



Offshore Ironsands Project

Air Dispersion Modelling Study - Gas Turbines

Prepared for

Trans-Tasman Resources Ltd

Prepared by

Tonkin & Taylor Ltd

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Executive summary

Trans-Tasman Resources Ltd is applying for marine consent for its proposed iron ore extraction activities located outside the 12 nautical mile limit off the South Taranaki coast. The activities include discharges to air from the combustion of Heavy Fuel Oil to meet the facilities energy requirements. An air dispersion modelling study of these emissions to air has been undertaken by Tonkin & Taylor Ltd (T+T).

The air pollutants considered in this study are fine particulate matter (PM10), sulphur dioxide, nitrogen dioxide and carbon monoxide from the operation of four HFO fired gas turbines located on the Floating Production, Storage and Offloading (FPSO) vessel.

The emission rates considered for the study were based on USEPA AP-42 emission factors and calculations by T+T using plant and process data supplied by Trans-Tasman Resources.

The proposed mining area is located in the open ocean approximately 22.4 km offshore. A 3D meteorological dataset was developed for the region using terrain and land use information, observations from six meteorological surface sites and 3D upper air data developed by another meteorological model (MM5).

The ground level concentrations of each contaminant have been predicted using the CALPUFF dispersion model over a 52 km x 40 km grid (100 metre grid resolution) surrounding the site. The maximum predicted ground levels concentrations anywhere within the modelling domain, as well as the maximum concentration on land, have been reported.

The predicted ground level concentrations of all contaminants considered are below the relevant health-based air assessment criteria.

1 Introduction

Trans-Tasman Resources Ltd (TTR) is applying for a marine consent under the Exclusive Economic Zone and Continental Shelf Act 2012 (EEZ Act) to undertake iron sand extraction from the sea bed in a number of areas outside the 12 nautical mile limit. The proposed process will excavate seabed material which will be transferred to a Floating Production, Storage and Offloading (FPSO) vessel which will process the seabed material into iron ore concentrate (Appendix A). The de-ored material will be discharged to the seabed into the previously extracted area. The proposed FPSO will generate electricity for the on-board operations using four Siemens SGT 500 gas turbines. The turbines will be fuelled by heavy fuel oil (HFO).

Tonkin and Taylor Ltd (T+T) has been engaged by TTR to prepare an air quality study to accompany their marine consent application for the proposed off shore activities. This study has been undertaken in accordance with our proposal dated 31 May 2013. These reports were initially prepared in 2013. T+T have been provided with information relating to TTR's additional scientific work undertaken since 2014 and this new information does not alter the conclusions of our earlier report.

Discharges to air from the HFO fired gas turbines will comprise combustion products; carbon monoxide, oxides of nitrogen, sulphur dioxide and fine particulate matter. The emissions to air have been characterised based on information provided by TTR and published emission factors. The maximum ground level concentrations of contaminants on land have been predicted using air dispersion modelling and the results of the modelling have been compared to appropriate air quality assessment criteria, including the National Environmental Standards for Air Quality (NESAQ).

2 Description of discharges to air

2.1 Introduction

This study considers the emissions to air from the electricity generators that are proposed to be installed on the FPSO to meet the facilities energy requirements. This section describes the generators and the nature of discharges to air.

2.2 Power generation

The operation on board the FPSO will require a total power capacity of approximately 80 MW, including requirements for propulsion motors, mining, processing, desalination and various low-voltage requirements. It is proposed that four Siemens SGT-500 modular gas turbines (as illustrated in Figure 2.1) be installed on the FPSO to meet this demand. The turbines will be fuelled with heavy fuel oil. Each gas turbine has its own stack which discharges products of combustion to atmosphere, as described in the following sub-section.

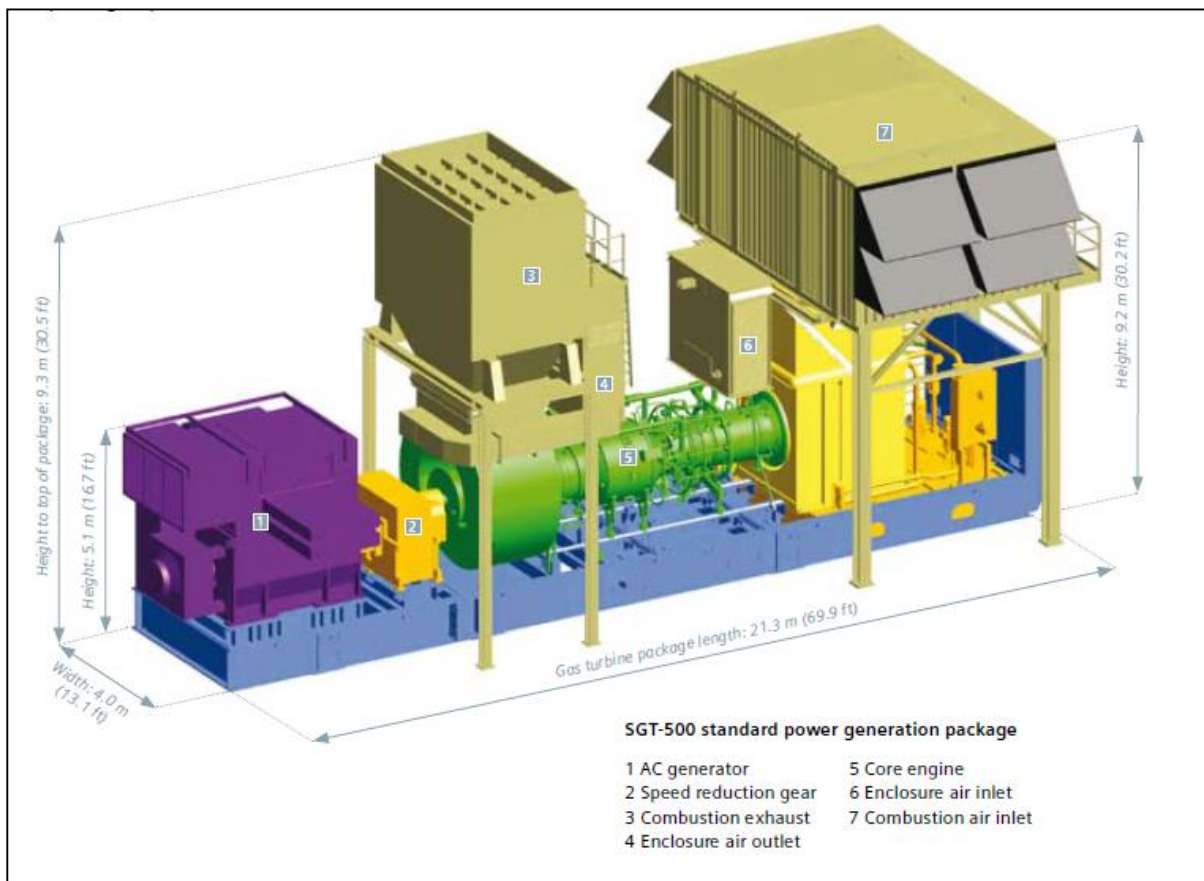


Figure 2.1: Emissions to air from the gas turbines

Each of the four proposed turbines can generate up to 19 MW electrical and has a maximum heat release of 56.5 MW (gross) at maximum continuous rating (MCR). The primary fuel for the boiler will be heavy fuel oil (HFO). A heat release rate of 56.5 MW (gross) corresponds to a fuel usage of 5.040 tonnes per hour of HFO, with a calorific value of 40.6 MJ/kg (gross). The four gas turbines operating at maximum capacity will use up to 177,000 tonnes per annum of HFO.

The combustion of HFO generates a number of contaminants. The major contaminants of interest with respect to potential effects are carbon monoxide (CO), oxides of nitrogen (NO_x), sulphur dioxide (SO₂) and fine particulate matter. Fine particulate matter has been assessed based on the fraction less than 10 micron aerodynamic diameter (PM₁₀).

Emission rates of PM₁₀ and CO have been calculated using AP-42 emission factors (USEPA 2003)¹. The USEPA document AP-42 is a compilation of emission factors and process information for more than 200 air pollution source categories. The emission factors have been developed and compiled from source test data, material balance studies and engineering estimates.

For this assessment it has been assumed that all particulate discharged from the gas turbines on proposed FPSO will be PM₁₀.

Emission rates of NO_x have been based on emission specifications of the gas turbines provide by TTR. The proposed Siemens gas turbines can be fitted with water injection to reduce the levels of nitrogen oxides emissions.

The emissions rate of SO₂ has been estimated based on the mass of sulphur in the HFO and assuming that all sulphur is converted to SO₂. The maximum sulphur content in the fuel specification for HFO is 4.5% w/w.

The emissions of combustion products have been estimated for on all four gas turbines operating at Maximum Continuous Rating (MCR). The airflow in the stacks is estimated to be 179.4 m³/s at 357°C, based on information provided by TTR. The flow rate is equivalent to 77.8 m/s at standard conditions of 0°C, 1atm, dry gas basis.

The emission parameters and contaminant mass emission rates used in the modelling study are shown in Table 2.1 and Table 2.2.

Table 2.1: Gas turbine stack emission conditions

Stack emission parameter	Value
Temperature (°C)	357
Stack height (above water) (m)	48.2
Stack exit velocity (m/s)	29.2
Stack exit diameter (m)	2.8
Flow rate (m ³ /s) at STP	77.8

Note: Data supplied by TTR

Table 2.2: Gas turbine contaminant emission rates

Contaminant	Emission rate (g/s)	Source
Particulate matter (PM10)	1.5	AP-42 emission factors
Nitrogen oxides (total NO _x expressed as NO ₂)	55.9	Emission specifications of the gas turbines provide by TTR.
Sulphur dioxide	125.4	Mass balance calculation assuming maximum sulphur content of 4.5% w/w
Carbon monoxide	1.14	AP-42 emission factors

¹ USEPA AP-42 Emission factors. External Combustion Sources, September 2003.

3 Environmental setting

3.1 Location and existing air quality

The proposed mining locations consist of four areas with high grade accumulation of iron sand extending beyond 12 nautical miles (22.4 km) off the South Taranaki coastline. The proposed mining area is approximately 66 km², in water depths ranging from 21 to 42 metres. The boundary of the proposed mining area is approximately one kilometre south of the unmanned offshore Kupe gas platform. The FPSO can be located anywhere inside the proposed mining area. For the purpose of predicting worst case concentrations of contaminants on land, the FPSO has been assumed to be located at the closes point to land, as indicated by the red dot on figure 3.1.

Other sources of air pollutants in the vicinity of the FPSO may include the Kupe facility and shipping emissions. Marine aerosols (salt spray) are a naturally occurring background source of fine particulate. The area with the highest predicted air concentrations on land is predominantly rural in nature and background levels of contaminants are expected to be low.

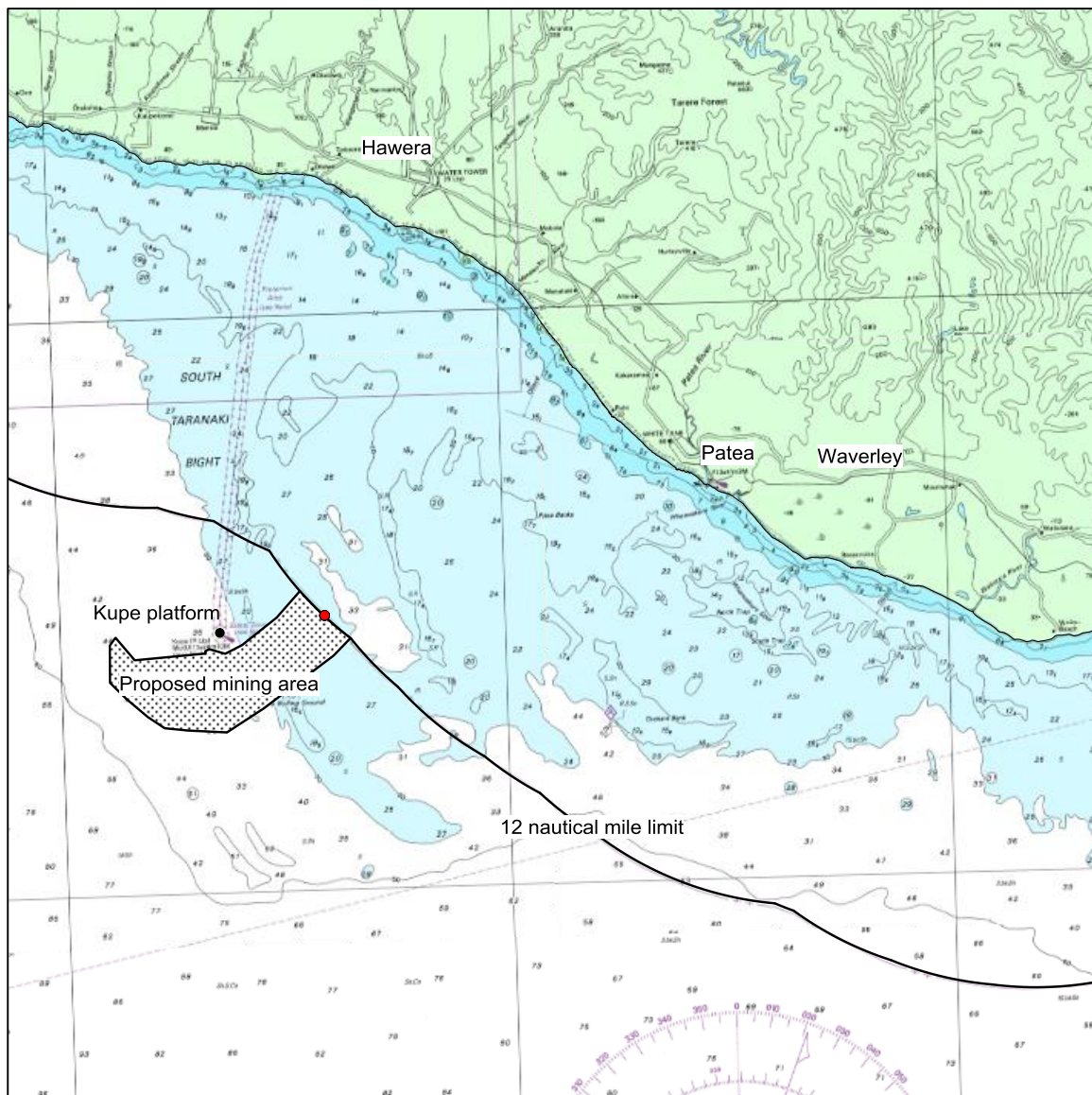


Figure 3.1: Location of proposed mining area

3.2 Meteorology

A 3-dimensionally varying meteorological dataset has been prepared for the modelling domain, as described in Section 5.2. This data incorporates observed and modelled weather data from a range of sources. A wind speed frequency distribution plot and wind rose for the indicative FPSO location is presented below (Figure 3.2 and Figure 3.3).

Wind speeds and direction over the area of interest are controlled by the prevailing weather systems which typically track from the west to the east. The prevailing winds are predominantly from the west and have higher average winds speeds when compared land based observations. Winds from the north east have a low occurrence which is likely to be due to the land mass of the North Island. A low occurrence of calm conditions (<0.5 m/s) and relatively low variations in sea temperature, result in a low frequency of inversion conditions developing. The low occurrence of calms and inversion conditions favours the dispersion of air pollutants.

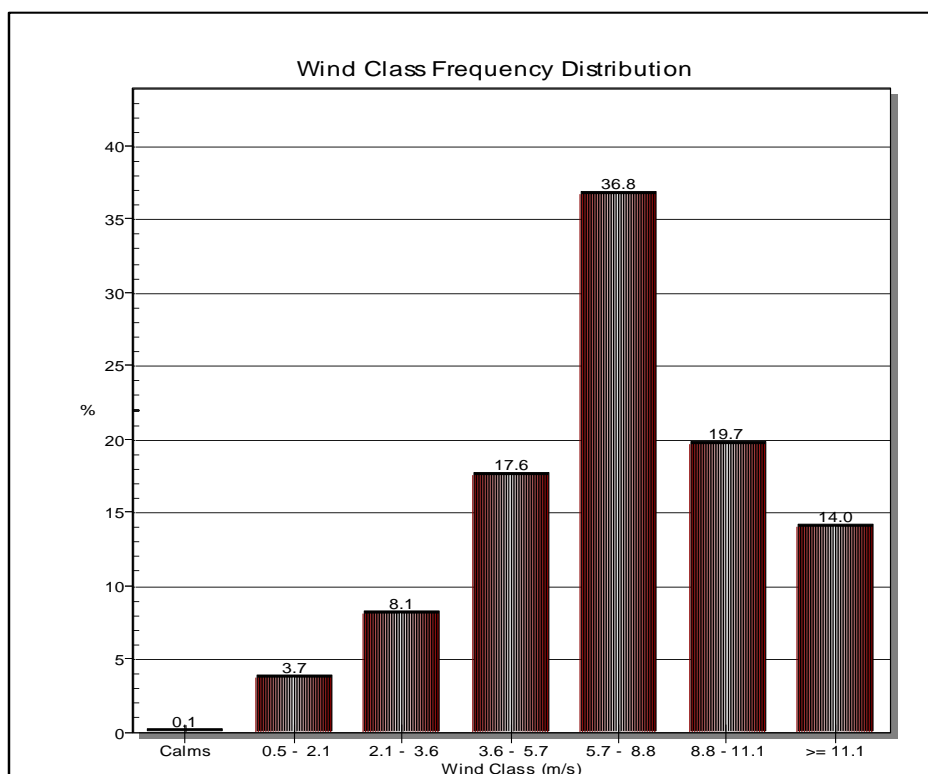


Figure 3.2: CALMET wind speed frequency

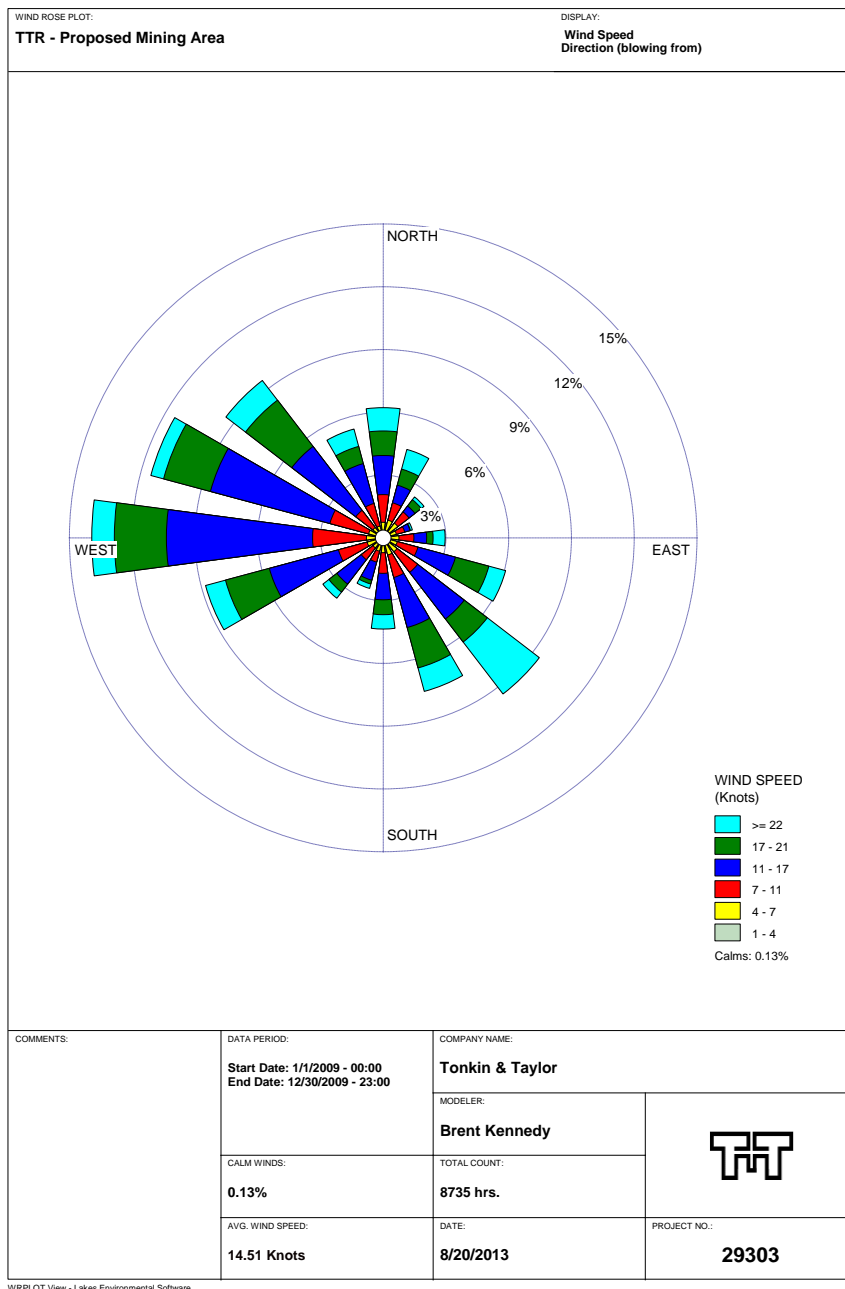


Figure 3.3: CALMET generated wind rose

4 Air quality assessment criteria

4.1 Introduction

Marine consent is required for the proposed offshore activity under the EEZ Act. In accordance with Section 39 of the EEZ Act, an Impact Assessment must be prepared to detail the scale and significance of the effects of the proposed activity may have on the environment. This air dispersion modelling study predicts the air concentrations of contaminants that would arise from discharges to air from the proposed electricity turbines on the FPSO. These air concentrations have been compared to relevant air assessment criteria, as described in the following sections.

4.2 National environmental standards

In 2004, Ambient Air Quality Standards (AAQS) for ambient (outdoor) air quality were introduced in New Zealand under the Resource Management (National Environmental Standards Relating to Certain Air Pollutants, Dioxins and Other Toxics) Regulations 2004 (NESAQ). The AAQS for the pollutants relevant to this assessment are set out in Table 4.1.

Table 4.1: Ambient air quality standards (Schedule 1 of the NESAQ)

Contaminant	Threshold concentration ($\mu\text{g}/\text{m}^3$)	Permissible excess
Particulate matter (PM ₁₀)	50 as a 24-hour mean	One 24-hour period in a 12-month period
Nitrogen dioxide	200 as a 1-hour mean	9 hours in a 12-month period
Sulphur dioxide	350 as a 1-hour mean	9 hours in a 12-month period
	570 as a 1-hour mean	Not to be exceeded any time
Carbon monoxide	10,000 as an 8-hour running mean	One 8-hour period in a 12-month period

4.3 New Zealand ambient air quality guidelines

The New Zealand Ambient Air Quality Guidelines (AAQG) were first published in 1994 and revised in 2002. There are AAQG for a range of contaminants and averaging periods not included in the AAQS. The AAQG for the pollutants relevant to this assessment are set out in Table 4.2 (noting that many of these are duplicated in the NESAQ).

Table 4.2: New Zealand Ambient Air Quality Guidelines (2002)

Contaminant	Concentration ($\mu\text{g}/\text{m}^3$)	Time average
Particulate matter (PM ₁₀)	50	24-hour
	20	annual
Nitrogen dioxide (NO ₂)	200	1-hour
	100	24-hour
Sulphur dioxide (SO ₂)	350	1-hour
	120	24-hour
Carbon monoxide (CO)	30,000	1-hour
	10,000	8-hour

4.4 World Health Organization ambient air quality guidelines

In 2006, the World Health Organization (WHO) published its first global air quality guidelines. The guidelines aim to improve air quality around the world to protect people's health and were developed by reviewing the information on the health effects of each pollutant. The WHO guidelines do not have any regulatory status in New Zealand; however they are relevant to the potential effects of air pollutants and are therefore considered for completeness. The WHO guidelines for the pollutants relevant to this assessment which differ from the AAQS and AAQG are set out in Table 4.3.

Table 4.3: World Health Organization guidelines (2006)

Pollutant	Concentration ($\mu\text{g}/\text{m}^3$)	Time average
Nitrogen dioxide (NO_2)	40	annual
Sulphur dioxide (SO_2)	20	24-hour

5 Dispersion modelling methodology

5.1 Introduction

Air dispersion modelling has been carried out using the CALPUFF non-steady state puff dispersion model. For this application, the primary advantage of the CALMET/CALPUFF suite over alternative Gaussian dispersion models (such as AUSPLUME) is its ability to simulate the effects of coastal fumigation and the differences in sensible heat flux between open water and land. For over-water situations, the Ministry for the Environment Good Practice Guide for Atmospheric Dispersion Modelling recommends the use of an advanced model (such as CALPUFF), which gives a realistic representation of the meteorology in the coastal area.

5.2 Meteorology dataset

5.2.1 Overview

Air dispersion modelling requires good meteorological information that is representative of dispersion conditions near the emission sources. For this assessment a meteorological modelling input file for CALPUFF was constructed for a single year using the associated meteorological modelling programme CALMET (v5.726).

In order to provide a sound basis for developing a meteorological data set for dispersion modelling using CALPUFF, meteorological measurements from six sites were used, for the January 2009 to January 2010 year.

The data was sourced from the following sites:

- New Plymouth AWS operated by the MetService;
- Spriggens Park, Wanganui EWS operated by NIWA;
- Stratford EWS operated by NIWA;
- Hawera AWS operated by MetService;
- Wanganui AWS operated by MetService; and
- Ohakea AWS operated by MetService.

One hour average data from these sites were incorporated into the CALMET model.

CALMET's upper air input data requirements were derived using the MM5 meteorological model. A three dimensional wind field (3D.DAT), larger than the CALMET domain, was generated from the MM5 dataset.

5.2.2 MM5 dataset

The Penn State Mesoscale Model (MM5) is a limited-area, nonhydrostatic, terrain-following sigma-coordinate model designed to simulate or predict mesoscale atmospheric circulation. It has been developed at Penn State and NCAR as a community mesoscale model and is continuously being improved by contributions from users at several universities and government laboratories.

Since MM5 is a regional model, it requires an initial condition as well as lateral boundary condition to run. To produce lateral boundary condition for a model run, one needs gridded data to cover the entire time period that the model is integrated.

A 2009 MM5 dataset for the area surrounding the proposed iron ore mining area was supplied by Atmospheric Studies Group at TRC Environmental in the United States. TRC Environmental has developed MM5 datasets tiles covering all New Zealand.

5.2.3 CALMET setup

CALMET is the meteorological model component of the CALPUFF model and is used to develop 3D wind fields for use in CALPUFF. CALMET also contains algorithms to compute the cloud cover and ceiling height for each CALMET grid point from the relative humidity and liquid water data contained in the MM5 dataset.

For this assessment CALMET has used the following data sources:

- Local surface meteorological data;
- Terrain and land use data; and
- Upper air data developed by MM5 (supplied by TRC).

Meteorological grid points were defined every 500m in the north-south and east-west directions in the 75 x 75 km meteorological model domain. The centre of the CALMET modelling grid was 276.228, 5591.415 km (UTM coordinates).

Variations of dispersion conditions with height were modelled using 12 vertical levels with grid points at 20m, 40m, 50m, 100m, 150m, 170m, 200,250m, 300, 500m, 1000m, 2000m, and 3000m above ground level.

Near the surface (<60 m) a greater weighting was given to wind speed and direction observations from the four meteorological monitoring site than to the wind field predicted by MM5.

5.3 CALPUFF model settings

5.3.1 Modelling Domain

A modelling domain of 52 x 40 km (2080 km²) was used for the air dispersion predictions. The bulk modelling domain is ocean, with land and some hills to the east of the proposed mining area. A 100 metre gridded receptor data file has been incorporated in the model.

5.3.2 Building wake effects

Airflow around buildings is often very complicated and may create zones of strong turbulence and downward mixing on the lee side of a building (Figure 5.1). This effect is known as building downwash. In such cases, the entrainment of exhaust gases released by short stacks or rooftop vents in the wake of a building can result in much higher ground-level concentrations close to the source than the model would otherwise predict. A well-designed stack can minimise building downwash effects.

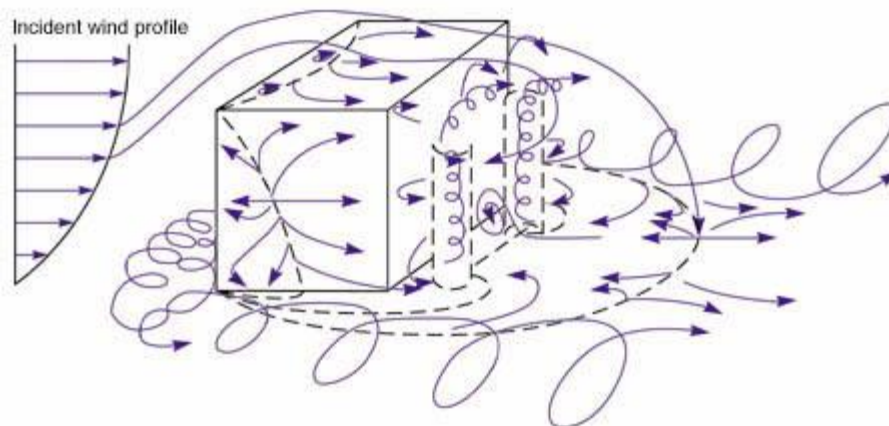


Figure 5.1: Schema of the turbulence created behind a building

For this assessment, the Plume Rise Model Enhancements (PRIME) has been used to simulate building downwash effects. This is the method recommended in the Ministry for the Environment Good Practice Guide for Dispersion Modelling (MfE, 2004) to account for building downwash effects.

There will be various cranes and other structures on the main deck of the FPSO. The main structure that has been considered with respect to building downwash effects is the wheelhouse and accommodation block.

5.3.3 Dispersion modelling parameters

Key CALPUFF dispersion modelling parameters selected for the assessment are listed below:

- Dispersion coefficients calculated internally from micrometeorological variables;
- Transitional plume rise modelled;
- The PDF (probability density function) method used for sigma-z convective boundary layer; and
- Partial plume penetration of mixed layers for area and point sources.

6 Results

The predicted maximum ground level concentrations from the dispersion modelling study are compared with the air assessment criteria in Table 6.1. Two sets of results are presented for each contaminant; the worst case offshore and onshore concentrations. The offshore result is the maximum predicted concentration anywhere in the modelling domain and occurs overwater near the FPSO. The onshore result is the maximum concentration that is predicted to occur on land when the FPSO is at the closest point to land (12 nautical miles offshore). The maximum predicted concentration onshore will decrease as the FPSO moves further away from the coast.

Concentration contour plots are shown in Appendix B.

Table 6.1: Maximum predicted ground level concentrations

Contaminant	Time average	Maximum Ground Level Concentration ($\mu\text{g}/\text{m}^3$)		Air assessment criterion ($\mu\text{g}/\text{m}^3$)
		Offshore	Onshore	
Particulate matter (PM10)	24 hour	1.2	0.2	50
	Annual	0.03	0.0086	20
Nitrogen dioxide	1 hour (99.9%)	94	26	200
	24 hour	43	8	100
	Annual	1.1	0.32	40
Sulphur dioxide	1 hour (99.9%)	211	61	350
	24 hour	97	17	120 (20*)
Carbon monoxide	1 hour (99.9%)	1.92	0.55	30,000
	8 hour	1.51	0.42	10,000

**Note: 20 $\mu\text{g}/\text{m}^3$ is the WHO 24-hour average guideline, which does not currently have any regulatory status in New Zealand.*

7 Conclusions

The maximum predicted ground level concentrations of contaminants anywhere in the modelling domain are within the relevant New Zealand air quality standards and guidelines. These maxima are predicted to occur over water close to the FPSO. The maximum predicted concentration of SO₂ as a 24-hour average exceeds the WHO ambient air quality guideline, however it is noted that this guideline is based on exposure over a 24-hour period and it is unlikely that there would be people exposed for this period of time given that the location is over water.

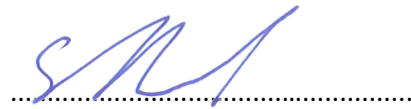
The maximum ground level concentrations predicted to occur on land of all contaminants considered are well within the relevant New Zealand air quality standards and guidelines. The maximum predicted ground level concentration of SO₂ on land approaches, but does not exceed, the 24-hour average WHO guideline.

8 Applicability

This report has been prepared for the benefit of Trans-Tasman Resources Ltd with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose without our prior review and agreement.

Tonkin & Taylor Ltd

Authorised for Tonkin & Taylor Ltd by:



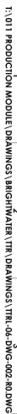
Gerard Bird

Project Director

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Appendix A: FPSO vessel proposed arrangement



TTR
Trent University

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DESIGN ENG	15/06/2013
DRAFTING	15/06/2013
PRODUCTION	15/06/2013
PROJECT APPROVAL	15/06/2013

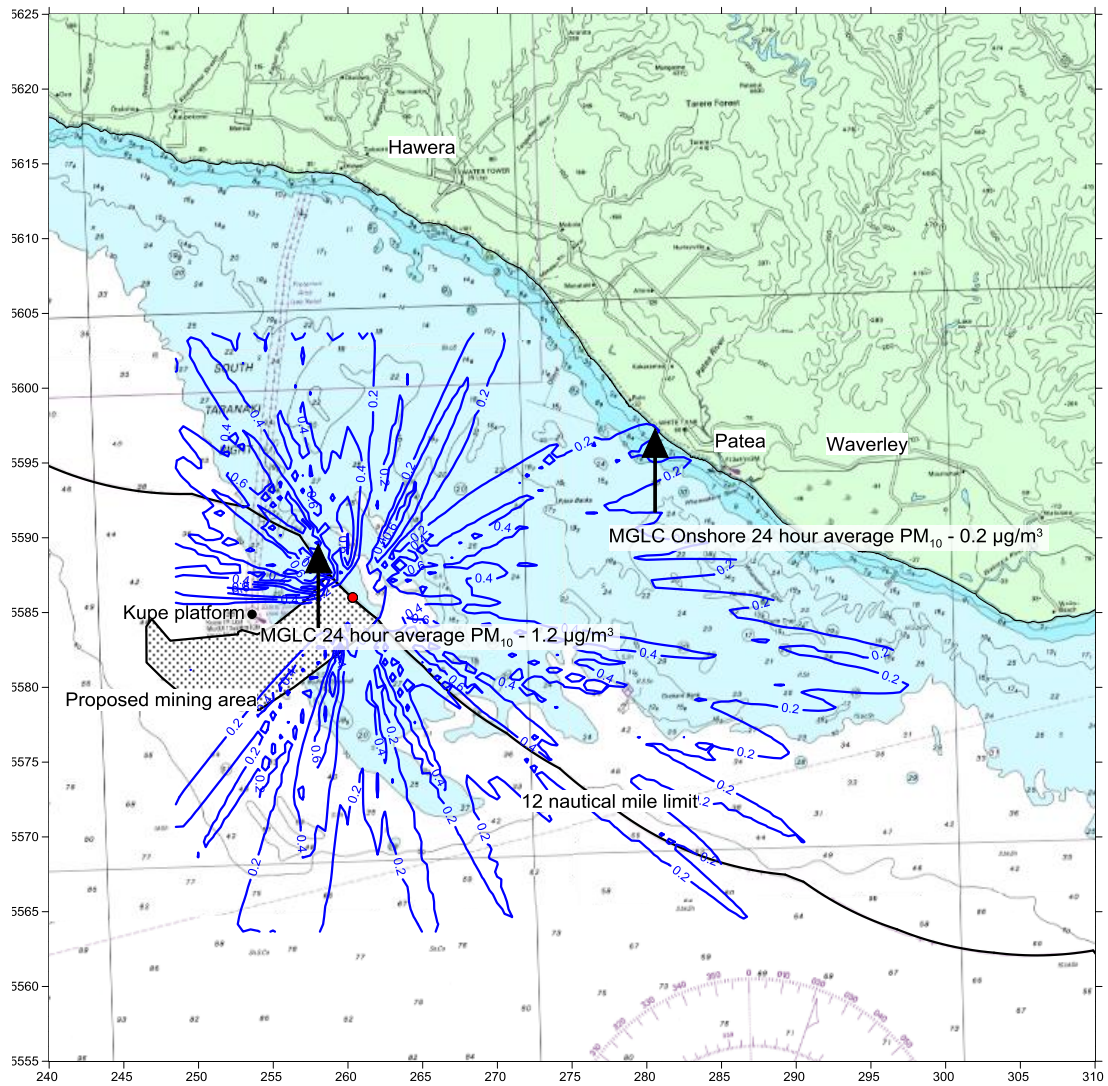
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Appendix B: Concentration contour plots

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CALPUFF Concentration Contours - 2009

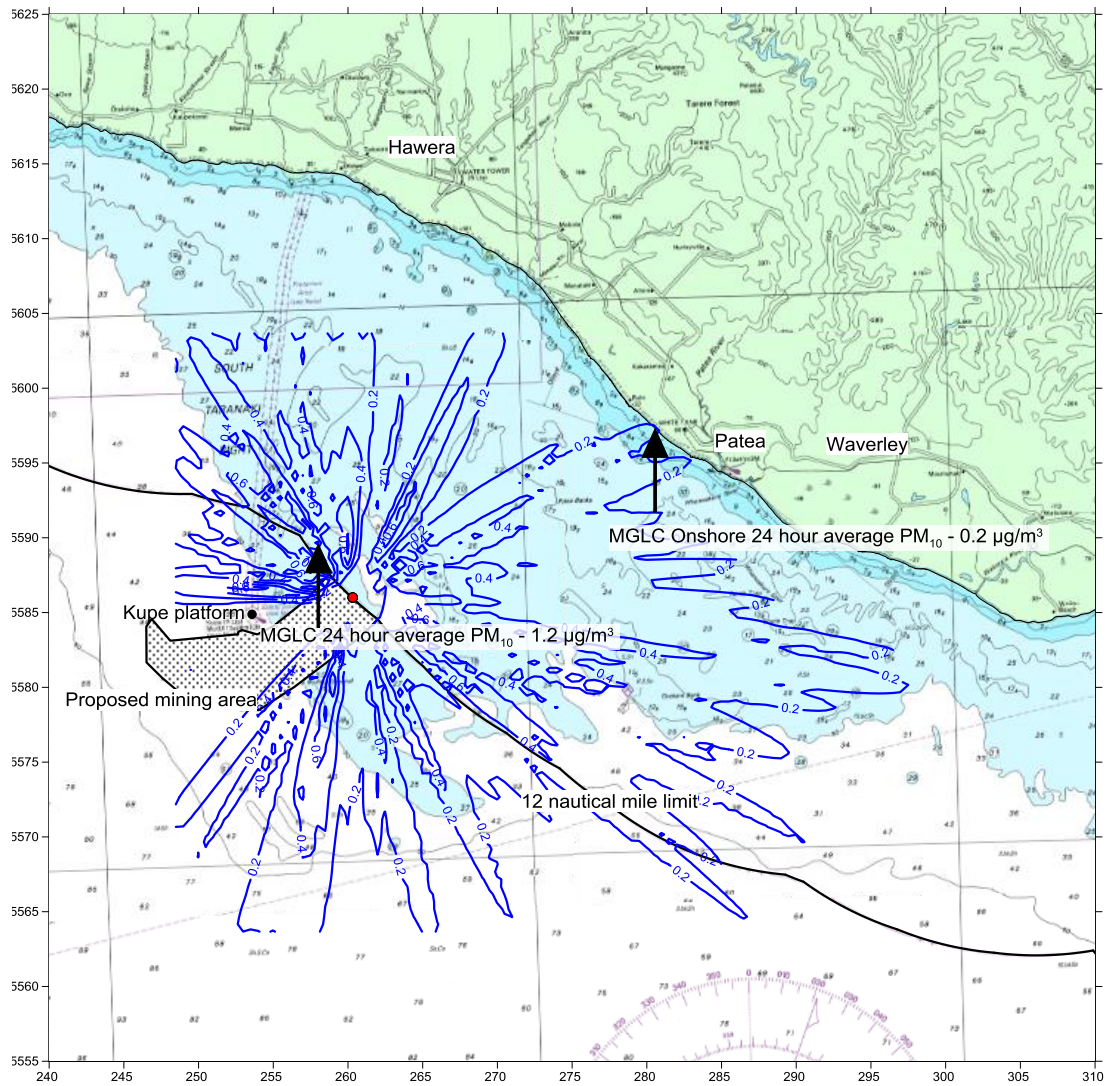
MGLC PM₁₀ (µg/m³ - 24 hour average)



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CALPUFF Concentration Contours - 2009

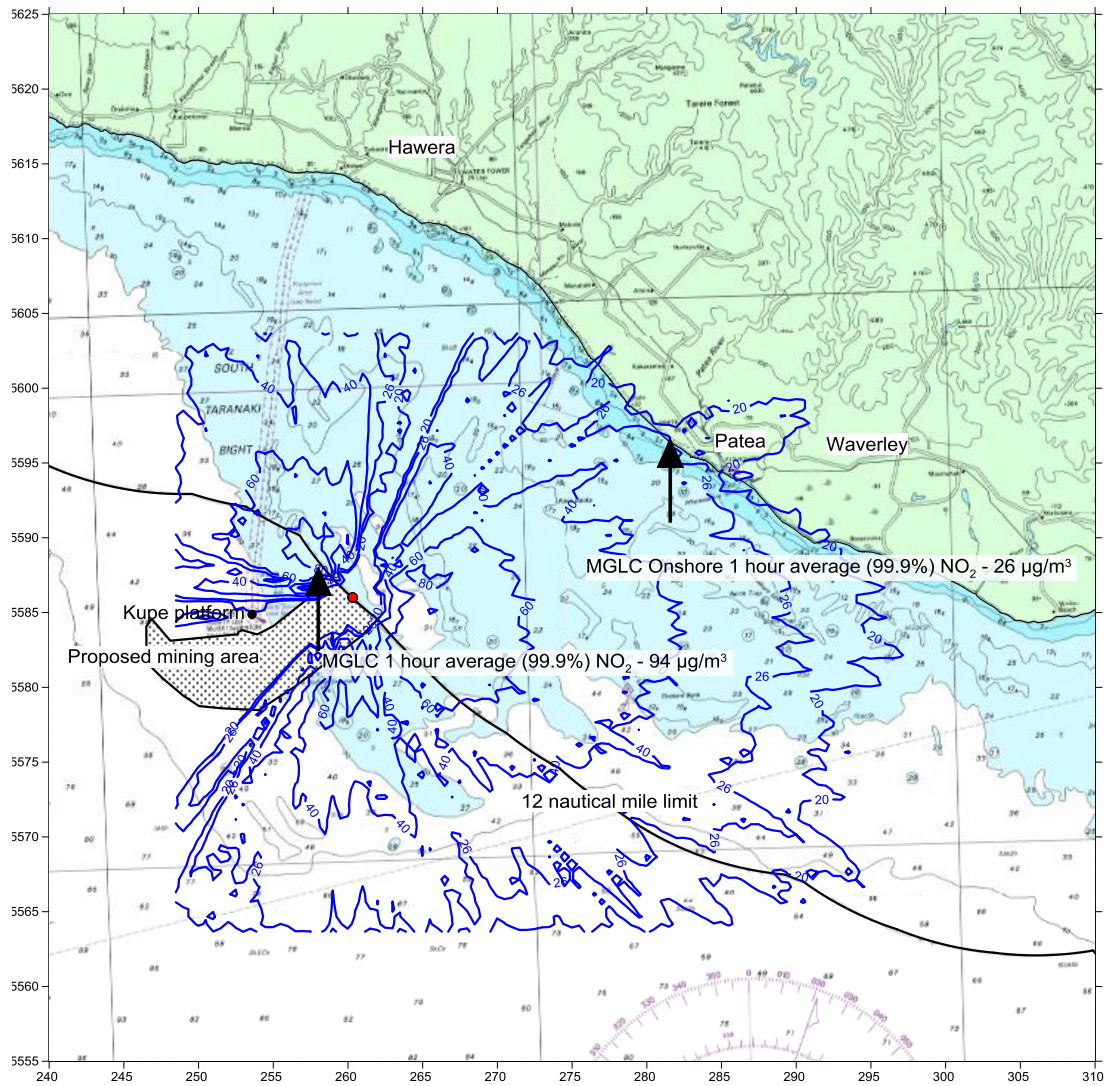
MGLC PM_{10} ($\mu\text{g}/\text{m}^3$ - 24 hour average)



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CALPUFF Concentration Contours - 2009

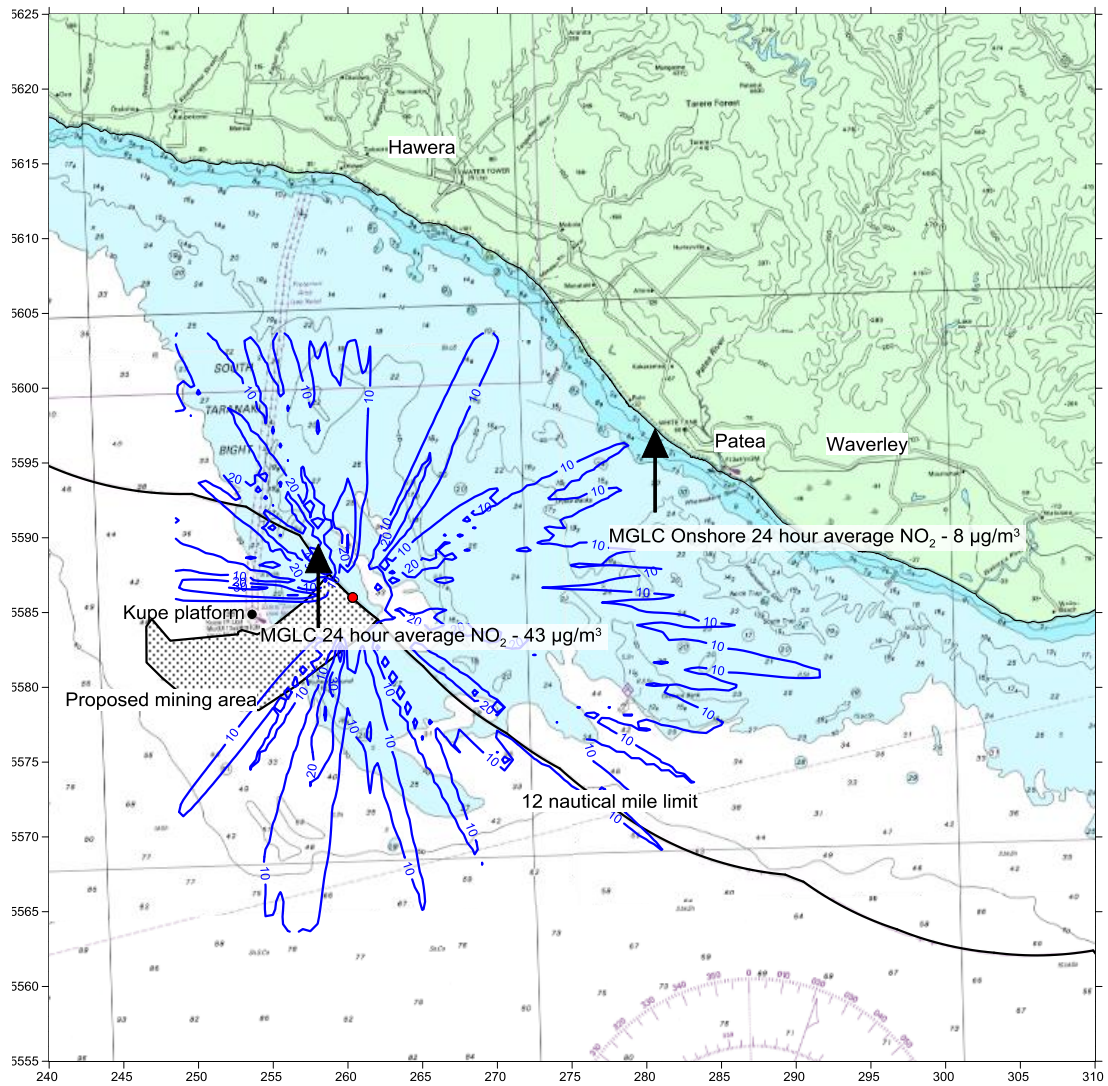
MGLC NO_2 ($\mu\text{g}/\text{m}^3$ - 1 hour average 99.9%)



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CALPUFF Concentration Contours - 2009

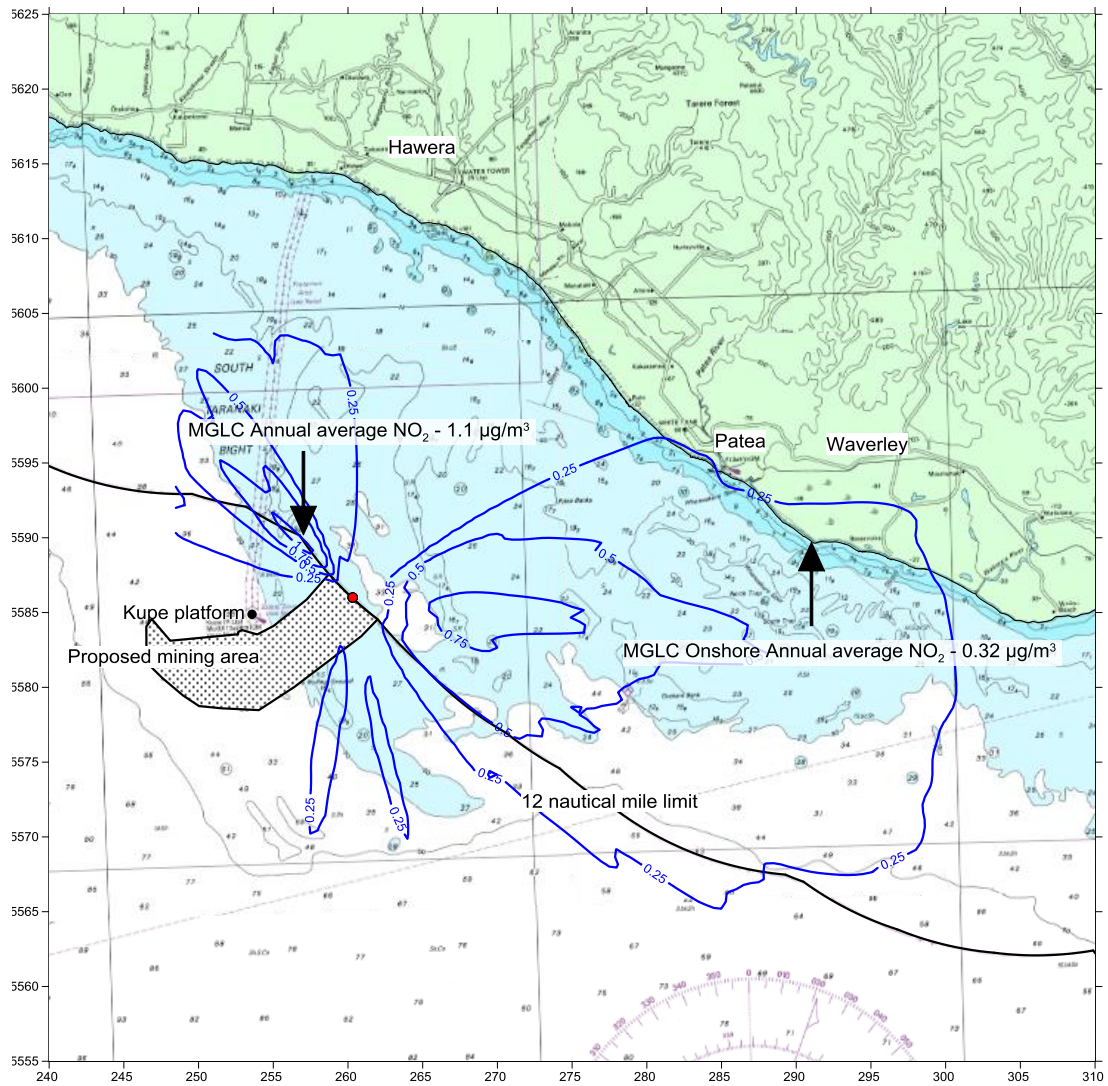
MGLC NO_2 ($\mu\text{g}/\text{m}^3$ - 24 hour average)



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CALPUFF Concentration Contours - 2009

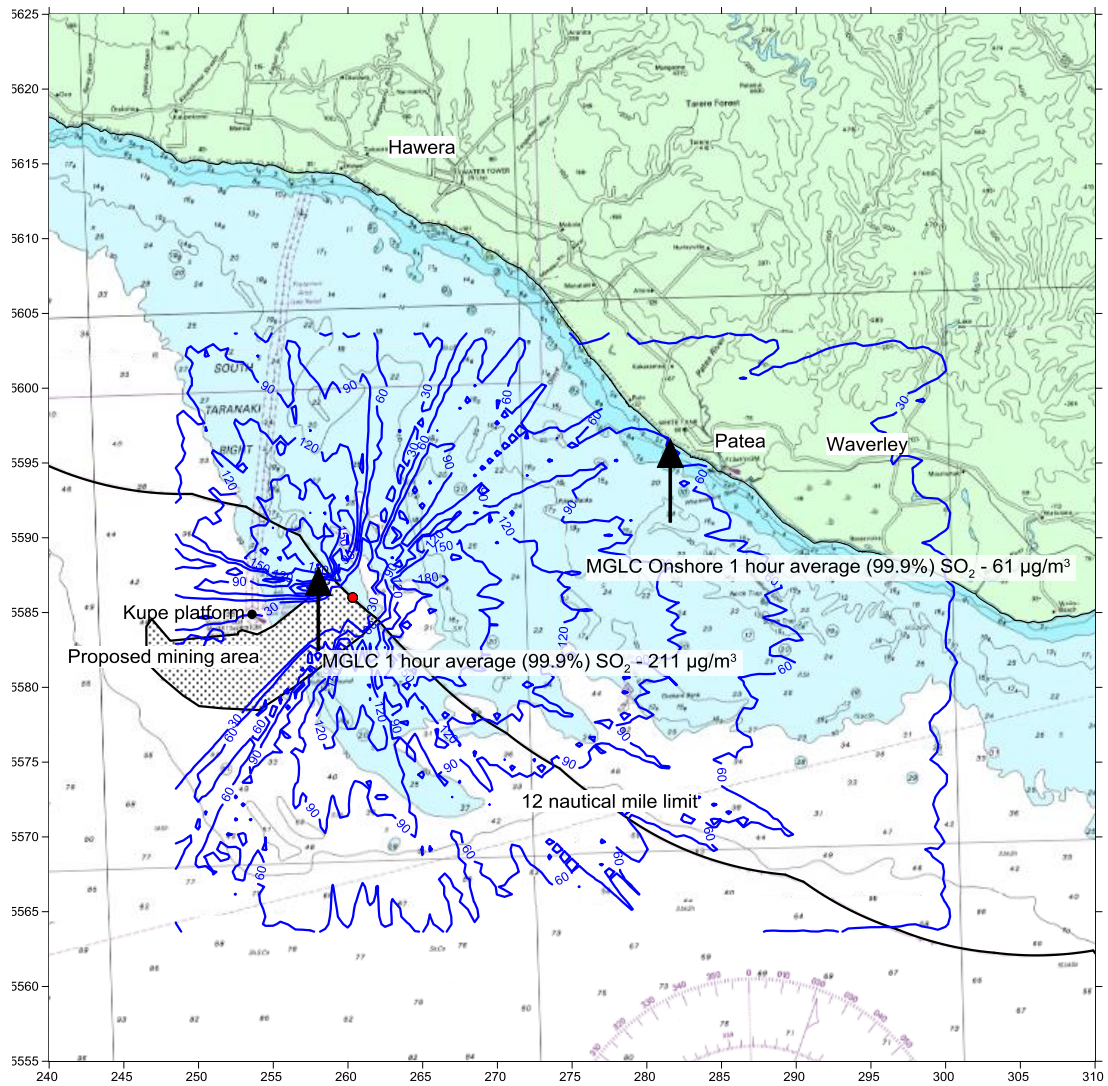
MGLC NO_2 ($\mu\text{g}/\text{m}^3$ - Annual average)



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CALPUFF Concentration Contours - 2009

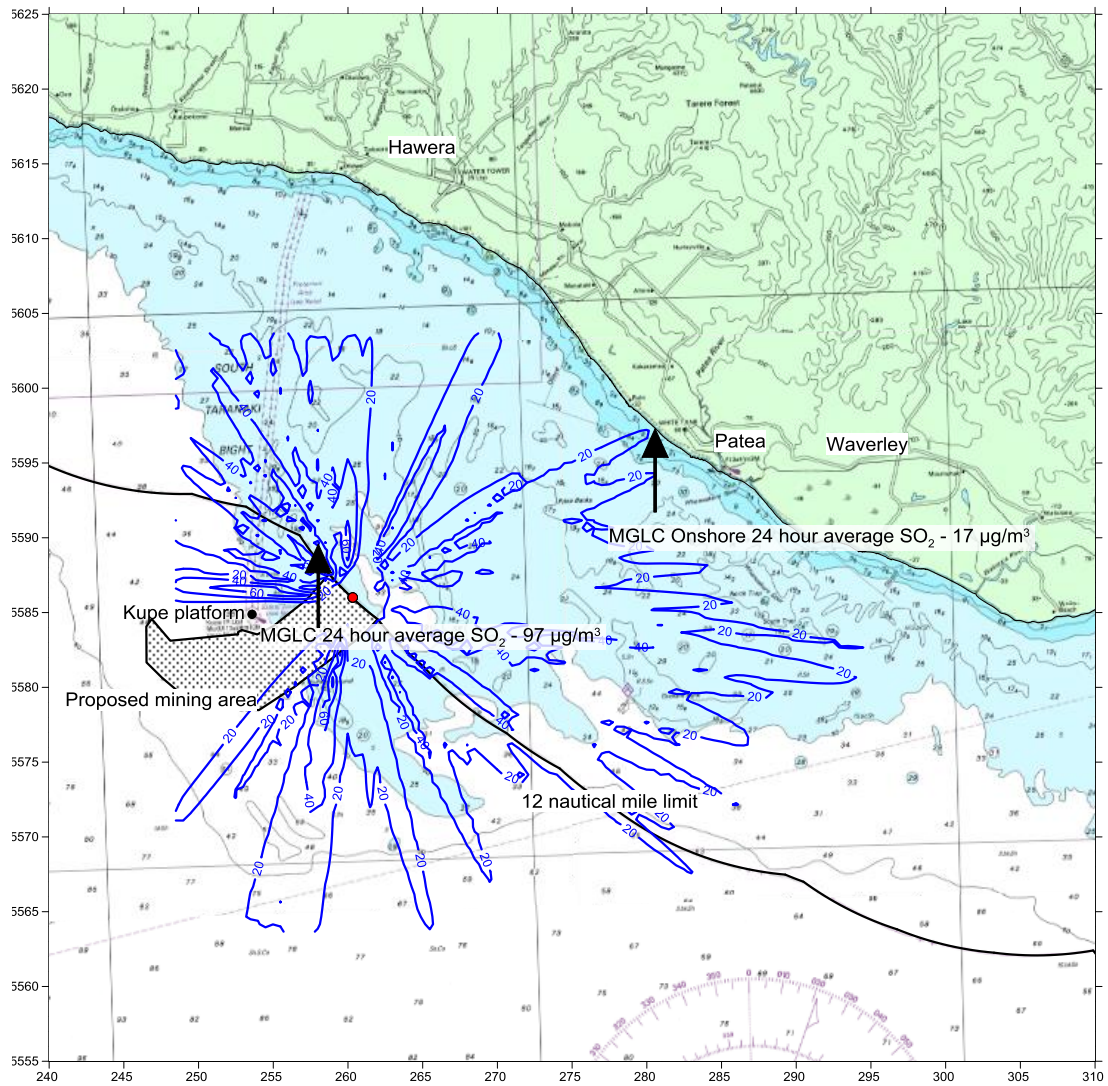
MGLC SO_2 ($\mu\text{g}/\text{m}^3$ - 1 hour average 99.9%)



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CALPUFF Concentration Contours - 2009

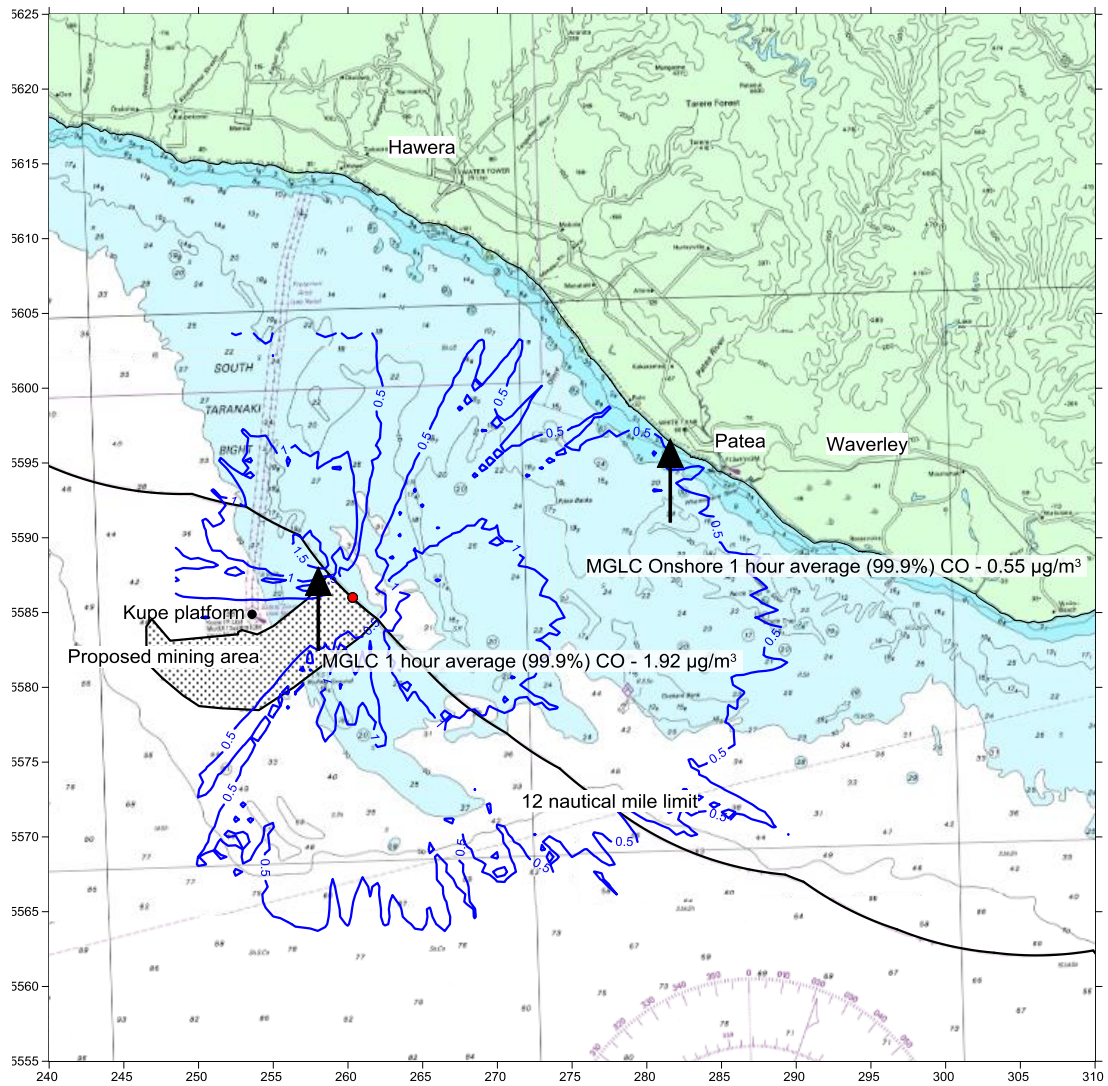
MGLC SO_2 ($\mu\text{g}/\text{m}^3$ - 24 hour average)



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CALPUFF Concentration Contours - 2009

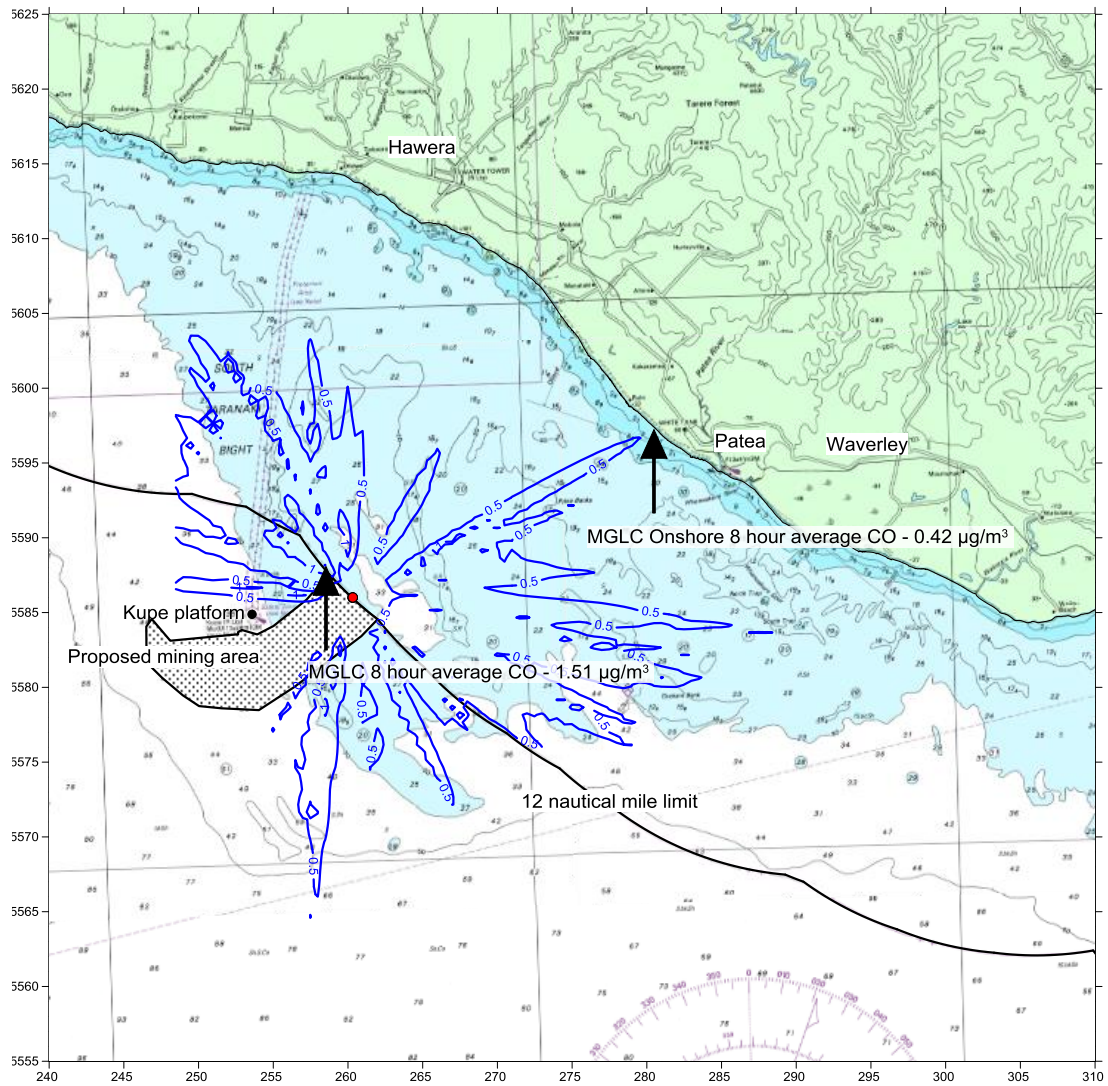
MGLC CO ($\mu\text{g}/\text{m}^3$ - 1 hour average 99.9%)



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CALPUFF Concentration Contours - 2009

MGLC CO ($\mu\text{g}/\text{m}^3$ - 8 hour average)



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