2	64	2700	2.6
	3	55	3500	3.5
	Average		2700	2.6

2.3.5 H_2SO_4/SO_2 Results

Table 14 H_2SO_4 and SO_2 Emissions

Sample		Mass (mg)		Concentration (mg/m^3/ 1 atm,, 0^oC, dry)		Mass Emission (kg/hr)	
		H_2SO_4	SO_2	H_2SO_4	SO_2	H_2SO_4	SO_2
Macraes Mix	**1**	660	60	9800	880	23	2.1
	2	600	72	8100	980	19	2.3
	3	420	100	5200	1300	13	3.1
	Average			7700	1100	18	2.5
Reefton Mix	**2**	550	61	13000	1400	13	1.3
	3	210	11	8100	410	8.0	0.41
	1	220	14	8700	560	8.7	0.56
	Average			9700	790	9.9	0.77

APPENDIX A: SAMPLING CONCEPTS EXPLAINED

A.1 Visual assessment of filters

A visual inspection of filters can give an idea of how well a combustion source is operating. A grey coloured filter or an ash coloured filter is an indication that the particulate discharge is ash and that combustion is complete. A black filter is one of the signs of incomplete combustion and that un-burnt fuel is being discharged. This should be interpreted with the combustion gas data.

A.2 Why measure Carbon dioxide and water concentrations?

This is mostly applicable to combustion sources, the composition of the air can change with variables such as ambient pressure, moisture carbon dioxide and temperature. All these variables affect the gas composition altering the air speed and flow. This can have a direct effect on how much air is sampled, how well the sampling is conducted and the overall outcome of the sampling.

When measuring flow, it is critical that you know the composition of the gas. If it is fresh air, then it is safe to assume the composition will be the same as the air we all breathe. If, however, it is a combustion source the composition of the gas will change. There will be elevated concentrations of carbon dioxide and water, and the oxygen levels lower. These are measured during the test and are used to calculate the flow rate.

A.3 What are velocity and flow rate?

Velocity is the speed in which the air is travelling up the duct. It is measured in meters per second. The flow rate is how much gas is travelling up the stack. The units are cubic meters (of air) per second. The flow rate is calculated from the velocity and the area of the duct.

For example, think of a small creek where the water is travelling fast, this has a high velocity but will have a low flow rate. Compare this to a larger river flowing slowly; this will have a low velocity but a high flow rate.

To calculate the flow rate the gas temperature and composition must be measured.

A.4 Concentration vs. Mass Discharge

The sample mass, in grams, is the amount of sample that has been collected on the filter or thimble in the stack. This mass is then divided by the volume of air sampled (m^3) to give the concentration of particulate in the stack.

kilograms per hour (kg/h) is reporting the discharge of kilograms of particulate discharged per hour. This is calculated from the concentration of the particulate and the flow rate. Concentration is how much is in the gas stream, whereas the kg/h is how much is discharged.

A.5 What is isokinicity?

Iso = same, kinetic = speed. It is important to sample particles at the same speed as they are travelling up the stack. At 100% isokinicity the rate in which the sample was gathered is the same as the rate in which the gas is travelling up the duct. Any deviations will mean sampling was less or greater than the stack flow rate.

If Isokinicity is greater than 100% then the smaller particles will be drawn into the nozzle and it will have a vacuum cleaner effect. If the Isokinicity is less than 100% then the smaller particles in the stack will avoid the nozzle. The effect of low isokinicity is to under sample the smaller particles and possibly get a lower result. The effect of a high isokinicity is to over sample the smaller particles and possibly get a higher result.

A.6 How is isokinicity determined?

The required sample rate to obtain 100% isokinicity is calculated before sampling commences. During sampling, the actual sampling rate is recorded and reported. This is compared to the sampling rates and the isokinicity is calculated by this comparison.

A.7 What are the velocity checks?

The standard requires that the velocity between tests does not change by more than 5%. Typically the flow rate is measured prior to a test and the measurements are used to calculate sample rate. If the velocity changes then the sample rate needs to be changed. If the process is variable then the velocity should be measured during sampling and the sample rate changed as the velocity changes.

A.8 Why are numerous points and planes sampled?

The size of a particle will affect how it travels up a duct. In a gas stream with particles greater than three microns in size they will behave differently. It is possible all the small particles can be found around the outside and the larger ones in the middle. To account for these differences, the standard requires a traverse of the duct be performed. The size of the duct dictates how many points must be sampled.

The position of the sampling port and the sampling platform often restricts how many points can be sampled.

A.9 Why are there numerous moisture and Carbon dioxide results?

The moisture and carbon dioxide can and does change from test to test. If the process is very steady and there is little variation in the process the carbon dioxide and moisture would not vary much.

Factors such as; how hard the process is working, fuel composition and how much excess air there is, can change the moisture and carbon dioxide concentrations. The individual results are averaged and presented in the averaged results above for carbon dioxide and moisture. A graph of carbon dioxide during the test gives extra information on how the process is working during the test.

APPENDIX B: SAMPLING METHODS

B.1 USEPA Method 5: Determination of Particulate Emissions from Stationary Sources

During out of stack sampling, the sample is drawn out of the stack before being passed through a filter which is generally located inside a hotbox. An out of stack method may be required for several different reasons:

- ***If the stack has condensing moisture, e.g. after a wet scrubber***
- ***If particulate is being determined concurrently with other samples such as dioxins, halides or trace metals.***
- ***For stacks where the stack gas has a temperature of above 450^{o}C.***

A diagram of the sample train used is shown in the diagram below. A substantial volume of gas is withdrawn from the stack and filtered to determine the mass of particulate.

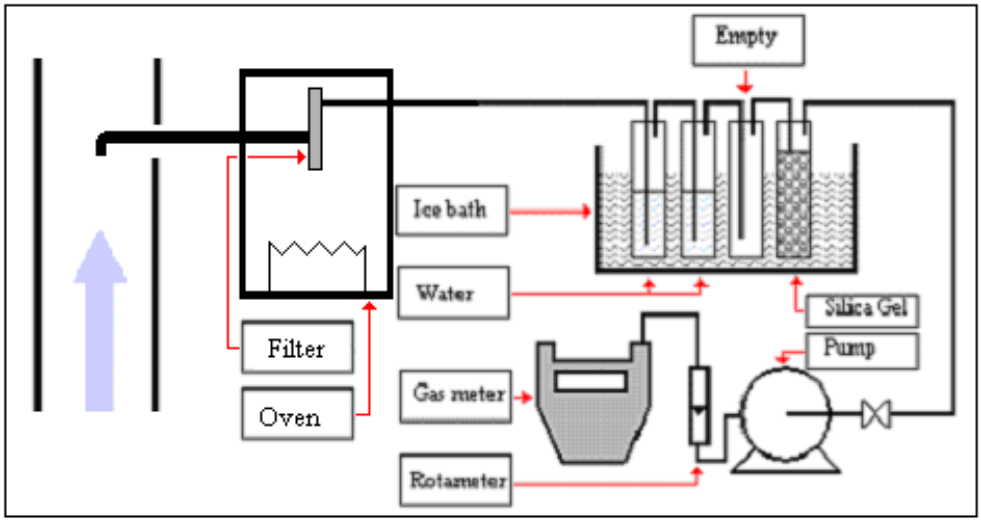


Figure 1 Sampling Train for Measuring Particulate – Out of Stack

This method uses the following elements:

Out of Stack filter

The filters used are 90mm diameter flat filters. They are either made of glass microfibre or quartz, depending on the application, and do not contain any organic binder. Filters are dried and weighed before and after sampling and the particulate concentration is calculated from the difference in mass. Field and lab blank filters are also measured, to ensure that the weighing process is precise.

During sampling the filters are located within a hotbox, outside of the stack.

Impinger train

A total of 4 impingers are used. The first 2 impingers are filled with 100 ml of distilled water followed by an empty impinger and one filled with silica gel. The purpose of the impingers is to remove moisture from the sample train, for the purposes of determining the concentration of moisture in the stack gases.

B.2 USEPA Method 8: Determination of Sulphuric Acid Mist and Sulphur Dioxide Emissions from Stationary Sources (Isokinetic)

K2 Environmental samples for sulphuric acid mist and sulphur dioxide according to USEPA Method 8. The sampling train used is shown in the figure below. Sulphuric acid mist (SO_3) is trapped in the first impinger of the train which contains 100 ml of 80% isopropanol. The resulting solution is analysed for SO_3 and reported as H_2SO_4. Sulphur dioxide (SO_2), is unimpeded by the first parts of the sampling train, and is trapped as sulphate ions in the 3% hydrogen peroxide solution contained within the second and third impingers.

The impinger solutions are collected in two fractions. The first includes impinger one and the filter. The second reaction includes impingers two and three. Analysis of each fraction is carried out to determine sulphates by barium chloride titrations.

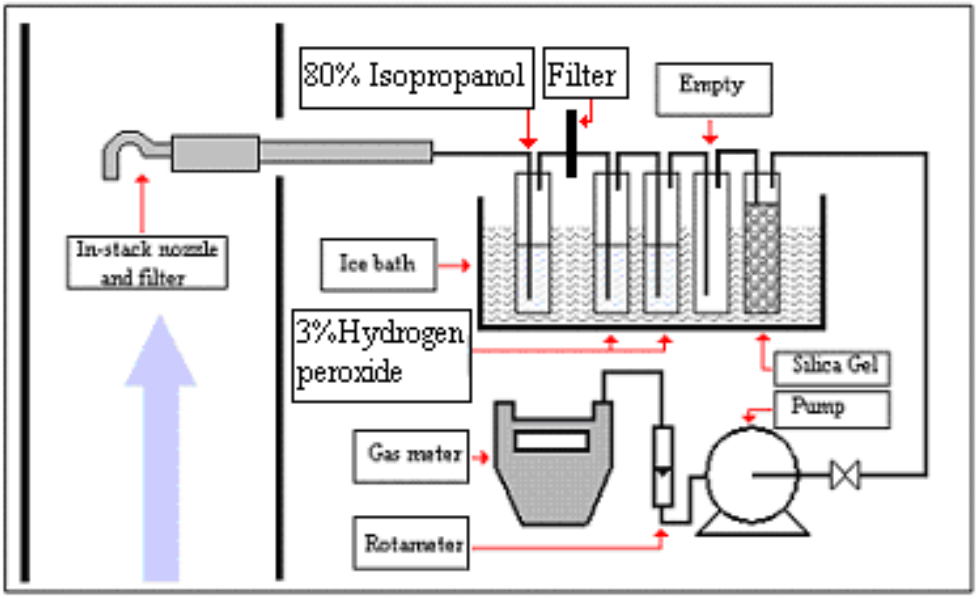


Figure 2 Sampling Train for H_2SO_4/SO_2

B.3 USEPA Method 29: Determination of Metal Emissions from Stationary Sources

Trace metals are sampled using a method based on USEPA Method 29. A sample is withdrawn from the source and filtered using an out of stack filter. The filter is heated to 120 ^{o}C to prevent any loss of trace metals through condensation. The filter is followed by six impingers, through which the gaseous sample passes. The first two impingers contain nitric acid, which traps all trace metals. The third impinger is empty. The forth and fifth impingers contain acidified permanganate to trap mercury. The sixth contains silica gel to remove any remaining moisture.

Blank Samples

A critical component of any trace metal sampling is the analysis of blanks. The low detection limits now obtainable by analytical instrumentation mean that it is necessary to be able to demonstrate that the elements found originate from the source and not from the sample media or other contamination source. The blanks that are gathered and analysed by K2 Environmental Ltd during trace metal analysis are detailed:

- Quartz filter
- 10 % Nitric Acid used in sample recovery
- 10 % Nitric Acid / 5% Peroxide trapping solution
- 4% Permanganate trapping solution (only if mercury is required)
- Field Blank.

A field blank is where the sampling train is prepared with all of the trapping solutions, however no sampling is performed. The sample train is then washed out following the same procedure as for samples. This gives a measure of any contamination being introduced by the glassware and washout procedure. Contamination can come from poorly cleaned glassware or from the actual components of the glass in the impingers. The analysis of blanks also allows the detection limits of the trace metal analysis to be reported.

The samples and the field blank are corrected according to the results from the blanks.

Sample Analysis

The train is divided into four components, which are each analysed separately.

Sample train components	Samples collected	Analysis for
Probe wash	Metals in the particulate phase	Total metals (excluding Hg)
Filter	Metals in the particulate phase	Total metals (excluding Hg)
Impingers 1,2 and 3	Metals in the vapour phase	Total metals (excluding Hg)
Impingers 4 and 5*	Mercury	Mercury (Hg)

*including any precipitate as this often contains mercury.

This four fraction split is selected as it provides information on whether the metals are discharged in the vapour phase or as particulate.

The phases which collect metals in the particulate phase require the metals to be converted to a liquid phase prior to analysis. The process of doing this is called digestion and involves applying heat and pressure to the filter while is immersed in nitric acid. This method uses a microwave digestion procedure. Other less rigorous digestion procedures are available; however they do not meet the requirements of this method.

The permanganate and any precipitate (from the fourth and fifth impingers) are analysed separately and the results combined. If they are not analysed separately, the precipitate must be broken down and homogenised with the permanganate solution. This procedure is less common as it is a difficult procedure, and if not undertaken correctly, the aliquot that is taken for analysis may not be representative of the sample. So the separate analysis prevents this error, giving a better representation of the nature of the stack discharge.

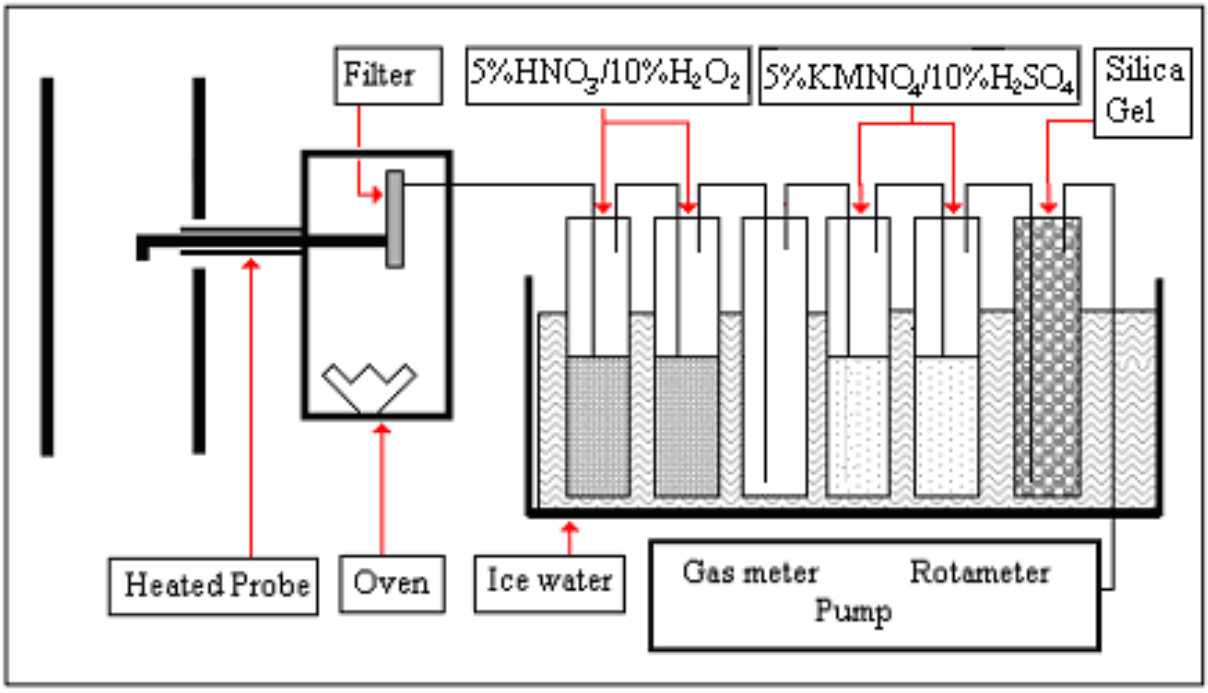


Figure 3 Trace metals Sampling Train

APPENDIX C: RAW DATA

C.1 Raw Data for Oceana Gold Macraes Gold Mine- Macraes Mix.

Duct/Stack information	
Sample points	
Pitot constant	0.824
Nozzle diameter (mm)	0
Ambient Pressure (Pa)	101325
Stack pressure (Pa)	-55.8
Stack Diameter (m)	1.08
Stack Width (m)	
Stack Depth (m)	
Molecular weight	21.5

Stack Diameters to Disturbance	
Down Stream	1.4
Upstream	2.3

Method	USEPA
Points	24
Two Traverses?	Y
Cyclonic Flow	Y
Method deviation	
Type of Duct	Circular Duct

Average Stack Gas Molecular Weight

	Vol % Dry	Vol % Wet	Multiplier	Mol Wt Dry	Mol Wt Wet
CO_2	0.00	0.00	0.44	0.00	0.00
O_2	21.00	6.72	0.32	6.72	2.15
CO	0.00	0.00	0.28	0.00	0.00
N_2	79.00	25.27	0.28	22.14	7.08
H_2O	----------	68.01	0.18	0.00	12.25
		Molecular Mass		28.86	21.48
		Density STP (kg/m^3)		1.3032	0.9703
		Density actual (kg/m^3)		1.0436	0.7990

Moisture in the Stack	Conc (%)
Test 1	91.0
Test 2	91.0

Test 1	Δp1 (Pa)	Stack Temp (°C)	Velocity (m/s)
1	35	99.0	8.6
2	57		11.0
3	58		11.1
4	56		11.0
5	54		10.7
6	59		11.3
7	66		12.0
8	68		12.1
9	71		12.4
10	76		12.8
11	72		12.4
12	56		11.0
13	51		10.5
14	48		10.2
15	62		11.6
16	53		10.7
17	50		10.4
18	53		10.7
19	62		11.6
20	60		11.4
21	56		11.0
22	47		10.1
23	62		11.6
24	53		10.7

Test 2	Δp2 (Pa)	Stack Temp (°C)	Velocity (m/s)
1	35	99.0	8.6
2	95		14.3
3	43		9.6
4	55		10.9
5	60		11.4
6	61		11.5
7	70		12.3
8	76		12.8
9	65		11.8
10	65		11.9
11	55		10.9
12	48		10.2
13	30		8.1
14	42		9.5
15	48		10.2
16	44		9.7
17	48		10.1
18	45		9.9
19	49		10.3
20	50		10.3
21	44		9.8
22	41		9.4
23	49		10.3
24	50		10.3

Gas Flows from Prelim Survey	**1**	**2**
Velocity (m/s)	11.12	10.60
Flow Rate (m^3/s)	10.18	9.71
(m3/s, 0°C, 1 atm, dry)	0.67	0.64
Flow Rate (m^3/h)	36664.43	34942.80
(m3/h, 0°C, 1 atm, dry)	2420.29	2306.64
Stack Temperature (^oC)	99	99
Stack Gas CO_2 (%, Dry)	0.0	0.0
Stack Gas Oxygen (%, Dry)	21.0	21.0

Velocity Check	1	2
Velocity (m/s)	11.12	10.60
Difference from Previous (%)		-4.7%

Temp. Correction (^oC)	0

C.2 Raw Data for Oceana Gold- Macraes Mix Trace Metals

Sample Point			
Sample Date	9-Mar-10	7-Apr-10	
Sampling Number	1	2	3
Start Time (Hr:min)	15:35	11:15	13:12
Finish Time (Hr:min)	15:45	11:30	13:27
Sample duration (Hr:min)	0:10	0:15	0:15
Minutes per point (min)	10	15	15

Duct/Stack information	
Sample points	
Pitot constant	0.824
Nozzle diameter (mm)	10
Ambient Pressure (Pa)	101325
Stack pressure (Pa)	-56.9
Stack Diameter (m)	1.08
Stack Width (m)	
Stack Depth (m)	
Molecular weight	19.2

Stack Diameters to Disturbance	
Down Stream	1.4
Upstream	2.3

Method	USEPA
Points	6
Two Traverses?	Y
Cyclonic Flow	N
Method deviation	
Type of Duct	Circular Duct

Average Stack Gas Molecular Weight

	Vol % Dry	Vol % Wet	Multiplier	Mol Wt Dry	Mol Wt Wet
CO_2	0.00	0.00	0.44	0.00	0.00
O_2	21.00	2.24	0.32	6.72	0.72
CO	0.00	0.00	0.28	0.00	0.00
N_2	79.00	8.43	0.28	22.14	2.36
H_2O	----------	89.33	0.18	0.00	16.09
		Molecular Mass		28.86	19.17
		Density STP (kg/m^3)		1.3032	0.8659
		Density actual (kg/m^3)		1.0426	0.6940

Moisture Start Weights	Impinger s					
	1	2	3	4	5	Drop Out
Test 1	508.1	517.8	402.3	690.5	565.9	1357.3
Test 2	512.6	512.6	402.4	452.5	499.7	1261.9
Test 3	566.2	517.0	521.9	402.7	451.5	1197.8

Moisture End Weights	Impinger s					
	1	2	3	4	5	Drop Out
Test 1	520.5	480.5	479.5	698.4	959.4	1368.6
Test 2	512.8	517.7	403.8	501.9	446.9	1602.5
Test 3	771.2	518.6	524.4	403.3	453.3	1201.9

Moisture Gain Loss	Impinger s					
	1	2	3	4	5	Drop Out
Test 1	12.4	-37.3	77.2	7.9	393.5	11.3
Test 2	0.2	5.1	1.4	49.4	-52.8	340.6
Test 3	205.0	1.6	2.5	0.6	1.8	4.1

Moisture in the Stack	Temp	Water Vol	Sample Vol	Mass	Conc	Conc
		(m^3, 0°C)	(m^3, 0°C)	(g)	(g/m^3)	(%)
Test 1	21.2	0.5790	0.0255	465.0	18222.2	95.8
Test 2	20.0	0.4282	0.0425	343.9	8094.2	91.0
Test 3	21.8	0.2684	0.0463	215.6	4655.8	85.3

Test 1	Δp1	Stack Temp	Velocity	Sample rate	Gas meter	Isokinicity
	(Pa)	(°C)	(m/s)	(L/min)	(m^3)	(%)
1	42	98.9	9.6		94.3030	
2	49	98.9	10.4		94.3030	
3	61	98.9	11.6		94.3030	
4	54	98.9	10.9		94.3030	
5	66	98.9	12.1	1.9	94.3030	144%
6	37		9.0		94.3305	
7	58		11.3		94.3305	
8	75		12.9		94.3305	
9	68		12.3		94.3305	
10	21		6.8		94.3305	
11	26		7.6		94.3305	
12	13		5.4		94.3305	
					94.3305	144%

Test 2	Δp2 (Pa)	Stack Temp (°C)	Velocity (m/s)	Sample rate (L/min)	Gas meter (m^3)	Isokinicity (%)
1	48	99.0	10.1	3.4	94.6704	89%
					94.7160	89%

Test 3	Δp3 (Pa)	Stack Temp (°C)	Velocity (m/s)	Sample rate (L/min)	Gas meter (m^3)	Isokinicity (%)
1	48	99.0	10.0	5.5	94.7740	61%
					94.8240	61%

Gas Flows from Prelim Survey	1	2	3
Velocity (m/s)	9.99	10.14	9.98
Flow Rate (m^3/s)	9.15	9.29	9.14
(m3/s, 0°C, 1 atm, dry)	0.66	0.66	0.66
Flow Rate (m^3/h)	32943.04	33426.20	32896.76
(m3/h, 0°C, 1 atm, dry)	2363.47	2363.47	2363.47
Stack Temperature (^{o}C)	99	99	99.00
Stack Gas CO_2 (%, Dry)	0.0	0.0	0.0
Stack Gas Oxygen (%, Dry)	21.0	21.0	21.0

Sample Volumes	1	2	3
Gas Meter Start (m^3)	94.3030	94.6704	94.7740
Gas Meter Finish (m^3)	94.3305	94.7160	94.8240
Gas Meter Temp (°C)	21.2	20.0	21.8
Volume (m^3,1atm,dry)	0.0275	0.0456	0.0500
Volume (m3, 0oC, 1 Atm, dry)	0.0255	0.0425	0.0463

Sample Number	1	2	3
Filter Number	AB1186/AB1185	AB1181	AB1183
Filter start (g)	1.1373	0.5673	0.5681
Filter after (g)	1.2059	0.6283	0.6003
Nozzle gain (g)	0.0000	0.0000	0.0000
Filter gain (g)	0.0686	0.0610	0.0322
Total Particulate (g)	0.0686	0.0610	0.0322

Weights: Initial	**1**	**2**	**3**
Filter Number	AB1186/AB1185	AB1181	AB1183
Before Weights	1.13753	0.56738	0.5681
	1.13727	0.56731	0.5681
	1.13709	0.56722	0.5680
Average Weight	1.1373	0.5673	0.5681

Weights: Final	**1**	**2**	**3**
Filter Number	AB1186/AB1185	AB1181	AB1183
After Weights	1.2065	0.6303	0.6015
	1.2063	0.6261	0.6001
	1.2049	0.6284	0.5992
Average Weight	1.2059	0.6283	0.6003

Concentration Results	**1**	**2**	**3**	**Average**
(mg/m3, 0oC, 1 Atm, dry)	2688.39	1434.86	695.49	**1606.25**
Mass Emission (mg/s)	1764.98	942.01	456.60	**1054.53**
Mass Emission (kg/h)	6.35	3.39	1.64	**3.80**
* correction basis % O_2				
* correction basis % CO_2	12	12	12	

Velocity Check	**1**	**2**	**3**
Velocity (m/s)	9.99	10.14	9.98
Difference from Previous (%)		1.5%	-1.6%

Temp. Correction (^oC)	0

Air Flow Rate (m^3/s 0 °C, 1 atm, dry)	Liquid Vol Nozzle Wash ml	Total Vol Wash Particulate ml	Liquid Vol Digest Spl 1 ml	Liquid Vol KMno4 soln ml	Gas Volume Spl 1 (m^3,0°C,1atm,dry)
0.66	110.00	160.00	633	326	0.0255

Air Flow Rate (m^3/s 0 °C, 1 atm, dry)	Liquid Vol Nozzle Wash ml	Total Vol Wash Particulate ml	Liquid Vol Digest Spl 2 ml	Liquid Vol KMno4 soln ml	Gas Volume Spl 2 (m^3,0°C,1atm,dry)
0.66	107.00	157.00	686	327	0.0425

Air Flow Rate (m^3/s 0 °C, 1 atm, dry)	Liquid Vol Nozzle Wash ml	Total Vol Wash Particulate ml	Liquid Vol Digest Spl 3 ml	Liquid Vol KMno4 soln ml	Gas Volume Spl 3 (m^3,0°C,1atm,dry)
0.66	105.00	155.00	558	256	0.0463

Test 1

	Blank Corrected Results			Particulate Concentration	Gas Concentration	Total	Mass Emission	
	Nozzle	Filter	Impinger					
	(µg)	(µg)	(µg)	(µg/m^3,0°C,1atm,dry)	(µg/m^3,0°C,1atm,dry)	(µg/m^3, 0°C,1 atm,dry,10% O_2)	(µg/s)	(g/hr)
Silver (Ag)	0	0	0.94	0.00	36.84	37	24	0.09
Arsenic (As)	289.65	753	109.64	40858.83	4296.52	45155	29645	106.72
Barium (Ba)	3.15	8.5	3.86	456.53	151.26	608	399	1.44
Beryllium (Be)	0	0	0.94	0.00	36.84	37	24	0.09
Cadmium (Cd)	0	0.215	0.611	8.43	23.94	32	21	0.08
Cobalt (Co)	0.25	10.45	1.82	419.31	71.32	491	322	1.16
Chromium (Cr)	0.41	12	5.6	486.32	219.45	706	463	1.67
Copper (Cu)	2.21	51.4	2.16	2100.84	84.64	2185	1435	5.17
Manganese (Mn)	1	24	0	979.69	0.00	980	643	2.32
Nickel (Ni)	0.47	16.3	14.64	657.17	573.70	1231	808	2.91
Phosphorous (P)	0	24	0	940.50	0.00	940	617	2.22
Lead (Pb)	4.09	9.5	4.58	532.56	179.48	712	467	1.68
Antimony (Sb)	7.44	19.8	2.26	1067.47	88.56	1156	759	2.73
Selenium (Se)	0.85	4.9	22.64	225.33	887.20	1113	730	2.63
Thallium (Tl)	0	0	0.331	0.000	12.97	13	9	0.03
Zinc (Zn)	1.2	88	73	3495.52	2860.69	6356	4173	15.02
Mercury (Hg)	0.018	0.804	38.161	32.21	1495.43	1528	1003	3.61

Test 2

	Blank Corrected Results			Particulate Concentration	Gas Concentration	Total	Mass Emission	
	Nozzle	Filter	Impinger					
	(µg)	(µg)	(µg)	(µg/m^3,0°C,1atm,dry)	(µg/m^3,0°C,1atm,dry)	(µg/m^3, 0°C,1 atm,dry,10% O_2)	(µg/s)	(g/hr)
Silver (Ag)	0	0.01	1.04	0.24	24	25	0	0
Arsenic (As)	82.65	633	609.64	16843.83	14348.734	31193	11058	40
Barium (Ba)	1.65	8.5	6.02	238.89	141.689	381	157	1
Beryllium (Be)	0	0	1.04	0.00	24.478	24	0	0
Cadmium (Cd)	0	0.065	0.491	1.53	11.556	13	1	0
Cobalt (Co)	0.52	8.95	14.23	222.89	334.923	558	146	1
Chromium (Cr)	0.35	13	7.5	314.21	176.523	491	206	1
Copper (Cu)	3.61	34.4	46.66	894.62	1098.209	1993	587	2
Manganese (Mn)	3.4	25	279.75	668.43	6584.309	7253	439	2
Nickel (Ni)	1.65	12.3	44.64	328.33	1050.665	1379	216	1
Phosphorous (P)	16	0	6038	376.58	142112.814	142489	247	1
Lead (Pb)	1.89	14.5	8.78	385.76	206.650	592	253	1
Antimony (Sb)	2.14	19.8	2.67	516.39	62.842	579	339	1
Selenium (Se)	0	3.7	28.64	87.08	674.083	761	57	0
Thallium (Tl)	0	0	0.251	0.000	5.908	6	0	0
Zinc (Zn)	9.5	48	114	1353.34	2683	4036	888	3
Mercury (Hg)	0	1.054	36.611	24.81	862	886	16.3	0.059

Test 3

	Blank Corrected Results			Particulate Concentration	Gas Concentration	Total	Mass Emission	
	Nozzle	Filter	Impinger					
	(µg)	(µg)	(µg)	(µg/m^3,0°C,1atm,dry)	(µg/m^3,0°C,1atm,dry)	(µg/m^3, 0°C,1 atm,dry,10% O_2)	(µg/s)	(g/hr)
Silver (Ag)	0	0	0.74	0.00	16	16	10	0
Arsenic (As)	51.65	323	509.64	8090.43	11005	19095.91	12537	45
Barium (Ba)	1.85	1	3.29	61.54	71	133	87	0
Beryllium (Be)	0	0	0.74	0.00	16	16	10	0
Cadmium (Cd)	0	0.005	0.301	0.108	6.50	6.61	4	0
Cobalt (Co)	0	4.35	7.07	93.94	153	247	162	1
Chromium (Cr)	0.25	3.5	4.9	80.98	106	186.8	123	0
Copper (Cu)	1.21	17.4	21.66	401.88	468	869.6	571	2
Manganese (Mn)	6.7	8	119.75	317.44	2586	2903.4	1906	7
Nickel (Ni)	0.95	6.3	77.64	156.56	1677	1833	1204	4
Phosphorous (P)	0	0	7138	0.00	154142	154142	101197	364
Lead (Pb)	1.89	3	6.58	105.60	142	247.7	163	1
Antimony (Sb)	1.84	3.3	2.2	111.00	48	159	104	0
Selenium (Se)	0	1.7	15.64	36.71	338	374	246	1
Thallium (Tl)	0	0	0.191	0.000	4.12	4.12	3	0
Zinc (Zn)	1.6	13	84	315.28	1814	2129	1398	5
Mercury (Hg)	0	0.604	10.081	13.04	217.7	231	151	0.545

Field Blank

	Blank Corrected Results							
	Nozzle	**Filter**	**Impinger**	**Particulate Concentration**	**Gas Concentration**	**Total**	**Mass Emission**	
	(µg)	(µg)	(µg)	(µg/m^3,0°C,1atm,dry)	(µg/m^3,0°C,1atm,dry)	(µg/m^3, 0°C,1 atm,dry)	(µg/s)	(g/hr)
Silver (Ag)	0	0	0.41	0	11	11	7	0.0
Arsenic (As)	0	0	219.64	0	5764	5764	3784	13.6
Barium (Ba)	0	0	1.16	0	30	30	20	0.1
Beryllium (Be)	0	0	0.41	0	11	11	7	0.0
Cadmium (Cd)	0	0	0.101	0	3	3	2	0.0
Cobalt (Co)	0	0	0.55	0	14	14	9	0.0
Chromium (Cr)	0	0	3.6	0	94	94	62	0.2
Copper (Cu)	0	0	3.96	0	104	104	68	0.2
Manganese (Mn)	0	0	80.75	0	2119	2119	1391	5.0
Nickel (Ni)	0	0	16.64	0	437	437	287	1.0
Phosphorous (P)	0	0	7638	0	200449	200449	131598	473.8
Lead (Pb)	0	0	1.28	0	34	34	22	0.1
Antimony (Sb)	0	0	0.83	0	22	22	14	0.1
Selenium (Se)	0	0	0.41	0	11	11	7	0.0
Thallium (Tl)	0	0	0.101	0	3	3	2	0.0
Zinc (Zn)	0	0	0	0	0	0	0	0.0
Mercury (Hg)	0	0	0	0	0	0	0	0.0000

C.3 Raw Data for Oceana Gold Macraes Goldmine- Macraes Mix Method 8

Duct/Stack information	
Sample points	
Pitot constant	0.824
Nozzle diameter (mm)	14
Ambient Pressure (Pa)	101325
Stack pressure (Pa)	-56.9
Stack Diameter (m)	1.08
Stack Width (m)	
Stack Depth (m)	
Molecular weight	19.1

Stack Diameters to Disturbance	
Down Stream	1.4
Upstream	2.3

Method	USEPA
Points	6
Two Traverses?	Y
Cyclonic Flow	Y
Method deviation	
Type of Duct	Circular Duct

Average Stack Gas Molecular Weight

	Vol % Dry	Vol % Wet	Multiplier	Mol Wt Dry	Mol Wt Wet
CO_2	7.50	0.77	0.44	3.30	0.34
O_2	21.33	1.89	0.32	6.82	0.61
CO	0.00	0.00	0.28	0.00	0.00
N_2	71.18	6.19	0.28	19.94	1.73
H_2O	----------	91.15	0.18	0.00	16.42
		Molecular Mass		30.07	19.10
		Density STP (kg/m^3)		1.3580	0.8626
		Density actual (kg/m^3)		1.0828	0.6897

Moisture Start Weights	Impingers 1	2	3	4	5	Drop Out
Test 1	1.0	0.0	0.0	0.0	0.0	0.0
Test 2	406.8	495.2	519.6	522.6	686.7	0.0
Test 3	604.6	496.3	520.3	509.0	409.0	688.9

Moisture End Weights	Impingers 1	2	3	4	5	Drop Out
Test 1	650.0	0.0	0.0	0.0	0.0	0.0
Test 2	900.0	516.4	522.6	522.4	688.9	0.0
Test 3	1209.0	547.4	519.9	520.1	420.3	690.4

Moisture Gain Loss	Impingers 1	2	3	4	5	Drop Out
Test 1	649.0	0.0	0.0	0.0	0.0	0.0
Test 2	493.2	21.2	3.0	-0.2	2.2	0.0
Test 3	604.4	51.1	-0.4	11.1	11.3	1.5

Moisture in the Stack	Temp	Water Vol	Sample Vol	Mass	Conc	Conc
		(m^3, 0°C)	(m^3, 0°C)	(g)	(g/m^3)	(%)
Test 1	21.2	0.8081	0.0679	649.0	9554.6	92.2
Test 2	16.7	0.6467	0.0742	519.4	7003.5	89.7
Test 3	22.7	0.8454	0.0803	679.0	8454.3	91.3

Test 1	Δp1	Stack Temp	Velocity	Sample rate	Gas meter	Isokinicity
	(Pa)	(°C)	(m/s)	(L/min)	(m^3)	(%)
1	42	98.9	9.5		345.0408	
2	49	98.9	10.3		345.0408	
3	61	98.9	11.5		345.0408	
4	54	98.9	10.8	6.1	345.0408	71%
5	66	98.9	12.0		345.0930	
6	37	98.9	8.9		94.2820	
7	58	98.9	11.2	6.4	94.2820	83%
8	75	98.9	12.7			
9	68	98.9	12.1			
10	21	98.9	6.7			
11	26	98.9	7.5			
12	13	98.9	5.3			
					94.3030	77%

Test 2	Δp2	Stack Temp	Velocity	Sample rate	Gas meter	Isokinicity
	(Pa)	(°C)	(m/s)	(L/min)	(m^3)	(%)
1	52	99.0	10.4	3.9	94.5778	100%
					94.6565	100%

Test 3	Δp3	Stack Temp	Velocity	Sample rate	Gas meter	Isokinicity
	(Pa)	(°C)	(m/s)	(L/min)	(m^3)	(%)
1	52	99.0	10.6	3.4	94.8630	127%
					94.9500	127%

Gas Flows from Prelim Survey	1	2	3
Velocity (m/s)	9.89	10.37	10.55
Flow Rate (m^3/s)	9.06	9.50	9.67
(m3/s, 0°C, 1 atm, dry)	0.66	0.66	0.66
Flow Rate (m^3/h)	32606.83	34201.13	34803.48
(m3/h, 0°C, 1 atm, dry)	2363.47	2363.47	2363.47
Stack Temperature (^oC)	99	99	99.00
Stack Gas CO_2 (%, Dry)	0.0	30.0	0.0
Stack Gas Oxygen (%, Dry)	21.0	22.3	21.0

Sample Volumes	1	2	3
Gas Meter Start (m^3)	345.0408	94.5778	94.8630
Gas Meter Finish (m^3)	94.3030	94.6565	94.9500
Gas Meter Temp (°C)	21.2	16.7	22.7
Volume (m^3,1atm,dry)	0.0732	0.0787	0.0870
Volume (m3, 0oC, 1 Atm, dry)	0.0679	0.0742	0.0803

Velocity Check	1	2	3
Velocity (m/s)	9.89	10.37	10.55
Difference from Previous (%)		4.9%	1.8%

Temp. Correction (^oC)	0

Test	Solution Type	Sample Volume (ml)	Titrations (ml)		
			$BaCl_2$ Volume 1	$BaCl_2$ Volume 2	$BaCl_2$ Volume 3
Oceana Gold Test 1	IPA	978.9	6.825	5.975	0
Oceana Gold Test 2	IPA	676.76	14.4	9.7	0
Oceana Gold Test 3	IPA	713.2	6.15	6	0
Oceana Gold Field Blank	IPA	0	0	0	-
Oceana Gold Reagent Blank	IPA	0	0	0	-

Sulphuric Acid Mist
H_2SO_4
Water sample

Stack / Test	H_2SO_4 (mg)	H_2SO_4 (g)	Concentration (mg/m^3, 0°C, 1 atm, dry)	Mass Emission (mg/s)	Mass Emission (kg/h)
Oceana Gold Test 1	650.06	0.65006	9570.22	6283.03	22.62
Oceana Gold Test 2	601.62	0.60162	8112.16	5325.79	19.17
Oceana Gold Test 3	394.03	0.39403	4906.12	3220.96	11.60

Test	Solution Type	Sample Volume (ml)	Titrations (ml)		
			$BaCl_2$ Volume 1	$BaCl_2$ Volume 2	$BaCl_2$ Volume 3
Oceana Gold Test 1	IPA	109.6	2	2	0
Oceana Gold Test 1	H202	217.2	9.2	9.25	0
Oceana Gold Test 2	IPA	130.2	0.1	0.1	0
Oceana Gold Test 2	H202	324.7	15.1	14.95	0
Oceana Gold Test 3	IPA	186.5	3	4.525	0
Oceana Gold Test 3	H202	326	21.375	21.75	0
Oceana Gold Field Blank	IPA	114.9	0.1	0.1	0
Oceana Gold Field Blank	H202	274.2	1	1	0

Sulphuric Acid Mist
H_2SO_4

Stack / Test	H_2SO_4 (mg)	H_2SO_4 (g)	Concentration (mg/m^3, 0°C, 1 atm, dry)	Mass Emission (mg/s)	Mass Emission (kg/h)
Oceana Gold Test 1	12.20	0.01220	179.63	117.93	0.42
Oceana Gold Test 2	0.59	0.00059	7.98	5.24	0.02
Oceana Gold Test 3	25.87	0.02587	322.05	211.43	0.76
Oceana Gold Field Blank	0.52	0.00052	7.05	4.63	0.02

Sulphur Dioxide SO_2

Stack / Test	SO_2 (mg)	SO_2 (g)	Concentration (mg/m^3, 0°C, 1 atm, dry)	Mass Emission (mg/s)	Mass Emission (kg/h)
Oceana Gold Test 1	59.50	0.05950	875.98	575.10	2.07
Oceana Gold Test 2	72.44	0.07244	976.73	641.24	2.31
Oceana Gold Test 3	103.66	0.10366	1290.65	847.34	3.05
Oceana Gold Field Blank	8.14	0.00814	109.84	72.11	0.26

C.4 Raw Data for Oceana Gold Macraes Goldmine- Reefton Mix

Duct/Stack information	
Sample points	
Pitot constant	0.824
Nozzle diameter (mm)	0
Ambient Pressure (Pa)	101325
Stack pressure (Pa)	-35
Stack Diameter (m)	1.08
Stack Width (m)	
Stack Depth (m)	
Molecular weight	23.9

Stack Diameters to Disturbance	
Down Stream	1.4
Upstream	2.3

Method	USEPA
Points	24
Two Traverses?	Y
Cyclonic Flow	Y
Method deviation	
Type of Duct	Circular Duct

Average Stack Gas Molecular Weight

	Vol % Dry	Vol % Wet	Multiplier	Mol Wt Dry	Mol Wt Wet
CO_2	0.00	0.00	0.44	0.00	0.00
O_2	21.00	11.45	0.32	6.72	3.66
CO	0.00	0.00	0.28	0.00	0.00
N_2	79.00	43.06	0.28	22.14	12.06
H_2O	----------	45.50	0.18	0.00	8.20
		Molecular Mass		28.86	23.92
		Density STP (kg/m^3)		1.3032	1.0805
		Density actual (kg/m^3)		1.0447	0.8808

Moisture in the Stack	Conc (%)
Test 1	96.0
Test 2	96.0
Test 3	96.0

Test 1	Δp1 (Pa)	Stack Temp (°C)	Velocity (m/s)
1	16	98.0	5.9
2	40		9.3
3	53		10.6
4	64		11.8
5	56		11.0
6	59		11.3
7	56		11.0
8	62		11.6
9	58		11.2
10	51		10.4
11	44		9.8
12	35		8.6
13	25		7.3
14	36		8.8
15	52		10.6
16	58		11.2
17	57		11.0
18	54		10.8
19	55		10.9
20	60		11.3
21	54		10.8
22	44		9.8
23	55		10.9
24	58		11.2

Test 2	Δp2 (Pa)	Stack Temp (°C)	Velocity (m/s)
1	15	98.0	5.7
2	30		8.1
3	45		9.8
4	51		10.5
5	60		11.3
6	54		10.8
7	53		10.7
8	58		11.2
9	55		10.9
10	49		10.2
11	42		9.5
12	40		9.2
13	36		8.8
14	43		9.7
15	52		10.6
16	55		10.9
17	57		11.1
18	53		10.7
19	54		10.8
20	59		11.3
21	59		11.3
22	54		10.8
23	54		10.8
24	59		11.3

Test 3	Δp3 (Pa)	Stack Temp (°C)	Velocity (m/s)
1	23	98.0	5.7
2	36		7.1
3	56		8.9
4	58		9.0
5	58		9.1
6	61		9.3
7	55		8.8
8	62		9.4
9	63		9.4
10	55		8.8
11	42		7.7
12	38		7.4
13	30		6.5
14	37		7.2
15	51		8.5
16	61		9.3
17	58		9.0
18	61		9.3
19	60		9.2
20	65		9.6
21	62		9.4
22	49		8.3
23	60		9.2
24	65		9.6

Gas Flows from Prelim Survey	**1**	**2**	**3**
Velocity (m/s)	10.29	10.24	8.57
Flow Rate (m^3/s)	9.43	9.38	7.85
(m3/s, 0°C, 1 atm, dry)	0.28	0.28	0.23
Flow Rate (m^3/h)	33943.92	33776.86	28273.36
(m3/h, 0°C, 1 atm, dry)	998.76	993.84	831.91
Stack Temperature (^oC)	98	98	98.00
Stack Gas CO_2 (%, Dry)	0.0	0.0	0.0
Stack Gas Oxygen (%, Dry)	21.0	21.0	21.0

Velocity Check	1	2	3
Velocity (m/s)	10.29	10.24	8.57
Difference from Previous (%)		-0.5%	-16.3%

Temp. Correction (^{o}C)	0

C.5 Raw Data for Oceana Gold- Macraes Gold Mine- Reefton Mix Trace Metals

Duct/Stack information	
Sample points	
Pitot constant	0.824
Nozzle diameter (mm)	10
Ambient Pressure (Pa)	101325
Stack pressure (Pa)	-55.8
Stack Diameter (m)	1.07
Stack Width (m)	
Stack Depth (m)	
Molecular weight	18.5

Stack Diameters to Disturbance	
Down Stream	1.4
Upstream	2.3

Method	USEPA
Points	24
Two Traverses?	Y
Cyclonic Flow	Y
Method deviation	
Type of Duct	Circular Duct

Average Stack Gas Molecular Weight

	Vol % Dry	Vol % Wet	Multiplier	Mol Wt Dry	Mol Wt Wet
CO_2	0.00	0.00	0.44	0.00	0.00
O_2	21.00	0.85	0.32	6.72	0.27
CO	0.00	0.00	0.28	0.00	0.00
N_2	79.00	3.21	0.28	22.14	0.90
H_2O	----------	95.94	0.18	0.00	17.28
		Molecular Mass		28.86	18.46
		Density STP (kg/m^3)		1.3032	0.8335
		Density actual (kg/m^3)		1.0450	0.6681

Moisture Start Weights	Impingers 1	2	3	4	5	Drop Out
Test 1	523.4	502.4	402.8	698.4	566.2	947.2
Test 2	566.6	504.7	516.0	410.4	442.0	1224.2
Test 3	569.8	512.8	526.0	423.7	444.3	1228.5

Moisture End Weights	Impingers					
	1	2	3	4	5	Drop Out
Test 1	527.4	502.5	402.2	694.8	1453.5	946.8
Test 2	761.0	602.1	586.5	487.6	454.4	1228.2
Test 3	919.2	525.1	526.5	423.4	446.8	1236.1

Moisture Gain Loss	Impingers					
	1	2	3	4	5	Drop Out
Test 1	4.0	0.1	-0.6	-3.6	887.3	-0.4
Test 2	194.4	97.4	70.5	77.2	12.4	4.0
Test 3	349.4	12.3	0.5	-0.3	2.5	7.6

Moisture in the Stack	Temp	Water Vol	Sample Vol	Mass	Conc	Conc
		(m^3, 0°C)	(m^3, 0°C)	(g)	(g/m^3)	(%)
Test 1	20.0	1.1042	0.0659	886.8	13462.1	94.4
Test 2	15.0	0.5676	0.0244	455.9	18714.0	95.9
Test 3	20.0	0.4632	0.0156	372.0	23907.4	96.7

Test 1	Δp1	Stack Temp	Velocity	Sample rate	Gas meter	Isokinicity
	(Pa)	(°C)	(m/s)	(L/min)	(m^3)	(%)
1	61	96.5	11.5	2.4	94.4203	97%
					94.4910	97%

Test 2	Δp2	Stack Temp	Velocity	Sample rate	Gas meter	Isokinicity
	(Pa)	(°C)	(m/s)	(L/min)	(m^3)	(%)
1	38	98.7	9.2	1.4	136.5750	124%
					136.6007	124%

Test 3	Δp3	Stack Temp	Velocity	Sample rate	Gas meter	Isokinicity
	(Pa)	(°C)	(m/s)	(L/min)	(m^3)	(%)
1	38	98.0	9.2	1.1	136.7053	100%
					136.7220	100%

Gas Flows from Prelim Survey	1	2	3
Velocity (m/s)	11.52	9.16	9.17
Flow Rate (m^3/s)	10.36	8.23	8.25
(m3/s, 0°C, 1 atm, dry)	0.28	0.28	0.28
Flow Rate (m^3/h)	37289.56	29644.85	29692.40
(m3/h, 0°C, 1 atm, dry)	996.30	996.30	996.30
Stack Temperature (^oC)	97	99	98.00
Stack Gas CO_2 (%, Dry)	0.0	0.0	0.0
Stack Gas Oxygen (%, Dry)	21.0	21.0	21.0

Sample Volumes	1	2	3
Gas Meter Start (m^3)	94.4203	136.5750	136.7053
Gas Meter Finish (m^3)	94.4910	136.6007	136.7220
Gas Meter Temp (°C)	20.0	15.0	20.0
Volume (m^3,1atm,dry)	0.0707	0.0257	0.0167
Volume (m3, 0oC, 1 Atm, dry)	0.0659	0.0244	0.0156

Sample Number	1	2	3
Filter Number	AB1033	AB1226	AB1229
Filter start (g)	0.5687	0.5650	0.5705
Filter after (g)	0.6806	0.6290	0.6249
Nozzle gain (g)	0.0000	0.0000	0.0000
Filter gain (g)	0.1119	0.0640	0.0545
Total Particulate (g)	0.1119	0.0640	0.0545

Weights: Initial	1	2	3
Filter Number	AB1033	AB1226	AB1229
Before Weights	0.5686	0.5623	0.5701
	0.5687	0.5676	0.5708
	0.5687		
Average Weight	0.5687	0.5650	0.5705

Weights: Final	1	2	3
Filter Number	AB1033	AB1226	AB1229
After Weights	0.6836	0.629	0.6249
	0.6793		
	0.6789		
Average Weight	0.6806	0.6290	0.6249

Concentration Results	**1**	**2**	**3**
(mg/m3, 0oC, 1 Atm, dry)	1699.20	2629.15	3499.34
Mass Emission (mg/s)	470.25	727.62	968.44
Mass Emission (kg/h)	1.69	2.62	3.49

Velocity Check	**1**	**2**	**3**
Velocity (m/s)	11.52	9.16	9.17
Difference from Previous (%)		-20.5%	0.2%

Temp. Correction (^{o}C)	0

Air Flow Rate (m^3/s 0 °C, 1 atm, dry)	Liquid Vol Nozzle Wash ml	Total Vol Wash Particulate ml	Liquid Vol Digest Spl 1 ml	Liquid Vol KMno4 soln ml	Gas Volume Spl 1 (m^3,0°C,1atm,dry)
0.28	196.00	246.00	1189	502	0.0659

Air Flow Rate (m^3/s 0 °C, 1 atm, dry)	Liquid Vol Nozzle Wash ml	Total Vol Wash Particulate ml	Liquid Vol Digest Spl 2 ml	Liquid Vol KMno4 soln ml	Gas Volume Spl 2 (m^3,0°C,1atm,dry)
0.28	100.00	150.00	374	232	0.0244

Air Flow Rate (m^3/s 0 °C, 1 atm, dry)	Liquid Vol Nozzle Wash ml	Total Vol Wash Particulate ml	Liquid Vol Digest Spl 3 ml	Liquid Vol KMno4 soln ml	Gas Volume Spl 3 (m^3,0°C,1atm,dry)
0.28	84.00	134.00	780	374	0.0156

Test 1

	Blank Corrected Results			Particulate Concentration	Gas Concentration	Total	Mass Emission	
	Nozzle	Filter	Impinger					
	(µg)	(µg)	(µg)	(µg/m^3,0°C,1atm,dry)	(µg/m^3,0°C,1atm,dry)	(µg/m^3, 0°C,1 atm,dry,10% O_2)	(µg/s)	(g/hr)
Silver (Ag)	0	0	2.04	0.00	30.97	31	9	0.03
Arsenic (As)	12.65	1483	579.64	22704.69	8799.21	31504	8719	31.39
Barium (Ba)	1.05	2	6.53	46.30	99.13	145	40	0.14
Beryllium (Be)	0.04	0	2.04	0.61	30.97	32	9	0.03
Cadmium (Cd)	0.012	0	0.531	0.18	8.06	8	2	0.01
Cobalt (Co)	0.02	4.15	53.82	63.30	817.01	880	244	0.88
Chromium (Cr)	2.55	4.5	4.9	107.02	74.38	181	50	0.18
Copper (Cu)	1.61	30.4	28.66	485.93	435.07	921	255	0.92
Manganese (Mn)	0	5	66.75	75.90	1013.30	1089	301	1.09
Sodium (Na)	0	0	0	0.00	0.00	0	0	0.00
Nickel (Ni)	8.45	10.3	62.64	284.63	950.91	1236	342	1.23
Phosphorous (P)	0	0	1738	0.00	26383.68	26384	7302	26.29
Lead (Pb)	0.52	35.5	14.88	546.80	225.89	773	214	0.77
Antimony (Sb)	0.35	417.8	9.13	6347.72	138.60	6486	1795	6.46
Selenium (Se)	0.04	3.1	2.74	47.67	41.59	89	25	0.09
Thallium (Tl)	0.012	0.015	0.501	0.410	7.61	8	2	0.01
Zinc (Zn)	14.5	0	76	220.12	1153.72	1374	380	1.37
Mercury (Hg)	0.085	0.334	5.511	6.36	83.66	90	25	0.09

Test 2

	Blank Corrected Results			Particulate Concentration	Gas Concentration	Total	Mass Emission	
	Nozzle	Filter	Impinger					
	(µg)	(µg)	(µg)	(µg/m^3,0°C,1atm,dry)	(µg/m^3,0°C,1atm,dry)	(µg/m^3, 0°C,1 atm,dry,10% O_2)	(µg/s)	(g/hr)
Silver (Ag)	0	0.01	0.39	0.41	16	16	0	0
Arsenic (As)	349.65	1383	859.64	71122.59	35286.886	106409	19683	71
Barium (Ba)	2.05	3	0.77	207.29	31.607	239	57	0
Beryllium (Be)	0	0	0.39	0.00	16.009	16	0	0
Cadmium (Cd)	0	0.045	0.251	1.85	10.303	12	1	0
Cobalt (Co)	0.49	4.95	23.82	223.30	977.774	1201	62	0
Chromium (Cr)	0.23	3.5	5.3	153.11	217.557	371	42	0
Copper (Cu)	1.31	29.4	66.66	1260.60	2736.289	3997	349	1
Manganese (Mn)	3.1	7	28.75	414.59	1180.143	1595	115	0
Nickel (Ni)	0.57	12.3	40.64	528.29	1668.209	2197	146	1
Phosphorous (P)	0	0	2938	0.00	120600.334	120600	0	0
Lead (Pb)	43.89	107.5	11.88	6214.32	487.656	6702	1720	6
Antimony (Sb)	219.84	1197.8	2.85	58191.92	116.988	58309	16105	58
Selenium (Se)	0	9.2	0.39	377.65	16.009	394	105	0
Thallium (Tl)	0	0.025	0.101	1.026	4.146	5	0	0
Zinc (Zn)	10.5	6	47	677.30	1929	2607	187	1
Mercury (Hg)	0	0.144	1.106	5.91	45	51	2	0.006

Test 3

	Blank Corrected Results			Particulate Concentration	Gas Concentration	Total	Mass Emission	
	Nozzle	Filter	Impinger					
	(µg)	(µg)	(µg)	(µg/m^3,0°C,1atm,dry)	(µg/m^3,0°C,1atm,dry)	(µg/m^3, 0°C,1 atm,dry,10% O_2)	(µg/s)	(g/hr)
Silver (Ag)	0	0	1.24	0.00	80	80	22	0
Arsenic (As)	399.65	983	1699.64	88858.86	109231	198089.75	54821	197
Barium (Ba)	1.25	1	4.07	144.60	262	406	112	0
Beryllium (Be)	0	0	1.24	0.00	80	80	22	0
Cadmium (Cd)	0	0.025	0.391	1.607	25.13	26.74	7	0
Cobalt (Co)	0.32	3.15	24.82	223.01	1595	1818	503	2
Chromium (Cr)	0.27	2	6.7	145.89	431	576.5	160	1
Copper (Cu)	1.71	18.4	109.66	1292.41	7048	8339.9	2308	8
Manganese (Mn)	0.6	0.5	47.75	70.69	3069	3139.4	869	3
Nickel (Ni)	0.58	7.3	63.64	506.42	4090	4596	1272	5
Phosphorous (P)	0	229	4738	14717.16	304497	319215	88343	318
Lead (Pb)	19.89	61.5	25.88	5230.70	1663	6893.9	1908	7
Silicon (Si)	0	0	0	0.00	0	0	0	0
Antimony (Sb)	119.84	777.8	7.19	57688.69	462	58151	16093	58
Selenium (Se)	0.46	11.9	1.24	794.34	80	874	242	1
Thallium (Tl)	0	0.005	0.301	0.321	19.34	19.67	5	0
Zinc (Zn)	0	0	104	0.00	6684	6684	1850	7
Mercury (Hg)	0	0.034	0.601	2.19	38.6	41	11	0.041

Field Blank

	Blank Corrected Results							
	Nozzle	Filter	Impinger	Particulate Concentration	Gas Concentration	Total	Mass Emission	
	(µg)	(µg)	(µg)	(µg/m^3,0°C,1atm,dry)	(µg/m^3,0°C,1atm,dry)	(µg/m^3, 0°C,1 atm,dry)	(µg/s)	(g/hr)
Silver (Ag)	0	0	0.41	0	12	12	3	0.0
Aluminium (Al)	0	0	0	0	0	0	0	0.0
Arsenic (As)	0	0	219.64	0	6228	6228	1724	6.2
Barium (Ba)	0	0	1.16	0	33	33	9	0.0
Beryllium (Be)	0	0	0.41	0	12	12	3	0.0
Cadmium (Cd)	0	0	0.101	0	3	3	1	0.0
Cobalt (Co)	0	0	0.55	0	16	16	4	0.0
Chromium (Cr)	0	0	3.6	0	102	102	28	0.1
Copper (Cu)	0	0	3.96	0	112	112	31	0.1
Manganese (Mn)	0	0	80.75	0	2290	2290	634	2.3
Nickel (Ni)	0	0	16.64	0	472	472	131	0.5
Phosphorous (P)	0	0	7638	0	216587	216587	59941	215.8
Lead (Pb)	0	0	1.28	0	36	36	10	0.0
Antimony (Sb)	0	0	0.83	0	24	24	7	0.0
Selenium (Se)	0	0	0.41	0	12	12	3	0.0
Tin (Sn)	0	0	0	0	0	0	0	0.0
Thallium (Tl)	0	0	0.101	0	3	3	1	0.0
Zinc (Zn)	0	0	0	0	0	0	0	0.0
Mercury (Hg)	0	0	0	0	0	0	0	0.0000

C.6 Raw Data for Oceana Gold Macraes Gold Mine- Reefton Mix Method 8

Duct/Stack information	
Sample points	
Pitot constant	0.823
Nozzle diameter (mm)	10
Ambient Pressure (Pa)	101325
Stack pressure (Pa)	-55.1
Stack Diameter (m)	1.07
Stack Width (m)	
Stack Depth (m)	
Molecular weight	18.5

Stack Diameters to Disturbance	
Down Stream	1.4
Upstream	2.3

Method	USEPA
Points	24
Two Traverses?	Y
Cyclonic Flow	N
Method deviation	
Type of Duct	Circular Duct

Average Stack Gas Molecular Weight

	Vol % Dry	Vol % Wet	Multiplier	Mol Wt Dry	Mol Wt Wet
CO_2	0.00	0.00	0.44	0.00	0.00
O_2	21.00	0.91	0.32	6.72	0.29
CO	0.00	0.00	0.28	0.00	0.00
N_2	79.00	3.43	0.28	22.14	0.96
H_2O	----------	95.65	0.18	0.00	17.23
Molecular Mass				28.86	18.49
Density STP (kg/m^3)				1.3032	0.8349
Density actual (kg/m^3)				1.0450	0.6692

Moisture Start Weights	Impingers 1	2	3	4	5	Drop Out
Test 1	523.4	502.4	402.8	698.4	566.2	947.0
Test 2	3641.7	0.0	0.0	0.0	0.0	0.0
Test 3	569.8	512.8	526.0	423.7	444.3	1228.5

Moisture End Weights	Impingers 1	2	3	4	5	Drop Out
Test 1	527.4	502.5	402.2	694.8	1453.5	946.8
Test 2	3985.4	0.0	0.0	0.0	0.0	0.0
Test 3	919.2	525.1	526.5	423.4	446.8	1236.1

Moisture Gain Loss	Impingers 1	2	3	4	5	Drop Out
Test 1	4.0	0.1	-0.6	-3.6	887.3	-0.2
Test 2	343.7	0.0	0.0	0.0	0.0	0.0
Test 3	349.4	12.3	0.5	-0.3	2.5	7.6

Moisture in the Stack	Temp	Water Vol	Sample Vol	Mass	Conc	Conc
		(m^3, 0°C)	(m^3, 0°C)	(g)	(g/m^3)	(%)
Test 1	28.3	1.1044	0.0641	887.0	13846.5	94.5
Test 2	20.0	0.4279	0.0239	343.7	14353.3	94.7
Test 3	15.0	0.4632	0.0158	372.0	23499.4	96.7

Test 1	Δp1	Stack Temp	Velocity	Sample rate	Gas meter	Isokinicity
	(Pa)	(°C)	(m/s)	(L/min)	(m^3)	(%)
1	48	96.5	10.2	2.1	94.5100	137%
					94.5600	137%

Test 2	Δp2	Stack Temp	Velocity	Sample rate	Gas meter	Isokinicity
	(Pa)	(°C)	(m/s)	(L/min)	(m^3)	(%)
1	49	98.7	10.3	2.0	136.5005	89%
					136.5295	89%

Test 3	Δp3	Stack Temp	Velocity	Sample rate	Gas meter	Isokinicity
	(Pa)	(°C)	(m/s)	(L/min)	(m^3)	(%)
1	49	98.0	10.4	1.3	136.6655	159%
					136.6915	159%

Gas Flows from Prelim Survey	1	2	3
Velocity (m/s)	10.20	10.34	10.39
Flow Rate (m^3/s)	9.18	9.29	9.34
(m3/s, 0°C, 1 atm, dry)	0.37	0.36	0.23
Flow Rate (m^3/h)	33030.11	33457.22	33621.75
(m3/h, 0°C, 1 atm, dry)	1337.17	1301.42	817.17
Stack Temperature (^oC)	97	99	98.00
Stack Gas Oxygen (%, Dry)	21.0	21.0	21.0

Sample Volumes	1	2	3
Gas Meter Start (m^3)	94.5100	136.5005	136.6655
Gas Meter Finish (m^3)	94.5600	136.5295	136.6915
Gas Meter Temp (°C)	28.3	20.0	15.0
Volume (m^3,1atm,dry)	0.0500	0.0290	0.0260
Volume (m3, 0oC, 1 Atm, dry)	0.0453	0.0270	0.0246

Velocity Check	1	2	3
Velocity (m/s)	10.20	10.34	10.39
Difference from Previous (%)		1.3%	0.5%

Temp. Correction (^{o}C)	0

Test	Solution Type	Sample Volume (ml)	Titrations (ml)		
			$BaCl_2$ Volume 1	$BaCl_2$ Volume 2	$BaCl_2$ Volume 3
Oceana Gold Test 1	IPA	561.3	7.9	7.85	0
Oceana Gold Test 1	H202	0	0	0	-
Oceana Gold Test 2	IPA	394.1	5.45	14.85	0
Oceana Gold Test 3	IPA	312.5	7.35	7.2	0

Sulphuric Acid Mist
H_2SO_4 **Water Sample**

Stack / Test	H_2SO_4 (mg)	H_2SO_4 (g)	Concentration (mg/m^3, 0°C, 1 atm, dry)	Mass Emission (mg/s)	Mass Emission (kg/h)
Oceana Gold Test 1	492.10	0.49210	10862.17	3006.11	10.82
Oceana Gold Test 2	196.23	0.19623	7262.26	2009.83	7.24
Oceana Gold Test 3	206.76	0.20676	8389.07	2321.68	8.36

Test	Solution Type	Sample Volume (ml)	Titrations (ml)		
			$BaCl_2$ Volume 1	$BaCl_2$ Volume 2	$BaCl_2$ Volume 3
Oceana Gold Test 1	IPA	123	10	9.9	0
Oceana Gold Test 1	H202	290.6	14.1	14.275	0
Oceana Gold Test 2	IPA	186.9	5.3	5.175	0
Oceana Gold Test 2	H202	369.5	1.975	2.025	0
Oceana Gold Test 3	IPA	191.3	1.425	1.4	0
Oceana Gold Test 3	H202	320.5	2.9	2.9	0

Sulphuric Acid Mist
H_2SO_4

Stack / Test	H_2SO_4 (mg)	H_2SO_4 (g)	Concentration (mg/m^3, 0°C, 1 atm, dry)	Mass Emission (mg/s)	Mass Emission (kg/h)
Oceana Gold Test 1	68.12	0.06812	1503.73	416.16	1.50
Oceana Gold Test 2	22.27	0.02227	824.07	228.06	0.82
Oceana Gold Test 3	6.15	0.00615	249.71	69.11	0.25

Sulphur Dioxide SO_2

Stack / Test	SO_2 (mg)	SO_2 (g)	Concentration (mg/m^3, 0°C, 1 atm, dry)	Mass Emission (mg/s)	Mass Emission (kg/h)
Oceana Gold Test 1	61.23	0.06123	1351.49	374.02	1.35
Oceana Gold Test 2	11.00	0.01100	407.10	112.67	0.41
Oceana Gold Test 3	13.80	0.01380	559.95	154.97	0.56

South Island – Head Office	North Island Office
PO Box 28147, Beckenham, Unit 24, 105 Bamford Street, Woolston, Christchurch Tel: 03 384 8966 Fax: 03 384 8960 Mobile: [redacted] Email: [redacted]	Unit 23, 203 Kirkbride Road, Manukau, Auckland Tel: 09 275 1261 Fax: 09 275 1263 Mobile[redacted] Email: [redacted]

Oceana Gold

Macraes Gold Mine
Production Facility

September 2011

Stuart Keer-Keer _____

Job Number: M221
Issue: 1
Report Date: November, 11

TABLE OF CONTENTS

1 INTRODUCTION 1

1.1 Summary of Results 1

2 SAMPLING DETAIL AND RESULTS 2

2.1 Mercury Results 2

INDEX OF TABLES AND FIGURES

Table 1 Summary of Results 1
Table 2 Mercury Results 2
Table 3 Mercury Results Continued 3
Table 4 Stack Gas Conditions 4
Table 5 Stack Gas Conditions Continued 5

1 INTRODUCTION

1.1 Summary of Results

Below is the average concentration and mass emission of mercury from each of the stacks.

Table 1 Summary of Results

Stack	Concentration ($\mu g/m^3$, dry, 0°C,1 Atm)	Mass Emission (g/hr)
Stack 1 KN - 01/02	40	0.16
Stack 2 KN - 01	46	0.31
Stack 3 KN - 02	1.5	0.010
Stack 4 KN – 03 Lower Level	3,000	1.2
Stack 5 KN – 03 Above Level	150	0.058
Stack 6 EW – 03	480	2.9
Stack 7 EW- 01	20	0.081
Stack 8 EW – 02	16	0.057
Stack 9 Calcining Oven	6,520,000	24
Stack 10 Furnace Oven 1	1500	5.8
Stack 11 Furnace Oven 2	250	0.95
Field Blank	30	

2 SAMPLING DETAIL AND RESULTS

Please note: These results are preliminary and subject to change. Further quality checks are required before they can be treated as final issue.

2.1 Mercury Results

Table 2 Mercury Results

Sample		Concentration (µg/m^3, dry, 0°C,1 Atm)			Mass Emission (g/hr)
		Particulate	Gaseous	Total	Total
Stack 1 KN[1]-01/02	1	0.21	39	39	0.16
	2	0.22	40	40	0.16
	Average	**24**	**39**	**40**	**0.16**
Stack 2 KN-01	1	0.73	46	47	0.28
	2	0.26	46	46	0.34
	Average	**0.50**	**46**	**46**	**0.31**
Stack 3 KN-02	1	0.54	2.2	2.8	0.019
	2	0.31	<0.16	0.31	0.0021
	Average	**0.41**	**2.2**	**1.5**	**0.010**
Stack 4 KN-03	1	760	540	1,300	2.2
	2	600	4100	4,700	0.21
	Average	**680**	**2300**	**3,000**	**1.2**
Stack 5 KN-03	1	0.96	62	63	0.023
	2	0.98	240	240	0.093
	Average	**0.97**	**150**	**150**	**0.058**
Field Blank		**<0.039**	**30**	**30**	

[1] KN= Kiln

Table 3 Mercury Results Continued

Sample		Concentration (µg/m^3, dry, 0°C,1 Atm)			Mass Emission (g/hr)
		Particulate	Gaseous	Total	Total
Stack 6 EW[2]-03	1	0.40	950	950	5.6
	2	0.36	1.4	1.8	0.014
	Average	**0.38**	**480**	**480**	**2.9**
Stack 7 EW-01	1	5.2	0.24	5.4	0.022
	2	7.9	27	35	0.14
	Average	**0.69**	**14**	**20**	**0.081**
Stack 8 EW-02	1	0.22	7.9	8.1	0.030
	2	0.19	23	24	0.084
	Average	**0.21**	**16**	**16**	**0.057**
Stack 9[3] Calcining Oven	1			4,600,000	8.9
	2			8,440,000	39
	Average			**6,520,000**	**24**
Stack 10 Furnace Oven	1	6.2	1500	1500	5.8
Stack 11 Furnace Oven	1	1.3	140	140	0.55
	2	1.4	350	350	1.4
	Average	**1.4**	**240**	**250**	**0.95**
Field Blank		**<0.039**	**30**	**30**	

[2] EW=Electro-Winning

[3] Due to the high moisture, size and location of the stack, a filter could not be used. Results can only be reported as total. Although there was noticeable amount mercury balls in solution.

Table 4 Stack Gas Conditions

Sample No.		Temp (°C)	Moisture (%)	Velocity (m/s)	Isokinicity (%)	Flow Rate[4]
Stack 1 KN[5]-01/02	**1**	22	2.6	7.9	97	1.1
	2	25	3.2	7.9	104	1.1
	Average	**23**	**2.9**	**7.9**	**100**	**1.1**
Stack 2 KN-01	**1**	24	3.0	12	93	1.7
	2	26	3.4	14	103	2.0
	Average	**25**	**3.2**	**13**	**98**	**1.8**
Stack 3 KN-02	**1**	16	1.7	13	101	1.9
	2	19	2.2	13	102	1.9
	Average	**17**	**1.9**	**13**	**102**	**1.9**
Stack 4 KN-03	**1**	320	10	6.8	94	0.050
	2	340	10	6.4	95	0.045
	Average	**330**	**10**	**6.6**	**95**	**0.048**
Stack 5 KN-03	**1**	210	16	4.4	111	0.10
	2	300	9.5	4.9	96	0.11
	Average	**250**	**13**	**4.7**	**103**	**0.10**

[4] m^3/s, 0°C, 1atm, dry

[5] KN= Kiln

Table 5 Stack Gas Conditions Continued

Sample No.		Temp (°C)	Moisture (%)	Velocity (m/s)	Isokinicity (%)	Flow Rate[6]
Stack 6 EW[7]-03	**1**	19	1.4	16	99	1.7
	2	16	1.6	20	99	2.1
	Average	**18**	**1.5**	**18**	**99**	**1.9**
Stack 7 EW-01	**1**	21	1.5	10.8	94	1.1
	2	21	1.3	10.8	96	1.1
	Average	**21**	**1.4**	**10.8**	**95**	**1.1**
Stack 8 EW-02	**1**	14	1.2	9.7	89	1.0
	2	17	1.1	9.4	99	1.0
	Average	**16**	**1.1**	**9.5**	**94**	**1.0**
Stack 9 Calcining Oven	**1[8]**	110	81	2.0	229	0.00054
	2	120	70	3.2	98	0.0013
	Average	**120**	**76**	**2.6**	**164**	**0.00092**
Stack 10 Furnace Oven	**1**	38	1.3	11	95	1.1
Stack 11 Furnace Oven	**1**	40	1.4	11	97	1.1
	2	47	1.4	11	108	1.1
	Average	**43**	**1.4**	**11**	**102**	**1.1**

6 m^3/s, 0°C, 1atm, dry

7 EW=Electro-Winning

8 Due to stack conditions of high moisture, sampling was run non-isokinetically

South Island – Head Office	North Island Office
PO Box 28147, Beckenham, Unit 24, 105 Bamford Street, Woolston, Christchurch Tel: 03 384 8966 Mobile: [redacted] Email: [redacted]	Unit 23, 203 Kirkbride Road, Manukau, Auckland Tel: 09 275 1261 Mobile [redacted] Email: [redacted]

Oceana Gold
Macraes Flat, Otago
Emission Assessment of Production Plant
12th-16th September 2016

Sample Team	**James Piesse, Alex Baboshko**
Report Author	**James Piesse**
Report Checked by	**David Orchard**
Key Technical Person	**Stuart Keer-Keer**

[redacted]

IANZ ACCREDITED LABORATORY
All tests reported herein have been performed in accordance with the laboratory's scope of accreditation

TABLE OF CONTENTS

1 EXECUTIVE SUMMARY 1

2 RESULTS 2

3 SAMPLING DETAILS 3

3.1 Sampling Performed 3

3.2 Methods 3

3.3 Deviation to the Method 3

3.4 Gold Plant Details 4

3.5 Sample Point Information for EWIN Stacks 6

3.6 Sample Point Information for Furnace Stack 6

3.7 Sample Point Information for Oven Stack 7

APPENDIX A SAMPLING CONCEPTS EXPLAINED 8

APPENDIX B SAMPLING METHODS 11

INDEX OF TABLES AND FIGURES

Figure 1 Trace Metal Sampling Train 12

Table 1 Summary of Results 1
Table 2 Mercury Emissions 2
Table 3 Gas Conditions 2
Table 4 Vacuums 7

1 EXECUTIVE SUMMARY

The following table summarises the results for sampling at Oceana Gold, Golden Point Road, RD3, Macraes Flat 9483, East Otago.

Note that the furnace stacks were combined into a single stack in 2016.

Table 1 Summary of Results

Year	Mercury Concentration (µg/m³,0°C, 1 atm, dry)					
	EWIN 1	**EWIN 2**	**EWIN 3**	**Furnace 1**	**Furnace 2**	**Oven**
2016	**51**	**Not Measured**	**20**	**14**		**100**
2013	Not Measured	Not Measured	Not Measured	12,000	2,400	74,000
2011	20	16	480	1,500	250	6,520,000

Year	Mercury Mass Emission (g/hr)					
	EWIN 1	**EWIN 2**	**EWIN 3**	**Furnace 1**	**Furnace 2**	**Oven**
2016	**0.21**	**Not Measured**	**0.13**	**0.11**		**0.012**
2013	Not Measured	Not Measured	Not Measured	57	10	23
2011	0.081	0.057	2.9	5.8	0.95	24

2 RESULTS

A brief description of the sampling procedures used during the programme is given in APPENDIX B. Calculation data can be provided upon request.

Table 2 Mercury Emissions

Stack	Concentration ($\mu g/m^3$, dry, 0°C,1 Atm)			Mass Emission (g/hr)
	Particulate	Gaseous	Total	
EWIN 1	0.24	51	51	0.21
EWIN 3	0.66	19	20	0.13
Furnace	1.3	13	14	0.11
Oven	3.7	98	100	0.012

Table 3 Gas Conditions

Sample No.	Temp (°C)	Moisture (%)	Velocity (m/s)	Isokinicity (%)	Flow Rate (m^3/s, 0°C, 1 atm, dry)
EWIN 1	25	1.4	12	104	1.1
EWIN 3	21	0.5	19	96	1.9
Furnace	50	1.7	36	76	2.0
Oven	22	0.1	1.7	205	0.032

3 SAMPLING DETAILS

3.1 Sampling Performed

On the 12th and 16th September 2016, samples were collected from the Gold Room discharge to determine the concentration and mass emission of Mercury present in the gases released to the atmosphere.

Other parameters measured were:

- Stack temperature
- Flow
- Stack gas moisture
-

The analysis for Mercury was subcontracted to an accredited laboratory

3.2 Methods

K2 Environmental is accredited for the following methods used in this report:

- Sampling Location (USEPA[1] Method 1)
- Measurement of Velocity (USEPA Method 2)
- Molecular Weight (USEPA method 3)
- Trace Metals (USEPA method 29)

Interpretations and opinions expressed in this report are outside of the scope of accreditation.

3.3 Deviation to the Method

- Due to equipment limitations the stacks were only able to be sampled at one point each
- Flows were still measured in accordance with USEPA method 2

[1] USEPA: United States Environmental Protection Agency

3.4 Gold Plant Details

Grinding Milling
Gold is mined within quartz deposits. Gold-rich ore is transported to the processing area where **grinding / milling** takes place.

Autoclave
The ore is then subjected to an acidification process in order to remove carbonates. This is achieved using sulphuric acid. The autoclave process involves high pressure oxidation of the gold ore.

Flash Towers
After autoclaving, the slurry is cooled in flash towers and tube heat exchangers.

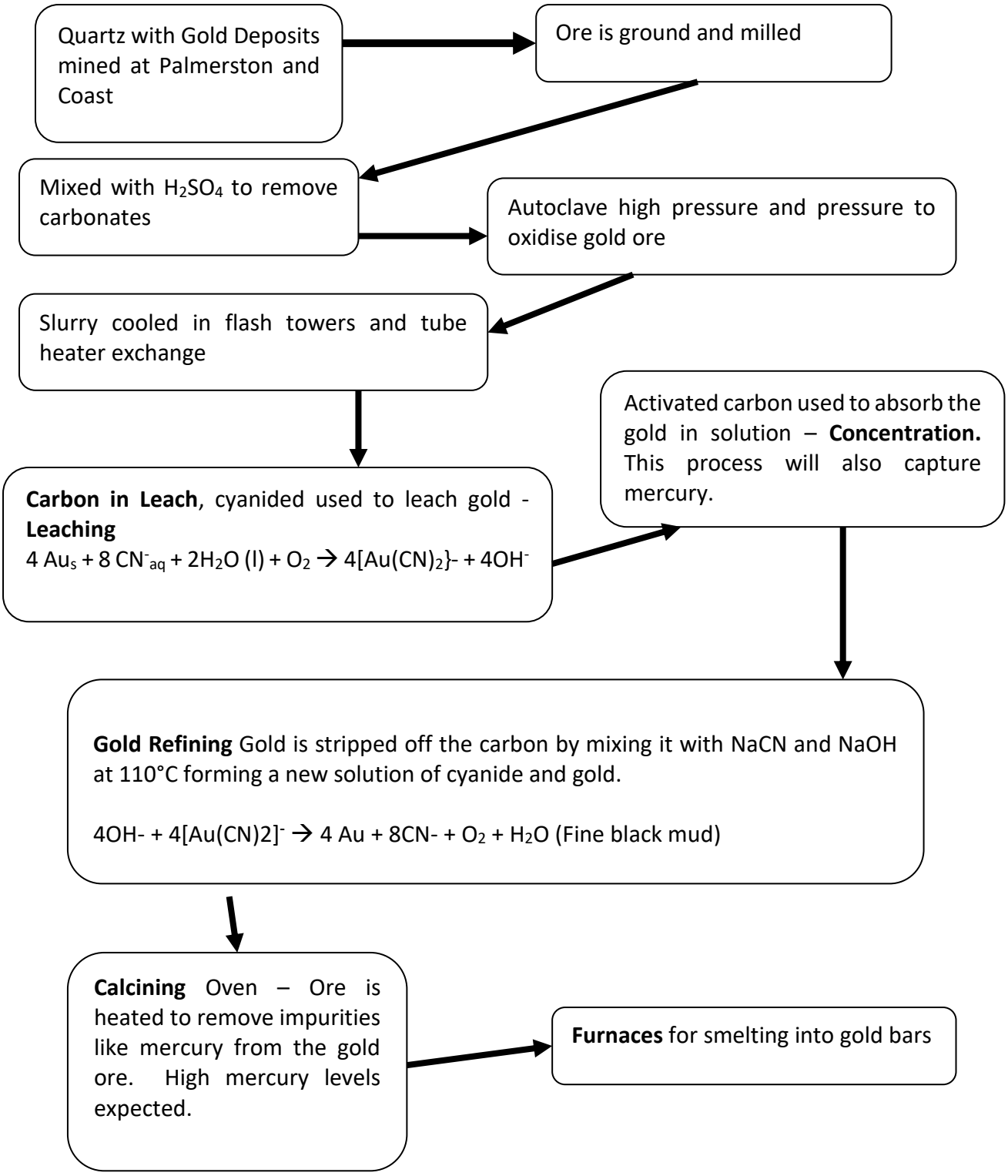
Carbon in Leach
Oxidised material from the autoclave is directed to the Carbon In Leach (CIL) process, where:-

- Cyanide is used to leach the gold
- Activated carbon is used to adsorb the gold in solution
- Gold stripped from carbon is finally recovered using electro winning (a process where gold in solution is extracted using cathodes)
    - The carbon is then recovered, stripped of its gold and re-used in the CIL
    - The carbon is dried in the kilns

This process also picks up other metals like mercury. The extracted material is then sent to the calcining oven.

Calcining Oven
Calcining is a process in which the ore is then heated to remove any impurities like mercury from the gold ore. The ore is heated at a temperature sufficient enough to draw off any impurities. *High mercury levels expected.*

Furnace
The ore is then sent to the furnaces for smelting into gold bars. Gold bars are then poured from the furnace treating the material 'won' in the electro winning stage. These bars are sent offsite for refining and sale.


Quartz with Gold Deposits mined at Palmerston and Coast
Ore is ground and milled
Mixed with H_2SO_4 to remove carbonates
Autoclave high pressure and pressure to oxidise gold ore
Slurry cooled in flash towers and tube heater exchange
Activated carbon used to absorb the gold in solution – **Concentration.** This process will also capture mercury.
Carbon in Leach, cyanided used to leach gold - **Leaching**
$4\,Au_s + 8\,CN^-_{aq} + 2H_2O\,(l) + O_2 \rightarrow 4[Au(CN)_2]^- + 4OH^-$
Gold Refining Gold is stripped off the carbon by mixing it with NaCN and NaOH at 110°C forming a new solution of cyanide and gold.
$4OH^- + 4[Au(CN)2]^- \rightarrow 4\,Au + 8CN^- + O_2 + H_2O$ (Fine black mud)
Calcining Oven – Ore is heated to remove impurities like mercury from the gold ore. High mercury levels expected.
Furnaces for smelting into gold bars

3.5 Sample Point Information for EWIN Stacks

Location and description

The sampling position is located approximately 5 stack diameters downstream from a flow disturbance and approximately 2 stack diameters upstream from a flow disturbance.

0.370 meter diameter circular duct.

Sample Date and Times

EWIN Stack	Date	Start	Finish
1	16/09/16	11:25	12:25
3	12/09/16	11:25	12:25

Sample Point Requirements

- USEPA requires 12 points on 2 traverses (a total of 24 points)
- Flows were measured at 12 points on 2 traverses (a total of 24 points)
- Sampling was performed at 1 points on 1 traverse due to equipment restrictions.

3.6 Sample Point Information for Furnace Stack

Location and description

The sampling position is located approximately 2 stack diameters downstream from a flow disturbance and approximately 3 stack diameters upstream from a flow disturbance.

0.295 meter diameter circular duct.

Sample Date and Times

Date	Start	Finish
16/09/16	09:15	10:15

Sample Point Requirements

- USEPA requires 10 points on 2 traverses (a total of 20 points)
- Flows were measured at 10 points on 2 traverses (a total of 20 points)
- Sampling was performed at 1 points on 1 traverse due to equipment restrictions.

3.7 Sample Point Information for Oven Stack

Location and description

The sampling position is located approximately 5 stack diameters downstream from a flow disturbance and approximately 10 stack diameters upstream from a flow disturbance.

0.160 meter diameter circular duct.

Sample Date and Times

Sample	Start	Finish
12/09/2016	14:55	15:55

Sample Point Requirements

- USEPA requires 12 points on 2 traverses (a total of 24 points)
- Flows were measured at 4 points on 1 traverses (a total of 4 points)
- Sampling was performed at 1 points on 1 traverse due to equipment restrictions

Table 4 Vacuums

Stack	Pre-Leak Check		Max Vacuum During Testing (kPa)	Post-Leak Check	
	(L/min)	At Vacuum (kPa)		(L/min)	At Vacuum (kPa)
EWIN 1	<0.2	-60	-20	<0.2	-60
EWIN 3	<0.2	-40	-22	<0.2	-40
Furnace	<0.2	-60	-35	<0.2	-60
Oven	<0.2	-40	-10	<0.2	-40

APPENDIX A SAMPLING CONCEPTS EXPLAINED

A.1. Why measure carbon dioxide and water concentrations?

This is mostly applicable to combustion sources, the composition of the air can change with variables such as ambient pressure, moisture carbon dioxide and temperature. All these variables affect the gas composition altering the air speed and flow. This can have a direct effect on how much air is sampled, how well the sampling is conducted and the overall outcome of the sampling.

When measuring flow, it is critical that you know the composition of the gas. If it is fresh air, then it is safe to assume the composition will be the same as the air we all breathe. If, however, it is a combustion source the composition of the gas will change. There will be elevated concentrations of carbon dioxide and water, and the oxygen levels lower. These are measured during the test and are used to calculate the flow rate.

A.2. What are velocity and flow rate?

Velocity is the speed in which the air is travelling up the duct. It is measured in meters per second. The flow rate is how much gas is travelling up the stack. The units are cubic meters (of air) per second. The flow rate is calculated from the velocity and the area of the duct.

For example, think of a small creek where the water is travelling fast, this has a high velocity but will have a low flow rate. Compare this to a larger river flowing slowly; this will have a low velocity but a high flow rate.

To calculate the flow rate the gas temperature and composition must be measured.

A.3. Concentration vs. Mass Discharge

The sample mass, in grams, is the amount of sample that has been collected on the filter or thimble in the stack. This mass is then divided by the volume of air sampled (m^3) to give the concentration of particulate in the stack.

Kilograms per hour (kg/h) are reporting the discharge of kilograms of particulate discharged per hour. This is calculated from the concentration of the particulate and the flow rate. Concentration is how much is in the gas stream, whereas the kg/h is how much is discharged.

A.4. What is isokinicity?

Iso = same, kinetic = speed. It is important to sample particles at the same speed as they are travelling up the stack. At 100% isokinicity the rate in which the sample was gathered is the same as the rate in which the gas is travelling up the duct. Any deviations will mean sampling was less or greater than the stack flow rate.

If Isokinicity is greater than 100% then the smaller particles will be drawn into the nozzle and it will have a vacuum cleaner effect. If the Isokinicity is less than 100% then the smaller particles in the stack will avoid the nozzle. The effect of low isokinicity is to under sample the smaller particles and possibly get a lower result. The effect of a high isokinicity is to over sample the smaller particles and possibly get a higher result.

A.5. How is isokinicity determined?

The required sample rate to obtain 100% isokinicity is calculated before sampling commences. During sampling, the actual sampling rate is recorded and reported. This is compared to the sampling rates and the isokinicity is calculated by this comparison.

A.6. What are the velocity checks?

The standard requires that the velocity between tests does not change by more than 5%. Typically the flow rate is measured prior to a test and the measurements are used to calculate sample rate. If the velocity changes then the sample rate needs to be changed. If the process is variable then the velocity should be measured during sampling and the sample rate changed as the velocity changes.

A.7. Why are numerous points and planes sampled?

The size of a particle will affect how it travels up a duct. In a gas stream with particles greater than three microns in size they will behave differently. It is possible all the small particles can be found around the outside and the larger ones in the middle. To account for these differences, the standard requires a traverse of the duct be performed. The size of the duct dictates how many points must be sampled.

The position of the sampling port and the sampling platform often restricts how many points can be sampled.

APPENDIX B SAMPLING METHODS

B.1. USEPA Method 29: Determination of Metal Emissions from Stationary Sources

Trace metals are sampled using a method based on USEPA Method 29. A sample is withdrawn from the source and filtered using an out of stack filter. The filter is heated to 120°C.

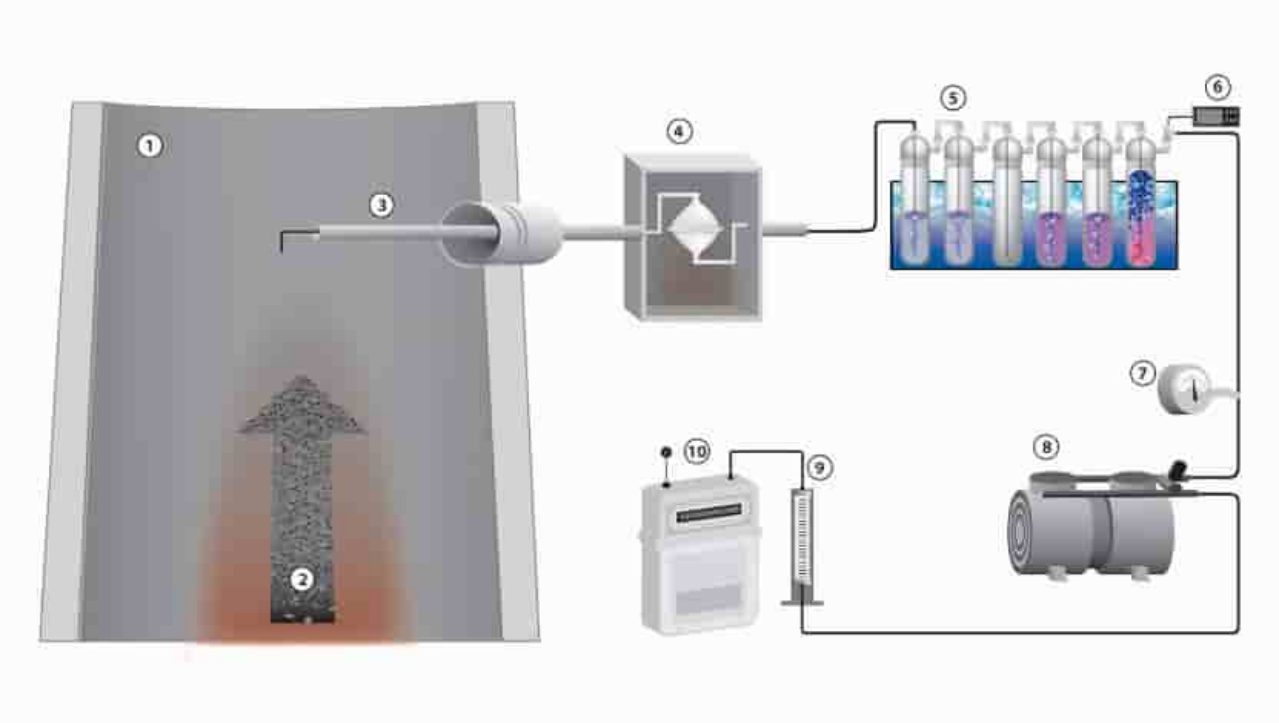


Figure 1 Trace Metal Sampling Train

1	Stack to be measured
2	Air flow containing particulate or gas
3	Glass probe and probe holder.
4	Hot box with a filter
5	Six impingers[2]:- • 10 % Nitric Acid and 5% Peroxide • 10 % Nitric Acid and 5% Peroxide • Empty • sulphuric acid and potassium permanganate – mercury only. • sulphuric acid and potassium permanganate – mercury only. • Silica gel
6	Temperature reader measure temperature of gas leaving impingers
7	Vacuum gauge
8	Air sampling pump
9	Rotameter to measure air flow rate
10	Gas meter to measure gas volume sampled. Has orifice meter gauge and temperature reader in outlet.

[2] Note that for this site only the last 3 impingers were used as only mercury was measured

K2 Environmental Ltd

Specialists in Air Quality Measurement

Stack Emissions Assessment

Oceana Gold

Macraes

X0263 • 21 December 2022 • Issue 1

All tests reported herein have been performed in accordance with the laboratory's scope of accreditation

Christchurch Head Office
Tel: 03 384 8966
Mobile: [redacted]
Email: [redacted]

Wellington
Tel: 04 595 4563
Mobile: [redacted]
Email: [redacted]

Hamilton
Mobile: [redacted]
Email: [redacted]

Auckland
Tel: 09 275 1261
Mobile: [redacted]
Email: [redacted]

K2 Environmental Ltd
www.k2.co.nz

K2 Environmental Ltd
Head Office
PO Box 28147
24/105 Bamford Street
Woolston, CHRISTCHURCH 8023

Job Number: X0263

Site Work Personnel: Max Van den Oever
Harvey Cudmore-Neame
Mike Creed

Site Work Date(s): 25th-27th October 2022

Report Submitted: 21 December 2022

Site Name: OceanaGold Macraes

Site Address: Golden Point Road, RD3, Macraes Flat 9483, East Otago, Macraes 9483

Written by:	**Reviewed by:**	**Key Technical Person:**
Harvey Cudmore-Neame BSc	Max van den Oever BSc	Stuart Keer-Keer MSc
[redacted]	[redacted]	[redacted]

Document History					
Issue	**Date**	**Description of Changes**	**Written by**	**Reviewed by**	**Approved by**
1	21/12/2022	First issue of report	Harvey Cudmore-Neame	Max van den Oever	Stuart Keer-Keer

TABLE OF CONTENTS

1 RESULTS 1

1.1 Trace Metals Results 1

1.2 Sulphur Dioxide Results 3

1.3 Acid Mist Results 3

1.4 Hydrogen Sulphide Results 4

1.5 Total Filterable Particulate Results 4

1.6 Gas Conditions 5

1.7 Combustion Gasses 5

1.8 Photos of Filters 5

2 SAMPLING DETAILS 6

2.1 Purpose of Sampling 6

2.2 Sampling Performed 6

2.3 Analysis Performed 6

2.4 Methods 7

2.5 Deviation to the Method 7

2.5.1 Sample point requirements 7

2.5.2 Analyser Calibrations 7

2.6 Disclaimer 7

2.7 Sample Point Information 8

APPENDIX A SAMPLING CONCEPTS EXPLAINED 10

APPENDIX B SAMPLING METHODS 13

APPENDIX C LAB REPORTS 20

APPENDIX D ELECTRONIC EQUIPMENT RECORDS 23

INDEX OF TABLES, FIGURES AND GRAPHS

Table 1 Trace Metals Emissions Summary 1
Table 2 Trace Metals Emissions Test 1 1
Table 3 Trace Metals Emissions Test 2 2
Table 4 Trace Metals Emissions Field Blank 2
Table 5 Trace Metal Gas Conditions 2
Table 6 Sulphur Dioxide (SO_2) Emissions 3
Table 7 Acid Mist (H_2SO_4)/(SO_3) Emissions 3
Table 8 H_2S Emissions 4
Table 9 Total Filterable Particulate Emissions 4
Table 10 Particulate and Sulphur Gas Conditions 5
Table 11 Combustion Gases 5
Table 12 Sampling Information 9
Table 13 Calibration check 24

Figure 1 Sampling Train for Measuring Particulate – Out of Stack 14
Figure 2 Trace Metal Sampling Train 15
Figure 3 Sulphur Dioxide and Acid Mist Sampling Train 17
Figure 4 Sampling Train for Hydrogen Sulphide 18
Figure 5 Combustion Gas Analysers 19

1 RESULTS

A brief description of the sampling procedures used during the programme is given in APPENDIX B. Calculation data can be provided upon request.

1.1 Trace Metals Results[1]

Table 1 Trace Metals Emissions Summary

Analyte	Mass (µg)	Concentration (µg/m³, 0°C, 1 atm, dry)			Mass Emission (g/hr)
		Particulate	Gaseous	Total	
Arsenic	20	110	95	210	1.3
Chromium	1.5	2.0	12	14	0.090
Copper	<7.0	<38	<49	<86	<0.53
Lead	<5.0	18	<37	<55	<0.30
Mercury	17	1.0	180	180	1.2
Zinc	<15	<37	157	<194	<1.3

Table 2 Trace Metals Emissions Test 1

Analyte	Mass (µg)	Concentration (µg/m³, 0°C, 1 atm, dry)			Mass Emission (g/hr)
		Particulate	Gaseous	Total	
Arsenic	7.0	34	5.7	40	0.208
Chromium	1.0	1.7	4.0	5.7	0.0297
Copper	<7.0	40	<17	<57	<0.297
Lead	<4.0	23	<5.7	<28	<0.148
Mercury	7.3	0.29	42	42	0.217
Zinc	4.0	5.8	23	29	0.148

[1] The first trace metals test was aborted due to moisture issues and was not able to be recovered. Only two trace metals test were completed.

Table 3 Trace Metals Emissions Test 2

Analyte	Mass (µg)	Concentration (µg/m³, 0°C, 1 atm, dry)			Mass Emission (g/hr)
		Particulate	Gaseous	Total	
Arsenic	32	180	185	370	2.4
Chromium	1.9	2.3	20	22	0.15
Copper	<7.0	<35	81	<115	<0.76
Lead	6.0	12	69	81	0.46
Mercury	27	1.7	310	310	2.1
Zinc	<25	<69	290	<360	<2.4

Table 4 Trace Metals Emissions Field Blank

Analyte	Mass (µg)	Concentration (µg/m³, 0°C, 1 atm, dry)	Mass Emission (g/hr)
Arsenic	<4.0	<35	<0.20
Chromium	0.30	2.7	0.015
Copper	<3.0	<27	<0.15
Lead	<1.0	<14	<0.049
Mercury	0.14	1.2	0.0069
Zinc	<6.0	<53	<0.29

Table 5 Trace Metal Gas Conditions

Sample No.	Temp (°C)	Moisture (%)	Velocity (m/s)	Isokinicity (%)	Flow Rate (m³/s, 0°C, 1 atm, dry)
1	94	70	4.1	120	0.43
2	94	95	5.4	324	0.090
Average	**94**	**83**	**4.3**	**164**	**0.26**

1.2 Sulphur Dioxide Results

Table 6 Sulphur Dioxide (SO_2) Emissions

Sample	Mass (mg)	Concentration (mg/m^3, dry, 0°C, 1 Atm)	Mass Emission (g/hr)
1	2.1	21	50
2	1.3	12	44
3	1.5	46	110
Average	**1.6**	**27**	**68**

A field blank was run. It had a sample mass of 0.37mg, if an average sample volume was used this would correspond to a concentration of 4.8mg/m^3, dry, 0°C, 1 Atm.

1.3 Acid Mist Results [2]

Table 7 Acid Mist (H_2SO_4)/(SO_3) Emissions

Sample	Mass (mg)	Concentration (mg/m^3, dry, 0°C, 1 Atm)	Mass Emission (g/hr)
1	2.49	26	60
2	0.46	4.5	16
3	0.0084	0.26	0.63
Average	**0.98**	**10**	**26**

A field blank was run. It had a sample mass of <0.010mg, if an average sample volume was used this would correspond to a concentration of <0.10mg/m^3, dry, 0°C, 1 Atm.

[2] Due to the high moisture of the stack, the acid mist results maybe inflated caused by the presence of water converting SO_2 into SO_3/H_2SO_4. The USEPA 8a train could not be used due to sample point restrictions. It was unsafe to lift it in place. We have a shorter probe now so future years could possibly do with 8a. Changes to the platform are suggested.

1.4 Hydrogen Sulphide Results

Table 8 H_2S Emissions

Sample	Mass (mg)	Concentration (mg/m³, dry, 0°C, 1 Atm)	Mass Emission (g/hr)
1[3]	<0.030	<0.62	<3.1
2	0.23	4.3	21
3	0.30	4.5	23
Average	**0.27**	**4.4**	**22**

A field blank was run. It had a sample mass of <0.030mg, if an average sample volume was used this would correspond to a concentration of <0.56mg/m^3, dry, 0°C, 1 Atm.

1.5 Total Filterable Particulate Results

Table 9 Total Filterable Particulate Emissions

Sample	Mass (mg)	Concentration (mg/m³, dry, 0°C, 1 Atm)	Mass Emission (kg/hr)
1	3.4	35	0.081
2	5.4	53	0.19
3[4]	19	600	1.4
Average	**4.4**	**44**	**0.14**

A lab blank filter was run. It had a sample mass of <0.94mg, if an average sample volume was used this would correspond to a concentration of<12mg/m^3, dry, 0°C, 1 Atm.

[3] Results from H_2S test 1 were not included in the averages because they were below the detection limit

[4] Results from particulate test 3 were not included in the averages because they of low isokinicity

1.6 Gas Conditions

Table 10 Particulate and Sulphur Gas Conditions

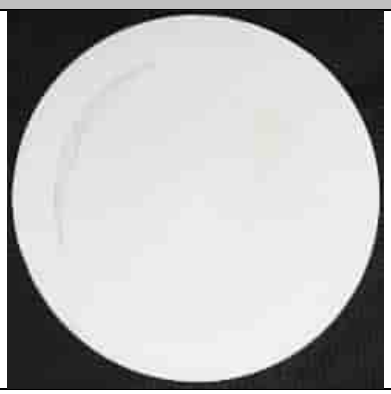
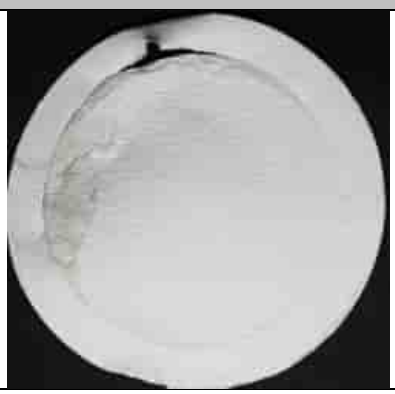
Sample No.	Temp (°C)	Moisture (%)	Velocity (m/s)	Isokinicity (%)	Flow Rate (m^3/s, 0°C, 1 atm, dry)
1	82	50.4	3.5	93	0.64
2	87	17.9	3.4	94	1.0
3	98	49.8	3.8	29	0.67
Average	**89**	**39.4**	**3.6**	**72**	**0.77**

1.7 Combustion Gasses

Table 11 Combustion Gases

Date	Sample	Carbon Dioxide (%)	Oxygen (%)	Carbon Monoxide (ppm)	Sulphur Dioxide (ppm)
26/10/22	**Minimum**	0.14	20.7	<1.0	<1.0
	Maximum	5.7	23.5	900	4.0
	Average	**1.5**	**21.5**	**210**	**<1.0**
27/10/22	**Minimum**	0.16	21.0	<1.0	<1.0
	Maximum	11	24.8	1,800	9.0
	Average	**4.9**	**22.2**	**650**	**<1.0**

1.8 Photos of Filters

Test 1	Test 2	Test 3
		

2 SAMPLING DETAILS

2.1 Purpose of Sampling

Sampling was performed as part of Oceana Gold's due diligence to the regional air plan.

2.2 Sampling Performed

On the 25th - 27th October 2022, samples were collected from the autoclave discharge to determine the concentration and mass emission in the gases released to the atmosphere of:

- Total filterable particulate
- hydrogen sulphide
- sulphur dioxide
- sulphur trioxide
- trace metals including mercury

Other parameters measured were:

- Carbon dioxide (CO_2)
- Stack temperature
- Flow
- Stack gas moisture

2.3 Analysis Performed

- The analysis for particulate was carried out at the K2 Environmental Laboratory. Analysis was performed on the 10 November 2022
- The analysis for sulphur dioxide and sulphur trioxide was carried out at the K2 Environmental Laboratory. Analysis was performed on the 9 November 2022
- The analysis for trace metals was subcontracted to an accredited laboratory. Analysis was performed on the 16 November 2022
- The analysis for Hydrogen Sulphide was subcontracted to an accredited laboratory. Analysis was performed on the 17 November 2022
- Lab reports for the analysis can be found in APPENDIX C which starts on page 20

2.4 Methods

- K2 Environmental is accredited for the following methods used in this report:
    - Sampling Location (USEPA[5] method 1)
    - Measurement of Velocity (USEPA method 2)
    - Molecular Weight (USEPA method 3)
    - Carbon Dioxide (USEPA Method 3A)
    - Moisture Determination (USEPA method 4)
    - Determination of Particulate Matter from Stationary Sources (USEPA method 5)
    - Sulphur Dioxide (USEPA Method 6C
    - Determination of Sulphuric Acid Mist and Sulphur Dioxide Emissions (USEPA method 8)
    - Carbon Monoxide (USEPA Method 10)
    - Determination of Hydrogen Sulphide (USEPA method 11)
    - Determination of Trace Metal Emissions from Stationary Sources (USEPA method 29)

2.5 Deviation to the Method

2.5.1 Sample point requirements

Sample points measured deviates from the method requirements of USEPA method 1

- The sampling method requires twelve points on two traverses, a total of 24 points
- Flow measurements were taken on twelve points on two traverses, a total of 24 points
- Sampling was performed on one point on two traverses, a total of two points
- The deviation was because sampling from more points was either not possible or deemed unsafe

2.5.2 Analyser Calibrations

- The USEPA methods for measuring gasses with an electronic analyser require on site calibration of the gas analysers on each day of testing
    - Because it is hazardous and impractical to transport gas cylinders the calibrations were performed in the K2 Environmental laboratory
    - Because the calibrations were done in the laboratory they were not performed on the day of sampling and were done the day before travelling to site and the day after returning from site
- The methods require that interferences to the gasses be checked during the calibrations. Because it is not possible to know what concentrations the interferences in the stack are present at without expensive testing this calibration check has not been performed

2.6 Disclaimer

- Sampling was conducted at a specific day and time and only represent a snapshot of what the running conditions were like on the day. This will not account for seasonal or production changes
- Interpretations and opinions expressed in this report are outside of the scope of accreditation.
- Raw data is available upon request

[5] USEPA: United States Environmental Protection Agency

2.7 Sample Point Information

Location and Description

The sampling position is located approximately one stack diameters downstream from a flow disturbance and approximately four stack diameters upstream from a flow disturbance.

0.78 metre diameter circular duct.

Sample Date and Times
26th and 27th of October 2022

Date	Analyte	Sample	Start	Finish
26th October 2022	Sulphur compounds and particulate	1	13:42	14:27
		2	16:50	17:30
		3	18:10	18:45
27th October 2022	Hydrogen sulphide	1	08:34	09:39
		2	10:05	11:07
		3	11:17	12:22
	Trace metals	1	13:17	14:17
		2	16:00	17:00

Sample Point Requirements

- The sampling method requires twelve points on two traverses, a total of 24 points
- Flow measurements were taken on twelve points on two traverses, a total of 24 points
- Sampling was performed at one point on two traverses, total of two points
- The deviation was because sampling from more points was either not possible or deemed unsafe

Table 12 Sampling Information

Sample		Pre-test Leak Check		During Testing		Post-test Leak Check	
		(L/min)	At Vacuum (kPa)	Max Gas Meter Temp (ºC)	Max Vacuum (kPa)	(L/min)	At Vacuum (kPa)
Particulate	1	<0.2	-40	21.6	0	NA	NA
	2	<0.2	-30	15.3	0	<0.2	-30
	3	<0.2	-45	13.6	0	<0.2	-30
Trace Metals	1	<0.2	-45	10.3	-20	<0.2	-35
	2	<0.2	-45	9.6	-5	<0.2	-40

APPENDIX A SAMPLING CONCEPTS EXPLAINED

.

A.1. Visual assessment of filters

A visual inspection of filters can give an idea of how well a combustion source is operating. The colour needs to be interpreted with the combustion gas data.

Colour of Filter	What it may suggest
White	Low level of particulate discharge
Grey	Some incomplete combustion, lower level of discharge. May have ash in the particulate
Black	Incomplete combustion – fuel is being discharged – some reasons are below. • Poor set up of the boiler – not enough oxygen • Air flow too high and the fuel does not have sufficient residence time Combustion temperature is too low

A.2. Why measure carbon dioxide and water concentrations?

- This is most applicable to combustion sources.
- The flow rate of a gas is affected by the molecular weight of a gas.
- Carbon dioxide and water can have a significant effect on the molecular weight and the flow rate.
- This can have a direct effect on how much air is sampled, how well the sampling is conducted and the overall outcome of the sampling.

A.3. Why are there numerous water and carbon dioxide results?

Carbon dioxide and moisture are not constant values. As the process changes the moisture and carbon dioxide can also change. Examples of what can change these are: -

- A boiler is burning more fuel to meet demand
- The amount of excess air has changed
- The fuel composition has changed (such change from chip to coal)
- There is less fuel available to the combustion.
- The fuel is wet

Individual results are averaged and reported. The results at any one point in time can provide information on the process.

A.4. What are velocity and flow rate?

Velocity is the speed in which the air is travelling up the duct. It is measured in meters per second. The flow rate is how much gas is travelling up the stack. The units are cubic meters (of air) per second. The flow rate is calculated from the velocity and the area of the duct.

For example, think of a small creek where the water is travelling fast, this has a high velocity but will have a low flow rate. Compare this to a larger river flowing slowly; this will have a low velocity but a high flow rate.

To calculate the flow rate the gas temperature and composition must be measured.

A.5. Concentration vs. Mass Discharge

The sample mass, in grams, is the amount of sample that has been collected on the filter or thimble in the stack. This mass is then divided by the volume of air sampled (m^3) to give the concentration of particulate in the stack.
Kilograms per hour (kg/h) are reporting the discharge of kilograms of particulate discharged per hour. This is calculated from the concentration of the particulate and the flow rate. Concentration is how much is in the gas stream, whereas the kg/h is how much is discharged.

A.6. What is Isokinicity?

- Iso = same,
- Kinetic = speed.

The standard requires particulate to be sampled at the same flow rate as they are moving up a duct. An isokinicity of 100% means that the sampling rate is the same as the flow rate up a duct.

Most standards permit isokinicity to be from 90 – 110%. Any deviations can result in over or under sampling of particles.

A.7. What are the velocity checks?

- The standard requires that the velocity between tests does not change by more than 5%.
- Often the velocity is measured prior to a test and the measurements are used to calculate sample rate.
- If the velocity changes then the sample rate needs to be changed.
- If the process is variable, then the velocity should be measured during sampling and the sample rate changed as the velocity changes.

A.8. Why are numerous points and planes sampled?

Particles in a particulate discharge will vary in size.

- The size of a particle will affect how it travels up a duct.
- Large particles will move slower than small particles
- How particles are distributed will be affected by their size and conditions in the duct.
- In a gas stream with particles greater than three microns in size they will behave differently.
- The size of the duct dictates how many points must be sampled.
- Taking samples from multiple points is a method of averaging out the differences.

APPENDIX B SAMPLING METHODS

B.1. USEPA Method 5: Determination of Particulate Emissions from Stationary Sources

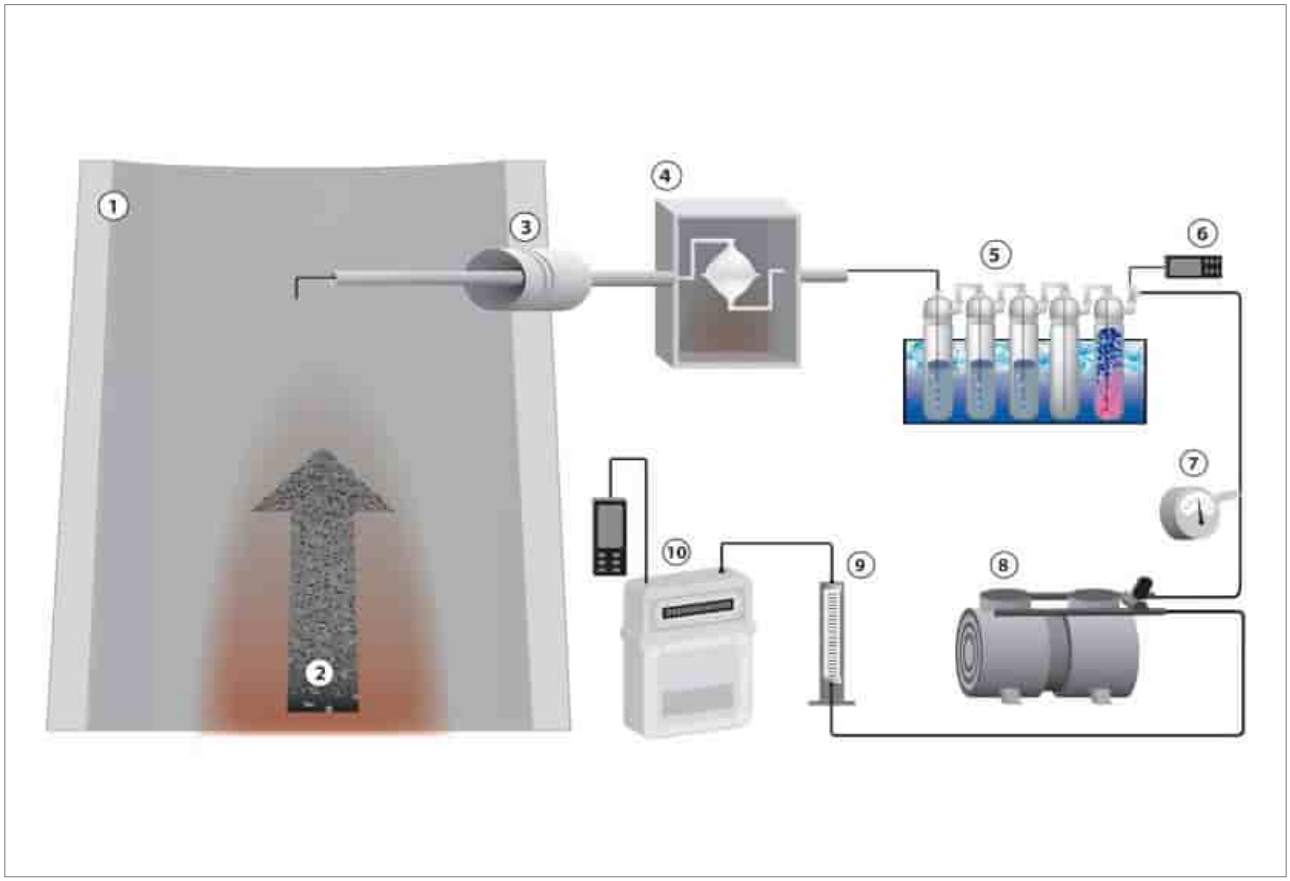


Figure 1 Sampling Train for Measuring Particulate – Out of Stack

1	Stack to be measured
2	Air flow containing particulate or gas
3	Glass probe and probe holder. If the stack temperature is over 400 °C the glass needs to be quartz.
4	Hot box with a filter. The filter captures the particulate. The hotbox is heated above the dew point of the gas usually 120°C. Particulate is not included in the acid mist result. If particulate result is required it can be included in the particulate result.
5	The first 2 impingers are filled with 100 ml of distilled water followed by an empty impinger and one filled with silica gel. The purpose of the impingers is to remove moisture from the sample train, for the purposes of determining the concentration of moisture in the stack gases.
6	Thermocouple Reader – measures the temperature of the gas sample line. This needs to be under 20°C.
7	Vacuum gauge – checks vacuum on the line. If there is a blockage it will show an increase.
8	Air sampling pump- draws air through the filter and sample train.
9	Rotameter to measure sample air flow rate
10	Gas meter to measure gas volume sampled.

B.2. USEPA Method 29: Determination of Metal Emissions from Stationary Sources

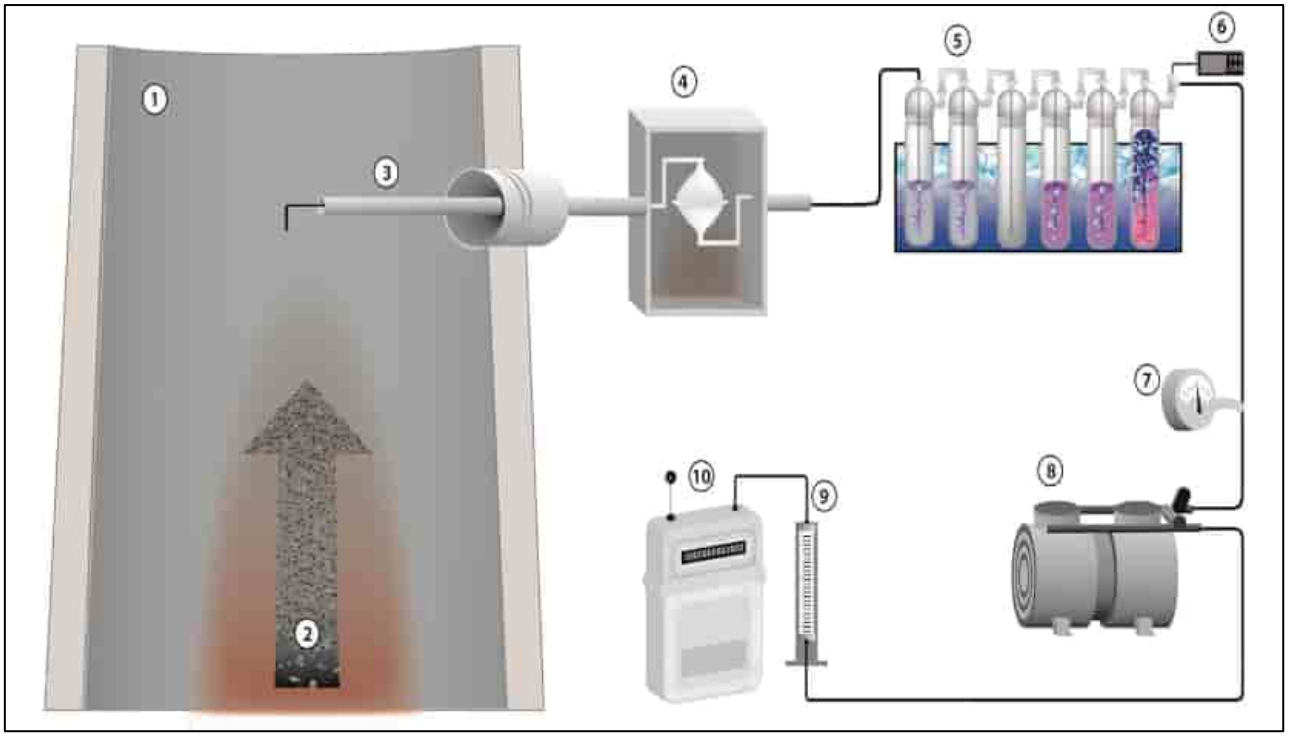


Figure 2 Trace Metal Sampling Train

1	Stack to be measured
2	Air flow containing particulate or gas
3	Glass probe and probe holder.
4	Hot box with a filter
5	Six impingers:- • 10 % Nitric Acid and 5% Peroxide • 10 % Nitric Acid and 5% Peroxide • Empty • sulphuric acid and potassium permanganate – mercury only. • sulphuric acid and potassium permanganate – mercury only. • Silica gel
6	Temperature reader measure temperature of gas leaving impingers
7	Vacuum gauge
8	Air sampling pump
9	Rotameter to measure air flow rate
10	Gas meter to measure gas volume sampled. Has orifice meter gauge and temperature reader in outlet.

Blank Samples

The trapping solutions used will contain low levels of the metals of interest. Analysis of blanks is critical so that results can be corrected for the amounts of metals in the unused trapping solutions. The analysis of blanks also allows the detection limits of the trace metal analysis to be reported.

The blanks that are gathered and analysed by K2 Environmental Ltd during trace metal analysis are detailed:

- Quartz filter and nozzle wash,
- 10 % Nitric Acid used in sample recovery
- 10 % Nitric Acid / 5% Peroxide trapping solution
- 4% Permanganate trapping solution (only if mercury is required)
- Field Blank.

Glassware Contamination

A field blank is where the sampling train is prepared with all of the trapping solutions, however no sampling is performed. The sample train is then washed out following the same procedure as for samples. This gives a measure of any contamination being introduced by the glassware and washout procedure.

Contamination can come from poorly cleaned glassware or from the actual components of the glass in the impingers.

B.3. USEPA Method 8: Determination of Sulphuric Acid Mist and Sulphur Dioxide Emissions from Stationary Sources (Isokinetic)

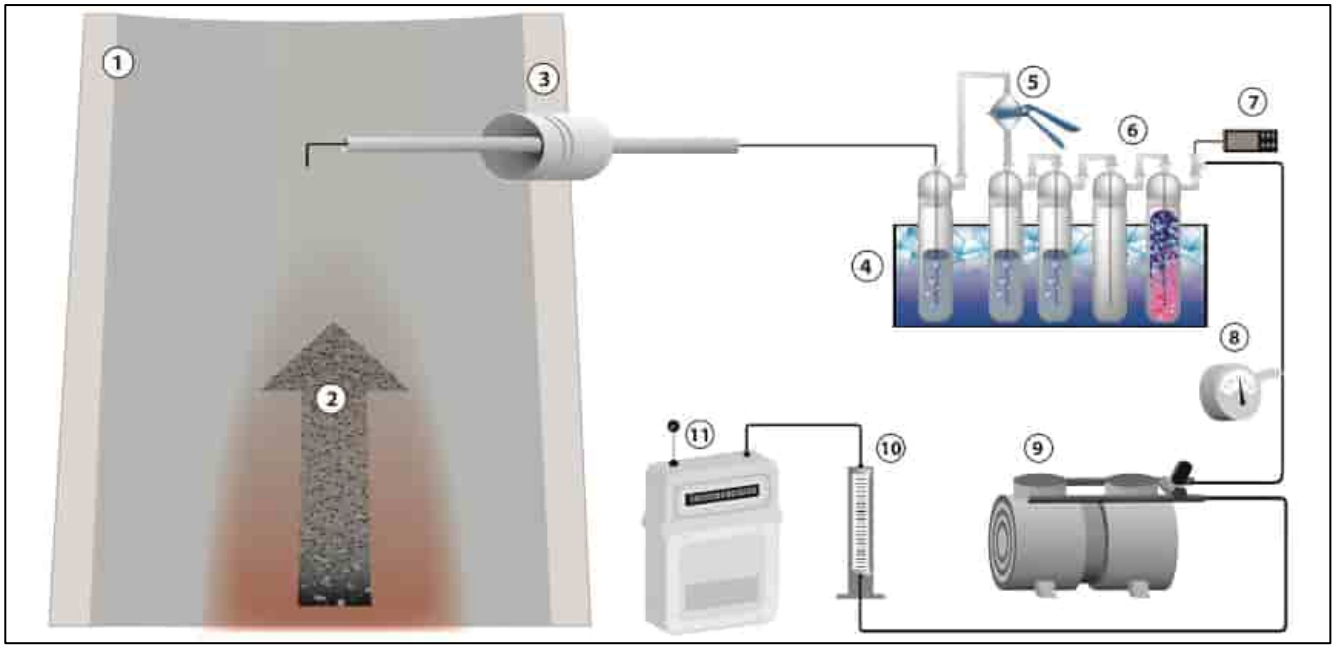


Figure 3 Sulphur Dioxide and Acid Mist Sampling Train

1	Stack to be measured
2	Air flow containing particulate and or sulphur dioxide.
3	Glass or Teflon probe.
4	One glass impinger containing isopropyl alcohol (to capture acid mist) followed by two impingers containing 3% hydrogen peroxide (to capture SO_2).
5	Inline 47mm glass fibre filter to capture acid mist.
6	Silica gel containing impinger. Changes to red when wet.
7	Temperature reader measure temperature of gas leaving impingers
8	Vacuum gauge- checks for blockages in the sample line.
9	Air sampling pump
10	Rotameter to measure sampling air flow rate
11	Gas meter to measure gas volume sampled. The air temperature is measured on the outlet.

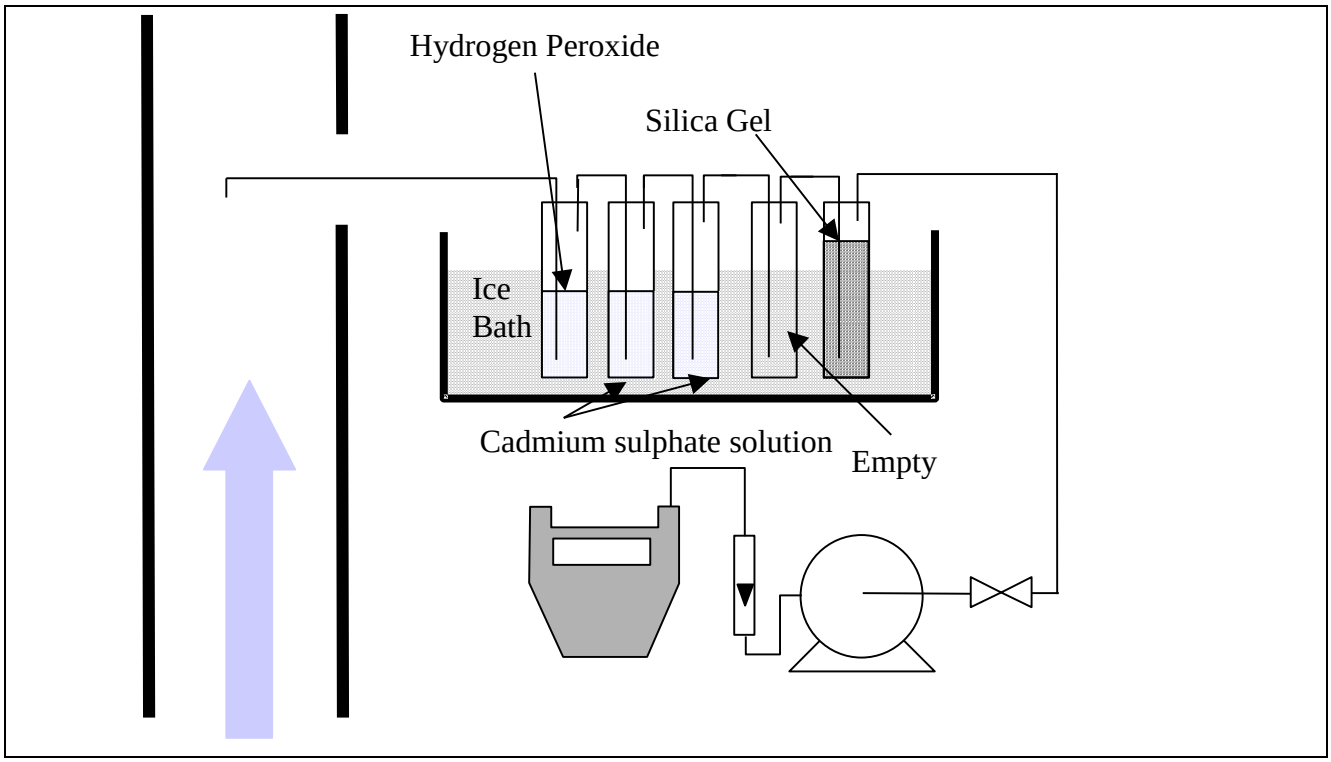
The samples are recovered at the end of sampling and analysed by barium chloride titrations.

B.4. USEPA Method 11: Determination of Hydrogen Sulphide Content

A sample is extracted from a source and passed through a series of midget impingers containing a cadmium sulphate ($CdSO_4$) solution; H_2S is absorbed, forming cadmium sulphide (CdS). The latter compound is then measured iodometrically. An impinger containing H_2O_2 is placed in front of the cadmium sulphate impingers to remove sulphur dioxide.

At the completion of sampling the probe should be disconnected from the impinger train. A charcoal tube is put in its place and the train is purged for 15 minutes at a rate of 1 litre per minute.

Figure 4 Sampling Train for Hydrogen Sulphide



B.5. **Combustion Gases**

The combustion gas analyser can analyse the following gases, meeting the requirements of the United States Environmental Protection Agency (USEPA) methods.

Gases	Method
Carbon Monoxide	USEPA Method 10
Carbon Dioxide	USEPA Method 3A
Oxygen	
Oxides of Nitrogen (NO, NO_2 and NO_x)	USEPA Method 7E
Sulphur Dioxide	USEPA Method 6C
Total Organic	USEPA Method 25B

K2 Environmental Ltd owns two combustion gas analysers. A sample of the stack gas is drawn from the stack, filtered, and the moisture removed from the gas conditioner system. The gas conditioner can be eliminated from the sample train if:

- The stack gas moisture levels are low
- Monitoring is to be done over a short period of time

The gas then passes through the analyser. Using infrared technology, the carbon dioxide concentration is measured, and then all other gases are measured using specially prepared chemical cells, specific to each gas. A field laptop is connected to the analyser to log and record the data.

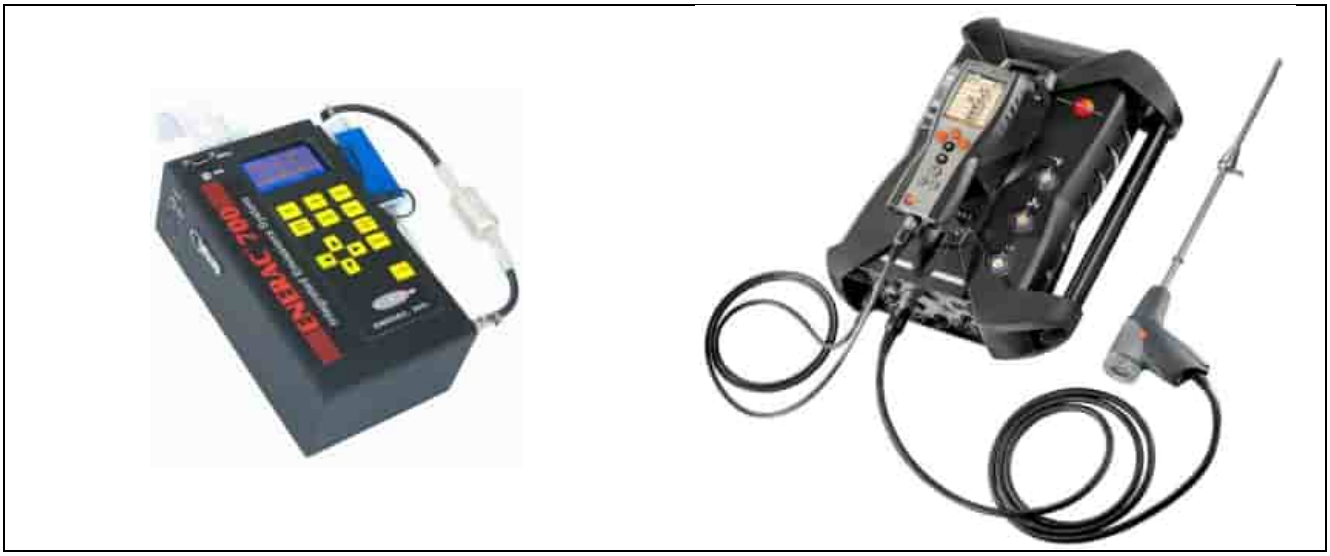


Figure 5 Combustion Gas Analysers

APPENDIX C LAB REPORTS

C.1. **Lab Report for Particulate**

K2 Environmental Ltd

Certificate of Analysis

All tests reported herein have been performed in accordance with the laboratory's scope of accreditation

Test Results

Sample Type		90mm GFA Filters			
Sample ID	Filter Number	Sample Details	Pre-Weight (mg)	Post-Weight (mg)	Particulate Weight (mg)
X0263-1	AD0555	Test 1	333.49	335.50	2.01
X0263-2	AC4861	Test 2	336.59	333.82	<0.62
X0263-3	AD0553	Test 3	334.71	335.81	1.10
Blank	AD0550	Lab Blank	340.91	340.97	<0.62

Sample Type	Nozzle washes - Acetone			
Sample ID	Sample Details	Pre-Weight (mg)	Post-Weight (mg)	Particulate Weight (mg)
X0263-5	Nozzle wash Test 1	18,729.94	18,731.04	1.10
X0263-6	Nozzle wash Test 2	46,365.16	46,370.35	5.19
X0263-7	Nozzle wash Test 3	46,006.83	46,024.57	17.74
Blank	Lab Blank	43,010.58	43,010.68	<0.31

Sampling Details

Client Name	Oceana Gold		
Sample Date	26-27 October 2022	Analysis Date	10 November 2022
Sampled By	[redacted]	Analysis By	[redacted]
Accreditation Reg Num.	911	Report Version	1
Methods Used	USEPA method 17		

This report must not be altered or reproduced except in full.
Detection limits are calculated using the 95% confidence interval (2x standard deviation)

[redacted]	[redacted]
Analyst	Key Technical Person Christchurch Office

Job Number: X0263 Issue Date: 21 November 2022 Page 1 of 1

C.2. **Lab Report for SO_2 and SO_3**

K2 Environmental Ltd

Certificate of Analysis

All tests reported herein have been performed in accordance with the laboratory's scope of accreditation

Test Results

Sample ID	Sample Description	Sample Mass (mg)	SO_2 Mass (mg)
X0263-9	SO_3 Autoclave Stack Test 1	199,000	2.49
X0263-10	SO_2 Autoclave Stack Test 1	214,300	2.05
X0263-11	SO_3 Autoclave Stack Test 2	124,300	0.46
X0263-12	SO_2 Autoclave Stack Test 2	196,000	1.25
X0263-13	SO_3 Autoclave Stack Test 3	103,400	<0.08
X0263-14	SO_2 Autoclave Stack Test 3	197,300	1.47
X0263-15	SO_3 Autoclave Stack Field Blank	95,200	<0.08
X0263-16	SO_2 Autoclave Stack Field Blank	138,400	0.37

Sampling Details

Client Name	Oceana Gold		
Sample Date	26 October 2022	**Analysis Date**	9 November 2022
Sampled By	[redacted]	**Analysis By**	[redacted]
Accreditation Reg Num.	911	**Report Version**	1
Methods Used	USEPA 8A		

This report must not be altered or reproduced except in full.

[redacted] **Analyst**	[redacted] **Key Technical Person** **Christchurch Office**

Job Number: X0263 Issue Date: 15 December 2022 Page 1 of 1

APPENDIX D ELECTRONIC EQUIPMENT RECORDS

D.1. **Testo Calibration Check data**

Table 13 Calibration check

Equipment Type	Equipment Serial Number	Date Last Calibrated	Gas	Pre-site average difference (%)	Post-site average difference (%)
Testo	60327546	11/04/2022	CO_2	-2.8	-2.9
			CO	-0.2	1
			O_2	-0.7	0.7
			SO_2	2.1	-3.3
			NO_2	1.3	1.5
			NO	0.6	0.2

Appendix B Deposition monitoring data

B1 Deposition sites beyond the mine boundary

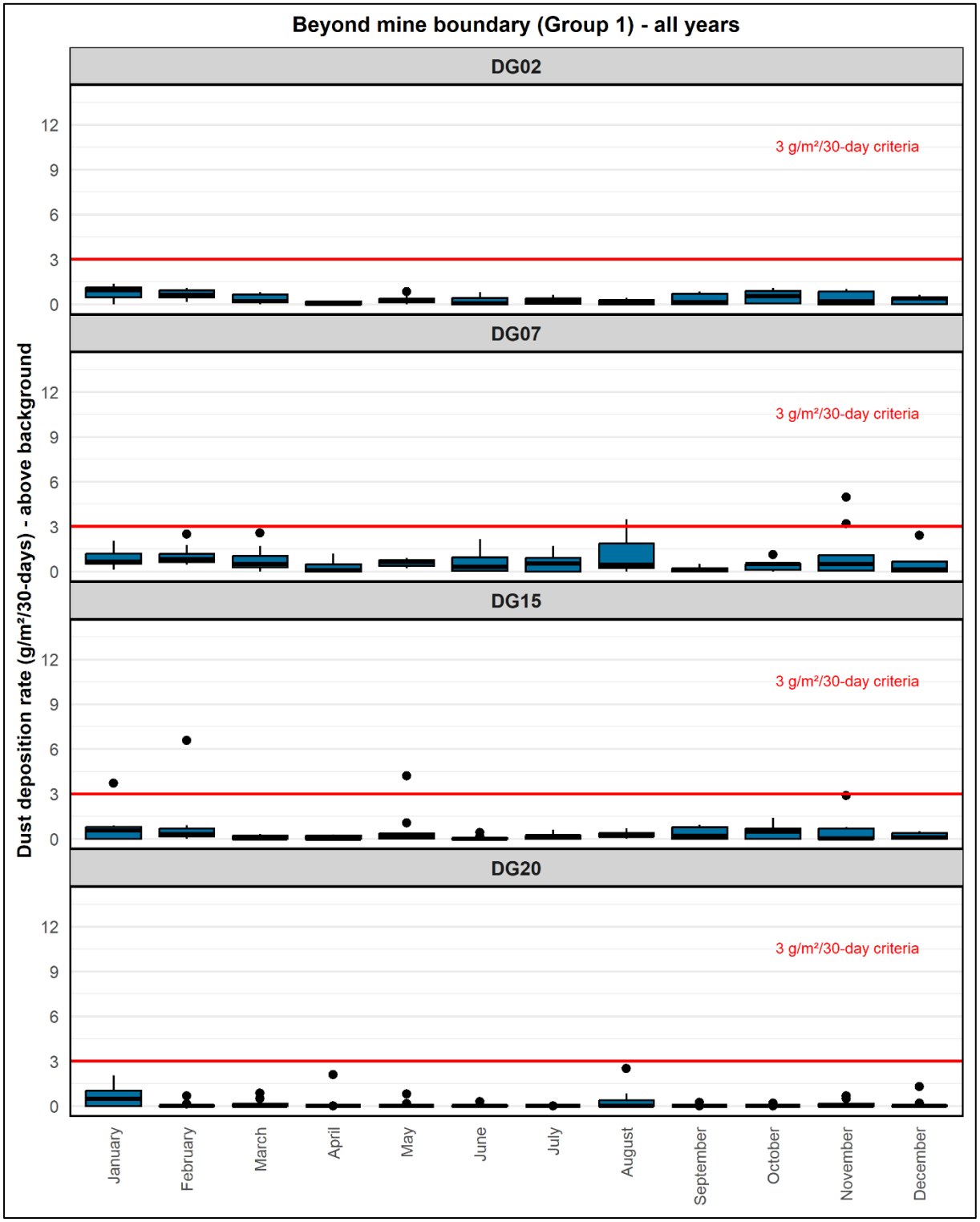


Figure Appendix B 10: Box and whisker plots for dust deposition monitoring sites beyond the mine boundary (Group 1) for the years 2015–2023.

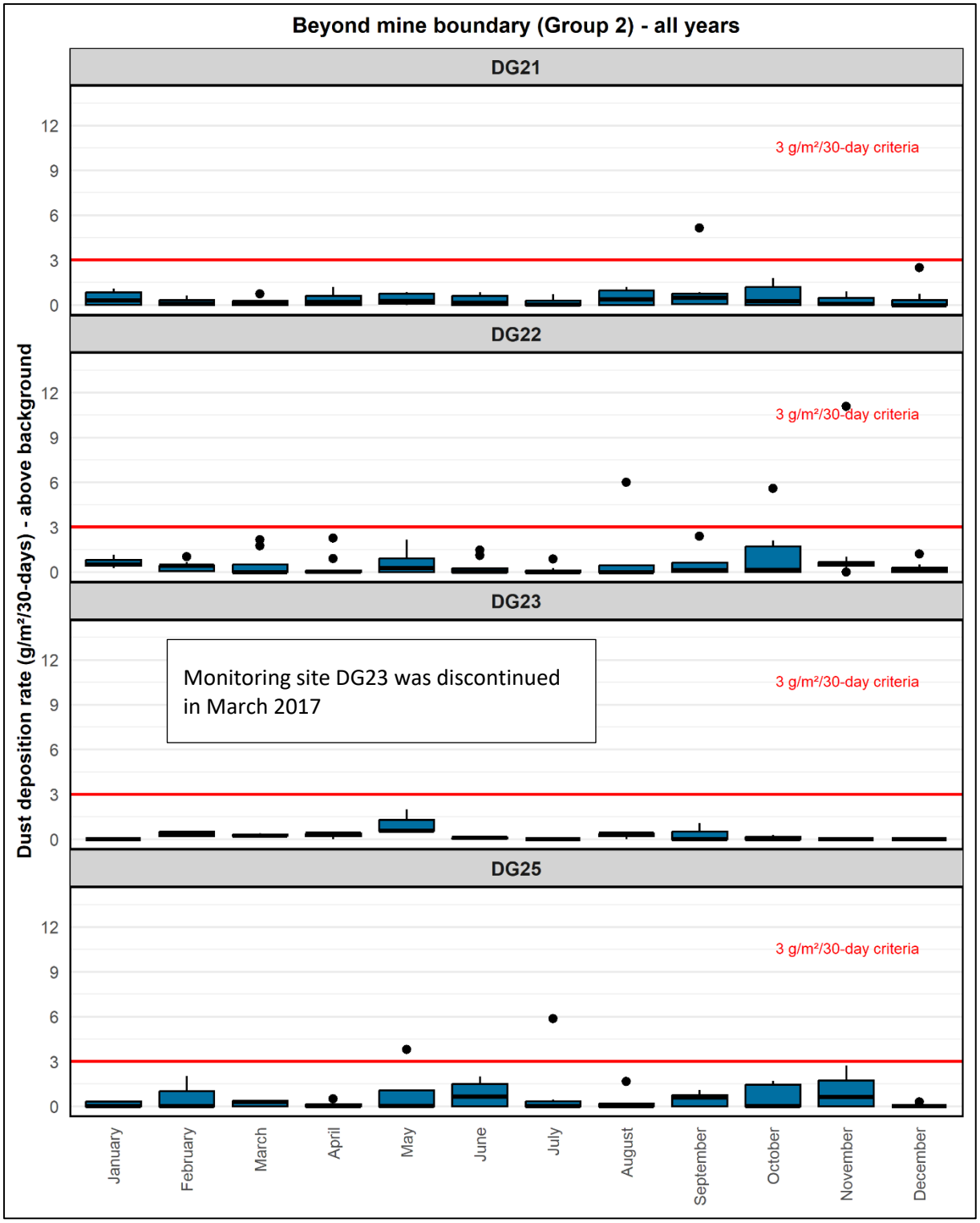


Figure Appendix B 11: Box and whisker plots for dust deposition monitoring sites beyond the mine boundary (Group 2) for the years 2015–2023.

B2 Deposition sites within the mine boundary

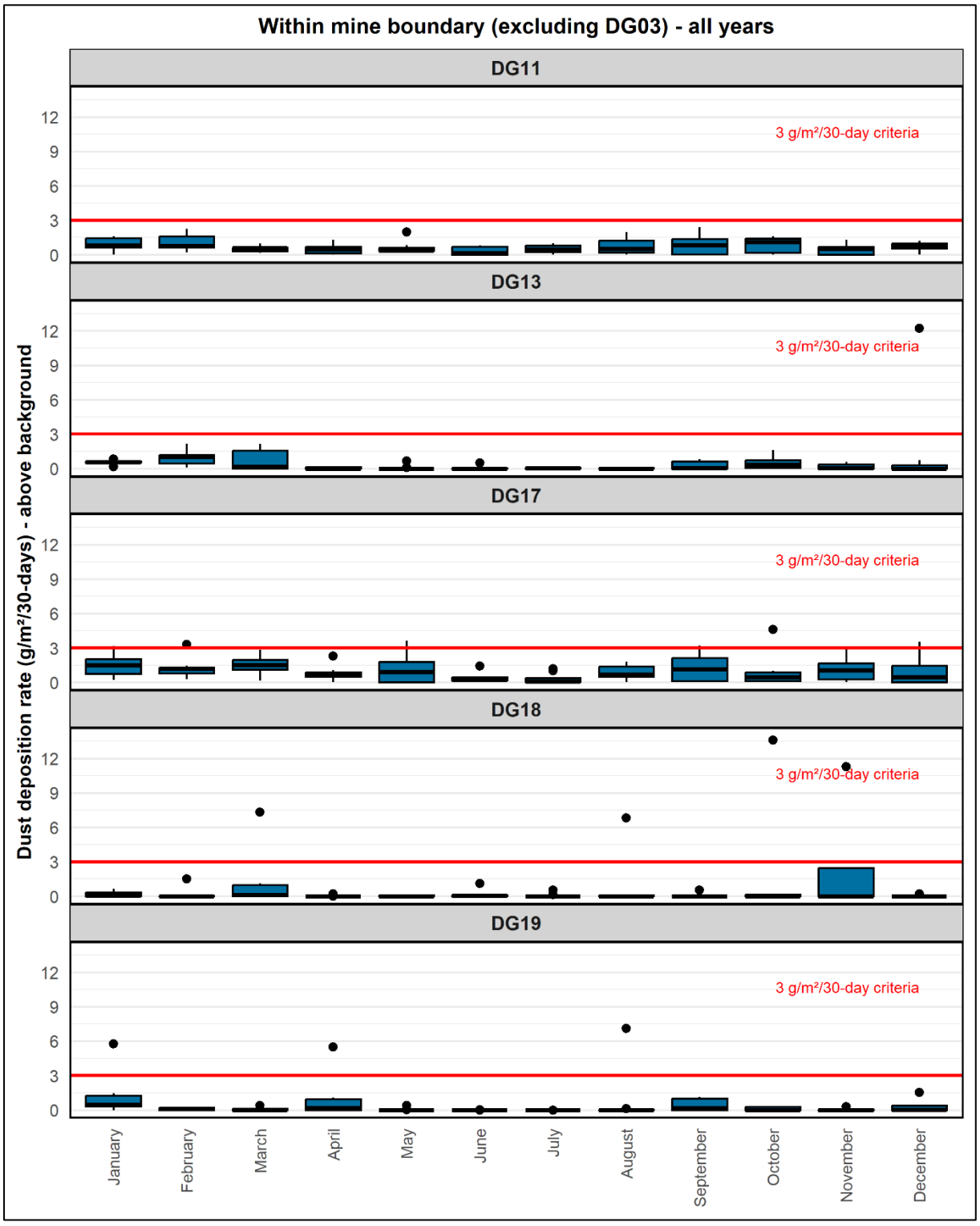


Figure Appendix B 12: Box and whisker plots for dust deposition monitoring sites within the mine boundary (excluding DG03) for the years 2015–2023.

Appendix C Air Quality Management Plan

Air Quality Management Plan

Approved date: xx August 2026

Document ID: MAC-210-PLN-000

This is no longer a controlled document once printed.
This document must not be released outside of the company without permission of the Departmental Manager

Department	**Environment and Social Performance**
Location/Site	Macraes

Approval table

	Position title	Name	Date
Authored by	Senior Environmental Advisor	[redacted]	04 Mar 11
Reviewed by	Environmental Advisor	[redacted]	26 Mar 26
Approved by	Superintendent - Environment	[redacted]	8 Apr 26

Document issuance and revision history

Document name: Dust Management Plan

Document id: MAC-210-PLN-000

Revision number	Revision date	Section	Page	Description	Effective Date
A	04 Mar 11			Initial Draft	[redacted]
B	18 Mar 11			Amendments to Draft A	[redacted]
C	01 May 13			Plan Review	[redacted]
D	09 Jul 14			General Review and Update to include Coronation	[redacted]
E	04 Aug 15			Plan Review	[redacted]
F	10 Aug 16			Plan Review	[redacted]
G	23 Jan 17			Review and update to include Coronation North	[redacted]
H	14 May 19			Review and update to include Frasers West	[redacted]
I	23 Nov 20			General Review and Update to include Deepdell North Stage III and Frasers West.	[redacted]

J	02 May 23			Review and update to include Golden Point Underground	[redacted]
K	15 Nov 24			Annual review and update to incorporate consent changes.	[redacted]
L	26 Mar 26			General review and update to include CCP2 RM10.351.52_V4 requirements and consent. Emergency contacts Section 15.5 updated.	[redacted]
M	21 Aug 26			Update to reflect MP4 FTAA application. This update has been prepared by a Suitably Qualified and Experienced Practitioner (SQEP).	Richard Chilton (Tonkin & Taylor Limited)

Document Revision History				
04/03/2011	**Author Name:**	**Richard Chilto (Tonkin & Taylor Ltd)**		
Discussed and Reviewed by:		**Date**	**Name**	**Approved**
Revision Approved by:		**Date**	**Name**	**Approved**

Table of Contents

1 REFERENCE AND COMPLIANCE 1

2 PURPOSE 2

3 SCOPE AND OBJECTIVES 3

4 AIR DISCHARGE CONSENTS 4

5 SITE OVERVIEW 6

5.1 Description of the Macraes district 6

5.2 Macraes Operation 9

6 AIR DISCHARGE SOURCES 15

6.1 Dust 15

6.2 Processing Plant 16

7 DUST MITIGATION MEASURES AND PROCEDURES 17

7.1 Introduction 17

7.2 Unpaved Surfaces 17

7.3 Vehicles 17

7.4 Stockpiles 17

7.5 Miscellaneous 17

7.6 Tailings 18

7.7 Excessive Dust Action Plan 18

8 MONITORING 19

8.1 Monitoring Equipment Specifications 22

8.2 Data Analysis and Reporting 23

8.3 Compliance Limits 23

8.4 Processing Plant Stack Emission Testing 25

8.5 Exceedance of a Compliance Limit 26

8.6 Annual Review Report 27

9 COMPLAINTS 28

10 RESPONSIBILITIES 29

11 CONSULTATION, REPORTING AND REVIEW 30
11.1 Neighbours 30
11.2 OGNZL to Otago Regional Council 30
11.3 Otago Regional Council to OGNZL 30
11.4 AQMP Review Procedure 30
12 DEFINITIONS 32
APPENDIX A: RESOURCE CONSENTS 33
APPENDIX B: TAILINGS STORAGE FACILITIES DUST CONTROL MANUAL 34
1 INTRODUCTION 1
2 RESPONSIBILITIES 1
3 ENVIRONMENTAL CONDITIONS 1
4 METHODS OF DUST CONTROL 2
4.1 Tailings Discharge 2
4.2 Rock Mattress Cover 2
4.3 Dust Suppression System 2
5 OPERATION 3
6 TRIAL DUST SUPPRESSION TECHNIQUES 3
6.1 Vital Bon-Matt Stonewall 3
6.2 Vital Strike 3
6.3 Ryecorn Grass Seed 3
7 MAINTENANCE 4
8 DAILY DUST SUPPRESSION DECISION TREE 5

1 REFERENCE AND COMPLIANCE

Level	Source
Legislation, Guidelines, Resource Consents	• Ministry for the Environment. 2016. Good Practice Guide for Assessing and Managing Dust. Wellington: Ministry for the Environment
	• Discharge Permit 96785_V5 - To discharge contaminants from mining operations and post mining rehabilitation to air in the vicinity of Macraes Flat.
	• Discharge Permit RM10.351.52.V4 - To discharge contaminants from mining operations and post mining rehabilitation to air for the purpose of undertaking mining operations
	• Discharge Permit RM12.378.15 - To discharge contaminants from mining operations and post mining rehabilitation to air for the purpose of undertaking mining operations (Coronation Waste Rock Stack, Coronation Pit and associated haul roads, utility areas and stockpiles).
	• Discharge Permit RM16.138.19_V1 - To discharge contaminants from mining operations and post mining rehabilitation to air for the purpose of undertaking mining operations (Coronation North Project).
	• Discharge Permit RM20.024.12 - To discharge contaminants from mining operations and post mining rehabilitation to air for the purpose of undertaking mining operations (Deepdell North Stage III Project).
	• Discharge Permit RM20.130.01_V1 - To discharge contaminants to air for the purpose of ventilating the Golden Point Underground Mine – Application dated March/April 2020 and GPUG Extension and Expansion application dated October 2023
	• **[Placeholder for MP4 FTAA permit conditions]**
Corporate	• Oceana Gold Environmental Performance Standards Manual – Operational Environmental Standard Air Quality
Site	• Annual Oceana Macraes – Ambient Air Monitoring Report – 2010 to 2025.

2 PURPOSE

The purpose of this Air Quality Management Plan (AQMP) is:

> *To facilitate the avoidance, remediation and mitigation of any adverse effects of contaminant discharges to air beyond the boundary of the site that may be generated from mining activities and to promote proactive solutions to the control of those discharges from the site.*

The AQMP gives effect to MP4 consent conditions **x, y, z** in the following sections **[to be inserted when consents are granted].**

The AQMP includes information on the following:

- The sources of contaminant discharges to air at the Macraes Operation;
- Mitigation and prevention measures;
- Monitoring methods;
- Mechanisms for remediation of adverse effects (should this be required);
- Methods for managing complaints regarding air quality and keeping records related to compliance; and
- Key responsibilities, consultation and reporting.

The AQMP is intended to be a working document and is to be reviewed annually and updated as necessary from those reviews. OGNZL may lodge an amended monitoring plan, management plan or other document for recertification at any time. Minor/administrative changes may be implemented without recertification where written notice is provided to ORC no less than 5 working days prior to publication of the amended document in accordance with Condition xx

Minor/administrative changes are limited to corrections of errors, updates to contact details, updates to reflect changes in organisational structure, formatting improvements, or other changes that:

- Do not alter the objectives, performance standards, mitigation methods, monitoring methodology, or reporting requirements of the certified document; and
- Do not materially affect the scale, location, or nature of activities authorised by these consents.

3 SCOPE AND OBJECTIVES

This AQMP applies to the entire OceanaGold (New Zealand) Limited (**OGNZL**) Macraes Operation and includes the activities authorised under the Macraes Phase Four Project (MP4), which extends the life of mining at the Macraes Operation for at least 10 years.

The objectives of this management plan are:

- To describe current and proposed air quality (mainly dust) management methods and procedures;
- To enable OGNZL to operate in full compliance with resource consent requirements including managing any adverse effects within the boundary of the site; and
- To describe the air quality monitoring regime and reporting of results.

4 AIR DISCHARGE CONSENTS

This AQMP covers (or, as part of previous iterations, has covered) the following areas/projects:

- The original mining operation at Macraes (up until May 2012);
- Macraes Phase III mine expansion area;
- Frasers Underground;
- Coronation Project area;
- Coronation North Project area;
- Frasers West Project (variation to the Macraes Phase III consent);
- Deepdell North Stage III project area;
- Frasers Co-Disposal Project;
- Continuity Consents Project Stage 2 (precursor consents to Macraes Phase 4);
- Golden Point Underground (including 2023 Variation); and
- MP4.

This AQMP has been prepared by a suitably qualified and experienced person, to meet the requirement for an AQMP, which is a resource consent condition in:

- Multiple air discharge consents held by OGNZL. Two air discharge consents are also held for the ventilation of the Frasers and Golden Point Underground mines. Details of these consents are summarised in **Table 4-1**.
- Resource consent for the discharge of contaminants to air associated with MP4 to authorise discharges from the new and existing active mining areas (Innes Mills, Golden Bar, Coronation, Coronation North and Golden Point Underground) together with the continued operation of the Processing Plant, for which the existing consents expire in 2032.

Table 4-1: Air Discharge Consents held by OGNZL.

Consent Number	Details
Discharge Permit 96785_V5	To discharge contaminants from mining operations and post mining rehabilitation to air in the vicinity of Macraes Flat. (All the mine site pre-May 2012)
Discharge Permit 2006.689	To discharge contaminants to air for the purpose of ventilating Frasers Underground Mine.
Discharge Permit RM10.351.52_V4	To discharge contaminants from mining operations and post mining rehabilitation to air for the purpose of undertaking mining operations
Discharge Permit RM12.378.15	To discharge contaminants from mining operations and post mining rehabilitation to air for the purpose of undertaking mining operations (Coronation Waste Rock Stack, Coronation Pit and associated haul roads, utility areas and stockpiles).
Discharge Permit RM16.138.19_V1	To discharge contaminants from mining operations and post mining rehabilitation to air for the purpose of undertaking mining operations (Coronation North Project).
Discharge Permit	To discharge contaminants from mining operations and post mining rehabilitation to air for the purpose of undertaking mining operations (Deepdell North Stage III Project).

RM20.024.12	
Discharge Permit RM20.130.01_V1	To discharge contaminants to air for the purpose of ventilating the Golden Point Underground Mine – Application dated March/April 2020 and GPUG Extension and Expansion application dated October 2023.
[placeholder for MP4 consent]	

Discharge Permits 96785_V5, RM10.351.52_V4, RM12.378.15, RM16.138.19_V1, RM20.024.12, and RM20.130.01_V1 include a condition requiring a dust management plan (DMP). However, this AQMP is considered to fulfil the DMP requirements of these permits as well as any additional requirements under the MP4 project.

5 SITE OVERVIEW

5.1 Description of the Macraes district

5.1.1 Topography, Land Use and Receptors

The Macraes Operation sits within a rural upland landscape of fluvially dissected rolling hills of moderate relief and with characteristic broad ridge crests; being the coastal extent of Central Otago's basin and range topography.

Prominent regional landscape features include the Nenthorn Valley, Taieri Ridge, Taieri Valley and the Rock and Pillar Range, which lie to the south and west, the Shag Valley and Horse Range to the east and the coastal hills and extinct volcanic cones of Palmerston and Waikouaiti to the south.

Pastoral farming is the broad land use in the area, followed by gold mining; the latter has a history in the area dating back to the 19th century. Macraes lies on the eastern edge of the schist country and the broader historic goldfields of Central Otago. The presence of the relatively large scale Macraes Operation is a noticeable and culturally significant element in the current landscape. The Macraes Operation is the modern 'face' of open pit gold mining; its presence and effect relative to landscape change is now an important factor contributing to the local landscape character.

The long-term, focal and cultural landscape feature of Macraes Flat is the Macraes Village with its hotel, school, churches, cemeteries and small clusters of houses and various outbuildings and shelterbelts. The village sits in isolation within 'the flat' and various local roads lead to even more isolated farms and homesteads. Scattered and isolated habitation is a feature of the open, rolling, landscape on the edge of basin and range topography that expands through to the upper Taieri and Maniototo.

The locations of sensitive receptors to the Mine are shown in **Figure 5-1** and **Figure 5-2**.

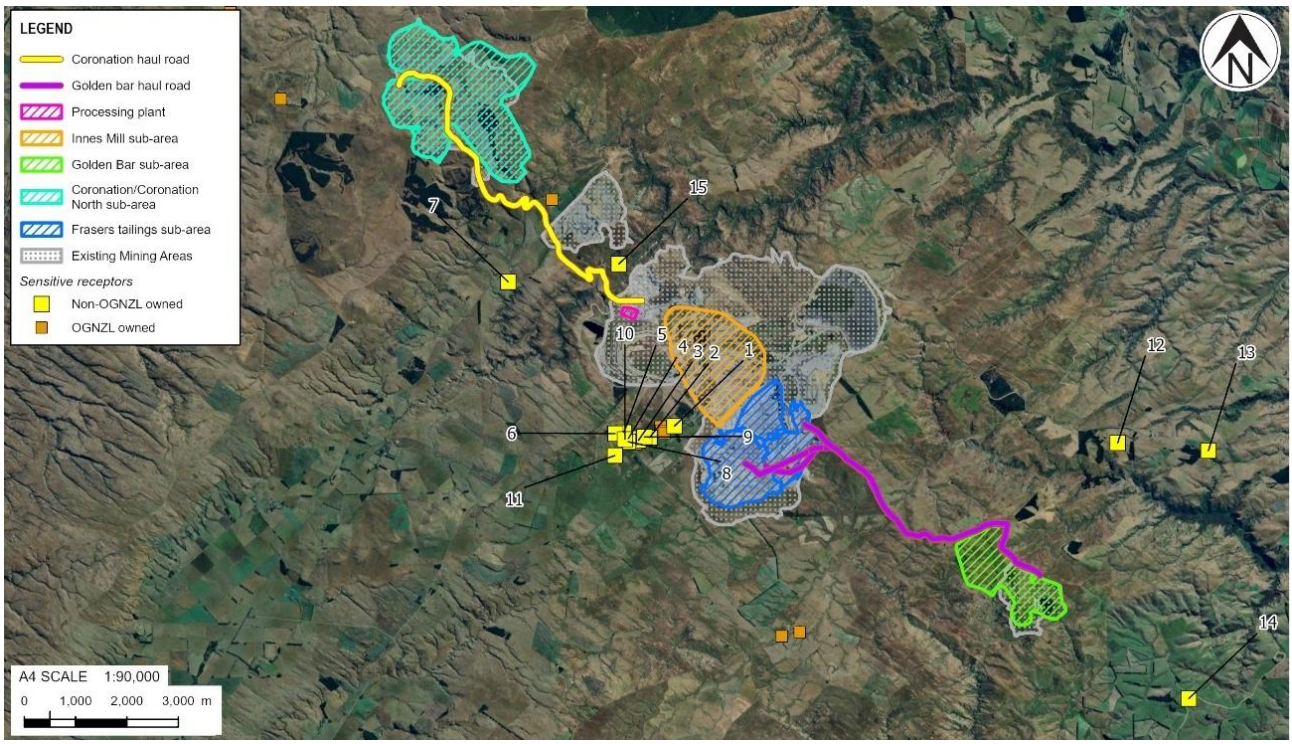


Figure 5-1: Sensitive receptor locations.

Figure 5-2: Sensitive receptor locations – Macraes Village.

5.1.2 Site Weather Conditions

The main features of the Macraes Flat climate are the relatively low rainfall (site average annual rainfall is 634 mm) and the moderately strong average wind speed of 3.77 m/s[1]. Both features can contribute to the generation and transport of dust. OGNZL measures wind speed and wind direction at a weather station located on Golden Point Road and at a second site adjacent to dust monitoring site 15 near the Macraes Village. A wind rose for the Macraes Village site for the period from 2017 to 2025 is shown in **Figure 5-3**. The predominant wind directions are from the west-southwest, northwest and east.

[1] Macraes Mining Company Ltd. Macraes Gold Project Discharges to Air Assessment of Environmental Effects December 1996.

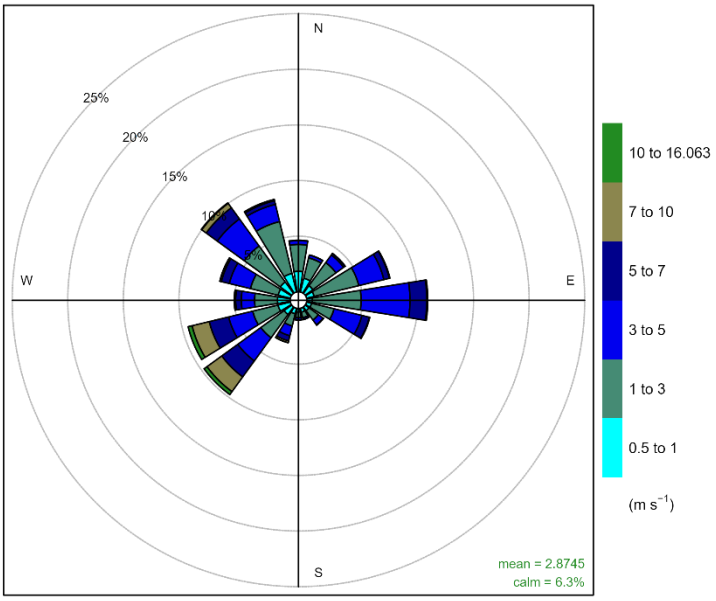


Figure 5-3: Wind rose (hourly average) for dust monitoring site DG15 (Macraes Village) from 2017 to 2025.

5.2 Macraes Operation

5.2.1 Key features

The Macraes Operation has been operational since 1990. The existing mining area extends to the north and south of Macraes-Dunback Road as shown on **Figure 5-4**.

The key features of the Macraes Operation[2] up to March 2026 are:

- The Deepdell South (now fully backfilled), Deepdell North, Golden Point, Round Hill, Innes Mills, Frasers, Golden Bar (currently a pit lake), Coronation, Coronation North, and Gay Tan Open Pits;
- Frasers and Golden Point Underground (Frasers is now closed);
- The Mixed Tailings, Southern Pit 11, Top Tipperary, and Frasers Tailings storage facilities;
- The Deepdell West and East, Northern Gully North and South, Frasers West, East, and South, Golden Bar, Coronation, Coronation North and Trimbells Waste Rock Stacks;
- A processing plant;
- Various offices, workshops and ancillary buildings or facilities;
- The Lone Pine Fresh Water Reservoir;
- Haul roads, light vehicle access roads, assorted silt ponds, topsoil stockpiles, oxide stockpiles and low-grade stockpiles;
- Works associated with road realignments of Macraes-Dunback Road and Golden Bar Road; and
- Dams in Camp Creek and Coal Creek (yet to be constructed).

The Coronation and Coronation North projects commenced in 2015 and 2017 respectively and are located on the Taieri Ridge. Mining consists of the Coronation and Coronation North Pits and associated waste rock stacks. Coronation and Coronation North are linked to the Processing Plant via a haul road and a culvert crossing across Deepdell Creek.

The Frasers West Project commenced in 2020 and established a new 16.5 ha Frasers West Pit, disposal of waste rock in Frasers Pit and Frasers South Pit; backfilling of the newly established Frasers West Pit using waste rock from the neighbouring Innes Mills and Frasers Slip Pits; and establishment of a new noise bund between the Frasers West Pit and Macraes Flat Township.

The Deepdell North Project area commenced in 2020 and involved re-mining the Deepdell North Pit and expanding it from 18.7 ha to 38 ha, creation of the Deepdell East Waste Rock Stack and backfilling of the existing Deepdell South Pit. Mining at Deepdell North is mostly completed.

The Top Tipperary Tailings Storage Facility (TTTSF) is located to the east of the Frasers-Innes Mills Pit. In late 2025 tailings disposal moved to the Frasers in-Pit Tailings Facility (FTSF) which is now the primary operational TSF. The Mixed Tailings Impoundment and the Southern Pit 11 tailings storage are currently in the process of being rehabilitated, whilst also providing some water storage.

The processing plant is centrally located on the southern side of Deepdell Creek and below the Southern Pit and Mixed Tailings facilities.

The Deepdell Pit, Round Hill/Golden Point Pit, the associated waste rock stacks, the Southern Pit 11 and Mixed Tailings Storage Facilities and sections of Coronation Pit and Waste Rock Stack lie in the Deepdell Creek Catchment, whilst the Frasers Pit and associated rock stacks lie predominantly in the North Branch of the Waikouaiti River catchment. The TTTSF and a small portion of Frasers East Waste Rock Stack lie in the Tipperary Creek Catchment. Coronation North Pit and Waste Rock Stack and sections of Coronation Pit

[2] The MP3 extension was not constructed and therefore this AQMP does not include the extension consented under the MP3.

and Waste Rock Stack lie in the Māori Hen Creek and Trimbells Gully Creek (tributaries of the Mare Burn in the Taieri River catchment).

To date, the mining footprint of the Macraes Operation totals 2,150 ha in disturbance, of which 650 ha has been rehabilitated.

The MP4 Project will extend the life of the Macraes Operation for at least 10 years. The key activities comprising MP4 are as follows:

- Open pit mining extensions at Golden Bar, Coronation, Coronation North and Innes Mills (including extensions to existing pits and pit backfilling where appropriate).
- Further development of the Golden Point Underground mine.
- Construction of the Frasers Tailings Storage Facility (FTSF) Stage 3 to accommodate an additional 118 million tonnes of tailings, together with mining and relocation of tailings from the Mixed Tailings Impoundment (MTI), Southern Pit Option 10 (SP10) and Southern Pit Option 11A (SP11A) to the FTSF.
- Increased waste rock storage within open pits and at existing waste rock stacks at Coronation, Coronation North, Innes Mills, Golden Bar, Golden Point and Frasers.
- Water management infrastructure including the consented Camp Creek and Coal Creek water storage dams; realignment of Macraes Road; relocation of the Open Pit Mining Workshop; and progressive mine closure and rehabilitation.
- The Processing Plant will continue to operate, processing ore through a pressure oxidation (POX) circuit to produce gold doré.

Elements of the MP4 project are shown in **Figure 5-5**.

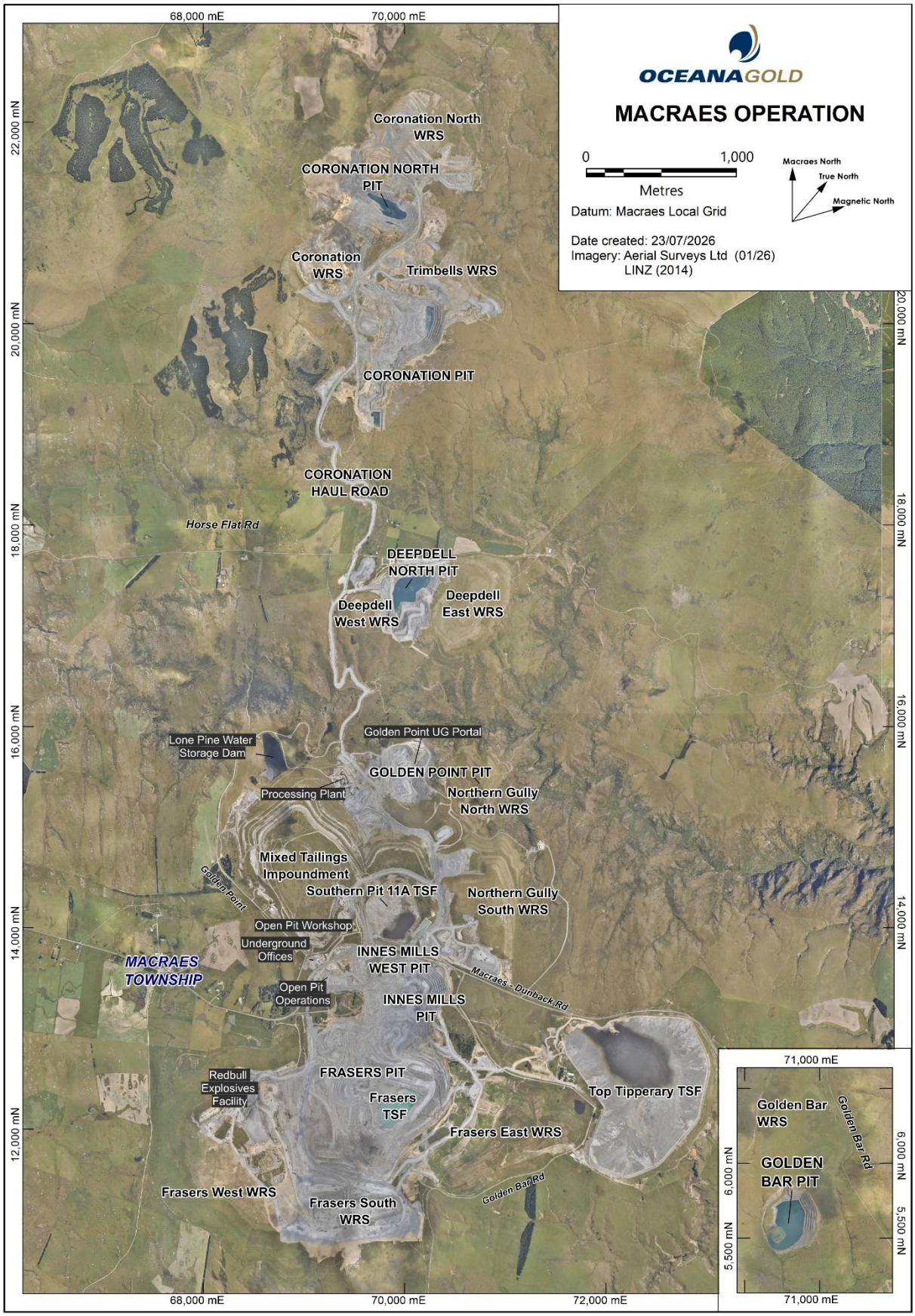


Figure 5-4: Macraes Operation Existing Mine Elements

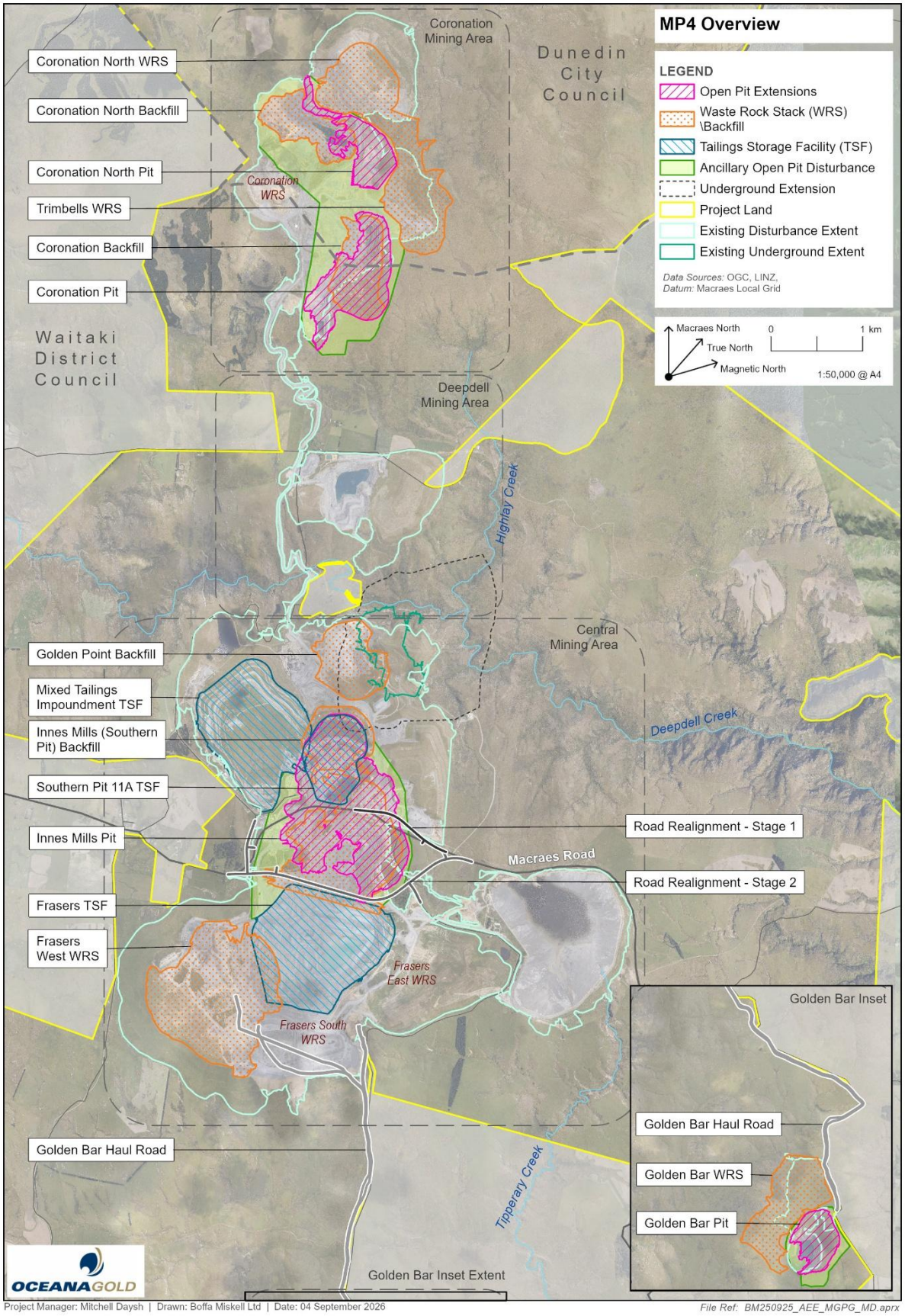


Figure 5-5: MP4 Elements

5.2.2 Mine Site Environment

The land in the vicinity of the Macraes Operation is rural and is of a similar character to the land surrounding the existing mine. The topography of the area is dominated by the large waste rock stacks and mine pits. More recently rehabilitated waste rock stacks have been shaped so that their profile, contours, skylines, and transitions blend with the surrounding natural landforms. The land to be mined is all owned by OGNZL, except for the Camp Creek Dam (yet to be constructed) site.

Figure 5-6 shows the areas of land in the vicinity of the mine which are owned by OGNZL, including areas of land leased and the boundaries of land owned by neighbours. The map also shows the locations of the existing and proposed mine activities and demonstrates the distances from the mining activities to the boundaries with neighbouring properties.

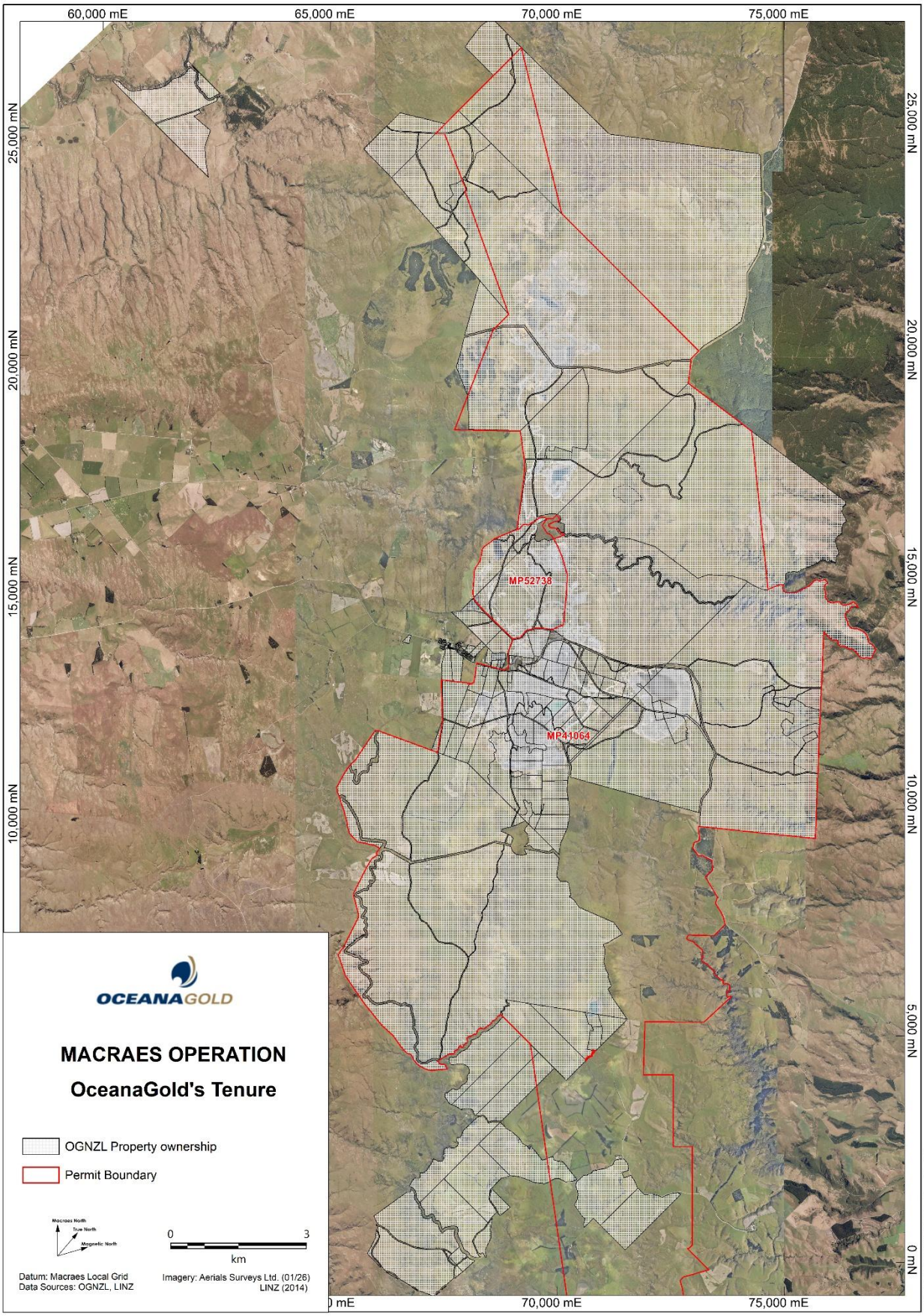


Figure 5-6: Land Owned and Leased by OGNZL

6 AIR DISCHARGE SOURCES

6.1 Dust

6.1.1 Potential Dust Sources

The following activities have the potential to generate particulate matter (i.e., dust) discharges:

- Blasting of rock;
- Excavation, including stripping of overburden and topsoil;
- Vehicle movements on unpaved surfaces (i.e. haul roads);
- Loading and unloading of materials;
- Wind generated dust from dry exposed surfaces such as stockpiles, tailings impoundment surfaces and non-rehabilitated surfaces;
- Crushing of materials;
- Drilling of blast holes; and
- Excavation and relocation of tailings.

Dust emissions from exposed surfaces generally increase with increasing wind speed. However, dust picked up by wind is only significant at wind speeds above 5 m/s. The smaller the particle size of the material on an exposed surface, the more easily the particles are able to be picked up and entrained in the wind. Moisture binds particles together preventing them from being disturbed by winds or vehicle movements. Similarly, vegetated surfaces are less prone to wind erosion than bare surfaces. The larger the areas of exposed surfaces the more potential there will be for dust emissions.

Vehicles travelling over exposed surfaces (i.e., haul roads) tend to pulverise any surface particles. Particles are lifted and dropped from rolling wheels and the surface. Dust is also sucked into the turbulent wake created behind moving vehicles.

The discharge of dust from haul roads has the potential to have effects on two scales. The first is individually from a source where the effects are localised in the immediate area surrounding the activity. Secondly, cumulative effects may be observed where the dust generated from all the nearby dust sources (such as machinery operating in the pit and adjacent haul roads) combine to affect the air quality of the area as a whole. Therefore, it is important that all dust sources be minimised as far as practical, including those well separated from sensitive locations, as all dust generated will influence the overall air quality in the area.

Key areas relating to point source dust emission and generation are tailings, active open pits, active waste rock stacks, primary haul roads and ancillary facilities outside of active mining areas.

6.1.2 Factors Influencing Dust Generation

There are five major factors which influence the potential for dust to be generated at the Macraes Operation. These are:

- Wind speed across the surface;
- The percentage of fine particles in the material on the surface;
- Moisture content of the material;
- The area of exposed surface; and
- Disturbances such as traffic, excavation, loading and unloading of materials and blasting.

Systems for controlling dust emissions need to include methods that modify the condition of the materials so that they have a lesser tendency to lift with the wind or disturbances such as vehicle movements, and methods that reduce the velocity of the wind at the surface.

Watering of exposed surfaces and materials that may be disturbed is a primary method of control.

The dust mitigation methods detailed in Section 7 are the methods that have been found to be effective over the last 30 years of operation at the Macraes site. They are used alone or in combination depending on the circumstances.

6.2 Processing Plant

6.2.1.1 Overview

Gold present in the Macraes ore is generally only visible when viewed under a microscope. The Macraes ore predominantly contains sulphide minerals with which the gold is bound. To extract the gold, the sulphide ore is treated through a series of stages that includes:

- Crushing;
- Grinding;
- Flotation;
- Pressure oxidation (POX);
- Carbon-in-Leach (CIL) elution;
- Electrowinning; and
- Smelting.

Tailings streams from flotation and detoxified CIL are discharged to the tailings storage facility (TSF), with decanted water recovered and recycled to the Processing Plant.

Potential air emission sources are associated primarily with crushing and materials handling, the POX autoclave off-gas (via the vent scrubber and stack), and smaller exhaust points from carbon regeneration, electrowinning ventilation, and smelting.

Discharge to air sources from the processing plant include the following:

- The POX plant stack;
- The Barring furnace stack;
- Fume hood collection above the electrowinning cells:
    - Electrowinning 1 (EWIN1);
    - Electrowinning 2 (EWIN2);
    - Electrowinning 3 (EWIN3);
- Carbon regeneration kiln 1 stack;
- Carbon regeneration kiln 2 stack;
- Carbon regeneration kiln 3 stack; and
- The retort oven.

7 DUST MITIGATION MEASURES AND PROCEDURES

7.1 Introduction

The following measures and procedures are implemented as necessary. Where relevant, the measures and procedures are also incorporated into contractors' responsibilities. Responsibilities for the implementation and monitoring of mitigation measures are set out in Section 10.

7.2 Unpaved Surfaces

Unpaved surfaces can include haul roads, waste rock stacks, and pits. Tailings impoundments are considered separately in Section 7.6.

- Limit the area of exposed surfaces.
- Retain as much vegetation as possible.
- Keep tailings impoundment, pit and haul road maintenance up to date, such as repair of potholes and the laying of fresh gravel or surfacing material.
- Keep haul road and exposed surfaces damp during dry conditions with water carts or fixed sprinklers. Monitor routinely through each day of operation (visual observations) during dry conditions to ensure water cart and/or sprinkler operation is effective. During particularly dry weather (which can be informed by weather forecasts) when there is a risk of dust being carried towards off-site sensitive receptors, water suppression using water carts is prioritised. At least two water carts operate on mine haul roads following periods where there has been no rainfall and the haul road surface is visibly dry.
- Cover exposed fine fill materials with coarse materials where practicable.

7.3 Vehicles

Vehicles include light vehicles, dump trucks and earthmoving machinery.

- Minimise traffic movements and control vehicle speeds to a maximum of 60 km/h on haul roads.
- Adhere to load sizes to avoid spillages.
- Minimise travel distances through appropriate site layout and design.

7.4 Stockpiles

Stockpiles include topsoil, brown rock, ore and waste rock.

- Limit the height and slope of stockpiles to reduce wind entrainment.
- Orientate stockpiles to maximise wind sheltering.
- Minimise drop heights.
- Stabilise stockpiles of any materials that are to be left undisturbed for more than three months.
- Maximise shelter from winds as practicable.

7.5 Miscellaneous

- Stabilise exposed soil as soon as practical following completion of works.
- Install wind fences or barricades where practicable and appropriate.
- Minimise the area of surfaces covered with fine materials.
- Remove topsoil and loose material covering rock prior to blasting.
- Schedule potentially dusty operations where possible to avoid times of the day and year when conditions are likely to be particularly dry and windy.
- Schedule blasts to consider wind conditions.

7.6 Tailings

In addition to the above measures, specific dust mitigation methods exist for the tailings impoundment surfaces. These mitigation methods are detailed in the Tailings Storage Facilities Dust Control Manual presented in Appendix B.

7.7 Excessive Dust Action Plan

In the event that personnel are unable to control dust adequately on the mine site and additional measures are required in order for OGNZL to comply with the provisions of the resource consents, OGNZL shall initiate an emergency action plan. OGNZL will maintain an in-house register of persons and contractors who have suitable equipment and personnel available that can be contacted at short notice in the event of a dust emergency occurring.

The emergency procedures may include, but are not limited to, the following:

- The use of additional water carts and irrigation systems; and
- Stopping work on areas of the site that are sources of excessive dust, where practical.

The Site Personnel Contacts list is included in Table 10-1.

8 MONITORING

The monitoring regime will be updated to reflect the recommendations of the T+T Air Quality Assessment (AQA) submitted as part of the substantive MP4 application. In summary, the existing dust deposition monitoring and meteorological monitoring will continue, the continuous total suspended particulate (TSP) monitoring at Macraes Village (DG15) will be replaced with continuous reference-standard PM_{10} monitoring, and a PM_{10} nephelometer will be established on OGNZL land near the residence at 1668 Macraes Road to provide an early-warning regime.

Under the existing air discharge consents 96785_V5, RM10.351.52_V4, RM12.378.15, RM16.138.19_V1, RM20.024.12, and the MP4 consent, the following monitoring will be undertaken:

- Dust deposition rate monitoring at monthly intervals at 16 sites;
- Continuous real-time PM_{10} monitoring at DG15 (Macraes Village) using a reference grade instrument (refer to Table 8-2);
- Continuous real-time PM_{10} monitoring on OGNZL land near the residence at 1668 Macraes Road using a nephelometer instrument (refer to Table 8-6);
- Continuous meteorological monitoring of conditions at two representative locations (Sites DG03 and DG15);
- Real time total suspended particulate (TSP) monitoring at located near DG07 (Woolshed TSP) for a period of at least 12 months following commencement of works at Frasers West and Deepdell North Stage III. ORC gave permission after completion of 12 plus months monitoring and review of the data by a suitably qualified expert that monitoring at DG11 (Macraes Road) could cease. Monitoring may be amended or suspended at DG07 after at least 12 months with the approval of the ORC; and
- Daily record kept of water used for dust suppression.

Note: Real time monitoring of TSP at site DG15 is replaced by the new PM_{10} monitoring instrument described above.

In addition to the resource consent monitoring, OGNZL has a process of checking weather forecasts and advising key operational personnel if strong winds are forecast. This process is set out in the *Tailings Storage Facilities Dust Control Manual*, included as **Appendix B**.

To ensure that controls are implemented and are effective in minimising dust emissions, OGNZL monitors weather conditions, the condition of potential dust generating areas and undertakes depositional dust and total suspended particulate monitoring.

Table 8-1 outlines the current dust monitoring programme.

The locations of the depositional and particulate matter monitoring sites are shown on **Figure 8-1**.

Table 8-1: Existing Dust Monitoring Programme

Monitoring Activities	Frequency
Check weather forecasts for strong winds and send electronic alerts to key personnel.	Daily
Observe weather conditions, wind via observations of wind speed effects.	Daily and as conditions change.
Inspect haul road surfaces for dampness and general condition.	Daily and as conditions change
Inspect exposed surfaces for dampness and to ensure that surface exposure is minimised.	Daily and as conditions change.
Inspect tailings impoundment surfaces for dampness.	Daily and as conditions change.
Inspect tailings impoundment dust suppression systems.	Twice daily during extended periods of no deposition.
Monitor dust deposition rates in 16 gauges surrounding the mine site.	Monthly
Monitor real time fine particulate matter (PM_{10}) at site DG15 using a reference standard monitor and at site DG11 using a nephelometer.	Continuously
Monitor real time TSP near to DG07 (Woolshed TSP) using a nephelometer.	Continuously
Monitor meteorological conditions at Dust Sites 3 and 15.	Continuously

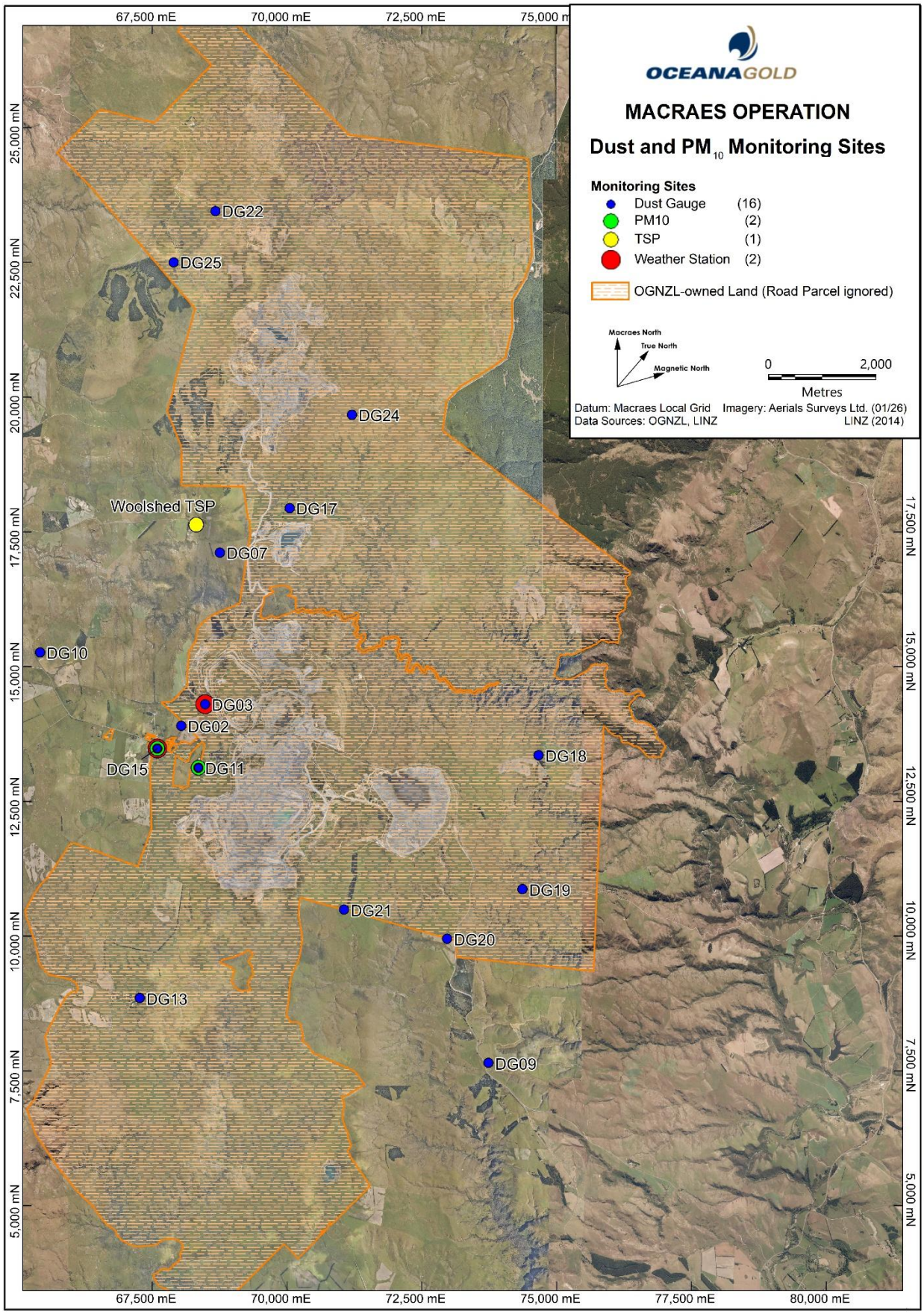


Figure 8-1: Aerial map of OGNZL air quality monitoring locations

8.1 Monitoring Equipment Specifications

Specifications of the equipment used to undertake the monitoring activities can be found in **Table 8-2** to **Table 8-6**.

Table 8-2: Monitoring Equipment at Site DG15

Monitor Type	Monitor Specifications
PM_{10} monitor (real time – reference grade instrument)	[place holder] Instrument must comply with: • Schedule 2 of the Resource Management (National Environmental Standards for Air Quality) Regulations 2004; or • AS/NZS 3580.9.17:2018 Methods for sampling and analysis of ambient air – Method 9.17: Demonstration of equivalence for ambient particulate matter monitoring methods.
Atmospheric monitoring site	Temperature sensor: Campbell Scientific 107 Anemometer: Vector A101M Wind Vane: Vector W200P Rain Gauge: TB3-0.2/P
Dustfall Gauge	Standard Dust Deposition Gauge. Dust gauges are analysed using the Horizontal Deposit Gauge Method.

Table 8-3: Monitoring Equipment at the location near to DG07 (Woolshed)

Monitor Type	Monitor Specifications
Nephelometer (real time total suspended particulate monitoring)	Thermo ADR-1500 Area Dust Monitor

Table 8-4: Monitoring Equipment at Site DG03

Monitor Type	Monitor Specifications
Atmospheric Monitoring Site	Temperature Sensor: Campbell Scientific 107 Temperature and RH Sensor: Vaisala HMP50Y Anemometer: Vector A101M Wind Vane: Vector W200P Rain Gauge: Ota Keiki Seisakusho 34-T Solar Radiation: Apogee SP110 Pyranometer
Dustfall Gauge	Standard Dust Deposition Gauge. Dust gauges are analysed using the Horizontal Deposit Gauge Method.

Table 8-5: Other Dust Monitoring Locations

Monitoring Type	Specifications
Dustfall Gauge	Standard Dust Deposition Gauge. Sixteen gauges are positioned in various locations around site (see Figure 8-1for locations). Dust gauges are analysed using the Horizontal Deposit Gauge Method.

Table 8-6: Monitoring Equipment at a location on OGNZL land near the residence at 1668 Macraes Road

Monitoring Type	Specifications
PM_{10} monitor (real time - nephelometer)	The instrument should be in general accordance with the instrumentation described in: • AS/NZS 3580.12.1:2015 (Methods for sampling and analysis of ambient air, Method 12.1: Determination of light scattering – Integrating nephelometer method).

8.2 Data Analysis and Reporting

8.2.1 Dustfall Gauge Data

Data from dustfall gauges is collected, analysed, and reported on a monthly basis by Environmental Standards Limited. Dustfall gauges are analysed using the Horizontal Deposit Gauge method. This method is detailed in the Draft International Standard ISO/DIS 4222.2 ("Air Quality Measurement of Atmospheric Dustfall – Horizontal Deposit Gauge Method" 1980).

Depositional dust results are included in the Quarterly Monitoring Reports supplied to the ORC.

8.2.2 Meteorological and Particulate Monitoring Data

Data analysis and reporting for the particulate monitoring and meteorological monitoring is undertaken on a quarterly basis. The Quarterly Monitoring Report is produced once all the data has been collected and analysed. Details of the methods for data analysis can be found in OGNZL's latest quarterly report for the Macraes site.

TSP results have historically been included in the Quarterly Monitoring Reports supplied to the ORC. This has been replaced with PM_{10} monitoring following the replacement of the TSP monitor at DG15.

8.3 Compliance Limits

8.3.1 Framework under MP4

Under the MP4 air discharge permit (AQA Appendix F), the following compliance and trigger framework applies. The pre- MP4 compliance limits set out below in Section 8.3.2 are retained for reference and describe the regime under the current consents until the MP4 air discharge permit takes effect.

Dust deposition monitoring

Insoluble dust deposition rates at monitoring sites DG02, DG07, DG11, DG15, DG20, DG21, DG22 and DG25 must not exceed **3 g/m²/30-days above background more than twice in any calendar year**. Background concentrations are calculated by averaging the insoluble dust deposition rates at background sites DG09, DG10 and DG24. Dust deposition monitoring is undertaken monthly in accordance with AS/NZS 3580.10.1:2016 (or its successor).

PM_{10} monitoring

Continuous real-time PM_{10} monitoring is to be undertaken at:

- DG15 (replacing the existing TSP monitoring); and
- Near the residence at 1668 Macraes Road on OGNZL land.

PM_{10} monitoring results are compared against the following 1-hour and 24-hour average trigger concentration values:

- **1-hour average** trigger concentration: **150 µg/m³**
- **24-hour average** trigger concentration: **40 µg/m³**

Where an exceedance of a trigger value:

- Coincides with winds from a south-easterly to north-westerly direction (between 135° and 315° relative to true north), no further action is required.
- For the nephelometer instrument, where an exceedance coincides with a relative humidity greater than 95% no further action is required.

For all other trigger exceedances, the cause must be investigated and, if required, additional dust control measures implemented.

TSP monitoring

Continuous real-time total suspended particulate (TSP) monitoring is undertaken at a location near to DG07 (Woolshed TSP – refer to Figure 8-1) in accordance with Condition 5 of Consent RM20.024.12 until expiry of that consent in 2027 after which time monitor can be decommissioned and reporting for it suspended.

The results of TSP monitoring at DG07 are compared against the following 1-hour and 24-hour average trigger concentration values:

- **1-hour average** trigger concentration: **250 µg/m³**
- **24-hour average** trigger concentration: **80 µg/m³**

Where an exceedance of a trigger value occurs:

- An alert message must be immediately sent to the operator; and
- A review of on-site dust sources must be undertaken and reported to ORC as detailed in Section 8.5.3.

8.3.2 Framework prior to MP4

Under resource consent RM10.351.52_V4 (Macraes Phase III, Frasers West Project, Frasers Co-Disposal and Continuity Consents) and 96785_V5, the following compliance limits apply:

- Insoluble dust deposition rates at sites DG07, DG11, DG20 and DG21 must not exceed 3 g/m²/30 days of insoluble dust above background more than twice in any calendar year;
- Insoluble dust deposition rates at sites DG02 and DG15 must not exceed 3 g/m²/30 days of insoluble dust above background;
- 24-hour average total suspended particulate at Site DG15 must not exceed 120 µg/m³;
- A trigger level of 250 µg/m³ (1-hour average) and 80 µg/m³ (24-hour average) applies to the total suspended particulate readings at Site DG11. Where a trigger level is exceeded a review of dust sources and dust control must occur – Note in 2023 the ORC gave permission for monitoring to cease at DG11 in accordance with the condition of consent;

- Background concentrations are calculated by averaging the deposition rates of insoluble dust at sites DG09, DG10, DG17 and DG24. If no result is available for one of these locations, the background concentration is calculated by averaging the remaining locations.

Under resource consent RM12.378.15 (Coronation), the following compliance limits apply:

- Insoluble dust deposition rates at sites DG07, DG20, DG21, DG22 and DG23 must not exceed 3 g/m²/30 days of insoluble dust above background more than twice in any calendar year;
- Insoluble dust deposition rates at sites DG02 and DG15 must not exceed 3 g/m²/30 days of insoluble dust above background;
- 24-hour average total suspended particulate at Site DG15 must not exceed 120 µg/m³ (this is superseded by the above PM_{10} monitoring trigger);
- Background concentrations will be calculated by averaging the insoluble dust deposition rates at sites DG09, DG10 and DG24. In the event that a result for one of these sites is unavailable, the background concentration will be calculated by averaging the remaining two sites.

Note - Development of the Coronation North Project resulted in DG23 needing to be decommissioned and a new site being established (DG25). This change is reflected in the updated consent RM16.138.19_V1, issued April 2017.

Under resource consent RM16.138.19_V1 (Coronation North), the following compliance limits apply:

- Insoluble dust deposition rates at sites DG07, DG20, DG21, DG22 and DG25 must not exceed 3 g/m²/30 days of insoluble dust above background more than twice in any calendar year;
- Insoluble dust deposition rates at sites DG02 and DG15 must not exceed 3 g/m²/30 days of insoluble dust above background;
- Twenty-four-hour average total suspended particulate at site DG15 must not exceed 120 µg/m³ (this is superseded *by the above PM_{10} monitoring trigger);*
- Background concentrations will be calculated by averaging the insoluble dust deposition rates at sites DG09, DG10 and DG24. In the event that a result for one of these sites is unavailable, the background concentration will be calculated by averaging the remaining two sites.

Under resource consent RM20.024.12 (Deepdell North Stage III), the following compliance limits apply:

- Insoluble dust deposition rates at sites DG07 and DG17 must not exceed 3 g/m²/30 days of insoluble dust above background more than twice in any calendar year.
- Twenty-four-hour average total suspended particulate at site DG15 must not exceed 120 µg/m³ (this is superseded by the PM_{10} monitoring trigger in Section 8.3.1);
- A trigger level of 250 µg/m³ (1-hour average) and 80 µg/m³ (24-hour average) applies to the total suspended particulate readings at Site DG07. Where a trigger level is exceeded a review of dust sources and dust control must occur *(This is superseded by the PM_{10} monitoring triggers in Section 8.3.1);*
- Background concentrations will be calculated by averaging the insoluble dust deposition rates at sites DG09, DG10 and DG24. In the event that a result for one of these sites is unavailable, the background concentration will be calculated by averaging the remaining two sites.

8.4 Processing Plant Stack Emission Testing

Under MP4, stack emission testing of the POX plant stack is to be undertaken once every three years by an independent stack testing agency to determine the concentration and mass emission rate for the following contaminant emissions:

- Sulphur dioxide (SO_2)
- Mercury (gaseous and particulate phase)
- Trace metals (including, as a minimum, arsenic, chromium, lead and nickel).

An emission limit is specified for nickel of 0.0084 kg/h.

Testing is to be carried out by a suitably qualified and experienced person. Any laboratory analysis of the samples is to be carried out by a company with International Accreditation New Zealand (IANZ) accreditation. The method of sampling and analysis for SO_2 shall be:

- USEPA Method 8: Determination of Sulphuric Acid Mist and Sulphur Dioxide Emissions from Stationary Sources.

The method of sampling and analysis for mercury and trace metals shall be:

- USEPA Method 29: Determination of metal emissions from stationary sources.
- Alternative equivalent testing methods may be used, provided that such methodologies have been agreed in writing with the ORC prior to being used.

Three samples for each contaminant group are to be collected. The volumetric gas flow rate, moisture content and temperature are to be determined and recorded.

The first test is to be undertaken within 12 months of commencement of the MP4 consent and at intervals not exceeding three years thereafter.

The results of the emissions tests, including a comparison against the emission limit for nickel, and a description of the testing methods are to be provided to the ORC within 40 working days of the tests being completed.

Monitoring of the other Processing Plant discharge stacks is not required, reflecting their small scale and the very low predicted effects of those discharges.

8.5 Exceedance of a Compliance Limit

If a trigger level is exceeded, OGNZL is to undertake an immediate review to determine the likely cause of the exceedance:

- Depositional dust at DG15, DG11 or DG07;
- PM_{10} at either of the two monitoring sites;
- TSP at a location near DG07 (Woolshed TSP – refer to Figure 8-1);
- Emission rate limits applying to the POX plant following stack emission testing.

8.5.1 Outcome of Review

If it is found that activities of OGNZL were the cause of the exceedance, then dust mitigation measures shall be reviewed by an independent consultant and a report prepared summarising the cause of the exceedance and recommending measures to improve dust mitigation, so the exceedance does not occur again. The report will be forwarded to the ORC within two months of the exceedance being identified.

8.5.2 Notification to ORC

The ORC will be notified within a 24-hour period of the exceedance becoming apparent and depending on whether the source is confirmed as likely having been from within the Macraes Site, a report detailing the findings of the investigation will be forwarded to the ORC within one month, or follow-up comment will be made in the Quarterly Monitoring Report (in the event of clear indication that the exceedance is not a result of OGNZL operational activities).

Under MP4, in the event of an **exceedance of the dust deposition limit**, ORC must be notified within 24 hours of receiving the laboratory result. An investigation must be undertaken and reported to Council within 5 days of the original notification and involves identifying the site, the result, the prevailing meteorological conditions and any likely cause. Where mining activities are identified as the likely cause, dust mitigation

measures must be reviewed by an independent consultant engaged in consultation with ORC, with the report provided to ORC within two months.

8.5.3 Monitoring of TSP at DG07

Where a **total suspended particulate trigger level is exceeded at the monitoring site located near to DG07 (Woolshed TSP)** , a review of dust sources and dust control must occur as required by Consent RM20.24.12. If the exceedance is likely to have been caused or contributed by onsite activities, then dust control management shall be revised and/or additional dust control measures implemented. Written notice of an exceedance that is caused or contributed to by site activities must be provided to the ORC within 10 working days of the exceedance.

8.6 Annual Review Report

An annual report of the ambient air monitoring results is to be forwarded to the ORC by 30 April each year. The annual report reviews and assesses the monitoring results for the previous calendar year and is to be undertaken by a suitably qualified independent reviewer, engaged by OGNZL. The relevant qualifications and experience of the reviewer can be found in Appendix B of each report.

The annual report shall include the following:

- The name, qualifications and experience of the reviewer;
- The methods used and the investigations undertaken for the review;
- Interpretation of the monitoring data reviewed;
- An assessment of the quality of the monitoring data;
- An assessment of the monitoring regime;
- A description and evaluation of each of the dust mitigation measures used;
- A record of complaints received and a summary of the responses and actions taken;
- Recommendations on whether:
    - The monitoring of dust is adequate or should be changed, and if changed the changes that are recommended;
    - The dust mitigation measures used by the consent holder are adequate, or should be changed, and the changes that are recommended; and
    - Any changes that should be made to the conditions of this consent.
- Any other matters that the reviewer considers should be drawn to the attention of OGNZL or the ORC.

9 COMPLAINTS

Complaints may be raised by one or more of the regulatory authorities, a member of the public or an OGNZL employee or contractor. It is the responsibility of the Environment and Social Performance Manager (or delegated to External Affairs and Social Performance Superintendent or Environmental Superintendent) to respond to and follow up all complaints regarding dust. The Environment and Social Performance Manager is responsible for ensuring suitably qualified personnel are available to respond to complaints at all times.

Actions to be taken as soon as possible by the Environment and Social Performance Manager

- All complaints are to be logged in the InForm Stakeholder database.
- Note the time, date, identity and contact details of the complainant. Wind direction, strength and weather conditions are to be recorded. Note if the complaint has been referred from a Consent Authority. The PM_{10} concentrations measured at DG15 at the time of the alleged discharge are also to be recorded, consistent with the proposed MP4 air discharge permit conditions.
- Ask the complainant to describe the dust emission: whether it is constant or intermittent, how long it has been going on for, is it worse at any time of day, does it come from an identifiable source.
- As soon as possible after receipt of a complaint undertake a site inspection. Note all dust-producing activities taking place, which staff member or contractor is responsible for the site and the dust mitigation methods that are being used. Order any remedial action necessary. If the complaint was related to an event in the recent past, note any dust-producing activities that were underway at that time, if possible.
- As soon as practical (preferably within two hours) visit the area from where the complaint originated to ascertain if dust is still a problem.
- If it becomes apparent that there may be a source of dust other than activities at the Macraes Operation causing the dust nuisance it is important to verify this. Photograph and document the source and emissions.
- If the complaint is received more than 12 hours after the event, conduct an investigation including collecting relevant weather data, identifying operational activities at the time of the incident, collecting camera footage and interviewing operational staff. Investigations should endeavour to identify root cause and contributing factors.
- As soon as possible after the investigations have been completed contact the complainant to explain what has been found and remedial actions taken.
- If necessary, update any relevant procedures to prevent any recurrence of problems.
- Complete complaint form and file on complaint register.

Follow-up Actions

- Advise the ORC as soon as practical that a complaint has been received and what the findings of the investigation were, and any remedial actions taken.

10 RESPONSIBILITIES

OGNZL as the holder of consents for the Macraes Operation site has the ultimate responsibility to ensure that all statutory requirements and conditions of consent are complied with, and mining activities are carried out in accordance with the AQMP. Complaint and emergency contact details are provided in Table 10-1.

Specifically, the following roles share operational responsibility for ensuring mining activities are carried out in accordance with the AQMP:

- Asset President – Macraes
- Open Pit Mine Operations Manager
- Process Manager
- Underground Operations Manager

These roles will have the following responsibilities:

- Overall responsibility at the site for ensuring that the dust control and mitigation measures and procedures outlined in Section 7 of the AQMP are implemented effectively.
- Overall responsibility to ensure that dust emissions are avoided and mitigated as far as is practicable.

The Environment and Social Performance Manager will have the following associated responsibilities:

- Responsibility to ensure that the dust monitoring programme is carried out as required.
- Responsibility to ensure that complaints are received and investigated as outlined in Section 9 of the AQMP.
- Responsibility to ensure the AQMP is current and reviewed at least annually.

All contractors and staff working on site are to ensure that their activities comply with the requirements of the AQMP.

Table 10-1: Complaint and emergency contact details.

Name **Position**	Mobile	Email
[redacted] Asset President – Macraes Operation	[redacted]	[redacted]
[redacted] Open Pit Mine Operations Manager	[redacted]	[redacted]
[redacted] Process Manager	[redacted]	[redacted]
[redacted] Environment & Social Performance Manager	[redacted]	[redacted]

11 CONSULTATION, REPORTING AND REVIEW

11.1 Neighbours

OGNZL will consult with the Macraes Community Incorporated (MCI) regularly, as part of the bi-monthly meeting process, to inform them of any issues relating to dust control at the Macraes Operation that may be of interest to the community and to obtain feedback from the community.

OGNZL will advise the Macraes Community through MCI of the contact phone numbers to be used to advise OGNZL of a complaint.

The Macraes Operation has a 'Concerns, Complaints and Grievance Mechanism' to use if the community has any issues. The relevant contact phone number or email address for the community to contact, and the process to follow, are laid out in the Macraes Operation Concerns, Complaints and Grievance Mechanism Standard Operating Procedure.

11.2 OGNZL to Otago Regional Council

OGNZL will maintain a regular and formal reporting regime with the ORC to inform them of any issues regarding dust control at the site that may be of interest to them and to obtain feedback on compliance and performance.

OGNZL will provide the ORC with contact numbers to be used to advise OGNZL of a dust complaint. The contact numbers and email addresses to be used for registering a complaint are included in Table 10-1.

OGNZL will inform the ORC of the following:

- Any complaints received regarding dust as soon as practical after receipt of the complaint;
- Any non-compliances with monitoring as outlined in Section 8. Any non-compliance will be reported to the ORC through the nominated compliance contact or via the compliance email address (compliance@orc.govt.nz); and
- Provide ORC with a copy of the AQMP if any significant revisions of the AQMP are made during the year.

11.3 Otago Regional Council to OGNZL

OGNZL requests that the ORC advises them of any complaints they receive regarding dust from the Macraes Operation immediately after the complaint has been lodged.

11.4 AQMP Review Procedure

The AQMP shall be reviewed as required taking into account:

- The outcome of any reviews completed as the result of any non-compliant results;
- The outcome of the annual review of all dust monitoring data; and
- Whether management practices are resulting in compliance with the conditions of the relevant air discharge consents.

11.4.1 Recertification process

OGNZL may lodge an amended monitoring plan, management plan or other document for recertification at any time. Minor/administrative changes may be implemented without recertification where written notice is

provided to ORC no less than 5 working days prior to publication of the amended document in accordance with Condition xx.

Minor/administrative changes are limited to corrections of errors, updates to contact details, updates to reflect changes in organisational structure, formatting improvements, or other changes that:

- Do not alter the objectives, performance standards, mitigation methods, monitoring methodology, or reporting requirements of the certified document; and
- Do not materially affect the scale, location, or nature of activities authorised by these consents.

12 DEFINITIONS

Term	Definition
AQA	Air Quality Assessment
AQMP	Air Quality Management Plan
CIL	Carbon-in-Leach
FTAA	Fast-track Approvals Act 2024
FTSF	Frasers in-Pit Tailings Facility
GPUG	Golden Point Underground Mine
MCI	Macraes Community Incorporated
MP4	Macraes Phase Four Project
MTI	Mixed Tailings Impoundment
OGNZL	OceanaGold (New Zealand) Limited
ORC	Otago Regional Council
PM_{10}	Particulate matter less than ten microns in aerodynamic diameter
POX	Pressure Oxidation
ROM	Run of Mine
SAG	Semi-Autogenous Grinding
SQEP	Suitably Qualified and Experienced Practitioner
TSF	Tailings Storage Facility
TTTSF	Top Tipperary Tailings Storage Facility

APPENDIX A: RESOURCE CONSENTS

- 96785_V5
- RM12.378.15
- RM16.138.19_V1
- RM20.024.12
- RM20.130.01_V1
- 2006.689
- RM10.351.52_V4
-
- Placeholder for FTAA MP4 air discharge permit when granted

APPENDIX B: TAILINGS STORAGE FACILITIES DUST CONTROL MANUAL

Tailings Storage Facilities

Dust Control Manual

July 2026

Table of Contents

1 INTRODUCTION 1

2 RESPONSIBILITIES 1

3 ENVIRONMENTAL CONDITIONS 1

4 METHODS OF DUST CONTROL 2

4.1 TAILINGS DISCHARGE 2

4.2 ROCK MATTRESS COVER 2

4.3 DUST SUPPRESSION SYSTEM 2

5 OPERATION 2

6 TRIAL DUST SUPPRESSION TECHNIQUES 3

6.1 VITAL BON-MATT STONEWALL 3

6.2 VITAL STRIKE 3

6.3 RYECORN GRASS SEED 3

7 MAINTENANCE 4

8 DUST SUPPRESSION DAILY DECISION TREE 5

1 INTRODUCTION

The Macraes Operation currently has four tailings storage facilities (TSFs). Two of these, Southern Pit Tailings Option 11A (SP11A) and Mixed Tailings Impoundment (MTI), are currently in a resting state with grass seed laid for dust suppression. All tailings discharge infrastructure at the MTI and SP11A has been disestablished. Tailings are currently being deposited into Frasers Tailings Storage Facility (FTSF - Stages 1 and 2) with occasional discharge to Top Tipperary TSF (TTTSF), which had been the primary active tailings storage facility since October 2013 and is now progressing toward closure. Under MP4, the FTSF Stage 3 is to be constructed to accommodate an additional 153 million tonnes of tailings, and tailings are to be hydraulically mined and relocated from the MTI, Southern Pit Option 10 (SP10) and SP11 to the FTSF. The dust control methods in this manual apply to all active and inactive TSF surfaces, including dust generated during the mining and relocation of tailings.

This manual details dust control methods used to control and minimise the transmission of dust particles around and away from the TSFs.

The design of all four TSFs has been carried out by Engineering Geology Ltd (EGL) and a description of the embankment design is contained in the design report for each TSF.

Details of the operation, maintenance and surveillance of the tailings storage facilities can be found in the respective Operation, Maintenance and Surveillance Manuals.

2 RESPONSIBILITIES

OGNZL, as owner of the TSFs, is ultimately responsible for the control of dust.

Supervision and monitoring of the quality of construction is undertaken by OGNZL staff as is regular monitoring, maintenance and surveillance as detailed in the respective Manuals.

The installation and maintenance of dust control systems is the responsibility of the processing department.

The operation of dust control systems and the tailings distribution system is the responsibility of the Process Supervisor. A Daily Dust Decision Tree (**Figure B8-1**) is available to assist with operation of dust control systems.

Whilst the above listed departments are responsible for the control of dust, it is the responsibility of all staff to report when dust control is required. The TSFs are inspected periodically throughout the day, however conditions may change between inspections. Any reports of excess dust should be reported to the Environmental, Projects or Processing departments.

3 ENVIRONMENTAL CONDITIONS

Strong winds during dry weather are a key environmental condition that can result in dust emissions from exposed and dry tailings. Winds are typically strongest during spring, but can also occur at other times of the year. Wind gusts in excess of 28 m/s (100 km/hr) are not uncommon.

Particles begin to be mobilised at wind speeds of 5 m/s (18 km/h), but especially above 7 m/s (25 km/h). This means that lower winds also influence the tailings surface and can mobilise dust where the surface

has dried. As the wind speed increases, the mobilised particles dislodge other particles and this can result in significant dust generation.

The finer the particles are, the more prone to movement they are. At Macraes, tailings discharge occurs sub-aerially from the embankment. This results in the coarser material being located closer to the embankment and finer material further from the embankment.

When conditions have been dry and windy for extended periods of time, the surface of the embankments becomes dry. This can cause the particles to become more easily entrained by the wind. When moisture is present on the surface, this binds to the tailings and increases the cohesion between particles making them harder to move. While wind speed cannot be controlled, the moisture of the tailings surface can and so this can determine the dust suppression technique used to control dust as seen in the below section.

4 METHODS OF DUST CONTROL

4.1 Tailings Discharge

During and immediately following periods of active tailings discharge the tailings beach surface remains sufficiently damp that the potential for windborne dust generation is very low.

Tailings deposition is via spigots at maximum 50 m intervals. Spigot opening is sequentially moved around the impoundment to decrease the chance that the tailings surface could dry out and become prone to dust creation. Tailings deposition is manually redirected around the impoundment through the use of knife gate valves to direct the tailings to a general area while spigots are used to control localised tailings deposition. This method of deposition also helps to keep the tailings surface level which limits localised drying conditions. Dust control requirements will therefore be minimal as tailings will be continuously discharged to this facility and the beach is unlikely to dry sufficiently to generate dust.

4.2 Rock Mattress Cover

Experience has shown that the area of the tailings surface with the most potential for dust generation is the tailings beach adjacent to the embankment crest.

As construction of tailings storage facilities is completed, capping of the surface commences. This involves placing a rock mattress cover over the tailings surface.

The rock mattress cover typically extends over nearly the entire impoundment except for the area at the rear of the facility surrounding the decant pond. For details of the rock mattress and capping refer to the design documents and closure plan for each impoundment.

4.3 Dust Suppression System

A dust suppression system is to be established on areas of tailings facilities that have not received capping material. This system needs to be operational from August to April each year, however, it is prudent to continue to have this system in place at all times.

The dust suppression system generally consists of an outer ring main feeding sprinklers laid out over the tailings surface, however various combinations of open ended pipe discharge can be used as necessary to ensure good coverage and wetting.

A dust suppression system should be installed as soon as practicable, once tailings deposition at a facility ceases and prior to capping.

Preservation of the crust on the dam surface is to be maximised by limiting traffic on the tailings surface wherever possible.

5 OPERATION

The tailings distribution system is operated by the Processing Superintendent and follows tailings deposition methodology recommended by the design engineers, EGL.

A site-specific model that predicts hourly wind speed, direction and rainfall (provided by the MetService) is used to assist in the prediction of wind events (note – if heavy rain or rainfall warnings are indicated for Fiordland and the West Coast this will often indicate strong winds on the East Coast). It is the responsibility of the Processing Superintendent to initiate action in accordance with the Model predictions.

The tailings or dust suppression system is to be used 12 hours prior to any anticipated high wind event (defined as an event of greater than 40 km/h winds for greater than 4 hours from a west or northwest direction).

Should wind speeds increase without warning then the system will be activated as required by process operations personnel and the Processing Superintendent will be notified.

6 TRIAL DUST SUPPRESSION TECHNIQUES

6.1 Vital Bon-Matt Stonewall

Stonewall is a co-polymer that is applied to the surface of the tailings. The product is diluted in water and then applied through a spray by any method. This could be from a water cart or a knapsack sprayer. The product creates a hard surface that is similar to that which would be seen if glue was applied to the surface. The tailings surface then becomes encapsulated underneath the Stonewall surface. This limits the dust generation by removing the potential for wind to erode the surface. Trials of this dust suppression technique occurred in 2015.

6.2 Vital Strike

Strike is a co-polymer based fertiliser to promote the growth of seed below its surface and increase soil stability. After seed has been broadcast, Strike is applied in much the same way as Stonewall. However, fertiliser is incorporated into the product which aids in the germination and growth of the seed. Trials of this dust suppression technique occurred in 2015.

6.3 Ryecorn Grass Seed

Previous trials involving broadcasting grass seed directly onto the tailings surface have been promising using a seed mix of ryecorn grass seed, organic matter and fertiliser. Further trials are planned in 2026.

7 MAINTENANCE

Inspections, monitoring and maintenance activities of dust suppression infrastructure are the responsibility of process operational personnel.

It is also the responsibility of all staff to report breakages or leaks in the pipes to their supervisor or the environmental team. Reports also need to be registered as an environmental incident through INX InControl.

8 DAILY DUST SUPPRESSION DECISION TREE

The Daily Dust Suppression Decision Tree is provided in **Figure B8-1**.

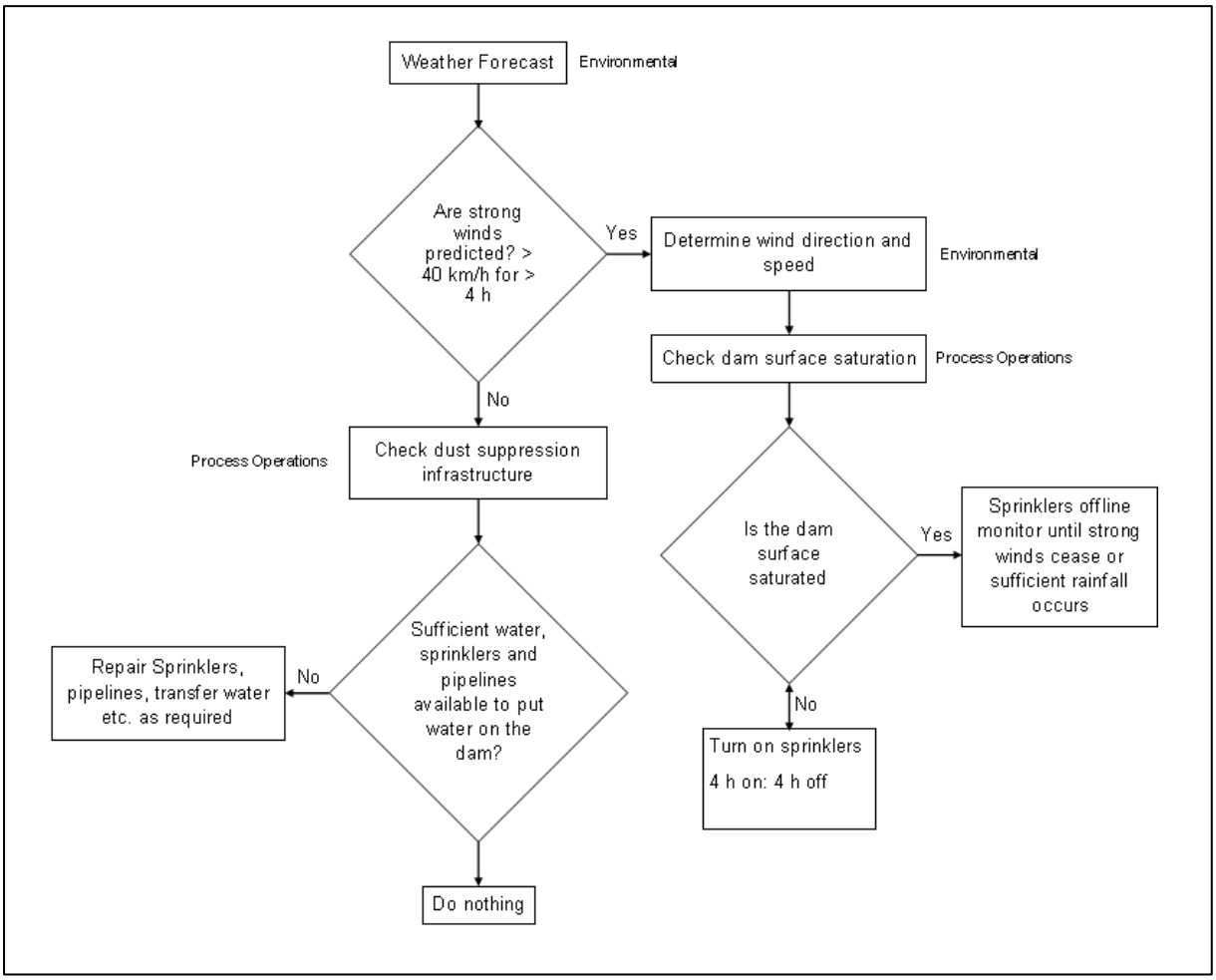


Figure B8-1: Daily Dust Suppression Decision Tree**.**

Appendix D CALPUFF configuration

Appendix D CALPUFF model configuration

D1 Overview

Dispersion modelling was undertaken using the CALPUFF model, as implemented in CALPUFF View Version 11.0.0 (Lakes Environmental Software). The model was run for all sources at the Oceana Gold Macraes site for a two-year period from 1 January 2022 to 31 December 2023 at an hourly time step, using the gridded meteorological fields generated by CALMET (refer to Appendix A).

Five chemical species were modelled and emitted: SO_2, SO_4, gaseous elemental mercury (HG0_GAS), particulate mercury (HGP_PARTICLE) and PM_{10} (used as a placeholder for scaling results for trace metals). Trace metal impacts from the POX plant were scaled from the results for PM_{10}. Nine point-sources were modelled. Key technical options included partial plume path terrain adjustment (MCTADJ = 3), the PRIME building downwash method (MBDW = 2), internally calculated dispersion coefficients (MDISP = 2) with probability density function dispersion under convective conditions (MPDF = 1), and modelling of both dry and wet deposition. Chemical transformation was not modelled (MCHEM = 0).

The parameter settings for each CALPUFF input group are summarised in Table Appendix D.1 to Table Appendix D.11. The stack discharge parameters and emission rates for each point source are summarised in Table Appendix D.12 and Table Appendix D.13, building downwash inputs are described in Section B4, and the discrete receptor locations are shown in Section B5.

D2 CALPUFF parameter settings

Table Appendix D.1: CALPUFF 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	16
NPTDAT	Number of PTEMARB.DAT input files	0
NARDAT	Number of BAEMARB.DAT input files	0
NVOLDAT	Number of VOLEMARB.DAT input files	0
NFLDAT	Number of FLEMARB.DAT input files	0
NRDDAT	Number of RDEMARB.DAT input files	0
NLNDAT	Number of LNEMARB.DAT input files	0
METDAT	CALMET gridded meteorological data files (CALMET.DAT)	16 sequential CALMET.DAT files spanning 1 January 2022 to 31 December 2023(1)

[1] The CALMET output was provided as 16 sequential files, each covering approximately 46 days (e.g. CALMET_2022-01-01-00-0000-2022-02-16-00-0000.DAT through to CALMET_2023-11-16-00-0000-2023-12-31-23-0000.DAT).

Table Appendix D.2: CALPUFF 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	2022
IBMO	Starting month	1
IBDY	Starting day	1
IBHR	Starting hour	0
IBMIN	Starting minute	0
IBSEC	Starting second	0
IEYR	Ending year	2023
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 modelling time-step (seconds)	3600
NSPEC	Number of chemical species modelled	5
NSE	Number of chemical species to be emitted	5
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

Table Appendix D.3: CALPUFF 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 modelled as elongated slugs? (0 = no, 1 = yes)	0
MTRANS	Model transitional plume rise? (0 = no, 1 = yes)	1
MTIP	Apply stack tip downwash to point sources? (0 = no, 1 = yes)	1
MRISE	Plume rise module for point sources (1 = Briggs, 2 = numerical)	1

Parameter	Description	Value
MTIP_FL	Apply stack tip downwash to flare sources? (0 = no, 1 = yes)	0
MRISE_FL	Plume rise module for flare sources (1 = Briggs, 2 = numerical)	2
MBDW	Building downwash method (1 = ISC, 2 = PRIME)	2
MSHEAR	Treat vertical wind shear? (0 = no, 1 = yes)	0
MSPLIT	Puff splitting allowed? (0 = no, 1 = yes)	0
MCHEM	Chemical transformation method (0 = not modelled, 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)	1
MDRY	Model dry deposition? (0 = no, 1 = yes)	1
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 characterisation method (only if MDISP = 1 or 5)	3
MDISP2	Missing dispersion coefficients method (only if MDISP = 1 or 5)	3
MTAULY	Sigma-y Lagrangian timescale method	0
MTAUADV	Advective-decay timescale for turbulence (seconds)	0
MCTURB	Turbulence method (1 = CALPUFF, 2 = AERMOD)	1
MROUGH	PG sigma-y and sigma-z surface roughness adjustment? (0 = no, 1 = yes)	0
MPARTL	Model partial plume penetration for point sources? (0 = no, 1 = yes)	1
MPARTLBA	Model partial plume penetration for buoyant area sources? (0 = no, 1 = yes)	0
MTINV	Strength of temperature inversion provided in PROFILE.DAT? (0 = no - compute from default gradients, 1 = yes)	0
MPDF	PDF used for dispersion under convective conditions? (0 = no, 1 = yes)	1
MSGTIBL	Sub-grid TIBL module for shoreline? (0 = no, 1 = yes)	0
MBCON	Boundary conditions modelled? (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 = US EPA LRT checks)	0

Table Appendix D.4: CALPUFF Input Group 3 - Species list

Parameter	Description	Value
CSPEC	Species included in model run	SO2
CSPEC	Species included in model run	SO4
CSPEC	Species included in model run	HG0_GAS
CSPEC	Species included in model run	HGP_PARTICLE
CSPEC	Species included in model run	PM10

Table Appendix D.5: CALPUFF 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
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	152
NY	Meteorological grid - number of Y grid cells	112
NZ	Meteorological grid - number of vertical layers	10
DGRIDKM	Meteorological grid spacing (km)	0.125
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)	447.5000
YORIGKM	Meteorological grid - Y coordinate for SW corner (km)	4969.2000
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	152
JECOMP	Computational grid - Y index of upper right corner	112
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

Table Appendix D.6: CALPUFF 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)	1
IWET	Output wet deposition fluxes to WFLX.DAT? (0 = no, 1 = yes)	1
IT2D	Output 2D temperature data? (0 = no, 1 = yes)	0
IRHO	Output 2D density data? (0 = no, 1 = yes)	0
IVIS	Output relative humidity data? (0 = no, 1 = yes)	0
LCOMPRS	Use data compression in output file (T = true, F = false)	T
IQAPLOT	Create QA output files suitable for plotting? (0 = no, 1 = yes)	1
IPFTRAK	Output puff tracking data? (0 = no, 1 = yes use timestep, 2 = yes use sampling step)	0
IMFLX	Output mass flux across specific boundaries? (0 = no, 1 = yes)	0
IMBAL	Output mass balance for each species? (0 = no, 1 = yes)	0
INRISE	Output plume rise data? (0 = no, 1 = yes)	0
ICPRT	Print concentrations? (0 = no, 1 = yes)	0
IDPRT	Print dry deposition fluxes? (0 = no, 1 = yes)	0
IWPRT	Print wet deposition fluxes? (0 = no, 1 = yes)	0
ICFRQ	Concentration print interval (timesteps)	1
IDFRQ	Dry deposition flux print interval (timesteps)	1
IWFRQ	Wet deposition flux print interval (timesteps)	1
IPRTU	Units for line printer output (e.g. 3 = ug/m3 - ug/m2/s, 5 = odour 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

Table Appendix D.7: CALPUFF 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 metres	1.0
ZHILL2M	Vertical dimension conversion factor to metres	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

Table Appendix D.8: CALPUFF 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

Table Appendix D.9: CALPUFF 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 (all 12 months)
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 (all 12 months)
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 (all 12 months)
RH_ISRP	Minimum relative humidity for ISORROPIA	50.0
SO4_ISRP	Minimum SO4 for ISORROPIA	0.4
BCKPMF	SOA background fine particulate (ug/m**3)	1.00 (all 12 months)

Parameter	Description	Value
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 (all 12 months)
NDECAY	Half-life decay blocks	0

Table Appendix D.10: CALPUFF Input Group 12 - Miscellaneous 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 modelling domain	20
Z0IN	Roughness length for modelling domain (m)	0.25
XLAIIN	Leaf area index for modelling domain	3.0
ELEVIN	Elevation above sea level (m)	0.0
XLATIN	Meteorological station latitude (deg)	-999.0
XLONIN	Meteorological station longitude (deg)	-999.0
ANEMHT	Anemometer height (m)	10.0
ISIGMAV	Lateral turbulence format (0 = read sigma-theta, 1 = read sigma-v)	1
IMIXCTDM	Mixing heights read option (0 = predicted, 1 = observed)	0
XMXLEN	Slug length (met grid units)	1
XSAMLEN	Maximum travel distance of a puff/slug (met grid units)	1
MXNEW	Maximum number of slugs/puffs released from one source during one time step	99

Parameter	Description	Value
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 problems in calculating virtual time or distance (m)	5000000
SVMIN	Minimum turbulence velocities sigma-v (m/s)	0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.37, 0.37, 0.37, 0.37, 0.37, 0.37
SWMIN	Minimum turbulence velocities sigma-w (m/s)	0.2, 0.12, 0.08, 0.06, 0.03, 0.016, 0.2, 0.12, 0.08, 0.06, 0.03, 0.016
CDIV	Divergence criterion for dw/dz across puff (1/s)	0, 0
NLUTIBL	TIBL module search radius (met grid cells)	4
WSCALM	Minimum wind speed allowed for non-calm conditions (m/s)	0.5
XMAXZI	Maximum mixing height (m)	3000
XMINZI	Minimum mixing height (m)	50
TKCAT	Emissions scale-factor temperature categories (K)	265, 270, 275, 280, 285, 290, 295, 300, 305, 310, 315
PLX0	Wind speed profile exponent for stability classes 1 to 6	0.07, 0.07, 0.1, 0.15, 0.35, 0.55
PTG0	Potential temperature gradient for stable classes E and F (deg K/m)	0.02, 0.035
PPC	Plume path coefficient for stability classes 1 to 6	0.5, 0.5, 0.5, 0.5, 0.35, 0.35
SL2PF	Slug-to-puff transition criterion factor (sigma-y/slug length)	10
FCLIP	Hard-clipping factor for slugs (0.0 = no extrapolation)	0
NSPLIT	Number of puffs created from vertical splitting	3
IRESPLIT	Hour for puff re-split	0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0
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

Parameter	Description	Value
EPSSLUG	Fractional convergence criterion for numerical SLUG sampling integration	0.0001
EPSAREA	Fractional convergence criterion for numerical AREA source integration	1E-006
DSRISE	Trajectory step-length for numerical rise integration (m)	1.0
HTMINBC	Minimum boundary condition puff height (m)	500
RSAMPBC	Receptor search radius for boundary condition puffs (km)	10
MDEPBC	Near-surface depletion adjustment to concentration (0 = no, 1 = yes)	1

Table Appendix D.11: CALPUFF Input Groups 13 to 20 - Source and receptor summary

Parameter	Description	Value
NPT1	Group 13 - Number of point sources	9
IPTU	Group 13 - Units used for point source emissions (e.g. 1 = g/s)	2
NSPT1	Group 13 - Number of source-species combinations with variable emission scaling factors	0
NPT2	Group 13 - Number of point sources in PTEMARB.DAT file(s)	0
NAR1	Group 14 - Number of polygon area sources	0
IARU	Group 14 - Units used for area source emissions (e.g. 1 = g/m**2/s)	1
NSAR1	Group 14 - Number of source-species combinations with variable emission scaling factors	0
NAR2	Group 14 - Number of buoyant polygon area sources in BAEMARB.DAT file(s)	0
NLN2	Group 15 - Number of buoyant line sources in LNEMARB.DAT file	0
NLINES	Group 15 - Number of buoyant line sources	0
ILNU	Group 15 - Units used for line source emissions (e.g. 1 = g/s)	1
NSLN1	Group 15 - Number of source-species combinations with variable emission scaling factors	0
NLRISE	Group 15 - Number of distances at which transitional rise is computed	6
NVL1	Group 16 - Number of volume sources	0
IVLU	Group 16 - Units used for volume source emissions (e.g. 1 = g/s)	1
NSVL1	Group 16 - Number of source-species combinations with variable emission scaling factors	0
NVL2	Group 16 - Number of volume sources in VOLEMARB.DAT file(s)	0

Parameter	Description	Value
NFL2	Group 17 - Number of flare sources defined in FLEMARB.DAT file(s)	0
NRD1	Group 18 - Number of road-link sources	0
NRD2	Group 18 - Number of road-links in RDEMARB.DAT file	0
NSFRDS	Group 18 - Number of road-link and species combinations with variable emission-rate scale-factors	0
NSFTAB	Group 19 - Number of emission scale-factor tables	0
NREC	Group 20 - Number of discrete receptors (non-gridded receptors)	2087
NRGRP	Group 20 - Number of receptor group names	0

D3 Point source parameters

The discharge parameters for the nine point sources are summarised in Table Appendix D.12, and the corresponding emission rates for each modelled species are summarised in Table Appendix D.13. Emission rates were specified in kg/hr (IPTU = 2). Source locations are consistent with the BPIP-PRIME inputs described in Section B4.

Table Appendix D.12: Point source discharge parameters

Source ID	Release height (m)	Stack diameter (m)	Exit velocity (m/s)	Exit temperature (K)	Momentum flux factor	UTM East (m)	UTM North (m)
POX	23.0	0.78	3.6	362.15	1	455274.85	4977041.40
BAR_F	11.5	0.295	36	323.15	0	455318.43	4976941.66
EWIN_1	12.87	0.37	12	298.15	0	455327.85	4976942.85
EWIN_2	12.87	0.37	9.5	289.15	0	455326.14	4976941.27
EWIN_3	13.87	0.37	19	294.15	0	455330.58	4976940.65
C_KILN_1	16.3	0.5	13	298.15	1	455332.60	4976955.21
C_KILN_2	18.5	0.5	13	290.15	1	455335.27	4976951.27
C_KILN_3	18.5	0.5	4.7	523.15	1	455338.11	4976948.24
RETORT	14.9	0.16	1.7	295.15	0	455322.92	4976943.25

Table Appendix D.13: Point source emission rates (kg/hr)

Source ID	SO2	SO4	HG0_GAS	HGP_PARTICLE	PM10
POX	0.07484	0.02772	8.273E-05	4.9986E-07	1*
BAR_F	-	-	9.36E-05	9.36E-06	-
EWIN_1	-	-	2.02E-04	9.504E-07	-
EWIN_2	-	-	5.76E-05	7.56E-07	-
EWIN_3	-	-	1.30E-04	4.5144E-06	-
C_KILN_1	-	-	2.981E-04	3.24E-06	-
C_KILN_2	-	-	1.505E-05	2.8044E-06	-
C_KILN_3	-	-	5.40E-05	3.492E-07	-
RETORT	-	-	1.129E-05	4.2624E-07	-

[1] A dash indicates the species is not emitted from that source. HG0_GAS = gaseous elemental mercury; HGP_PARTICLE = particulate mercury.

* PM_{10} was modelled at a unit emission rate of 1 kg/hr and used to calculate trace metal concentrations.

D4 Building downwash

Building downwash effects were modelled using the PRIME algorithm (MBDW = 2), with projected building dimensions derived using the Building Profile Input Program (BPIP-PRIME). Four buildings adjacent to the process plant stacks were included, as summarised in Table Appendix D.14. The nine point source stacks included in the BPIP analysis are listed in Table Appendix D.15, and the stack and building locations are shown in Figure Appendix D.1.

Table Appendix D.14: Buildings included in the BPIP-PRIME analysis

Building	Base elevation (m)	Height (m)	Corner coordinates (UTM East, North; m)
BLD_3	454	11	• 455317.30, 4976941.95 • 455322.89, 4976936.36 • 455329.78, 4976943.76 • 455326.67, 4976946.92 • 455325.83, 4976946.07 • 455323.45, 4976948.22
BLD_4	454	12	• 455325.20, 4976938.95 • 455329.22, 4976935.00 • 455333.90, 4976939.58 • 455329.84, 4976943.81
BLD_5	452	10	• 455328.25, 4976952.71 • 455336.19, 4976944.25 • 455343.17, 4976951.15 • 455334.52, 4976959.43
BLD_6	452	15	• 455336.23, 4976944.37 • 455343.11, 4976951.19 • 455336.74, 4976957.29 • 455333.55, 4976954.03 • 455331.39, 4976956.11 • 455328.24, 4976952.75

Table Appendix D.15: Stacks included in the BPIP-PRIME analysis

Stack ID	Base elevation (m)	Height (m)	UTM East (m)	UTM North (m)
POX	446.18	23.00	455274.85	4977041.40
BAR_F	453.98	11.50	455318.43	4976941.66
EWIN_1	453.75	12.87	455327.85	4976942.85
EWIN_2	453.91	12.87	455326.14	4976941.27
EWIN_3	454.02	13.87	455330.58	4976940.65
C_KILN_1	451.45	16.30	455332.60	4976955.21
C_KILN_2	451.86	18.50	455335.27	4976951.27
C_KILN_3	453.51	18.50	455338.11	4976948.24
RETORT	453.77	14.90	455322.92	4976943.25

Figure Appendix D.1: Stack and building locations at the process plant included in the BPIP-PRIME analysis

D5 Receptors

A total of 2,087 discrete (non-gridded) receptors were used in the model. The receptor locations across the modelling domain are shown in Figure Appendix D.2.

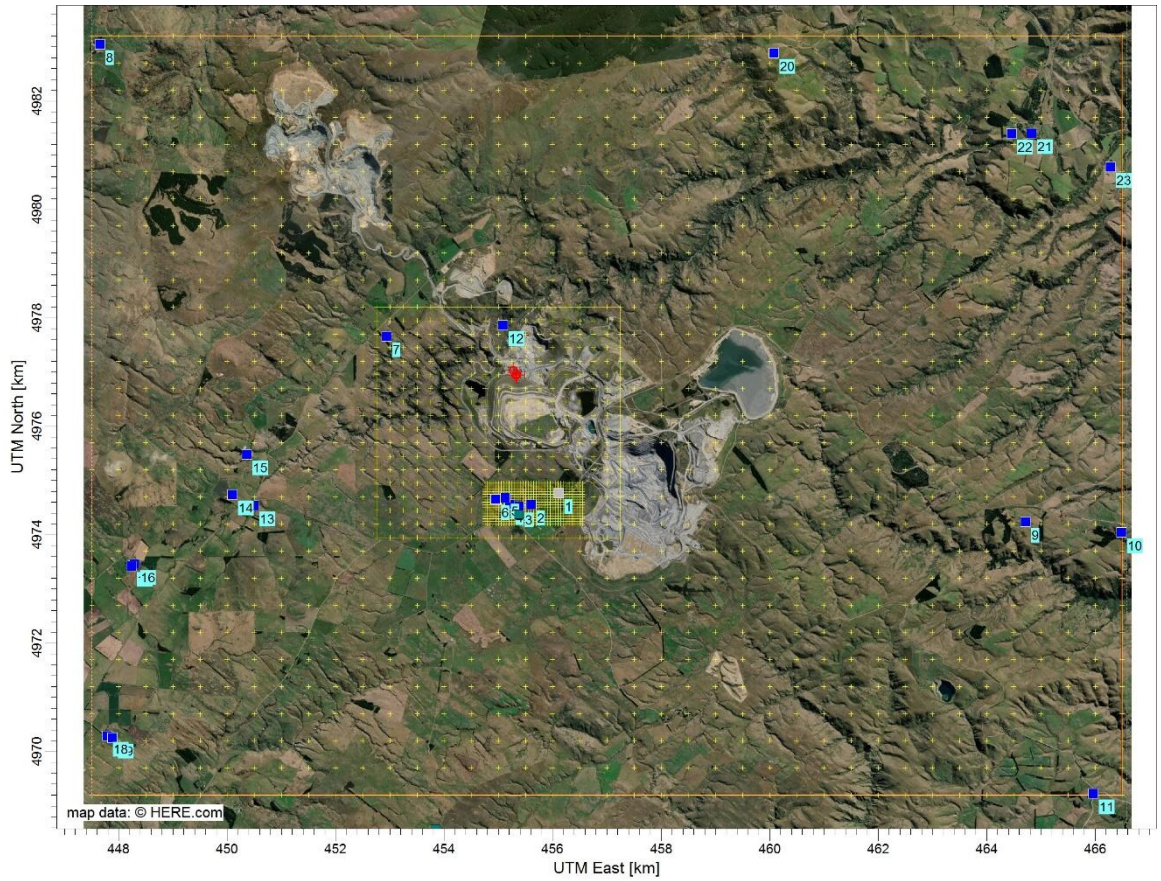


Figure Appendix D.2: Discrete receptor locations across the CALPUFF modelling domain

Appendix E CALMET and WRF configuration

Appendix E CALMET and WRF configuration

E1 Overview

Meteorological fields for the dispersion modelling were generated using the CALMET diagnostic meteorological model, as implemented in CALPUFF View Version 11.0.0 (Lakes Environmental Software). The model was run for a two-year period from 1 January 2022 to 31 December 2023 at an hourly time step.

The CALMET domain comprises 152 x 112 grid cells at a spacing of 0.125 km (approximately 19 km x 14 km), with the south-west corner at 447.5 km East, 4969.2 km North (UTM Zone 59S, WGS-84 datum). Ten vertical layers were used, with cell face heights from the surface up to 4,000 m.

A hybrid observational/prognostic approach was adopted (NOOBS = 1). Hourly surface observations for the following two locations were included:

- Station 1: Observational data from the Macraes Village meteorological site.
- Station 2: Synthetic data extracted from a separate CALMET run using prognostic only data (NOOB S=0) for the location of Macraes Village meteorological site. The location of this second site was placed off the meteorological grid so that it does not unduly influence results. However, its purpose is to enable the model to run during instances when there may be a gap in the dataset for the Macraes Village meteorological site.

The surface station data was combined with prognostic meteorological data (24 3D.DAT files derived from the WRF model), which were used as the initial guess wind field (IPROG = 14). The WRF prognostic inputs were prepared by Zephyr Environmental with details of the model configuration attached to this appendix.

The parameter settings for each CALMET input group are summarised in Table Appendix E.1 to Table Appendix E.7. Terrain elevations and land use across the modelling domain are shown in Figure Appendix E.1 and Figure Appendix E.2.

E2 CALMET parameter settings

Table Appendix E.1: CALMET Input Group 0 - Input and output file names

Parameter	Description	Value
GEODAT	Input file of geophysical data (GEO.DAT)	GEO.DAT
SRFDAT	Input file of hourly surface meteorological data (SURF.DAT)	SURF.DAT
PRCDAT	Input file of hourly precipitation data (PRECIP.DAT)	Macraes_precip.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)	24
NIGF	Number of IGF-CALMET.DAT files used as initial guess	0

Table Appendix E.2: CALMET Input Group 1 - General run control parameters

Parameter	Description	Value
IBYR	Starting year	2022
IBMO	Starting month	1
IBDY	Starting day	1
IBHR	Starting hour	0
IBSEC	Starting second	0
IEYR	Ending year	2023
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 modelling 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

Table Appendix E.3: CALMET 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
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	152
NY	Meteorological grid - number of Y grid cells	112
DGRIDKM	Meteorological grid spacing (km)	0.125
XORIGKM	Meteorological grid - X coordinate for SW corner (km)	447.5000
YORIGKM	Meteorological grid - Y coordinate for SW corner (km)	4969.2000
NZ	Meteorological grid - number of vertical layers	10
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

Table Appendix E.4: CALMET 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
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

Table Appendix E.5: CALMET Input Group 4 - Meteorological data options

Parameter	Description	Value
NOOBS	Observation mode (0 = stations only, 1 = surface/overwater stations with prognostic upper air, 2 = prognostic data only)	1
NSSTA	Number of surface stations	2
NPSTA	Number of precipitation stations	1
ICLDOUT	Output the CLOUD.DAT file? (0 = no, 1 = yes)	0
MCLOUD	Method to compute cloud fields (1 = from surface obs, 2 = from CLOUD.DAT, 3 = from prognostic (Teixera), 4 = from prognostic (MM5toGrads))	4
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

Table Appendix E.6: CALMET 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)	1
ICALM	Extrapolate surface winds even if calm? (0 = no, 1 = yes)	0
BIAS	Weighting factors for surface and upper air stations (NZ values)	0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0
RMIN2	Minimum upper air station radius of influence for surface extrapolation exclusion (km)	4
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
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)	4
RMAX2	Maximum radius of influence over land aloft (km)	5
RMAX3	Maximum radius of influence over water (km)	0

Parameter	Description	Value
RMIN	Minimum radius of influence used in wind field interpolation (km)	0.5
TERRAD	Radius of influence of terrain features (km)	2
R1	Relative weight at surface of step 1 fields and observations (km)	2
R2	Relative weight aloft of step 1 field and observations (km)	3
RPROG	Weighting factors of prognostic wind field data (km)	0
DIVLIM	Maximum acceptable divergence	5E-006
NITER	Maximum number of iterations in the divergence minimisation 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

Table Appendix E.7: CALMET Input Group 6 - Mixing height, temperature and precipitation parameters

Parameter	Description	Value
CONSTB	Mixing height constant: neutral, mechanical equation	1.41
CONSTE	Mixing height constant: convective equation	0.15
CONSTN	Mixing height constant: stable equation	2400
CONSTW	Mixing height constant: overwater equation	0.16
FCORIOL	Absolute value of Coriolis parameter (1/s)	0.0001
IAVEZI	Spatial mixing height averaging? (0 = no, 1 = yes)	1
MNMDAV	Maximum search radius in averaging process (grid cells)	1
HAFANG	Half-angle of upwind looking cone for averaging (degrees)	30
ILEVZI	Layer of winds used in upwind averaging (between 1 and NZ)	1
IMIXH	Convective mixing height method (1 = Maul-Carson, 2 = Batchvarova-Gryning; - for land cells only, + for land and water cells)	1
THRESHL	Overland threshold boundary flux (W/m**3)	0
THRESHW	Overwater threshold boundary flux (W/m**3)	0.05
ITWPROG	Overwater lapse rate and deltaT options (0 = from SEA.DAT, 1 = use prognostic lapse rates and SEA.DAT deltaT, 2 = from prognostic)	0
ILUOC3D	Land use category in 3D.DAT	16
DPTMIN	Minimum potential temperature lapse rate (K/m)	0.001
DZZI	Depth of computing capping lapse rate (m)	200
ZIMIN	Minimum overland mixing height (m)	50
ZIMAX	Maximum overland mixing height (m)	3000
ZIMINW	Minimum overwater mixing height (m)	50
ZIMAXW	Maximum overwater mixing height (m)	3000
ICOARE	Overwater surface fluxes method	10
DSHELF	Coastal/shallow water length scale (km)	0
IWARM	COARE warm layer computation (0 = off, 1 = on)	0
ICOOL	COARE cool skin layer computation (0 = off, 1 = on)	0
IRHPROG	Relative humidity read option (0 = from SURF.DAT, 1 = from 3D.DAT)	1
ITPROG	3D temperature read option (0 = stations, 1 = surface from station and upper air from prognostic, 2 = prognostic)	2
IRAD	Temperature interpolation type (1 = 1/R, 2 = 1/R**2)	2
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

Parameter	Description	Value
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

E3 Terrain and land use

Terrain elevations and land use categories across the CALMET modelling domain were derived from the geophysical data file (GEO.DAT) and are shown in Figure Appendix E.1 and Figure Appendix E.2 respectively. The locations of the two surface meteorological stations are also shown.

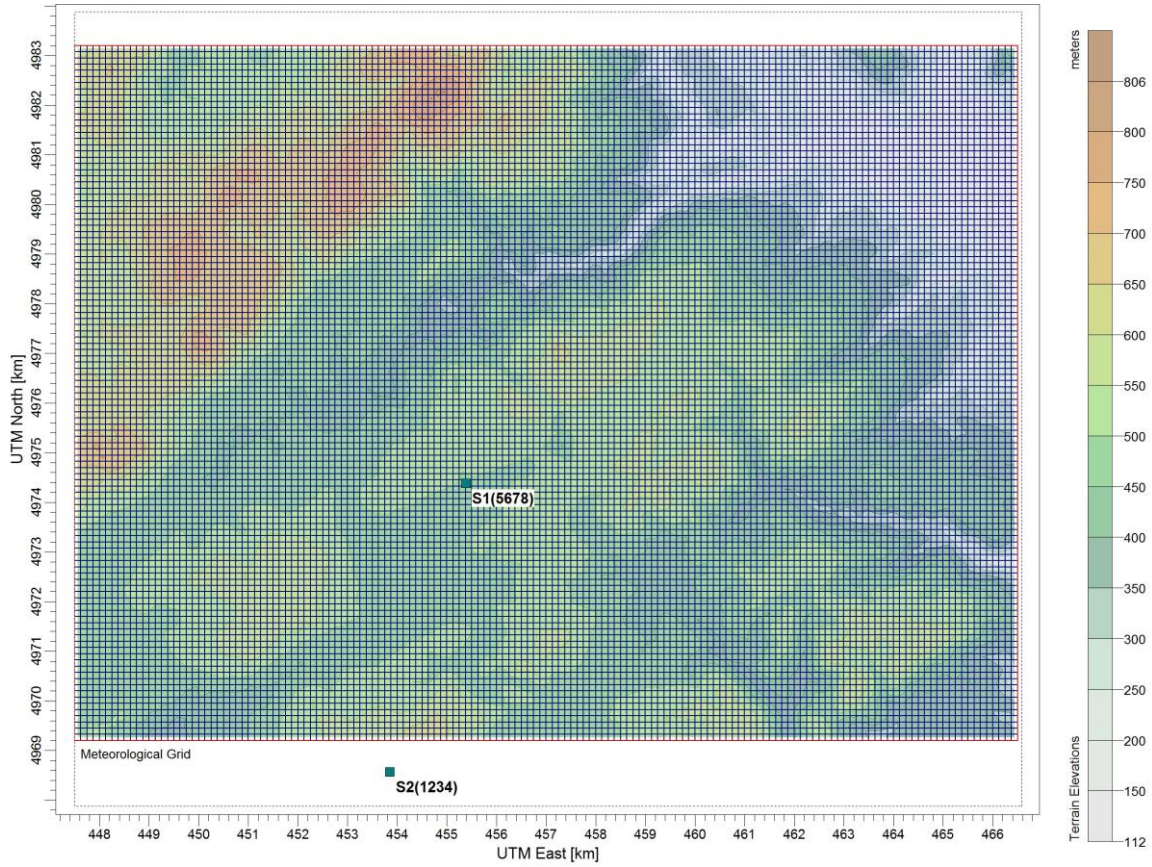


Figure Appendix E.1: Terrain elevations across the CALMET modelling domain, showing the meteorological grid and surface meteorological station locations

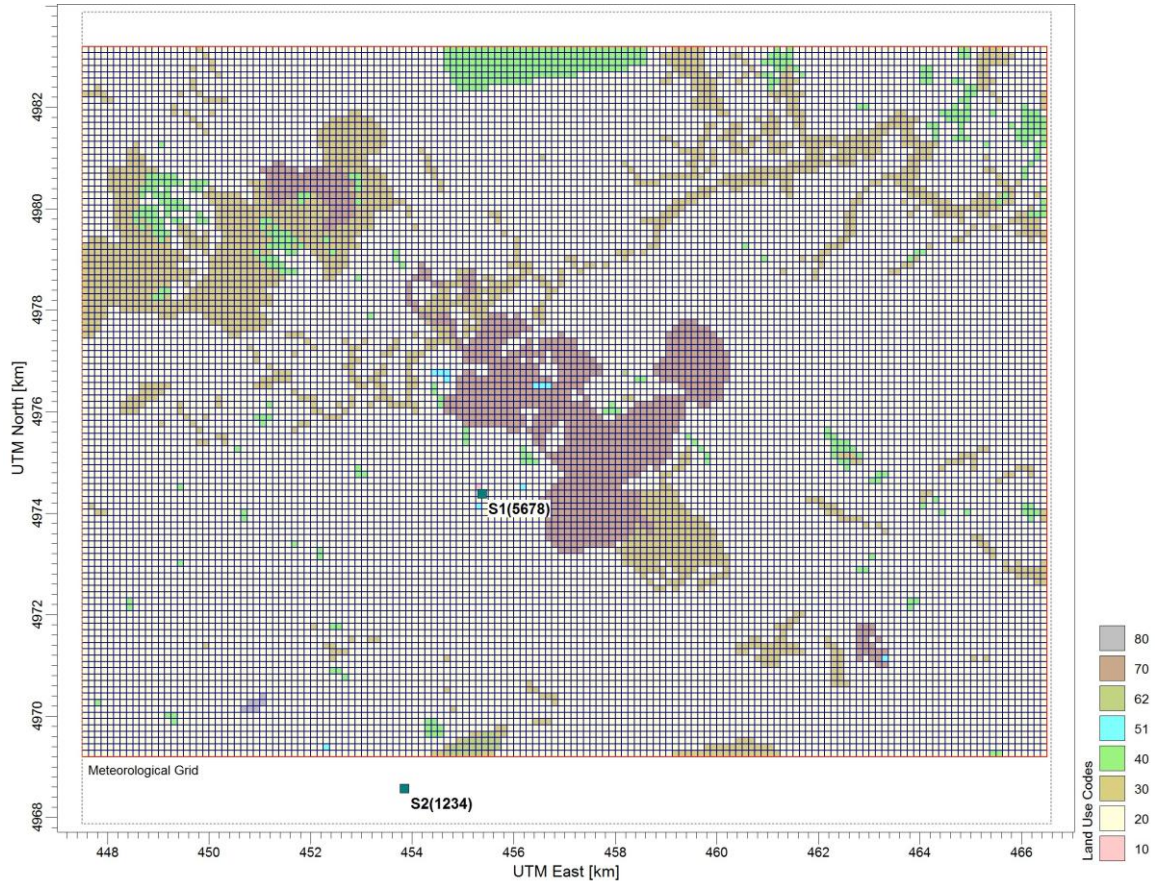


Figure Appendix E.2: Land use categories across the CALMET modelling domain

Weather Research and Forecasting (WRF) Technical Report

18 February 2026	

Document details

Document title	WRF Technical Report
Project number	0462
Release Date	18 February 2026
Version	0.0
Author	Patricia Thorpe
Reviewer	Iain Cowan
Client	Tonkin & Taylor Pty Ltd

Document history

Version	Date	Author	Reviewed by	Comments
0.0	17/02/26	Patricia Thorpe	Dr Iain Cowan	-

Patricia Thorpe

Environmental Consultant

Dr Iain Cowan

Principal

Zephyr Environmental Pty Ltd

PO Box 41

Rozelle NSW 2039

DISCLAMER

The information and files provided in this report by Zephyr Environmental Pty Ltd is based on outputs from the Weather Research and Forecasting (WRF) model. Quality checks and validation of the results have not been performed on the data. Users are advised to exercise their own discretion and validate the information independently before making any decisions based on these data.

The model outputs cover specific temporal and spatial domains, and users should be aware of these limitations and perform the necessary validations required for their specific application (e.g. dispersion modelling). Zephyr does not assume any liability for any liability resulting from the use of this information. Users are encouraged to consult additional sources and apply professional judgment when interpreting the data provided in this report.

For further information or clarification, please contact Zephyr Environmental Pty Ltd at www.zephyrenviro.com/products and wrf@zephyrenviro.com.

Table of Contents

1 INTRODUCTION 5

2 WRF MODELLING 6

2.1.1 Modelling period 6

2.1.2 Initialisation datasets 6

2.1.3 Domain parameters 6

2.1.4 Geospatial WRF inputs 7

2.1.5 Selected WRF options 9

3 WRF DATA POST PROCESSING 13

3.1. Further user processing 13

4 MODEL LIMITATIONS AND UNCERTAINTY 14

REFERENCES 15

Table of Figures

Figure 2-1: Extent of grids used in WRF 7

Figure 2-2: Land use surrounding the Subject Site 8

Figure 2-3: Terrain from AW3D30 surrounding the Subject Site 9

Table of Tables

Table 2-1: Brief WRF parametrisation options description 9

Table 2-2: WRF modelling specifications used in the simulation 11

Table 5-1: WRF limitations and uncertainties 14

1 INTRODUCTION

Meteorological data is required for all manner of applications but is often unavailable near to the area of interest. A process known as prognostic modelling can be used to synthesise a meteorological dataset for subsequent use. The dataset should be representative of the local conditions and should be completed using a model that is well validated in making accurate predictions.

The Weather Research Forecasting (WRF) model is at the forefront of prognostic models and is well validated in the scientific literature to produce meteorological data (Witha, et al., 2019; Solbakken, Birkelund, & Samuelsen, 2021; Cowan & Chilton, 2022; Machado, Martin, & Wong, 2024). The WRF model was designed as a numerical weather prediction model and is widely-used tool in meteorological modelling. The WRF model is designed to simulate and predict weather patterns by using complex mathematical equations and high-resolution data (Skamarock, et al., 2008).

Developed through a collaborative effort involving the (United States) National Center for Atmospheric Research (NCAR), the National Oceanic and Atmospheric Administration (NOAA), and other institutions, WRF features two dynamical cores, a data assimilation system, and a software architecture that supports parallel computation and system extensibility. The WRF model can simulate a wide range of meteorological phenomena across scales from tens of metres to thousands of kilometres, making it highly versatile for various applications

By running simulations with the WRF model, it is possible to reconstruct and analyse past meteorological conditions as well as to generate forecasts for various weather conditions, such as temperature, precipitation, and wind, which are essential for planning and decision-making in fields ranging from agriculture to disaster management. The analyses are crucial for assessing changes in climate over time and for validating climate models used in predicting future scenarios.

The model can be used with reanalysis datasets to downscale data from global weather datasets to local conditions. Atmospheric data obtained from WRF can be used to evaluate meteorological conditions against site observations and can also serve as input for higher-resolution models like CALMET.

Zephyr Environmental Pty Ltd (Zephyr) was engaged by Tonkin + Taylor to run the WRF prognostic model and produce CALMET compatible files for a project location located at latitude -45.359086 longitude 170.429275 for the calendar years 2022 to 2023 inclusive.

This report details:

- The setup of WRF model
- Process of providing outputs to the dispersion model.

2 WRF MODELLING

WRF is a widely used three-dimensional numerical meteorological model which contains non-hydrostatic dynamics, and a variety of physics options for parameterizing cumulus clouds, microphysics, the planetary boundary layer, and atmospheric radiation.

The WRF model offers different options for the representation of convective processes, turbulent transports, evolution of surface temperature and soil moisture, and soil–air interaction as described in Table 2-1.

WRF requires:

- Definition of modelling period
- Selection of initialisation dataset
- Definition of domain parameters
- Geospatial inputs
- Selection of options.

This WRF modelling was completed using WRF version 4.6.0.

2.1.1 Modelling period

WRF modelling was completed for the requested period 1 January 2022 to 31 December 2023 (inclusive).

2.1.2 Initialisation datasets

The WRF model requires initialisation conditions to provide the boundary conditions for the model which are then processed to finer resolutions through an understanding of atmospheric physics, geospatial information and the interaction of the atmosphere with the land. Many datasets are available globally which can be used within the WRF model.

Our experience is that the data from the European Centre for Medium Weather Forecasts (ECMWF) global reanalysis dataset, known as ERA5 provides an output that compares well to observed data. This is because the ERA5 dataset is a reanalysis dataset which has assimilated a great deal of observational data, including surface pressure, sea level pressure, geopotential height, temperature, sea surface temperature, soil values, ice cover, relative humidity, u- and v- wind components, vertical motion, vorticity, winds and in-situ data such as moisture from radiosondes and pressure from surface observations. Also included in these datasets are additional precipitation data, profiler data, dropsondes, pilot balloons, aircraft temperatures and winds, land surface and moisture data and cloud motion vectors from geostationary satellites.

The ERA5 dataset provides information both for the surface conditions and 137 mandatory vertical levels. There are over 25 different variables including geopotential height, temperature, relative humidity and u- and v- wind components.

Data from the ERA5 dataset is available globally every hour on a 27 km grid, however data were extracted from the dataset every 3 hours to minimise download time without loss in fidelity of the data.

2.1.3 Domain parameters

The process of developing the output required for applications such as atmospheric dispersion models using WRF requires the use of a nested approach. 1 km is the highest resolution that it is recommended WRF be used for such applications. Where higher resolution is required, WRF output

can be passed through diagnostic models to further resolve higher resolution terrain and land use, however this will require alternative output formats.

As discussed, the selected initialisation dataset was the ERA5 dataset, and this has an initial resolution of approximately 27 km. The WRF user guide recommends that the factor for nested grids is between 3 and 5, however a grid with the resolution equal to the initialisation data is not required. Thus, the modelled grids corresponded to resolutions of 9 km, 3 km and 1 km.

The locations of the modelled grids are shown in Figure 2-1.

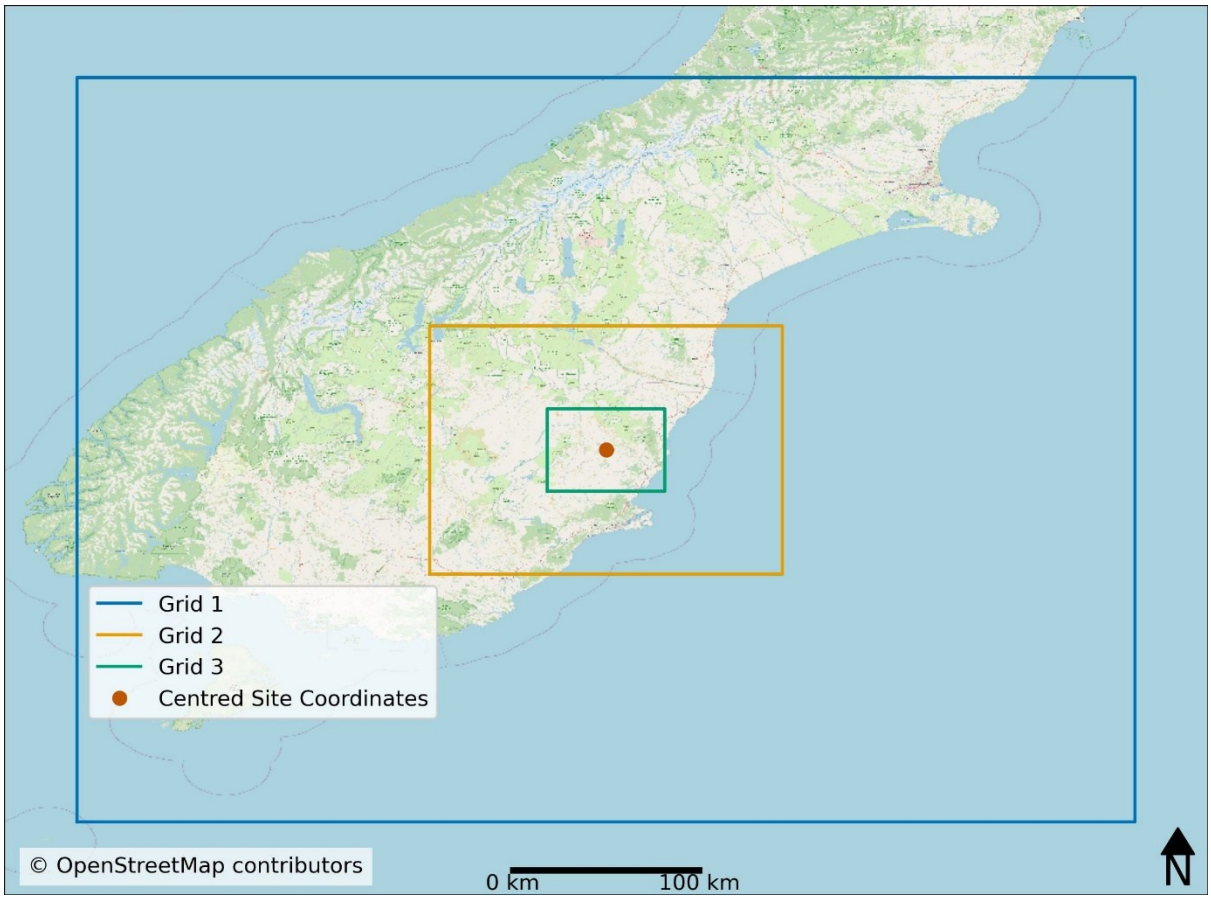


Figure 2-1: Extent of grids used in WRF

2.1.4 Geospatial WRF inputs

WRF geospatial inputs are available from the US National Center for Atmospheric Research (NCAR) with default sets of static data for terrain, vegetation/land use and soil type. NCAR distributes various resolutions of global terrain and land-use data bases to support WRF simulations. The data bases are:

- 5-arc-minutes (approximately 9.25 km in mid-latitudes)
- 2-arc-minutes (approximately 4.00 km in mid-latitudes)
- 30-arc-seconds (approximately 0.900 km in mid-latitudes)
- 15-arc-seconds (approximately 0.450 km in mid-latitudes), which is only available for MODIS land use category.

Experience with WRF has determined that improved agreement with observed data can be achieved where locally collected land use and terrain data are used.

2.1.4.1 Land use

For the Subject Site, land use inputs to the WRF model were obtained from the Global map of Local Climate Zones (LCZ) that describes the heterogeneous urban land surface.

Figure 2-2 provides the land use data for the innermost grid of the model surrounding the Subject Site as used by WRF.

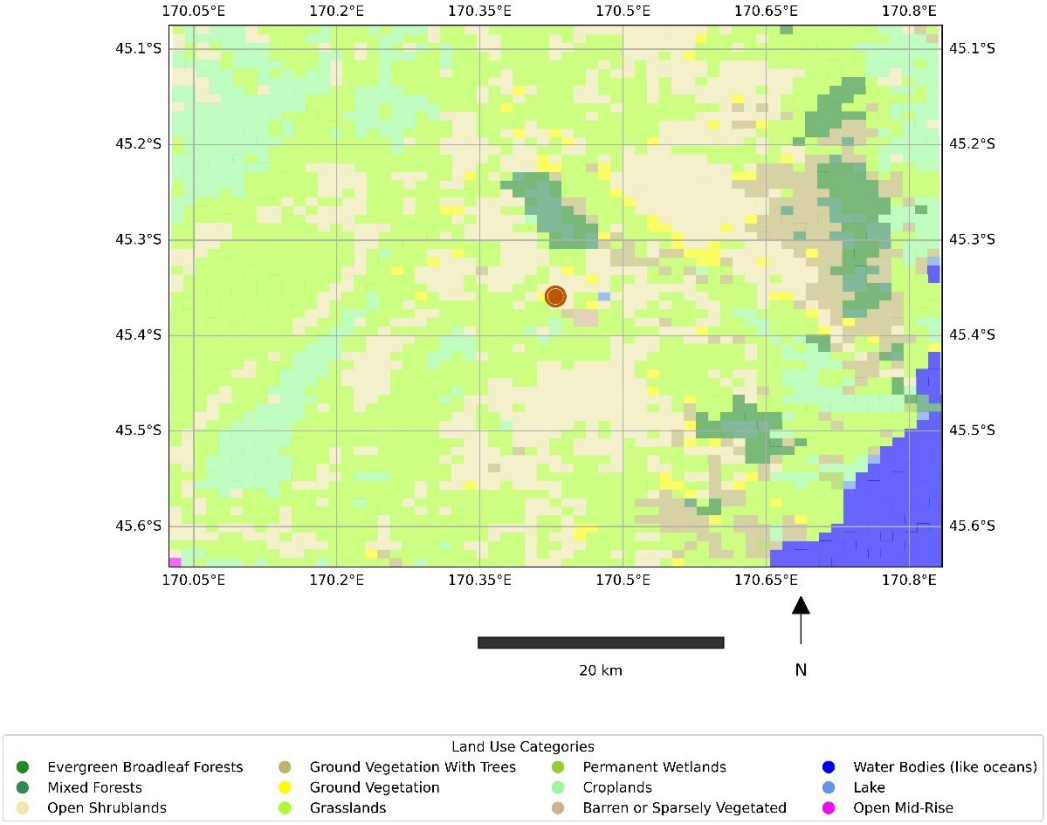


Figure 2-2: Land use surrounding the Subject Site

2.1.4.2 Terrain

For terrain, the Shuttle Ray Topography Mission data was used as the default dataset.

Figure 2-3 provides the terrain for the innermost grid of the model surrounding the Subject Site.

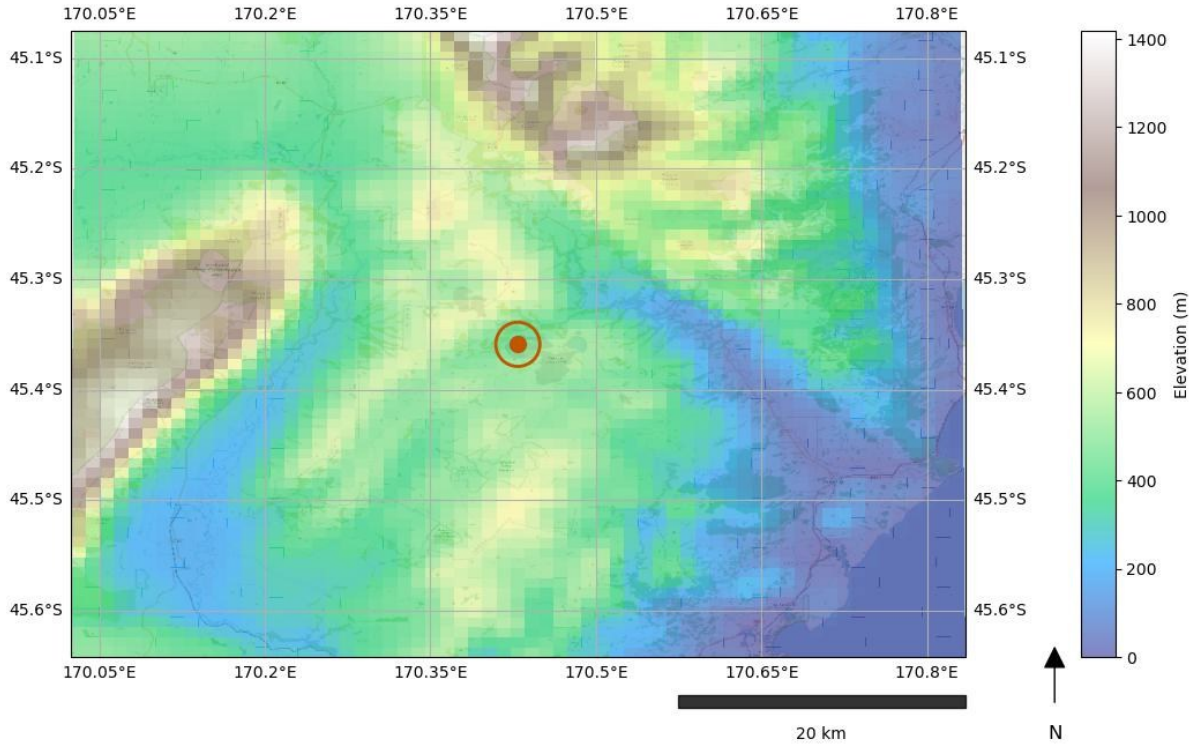


Figure 2-3: Terrain from AW3D30 surrounding the Subject Site

2.1.5 Selected WRF options

Various physical schemes which describe the interaction of the land and the atmosphere and the behaviour of the atmosphere are available within the WRF system (Table 2-1).

Table 2-1: Brief WRF parametrisation options description

Process	Description
Radiation	Radiation Parameterizations: These schemes represent the transfer of radiation in the atmosphere. Examples include: ▪ RRTMG (Rapid Radiative Transfer Model for General Circulation Models) used to calculate the radiative transfer of electromagnetic radiation through a planetary atmosphere (Iacono, et al., 2005) ▪ Dudhia scheme: Dudhia (1989) shortwave and Rapid Radiative Transfer Model (RRTM) longwave radiation schemes (Mlawer, Taubman, Brown, Iacono, & Clough, 1997). ▪ CAM (Community Atmosphere Model) scheme
Planetary Boundary Layer	▪ The Yonsei University (YSU), a nonlocal scheme that includes countergradient flux terms that enables realistic development of a well-mixed layer (Hong & Pan, 1996). ▪ The Mellor–Yamada–Janjic (MYJ) a local implementation of the Mellor–Yamada 2.5 scheme (Janjic, 2002).
Convection	▪ The Grell–Devenyi (GRELL) that includes convective effects from ensembles generated with different closure assumptions (Grell & Devenyi, 2002).

Process	Description
	▪ The Kain–Fritsch (KF), based on a simplified cloud model that also includes shallow convection (Kain, 2004). ▪ The Betts–Miller–Janjic (BMJ) in which deep convection is similar to other adjustment schemes except that it uses a thermodynamic profile that results from mixing the convectively unstable layer. This scheme has been used extensively in weather forecasts at the National Centers for Environmental Prediction (NCEP) and has been improved over the years (Betts 1986; (Janjic, 1994; Betts, 1986).
Soil models	▪ NOAH, a four-layer model that forecasts soil moisture and temperature. It includes a time-varying green vegetation fraction, soil type and snow cover with up to two vertical layers (Chen & Dudhia, 2001). ▪ The Rapid Update Cycle (RUC) land surface model: a six-level soil model to calculate soil fluxes on the basis of time-dependent solutions for temperature and moisture in soil. It includes the effect of evapotranspiration from vegetation and complex canopies (Smirnova, Brown, & Benjamin, 1997). ▪ The 5-layer thermal diffusion scheme and the five-layer soil model are both simplified land surface models based on the MM5 soil temperature model. The 5-layer thermal diffusion scheme uses a fixed deep-layer temperature and does not account for vegetation effects, while the five-layer soil model predicts ground surface temperature at five levels with constant soil moisture determined from seasonal and soil type tables. Both models use constant soil moisture and do not vary moisture through model integration (Dudhia, 1996).
Microphysics	▪ Eta–Ferrier (Ferrier, et al., 2002): This scheme is formulated for grid scales that are not able to explicitly resolve clouds and it is computationally efficient. Microphysics parameterizations are used to simulate the processes of cloud formation, precipitation, and related phenomena. ▪ Thompson: A new bulk microphysical parameterization (BMP) has been developed for use with WRF. Compared to earlier single-moment BMPs, the new scheme incorporates a large number of improvements to both physical processes and employs numerous techniques found in far more sophisticated spectral/bin schemes using look-up tables. This scheme is a new scheme with ice, snow and graupel processes suitable for high-resolution simulations.
Cumulus	These parametrisation schemes represent the effects of deep convection and cumulus clouds, including: ▪ Kain-Fritsch (KF) scheme ▪ Betts-Miller-Janjic (BMJ) scheme ▪ Grell-Freitas (GF) scheme ▪ Tiedtke scheme
Ocean and Ice Parameterisations	▪ OASIS (Ocean-Atmosphere Sea Ice Scheme) ▪ GFS (Global Forecast System) ice and ocean schemes
Urban Physics	▪ Urban Canopy Model (UCM); single layer

Process	Description
	▪ Building Environment Parameterisation (BEP): This is a multi-layer urban canopy model that allows for buildings higher than the lowest model levels. ▪ Building Energy Model (BEM); adds heating and air-conditioning to BEP

Table 2-2 provides a listing of the options selected within the WRF setup for this simulation. Further discussion on the selected options is provided below.

Table 2-2: WRF modelling specifications used in the simulation

Metric	Grid 1	Grid 2	Grid 3
Horizontal grid spacing	9 km	3 km	1 km
Number of grid points	64x 64	64x 64	64x 64
Extent (km x km)	576 x 576	192 x 192	64 x 64
Initial conditions	ERA5 from ECMWF	Grid 1	Grid 2
Physics suite	Conus		
Microphysics	Thompson		
Cumulus	Tiedtke		
Longwave radiation	Rapid Radiative Transfer Model for General Circulation Models		
Shortwave radiation	Rapid Radiative Transfer Model for General Circulation Models		
Planetary boundary layer	Mellor–Yamada–Janjic		
Surface layer	Mellor–Yamada–Janjic		
Land and Soil Model (LSM)	Noah		
Urban Physics	Building Environment Parameterisation		
Top of model (hPa)	5000		
Number of landuse categories	60		
Number of soil layers	4		
Number of vertical levels	38		
Damping depth (meters)	5000		

The selections detailed in Table 2-2 from the available options detailed in Table 2-1 were made for the following reasons:

- Physics suite: Conus - WRF offers two physics suites, Conus and Tropical. The Conus physics suite is for locations with a temperate to cold (but not polar) climate. The Subject Site sits comfortably within this climatic zone.
- Microphysics: Thompson - A new bulk microphysical parameterization (BMP) has been developed for use with WRF. Compared to earlier single-moment BMPs, the new scheme incorporates a large number of improvements to both physical processes and employs numerous techniques found in far more sophisticated spectral/bin schemes using look-up tables. This scheme is a new scheme with ice, snow and graupel processes suitable for high-resolution simulations. This is therefore the latest scheme available and considered to be the most accurate of those available within the model.
- Shortwave and Longwave Radiation: Rapid Radiation Transfer Model (RRTMG) - This a recent version of the rapid radiation transfer model (RRTM) with random cloud overlap (RRTMG).

RRTMG provides more sophisticated cloud treatment and better suited for climate applications than RRTM (option 1). RRTMG also handles cloud fraction whereas RRTM is binary in terms of yes or no for whether cloud cover exists. Based on available guidance, this scheme is considered to be a highly accurate and efficient method. This scheme also incorporates the effects of the comprehensive absorption spectrum taking water vapour, carbon dioxide and ozone into account. This scheme handles better cloud interactions with the Thompson MP scheme.

- Land Surface Model: NOAH – To incorporate the air-soil interaction in the WRF simulation, the Noah Land-Surface Model (LSM) was chosen. Seasonally varying vegetation and soil type are used in the model to handle evapotranspiration. The LSM model also has the effects such as soil conductivity and gravitational flux of moisture. The land-surface model is capable of predicting soil moisture and temperature in four layers (10, 30, 60 and 100 cm thick), as well as canopy moisture and water-equivalent snow depth. This is the default land surface model in WRF.
- Planetary Boundary Layer (PBL): Yonsei University (YSU) - This scheme has the enhanced stable boundary layer diffusion algorithm is also devised that allows deeper mixing in windier conditions. It has the ability to predict & simulates vertical mixing. This scheme also seems to show better performance during stable conditions. This scheme is used for WRF analyses with resolutions of 1 km grid resolution.
- Cumulus Parameterization: Kain-Fritsch in 9 km, 3 km resolution grids - This scheme generally focuses on column moisture, temperature tendencies and surface convective rainfall. It is recommended that cumulus parameterization should not be used at grid sizes < 5-10 km, as the smaller grid size is sufficient to resolve updrafts and downdrafts. Therefore, this scheme will not be used for WRF analyses with resolutions less than 3 km grid resolution.
- Urban Physics: Building Environment Parameterisation - This is a multi-layer urban canopy model that allows for buildings higher than the lowest model levels and maintains model stability whilst using the urban physics schemes.

3 WRF DATA POST PROCESSING

The WRF model provides a three dimensional output that is not directly compatible with dispersion models such as CALMET. Lakes Software provides the CALPUFF modelling suite which includes CALWRF. The CALWRF program reads the WRF-ARW model output and creates a 3D.DAT file suitable for input into CALMET.

The CALWRF program has been used to process data centred on the project location (latitude - 45.359086˚ longitude 170.429275˚) for the calendar years 2022 to 2023 inclusive) to provide a 50 km x 50 km grid at 1 km resolution.

The results are provided as monthly files which can be used to drive CALMET using prognostic data only or in combination with observational data.

3.1. Further user processing

To keep the files as small as possible for download, the files have been compressed using Gunzip in a tarball and are known as tar.gz files. These can be uncompressed in linux using the command:

- tar -xzvf filename.

The files can be uncompressed in windows using 7-Zip which is an open source utility. To do this the user should install 7-zip and then:

- Right-click on the tar.gz file you want to extract and select "7-Zip" > "Extract Here."
- The contents of the archive will be extracted to the same directory as the archive. The now uncompressed .tar file should be visible in the directory listing.
- Locate the .tar file, right click and select "7-Zip" > "Extract Here."
- The contents of the tar file will be extracted to the same directory as the archive.

The user must then use CALMET to further downscale the provided prognostic data using their knowledge of appropriately configuring and running CALMET. The files produced from CALMET can then be used in CALPUFF for dispersion modelling.

4 MODEL LIMITATIONS AND UNCERTAINTY

WRF is a numerical model and a sophisticated tool used for simulating and forecasting of weather conditions. Despite its advanced capabilities, there are inherent limitations and uncertainties that can affect the accuracy and reliability of its outputs. Understanding these limitations is crucial for interpreting model results and applying them effectively as well as selecting the parametrisation schemes that will best fit the model to real conditions. The key factors that contribute to these uncertainties are detailed in Table 4-1 . Each of these factors can introduce errors or biases into the model predictions, and recognizing their impact helps in evaluating the overall performance and validity of WRF simulations.

Table 4-1: WRF limitations and uncertainties

Limitation	Description
Spatial variability of systematic errors	The accuracy of WRF simulations can be limited by the resolution of the model grid. Higher resolution grids provide more detailed simulations but are computationally expensive. Lower resolution grids might miss fine-scale atmospheric features. Accuracy of atmospheric models are also still limited in region with high topography complexity (Singh, et al., 2021). These issues are of lower concern in locations where the topography and land use is non-complex.
Diurnal cycle of systematic errors	Systematic errors (biases) are associated with several variables such as forecast time, and time of day averaged over all experiments (i.e., for the ensemble mean) (Ruiz, Saulo, & Nogues-Paegle, 2010).
Parameterisation Schemes	WRF uses various parameterization schemes to represent physical processes (e.g., convection, cloud formation) that occur at scales smaller than the model grid. The choice of parameterization can significantly impact model outputs and introduce uncertainties (Yu, Bai, Chen, & Shao, 2022). To overcome this, the approach has been to use default parameterisation schemes where available which are those which are best validated in the literature.
Initial and Boundary Conditions	The accuracy of WRF forecasts depends on the quality of the initial and boundary conditions, which are derived from global reanalysis datasets. Errors in these conditions can propagate into the model outputs (Figurski, Nykiel, Jaczewski, Baldysz, & Wdowikowski, 2022). As discussed, Zephyr has found that the ERA5 dataset appears to introduce the least errors of the globally available initial conditions datasets tested due to the reanalysis basis of the data.
Topographic and Land Surface Representations	WRF's accuracy can be affected by how it represents topography and land surface characteristics, such as effects on radiation and diurnal variations of the surface sensible heat flux. Inaccurate representations of surface features can lead to errors in simulating local weather patterns (Arthur, Lundquist, Mirocha, & Chow, 2018). To overcome this, Zephyr has used the most recent land use and terrain data.
Model Calibration and Validation	WRF models need to be calibrated and validated against observational data. Calibration errors and limitations in validation data can impact the reliability of the model outputs (Gneiting, 2014). It is important that this is completed prior to use in a dispersion model.
Computational Limitations	High-resolution simulations require significant computational resources. Limited computational power can constrain the model's ability to perform long-term or very fine-scale simulations (Vourlioti, et al., 2023).

Whilst every care has been taken in the setup of the WRF model, the model has been set up as described in this document and in use of this data the disclaimer is accepted.

REFERENCES

Arthur, R., Lundquist, K., Mirocha, J., & Chow, F. (2018, October 01). Topographic Effects on Radiation in the WRF Model with the Immersed Boundary Method: Implementation, Validation, and Application to Complex Terrain. *American Meteorological Society, 146(10)*, 3277-3292. doi:https://doi.org/10.1175/MWR-D-18-0108.1

Betts, A. (1986). A new convective adjustment scheme. Part I: Observational and theoretical basis. *Quart. J. Roy. Meteor. Soc., 112*, 677–691.

Chen, F., & Dudhia, J. (2001). Coupling an advanced land-surface/hydrology model with the Penn State–NCAR MM5 modeling system. Part I: Model description and implementation. *Mon. Wea. Rev., 129*, 569–585.

Cowan, I., & Chilton, R. (2022). Development of prognostic meteorology for atmospheric dispersion modelling – a comparison of the various options used in Australia and New Zealand. *26th Clean Air Socity of Australia and New Zealand Conference.* Adelaide: CASANZ.

Dudhia, J. (1996, July 22-24). A multi-layer soil temperature model for MM5. Workshop Boulder. In Proceedings of the Sixth Annual PSU/NCAR Mesoscale Model Users' Workshop. 49–50.

EPA Victoria. (2013, October 7). *EPA Publication 1550: Construction of Input Meteorological Data Files for EPA Victoria's Regulatory Air Pollution Model (AERMOD).* Retrieved from EPA Victoria: https://www.epa.vic.gov.au/-/media/epa/files/publications/1550.pdf

Ferrier, B., Jin, Y., Lin, Y., Black, T., Rogers, E., & DiMego, G. (2002). Implementation of a new grid-scale cloud and precipitation scheme in the NCEP Eta model. *15th Conf. on Numerical Weather Prediction*, 280–283. San Antonio, TX: Amer. Meteor. Soc.

Figurski, M., Nykiel, G., Jaczewski, A., Baldysz, Z., & Wdowikowski, M. (2022). The impact of initial and boundary conditions on severe weather event simulations using a high-resolution WRF model. Case study of the derecho event in Poland on 11 August 2017. *Meteorology Hydrology and Water Management, 10(2)*, 60-87. doi:https://doi.org/10.26491/mhwm/143877

Gneiting, T. (2014, March 18). Calibration of Medium-Range Weather Forecasts. *Forecast Department*. Heidelberg Institute for Theoretical Studies and Karlsruhe Institute of Technology. Retrieved from https://www.ecmwf.int/sites/default/files/elibrary/2014/9607-calibration-medium-range-weather-forecasts.pdf

Golder, D. (1972). Relations among stability parameters in the surface layer. *Boundary Layer Meteorology 3, 47–58.*

Grell, G., & Devenyi, D. (2002). A generalized approach toparameterizing convection combining ensemble and data assimilation techniques. *Geophys. Res. Lett, 29*. doi:doi:10.1029/2002GL015311

Hong, S., & Pan, H. (1996). Nonlocal boundary layer vertical diffusion in a medium-range forecast model. *Mon. Wea. Rev, 124*, 2322–2339.

Iacono, M., Mlawer, E., Delamere, J., Clough, S., Mocrette, J., & Hou, Y. (2005, March 14). Application of the Shortwave Radiative Transfer Model, RRTMG_SW, to the National Center for

Atmospheric Research and National Centers for Environmental Prediction General Circulation Models. *Fifteenth ARM Science Team Meeting Proceedings*. Retrieved from https://www.arm.gov/publications/proceedings/conf15/extended_abs/iacono_mj.pdf

Janjic, Z. (1994). The step-mountain Eta coordinate model: Further developments of the convection, viscous sublayer, and turbulence closure schemes. *Mon. Wea. Rev, 122*, 927–945.

Janjic, Z. (2002). Nonsingular Implementation of the Mellor–Yamada level 2.5 scheme in the CEP Meso model. *NCEP Office Note 437*, 61 pp.

Kain, J. (2004). The Kain–Fritsch convective parameterization: An update. *J. Appl. Meteor, 43*, 170–181.

Machado, H., Martin, A., & Wong, S. (2024). Comparative Study of WRF and TAPM Meteorological Models in Southeast and Nortwest Queensland. *27th Clean Air Society of Australia and New Zealand Conference.* Hobart: CASANZ.

Mlawer, E., Taubman, S., Brown, P., Iacono, M., & Clough, S. (1997). Radiative transfer for inhomogeneous atmosphere: RRTM, a validated correlated-k model for the long wave. *J. Geophys. Res., 102(16)*, 663–682.

NSW EPA. (2022, August). Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales. New South Wales: © 2022 State of NSW and the NSW Environment Protection Authority.

Ruiz, J. J., Saulo, C., & Nogues-Paegle, J. (2010, August). WRF Model Sensitivity to Choice of Parameterization over South America: Validation against Surface Variables. *Monthly Weather Review, 138*, 3342-3355. doi:DOI: 10.1175/2010MWR3358.1

Rye, P. (2017, December). Comparison of winds modelled using TAPM and WRF. *Air Quality and Climate Change, 51(3)*, 68-72. Retrieved from https://search.informit.org/doi/abs/10.3316/INFORMIT.414632267444187

Shrivastava, R., Dash, S., Oza, R., & Hegde, M. (2015). Comparison of Two Prognostic Models WRF and TAPM for Short Ranged Forecasts for Kaiga, India . *Internation Journal of Earth and Atmospheric Science, 2(3)*, 97-108. Retrieved from https://jakraya.com/journal/pdf/6-ijeasArticle_4.pdf

Singh, J., Singh, N., Ojha, N., Sharma, A., Pozzer, A., Kumar, N., . . . Katamarthi, R. (2021). Effects of spatial resolution on WRF v3.8.1 simulated meteorology over the central Himalaya. *14(3)*, 1427-1443. doi:https://doi.org/10.5194/gmd-14-1427-2021

Skamarock, W., Klemp, L., Duhia, J., Gill, D., Barker, D., Duda, M., & Powers, J. (2008). A Description of the Advanced Research WRF Version 3 (No. NCAR/TN-475+STR). University Corporation for Atmospheric Research. doi:10.5065/D68S4MVH. Retrieved from https://opensky.ucar.edu/islandora/object/technotes:500

Smirnova, T., Brown, J., & Benjamin, S. (1997). Performance e of different soil model configurations in simulating ground surface temperature and surface fluxes. *Mon. Wea. Rev, 125*, 1870–1884.

Solbakken, K., Birkelund, Y., & Samuelsen, E. M. (2021). Evaluation of surface wind using WRF in complex terrain: Atmospheric input data and grid spacing. *Environmental Modelling & Software, 145*. doi:https://doi.org/10.1016/j.envsoft.2021.105182

VIC EPA. (2013, October). Construction of input meteorological data files for EPA Victoria's regulatory air pollution model (AERMOD). *Publication 1550* . EPA Victoria, 200 Victoria St, Carlto.

Vourlioti, P., Kotsopoulos, S., Mamouka, T., Agrafiotis, A., Nieto, F., Sánchez, C., . . . González, S. (2023). Maximizing the potential of numerical weather prediction models: lessons learned from combining high-performance computing and cloud computing. *20*, 1-8. doi:https://doi.org/10.5194/asr-20-1-2023

Witha, B., Hahmann, A. N., Sile, T., Dörenkämper, M., Ezber, Y., Bustamante, E. G., . . . Navarro, J. (2019). *Report on WRF model sensitivity studies and specifications for the mesoscale wind atlas production runs: Deliverable D4.3.* NEWA - New European Wind Atla.

Yu, E., Bai, R., Chen, X., & Shao, L. (2022, November). Impact of physical parameterizations on wind simulation with WRF V3.9.1.1 under stable conditions at planetary boundary layer gray-zone resolution: a case study over the coastal regions of North China. *Geosci. Model Dev., 15(21)*, 8111-8134. doi:https://doi.org/10.5194/gmd-15-8111-2022

Appendix F WRF data wind roses

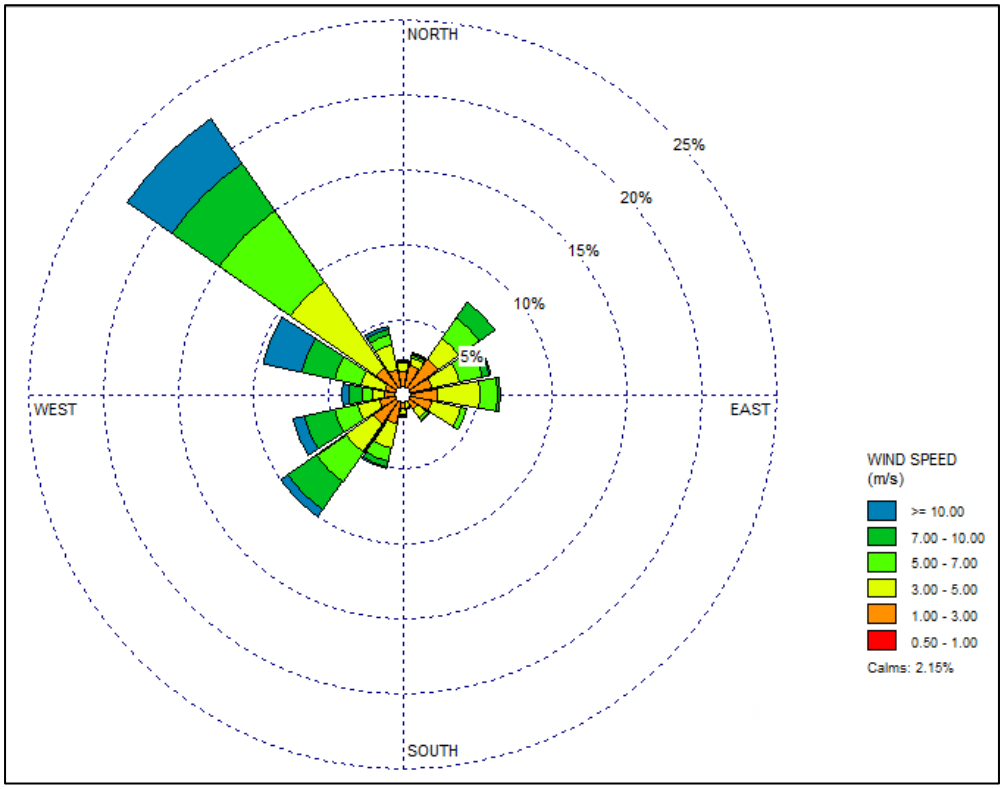


Figure Appendix F 13: WRF data for mine location.

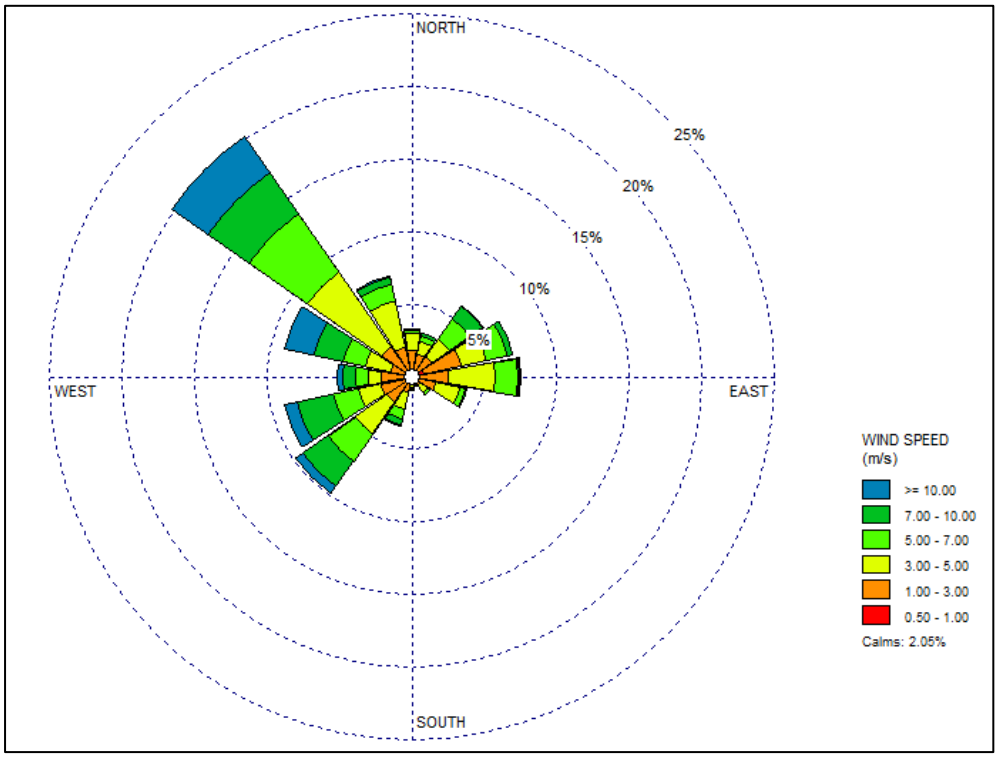


Figure Appendix F 14: WRF data for village location.

Appendix G Proposed air discharge permit conditions

RMFT26.[069]: Discharge Permit (Air) Mining Area (including discharge from return vents at GPUG), and the Golden Bar Mining Area of the Macraes Operation.

Condition number	Proposed condition
1.	This consent authorises the discharge of contaminants to air, including (but not limited to) particulate matter, sulphur dioxide, mercury and trace metals from mining operations, ore processing, and all associated activities in the Macraes MP4 project area operations, including but not limited to: 1. Mining operations at Innes Mills, Golden Bar, Coronation, Coronation North, and Golden Point Underground; 2. Operation of the Processing Plant, including the pressure oxidation (**POX**) plant; 3. Waste rock stacks and tailings storage facilities; 4. Haul roads and associated infrastructure; and 5. Rehabilitation activities.
2.	For the purpose of this consent, the Macraes MP4 project area is that property owned by the Consent Holder as identified on Figure X in Schedule 4.
3.	No activity authorised by this consent may be undertaken until Discharge Permits 96785.V5, 2006.689, 2007.511, RM10.351.52.V4, RM12.373.15, RM16.138.19.V2, and RM20.130.01.V1 have been surrendered or have expired.
4.	The Consent Holder must manage mining, processing and associated activities such that any discharge of contaminants to air does not cause an offensive or objectionable effect beyond the boundary of the Macraes MP4 project area as identified on Figure X in Schedule 4.
Air Quality Management Plan	
5.	Prior to the exercise of this consent, the Consent Holder must submit an Air Quality Management Plan (**AQMP**) that is prepared by a SQEP – Air Quality to the Otago Regional Council for certification in accordance with Conditions 9–20 of Schedule 1 (Common Conditions). ***Advice note:*** *for the purpose of this condition, a SQEP may include consent holder staff, such as environmental advisors, where those staff are suitably qualified and experienced.*
6.	The certified AQMP must be implemented and maintained for the duration of this consent. In the event of any inconsistency between the certified AQMP and the conditions of this consent, the conditions of this consent prevail.
7.	The objectives of the AQMP are to: 1. Describe the management and operational regime that will be implemented to ensure that contaminant discharges to air (primarily dust) from the Macraes MP4 project area do not result in adverse impacts beyond the boundary of the Macraes MP4 project area; 2. Describe the air quality (primarily dust) management methods and procedures that will be implemented to enable compliance with the conditions of this consent;

Condition number	Proposed condition
	3. Describe current and proposed air quality (primarily dust) management methods and procedures; 4. Enable the Consent Holder to operate in full compliance with resource consent requirements; and 5. Describe the air quality monitoring regime and reporting of results.
8.	The AQMP must, as a minimum, include a detailed description of the: 1. Sources of contaminant discharges to air from the Macraes MP4 project area; 2. Location of sensitive receptors; 3. Dust mitigation measures for each dust source, including, as a minimum, measures for: i. Vehicle movements on unpaved haul roads and trafficked surfaces; ii. Mining operations including drilling, blasting, excavation and loading; iii. Ore and waste rock stockpiles; iv. Tailings storage facilities; v. Processing plant operations; and vi. Progressive rehabilitation and stabilisation of disturbed surfaces; 4. PM_{10} monitoring procedures at two monitoring sites, including: i. Trigger concentration values and meteorological exceptions; ii. Investigation and response procedures when valid trigger exceedances occur; iii. Additional dust control measures to be implemented following trigger exceedances; and iv. Procedures for recording and reporting trigger alert messages; 5. Dust deposition monitoring procedures, including: i. The location of dust deposition monitoring sites; ii. Sampling methodology consistent with AS/NZS 3580.10.1:2016 or its successor; iii. Sampling frequency; and iv. Dust deposition monitoring limits and associated response actions; 6. Meteorological monitoring procedures; 7. Operational monitoring procedures, including routine visual inspection procedures; 8. Complaint receipt and response procedures; and 9. Procedures for auditing, reviewing and updating the AQMP.
Dust Mitigation	
9.	The Consent Holder must take all practicable measures to minimise the discharge of dust from mining activities, including but not limited to: 1. Using water carts and sprinklers to dampen haul roads and dust generating surfaces during dry conditions; 2. Using water suppression at tailings storage facilities to prevent tailings from becoming dry, particularly around edges; 3. Applying water to tailings prior to and during removal, handling and relocation to ensure tailings remain damp at all times; 4. Minimising drop heights from trucks and excavation equipment; 5. Limiting vehicle speeds to a maximum of 60 kilometres per hour on haul roads; 6. Taking into account wind speed and direction when undertaking dust generating activities to prevent adverse effects at sensitive receptors; and

Condition number	Proposed condition
	7. Modifying activities and dust control measures in response to exceedance of PM_{10} trigger levels. 8. The application of water to tailings when using dry mining methods so that tailings are maintained in damp condition at all times when being excavated and handled during re-working of tailings to lower the mixed tailings impoundment.
10.	The Consent Holder must undertake dust deposition monitoring in accordance with AS/NZS 3580.10.1:2016 (or its successor standard) at monthly intervals at the monitoring sites DG02, DG07, DG11, DG15, DG20, DG21, DG22, and DG25 shown on Figure X in Schedule 4.
11.	Insoluble dust deposition rates at sites monitoring sites DG02, DG07, DG11. DG15, DG20, DG21, DG22 and DG25, as shown on Figure X in Schedule 4, must not exceed 3 grams per square metre per 30 days (g/m2/30 days) of insoluble dust above background more than twice in any calendar year.
12.	Background concentrations must be calculated by averaging the insoluble dust deposition rates at background monitoring sites DG09, DG10 and DG24 shown on Figure X in Schedule 4.
13.	If the limit specified in Condition Air11 is exceeded, the Consent Holder must: 1. Within **10 working days** of receiving the laboratory result, notify ORC in writing, identifying the monitoring site, the result, prevailing meteorological conditions during the sampling period, and any likely cause; 2. Undertake a review of the cause of the exceedance and provide a report detailing the findings of the review into the cause of the exceedance to the Otago Regional Council no later than 30 working days after the non-compliant monitoring result is received; 3. Engage an independent consultant in consultation with the Otago Regional Council If the report produced in accordance with Condition Air13b shows that activities within the Macraes MP4 project area caused the exceedance, to assess whether changes to the dust mitigation measures within the site are necessary to prevent, to the extent practicable, the exceedance from reoccurring in the future; and 4. The Consent Holder must provide a report to the Otago Regional Council within 60 working days of the non-compliant monitoring result being received setting out the results of the independent consultant review and identifying any measures recommended to prevent, to the extent practicable, the exceedance from reoccurring in the future. ***Advice Note**: The reports required under Conditions Air13b and Air13d may be combined into a single report, subject to meeting the timeframe specified in Condition Air13a and the requirement under Condition Air13c to consult with the Otago Regional Council.*
PM_{10} Monitoring	
14.	The Consent Holder must undertake continuous real-time PM_{10} monitoring at site DG15 and at location DG11 as shown on Figure X in Schedule 4. The PM_{10} monitoring instrument at DG15 must comply with the methods set in Schedule 2 of Resource Management (National Environmental Standards for Air Quality) Regulations 2004 or with AS/NZS 3580.9.17:2018 Methods for sampling and analysis of ambient air - Method 9.17: Demonstration of equivalence for ambient particulate matter monitoring methods. The PM_{10} monitoring instrument at location XXX may be a nephelometer instrument that is in general accordance with the instrumentation described in AS/NZS 3580.12.1:2015 (Methods for sampling and analysis of ambient air, Method 12.1: Determination of light scattering - Integrating nephelometer method).

<table>
<tr><th>Condition number</th><th>Proposed condition</th></tr>
<tr><td>15.</td><td>The results of PM_{10} monitoring undertaken in accordance with Condition Air14 must be compared to the following trigger concentration values:
1. 1-hour average concentration of 150 micrograms per cubic metre (µg/m³); and
2. 24-hour average concentration of 40 micrograms per cubic metre (µg/m³).</td></tr>
<tr><td>16.</td><td>If a trigger concentration value identified in Condition Air15 is exceeded, then a trigger alert message must be immediately sent to the Consent Holder and:
1. Where the trigger concentration value exceedance coincides with the following meteorological conditions (time averaged in accordance with the equivalent trigger averaging period) no further action is required by the Consent Holder if:
i. Relative humidity measurement exceeds 95% for the nephelometer instrument operated at location XXX; or
ii. The prevailing wind is from a southeasterly to north-westerly direction (between 135 degrees and 315 degrees relative to true north).
2. For all trigger alert messages that do not meet the conditions in (a) above, the Consent Holder must investigate the cause of the exceedance and if required, implement additional dust control measures as set out in the certified air quality management plan (AQMP) required by Conditions Air5 – Air9.
3. If a trigger alert message is received again within a 7-day period of a response being actioned in accordance with Condition Air16b and an investigation into the cause of the exceedance determines that the exceedance was caused by mining activities, the need for further dust management measure must be reviewed and, if required, implemented.
4. A record of trigger alert messages that meet Condition Air16b and c and responses must be included in the annual report required by Condition Air23.</td></tr>
<tr><td colspan="2">Meteorological Monitoring</td></tr>
<tr><td>17.</td><td>The Consent Holder must continuously monitor and record meteorological conditions:
1. At site DG03 as shown on Figure X in Schedule 4. As a minimum, the meteorological data collected must include wind speed, wind direction, temperature and rainfall.
2. At site DG15 as shown on Figure X in Schedule 4. As a minimum, the meteorological data collected must include wind speed, wind direction, humidity, temperature and rainfall.
All meteorological data must be recorded continuously with date and time stamps and must be made available to Otago Regional Council upon request within 10 working days.</td></tr>
<tr><td>18.</td><td>The Consent Holder must keep a daily record of water used for dust suppression and must make these records available to the Consent Authority on request.</td></tr>
<tr><td colspan="2">Processing Plant Stack Emissions</td></tr>
<tr><td>19.</td><td>The mass emission rate of contaminants discharged from the POX plant stack must not exceed the limits specified:
<table><tr><td>Contaminant</td><td>Maximum mass emission rate limit (kg/hr)</td></tr><tr><td>Nickel</td><td>0.0084</td></tr></table></td></tr>
</table>

Condition number	Proposed condition
20.	The Consent Holder must undertake POX plant stack emission testing once every three years for sulphur dioxide, mercury (gaseous and particulate phase), and trace metals (including as a minimum arsenic, chromium, lead and nickel). The first stack emission test must be undertaken within 12 months of the commencement of this consent, and subsequent tests must be undertaken at intervals not exceeding three years thereafter. Results of stack emission testing must be provided to the Otago Regional Council within **2 months** of the test being undertaken.
21.	Testing must be undertaken by a suitably qualified and experienced person using methods appropriate for the contaminants being measured. Any sample analysis required as part of the stack emission testing programme shall be carried out by a laboratory accredited by International Accreditation New Zealand (IANZ) for the specific analytical methods used.
Reporting	
22.	The Consent Holder must report the results of all monitoring undertaken in accordance with this consent to the Otago Regional Council on a quarterly basis following the first exercise of this consent, in a format agreed upon in consultation with the Consent Authority.
23.	The Consent Holder must, in consultation with the Otago Regional Council, engage an independent reviewer to undertake an annual review and assessment of all dust deposition rate data, PM_{10} monitoring data and stack emission testing data. Following the annual review and assessment, the Consent Holder must provide an annual report to the Otago Regional Council which must include: 1. The name, qualifications, and experience of the reviewer; 2. The methods used and the investigations undertaken for the review; 3. Interpretation of the monitoring data reviewed; 4. An assessment of the quality of the monitoring data; 5. An assessment of the particulate monitoring regime; 6. An assessment of the record of trigger alert messages and responses maintained in accordance with Condition Air16; 7. A description and evaluation of the dust mitigation measures used by the Consent Holder; 8. Recommendations on whether: i. The monitoring is adequate or should be changed, and if changed, the recommended changes; ii. The mitigation measures are adequate or should be changed, and if changed, the recommended changes; and iii. Whether any changes should be made to the conditions of this consent and if so, the recommended changes. 9. Any other matters that the reviewer considers should be drawn to the attention of the Consent Holder or the Otago Regional Council. The Consent Holder must provide the annual report required by this condition to the Otago Regional Council by **30 April each year**.
Non-compliance Notification	

Condition number	Proposed condition
24.	In the event of any non-compliance with the conditions of this consent, the consent holder must notify Otago Regional Council within 24 hours of the non-compliance being detected. Within five working days the consent holder must provide written notification to Otago Regional Council providing details of the non-compliance. This notification will at a minimum include an explanation of the cause of the non-compliance, the steps taken to remedy the situation and steps taken to mitigate any future occurrence of the non-compliance.

Together we create + sustain a better world