# AIR QUALITY MODELLING FOR THE EXPANSION OF THE KEMERTON INDUSTRIAL ESTATE

**Prepared for**

**Air Assessments**

**by**

**Environmental Alliances Pty Ltd**

**November 2010**

***Disclaimer and Limitation***

Environmental Alliances Pty Ltd (EAPL) will act in all professional matters as a faithful adviser to the Client and exercise all reasonable skill and care in the provision of its professional services.

This report has been prepared on behalf of and for the exclusive use of the Client, and is subject to and issued in accordance with the agreement between the Client and EAPL. EAPL accepts no liability or responsibility whatsoever for it in respect of any use of or reliance upon this report by any third party.

This report is based on the scope of services defined by the Client, budgetary and time constraints requested by the Client, the information supplied by the Client (and its agents), and methods consistent with the preceding.

EAPL has not attempted to verify the accuracy or completeness of the information supplied.

Copying of this report or parts of this report is not permitted without the authorisation of the Client or EAPL.

**Client: Air Assessments**

| **Job No: K1168** | **Version** | **Prepared by** | **Reviewed by** | **Submitted to Client** | |
|---|---|---|---|---|---|
| **Status** | | | | **Copies** | **Date** |
| Preliminary Draft Report | 1 | DP | Air Assessments | *.doc | 1/7/2010 |
| Draft Report | 2b | DP | Air Assessments | *.doc | 10/8/2010 |
| Draft Report | 4 | DP | Air Assessments | *.doc | 23/8/2010 |
| Draft Report | 4a | DP | Air Assessments | *.doc | 1/9/2010 |
| Draft Report | 4b | DP | Air Assessments | *.doc, *.pdf | 2/9/2010 |
| Final Report | 4c | DP | - | *.pdf | 10/11/2010 |

Environmental Alliances Pty Ltd
Tel: (08) 9343 0554
Fax: (08) 9343 0079
ABN: 75 103 600 620

# TABLE OF CONTENTS

## LIST OF TABLES

## LIST OF FIGURES

## LIST OF APPENDICES

# 1. INTRODUCTION

The Kemerton Industrial Park (KIP) is 17 kilometres north-east of Bunbury (see Figure 1). The Park comprises over 5,400 hectares of land including a bushland buffer zone.

In 2007, the KIP was the subject of a strategy planning exercise which drew on the findings of 20 years' of studies to formulate a development plan for the estate. The Strategy Plan is a precursor to a formal Structure Plan and attendant rezoning of the estate to permit development envisaged by the Strategy Plan.

Studies which informed the Strategy Plan were noise, air quality and risk modelling as presented in Woodward Clyde (1997). This study assumed an expanded core for the industrial estate as proposed at that time with a matching expanded buffer. It presented results from noise modelling, sulphur dioxide emissions and risk profiles for a range of industries distributed through the estate to produce cumulative impact contours, assessing whether and how these contours fitted the estate buffer and whether they met EPA criteria at buffer boundaries.

Since 1997, further investigations and reviews have led to a reduction in the size of the estate core which have been reflected in the boundaries in a recently completed Strategy Plan (Thompson Mcrobert Edgeloe 2009).

# 2. STUDY OBJECTIVE

To assist in developing the Structure Plan, Landcorp and the Department of State Development (DSD) are seeking updated air quality modelling for a suite of conceptual industries located within the reduced KIP industrial core as defined in the 2007 Strategy Plan. The objective of the modelling is to predict zones of gaseous emission, particulate and odour impact from a mix of generic sources located within the KIP industrial core to:

- Determine the adequacy or otherwise of the estate buffer to contain emission impacts within Environmental Protection Authority (EPA) criteria; and
- Guide distribution of high, medium and low emission impact industries within the industrial core.

The location and types of generic sources to be modelled were nominated by Landcorp on the basis of those types of industries likely those that support existing south-west industries and strengthen the economic base of the region by adding value to primary and secondary resources.

The three development scenarios for which air emissions have been modelled in this report are:

- Existing industry (base case);
- Existing industry and approved future industry; and
- Existing industry, approved future industry and numerous hypothetical future industries, representing a "mature" industrial estate.

The air emissions modelled for each scenario were nitrogen oxides (NOx) – where the environmental impact defined by nitrogen dioxide (NO2), and sulphur dioxide (SO2).

Odour from the existing Water Corporation Waste Water Treatment Plant (WWTP) also modelled as a stand-alone indicator of existing odour levels.

An assessment of impacts was made by comparing predicted cumulative ground level concentrations with criteria typically specified by the EPA for acceptable air quality impacts to sensitive locations.

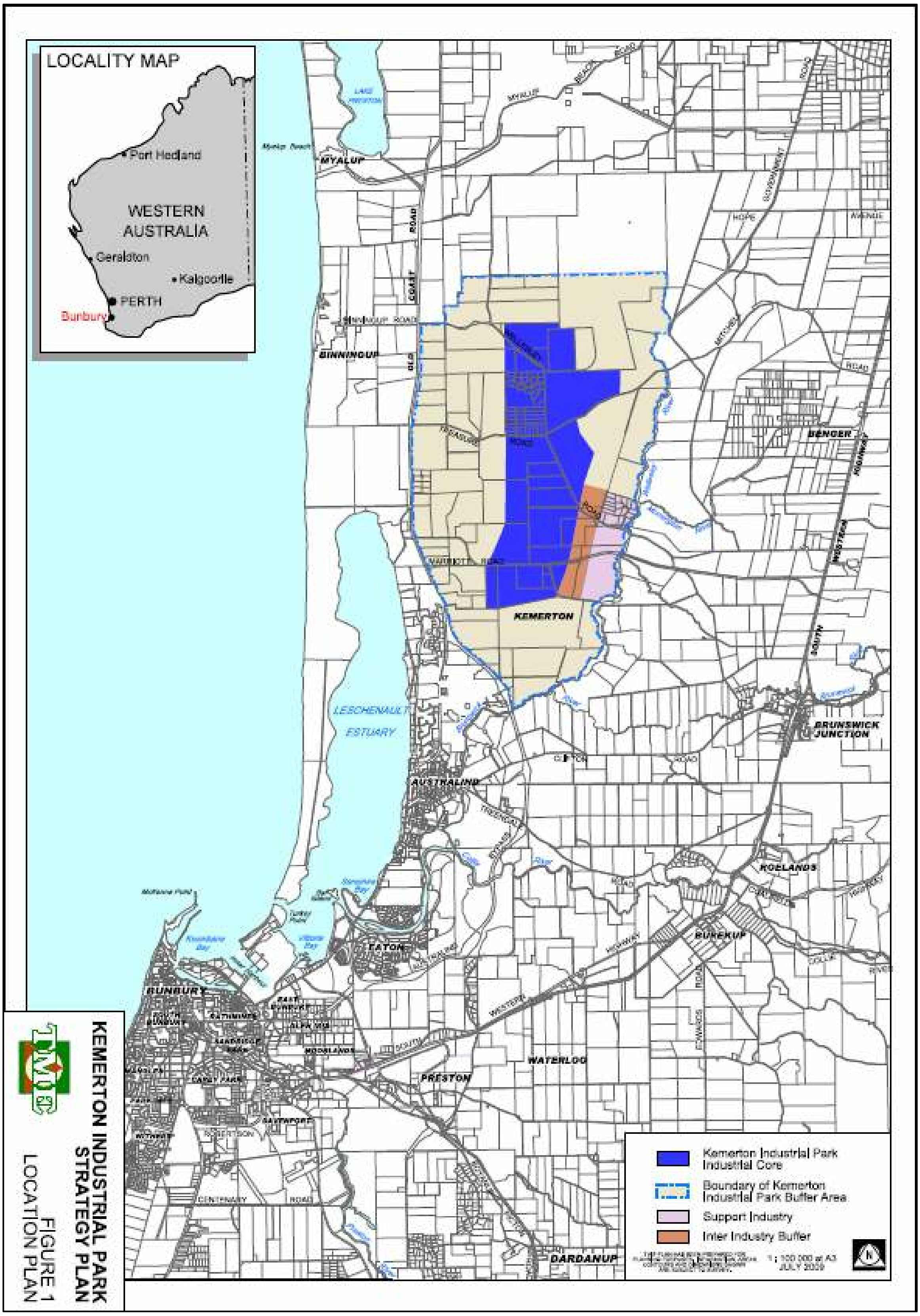



**Figure 1 Location of Kemerton Industrial Park**

## 3. SELECTION OF DISPERSION MODEL

For modelling air emissions from sources within Kemerton, the following dispersion processes are considered important:

- Surface dispersion from low-level sources which will be dependent on the local surface winds. Of importance for odorous sources is that stagnation or ponding of the air may occur to the east of the range of sand hills in the low lying area there; and
- Convective dispersion processes for medium to tall stacks.

The US Environmental Protection Agency's (USEPA's) CALPUFF model was used for these types of sources. CALPUFF (and its meteorological pre-processor CALMET) is the USEPA's preferred model for assessing the long range transport of pollutants. It is also can be used for near-field applications involving complex meteorological conditions such as when there is dispersion over land and sea..

For tall stacks and buoyant plumes TAPM (The Air Pollution Model) could be an alternative model as it is considered very good for modelling convective dispersion and is shown to be reasonably accurate in modelling the airflow and dispersion around elevated terrain in verification studies undertaken by CSIRO. TAPM's ability to correctly model emissions from low-level sources during calm and light wind conditions is, however, more problematic. Additionally for short stacks in the region up to 50m it is considered that TAPM may be over-predicting the ground level concentrations, particularly at night. TAPM may be preferred for the prediction of dispersion of taller stacks if able to be supported by ambient monitoring data to enable verification.

Other Gaussian models notably AUSPLUME were not selected as AUSPLUME is not theoretically able to model dispersion below winds of about 1 m/s and is likely to over-predict concentrations under these conditions at distances of greater than several kilometres. Also, AUSPLUME cannot accurately model convective conditions for stacks less than 100m high and has a very simplistic treatment of plume dispersion over elevated terrain.

There may be some effect on plume rise and dispersion during the onset of summer-time sea breezes from the formation of the Thermal Internal Boundary Layer (TIBL) that occurs when onshore winds flow over hot land surfaces. The TIBL is important for tall stacks and/or very buoyant plumes and can lead to fumigation of the plume at distances of several kilometres downwind and higher ground-level concentrations than would otherwise occur for similar conditions. The KIP is, however, 5 to 8 kms from the coast and 3 to 5 km from Leschenault inlet. TIBL effects could result in some plume trapping for tall stacks and hence higher ground levels concentrations than predicted to the NE of the KIP, however this influence was considered to be minor.

## 4. METHODOLOGY

The methodology used in this assessment is as follows:

1. Review existing meteorological data collected within the Kemerton Industrial Park and identify the most suitable time period to use for dispersion modelling based on data recovery and quality.
2. Use the CSIRO's TAPM model to firstly generate meteorological data for the same period using its internal data bases of observational data.
3. Compare the meteorological data predicted by TAPM to the measured data as an indicator of data and model accuracy.
4. Develop a meteorological data set for the CALPUFF model.
5. Run the model for existing NOx and SO2 emissions for each of the three development scenarios.

# 5. REVIEW OF METEOROLOGICAL DATA

The client provided available data from the Landcorp weather station for 1995 to 2001, when the station was decommissioned. The data comprised 10-minute averages of:

- wind speed at 10m;
- wind direction at 10m;
- standard deviation in wind direction (sigma theta) at 10m;
- temperature at 10m;
- temperature at 1.5 m; and
- dew point temperature at 10m.

The weather station was located on the top of the north-south ridge line in a cleared paddock with an estimated local roughness length of about 0.2 m. The paddock was to the west of the industrial estate in the buffer and should provide data adequately representative of winds across the estate.

The data was checked for time gaps, unrealistically high/low values, plotting as time series and the plots reviewed.

There were substantial gaps in the data from about 1996 to 2000 (see details in Appendix 1). Data before 1997, while of good quality, was not considered for this study since it cannot be complemented by data from other sources for which data is available only for more recent years[1].

The most recent period in the Landcorp data containing 12 continuous months with the greatest data recovery was 1/4/2000 to 31/3/2001. This period was originally selected to be used for modelling on the basis of the most complete data recovery within the most recent 12 month period.

It appeared however, that the anemometer was probably deteriorating with time (not maintained as well as it should be) illustrated by the very high percentage of calms" – wind speeds less than 0.5 m/s being 8.6% compare to earlier years of around 1%. Even the frequency of high winds speeds seem lower than previous years.

Data from the Landcorp anemometer for the 1999 year had previously been supplied to Environmental Alliances in 2003 for modelling emissions from Simcoa. While there was 7.6% of the year missing from this data, the anemometer wind speeds did not exhibit anywhere near the same degree of under-measurement in the subsequent year.

It was therefore considered that the 1999 data was preferable for dispersion modelling purposes and the missing data filled by data from the TAPM model.

[1] For example, TAPM's prognostic data base commences in 1997; the BoM's automated weather station in Bunbury commenced operating in 1999.

A summary of the gaps in the anemometer data for which TAPM data were substituted is outlined below:

- 5/4/99 0600 – 12/4/99 0400.
- 13/6/99 1200 – 13/6/99 1800.
- 17/6/99 1400 – 2/7/99 1000.
- 3/11/99 1400 – 4/11/99 0900.
- 3/12/99 1500 – 7/12/99 1600.
- 17/12/99 0400 – 17/12/99 1100.

# 6. GEOPHYSICAL PARAMETERS FOR MODELLING

## 6.1 DOMAIN AND GRID INTERVALS

The modelling domain was sized to about 2 kms outside the outer extent of the KIP buffer.

The TAPM modelling grid was defined by 43 x 51 cells with the following nests – 20km, 10km, 3km, 1km and 300m centred on the KIP.

The CALPUFF modelling grid was defined inside the inner-most TAPM grid by 44 x 59 cells with a resolution of 250m.

## 6.2 TERRAIN HEIGHTS

The terrain heights from the nine-second (approx. 250 m) DEM data supplied by Geoscience Australia as typically used with TAPM have previously been found to be of inadequate resolution to accurately define small ridges and hills typical of the Kemerton region. Therefore, the Shuttle Radar Topography Mission (SRTM) data were used instead. These data for Australia have a resolution of approximately 90 m.

The terrain heights overlayed on an aerial photo are shown in Figure 2.

The industrial estate is mildly undulating with a small north-south ridge on the west side that is 20 to 30m higher than KIP land. It is considered unlikely that terrain (in itself) will have a substantial effect in the dispersion of air emissions from all but surface releases. For surface releases, the ridge line may induce ponding of cold air at night between the ridge and towards the Darling escarpment further to the east.

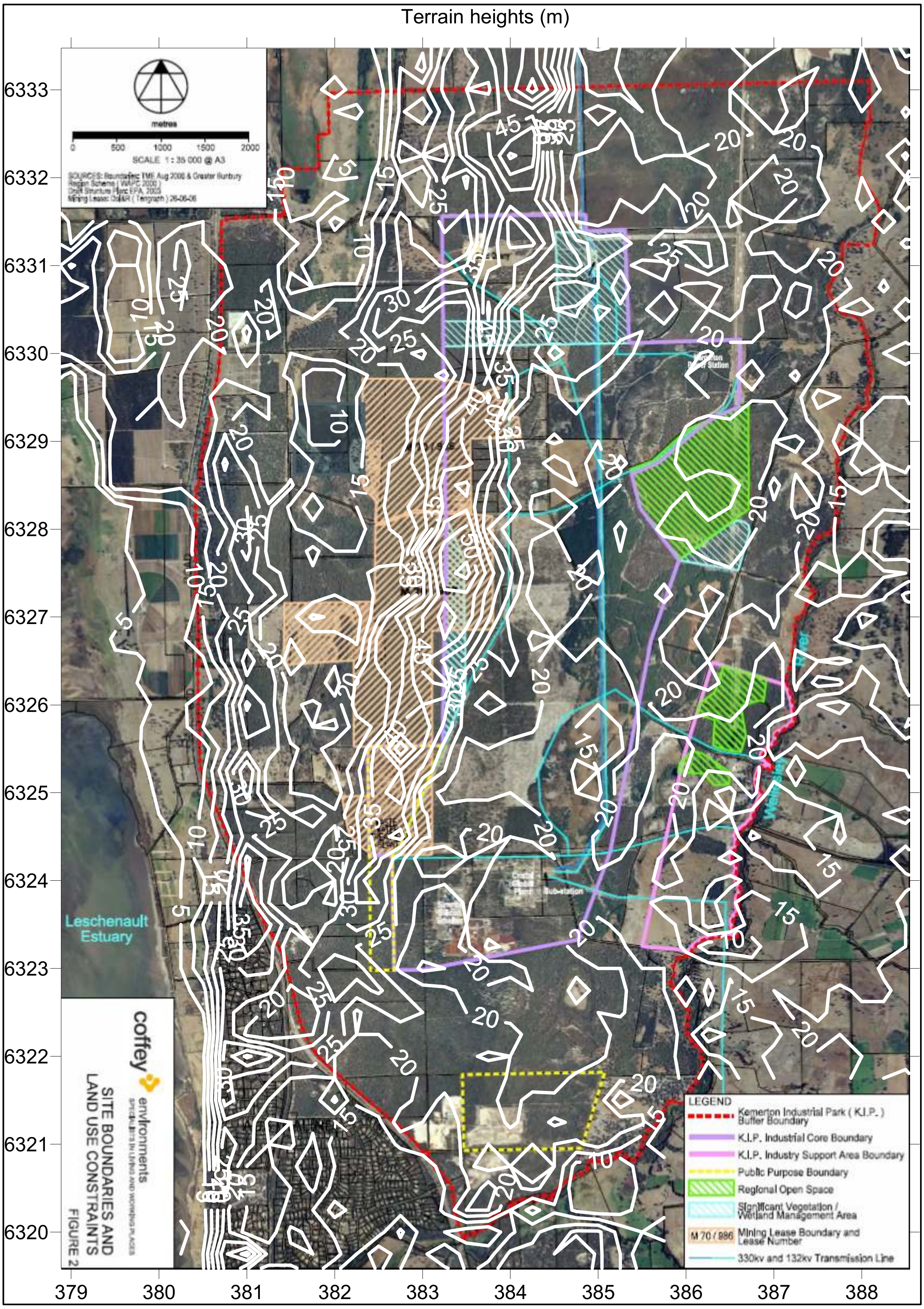



**Figure 2 Terrain heights used in modelling**

### 6.3 LAND USE CHARACTERISTICS

Land use categories were manually defined using aerial photos.

The dispersion-related parameters for each land use type are shown in Table 1.

For CALMET, the geophysical parameters include descriptions of land use type, elevations and surface characteristics (such as roughness, leaf surface area, albedo and Bowen ratio). These were specified for each grid cell comprising the modelling domain.

**Table 1 Land use categories and associated geophysical parameters**

| Description | TAPM application | | | CALMET application | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Land use description | Land Use Category | Hf parameter [c] (m) | Land use description | Land Use Category | Zo [d](m) | Albedo[e] | Bowen Ratio[f] | Leaf Area Index [g] |
| Urban residential | Urban low | 31 | 8.0 | Urban | 10 | 0.4[a] | 0.18 | 1.5 | 0.2 |
| Cleared land used for pasture | Pasture/herbfield – sparse | 26 | 0.35 | Agricultural land – unirrigated | 20 | 0.25 | 0.15 | Summer: 3<br>Autumn/Spring:1<br>Winter: 0.75 | 1[b] |
| Rangeland | n/a | n/a | n/a | Rangeland | 30 | 0.2 | 0.25 | Summer: 3<br>Autumn/Spring:1<br>Winter: 0.75 | 0.5 |
| Inlet | n/a | n/a | n/a | Bays and Estuaries | 54 | 0.001 | 0.10 | 0.0 | 0.0 |
| Large Water Body | n/a | n/a | n/a | Large Water Body | 55 | 0.001 | 0.10 | 0.0 | 0.0 |
| Barren | n/a | n/a | n/a | Barren | 70 | 0.05 | 0.3 | Summer: 4<br>Autumn/Spring:1<br>Winter: 0.75 | 0.05 |

(a) Modified from CALMET default of 1.0 which is based on cities.
(b) Modified from CALMET default of 3.0 based on less vegetation coverage for this interpretation.
(c) Hf parameter is a measure of vegetation height.
(d) Zo is the roughness length
(e) Albedo is the ratio of the reflected outgoing radiation to incoming short wave radiation
(f) Bowen ratio is the ratio of sensible to latent heat flux
(g) Leaf Area Index is the ratio of leaf area to land area (eg a value of 2 would indicate that are 2 $m^2$ of leaf area per $m^2$ of land).

## 7. TAPM-PREDICTED METEOROLOGY

### 7.1 SUMMARY OF TAPM SETUPS

TAPM V4 was run for the 1999 calendar year.

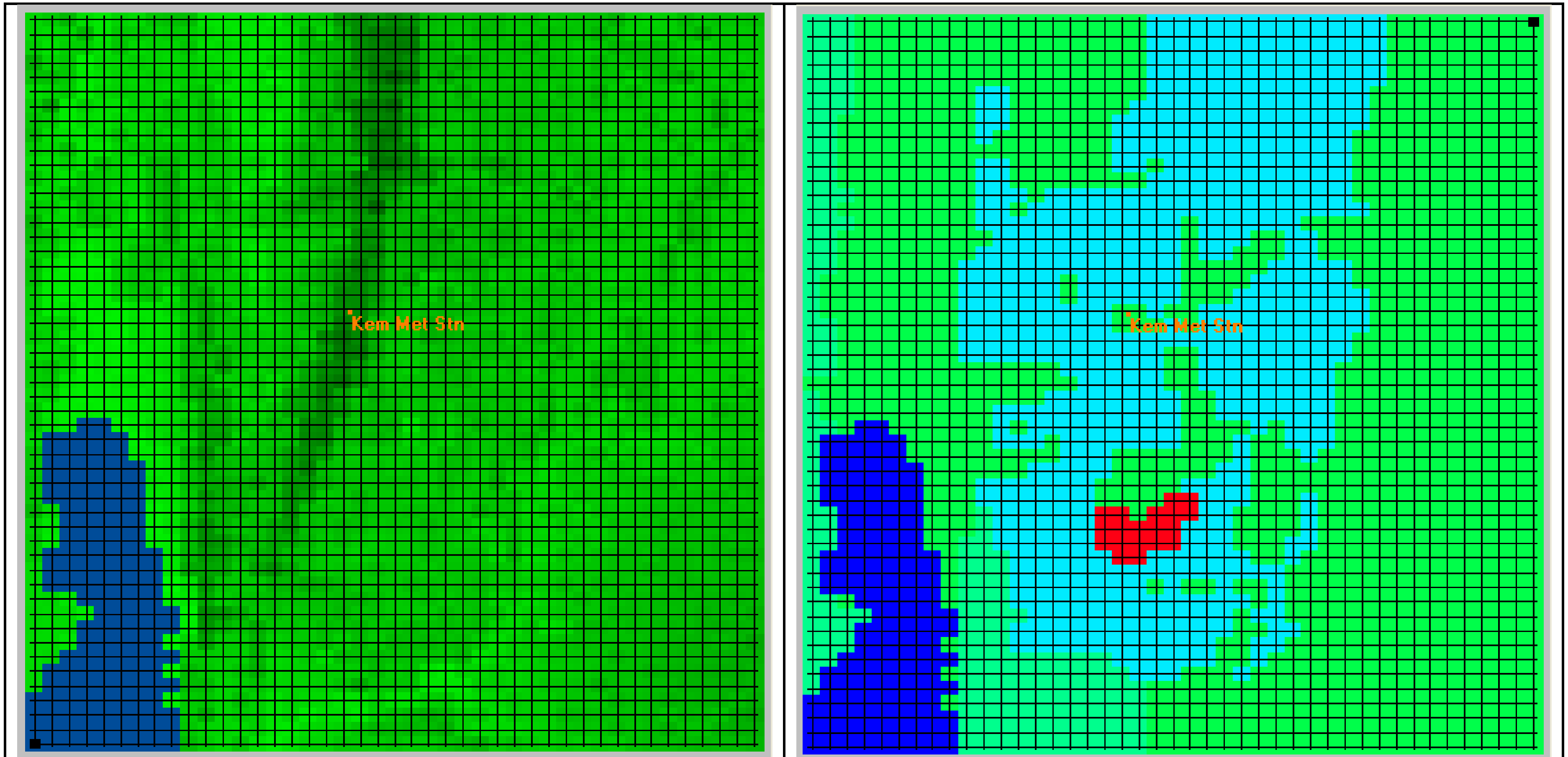
While TAPM is generally not intended to require user modification of meteorological processing settings, it appears that CSIRO when using the model apply changes to the initial deep soil moisture settings. These values affect the latent heat contribution to surface heat flux and hence the temperature profile. The default values are 0.15 kg/kg for all months of the year. For dispersion modelling in the Pilbara, 0.05 kg/kg was used for all months (Physick and Blockley 2001). For dispersion modelling at Collie, CSIRO used 0.10 for November-April, 0.20 for May-August and 0.15 for September-October after some preliminary comparisons of predicted temperatures compared to observations (Physick and Edwards 2004).

The Collie values were considered reasonably appropriate for Kemerton. It was considered that the main effect from modifying the default values to those used for Collie would be to increase the daytime heat flux and hence the strength of predicted sea-breezes.

For dispersion modelling at Kemerton, initial soil moistures were set at 0.10 for November-March, 0.15 for April, 0.20 for May-August and 0.15 for September-October.

The other TAPM setups were:

- Grid domain of 43 x 51 cells nested at 20km, 10km 3km 1km and 300m;
- Terrain heights in the inner-most grid were modified based on SRDT 90m data;
- Land uses in the inner-most grid were redefined based on aerial photography (see resulting land uses in Figure 3);
- Land /water data in the inner-most grid were redefined for consistency with the land uses;
- Soils in the inner-most grid were redefined to loamy sand; and
- No incorporation of surface wind observations.




Relative heights indicated by progressively darker shading

Category 0 – Water
Category 7 – Forest low dense
Category 13 – Shrubland mid dense
Category 31 – Urban

**Figure 3 Terrain height (left) and land use (right) illustrations as modified for TAPM inner-most grid**

## 7.2 WIND DIRECTION DATA FROM ANEMOMETER

A comparison of the TAPM-predicted versus measured10m wind directions at the Landcorp anemometer site is shown in Figure 4 below.

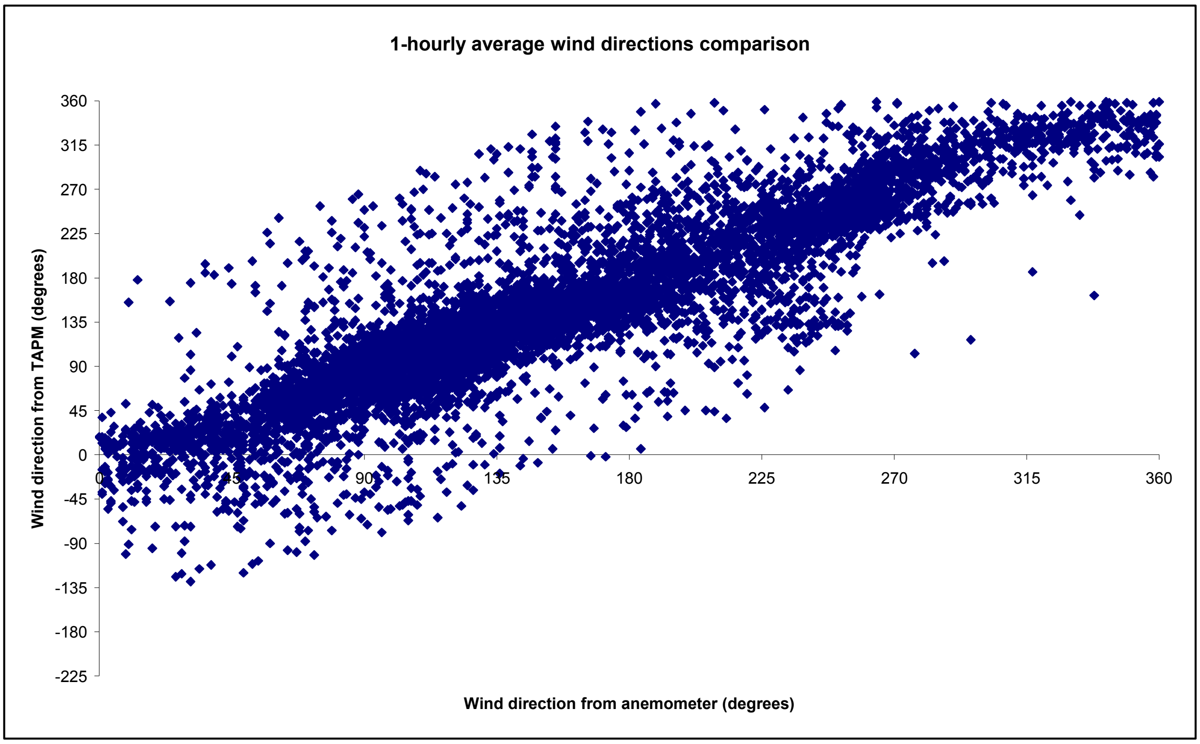



**Figure 4 TAPM-predicted versus measured wind directions at 10m**

These show generally a very good correspondence.

There is a slight inconsistency when measured winds are 240º and TAPM-predicted winds are around 90 - 130º and outside the normal range of scatter. It is thought that this is due to TAPM's timing of the predicted sea breeze being an hour or two late. Given the relatively few number of data points that exhibit this anomaly, it was considered that it would not significantly affect modelling results for the purpose of this study.

## 7.3 WIND SPEED DATA FROM ANEMOMETER

A comparison of the predicted versus measured 10m wind speeds at the Landcorp anemometer site is shown in Figure 5 below.

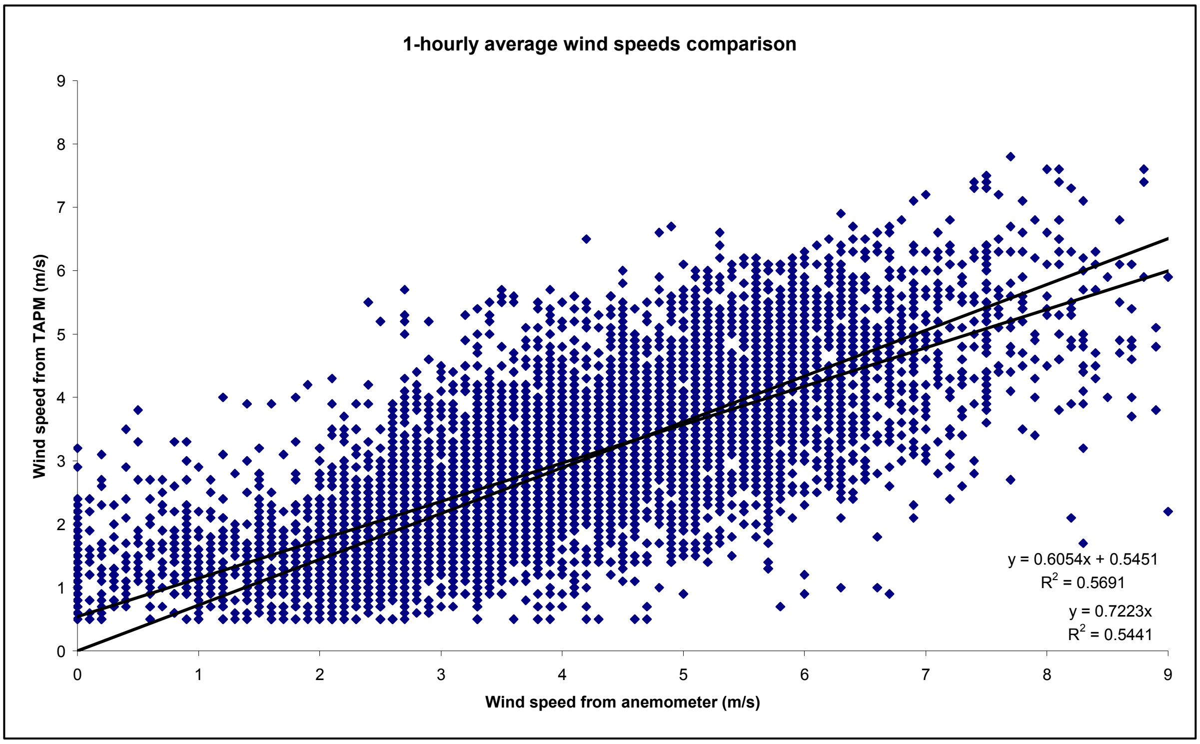



**Figure 5 TAPM-predicted versus measured wind speeds at 10m**

The TAPM-predictions show lower overall wind speeds except where the measured wind speeds approach zero. Previous experience is that TAPM V4 over-predicts the wind speed for low actual wind speeds. The difference between the TAPM and measured wind speeds around calms is therefore exaggerated by the relatively high stalling threshold of the anemometer. Also, it is typical for TAPM to under-predict high wind speeds.

To construct a complete annual wind file without data gaps for modelling, the 7.6% of missing observations in the wind speed data ($WS_a$) were filled with TAPM-predicted wind speeds ($WS_T$) adjusted as follows:

$$WS_a = \mathrm{Max}(1.65\ WS_T - 0.9,\ 0) \qquad (WS_T \leq 4.6\ \mathrm{m/s})$$

$$WS_a = 1.38\ WS_T \qquad (WS_T > 4.6\ \mathrm{m/s}) \qquad \textbf{Equation 1}$$

where $WS_a$ is the adjusted wind speed and $WS_T$ is the TAPM-predicted wind speed.

Appendix 1 contains an annual wind rose using the combined data.

## 7.4 TEMPERATURE DATA FROM WEATHER STATION

A comparison of the predicted versus measured 10m ambient temperatures at the Landcorp anemometer site is shown in Figure 6 below.

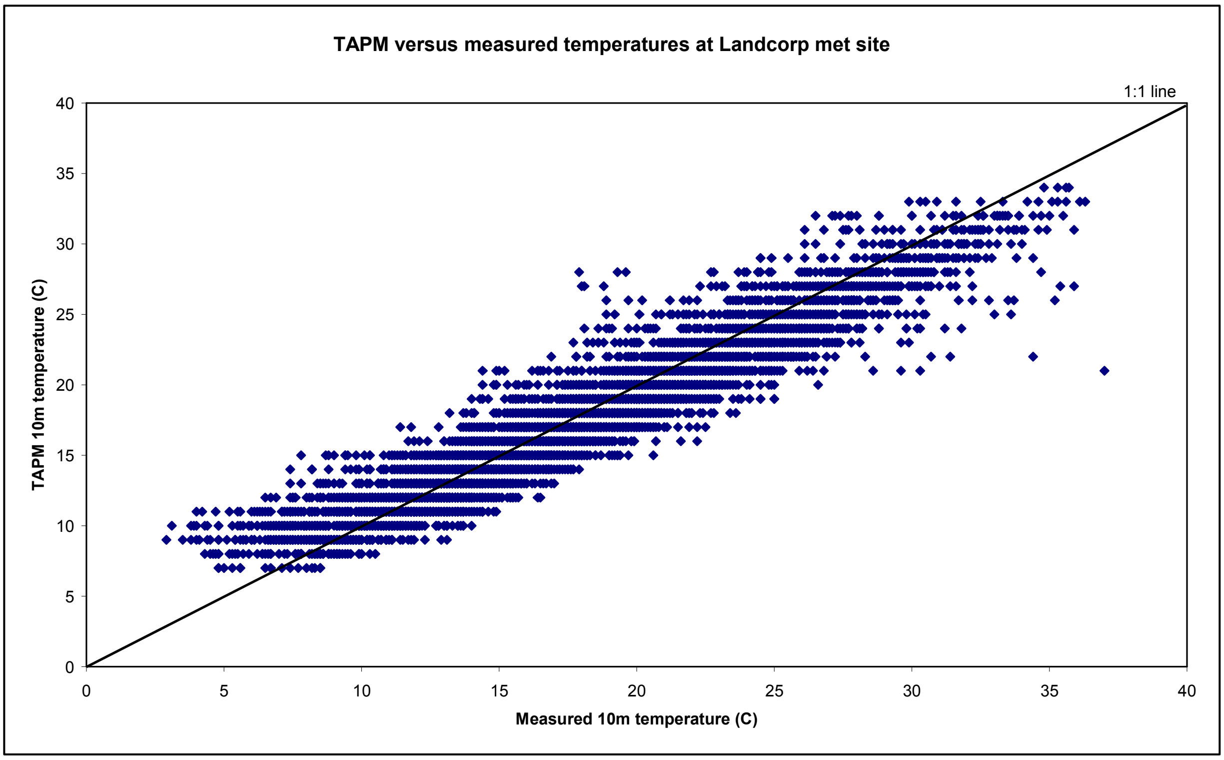



**Figure 6 TAPM-predicted versus measured temperatures at 10m**

These show a good correspondence with the TAPM-predicted temperatures slightly higher at the low end of the range and slightly lower at the high end of the range. The TAPM-substituted data were considered acceptable for the CALPUFF modelling.

## 7.5 CLOUD DATA

Cloud observations were obtained from Perth Airport as it was the only site nearby with measurements around the clock. Other Bureau of Meteorology sites such as Harvey and Donnybrook were also incorporated however they consist of observations only at 0900 and 1500 hours.

The Perth Airport observations were combined with those from Harvey and Donnybrook and further slightly modified by assuming that cloud was 8 oktas during measured rainfall at Bunbury[2] and subsequently smoothed over hours when there was no cloud by limiting changes to 2 oktas/hour to compensate for periodic missing observations from the measured data. The resulting cloud data were used for CALPUFF modelling.

An alternative to the observations was to use the TAPM-predicted data. This was not done however, as a comparison at Perth Airport indicates that TAPM significantly under-predicted the cloud amounts, as shown in the cloud frequency distribution in Figure 7.

[2] Automatic weather station data commenced from May 1999.

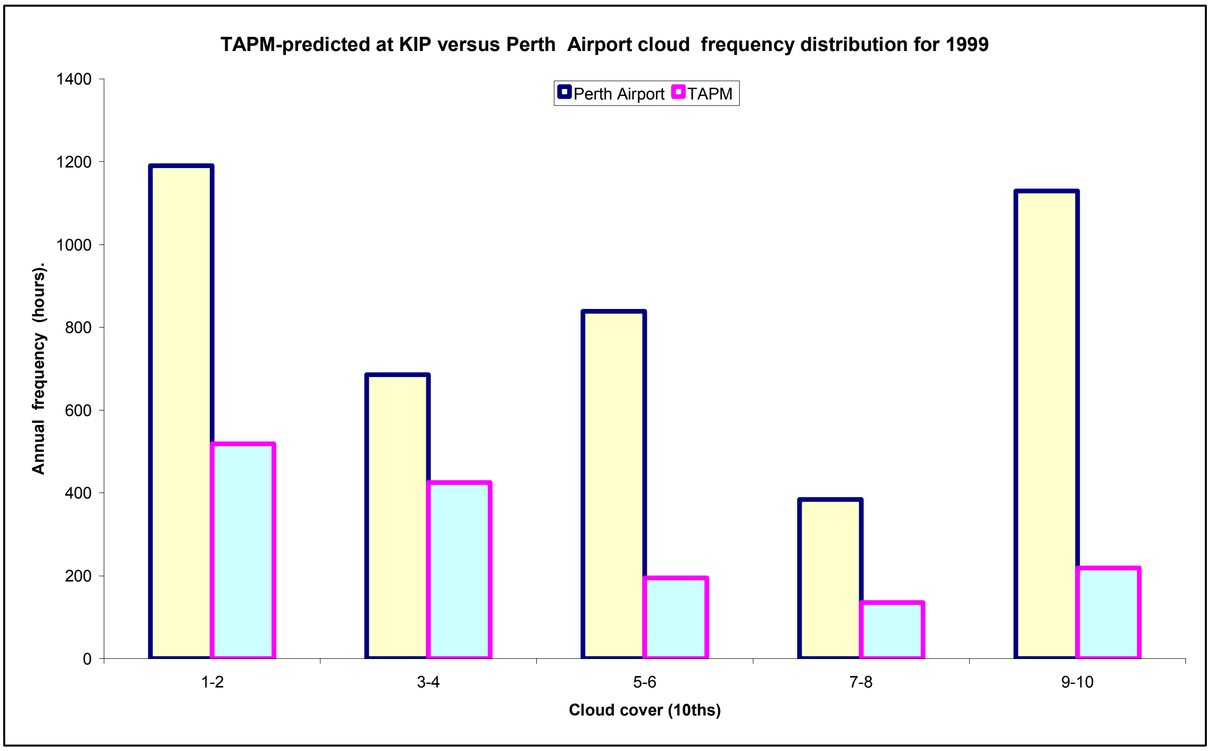



**Figure 7 TAPM-predicted versus Perth Airport cloud cumulative frequency distributions**

## 8. CALMET SETUPS

CALMET requires surface observational data and upper air profile data. As described previously, surface observational data for CALPUFF modelling was sourced as follows:

- wind speeds from measured data with gaps filled using adjusted TAPM predictions;
- wind directions from measured data with gaps filled using adjusted TAPM predictions;
- cloud cover and heights from Perth Airport;
- ambient temperatures from measured data with gaps filled using adjusted TAPM predictions;
- relative humidity and pressure from TAPM; and
- rainfall data from the BoM at Bunbury.

Upper air profile data was derived from the TAPM model.

Other CALMET setups are described in Appendix 2.

# 9. ANALYSIS OF CALMET RESULTS

The annual wind speed and direction frequency "rose" at the anemometer site is shown in Figure 8. Seasonal wind roses are shown in Figure 9. These indicate a strong bias towards south-easterly winds in summer to a wider northerly arc during winter.

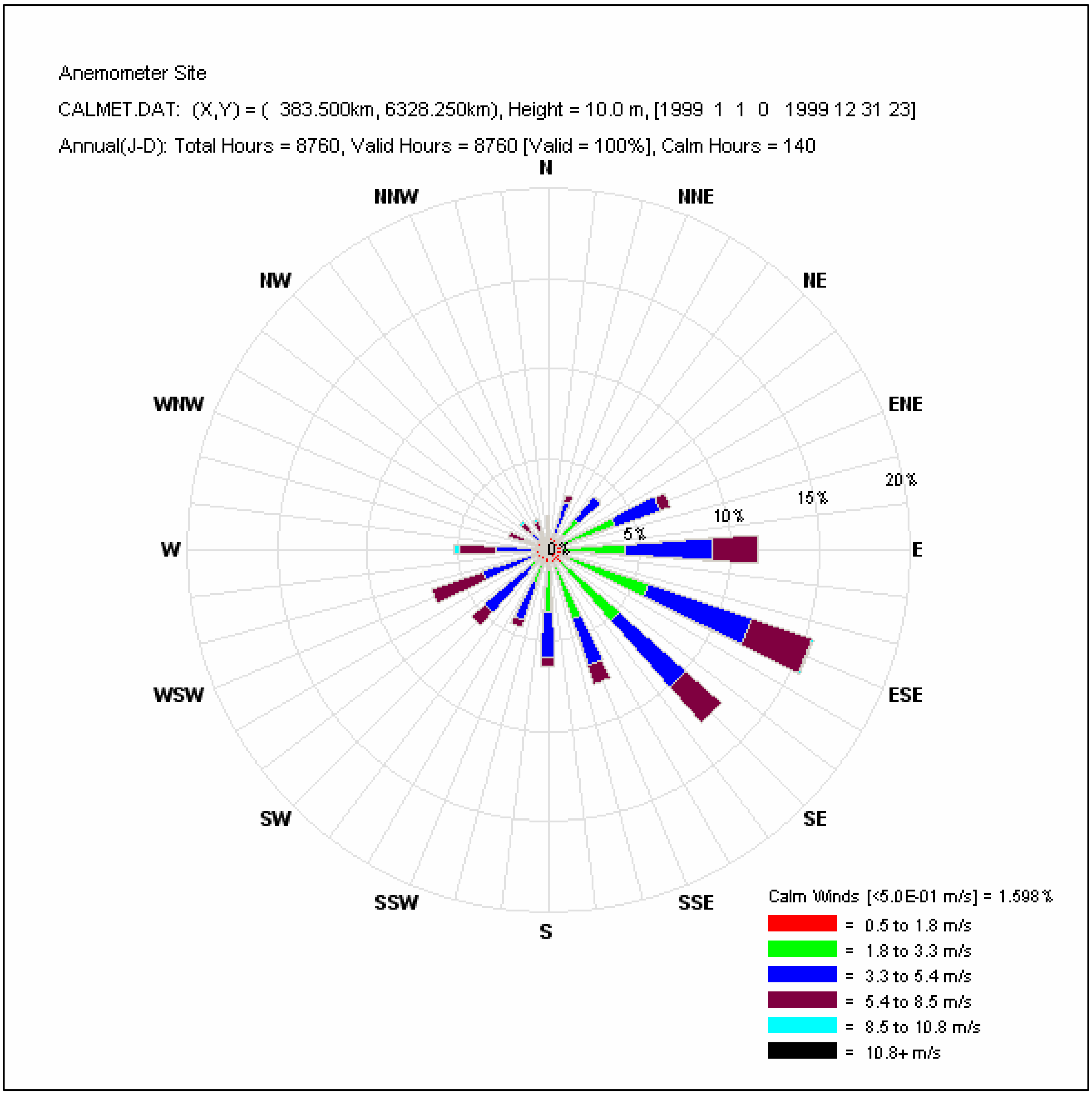



**Figure 8 Annual wind rose at the Landcorp anemometer site**

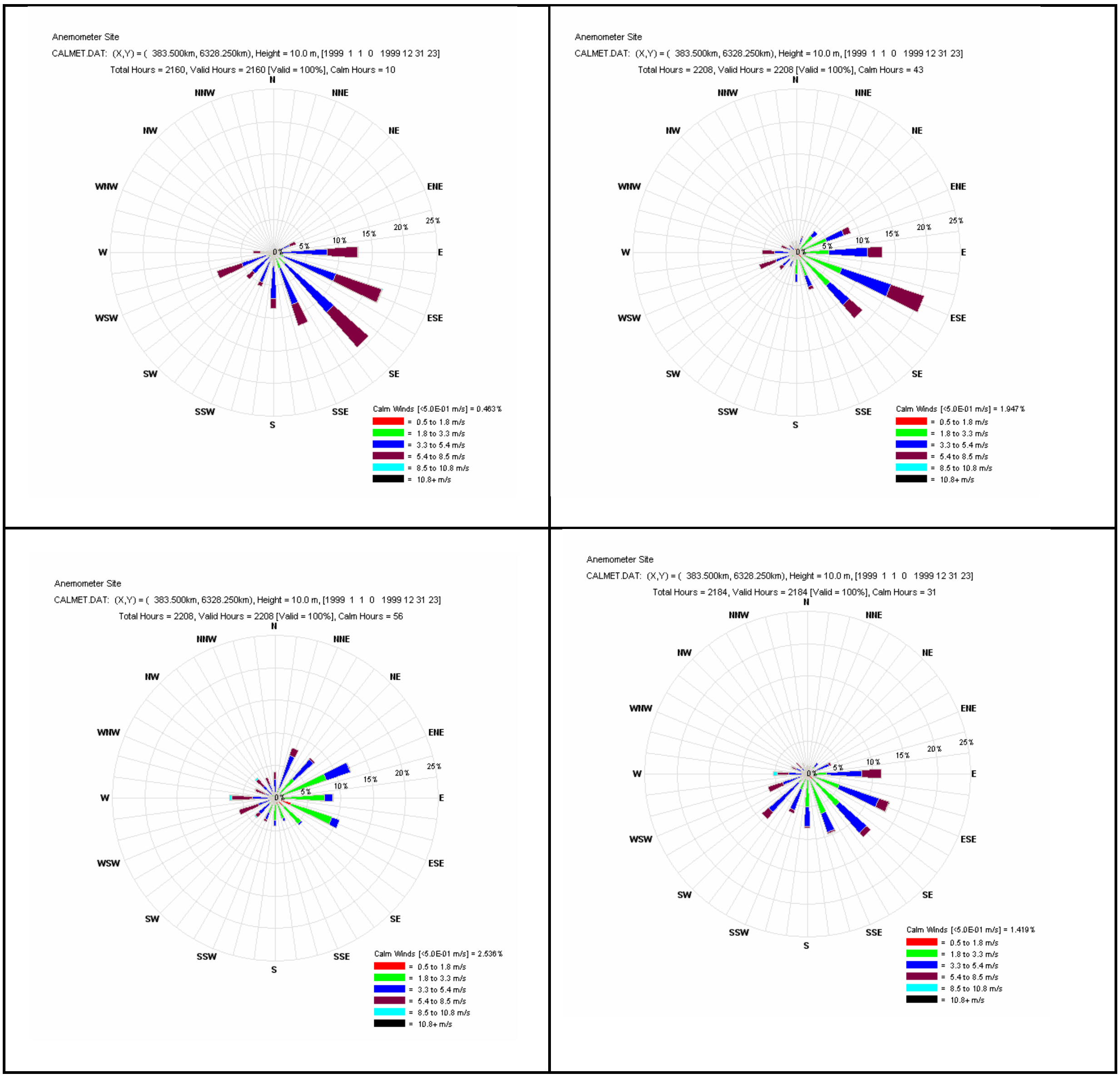



**Figure 9 Summer (top left), autumn (top right), winter (bottom left) and spring (bottom right) wind roses at the anemometer site**

## 9.1 STABILITY DISTRIBUTIONS

Stability is a useful indicator of the turbulence characteristics of meteorological data use for modelling. The annual CALMET predicted stability distributions (based on two classification schemes) are shown in Table 2. The PG scheme is used by CALPUFF for the option of predicting dispersion using the Pasquil Gifford estimates of plume spread. The Golder (1972) relationship is more indicative of the dispersion calculated within CALPUFF if the micrometeorology scheme for determining dispersion (based on turbulence parameters), is selected.

For low-buoyancy near-surface releases, the distribution of D to F is the most important issue for far-field dispersion. The CALMET PG stability distributions exhibit a similar percentage of stable (E + F class) versus neutral (D class) conditions compared to most of the other distributions, and does not appear to be unreasonable. The CALMET Golder stability distributions show a much larger proportion of neutral conditions and lower proportion of extremely stable (F class) conditions.

It is considered that this is due in part, to the anemometer's location being on the north-south ridge in the KIP. This means that, despite the anemometer threshold being high – tending to under-estimate wind speeds, the proportion of low-range wind speeds is higher than would be measured on less relatively elevated terrain. The net outcome is that wind speeds for the bulk of the less relatively elevated terrain over the KIP are over-estimated and hence the proportion of stable conditions determined from turbulence parameters underestimated. The effect on modelling results is further discussed in Appendix 3.

**Table 2 Estimated stability distribution at Kemerton for 1999 compared to other distributions**

| Stability Class | Proposed Aluminium Smelter using Glen Iris data (Helleman & Associates 1985) | Air Quality Modelling for Kemerton Industrial Estate Expansion using Landcorp 1995 data (WNI 1997) | 1999 | | | |
|---|---|---|---|---|---|---|
| | | | Proposed Simcoa expansion using Turner method (EA 2007) | TAPM (this study) | CALMET (this study) using PG scheme | CALMET (this study) using Golder (1972) scheme based on L and Z0 |
| A | 3.3 | 2.1 | 1.1 | **1.6** | **0.1** | **1.0** |
| B | 2.9 | 8.9 | 10.3 | **13.2** | **5.5** | **1.1** |
| C | 16.7 | 21.5 | 18.4 | **15.4** | **18.2** | **11.1** |
| D | 43.0 | 35.9 | 28.3 | **32.6** | **38.7** | **58.9** |
| E | 14.1 | 15.1 | 20.2 | **15.3** | **17.3** | **20.0** |
| F | 20.0 | 16.6 | 21.7 | **21.9** | **20.2** | **7.9** |

## 9.2 WINDS ACROSS COASTAL PLAIN

TAPM-predicted annual wind roses for western edge of KPI buffer, centre (Landcorp anemometer site) and eastern edge are shown in Figure 7. These illustrate fairly marked differences in prevailing surface wind speeds – winds are lighter towards the Scarp, and wind directions – much higher relative occurrence of easterly winds around the centre of the KIP and easterly winds become more south-easterly nearer the Scarp.

It was considered whether to use the TAPM wind speed (and possibly wind direction) predictions as "pseudo observations" west and east of the KIP for CALMET's generation of the wind field. This was not done however, since inconsistencies between the measured winds and TAPM-winds, although usually small, may also produce artificial distortions in the horizontal wind field which would increase dispersion and hence be non-conservative. If TAPM winds had been used instead of observations (with the wind speeds adjusted based on the measurements), this may be an option worth pursuing in future modelling since the issue of wind variation across the coastal plain does appear to warrant further consideration. Another option would be to use any other available measured wind data from east and west of the KIP.

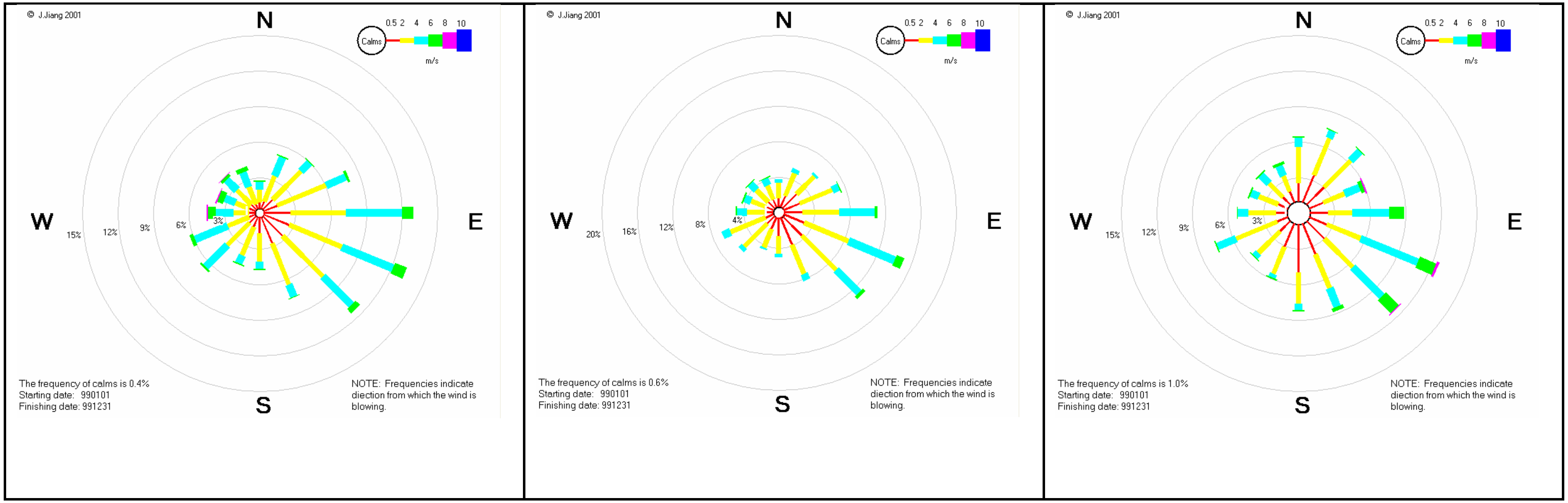



**Figure 10 TAPM-predicted annual wind roses for western edge of KPI buffer, centre (Landcorp anemometer site) and eastern edge**

## 10. CALPUFF SET-UP

Dispersion options used included:

- Dispersion coefficients calculated internally from micrometeorological variables;
- Calms defined as wind speeds less than 0.5 m/s; and
- CALPUFF terrain adjustment by adjusting the vertical dimensions of the plume puff.

Otherwise, CALPUFF defaults were used.

Note that the PDF scheme for convective conditions was not used. This means that maximum impacts near to elevated sources (ie inside the KIP) may be underestimated. Outside the KIP, concentrations are likely to be overestimated.

## 11. AMBIENT CRITERIA

The WA EPA does not have state-wide standards for emissions into ambient air, but are in the process of implementing a State-wide Environmental Protection Policy. This policy would apply National Environmental Protection Measure (NEPM) standards to protect human health throughout the state, where current Environmental Protection Policies do not exist. It is understood that the NEPM will apply at residential areas or places where people may congregate, such as beaches or picnic areas and not within buffer zones of industrial areas that are defined within planning. The NEPM standards are listed in Table 3.

### Table 3 National Environmental Protection Measure - Air Quality Standards and Goals

| Pollutant | Averaging Period | Maximum Concentration | | Goal |
|---|---|---|---|---|
| | | (ppm) | ($\mu g/m^3$)[(a)] | Maximum allowable exceedences within 10 years (2008) |
| Carbon Monoxide | 8-hour | 9.0 | 11,240 | 1 day a year |
| Nitrogen Dioxide | 1-hour | 0.12 | 246 | 1 day a year |
| | 1-year | 0.03 | 62 | none |
| Photochemical Oxidants (as ozone) | 1-hour | 0.10 | 214 | 1 day a year |
| | 4-hours | 0.08 | 171 | 1 day a year |
| Sulfur Dioxide | 1-hour | 0.20 | 572 | 1 day a year |
| | 1-day | 0.08 | 228 | 1 day a year |
| | 1-year | 0.02 | 57 | none |
| Lead | 1-year | - | 0.5 | none |
| Particles as PM10 | 1-day | - | 50 | 5 days a year |
| **Advisory Reporting Standards and Goal** | | | | |
| Particles as PM2.5 | 1-day | - | 25 | Goal is to gather sufficient data nationally to facilitate a review of the advisory Reporting standard as part of the review of this Measure scheduled to commence in 2005 |
| | 1-year | - | 8 | |

[(a)] Concentrations of gaseous pollutants in italics have been converted from the NEPM standard quoted at 0 deg C and 101.3kPa.

The allowable exceedences in the above Table have not been incorporated in this study which incorporates a little conservatism.

For assessing the potential impacts on vegetation, as there are no guidelines/standards within Australia for the pollutants of most concern $SO_2$ and $NO_X$, the WHO air quality guidelines for Europe (WHO, 2000) have been used (see Table 4). These are considered applicable outside the industrial area and buffer zone.

### Table 4 World Health Organisation Air Quality Guidelines for Europe (WHO 2000)

| Substance | Vegetation Category | Guideline (µg/m$^3$) | Averaging Period |
|---|---|---|---|
| Sulfur Dioxide | Agricultural Crops | 30 | Annual and winter mean |
| | Forests and Native Vegetation | 20 | Annual and winter mean |
| | Lichens | 10 | Annual mean |
| Oxides of Nitrogen | All Vegetation | 75 | 24-hour |
| | All vegetation | 30 | Annual mean |

Note: Concentrations are expressed at 0$^o$ C and 101.3 kPa.

To assess odour impacts, the DEC has published the following two-part "green light" odour criteria which apply at existing or proposed sensitive premises:

A) 2 ou, 3 minute average, 99.5$^{th}$ percentile; and

B) 4 ou, 3 minute average, 99.9$^{th}$ percentile criterion.

Proposals which do not meet the two-part "green-light" criterion are to be assessed on a case-by-case basis. It is understood that this criterion does not to apply within buffer zones.

For proposals where the "green light" criterion do not apply, the DEC have tended to adopt an informal criteria of 2.5 ou 1-hour 99.5$^{th}$ percentile criteria based on Queensland criteria for surface sources or wake effected sources. This is generally used with Western Australia except by the Water Corporation which considers that for WWTP modelling (using their methodology), a 5 ou 1-hour 99.9$^{th}$ percentile provides the best measure of the extent of where annoyance and/or complaints will occur to.

In this study, the numerical value of the criteria is less important than the shape of the contours since indicative emissions are only used for the modelling and compliance is not being sought. For comparison, both the 1-hour 99.9 and 99.5 percentile contours have been predicted to indicate general buffer requirements.

## 12. EMISSIONS DATA AND SOURCE CONFIGURATIONS

### 12.1 INDUSTRY SCENARIOS MODELLED

As referred to previously, emissions scenarios for modelling were defined as three categories:

1. Existing;
2. Existing plus approved; and
3. Existing, approved and future hypothetical.

The following sections describe the emission parameters for each industry and source.

## 12.2 EXISTING INDUSTRIES

### 12.2.1 Kemerton Power Station

The Kemerton Power Station is gas-fired hence the most significant emission is NOx.

SO2 emissions of any significance will only occur during short-term burns of liquid fuels. While this expected to be occur for no more than 100 hours per year (EPA 2003), the SO2 emissions has been treated for modelling purposes as being continuous.

The discharge parameters used for modelling emissions from the KPS are shown in Table 5.

**Table 5 Discharge parameters for KPS**

| Parameter Units | Value | |
|---|---|---|
| | Gas Fired | Distillate Fired |
| Net Gross Power (MW) | 173 | 165 |
| Stack Height (m) | 35 | |
| Location GDA94 (mE, mN) | 386195, 6329806 | |
| Stack Diameter (Equivalent) (m) | 5.5 | |
| Exit Volume ($Am^3/s$) wet | 1278 | 1228 |
| Exit Temperature ($^oC$) | 538 | 517 |
| Exit Velocity (m/s) | 53.8 | 51.7 |
| NOx Exit Concentration – typical (ppmv, dry,15% O2) | 16.1 | 50.3 |
| NOx Emission Rate- typical (g/s) | 14.2 | 45.3 |
| Particulate Emission Rate per unit (g/s) – SKM, 2003 | 1.0 | 3.81 |
| SOx Emission Rate (g/s) | Negl | 1 |

Ref: SKM (2003) except where updated in Air Assessments (2006). Emissions are based on use of wet compression where water as a fine mist/fog is injected into the inlet to increase the efficiency of the gas turbine.

### 12.2.2 Millennium Inorganic Chemicals

The Millennium Inorganic Chemicals (MIC) titanium dioxide pigment facility located in the Kemerton Industrial Park emits NOx and SO2 from its main stack.

The discharge parameters used for this source is shown in Table 6.

## Table 6 Discharge parameters for Millennium Inorganic Chemicals

| Parameter | Millennium Inorganic Chemicals |
|---|---|
| Stack height (m above ground) | 66 |
| Location GDA94 (mE, mN) | 384144, 6324040 |
| Stack diameter (m) | 0.6 |
| Volume flow rate ($m^3$/s) | 10.5 |
| Exit temperature (°C) | 318 |
| Exit velocity (m/s) | 37 |
| NOx emission rate (g/s) | 12 |
| SO2 emission rate (g/s) | <5.5 (c) |

(a) From SKM (2003).
(c) Based on licence limit maximum.

### 12.2.3 Simcoa

The Simcoa silicon smelter emits NOx and SO2 from its baghouse roof vent and retort stack. The discharge parameters used for this source is shown in Table 7.

## Table 7 Discharge parameters for Simcoa existing baghouse

| Parameter | Simcoa Existing Baghouse Building (Baghouse 1 serving Furnaces 1 & 2) | Simcoa Retort |
|---|---|---|
| Release height (m above ground) | 29 | 48 |
| Volume flow rate (Nm3/s) | 223 | 27.6 |
| Volume flow rate (m3/s) | 264 | 63.1 |
| Emission area (m2) | 119 | N/a |
| Exit temperature (°C) | 50 | 350 |
| No of point sources | 7 | 1 |
| Stack area (m2) | 17.1 per point source | 1.8 |
| Stack diameter (m) | 4.66 per point source | 1.5 |
| Exit velocity (m/s) | 2.21 | 35.7 |
| PM10 emission rate (g/s | 0.066 | 0.80 |
| NOx as NO2 emission rate (g/s) | 7.1 | 0.93 |
| SO2 emission rate (g/s) | 4.92 | 2.28 |

Ref: Environmental Alliances (2008) “base case” configuration. Also see Appendix 4 for further details on modelling configuration for Simcoa baghouse.

### 12.2.4 Water Corporation

The Water Corporation operate a waste water treatment facility in the south of the Industrial Core.

The key air emission is odour.

The existing odour emissions rate has not been quantified since the plant lies within an industrial buffer.

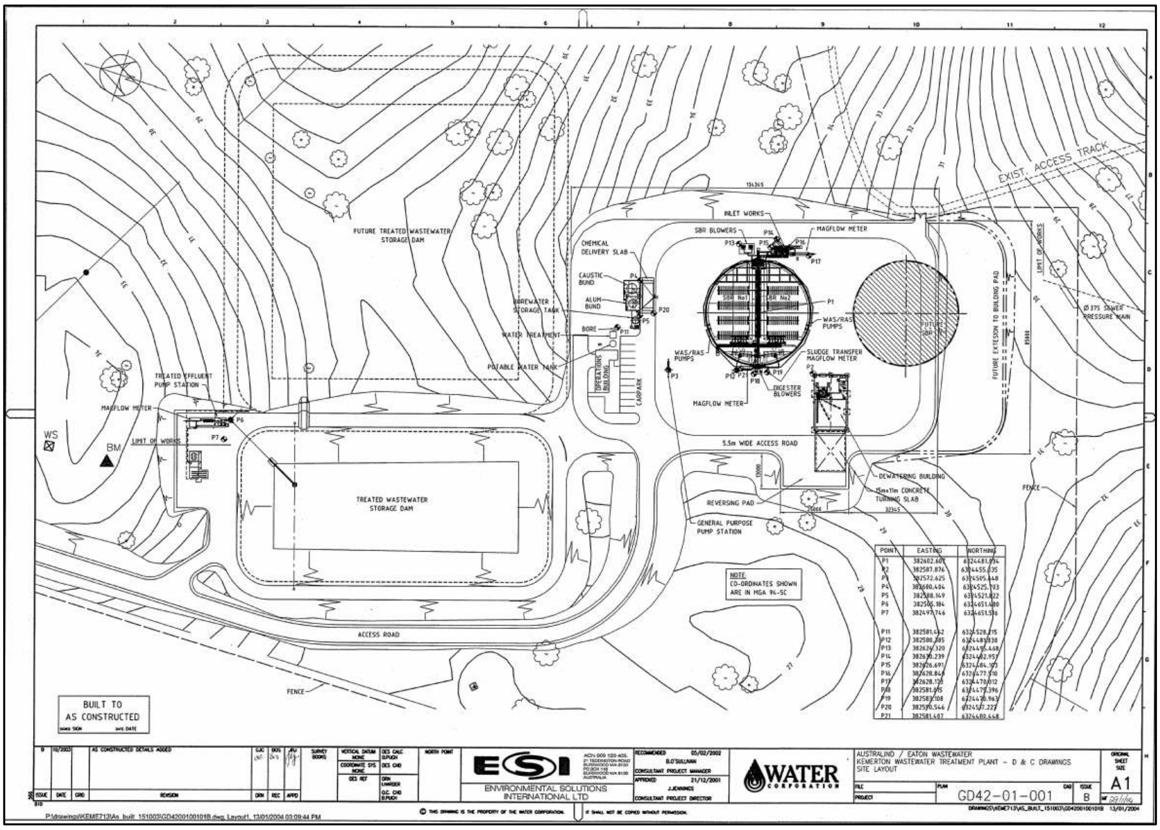
As advised by the Water Corporation, a preliminary odour emission rate of 90,000 ou/m$^3$/s has been modelled based conservatively, on an estimated ultimate capacity of 30ML/d. It is understood that this capacity has yet to be reached therefore the modelled ambient odour levels as an estimate of "existing" odour is likely to be extremely conservative.

The discharge parameters used for these sources are shown in Table 8.

### Table 8 Discharge parameters for Water Corporation facility

| Parameter | Water Corporation facility – main pond |
|---|---|
| Easting, Northing (GDA94 mE, mN) | 382469, 6324527 382441, 6324616 382473, 6324626 382502, 6324537 |
| Area –actual area of modelled source (m$^2$) | 3180 |
| Odour emission rate (ou/s) | 90,000 |
| Height (m above ground) | 0 |

Parameters based on conservative estimate of an ultimate capacity of 30ML/d and emission area of 40,000 m2. Ref: Water Corporation email to Landcorp dated 18/2/2010.




### Figure 11 Layout of Water Corporation Waste Water Treatment facility

## 12.3 OTHER INDUSTRIES

There is an existing abattoir in the buffer west of the Industry Core. The abattoir has operated there for 30 years and has a non-conforming use right, although it has experienced some problems with waste management (Thompson Mcrobert Edgeloe 2009).

## 12.4 APPROVED FUTURE INDUSTRIES

### 12.4.1 Simcoa

Simcoa has received approval for a new furnace. The emissions from this facility were modelled as described in Environmental Alliances (2008).

SO2 emissions from the existing baghouse and retort are expected to also change with the proposal.

The data assumptions used for the dispersion modelling of emissions for expansion scenario F3 (maximum emissions) are shown in Table 9 and Table 10 below.

**Table 9 Discharge parameters for Simcoa existing baghouse and retort following expansion**

| Parameter | Simcoa Existing Baghouse Building (Baghouse 1 serving Furnaces 1 & 2) | Simcoa Retort |
|---|---|---|
| SO2 emission rate (g/s) | 5.5 | 3.5 |

Ref: Environmental Alliances (2008) "base case" configuration. Also see Appendix 4 for further details on modelling configuration for Simcoa baghouse.

**Table 10 Discharge parameters for proposed new baghouse with three stacks**

| Parameter | Simcoa Proposed Baghouse 2 serving Furnace 3 or Furnaces 3 & 4 [a] |
|---|---|
| Stack heights (12m on top of new baghouse roof height of 25.9 m) (m) | 37.9 |
| Location GDA94 (mE, mN) | 383386,6323832 383386,6323822 383386,6323811 |
| Volume flow rate (Nm3/s) | 112 |
| Volume flow rate (m3/s) | 132 |
| Exit temperature (°C) | 50 |
| No of point sources | 3 |
| Stack area (m2) | 6.16 per point source |
| Stack diameter (m) | 2.8 per point source |
| Exit velocity (m/s) | 7.14 |
| PM10 emission rate (g/s) | 0.066 |
| NOx as NO2 emission rate (g/s) | 7.1 |
| SO2 emission rate (g/s) | 9.3 |

[a] Design not been finalised at time of assessment – emissions rates are maximums.
Ref: Environmental Alliances (2008)

# 13. FUTURE INDUSTRIES

## 13.1 NATURE OF FUTURE INDUSTRIES

The Kemerton Strategy Report (Landcorp 2009) has described the likely nature of future industries that locate in the KIP Industry Core as "those that support existing South West industries and strengthen the economic base of the region by adding value to primary and secondary resources… (belonging)… "to one or more of the following categories:

- Chemical and resource processing (e.g. existing Crystal inorganic chemicals and Simcoa silicon smelter);
- High technology (e.g. titanium applications);
- Downstream processing (e.g. silicon applications); and
- Power generation (e.g. gas fired, biomass fired)".

### 13.2 EMISSIONS ASSUMPTIONS

It is likely that most future industries will burn fossil fuels and hence emit NOx. SO2 is a common impurity in many refined substances, which ultimately reports as waste in air emissions.

The assumptions for future industrial sources were based on:

- locations and heights of stacks used for noise modelling, which were based on typical stacks for generic industries; and
- emission parameters for the generic sources listed in Table 11 below, based on typical new plants within Western Australia.

**Table 11 Emission parameters for generic future industries**

| Hypothetical generic source type | Stack Height (m) | Stack Tip Diameter (m) | Exit Temperature (C) | Exit Velocity (m/s) | Exit Volume ($Am^3/s$) | NOx Emission Rate (g/s) | SO2 Emission Rate (g/s) |
|---|---|---|---|---|---|---|---|
| Short Low Buoyancy Source | 5 | 0.4 | 50 | 20 | 2.5 | 0.5 | Negl |
| Mid Size GT | 40 | 3.7 | 100 | 13.2 | 138 | 6.3 | Negl |
| Pellet Plant Large Main Stack | 60 | 8.2 | 140 | 18 | 960 | 30 | Negl |
| Tall Hypothetical stack | 100 | 3.6 | 164 | 20 | 200 | 100 | 100 |

The emission assumptions for each hypothetical future source are shown in Table 12 below and their location in Figure 12. These locations and stack heights have been chosen to be consistent with noise modelling for the estate (Herring Storer 2010)

## Table 12 Emission assumptions for future sources

| Scale | Easting | Northing | Map ID | Stack Height (m) | Exit Velocity (m/s) | Stack diameter (m) | Exit Temp (C) | Nox emission rate (g/s) | SO2 emission rate (g/s) |
|---|---|---|---|---|---|---|---|---|---|
| Small industries | 383648 | 6324590 | **S1** | 5 | 20 | 0.4 | 50 | 0.5 | |
| | 383976 | 6325161 | **S2** | 5 | 20 | 0.4 | 50 | 0.5 | |
| | 383710 | 6325839 | **S3** | 5 | 20 | 0.4 | 50 | 0.5 | |
| | 385342 | 6326893 | **S4** | 5 | 20 | 0.4 | 50 | 0.5 | |
| | 385371 | 6327740 | **S5** | 5 | 20 | 0.4 | 50 | 0.5 | |
| | 384769 | 6325639 | **M1a** | 40 | 13.2 | 3.65 | 100 | 6.3 | |
| Medium Industries | 384744 | 6325613 | **M1b** | 5 | 20 | 0.4 | 50 | 0.5 | |
| | 383969 | 6326407 | **M2a** | 5 | 20 | 0.4 | 50 | 0.5 | |
| | 383994 | 6326434 | **M2b** | 40 | 13.2 | 3.65 | 100 | 6.3 | |
| | 384441 | 6327876 | **M3a** | 5 | 20 | 0.4 | 50 | 0.5 | |
| | 384466 | 6327902 | **M3b** | 40 | 13.2 | 3.65 | 100 | 6.3 | |
| | 383738 | 6328266 | **M4a** | 5 | 20 | 0.4 | 50 | 0.5 | |
| | 383763 | 6328292 | **M4b** | 40 | 13.2 | 3.65 | 100 | 6.3 | |
| | 385207 | 6328886 | **M5a** | 5 | 20 | 0.4 | 50 | 0.5 | |
| | 385232 | 6328913 | **M5b** | 40 | 13.2 | 3.65 | 100 | 6.3 | |
| Medium-Large Industries | 384467 | 6327158 | **ML1a** | 5 | 20 | 0.4 | 50 | 0.5 | |
| | 384492 | 6327184 | **ML1b** | 60 | 18 | 8.24 | 140 | 30 | |
| | 383766 | 6328856 | **ML2a** | 5 | 20 | 0.4 | 50 | 0.5 | |
| | 383791 | 6328882 | **ML2b** | 60 | 18 | 8.24 | 140 | 30 | |
| | 384748 | 6329819 | **ML3a** | 5 | 20 | 0.4 | 50 | 0.5 | |
| | 384773 | 6329845 | **ML3b** | 60 | 18 | 8.24 | 140 | 30 | |
| Large Industries | 383748 | 6327584 | **L1a** | 100 | 20 | 3.57 | 164 | 100 | 100 |
| | 383722 | 6327558 | **L1b** | 5 | 20 | 0.4 | 50 | 0.5 | |
| | 384430 | 6328645 | **L2a** | 100 | 20 | 3.57 | 164 | 100 | 100 |
| | 384405 | 6328619 | **L2b** | 5 | 20 | 0.4 | 50 | 0.5 | |
| | 383867 | 6329678 | **L3a** | 100 | 20 | 3.57 | 164 | 100 | 100 |
| | 383842 | 6329652 | **L3b** | 5 | 20 | 0.4 | 50 | 0.5 | |
| **Total s** | | | | | | | | **429.5** | **300** |

As an indication of scale:

- the total NOx emissions of 430 g/s compare to the total NOx emissions for the Kwinana Industrial Area reported for NPI purposes of 260 g/s; and
- the total SO2 emissions of 300 g/s compare to the total emissions for the Kwinana Industrial Area reported for NPI purposes of 300 g/s.

It is anticipated that future SO2 emitting industries will be subjected to a higher level of control than future NOx-emitting industries.

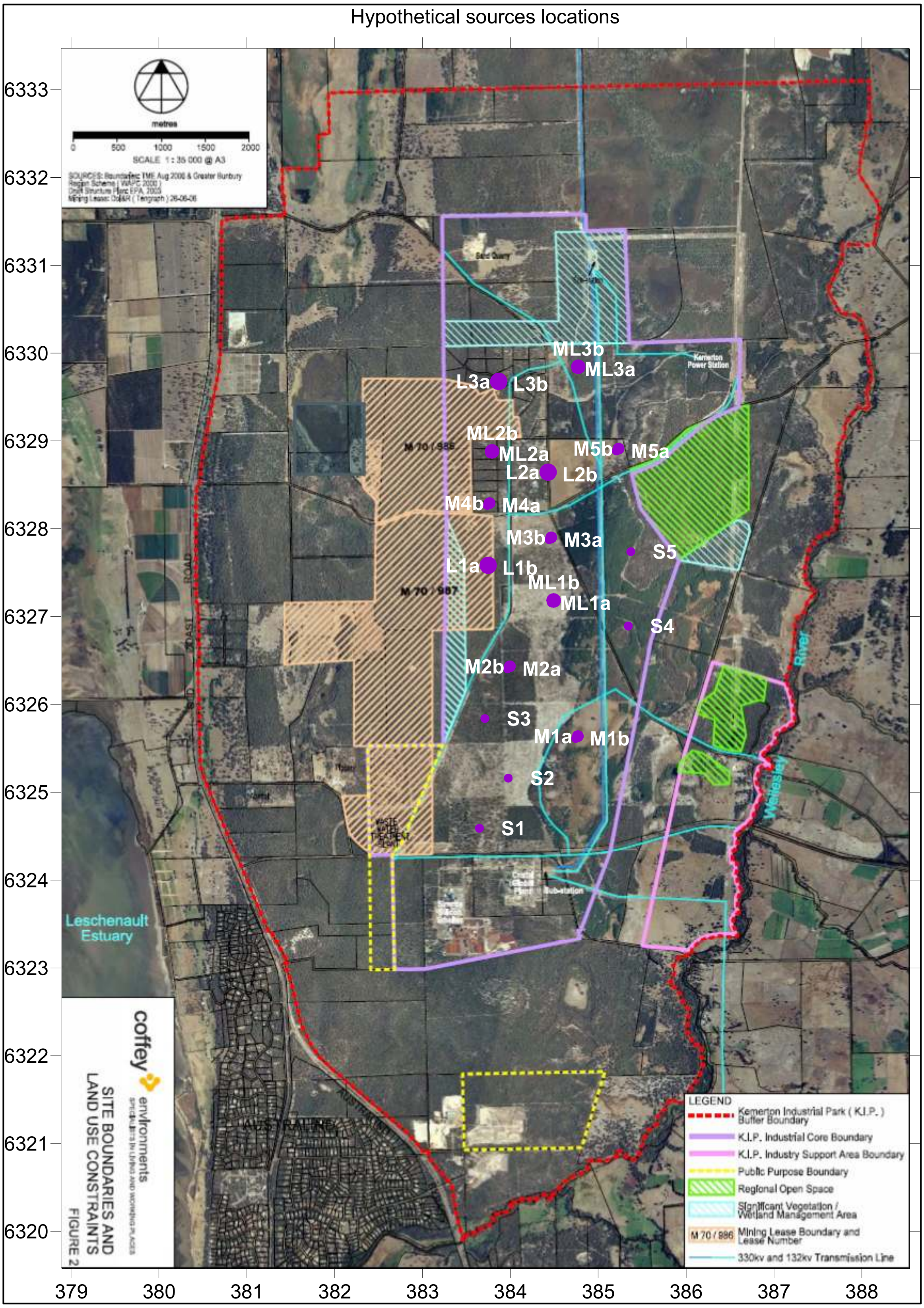



**Figure 12 Locations of hypothetical future sources**

# 14. MODELLING RESULTS

## 14.1 NOX AND SO2 FOR DEVELOPMENT SCENARIOS

The emissions modelled were NOx and SO2. NO2 was determined from NOx using the Ozone Limiting Method (OLM) as described in Appendix 5.

The predicted contours for each substance are presented for each emitted substance in order of:

1. Scenario 1: Existing industries;
2. Scenario 2: Existing and approved industries; and
3. Scenario 3: Existing and approved industries and hypothetical sources.

This allows the changes in air quality levels to be gauged for each scenario.

Predicted maximum 1-hour average NO2 concentrations are shown in Figure 13, Figure 14 and Figure 15. The key outcome is that the 1-hour criterion level of 246 $\mu g/m^3$ is not exceeded for any of the scenarios including the full development of the estate (Scenario 3). This is because the proportion of NO2 in the emissions NOx is relatively small - less than 10%, and the conversion of the remaining 90% of the NO to NO2 limited by the amount of available ozone.

Predicted maximum 1-hour average SO2 concentrations are shown in Figure 16, Figure 17 and Figure 18. Again, the key outcome is that the 1-hour criterion level of 572 $\mu g/m^3$ is not exceeded for any of the scenarios including the full development of the estate (Scenario 3).

Predicted odour concentrations from the Water Corporation's Waste Water Treatment plant are shown in Figure 19. It needs to be emphasised that the odour emission rates used are provisional estimates only. Notwithstanding, both of the odour criteria are met at the buffer. The generalised criterion used by the DEC (2.5 ou 99.5 percentile shown in bold orange) is a little more conservative than the specific criterion (5 ou 99.9 percentile shown in bold pink) preferred by the Water Corporation.

A summary of the modelling results compared to criteria is shown in Table 13.

### Table 13 Summary of predicted concentrations outside buffer compared to criteria

| Scenario | Maximum NO2 concentration outside buffer in $\mu g/m^3$ and % of criterion (%) | Maximum SO2 concentration outside buffer in $\mu g/m^3$ and % of criterion (%) |
|---|---|---|
| Criterion | 246 | 572 |
| 1. Existing industry | 59 (24) | 55 (9.6) |
| 2. Existing and approved industry | 65 (26) | 72 (13) |
| 3. Existing, approved and hypothetical industries | 71 (29) | 169 (30) |

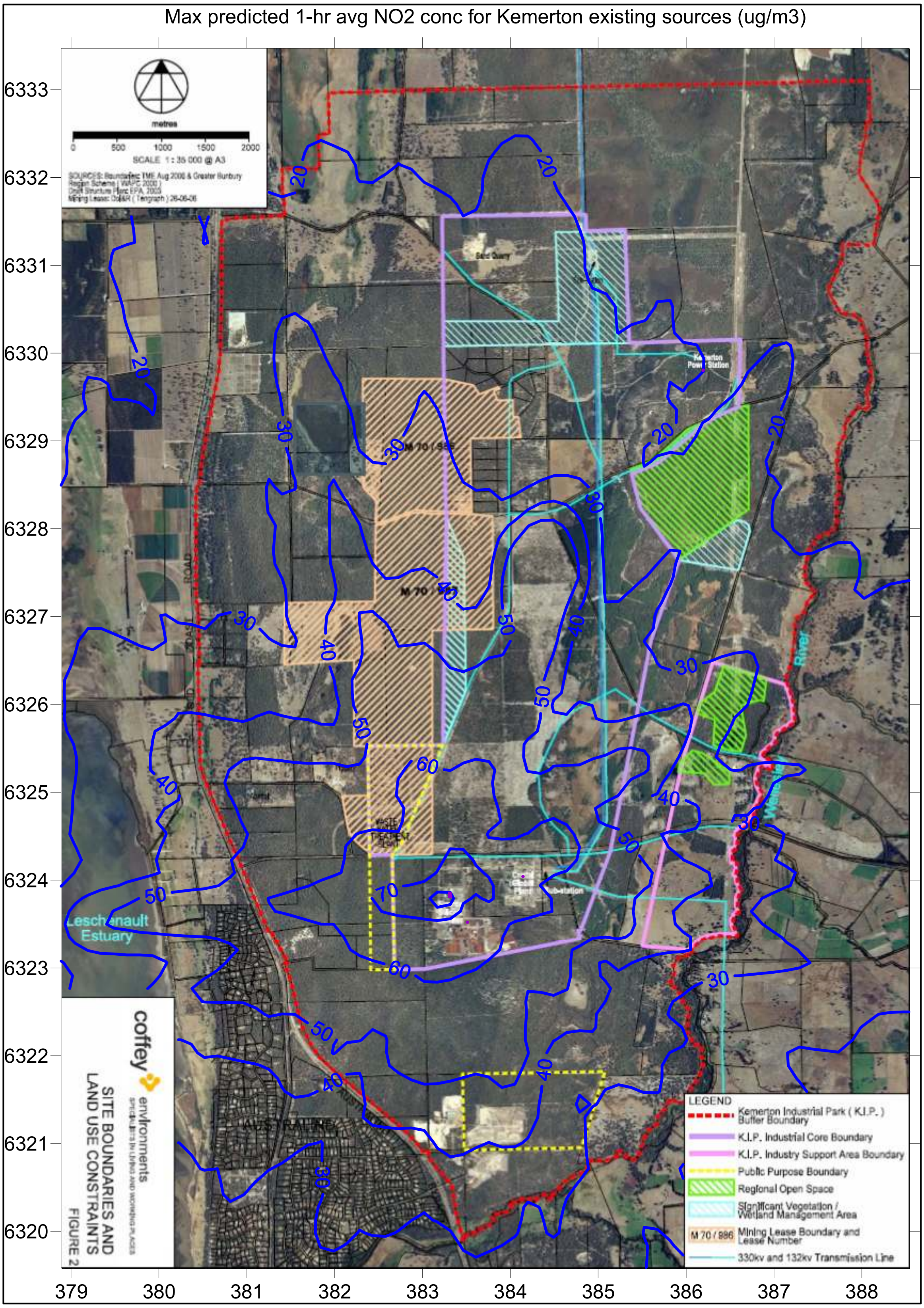



**Figure 13 Maximum predicted 1-hour average NO2 concentrations for Kemerton existing sources**

NEPM criterion = 246 µg/m$^3$ (This is not shown on the Figure since the concentrations do not reach this level).

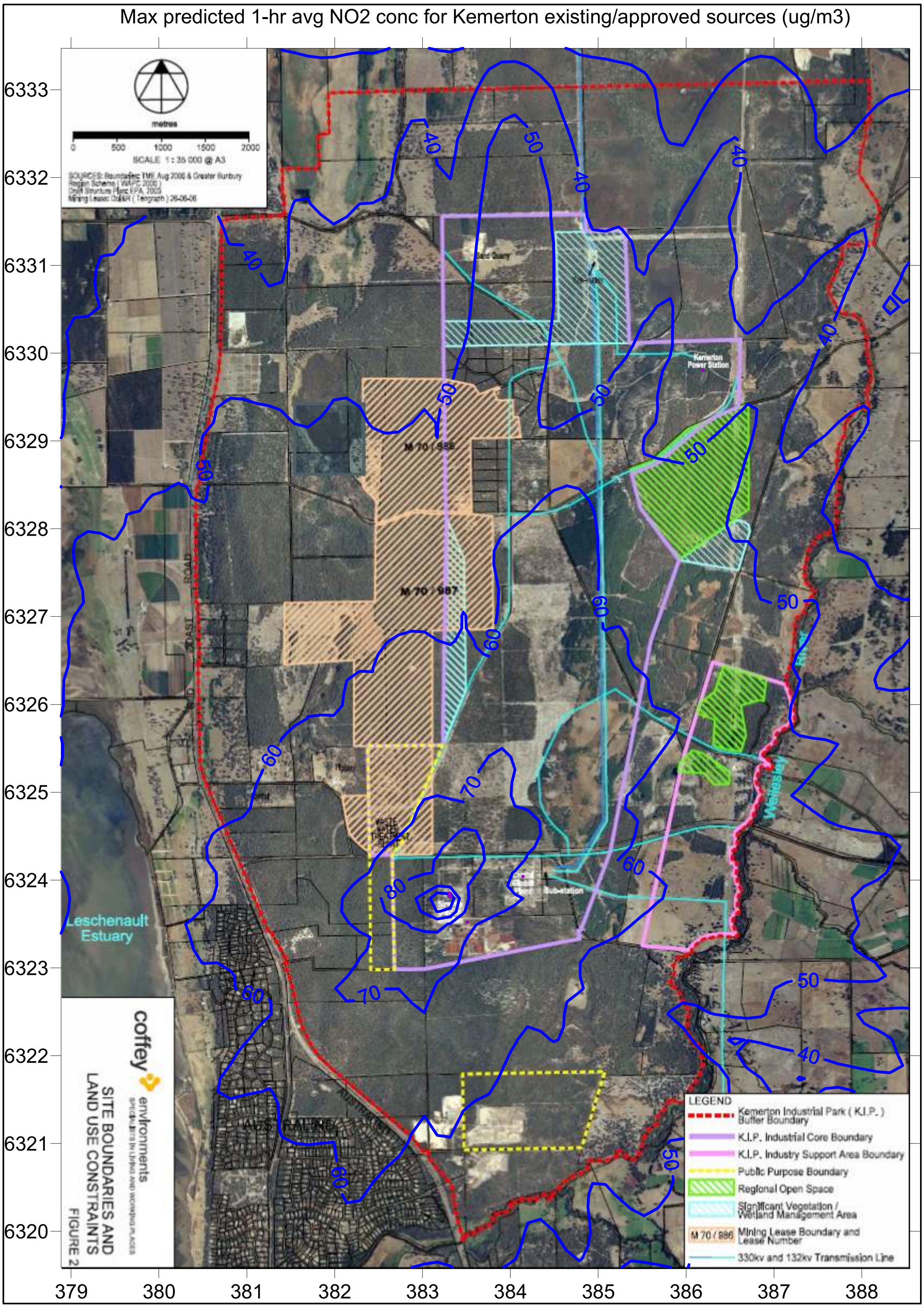



**Figure 14 Maximum predicted 1-hour average NO2 concentrations for Kemerton existing and approved sources**

NEPM criterion = 246 µg/m$^3$ (This is not shown on the Figure since the concentrations do not reach this level).

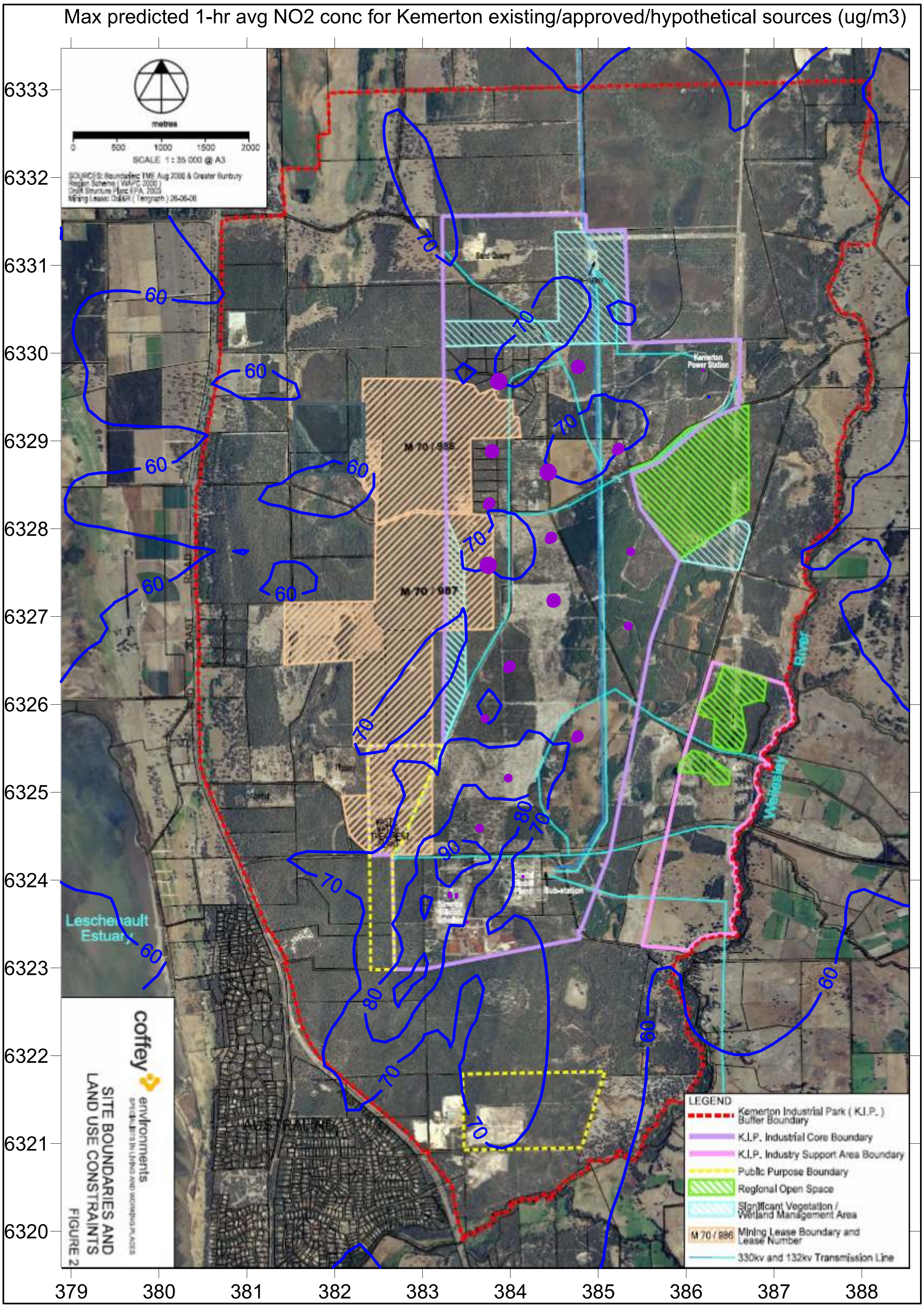



**Figure 15 Maximum predicted 1-hour average NO2 concentrations for Kemerton existing, approved and hypothetical sources**

NEPM criterion = 246 µg/m$^3$ (This is not shown on the Figure since the concentrations do not reach this level).

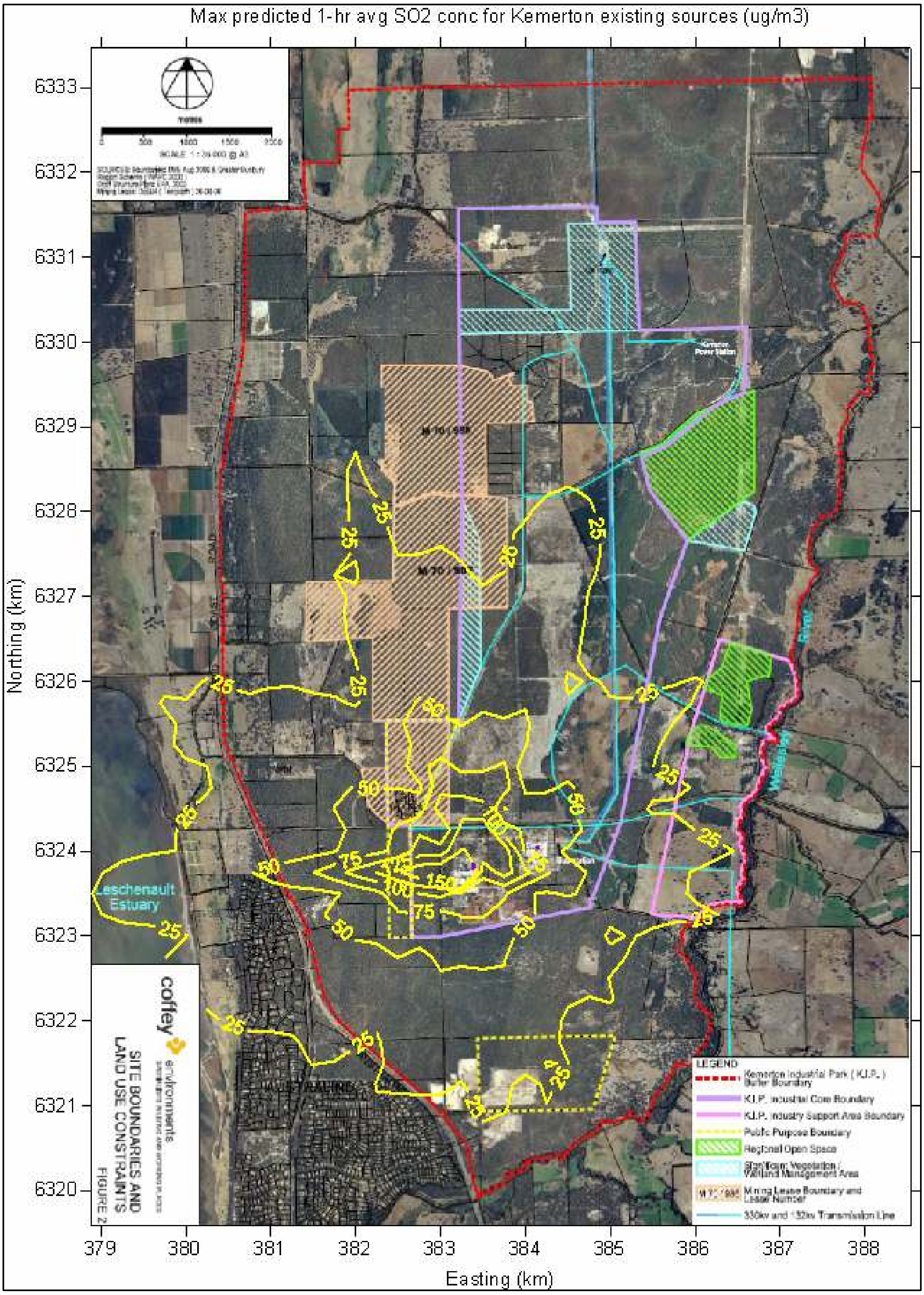



**Figure 16 Maximum predicted 1-hour average SO2 concentration for Kemerton existing sources**

NEPM criterion = 572 μg/m$^3$ (This is not shown on the Figure since the concentrations do not reach this level).

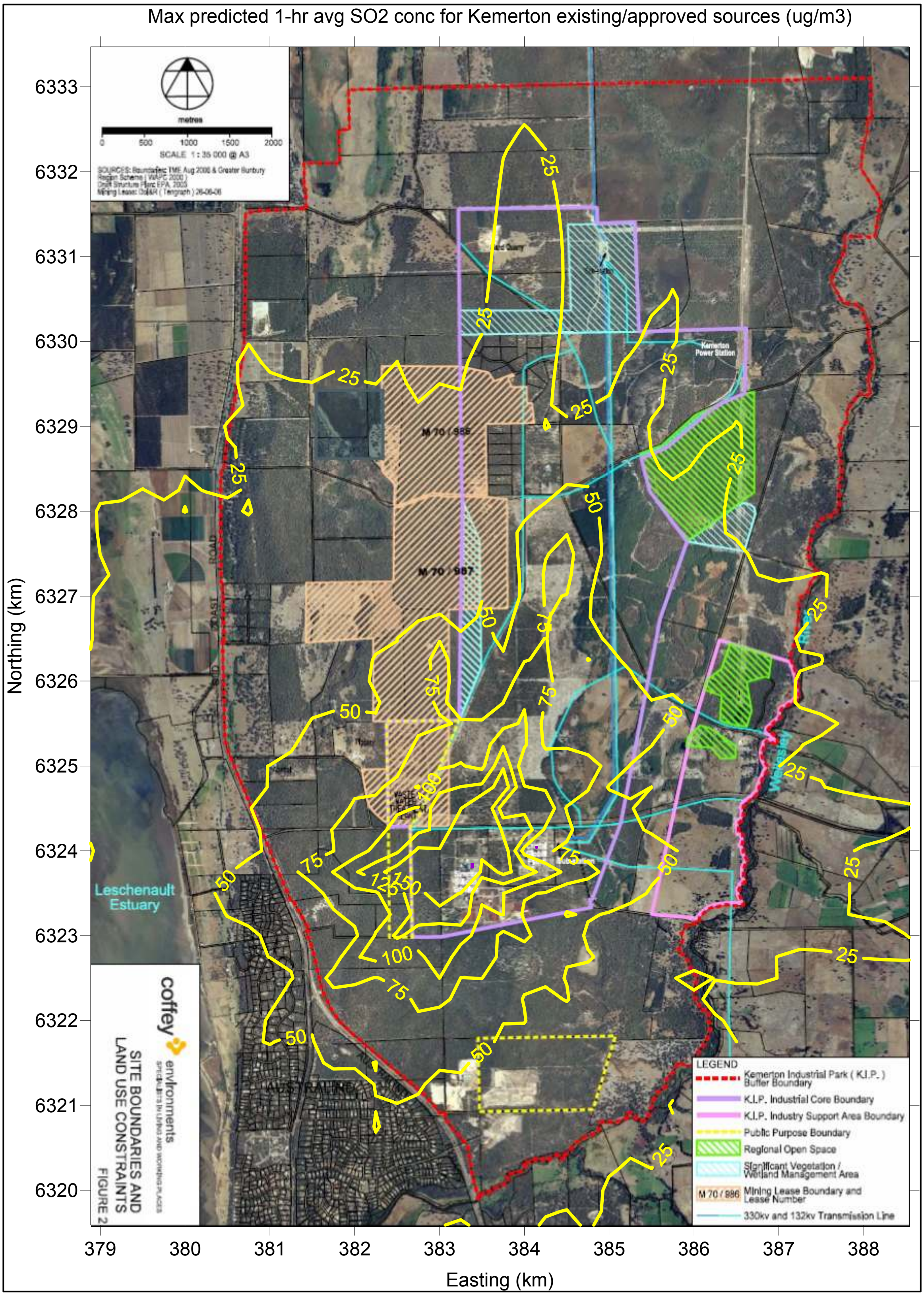



**Figure 17 Maximum predicted 1-hour average SO2 concentration for Kemerton existing and approved sources**

NEPM criterion = 572 µg/m$^3$ (This is not shown on the Figure since the concentrations do not reach this level).

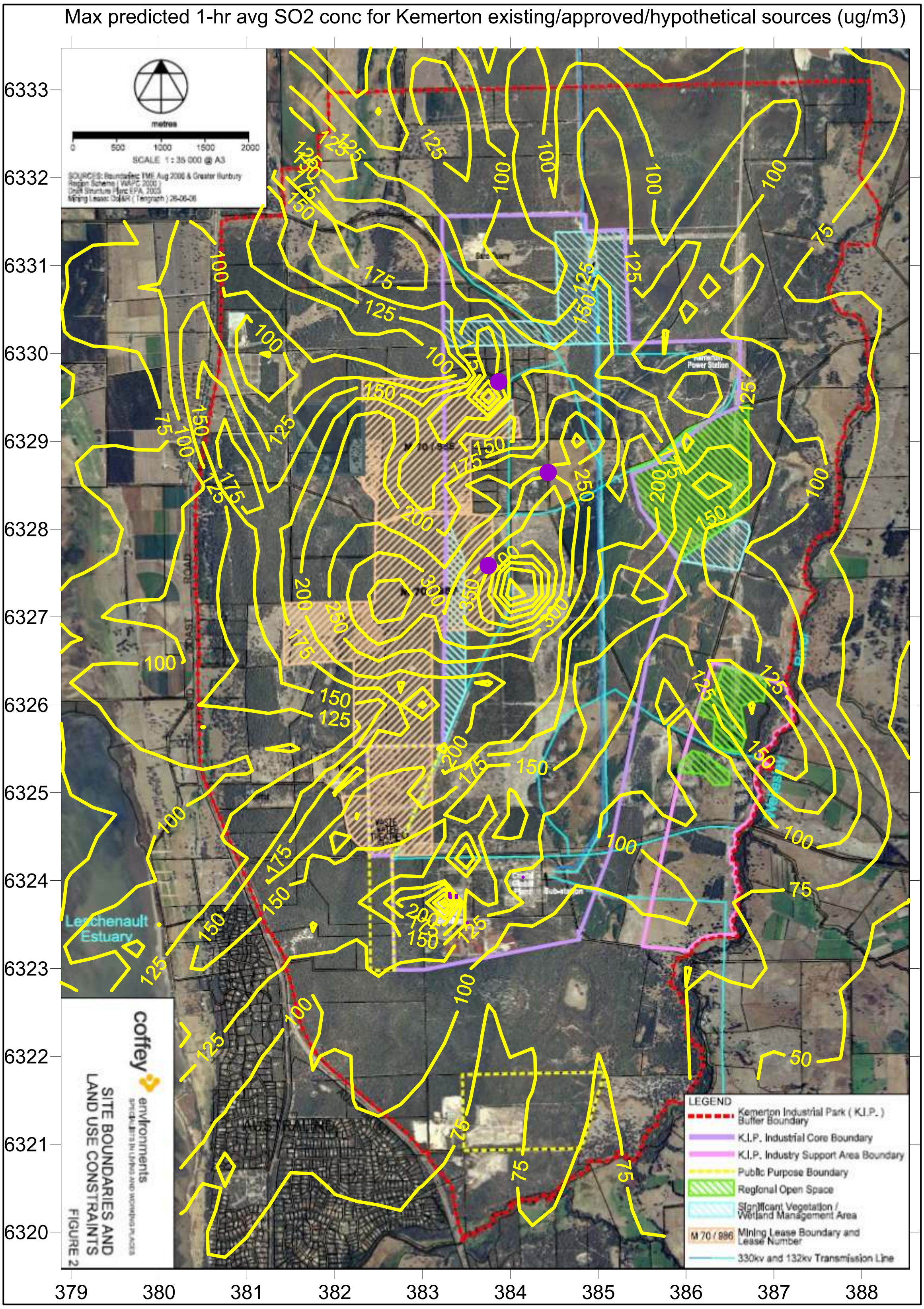



**Figure 18 Maximum predicted 1-hr avg SO2 concentration for Kemerton existing, approved and hypothetical sources**

NEPM criterion = 572 µg/m$^3$ (This is not shown on the Figure since the concentrations do not reach this level).

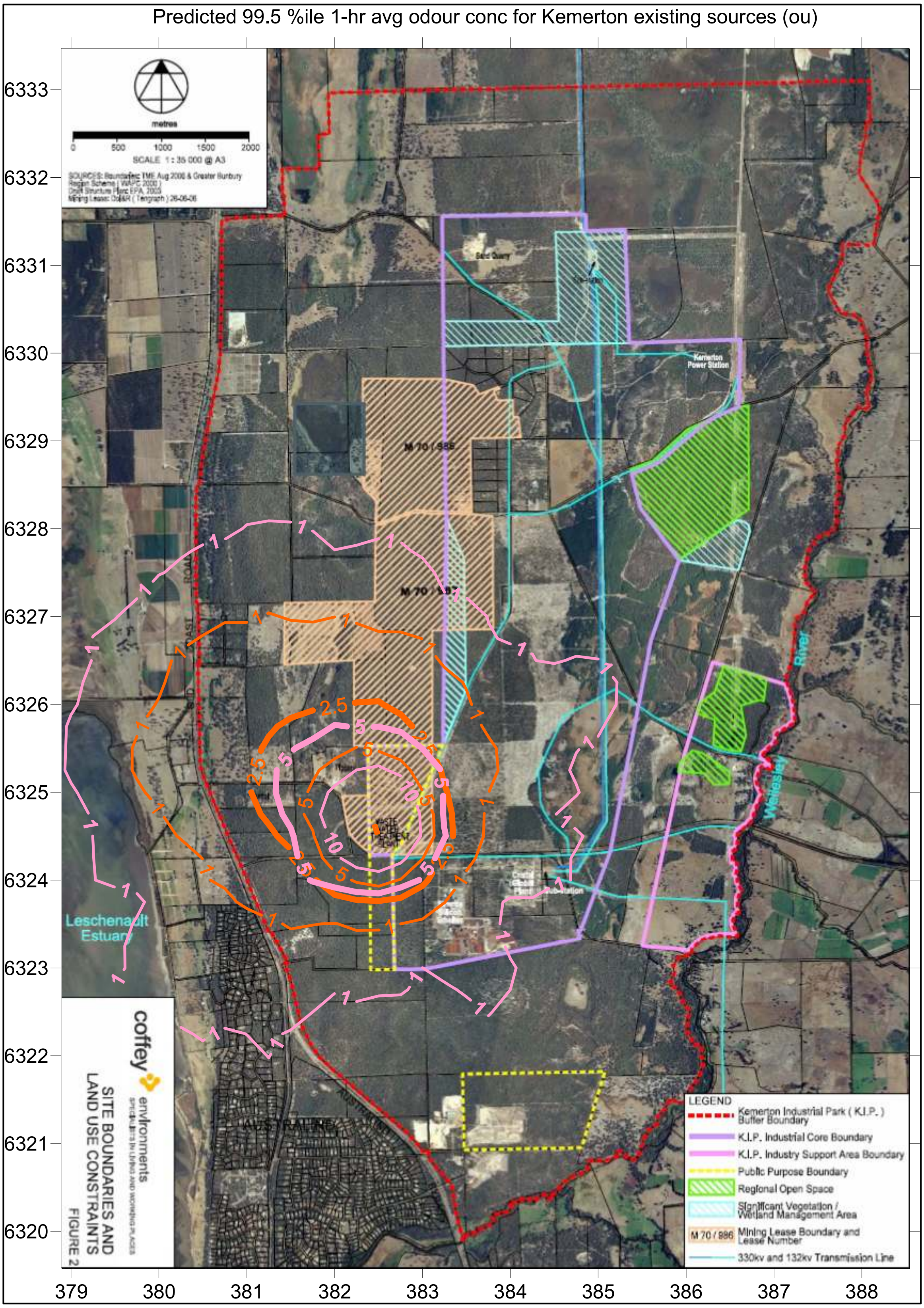



**Figure 19 Predicted 99.5 and 99.9 percentile 1-hour average odour concentrations for Kemerton existing sources**

99.5 percentiles in orange – criterion = 2.5 ou

**99.9 percentiles in pink – criterion = 5 ou**

## 14.2 GENERAL PATTERN OF GROUND LEVEL CONCENTRATIONS FOR VARIOUS SOURCE HEIGHTS

The general shape of buffer requirements for a 5m and 100m source located at the approximately centre of the KIP are shown in Figure 20.

The contours are relative and sized at a nominal level at which part of the contour just reaches the extent of the buffer.

The concentrations are calculated from Robust Highest Concentration (RHC) statistic from Hurley (2002) given by:

$$RHC = C(R) + (\overline{C} - C(R))\ln((3R-1)/2)$$ **Equation 2**

with C(R) the $R^{th}$ highest concentration and $\overline{C}$ the mean of the top *R*-1 concentrations. The value of *R* = 11 is used here so that *C* is the average of the top ten concentrations.

The RHC is effectively a trend line towards the highest concentration, based on the top 10 highest concentrations. This is preferred to the actual maximum value because it mitigates against the undesirable influence of atypical events that might be present in the annual meteorological data for the modelled year that may cause unrepresentative predicted maximum concentrations - while still representing the magnitude of the maximum concentration (unlike percentiles).

The 100m source causes less uniform distribution of ground level impacts as the maximum impact away from the source is determined by discrete combinations of weather parameters that affect plume rise and/or bring the elevated plume rapidly to the ground. Therefore maximum impacts from taller sources away from the source can be difficult to predict. Nevertheless, there would be an advantage siting a tall source relatively towards the north-east within the KIP to optimise ground level impacts outside the buffer.

For the 5m source, the maximum ground level impacts are distributed fairly uniformly around the source with a lesser elongation to the south-west. There would also be a small advantage siting a short source slightly north-east within the KIP to optimise ground level impacts outside the buffer.

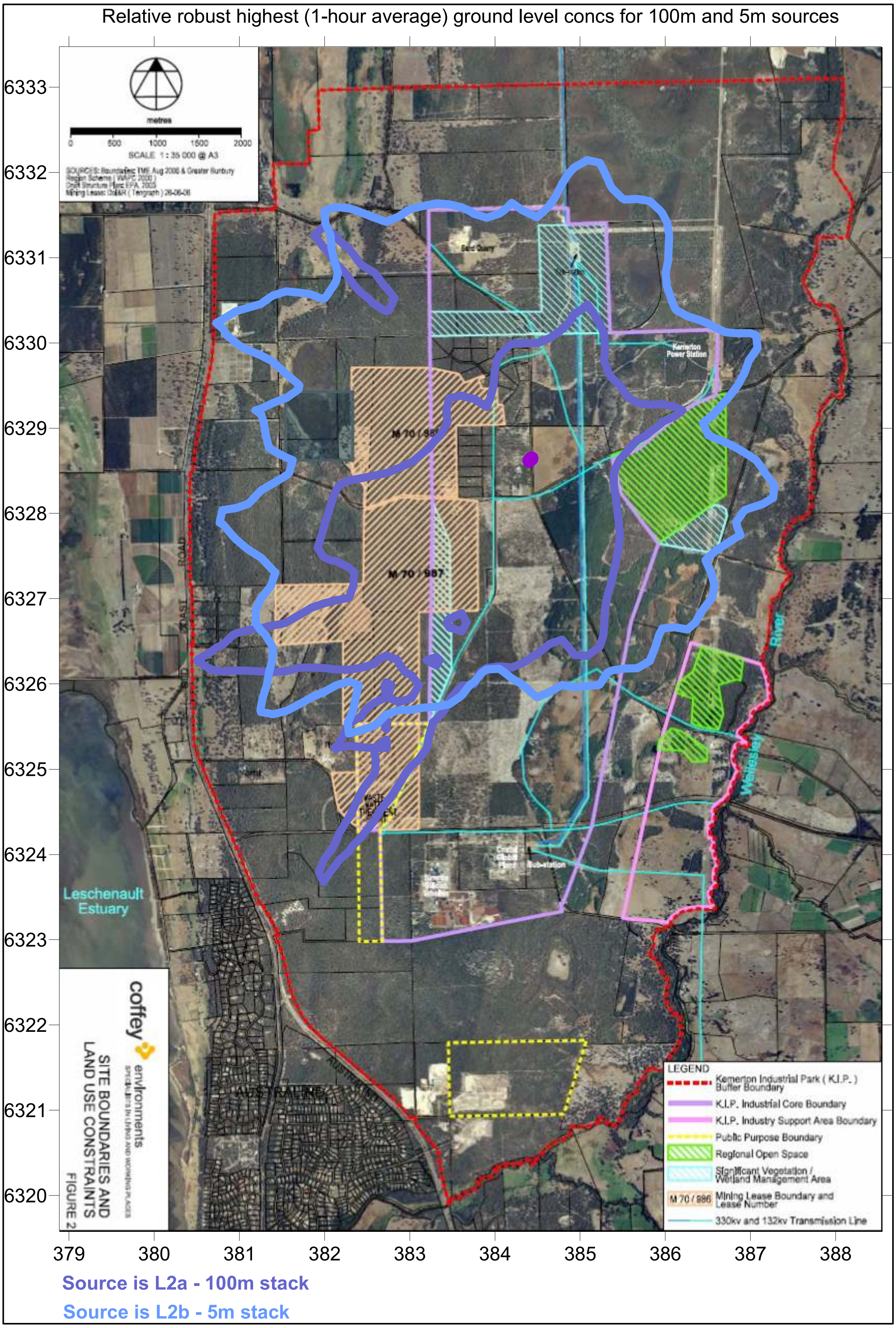



**Figure 20 Relative ground level impacts from 100m and 5m sources**

# 15. SUMMARY AND RECOMMENDATIONS

This report presents an evaluation of the requirements for an air quality buffer around the Kemerton Industrial Park. This evaluation is based on the use of the most recent regulatory air quality modelling methodology, site meteorological data together with existing and anticipated future representative source types.

**Modelling Results**

Modelling for a range of scenarios with emissions of NOx and SO2 (the pollutants generally of most concern from industry) at emission rates comparable to those currently from the Kwinana industrial estate indicate that the resultant concentrations will be well below the accepted criteria. The 1-hour criterion for NO2 and SO2 are predicted not to be exceeded outside the KIP buffer for any of the scenarios including the full development of the estate (see Table 14).

## Table 14 Predicted concentrations outside buffer relative to criteria

| Scenario | Maximum NO2 conc outside buffer relative to criterion (%) | Maximum SO2 conc outside buffer relative to criterion (%) |
|---|---|---|
| 1. Existing industry | 24 | 9.6 |
| 2. Existing and approved industry | 26 | 13 |
| 3. Existing, approved and hypothetical industries | 29 | 30 |

The maximum impact relative to criterion is 30% from SO2 for scenario 3 although the NO2 impact relative to criterion is almost the same.

This suggests that the intended uses of the industrial core, and size and shape of the buffer, are appropriate for likely future development of the KIP and includes a useful margin of safety. It would be expected that future industries minimise emissions commensurate with high international standards for the protection of the environment and that a margin of safety be retained.

It is also predicted that odour concentrations from the Water Corporation's Waste Water Treatment Plant are below criteria used for the protection of adverse impacts at sensitive receptors outside the buffer.

An assessment of preferred locations for industries was also conducted with the findings that:

- There would be an advantage siting a tall source relatively north-east within the KIP to optimise ground level impacts outside the buffer; and
- There would be a slight advantage siting a short source similarly north-east within the KIP to optimise ground level impacts outside the buffer.

It is therefore particularly important to maintain the buffer west and south of the industrial core.

**Review of Available Weather Data**

Though the study findings have indicated the adequacy of planning for the estate, this study has highlighted the need for high quality baseline meteorological and air quality data relevant to air quality planning in a similar fashion to what was undertaken for Kwinana in the1970s and the Burrup in the 1990s. In these cases, high quality weather data was collected to support the modelling of air emissions from major developments within the industrial estates.

It is considered that the Landcorp meteorological data collected from 1995 to 2001, though being adequate for general planning, is not adequate to form the basis of a high quality meteorological data set for the level of quality of dispersion modelling of air emission that may be required as future industries are established in the KIP. The main reasons are the high wind speed threshold of the anemometer that appeared in the later years of monitoring, and that the site was on top of a ridge line. The issue with the wind speed thresholds means that calm-to-light wind conditions, which are important for the dispersion of air emissions from near-ground level, low buoyancy sources, may not be accurately characterised. The issue regarding the siting is most relevant for surface releases where the winds on the low lying areas to the east of the ridge cannot be properly characterised by wind measurements on the ridge itself.

It is recommended that a permanent weather station at a site to the east of the ridge line towards the centreline of the estate measuring the following parameters be installed:

- anemometers at 30m and 10m which meet the specifications for "sensitive accurate sensors" as defined in Australian Standard AS2923-1987;
- aspirated temperature at 2m and 10m; and
- solar radiation, relative humidity, rainfall and possibly net radiation.

In any future modelling, the development of wind field using CALMET could usefully include data from any available continuous measurement sites within 5 kms of so west and east of the KIP. This should permit a better representation of wind variations east-to-west across the coastal plain. While the BoM and Bunbury Port Authority anemometers at Bunbury would be suitable for a western site, there is no readily available source of continuous meteorological data available for east of the KIP. It is understood that the Alcoa Wagerup refinery does, however, operate several anemometers and these could be suitable. It is recommended that Alcoa be approached with a view to making these data available for air quality studies at Kemerton.

The potential expansion of Simcoa will increase ambient SO2 concentrations. While expected to be below criteria, it is anticipated that the DEC will take a conservative approach to approving future SO2-emitters in the absence of data verifying existing impacts and for the validation of dispersion modelling.

Similarly, NOx emissions are a ubiquitous combustion by-product and likely to be emitted from most future industries. The proximity of forests and the expansion of the Bunbury region will increase ozone precursor emissions. It will be important for the future expansion of Kemerton that NO2/ozone impacts can be demonstrably managed.

It is therefore also recommended that when predicted ground level concentrations of SO2 and/or NO2 exceed 50% of criteria levels outside the buffer (following further industrial development within the KIP), continuous ambient SO2 and NOx (speciation of NO and NO2) monitoring be implemented.

## 16. REFERENCES


Air Assessments, 2006, "Kemerton Power Station – Air Quality Impact of Wet Compression", Fax report to ATA Environmental, 20/12/2006.

Bureau of Meteorology, 2004, "Instrument Test Report 677, The Conversion Equation of the Synchrotec 706 Anemometer", 5 March 2004.

Environmental Alliances, 2008, "Predicted SO2, NO2 and PM10 impacts from two new furnaces baghouse with stacks (scenario F3)", Fax report for Simcoa Operations dated 8/11/2008.

Environmental Alliances, 2006, "Dispersion Modelling Of Sulphur Dioxide Emissions From Proposed Expansion Options At Simcoa Silicon Smelter, Kemerton", Prepared for Simcoa, January 2006.

Golder, D. 1972, "Relations among stability parameters in the surface layer", Boundary Layer Meteorology, 3, 47-58.

Hurley, P.J., Physick W.L. and Luhar, A.K., 2002, "The Air Pollution Model (TAPM) Version 2. Part 2: Summary of Some Verification Studies", CSIRO Atmospheric Research Technical Paper No. 57.

National Environment Protection Council (NEPC), 1998, National Environment Protection Measure for Ambient Air Quality, 26 June 1998.

NEPC, 2002, "National Environment Protection (Ambient Air Quality) Measure Impact Statement for PM2.5 Variation Setting a PM2.5 Standard in Australia", October 2002.

Physick B. and Edwards M., 2004, "Air pollution modelling in the Collie region for the Griffin Energy proposed Bluewaters Power Station: Part II", CSIRO Report C/0896

Physick, W. and Blockley, A., 2001, "An Evaluation of Air Quality Models for the Pilbara Region", June 2001.

SKM, 2003, "Kemerton Power Station Air Quality Assessment", Rev 0, November 2003.

Standards Australia, 1987, "Australian Standard 2923-1987 Ambient Air - Guide for measurement of horizontal wind for air quality applications".

Thompson Mcrobert Edgeloe, 2009, "Kemerton Industrial Park Strategy Plan", Prepared For Landcorp, November 2009.

U.S. Federal Register, 2001, "Part II Environmental Protection Agency 40 CFR Ch. I (7–1–01 Edition) Part 51, Appendix W —Guideline On Air Quality Models".

US EPA, 1999 ,Guideline on Air Quality Models, US EPA, 40 CFR Ch I (7-1-99 Edition).

WNI Science & Engineering, 1997, "Air Quality Modelling for Kemerton Industrial Estate Expansion", 2 April 1997.

Woodward Clyde 1997, "Kemerton Industrial Park Expansion Study", 16 April 1997.

WHO, 2000, "Air Quality Guidelines for Europe 2nd Ed", World Health Organisation, Regional Publications, European Series Number 91.

## 17. GLOSSARY

**General terms**

| | |
|---|---|
| $\mu g/m^3$ | micrograms per cubic metre of air. |
| µm | microns or micrometers. |
| BoM | Bureau of Meteorology. |
| DEC | Department of Environment and Conservation |
| KEPP | Kwinana Environmental Protection Policy taken to jointly comprise the Environmental Protection (Kwinana) (Atmospheric Waste) Policy 1992 and Environmental Protection (Kwinana) (Atmospheric Waste) Regulations 1992. |
| Km | kilometres. |
| M | metres. |
| m/s | metres per second. |
| m/s | Cubic metres per second. |
| NEPM | National Environment Protection Measure for Ambient Air Quality dated 26 June 1998. |
| ou | odour units. An odour unit is a dimensionless ratio defined as the volume which an odorous sample would occupy when diluted to the odour detection threshold, divided by the volume of the odorous sample. |
| Percentile | the division of a distribution into 100 groups having equal frequencies. |
| PM10 | Airborne particles with an equivalent aerodynamic diameter of less than 10 µm. |
| PM2.5 | Airborne particles with an equivalent aerodynamic diameter of less than 2.5 µm. |
| ppm | parts per million by volume. |
| TSP | Total Suspended Particulates. |

**Wind direction references**

| | |
|---|---|
| NNE | north-north-east |
| NE | north-east |
| ENE | east-north-east |
| ESE | east-south-east |
| SE | south-east |
| SSE | south-south-east |
| SSW | south-south-west |
| SW | south-west |
| WSW | west-south-west |
| WNW | west-north-west |
| NW | north-west |
| NNW | north-north-west |

## Appendix 1 Review of Landcorp met data for Kemerton

The meteorological data for the Landcorp weather station at Kemerton supplied by the BoM in 2009 was amalgamated with previously supplied data to form a composite data set from November 1994 to April 2001.

The resulting data recovery for each parameter is shown in Table 15.

Annual wind speed statistics from Landcorp anemometer are shown in Table 16. These illustrate the increasing percentage of calms in the later (post 1999) period of monitoring. Commensurately, there is also a decreasing occurrence of winds in the high wind speed ranges. Therefore it appears that the anemometer (bearing) wear over the years may have been the cause of the higher wind speed measurement threshold and consequently lower winds speeds measured, in the later years of data collection. This is supported by data presented in (Bureau of Meteorology, 2004) which showed that the wind speed ("turn on") threshold for a Synchrotac which has not been well serviced increased from 0.7 m/s to 1.3 m/s.

Furthermore, the Australian Standard AS2923-1987 for wind measurement quotes a wind speed threshold of $< 0.5$ m/s for "measurement programs where the wind data have a very significant impact on project objectives, and must be reliable and of high accuracy" (Standards Australia 1987). Hence even an anemometer wind speed threshold of 0.7 m/s is too high for the purposes of providing data of adequate quality to underpin significant industrial developments in the KIP.

Wind speed and direction frequency roses are shown in Figure 21. These show generally similar trends in wind direction, notwithstanding that the increasing wind speed threshold –particularly after 1999, also means that corresponding wind directions in the later period of data may not necessarily be useable.

The 1999 year has a greater relative proportion of winds from the east-south-east to south-south-east and fewer winds from the north-west compared to other years. Given that the 2000 year wind directions were similar to those for 1995 and 1996, the 1999 differences were considered to be due to annual variability rather than anemometer problems.

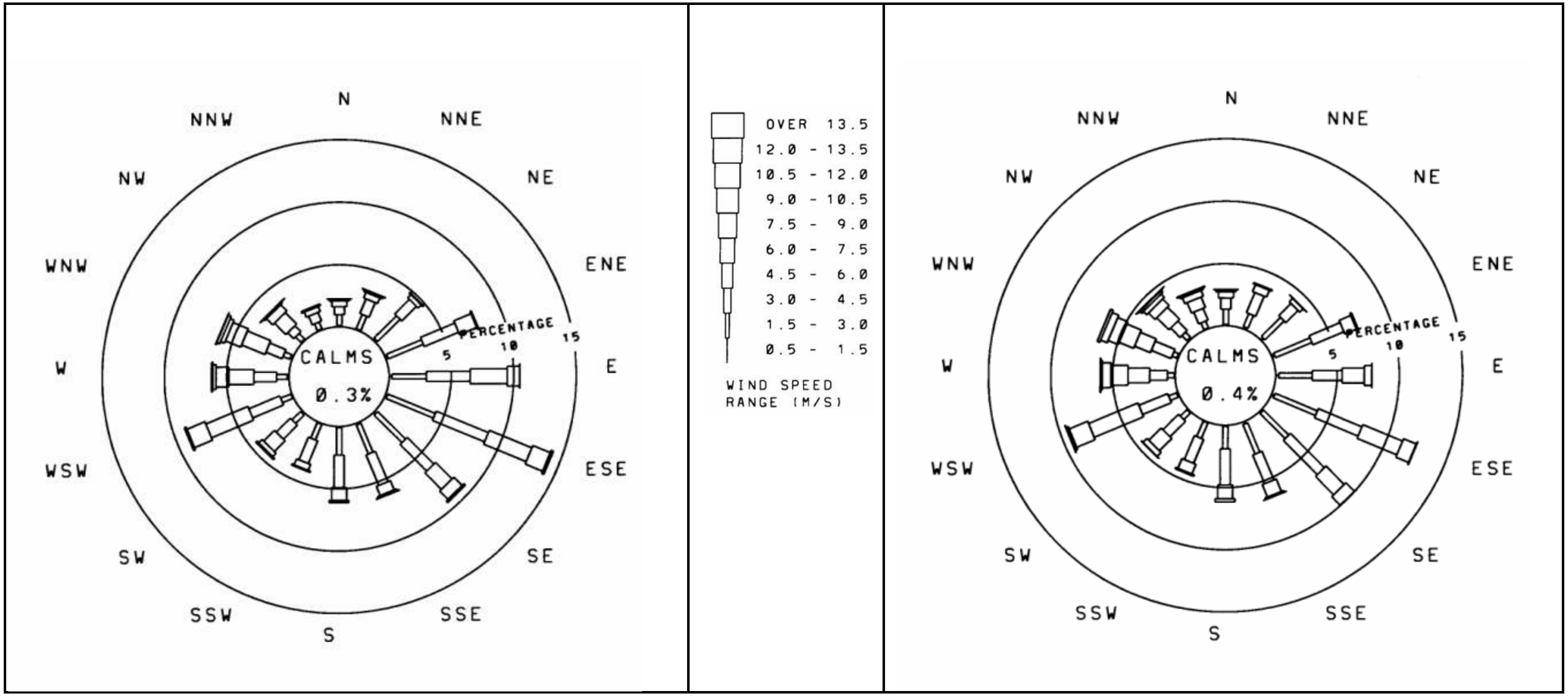
## Table 15 Data recovery from Landcorp weather station at Kemerton

| Month | Year | Data recovery (%) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Wind speed | Wind direction | Sigma theta | Wind gust | Temperature at 10m | Temperature at 1.5m | Dew Point Temp |
| NOV | 1994 | 8.2 | 8.2 | 8.2 | 8.2 | 0 | 0 | 0 |
| DEC | 1994 | 57 | 57 | 57 | 57 | 52.3 | 52.3 | 52.3 |
| JAN | 1995 | 92.1 | 92.1 | 92.1 | 91.7 | 92.1 | 91.7 | 91.7 |
| FEB | 1995 | 86.8 | 86.8 | 86.8 | 86.8 | 86.8 | 86.8 | 86.8 |
| MAR | 1995 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| APR | 1995 | 93.3 | 93.3 | 93.3 | 93.1 | 93.3 | 93.1 | 93.1 |
| MAY | 1995 | 82.3 | 82.3 | 82.3 | 82.3 | 82.1 | 82.1 | 82.1 |
| JUN | 1995 | 77.5 | 77.5 | 77.5 | 77.1 | 77.5 | 77.1 | 77.1 |
| JUL | 1995 | 82.1 | 82.1 | 82.1 | 81.3 | 82.1 | 81.5 | 81.5 |
| AUG | 1995 | 100 | 100 | 100 | 99.6 | 100 | 99.6 | 99.6 |
| SEP | 1995 | 98.2 | 98.2 | 98.2 | 97.9 | 98.2 | 97.9 | 97.9 |
| OCT | 1995 | 100 | 100 | 100 | 99.3 | 100 | 99.3 | 98.8 |
| NOV | 1995 | 96.5 | 96.5 | 96.5 | 95.3 | 96.5 | 95.3 | 95.3 |
| DEC | 1995 | 97 | 97 | 97 | 96.8 | 97 | 96.8 | 96.8 |
| JAN | 1996 | 99.1 | 99.1 | 99.1 | 99.1 | 99.1 | 99.1 | 99.1 |
| FEB | 1996 | 99.7 | 99.7 | 99.7 | 99.7 | 99.7 | 99.7 | 99.7 |
| MAR | 1996 | 60.3 | 60.3 | 60.3 | 60.3 | 60.3 | 59.7 | 25.9 |
| APR | 1996 | 71.3 | 71.3 | 71.3 | 71.3 | 71.3 | 71.3 | 0 |
| MAY | 1996 | 75.3 | 75.3 | 75.3 | 75.3 | 75.3 | 75.3 | 0 |
| JUN | 1996 | 72.4 | 72.4 | 72.4 | 72.4 | 72.4 | 72.4 | 0 |
| JUL | 1996 | 88.6 | 88.6 | 88.6 | 88.6 | 88.6 | 88.6 | 0 |
| AUG | 1996 | 93.7 | 93.7 | 93.7 | 93.7 | 93.7 | 93.7 | 0 |
| SEP | 1996 | 97.6 | 97.6 | 97.6 | 97.6 | 97.6 | 97.6 | 0 |
| OCT | 1996 | 96.4 | 96.4 | 96.4 | 96.4 | 96.4 | 96.4 | 0 |
| NOV | 1996 | 67.1 | 67.1 | 67.1 | 67.2 | 45.6 | 45.6 | 0 |
| DEC | 1996 | 43.3 | 43.3 | 43.3 | 43.3 | 43.3 | 43.3 | 43.3 |
| JAN | 1997 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| FEB | 1997 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MAR | 1997 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| APR | 1997 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MAY | 1997 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| JUN | 1997 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| JUL | 1997 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| AUG | 1997 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SEP | 1997 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 |
| OCT | 1997 | 99.1 | 99.1 | 99.1 | 99.1 | 99.1 | 99.1 | 99.1 |
| NOV | 1997 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| DEC | 1997 | 97.4 | 97.4 | 97.4 | 97.4 | 97.4 | 97.4 | 97.4 |
| JAN | 1998 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| FEB | 1998 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MAR | 1998 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| Month | Year | Data recovery (%) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Wind speed | Wind direction | Sigma theta | Wind gust | Temperature at 10m | Temperature at 1.5m | Dew Point Temp |
| APR | 1998 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 |
| MAY | 1998 | 99.3 | 99.3 | 99.3 | 99.3 | 99.3 | 99.3 | 99.3 |
| JUN | 1998 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 | 97.5 |
| JUL | 1998 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| AUG | 1998 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SEP | 1998 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| OCT | 1998 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| NOV | 1998 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DEC | 1998 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| JAN | 1999 | 100 | 100 | 100 | 0 | 100 | 0 | 0 |
| FEB | 1999 | 100 | 100 | 100 | 0 | 100 | 0 | 0 |
| MAR | 1999 | 100 | 100 | 100 | 0 | 100 | 0 | 0 |
| APR | 1999 | 76.7 | 76.7 | 76.7 | 0 | 76.7 | 0 | 0 |
| MAY | 1999 | 100 | 100 | 100 | 0 | 100 | 0 | 0 |
| JUN | 1999 | 54.2 | 54.2 | 54.2 | 0 | 54.2 | 0 | 0 |
| JUL | 1999 | 100 | 100 | 95.3 | 0 | 100 | 0 | 0 |
| AUG | 1999 | 100 | 100 | 100 | 0 | 100 | 0 | 0 |
| SEP | 1999 | 100 | 100 | 100 | 0 | 100 | 0 | 0 |
| OCT | 1999 | 100 | 100 | 100 | 0 | 100 | 0 | 0 |
| NOV | 1999 | 95.4 | 95.4 | 95.4 | 0 | 95.4 | 0 | 0 |
| DEC | 1999 | 85.8 | 85.8 | 85.8 | 3.9 | 85.8 | 3.9 | 3.9 |
| JAN | 2000 | 81.3 | 81.3 | 81.3 | 81.3 | 81.3 | 81.3 | 81.3 |
| FEB | 2000 | 98.7 | 98.7 | 98.7 | 98.7 | 98.7 | 98.7 | 98.7 |
| MAR | 2000 | 95.9 | 95.9 | 95.9 | 95.9 | 95.9 | 95.9 | 95.9 |
| APR | 2000 | 99.8 | 99.8 | 99.8 | 99.8 | 99.8 | 99.8 | 99.8 |
| MAY | 2000 | 98.9 | 98.9 | 98.9 | 98.9 | 98.9 | 98.9 | 98.9 |
| JUN | 2000 | 100 | 99.9 | 99.9 | 100 | 100 | 100 | 100 |
| JUL | 2000 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| AUG | 2000 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| SEP | 2000 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| OCT | 2000 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| NOV | 2000 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| DEC | 2000 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| JAN | 2001 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| FEB | 2001 | 99.4 | 99.4 | 99.4 | 99.4 | 99.4 | 99.4 | 99.4 |
| MAR | 2001 | 99.8 | 99.8 | 99.8 | 99.8 | 99.8 | 99.8 | 99.8 |
| APR | 2001 | 97.1 | 97.1 | 97.1 | 97.1 | 97.1 | 97.1 | 97.1 |

**Table 16 Annual wind speed statistics from Landcorp anemometer**

| Wind speed range (m/s) | Frequency (%) | | | |
|---|---|---|---|---|
| | 1995 | 1996 | 1999 | 2000 |
| 12 - 13.5 | 0.0 | 0.0 | 0.0 | 0.0 |
| 10.5 - 12 | 0.0 | 0.3 | 0.0 | 0.0 |
| 9 - 10.5 | 0.4 | 1.0 | 0.3 | 0.2 |
| 7.5 – 9 | 1.5 | 2.4 | 1.5 | 1.5 |
| 6 - 7.5 | 9.5 | 9.5 | 8.5 | 8.4 |
| 4.5 – 6 | 24.3 | 24.0 | 24.6 | 22.4 |
| 3 - 4.5 | 33.7 | 33.8 | 32.4 | 29.2 |
| 1.5 – 3 | 28.3 | 26.2 | 26.7 | 20.2 |
| 0.5 - 1.5 | 2.1 | 2.2 | 3.8 | 5.5 |
| Calms (%) | 0.3 | 0.4 | 2.1 | 12.6 |
| Average (m/s) | 4.1 | 4.2 | 4.0 | 3.4 |


N
NNE
NE
ENE
E
ESE
SE
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
PERCENTAGE
5
10
15
CALMS
0.3%
OVER 13.5
12.0 - 13.5
10.5 - 12.0
9.0 - 10.5
7.5 - 9.0
6.0 - 7.5
4.5 - 6.0
3.0 - 4.5
1.5 - 3.0
0.5 - 1.5
WIND SPEED
RANGE (M/S)
N
NNE
NE
ENE
E
ESE
SE
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
PERCENTAGE
5
10
15
CALMS
0.4%

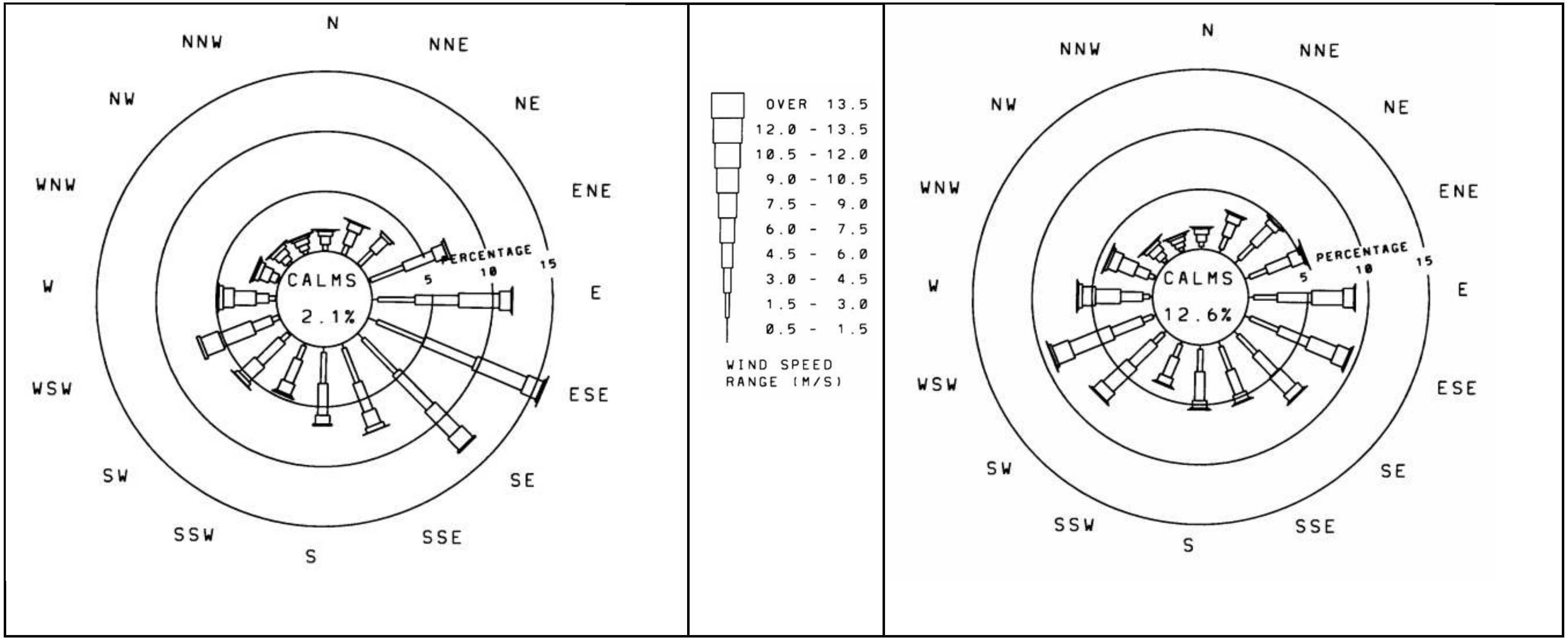



**Figure 21 Annual wind roses from Landcorp anemometer**

## Appendix 2 CALMET input control parameters

CALMET generates an initial wind field based on assumed uniformity of the surface meteorological data and profile observations over the wind field, followed by adjustments for terrain and heat fluxes based on the geophysical data. The step 1 windfield is modified by merging in the observational data, based on user-specified assumptions in CALMET.

Defaults were used except where indicated as below.

The selection of biases for vertical cell face heights is shown in Table 17.

### Table 17 Selection of biases for vertical cell face heights

| Cell face height (m) | 0 | 20 | 40 | 80 | 160 | 320 | 640 | 1280 |
|---|---|---|---|---|---|---|---|---|
| Biases for initial wind field (-1 lower to 1 upper) | - | -1.0 | -1.0 | -1.0 | -0.75 | -0.5 | -0.25 | 0 |

These are intended to allow the TAPM-generated upper winds to have only a low relative level of influence on the CALMET upper winds progressively increasing to an equal weighting only at the top level. This should minimise the possibility of vertical wind shears being predicted and promote conservative predictions of plume ground levels concentrations.

The option to "Extrapolate surface calms to upper layers" was set to off to avoid unrealistically low wind speeds at upper levels.

Key parameters in the wind field determination are shown in Table 5.

### Table 18 CALMET settings for step 2 wind field determination

| **Parameter** | **Value** |
|---|---|
| Maximum radius of influence over land in the surface layer (RMAX1) | 1 km |
| Maximum radius of influence over land aloft (RMAX2) | 2 km |
| Maximum radius of influence over water (RMAX3) | 4 km |
| Relative weighting of the first guess field and observations in the surface layer (R1) | 0.5 km |
| Relative weighting of the first guess field and observations in the layers aloft (R2) | 1 km |
| Radius of influence of terrain features (TERRAD) | 2 km |

The field options were designed to use the step 1 wind field over land except in the immediate vicinity of the anemometer site and where influenced by terrain.

## Appendix 3 Sensitivity test of modelling results using PG curves

As discussed in Section 9.1, there was a considerable different in the stability distributions determined from the meteorological data between the Pasquil Gifford approach and turbulence parameters calculated internally in CALMET. The latter of these was used for the CALPUFF modelling.

To assess the potential these differences in stability determinations make in modelling, CALPUFF as re-run for the existing SO2 scenario using Pasquil Gifford dispersion curves to estimate dispersion rather than turbulence parameters. The Pasquil Gifford dispersion curves were taken as being representative of 10 minute averages (e.g. the variable tpg was set to 10 minutes[3]).

The resulting maximum 1-hour average SO2 concentrations for Scenario 1 are compared in Figure 24.

This shows that the maximum concentrations can be about twice as high to the north and west of the KIP using the PG curves and around 50% higher to the south and east.

In order to try and assess which predictions were more realistic, a comparison was made with the only known ambient pollutant data measured in the region.

In support of environmental approvals for a proposed expansion during 2003, Simcoa commissioned Ecotech to install and operate an ambient SO2 monitor in a residential area SSW of the Kemerton Industrial Area over the period 4/12/2003 to 8/1/2004 (complete days).

The time series measured ambient 1-hour average SO2 concentrations from these data are shown in Figure 22.

The measured ambient 1-hour average SO2 data from the monitoring location are plotted against wind direction in Figure 23. This was done to estimate the contribution to the measurements from the KIP industries – principally from Simcoa.

[3] The default within CALPUFF is to set tpg to 60 minutes to be consistent with the USEPA regulatory practice used in ISC3. This is generally considered to over-estimate predicted concentrations.

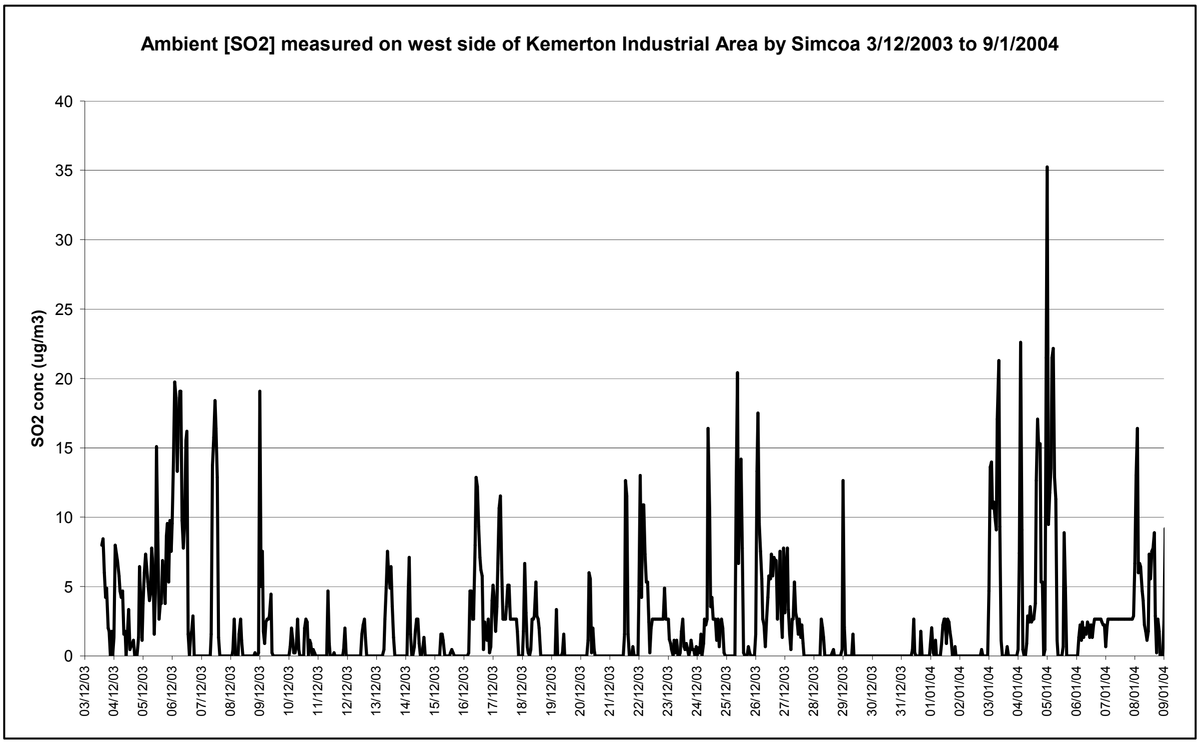



**Figure 22 Time series of measured SO2 concentrations at ambient monitoring location 3/12/2003 to 9/1/2004**

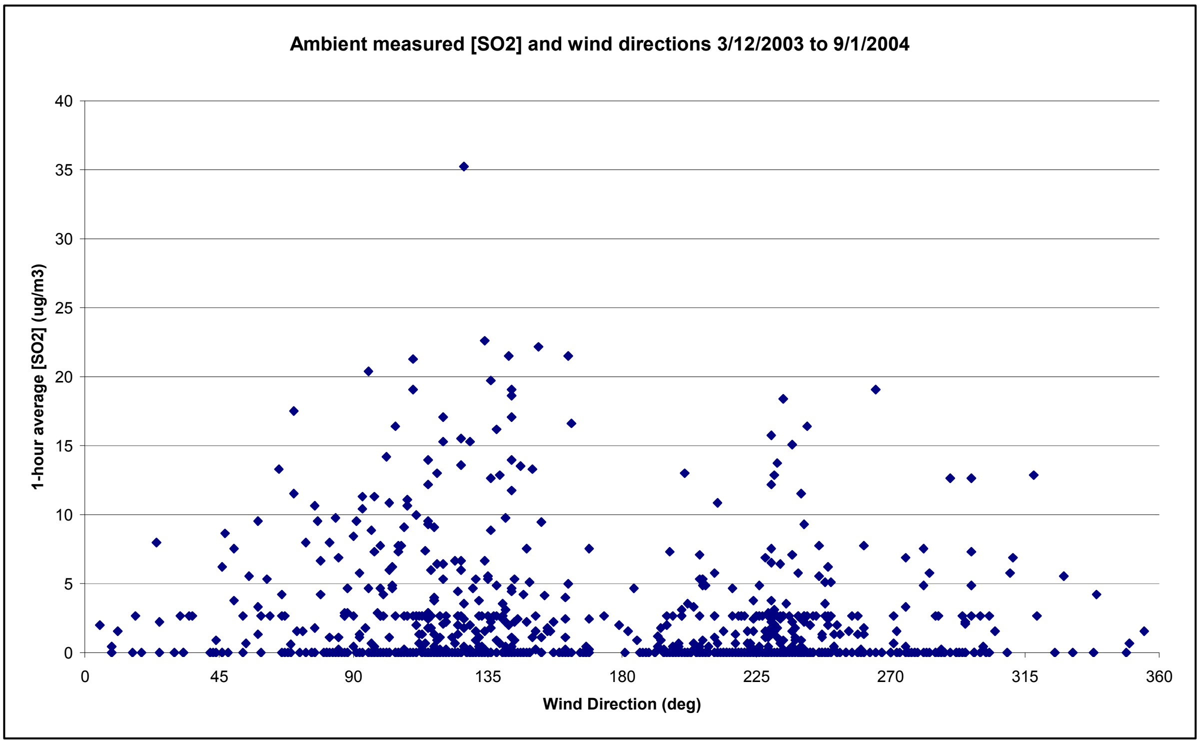



**Figure 23 Ambient measured SO2 concentrations and wind directions 3/12/2003 to 9/1/2004**

Note: The bearing from the Simcoa baghouse to the ambient monitoring location is 16º.

The top 10 measured 1-hour average concentrations for winds from the KIP area are shown in Table 19. These are compared to CALPUFF modelling predictions for existing SO2 emissions. The predictions use 1999 meteorology compared to the measurement period of 4/12/2003 to 8/1/2004 therefore the comparison is indicative only.

### Table 19 Comparison of top ten 1-hour average modelled and measured concentrations at ambient monitoring location

| Rank | 1-hour average SO2 concentration at ambient monitor for wind direction arc from 348.75° to 56.25° - KIP (µg/m³) | | | | |
|---|---|---|---|---|---|
| | Measured over 4/12/2003 to 8/1/2004 | Modelled using micrometeorology dispersion | | Modelled using PG dispersion | |
| | | 1999 (entire year) | 1/1/99-8/1/99 and 4/12/99-31/12/99 | 1999 (entire year) | 1/1/99-8/1/99 and 4/12/99-31/12/99 |
| 1 | 8.6 | 23.6 | 10.9 | 36.4 | 10.6 |
| 2 | 8.0 | 22.7 | 9.2 | 27.7 | 10.1 |
| 3 | 7.5 | 22.7 | 8.0 | 24.3 | 9.6 |
| 4 | 6.2 | 20.9 | 6.1 | 21.2 | 8.7 |
| 5 | 5.5 | 19.7 | 3.6 | 19.3 | 6.8 |
| 6 | 3.8 | 18.2 | 3.1 | 19.1 | 3.4 |
| 7 | 2.7 | 17.7 | 2.4 | 18.3 | 3.1 |
| 8 | 2.7 | 16.8 | 2.1 | 17.5 | 2.6 |
| 9 | 2.7 | 16.7 | 1.9 | 17.2 | 1.3 |
| 10 | 2.7 | 16.7 | 1.8 | 17.2 | 1.2 |
| RHC | - | 26.9 | - | 32.2 | - |

The CALPUFF predictions using micrometeorology dispersion option tends to predict lower concentrations for the highest few ranked concentrations than the PG option (ie 54%, 22%, 7% lower) but fairly similarly to the PG option after that.

Unfortunately, the monitor location was where differences between the CALPUFF predictions made using micrometeorology and PG curves is not the highest. Given this and the very duration of the monitoring period, it therefore cannot be reasonably determined which of the model options is more accurate.

One key outcome is that modelling predictions at or near annual maximums can be considerably influenced by selections of model options. It would be preferable for environmental impact assessment purposes to use the RHC or a percentile such as the 9$^{th}$ highest to assess “peak” impacts.

As discussed in Section 9.1, the maximum predicted NO2 and SO2 concentrations from the maximum emissions scenario (Scenario 3 - Existing industry, approved future industry and hypothetical future industries) were 29% and 30% of their respective criteria outside the KIP buffer.

The maximum predicted 1-hour average SO2 concentrations using PG curves for Scenario 3 are compared in Figure 25. This indicates that the use of PG curves results in very much higher maximum concentrations within the KIP and generally around 50% higher concentrations outside the KIP, although there are some fumigation impacts evident. Even so, the maximum predicted concentration outside the KIP is approximately 400 µg/m$^3$ which is still well below the criterion level of 572 µg/m$^3$. Therefore, it is still very likely that the criteria levels for the maximum development scenarios will be met, even using alternative modelling assumptions.

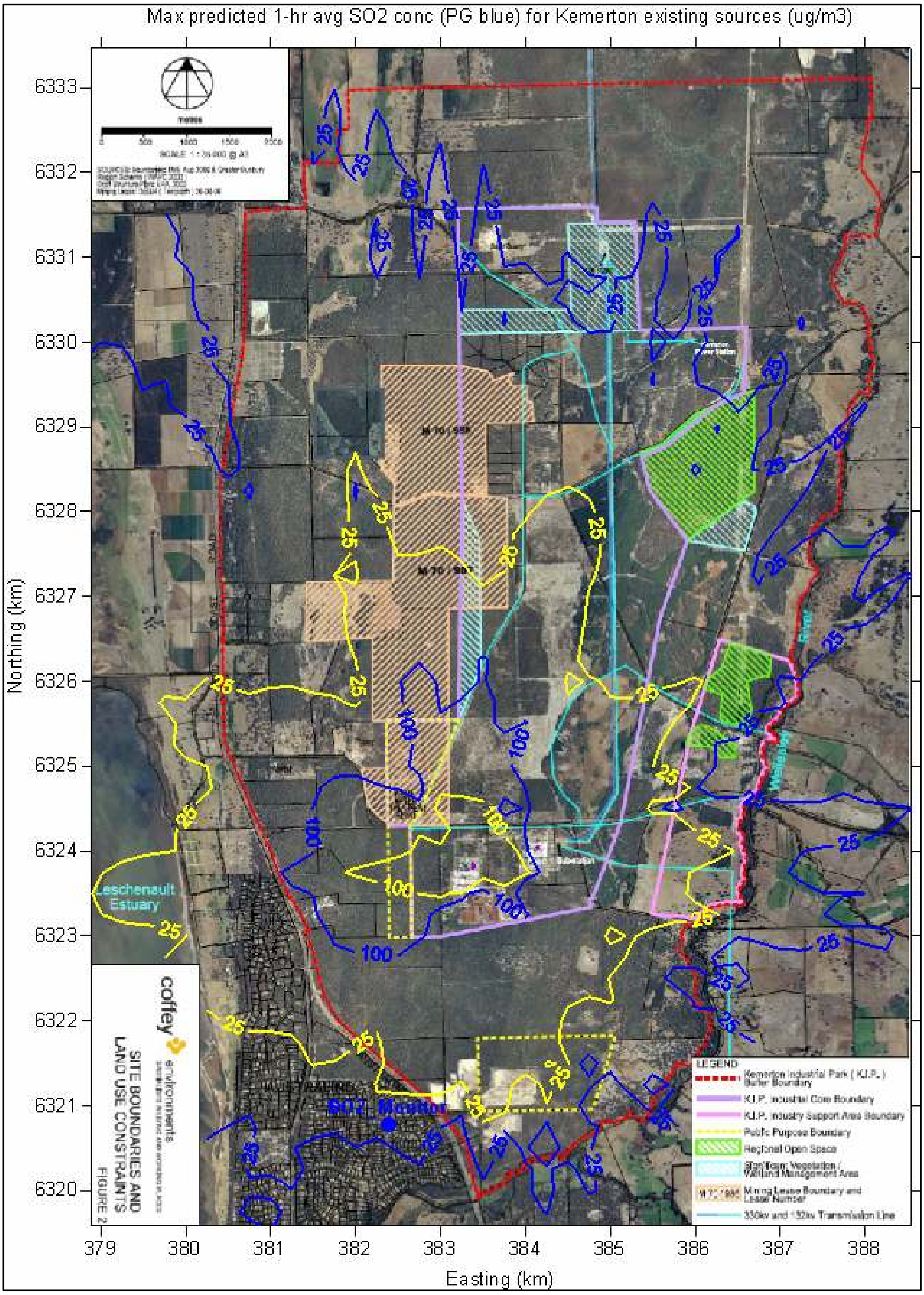



**Figure 24 Comparison of existing maximum 1-hour SO2 concentrations for existing sources (Scenario 1) predicted using CALPUFF micrometeorological dispersion (yellow) and PG curves (blue)**

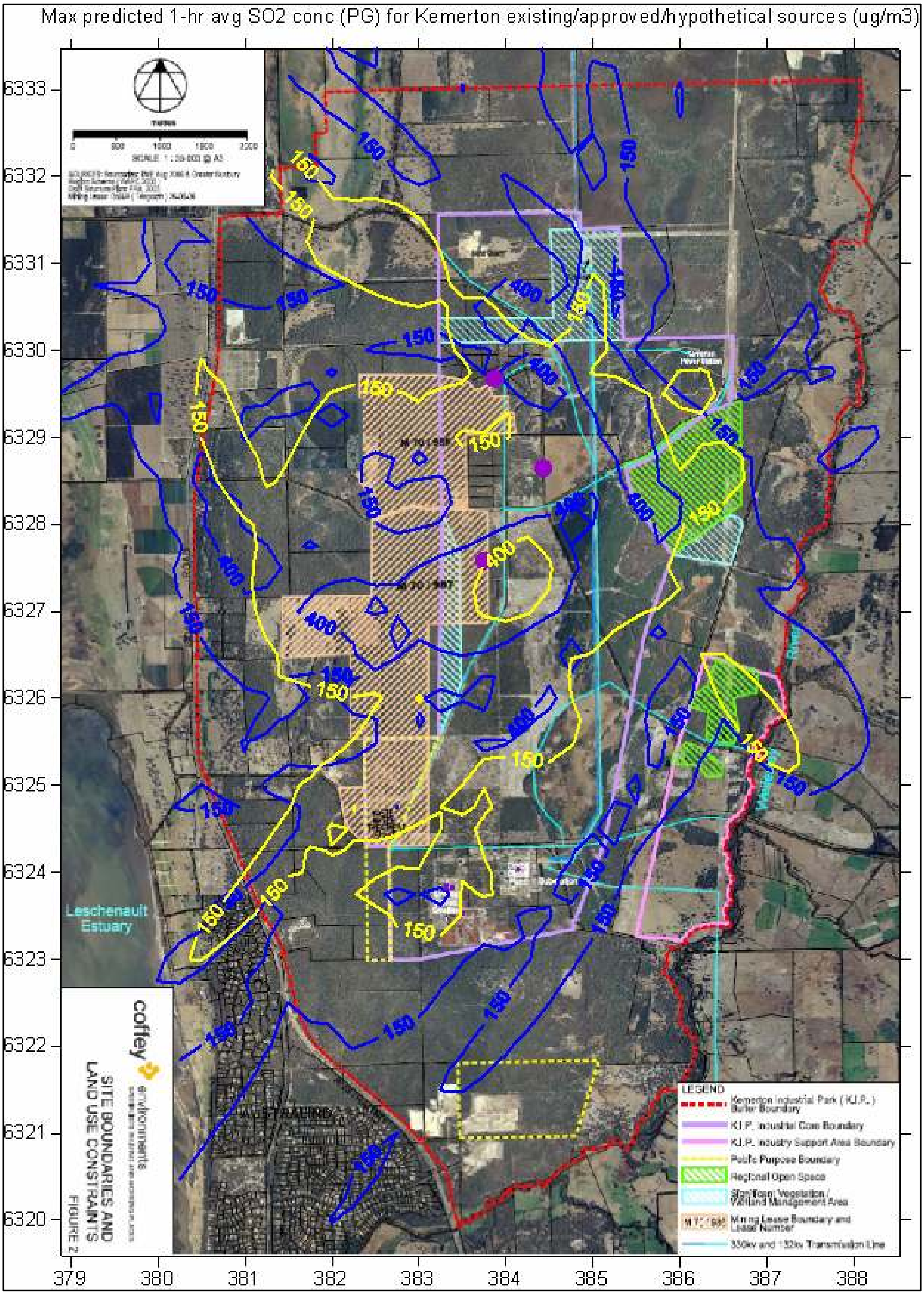



**Figure 25 Comparison of existing maximum 1-hour SO2 concentrations for existing, approved and hypothetical sources (Scenario 3) predicted using CALPUFF micrometeorological dispersion (yellow) and PG curves (blue)**

## Appendix 4 Modelling configuration for Simcoa baghouse

### *Existing baghouse*

The existing baghouse building is located on the site about 40 metres north of the Furnace and Product Handling Buildings.

The baghouse emissions are discharged through two ridge vents above the roof of the baghouse.

The mechanisms underlying dispersion include:

- For all wind directions, the plume rise will be affected by wakes on the leeward side of the baghouse building (and the adjacent silos).
- During SW to SE winds, the airstream around the baghouse building as a whole will be affected by the wake of the Furnace and Product Handling buildings, located to the south of the baghouse.
- The emissions having an exit temperature of 50ºC, will have some buoyancy. The effect of buoyancy on plume rise will be greatest ("enhanced") when winds are along the longest axis of the building and least when winds are across the building.

There is no generally available dispersion model which incorporates the features necessary to precisely deal with all of these mechanisms (ie buoyant ridge vent emissions[4] with building-wake effects from the associated and adjacent buildings).

The above mechanisms except the enhancement of plume buoyancy for winds along the building axis are, however, able to be addressed through the Plume Rise Model Enhancements (PRIME) feature which have been incorporated into several dispersion models including CALPUFF (neglecting the enhanced buoyancy will be conservative).

In addition to conventional plume rise approaches, the PRIME algorithm incorporates enhanced plume dispersion coefficients due to the wake turbulence, and reduced plume rise caused by descending streamlines and increased entrainment in the wake of a structure.

In order to make use of the PRIME algorithm, the baghouse vent line was defined for modelling as seven individual point sources running along the axis of the ridge. The cross-sectional area of each point source was defined as $1/7^{th}$ of the area of the vent line. Similarly, the substance emission rate for each point was $1/7^{th}$ of the total emission rate. This approach should underestimate plume rise for wind directions approaching the main axis of the building (ie during north and south winds).

In order to approximate the shape of the baghouse building for modelling, two tiers were defined:

- the first at the height of the baghouse building roof (height = 25.9 metres); and
- the second at the height of the ridge itself (height = 29 metres).

Wake effects from the Silos, Product handling Buildings and the Furnace Building were also taken into account. The cross-wind building dimensions for estimating wake effects were determined using the BPIP utility. A diagram illustrating the modelled building configuration in plan view is shown in Figure 26.

---

[4] The buoyant line source algorithm in CALPUFF was not considered preferable since it is designed for aluminum smelter potrooms which are not as tall as the baghouse and for which building downwash is not an issue and therefore not incorporated into the algorithm

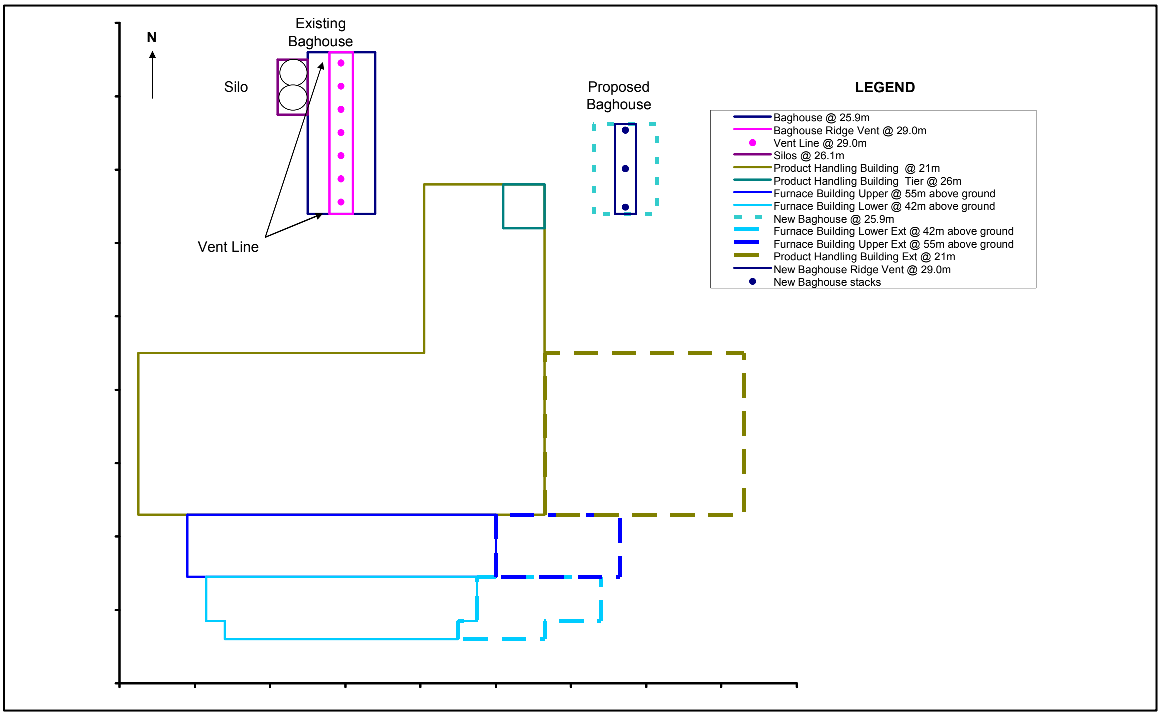



**Figure 26 Simcoa baghouses layout configuration used for modelling**

### *New baghouse*

The proposed new baghouse will have three stacks 12m above the building ridge height to reduce the effect of building wakes on plume rise and hence assist the dispersion of air emissions.

The precise configuration of the new baghouse has yet to be finalised. Since the new baghouse is one-half of the capacity of the existing baghouse, the buoyancy of the emissions were effectively halved by halving the area of each point comprising the ridge vent (ie from 4.66 $m^2$ per point source to 3.30 $m^2$ per point source). Any future modelling should use the actual specification of the baghouse when they are finalised.

### *Retort stack*

Emissions from the Simcoa retort stack were also treated as building wake affected, however wake effects in this case were minor.

(From Environmental Alliances 2006)

## Appendix 5 Description of Ozone Limiting Method for Estimating NO2 Concentrations

The Ozone Limiting Method (OLM) (NSW EPA 2005) for estimating ambient $NO_2$ concentrations from $NO_x$ emission sources is based on the assumption that approximately 10% (a conservative value for most combustion sources) of the $NO_x$ emissions in the exhaust are generated as $NO_2$. If the ozone concentration is greater than 90% of the predicted $NO_x$ concentrations, all the $NO_x$ is assumed to have been converted to $NO_2$. Otherwise, the $NO_2$ concentrations is calculated assuming total conversion of the ozone and adding the 10% of the $NO_x$ that was emitted as $NO_2$.

$$[NO_2]_{total} = \{0.1 \times [NO_X]_{pred}\} + MIN\{0.9 \times [NO_X]_{pred}, or (46/48) \times [O_3]_{bkgd}\} + [NO_2]_{bkgd}$$

**Equation 3**

Where-

$[NO_2]_{total}$ is the predicted concentration of $NO_2$ (vol/vol).

$[NO_x]_{pred}$ is the dispersion model prediction of the ground-level concentration of $NO_x$ (vol/vol).

MIN means the minimum of the two quantities within the braces.

$[O_3]_{bkgd}$ is the background ambient $O_3$ concentration (vol/vol).

(46/48) is the molecular weight of $NO_2$ divided by the molecular weight of $O_3$.

$[NO_2]_{bkgd}$ is the background ambient $NO_2$ concentration (vol/vol).

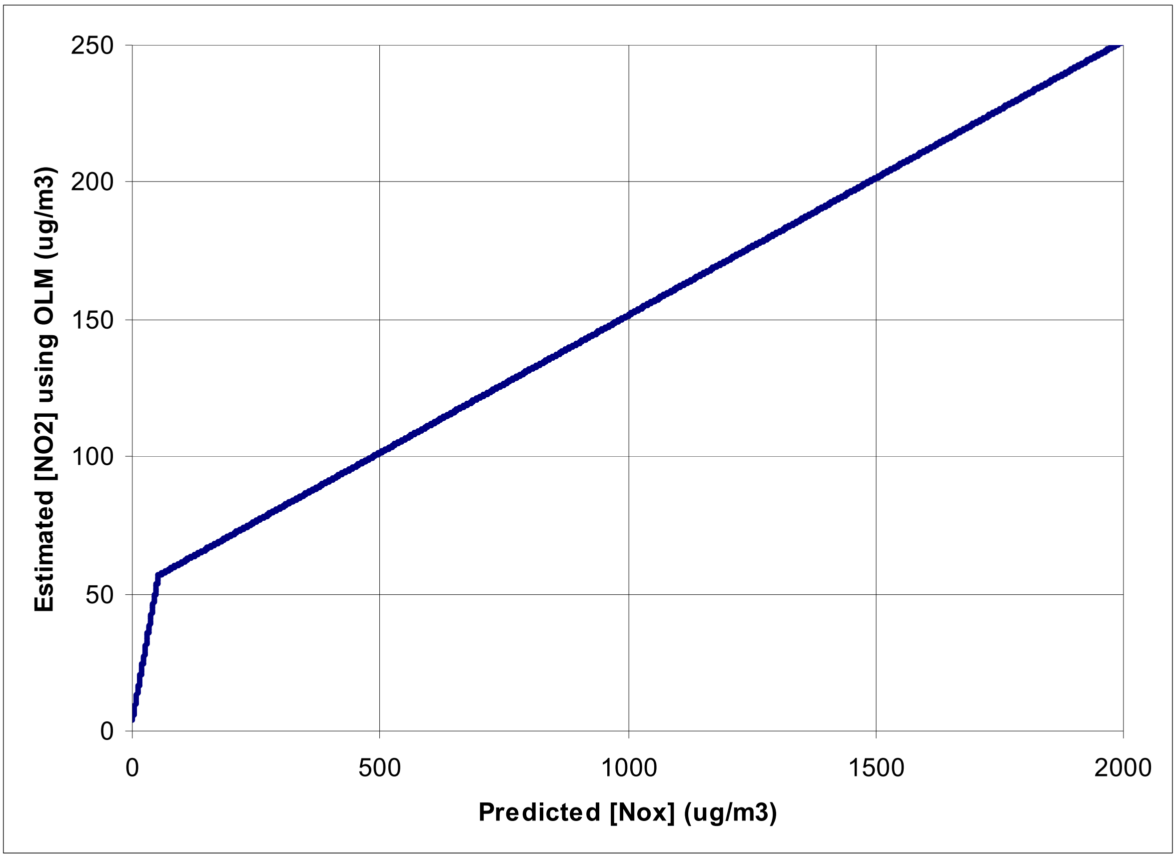



**Figure 27 Relationship Between Predicted NOx Concentration and Estimated $NO_2$ Concentration**

Notes:

Assumed ozone ($O_3$) background is 26 ppb.

Assumed nitrogen dioxide ($NO_2$) background is 2 ppb.