Katestone Environmental
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Health and Emissions Working Group
Wagerup 3 Refinery Expansion
PO Box 252
Applecross WA 6153

25th January 2005

Attention: Bradley Chenoweth, facilitator

Re: DESKTOP REVIEW OF THE CSIRO PHASE 1, 2 AND 3A REPORTS FOR
ASSESSMENT OF THE ALCOA WAGERUP REFINERY EXPANSION

Dear Bradley,

Katestone Environmental has been commissioned by Alcoa to supply independent expert advice, in the form of a desktop review of project studies related to Alcoa's Wagerup 3 refinery expansion, in order to assist the Emissions and Health Working Group. The project reports to be included in this desktop review are:

- "Meteorological and Dispersion Modelling Using TAPM for Wagerup Phase 1: Meteorology" Prepared for Alcoa World Alumina Australia by CSIRO Atmospheric Research, November 2004. – Final report

- "Meteorological and Dispersion Modelling Using TAPM for Wagerup Phase 2: Dispersion" Prepared for Alcoa World Alumina Australia by CSIRO Atmospheric Research, November 2004. – Draft report

- "Meteorological and Dispersion Modelling Using TAPM for Wagerup Phase 3a: HRA (Health Risk Assessment) Concentration Modelling – Current Emissions Scenario" Prepared for Alcoa World Alumina Australia by CSIRO Atmospheric Research, 10 December 2004. – Draft final report

The desktop review is intended to assess the reports to determine if the information is adequate, whether the methodologies used are adequate in determining the impacts on air quality due to the refinery and whether the conclusions drawn from the work are appropriate. This review is not intended as an audit of the provided input information (eg. the completeness of the emissions inventory), an evaluation of the process or technology, or an assessment of the air quality impacts of the project; these tasks are for the governing environmental authorities. This review focuses on the modelling methodology and the conclusions drawn from it.

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One issue that has made this review quite difficult is the lack of understanding of the importance of some of the model uncertainties on the overall outcomes of the study. The results presented in the Phase 3a report are simply a list of concentrations predicted at a range of receptor locations for a large set of pollutants. The results are not compared to any ambient air quality guidelines (we believe this is being done in a subsequent report) and the results of the health risk assessment (HRA) had not been finalised when this review was undertaken. We have tried to concentrate the review on what is important for a HRA. However, without knowing if the risk levels that have been predicted are well below acceptable levels or close to the recommended acceptable level, our task has been made more difficult. For this reason we have tended to be conservative and have identified any issues that we believe would be important if the predicted levels resulted in a risk close to the recommended level.

The situation at Wagerup is very complex and a large number of highly regarded experts in the field of atmospheric science have been involved in one way or another in trying to identify the cause of community complaints. To date the definitive answer as to the exact cause of the odour and health problems at Wagerup has not been determined.

The use of TAPM for assessing the air quality impacts of the proposed Wagerup Refinery expansion was agreed on by the study team and authorities as the most appropriate model to predict the impacts from the Wagerup Refinery Stack sources. This was to be tested in the initial two reports (Phase 1 – meteorology and Phase 2 - dispersion) and then used in the final Phase 3 report to determine the ground level concentrations of all pollutants for input into the HRA. TAPM is a complex model that not only predicts the dispersion of plumes but also generates it's own meteorological fields. It is very computationally intensive and therefore takes a long time to simulate the atmospheric processes for a one-year period. Ideally for an assessment where the annual contributions are important and it is know that there is significant inter-annual variability in the region, more than one year should be assessed. Due to the computationally intensive nature of TAPM this is rarely done.

It is commendable that CSIRO has tested the TAPM scheme against many data sets and that many other researchers and consultants throughout Australia and many other countries have used the model. The performance of TAPM is quite mixed it appears to be more useful than many comparable models. It has been recognised by the developers that there are circumstances in which the model over-predicts surface wind speeds and may have problems with dispersion in complex terrain. We point out that any model or measurement process has associated errors for which it is important to estimate the likely influence on the conclusion of a given study.

Our understanding of the focus of the study undertaken by CSIRO wasn't to determine if the model, in relative terms, adequately predicts the meteorology and dispersion compared to its performance elsewhere, but to determine if the model is suitable for assessing the meteorological conditions and dispersion mechanism that results in known complaints and high ground level concentrations in Wagerup area due to the Refinery emissions.

To achieve the latter, the study needs to show that the model biases (or errors) are clearly defined in terms of model capability (i.e. the model may not be able to simulate a feature such as the eddies generated when winds come over the escarpment) or poor performance (e.g. frequency of winds in a certain direction) and then review the predicted impacts of pollutants on the environment in light of these limitations.

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Our major criticism with the work undertaken by CSIRO for this study is the failure of CSIRO to incorporate and account for their own recommendations and identified errors in the model for earlier stages of the work into the Phase 3 study. The main example of this is the under-prediction of winds in the critical light to moderate wind speed range and from the north. This should be proven to not impact on the outcomes of the dispersion modelling and subsequent health risk assessment inputs, which means not only maximum short-term concentrations but also long-term averages. The other significant example is the use of a different configuration for the final modelling (Phase 3) compared to the dispersion verification study (Phase 2). We believe that some of these issues are being addressed by CSIRO for the final report.

Generally to use of TAPM for modelling the Refinery plumes should be suitable, and is probably the best available model. Most of the issues raised in our review will help quantify the uncertainties and justify its use. We have asked for more information to be included in the final report for various stages of the work and that the main question of "is the model predicting the right answer for the right reason" be answered.

If you have any questions about the review please contact me directly.

Yours sincerely

Christine Killip

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**REPORT FROM KATESTONE ENVIRONMENTAL
TO ALCOA WORLD ALUMINA AUSTRALIA**

**DESKTOP REVIEW OF THE CSIRO PHASE 1, 2 AND 3A FOR
ASSESSMENT OF THE ALCOA WAGERUP REFINERY
EXPANSION**

January 2005

KATESTONE ENVIRONMENTAL PTY. LTD.

DOCUMENT DETAILS

Job Number: KE0501316	*Date:* 15/02/05
Title: Desktop Review Of The CSIRO Phase 1,2 And 3a For Assessment Of The Alcoa Wagerup Refinery expansion	
Client: Alcoa World Alumina Australia	
Document reference: Desktop review of CSIRO Phase 1-3 reports.doc	

Revision No.	*Prepared by:*	*Reviewed by:*	*Approved by:*	*Date*
Draft	Christine Killip	Peter Best	Peter Best	25th Jan 2005
Final	Christine Killip	David Hannam	Christine Killip	15th Feb 2005

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Desktop Review of the CSIRO Phase 1,2 and 3a for Assessment of the Alcoa Wagerup Refinery Expansion

1. Scope of Expert Review

Katestone Environmental has been commissioned by Alcoa to supply independent expert advice, in the form of a desktop review of project studies related to Alcoa's Wagerup 3 refinery expansion, in order to assist the Emissions and Health Working Group. In addition the desktop review may be used by Alcoa to provide additional information to regulatory agencies and the public.

The terms of reference for the desktop review are as follows:

- Comment on the completeness of the information presented;
- Comment on the suitability of the measurements performed for assessing the project impacts;
- Comment on the correctness of the analysis performed on the data presented;
- Comment on the suitability of methodology used to make predictions.
- Comments in relation to conclusions reached in the report being reviewed.

Generally this means that the work presented in the reports will be reviewed to determine if the information is adequate, whether the methodologies used are adequate in determining the impacts on air quality due to the refinery and whether the conclusions drawn from the work are appropriate. This review is not intended as an audit of the provided input information (eg. the completeness of the emissions inventory), an evaluation of the process or technology, or an assessment of the air quality impacts of the project; these tasks are for the governing environmental authorities. This review focuses on the modelling methodology and the conclusions drawn from it.

The project reports to be reviewed in this report are:

"Meteorological and dispersion Modelling Using TAPM for Wagerup Phase 1: Meteorology" Prepared for Alcoa World Alumina Australia by CSIRO Atmospheric Research, November 2004. – Final report

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Other reports and information have been supplied by Alcoa to help clarify the information in the above reports and plant operations. Monitoring and meteorological data from the Wagerup sites were also supplied. A list of reports used in this assessment is included in the references.

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2.   Background

2.1   Refinery operations and air quality studies

Alcoa operates three alumina refineries in Western Australia at Wagerup, Kwinana and Pinjarra. As has happened at other major alumina refineries elsewhere in Australia (e.g. the QAL refinery in Gladstone, the Nabalco refinery in the Northern Territory), the processes involved in producing alumina can readily give rise to significant emissions of dust, odour and gaseous products such as combustion gases in sufficient quantities to generate amenity impacts at local communities and, in some cases, short-term health impacts.

The proposed addition of a third unit at Wagerup Refinery and an almost doubling of refinery capacity to 4.7 Mtpa has resulted in a very extensive consideration of the various emission sources within the refinery and their potential impacts on people in the nearby community and for on-site personnel. These investigation programmes have included a number of short-term studies of emission concentrations for the main sources, multiple studies of odour emission characteristics, the conduct of meteorological and air quality monitoring at various locations in the region and short-term studies of upper-level meteorology and tracer gas dispersion (mainly during winter conditions thought to be the most adverse for odour complaints). The current agreed monitoring programme includes the use of a very innovative gas chromatograph to identify continuously the short-term concentrations of key gaseous components and an Opsis monitor to conduct multi-parameter monitoring over long distances (200-400 m) rather than at isolated locations (Environ, 2004).

As a result of these studies, Alcoa has embarked upon various programmes to reduce the odour emissions from key sources and to minimise the emissions of nitrogen oxides from power station borders.

These programmes constitute a major commitment of resources by Alcoa and have been reviewed for scope and technical approach by various government agencies, including a parliamentary committee.

The CSIRO involvement follows previous dispersion and meteorological investigations by SKM Consultants. In addition to synthesizing the information from the various monitoring studies, SKM undertook dispersion modelling using a variety of readily available dispersion models to determine which was likely to give the better description of the processes taking place at the Wagerup Refinery. It was found that the CSIRO TAPM model gave a seemingly better description of extreme events due to stack emissions at 2-3 monitoring locations compared to Calpuff, Ausplume and Dispmod. This report was used by Environ Consultants to define a three stage programme using the TAPM model to produce a "validated" method of predicting the air pollution meteorology at the Wagerup site, checking as much as possible the predictions of the preferred modelling approach against continuous monitoring at two locations and the tracer gas dispersion study. The "validated" model was then to be used to predict the air quality statistics for all key pollutants for the current and expanded plant. The results of these latter Phase 3 components are then to be used in a health risk assessment by others in order to determine whether there is any likelihood of conventional health impacts and to determine whether there are any significant increases due to the expanded plant.

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The odour reduction programme undertaken by Alcoa focused on the dramatic reduction of volatile organic emissions from the digestion system and other non-stack sources and a better quantification of the nature of the emitted odour. This ongoing programme and the difficulties in undertaking standardised and repeatable odour measurements in a dynamic environment has resulted in some uncertainty in the odour emission rates and different distributions of the odour emissions between various sources. These odour aspects are important, as the major community concerns have been about odours and their association with temporary health ailments.

The work undertaken by CSIRO for the current expansion project used the odour complaints database as a means of verification of the model, but the scope of work for the current TAPM modelling does not include predictions of odour. This is being addressed in other reports. However, it is important to note that due to the limitations of ambient monitoring, a significant number of emissions (mainly VOCs) emitted from the refinery cannot be measured (due to low levels), but are still above odour detection limits. The only long-term ambient monitoring conducted that is useful to model validation is the NO_x monitoring at two sites. Nitrogen oxides are not emitted from all sources on the site; in order to adequately assess the skill of a model for predicting impacts for all the pollutants included in the HRA, a full assessment of the odour complaints information is essential.

3. Key issues in overall assessment

For a doubling of capacity of a major industrial facility such as the Wagerup Alumina Refinery, we would expect that the key issues involved in undertaking an assessment of the air quality impact would cover the following questions:

- What are the major sources for ground-level impact of various key compounds at nearby receptors?
- What are the dispersion characteristics and stacktop methodology for these sources?
- In the assessment of plume dispersion, are there likely to be any deviations from straightline trajectories for the important adverse dispersion conditions?
- What are the influences of buildings, source structure and plume buoyancy on dispersion (especially in this case when there are multiflue stacks, multiple stacks and the likelihood of variability on such effects with wind direction)?
- How accurate are the predictions of on-site lower-level meteorology and is there likely to be a sensible extrapolation to stack-top meteorology and boundary layer parameters important for evaluating air quality impacts?
- Can it be verified that the chosen dispersion models, meteorological simulation and chemical transformations have the correct physical and transformal mechanisms to describe the key features of the observed impact?
- Can the uncertainties and potential biases of the simulation schemes be estimated?
- Does the performance evaluation undertaken go past simple statistical measures to ensure good performance for the key concerns in the important adverse dispersion conditions?
- Has there been a consistent use of validated ("models") noting that in reality there is no such thing as a properly validated model, even if ground-level pollution monitoring had been very extensive as in some very extensive past American and European monitoring exercises?

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With the above preliminary evaluation and the characteristics of each source, some questions can be formulated as to what aspects should be well treated by a meteorological and air quality simulator. The plume heights range between 26 m for the Tank Vent and 240 m for the Calciner Multiflue for 10 m winds of 3 m/s. Due to the significant volume of air from the larger cooling towers they have relatively high plume heights. The plumes from the calciner and power station multiflues and from the gas turbine and some cooling towers are likely to have a significant plume rise for full load operation under most stacktop exit conditions. In light winds, the multiflue plumes will rise to 200 m or more above ground-level. To result in significant ground-level impacts, it is likely that the significant vertical downwind movement that occurs in moderate to strong convection will be required (at least for repeated groundings over a multi-hour period). This plume grounding can occur in a variety of conditions and be relatively independent of the height of the boundary layer. In contrast, it would be expected that in the early to mid morning, brief but relatively intense groundings of the plume can occur as the solar-induced heating of the ground gives rise to convective turbulence that begins to reach the height of the various elevated plumes. Unfortunately, the accurate prediction of morning fumigation requires a full and relatively precise determination of the boundary layer height and characteristics and the resulting plume rise. It is quite easy to predict incorrectly the height and duration of morning fumigation (as is seen in several of the CSIRO figures). In these and the more unusual cases of wind-shear dominated convective dispersion, the power of a good meteorological simulator (such as TAPM) should be such as to improve descriptions from conventional simpler dispersion schemes.

For impact at nearby communities, it is important to determine the degree of plume overlap, to forecast adequately the direction of plume travel and to also ensure that there are few predictions of significant impact for atmospheric conditions known not to give rise to concentrations at the representative monitoring stations. We believe it is of key importance to determine the conditions for significant exposure at communities (e.g. peak short-term concentrations for odour, daily and annual averages for the health risk assessment).

Armed with such knowledge the evaluation of the expansion can then proceed by looking at how much the emission rates and characteristics are likely to be changed in an expansion and how best to treat any new stacks or sources. A few preliminary remarks on the possible 'validation' of a model may assist in suggesting the level of critical review that is currently practical for meteorological and dispersion simulation.

4. Model validation

Models such as TAPM take the measured surface and upper-level meteorology at the regional airport sites as inputs to the simulation techniques. The general philosophy is that a suitable set of governing equations of motion together with an adequate description of topography and land-use should facilitate the simulation of near-surface flows and dispersion at points remote from the measurement sites. The model should give an appreciable level of additional skill in the prediction of conditions at these sites, presumably much more than any more heuristic approaches (such as diagnostic approaches) using the available measurements. The model should be expected to produce the main regional and local flow circulations, at least at locations that are well outside any disturbed zones caused by terrain-induced turbulence or away from locations for which the roughness lengths are quite different than assumed in the land-use classification adopted in the modelling.

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TAPM like other models cannot hope to deal with the full range of conditions and locations experienced in the real world. The model has to find a compromise in use and parameterisation of the important processes at various scales. It is very difficult to simulate well at the neighbourhood scale (e.g. at a resolution of 1 km or less) without returning to a very much more detailed description of the energy and exchange processes and a fuller understanding of internal boundary layer dynamics. Recent work on neighbourhood scale models (e.g. Models-3 developments, the latest versions of MM5) have suggested that a better parameterisation is required to get a good simulation of near-surface flows, even at rural sites. Much of this work is based on Australian studies of the influences of vegetation and urban canopies.

Model performance indices are useful to evaluate the sensitivities of a given model for a stated location/region to changes in model inputs and parameters. They are also (and probably more useful) in comparing the performance of totally different models at a given location. They are rarely useful for comparing performance in different regions or for different purposes. Any quantitative measures should be used as a supplement to detailed graphical representations, as measures can be similar for quite different model performance, in many situations.

Model "validation" exercises can rarely do more than demonstrate that the preferred model is fit for the task, to a given level of satisfaction or application. The exercise should be as much about determining where the model fails as much as where it succeeds. It is important to know what model artefacts there are and whether in some situations the model biases may be important.

It is laudable that CSIRO has tested out the TAPM scheme against many data sets and that many other researchers and consultants throughout Australia and many other countries have used the model. The results are quite mixed although TAPM appears to be more useful than many comparable models. It has been recognised by the developers that there are circumstances in which the model over-predicts surface wind speeds and may have problems with dispersion in complex terrain. Indeed, such comparisons tend to return the spotlight to the use of surface measurements to characterise what is happening at the neighbourhood scale. We note that these subjects are the focus of much recent research. We point out that any model or measurement process has associated errors for which it is important to estimate the likely influence on the conclusion of a given study.

5.   Review of reports

5.1   General comments on all reports

One issue that has made this review quite difficult is the lack of knowledge of the impact of some of the model uncertainties on the overall outcomes of the study. The results presented in the Phase 3a report are simply a list of concentrations predicted at a range of receptor locations for a large set of pollutants. The results are not compared to any ambient air quality guidelines (we believe this is being done in a subsequent report) and the results of the HRA have not been finalised when this review was undertaken. We have tried to concentrate the review on what is important for a HRA; without knowing if the risk levels predicted are well below acceptable levels or close to the recommended acceptable level, our task has been

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made more difficult. For this reason we have tended to be conservative and have identified any issues that we believe would be important if the predicted levels resulted in a risk close to the recommended level.

Work continuity

The process of splitting up the work into three distinctly separate reports is generally a good idea as it means that one aspect can be agreed upon before the next stage of work is undertaken. However, it is important that the key findings or issues identified in each report are considered when the next stage of work is undertaken. Each of the CSIRO reports was kept very separate and key issues were not transferred into the next stage of work. Specifically:

- The issue of over-predicted wind speed by TAPM needed to be shown not to adversely impact on the dispersion of plumes in the validation of air quality impacts.
- Differences in the wind direction distribution predicted by TAPM needed to be shown not to adversely impact on ground level concentrations (particularly annual averages) in the validation of air quality impacts.
- The input requirements for the HRA (i.e. short-term maximum and annual average concentrations) should be addressed in the dispersion validation report.
- The final "verified" version/setup of TAPM identified in the dispersion validation report should then be used for the HRA concentration modelling.
- These issues will be addressed in more detail in the following sections.

Selection of modelled year and inter-annual variability

The modelling was conducted for the period April 2003 – March 2004. This period was selected for the validation process to allow comparison with the best available information on ambient air quality and meteorology. The CSIRO Air Quality Review (CSIRO, May 2004) noted "*the variability in the meteorology could be a factor in year-to-year changes in (increases or decreases) in the frequency of odour complaints from a particular site*". The selection of the period for modelling as input into the HRA was not determined based on the "worst year" or "best year" of meteorological conditions conducive to pollution events. If inter-annual variability is an important factor in the region, this needs to be taken into account in the HRA. Recent modelling undertaken by Katestone for a Nickel refinery in New Caledonia indicated significant variability in modelling results depending on the chosen year (six years were modelled). Some locations received a two-fold increase in annual concentrations, while other areas went from no exceedances of a concentration threshold to over 20 events.

Recommendation: Assessment of the impact of inter-annual variability in meteorological conditions on ground-level concentrations (and HRA outcomes) should be considered.

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5.2   Phase 1 report – Meteorology

The objective of the Phase 1 report was:

"To evaluate the capability of TAPM (version 2.6) with a detailed Wagerup specific land-use specification to acceptably produce hourly-averaged meteorological predictions matching available field observations in the Wagerup region, especially under a range of conditions that include both light and moderate wind speeds".

The Phase 1 report has been reviewed in light of the above objective and keeping in mind that it is to be used to predict the dispersion of pollutants from the refinery for use in a Health Risk Assessment.

For dispersion modelling the key meteorological parameters that are important to predict well are the wind speed and boundary layer structure. Wind speed governs the rate of dispersion and boundary layer structure (which can in its simplest form can be thought of as the temperature of the air at various heights above the ground) governs the height over which the plumes can mix. These parameters can be combined together into classes known as atmospheric stability. A plume will disperse differently for each stability class.

Predictions of surface winds

The model's performance at Bancell Road station for wind speed is poor. From inspection of the scatter plots (CSIRO 2004b, Figure 10) it can be seen that for some events with measured wind speeds below 5 m/s, TAPM is predicting 10-20 m/s (ten times higher in some instances). The stronger winds are predicted from the east (which is the dominant wind direction for measured strong winds) mainly during the nighttime. The scatter plots show a paired comparison; that is, the predictions are compared with the measurements for the same hour. An unpaired comparison is presented as a frequency distribution (e.g. CSIRO 2004b Figure 12). On inspection of the frequency of wind speed, the model under-predicts the frequency of light to moderate winds by 30% (65% of observed winds are less then 5 m/s, TAPM predicts only 44%) and winds less than 2 m/s (light winds) by 50%. TAPM underestimates the frequency of the northerly winds by 50%.

Although the index of agreement (IOA) for the nighttime wind speed at Bancell Road at 30 m is above 0.64 (within acceptable range), the predicted mean wind speed is over 160% of the observed measurements.

The winter period is important for transport of emissions from the refinery to the closest town of Yarloop during stable to neutral conditions and light to moderate northerly winds (SKM, 2002). The model significantly under-predicts the frequency of light to moderate winds (<5 m/s) with observations below this value for approximately 60% of the time and TAPM predictions only 40% for the winter period. The frequency of predicted winds from the northerly sector is less than half the observed. The frequency of light to moderate winds from the northerly sector has not been reported.

Based on the frequency of odour complaints, the most critical time for odour impacts in Yarloop is daytime and particularly the morning period from 8 am to 11 am. The model performs considerably better during the daytime with good agreement between the observed and predicted frequency distributions but still a low agreement for paired comparison of observations with predictions (r = 0.52).

The significance of the models under-prediction of northerly winds or wind speeds during winter has not been reflected in the dispersion modelling outcomes. The lack of winds predicted in the critical range (e.g. light to moderate from the north) for Yarloop could result in an under-prediction in the frequency of short-term events and a lower annual average. This would result in a lower risk rating in the HRA. Although this may not be a significant issue, say if the HRA showed very low risk (note that this review has been completed before the results of the HRA were available), the significance has not been investigated.

The model predictions are worse for the 10 m winds at Bancell Road compared to the 30 m measurements, with the IOA below 0.5; most of the error is in the east-west component of the winds. The model's performance at the RDA monitoring station is much better than that at Bancell Road.

The sensitivities of the model's performance to the detailed Wagerup-specific land-use database (and surface roughness), refinery generated surface heat flux or deep-soil volumetric moisture content does not account for the large differences between the modelled meteorology and observations.

This would indicate that an outcome from one of the objectives of the study (to evaluate the capability of TAPM under light and moderate winds) is the inability of the TAPM model to adequately predict light to moderate winds at Bancell Road.

CSIRO speculate that this discrepancy between the observed and predicted wind speed and direction could be a result of terrain resolution or errors in the synoptic analyses (the input meteorological information initialising the model). It would be helpful if these avenues were fully investigated to determine if they are indeed the cause of the model discrepancy.

The model error is also thought to be due to the model probably not predicting effects due to the Darling escarpment as TAPM cannot resolve such processes as leeward and windward eddies which may be associated with flows over the escarpment. This could justify the difference in predicted and observed easterly winds, but, as there are no major communities to the west of the Refinery, it may not be a significant issue. However, the model errors for conditions suitable for transport to the populated areas should be explained and quantified.

Recommendation: The model under-predictions of the frequency of light to moderate wind speeds and the frequency of winds in the northerly sector during the time of maximum odour complaints (8 – 11 am) should be investigated and their significance on predicted HRA concentrations presented.

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Boundary-layer profiles

A comparison of the modelled profiles with measured radiosonde data was undertaken for the results from a short field study conducted during July 2003. Some of the radiosonde measurements show very light winds well above stack top height, and elevated temperature inversions at heights that would impact on the dispersion of plumes from the Refinery. TAPM does not resolve many of these characteristics. No conclusions have been made by CSIRO as to the impact on dispersion modelling results due to the model discrepancies and if they are significant.

Conclusions and acceptability of model predictions

Section 10 of the CSIRO 2004b report presents a summary of one performance measure (the index of agreement) from other modelling studies undertaken using either TAPM or other similar prognostic models. It is not particularly relevant to compare the model's performance at Wagerup with studies undertaken in far more complex meteorological situations, such as Hong Kong, where the coastal environment and mountainous terrain would prove a challenge to most models or for 3-day field studies rather than annual statistics.

The conclusions presented in the CSIRO report do not indicate if the key component of the project objective was met, i.e. did TAPM acceptably simulate meteorological conditions in the Wagerup region, particularly for light to moderate winds. It is inferred that, because it is comparable (if not slightly worse for wind speed) to the model's performance elsewhere, it is acceptable. Whilst it is understood that a model can only be a representation of the true physics of the atmosphere and that errors and uncertainties are common features of modelling, it needs to be proven that the model is adequate for the purpose of this study, i.e. the prediction of the impacts due to stack sources at the Refinery at a range of locations, for a range of meteorological conditions causing complaints and the estimation of short-term and long-term average exposure statistics (for current and future emission scenarios) as input into a Health Risk Assessment.

Recommendation: To increase peer acceptance of the project modelling, further investigations are necessary to identify the significance of the predicted errors in the meteorology, particularly in light to moderate winds, for the dispersion of the refinery plumes.

5.3   Phase 2 report – Dispersion

The objective of the Phase 2 report was:

"Based on acceptable performance of the model compared to observed meteorology (in Phase 1), to then use TAPM (version 2.6) and a database of emissions from the Wagerup Refinery to model hourly-averaged ambient air concentrations of pollutants for appropriate periods and compare them with observations. Identify dominant pathways for the transport of the refinery emissions to the ground level in the surrounding district."

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This objective infers that, if the meteorology is predicted well by the model, then the acceptable prediction in ground-level concentrations will follow. This should generally be the case assuming that the key pathways are adequately predicted and there is a good knowledge of the emission variability of the most important emission sources. As noted earlier, these components have not been fully evaluated in the meteorological modelling report.

Evaluating the performance of dispersion models

One problem with all model evaluation is the quality of information used as input in the model (i.e. the emission rates, flow rates) and the quality of the measurements used for comparison. The variability in emission conditions is evident from the results of emission conditions during the ANSTO tracer gas study with some variability in stack exit conditions from day-to-day. Furthermore, the estimates provided by Alcoa to CSIRO on average and peak emissions suggest that there may be a large variability of the order of a factor of 2-4 over a one-year period. Our experience at various industrial installations suggests that assuming continuous full load operation for any validation exercise may be quite misleading. Even primary pollutants such as nitrogen oxides are likely to have diurnal characteristics both for calciner and power station operations and may have significant fluctuations over a year as various sources change due to production variability, maintenance and upset conditions.

Katestone has reviewed the air quality monitoring data from Boundary Road and Upper Dam sites. From the wind characteristics and pollutant ratios, it appears that Boundary Road may be highly influenced by regional NO_x emissions (for most of the events recorded at both monitoring stations) typically during northerly flows, resulting in a very poor quality refinery signal to undertake a model validation study. The subset of air quality data from Boundary Road site for the wind directions from the Refinery were used in the investigation by CSIRO, but this information will also be contaminated by non-refinery emissions. More filtering of the data is required before inclusion in the validation study. The information from Upper Dam is of higher quality and more weight could be given to the models performance at this site.

The following figures show the clear difference in quality of data from each site.

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Figure 1: **Source identification using non-parametric regression for Boundary Road and Upper Dam NO$_x$ data**

Boundary Road
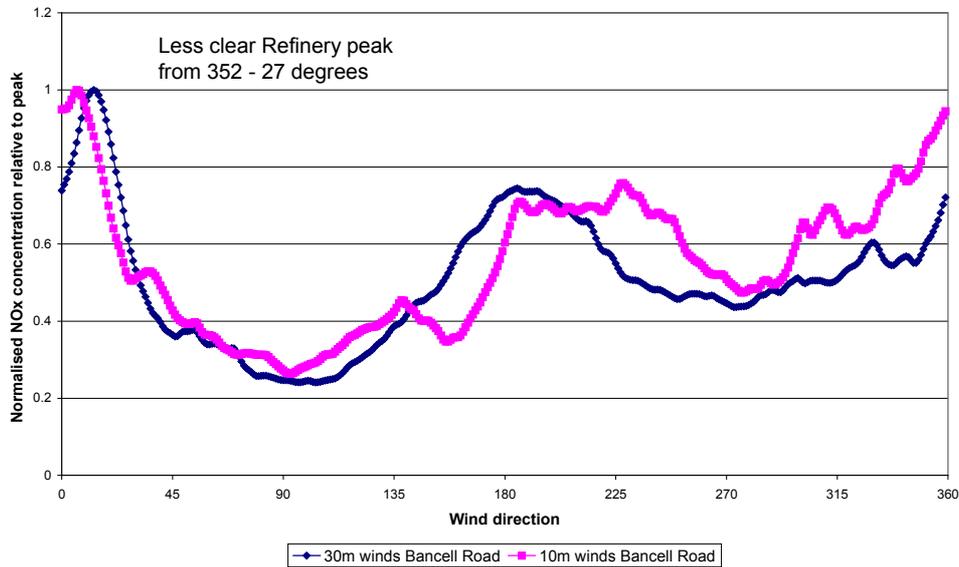
Upper Dam
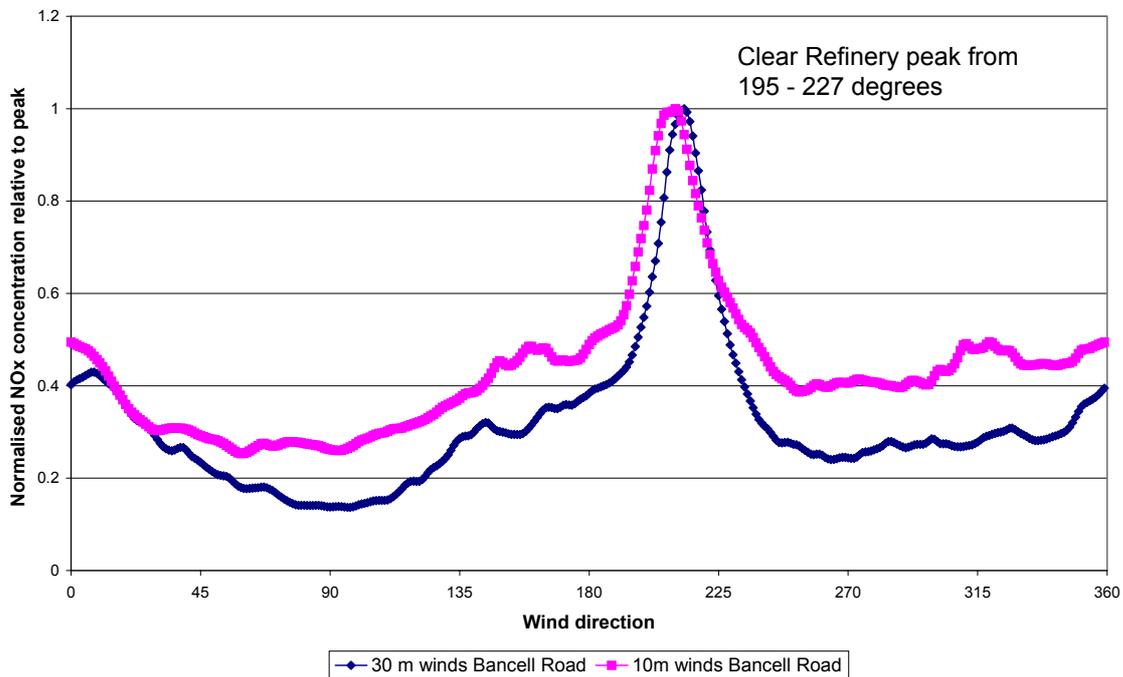
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Figure 2: **(a) 6 minute NO$_x$ recorded at Boundary Road for Refinery sector versus NO$_x$ recorded at Upper Dam (b) 6 minute NO$_x$ recorded at Upper Dam for Refinery sector versus NO$_x$ recorded at Boundary Road**

(a) Boundary Road
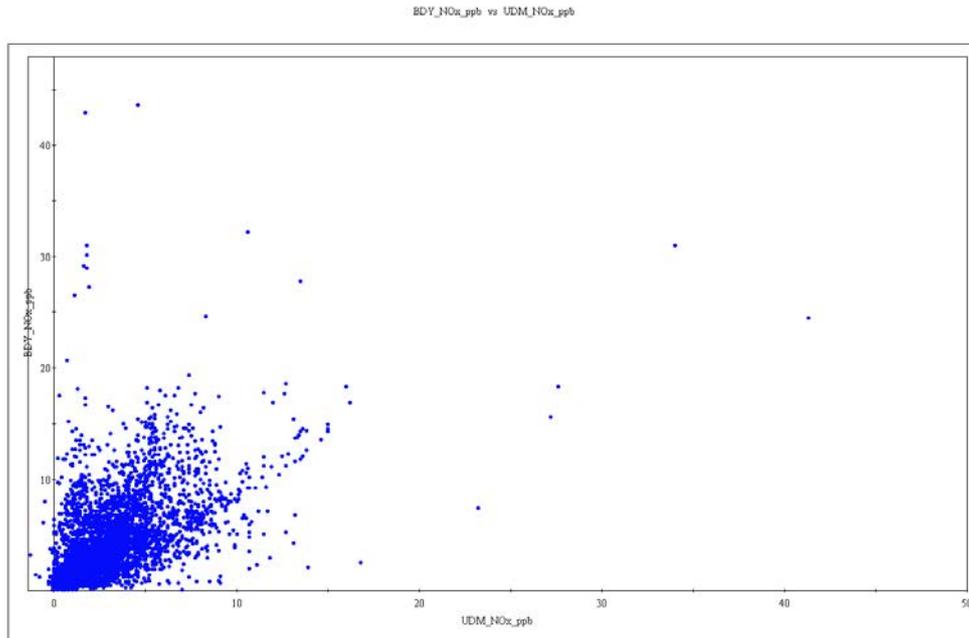
(b) Upper Dam
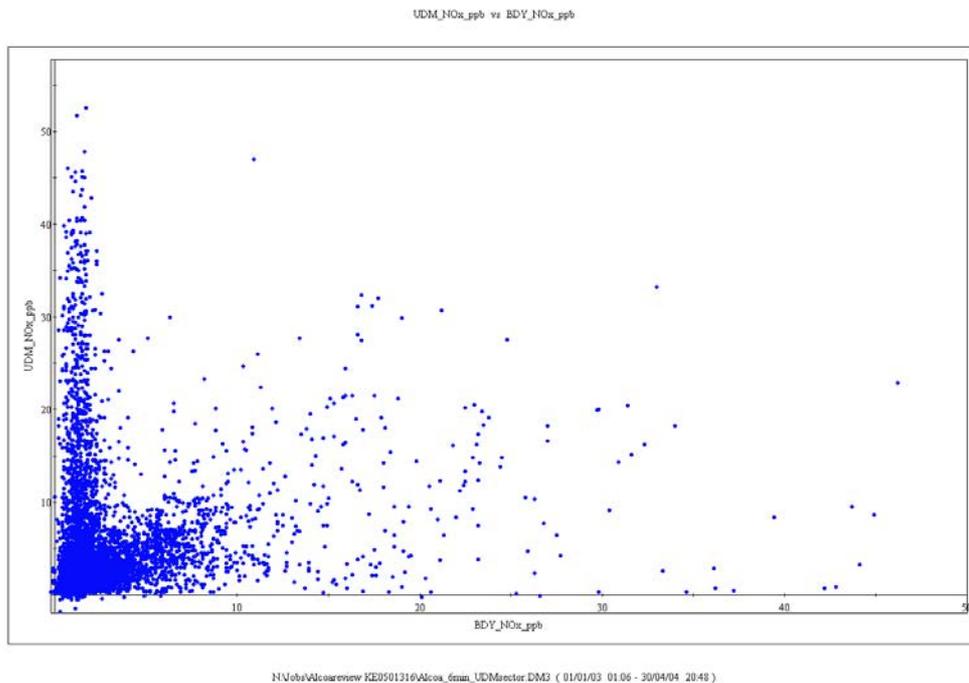
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Figure 3: **NO$_2$/NO$_x$ ratio versus NO$_x$ concentrations for winds from refinery sector for (a) Boundary Road and (b) Upper Dam**

(a)

NOx_ppb vs NO2NOxratio
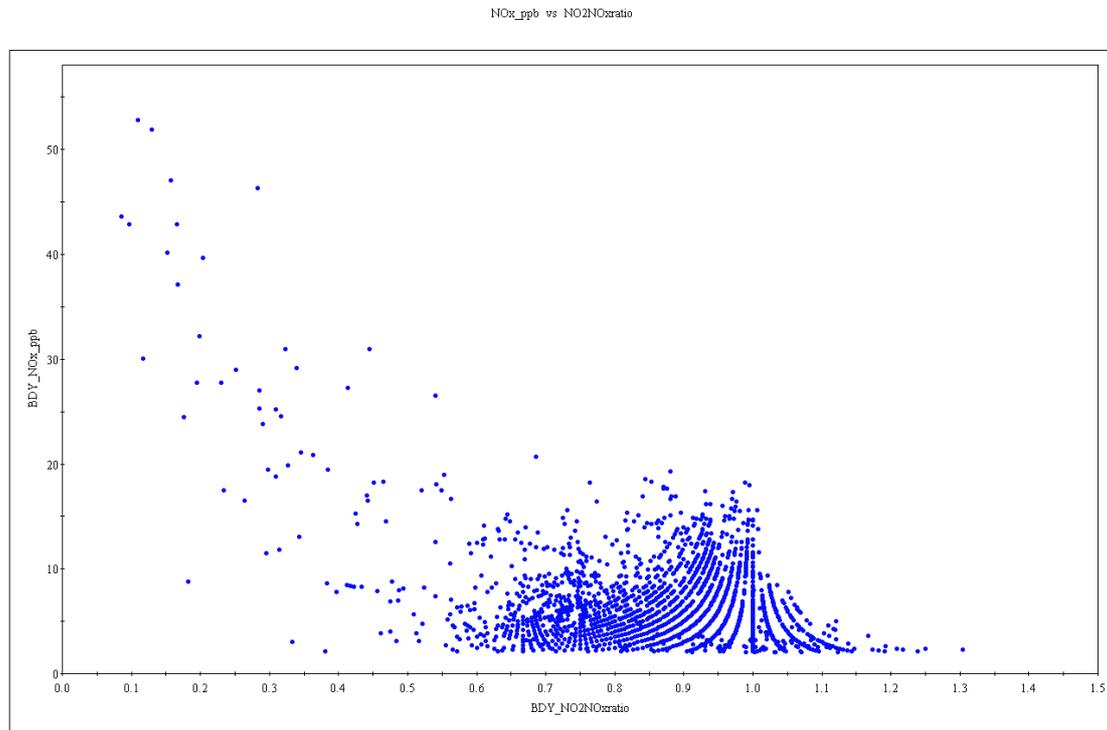
N:\Jobs\Alcoareview KE0501316\Alcoa_6min_BDYsector.DM3 (01/01/03 06:00 - 29/04/04 04:12)

(b)

NOx_ppb vs NO2Noxratio
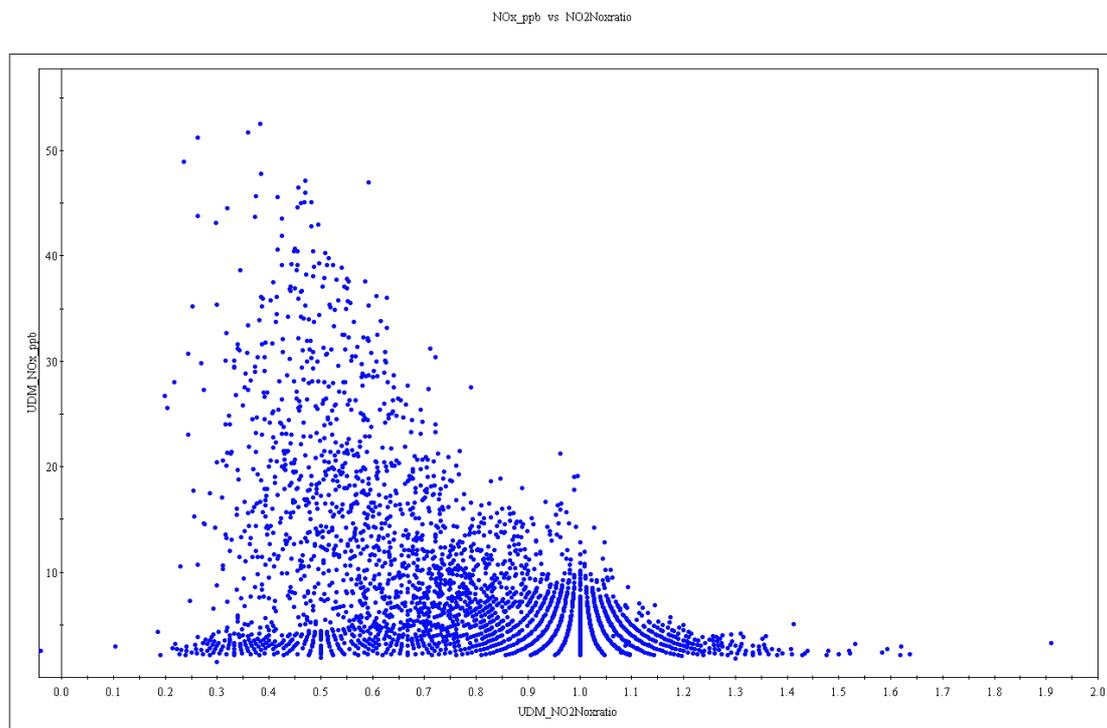
N:\Jobs\Alcoareview KE0501316\Alcoa_6min_UDMsector.DM3 (01/01/03 01:06 - 30/04/04 20:48)

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Figure 1 shows that there is a clear refinery signal in the Upper Dam site data but a variety of possible sources for the other site. Figure 2 suggests that there are many instances of concurrent events at both sites, suggesting a regional, rather than refinery source.

The ratios of nitrogen dixode to total nitrogen oxides for the refinery sources are expected to be around 0.1 at stack exit and 0.2 - 0.3 within the first 3 kilometres or so from the relevant sources. Figure 3 then shows that there is an obvious refinery source for the Upper Dam data but other sources are important for some of the moderate-size events.

These results suggest that a very careful culling of events is required in any model validation study for the area. The Upper Dam site is obviously the preferred choice for the use of nitrogen oxide information.

Having chosen the reliable subset for a refinery signal in the concentration records, it is necessary to select appropriate performance measures.

Q-Q plots, as used in the CSIRO reports, are one of the standard methods for evaluating model performance, but in recent years (e.g. Cooper 1999) several authors have recommended that models should be tested on more than just the overall frequency distribution. Olesen (2001) notes that a model evaluation is not complete without diagnostic studies, attempting to ensure that the model gives the right result for the right reason. Willmott (1981) in introducing the index of agreement to compare the overall performance of different models in physical geography noted that a full use of graphical techniques should complement the use of a range of single measures. A framework for testing dispersion model performance has been documented in the Standard Guide for Evaluation of Atmospheric Dispersion Model Performance (ASTM, 2000). This uses various techniques, including Q-Q plots, but on various sub-sets of data for each comparison to ensure that the same meteorological conditions are grouped together and the model tested for each group or regime. In this fashion, the biases of any model can be determined so that the relative degree of confidence of model predictions in different circumstances can be delineated.

The modelling results presented in the CSIRO report also show the importance of grouping data. Figure 12, which shows the Q-Q plots for Upper Dam site for winter, summer and nighttime and daytime, can be compared with Figure 8 (the Q-Q plot for all hours). The seemingly very good agreement of the predicted frequency distribution with the observations on an all hours basis is much less impressive when broken down into an under-prediction during winter, over-prediction during summer, over-prediction during the daytime and under-prediction during nighttime.

Recommendation: Using techniques described in ASTM (2000), test the model's performance for key meteorological regimes, particularly those important to the transport of emissions to sensitive residential areas.

A key feature that was not predicted by the TAPM meteorological simulations was the frequency of northerly winds. With the addition of data assimilation this is overcome and events are more frequently predicted at Boundary Road. The model run with data assimilation also proves to be the better choice for the Upper Dam site. The CSIRO authors conclude that data assimilation improves the model's performance at both of the monitoring stations. The subsequent decision to leave out assimilation in the final concentration predictions in the

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Phase 3a modelling needs more justification than currently presented. If it is not appropriate to use data assimilation with a radius of influence that covers areas of different meteorological conditions, why was it tested in the Phase 2 report? From inspection of the wind roses in Figure 4 for the RDA and Bancell Road sites the overall distribution of winds is comparable at both sites. Again we recommend that the final configuration used in the modelling for the HRA needs to be the configuration of the model tested and shown to be the most appropriate in the Phase 2 report and the use of data assimilation using the 30 m wind data from Bancell Road is recommended.

The CSIRO report also evaluates the performance against information from the RDA site to the west of the refinery. The meteorological monitoring data recorded at RDA site may be invalid or contains errors as there are few winds from the north-north west or northerly sectors. The figures below show the wind roses for RDA and 30 m winds at Bancell road site for the period of concurrent data (December 2003 to April 2004).

Figure 4:   Comparison of wind roses for concurrent data recorded at (a) RDA and (b) Bancell Road 30m
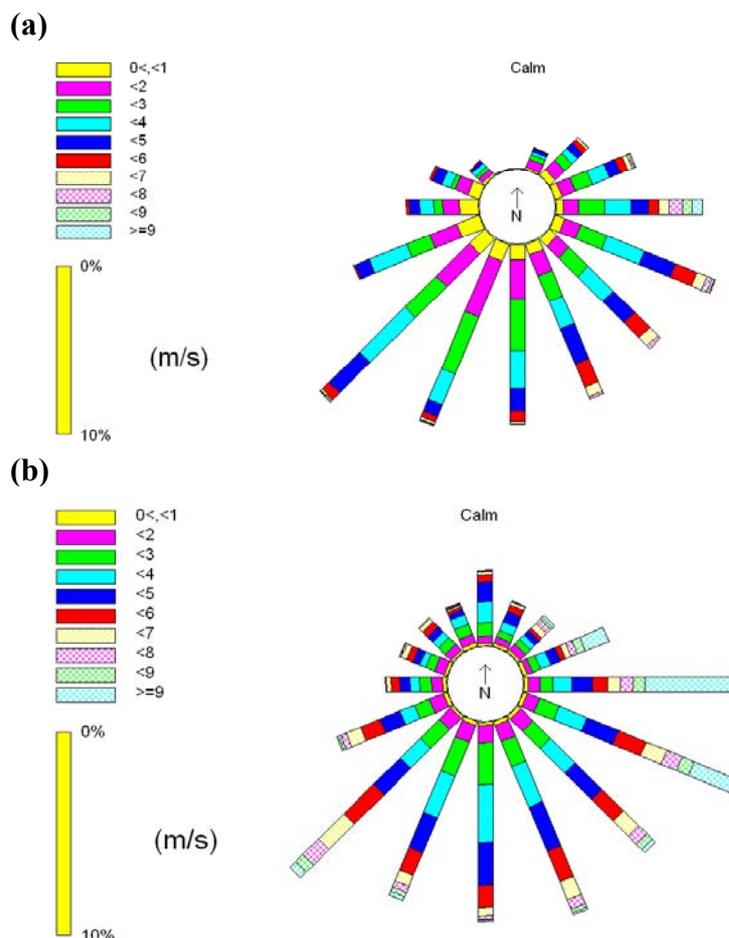
(a)

(b)

Buoyancy enhancement

The model comparisons presented in the majority of the Phase 2 report are without the use of combined plumes and the effects of buoyancy enhancement. As shown in the Phase 3a report (Section 4.4), the effect of buoyancy enhancement on ground-level concentrations is significant (almost a factor of 2 in some locations).

In the multi-flue configuration the flues have a radius in the range 0.95 - 1.2 m and are separated by only a few metres. Available experience suggests that, for full capacity operations, these plumes are likely to merge quickly and the final plume rise is likely to be very similar to the case where all the evaluations were emitted from a single stack. Various studies using computational fluid dynamics approaches e.g. the work of Brown and Fletcher (2003) have suggested that the multiflue stacks can on occasions have some aerodynamic impact on the behaviour of the plumes. We suspect that the observations by Pitts, cited in the CSIRO report, that plume separation does indeed occur may be a result of an uneven distribution of volume flows during less than full capacity operation. We would expect that the plumes from the flues of the multiflue stacks will merge quickly for most conditions and that modelling the flues as one stack would result in a reasonably realistic representation of the plume buoyancy. The practice of combining closely located flues into a single "effective stack" is common practice. However, as buoyancy enhancement is to be used in the Phase 3a modelling, it should have been tested in the model verification study.

Recommendation: Test the model's performance at Upper Dam using buoyancy enhancement for the multiflue stacks, as used in the Phase 3a modelling.

Advice from Alcoa while completing this review is that this issue is currently being addressed.

Tracer gas study

The tracer gas study comparisons do include modelling with a buoyancy enhancement (but with different combinations to those used in the Phase 3a report), making difficult any comparison of the model performance for both situations. This is also compounded by the lack of consistent meteorological data for assimilation (30 m tower was not yet installed).

It is interesting to note that, for the tracer gas study, the contributions from the various individual plumes to ground-level concentrations have been assessed. This type of information would be useful when analysing the models performance at Upper Dam, as it is likely to show that the model performance varies depending on the source.

From Figure 19 it can be seen that the model under-predicts the impacts due to the calciner multiflue with buoyancy enhancement but the boiler multiflue is slightly over-predicted. The Calciner 4 is a much lower plume and stack than the other two sources and its impact is also over-predicted for the most part, except for the top two concentrations.

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Key pathways

Extensive experience by many researchers in Australia and elsewhere for the near-coastal location (including in a Mediterranean climate with high solar insulation in summer such as at Wagerup) would suggest that high ground-level concentrations from moderate sized industrial stacks with reasonable buoyancy can be expected in the following conditions:

- Morning fumigation.
- Convection in a relatively shallow boundary layer prior to the arrival of any seabreeze.
- Convection within the seabreeze.
- Transition events with wind shear effects can be important.
- Unusual nighttime events (either due to high windspeeds, the presence of building wakes or with low production capacities in a shallow nocturnal boundary layer).

The seabreeze was not identified by CSIRO as an important factor governing the dispersion of plumes within the Wagerup area, presumably because attention was focused on impacts in the township of Yarloop, which is not upwind of the Refinery during seabreeze conditions (typically south-westerly winds).

Section 6 in the CSIRO report is well presented and possibly the most important section in all of the reports. The following comments may add to the conclusions drawn from this section of work:

- Is it possible to compare the actual number of odour complaints with predicted number of impacts from the model?
- How does the frequency of occurrence of model events look if a higher threshold value was chosen?
- From an inspection of the measured meteorological data during the time of the events for the evening peak (6-9pm), what is the cause of these events and why does the model not predict them?
- The wind speed range identified by the TAPM modelling as resulting in the most frequent cause of odour events is 2-6 m/s. This was also found in other studies (SKM 2002) as the most important wind speed range. How will the model's significant under-prediction of winds in this range impact on the results?

5.4   Phase 3a report – Concentration Modelling for HRA

The Phase 3 report had the objective to:

"to run TAPM with Wagerup specified input for four scenarios of emissions(current-average, current-Peak, expanded – average, expanded-peak) for agreed sources to produce selected concentration statistics at receptor points for input in to the HRA and the Public Environmental Review Document. Investigate the temporal variation of concentrations around, and mechanism causing the modelled short-term peak concentrations."

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Issues identified earlier in this review about the suitability of the actual configuration used in this final modelling stage will not be reiterated here, but they are very important and should be addressed before the reports are finalised.

Additional sources that have not been modelled as yet are included in this stage of work, such as the cooling towers and various vent sources. Most of these sources are low-level sources with low buoyancy and minimal plume rise. The performance of TAPM in modelling these types of sources has not been stated.

To help identify the key pollutants for a HRA for a refinery sources, the HRA undertaken for the Pinjarra upgrade was reviewed (Toxikos, 2003). For the acute hazard (i.e. short-term impacts) nitrogen dioxide was identified as the most dominant species, followed by mercury, arsenic, $PM_{2.5}$ and formaldehyde. For the chronic hazard (long-term impacts) nitrogen dioxide was the dominant species followed by manganese and compounds, $PM_{2.5}$, acetaldehyde and nickel and compounds.

From an inspection of the emission rates presented in Table 2 in the CSIRO Phase 3a report the dominant sources can be identified as:

- Nitrogen dioxide (acute and chronic) – Boilers and gas turbine.
- Mercury (acute) – Boiler 2/3 (Non-con), cooling lake, liquor burner and 25A vent.
- Arsenic (acute) – Liquor burner.
- $PM_{2.5}$ (acute and chronic) – Calciners (note: only dust emissions reported in CSIRO report).
- Formaldehyde (acute) – Calciners and cooling towers.
- Manganese and compounds (chronic) – Boilers and 25A vent.
- Acetaldehyde (chronic) – Calciners and cooling towers.
- Nickel and compounds (chronic) – Boiler 2/3 (Non-con) and 25A vent.

This implies that it is very important to model the plumes from the two multi-flue stack correctly and the difference of a factor of almost two modelling with and without plume buoyancy enhancement may be critical to the HRA outcomes.

Table 1:   Characteristics of key Refinery sources

	Stack Height (m)	Internal diameter (m)	Exit Velocity (m/sec)	Exit Temp degrees C	Buoyancy m³/s⁴	Plume rise (3 m/s winds)	Plume height (m a.g.l)
Liquor Burner	100	0.94	27.9	65	7	24	124
Calciner 1	100	1.9	21.6	159	59	70	170
Calciner 2	100	1.9	20.8	160	57	68	168
Calciner 3	100	2.16	19.6	196	82	82	182
Calciner Multiflue	100	3.44	20.6	177	202	142	242
Calciner 4	48.8	2.36	20.1	157	84	116	165
Boiler 1	65	2.4	14.5	101	42	66	131
Boiler 2	65	2	16.2	124	40	73	130
Boiler 3	65	2	13.7	131	35	67	124
Boilers Multiflue	65	3.71	14.6	117	116	120	185
Gas turbine	48.8	3.04	22.4	98	100	135	184

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	Stack Height (m)	Internal diameter (m)	Exit Velocity (m/sec)	Exit Temp degrees C	Buoyancy m^3/s^4	Plume rise (3 m/s winds)	Plume height (m a.g.l)
45K Cooling Tower 2 and 3	16.3	8	15.3	35	78	160	176
45K Cooling Tower 1	8	7	13.7	35	53	134	142
50 Cooling Tower 1 and 2	4	7.07	3.7	35	15	44	48
25A Tank Vents	20	0.5	12.9	98	2	6	26

No information is supplied in the report on the details of the Boiler 2/3 (Non-con). This should be included in the final report.

Short-term peak concentrations

The development of a fluctuations model within TAPM is to be applauded and presumably is one of the reasons for its choice in the current project. Indeed the team of Drs. Borgas, Luhar, Hibberd and Sawford in Melbourne constitute a considerable proportion of the expertise worldwide in the prediction of very short-term average concentrations, using theoretical, experimental or physical simulation techniques.

This work aims to supersede the fairly heuristic approaches used in the peak-to-mean approaches summarised in the report by Katestone to the NSW EPA (Katestone Scientific, 1995, 1998). These reports summarised the evidence for many source types, including the buoyant plume tall stack sources of interest to this project. For the near- and mid-field areas near a tall stack (i.e. in and around where the maximum concentration occurs), the peak 1 second concentration can be a factor of 20-40 higher than the 1 hour average. This has been confirmed recently by detailed measurements around a major power station stack in Central Queensland.

For smaller sources (i.e. intermediate stack heights in the 60-100 m range and moderate buoyancies) these peak-to- mean ratios may be too high. Physical simulations by Hibberd and Weil (summarised in the recent article by Luhar and Sawford (2005)) do suggest that concentration intensities vary from around 1.5 down to 0.5 as the distance increases away from the maximum concentration from a reasonably tall stack. These values will depend on meteorological conditions, ratio of stack to mixing height and on whether there are multiple sources.

In the current case, overlap between the calciner and power station multiflues may often occur and can be expected to reduce the concentration variance and corresponding peak-to-mean ratio. Hibberd's water tank simulations are the main source of measurements to test out any prediction scheme in this case. Unfortunately, at the moment, we do not have details of the TAPM scheme or its verification against measurements. If it does appear that the variance or peak-to-mean factors are much smaller than expected from past experience, it is particularly important to know why and how this depends on source and receptor configurations.

An alternative approach to test out the TAPM predictions of relatively low power exponents for concentration ratios is to compare the modelled peak-to-mean ratios and those measured from the six-minute data recorded at Upper Dam. This use of measurement information has been undertaken by Katestone and presented below.

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Figure 3 below presents a scatter plot of the measurements from Upper Dam site when winds were from the Refinery for hourly averages verses peak 6-minute concentrations recorded for each hour. It can be seen that for the highest hourly average concentrations recorded (>30 $\mu g/m^3$) at the Upper Dam site the peak 6-minute average is about 1-1.5. For lower concentrations the spread in the ratio is much greater with ratios up to 2.5 for concentrations of 20 $\mu g/m^3$. This shows that for differently hourly average concentrations the peak concentrations within the hour can be the same (e.g. 30 $\mu g/m^3$ x 1.5 or 18 $\mu g/m^3$ x 2.5 both equal a peak 6-minute concentration of 45 $\mu g/m^3$).

Figure 5:   **Analysis of Upper Dam for peak 6 minute verses 1 hour average NO_x data for winds from Refinery sector (195-227°)**

NOx_ppb vs NOxP6minto1hr

N:\Jobs\Alcoareview KE0501316\Alcoa_1hr_6minPtoM_UTMsector.DM3 (01/01/03 01:00 - 30/04/04 20:00)
Subset (-,00-2300,UDM_NOx_ppb>5)
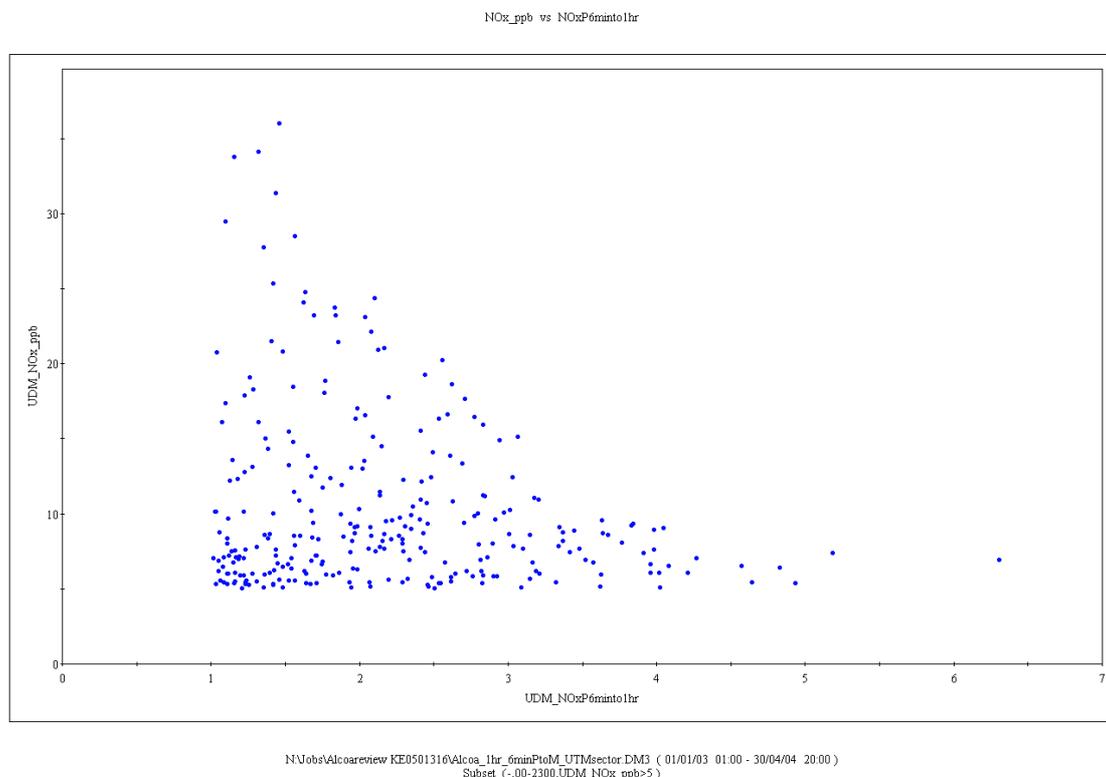
Figure 4 presents the frequency distribution of measurements from the Upper Dam site for the times winds were blowing from the Refinery. From the hourly average frequency distribution the peak 6-minute concentrations have been estimated using the method described in the CSIRO report with exponents in the range 0.12 to 0.23. The distribution of 6-minute concentrations indicates that the exponents used by CSIRO are within the range of the measurements (0.23 is actually slightly high).

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Figure 6:   **Cumulative frequency distribution of measurements of NO$_x$ at Upper Dam for winds from the Refinery for hourly and 6 minute averages and for estimated 6 minute averages using exponents of 0.12 and 0.23.**
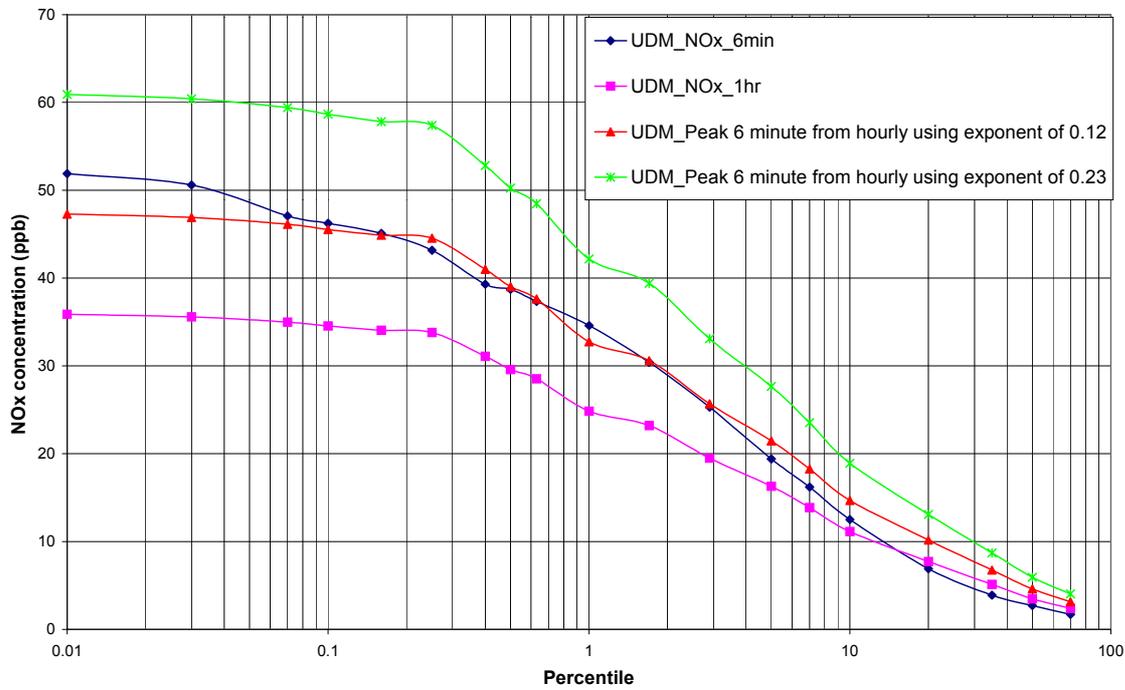
The peak to mean ratios found from the measurements are much lower than expected based on experience elsewhere. It is not known if this relatively small power law exponent would translate for much shorter-term peaks, say 1 second, which are likely to drive the probability of complaints.

Due to the wide range of types of sources the peak concentration fluctuations may vary significantly depending on pollutant, location and meteorological conditions. It is not clear from the description of the methodology used by CSIRO for estimating peak sub-hourly concentrations if the peak is determined for each source at each location for each hour or if all sources have been modelled together. This is important, as the peak concentrations due to stack source can be significantly higher that those from low level wake effected sources or area sources (as noted in the CSIRO report). This needs to be clarified in the final report.

Table 9 presents the predicted concentrations for all pollutants for a range of averaging period at the identified receptor locations. The use of this information (if all of it or just parts) has not been presented, but is unusual to present only the 95th percentile for the 24 hour average, and not the maximum.

Section 4.2 in the CSIRO Phase 3a report presents information on the uncertainty in the modelled concentrations, but only for the robust highest concentration (RHC). Table 5 in the CSIRO report presents a list of ratios of modelled to observed RHC for other studies undertaken by CSIRO. Some of the studies included in the list would not appear to be relevant to the Wagerup study (such as the Melbourne studies for ozone) and presenting an average of the ratios is not suitable as the errors cancel out. A summary of the uncertainty found in the Wagerup study only for all averaging periods would be more useful. This should include information on the estimated inter-annual and emission variability, which could have significant impacts on the annual average concentrations. For a HRA the annual averages are just as important as the peak concentrations and should therefore be addressed accordingly.

5.5   Summary of review

This review has been conducted over a relatively short time with the information coming to hand only recently. As for other investigators, we note that the refinery presents a very complex emission situation that requires considerable testing and evaluation and the use of supplementary and perhaps non-standard techniques to resolve many of the issues. It appears that CSIRO staff have also had to work with short deadlines and with tools that are still under beta testing (and not yet released for general evaluation and comment). The choice of TAPM for the analysis by comparison with other simpler models appears reasonable and a significant amount of work has been undertaken by CSIRO including numerous sensitivity studies. The present analysis of data shows that the NO_x signal at Boundary Road is not strong and that it may not be a good signal to verify the modelling and furthermore may not represent what is causing the complaints in Yarloop.

The immediate tasks for the finalisation of the CSIRO report should be to ensure a logical and self-consistent set of model results and statements of outcomes as required in the project specification. Whilst some model performance may be disappointing, it's importance must be clearly stated and the team undertaking the HRA made fully aware of the various sensitivities.

The utility of TAPM for representing short-term concentrations from the various sources needs to be clearly indicated as it was one of the attractions for choosing this approach. It may be worthwhile providing a more explicit set of assumptions and limitations for the performed work, as well as possible suggestions for the improvement of validation procedures (e.g. better continuous emissions information, the use of ambient monitoring possible alternative pollutants at the two long-term sites to firm up the likely sources of peak concentrations).

6.   Specific expertise of the review team

Christine Killip and Dr Peter Best of Katestone Environmental have compiled this report. Katestone Environmental has particular experience and technical expertise in the following areas of relevance to the current review:

- Coastal dispersion and meteorology.
- Performance of advanced air quality dispersion models for near-coastal sites.
- Performance of TAPM-type models in simulating meteorology in a wide range of conditions and countries.

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- The air quality impact assessments of refineries and power stations.
- The odour assessment of industries, with particular emphasis on community impacts.
- Assessment of industrial projects in Western Australia such as at Kwinana, Kalgoorlie, Collie and Hill River.
- Community impact assessments of roadway projects and odour impacts from intensive agricultural and major industries.

7.   References:

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17th March 2005

Attention: Bradley Chenoweth, facilitator
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Wagerup 3 Refinery Expansion
PO Box 252
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Dear Bradley,

Re: DESKTOP REVIEW OF THE CSIRO PHASE 2, 3A AND 3B REPORTS FOR ASSESSMENT OF THE ALCOA WAGERUP REFINERY EXPANSION

Katestone Environmental has been commissioned by Alcoa to provide independent expert advice, in the form of a desktop review of project studies related to Alcoa's Wagerup 3 refinery expansion, in order to assist the Emissions and Health Working Group. A detailed analysis of the Wagerup 3 refinery expansion project reports is presented in Katestone Environmental review report entitled "Desktop Review of the CSIRO Phase 2, 3A and 3B Reports for Assessment of the Alcoa Wagerup Refinery Expansion, March 2005".

The desktop review considers the final air dispersion modelling reports for the Wagerup 3 refinery expansion prepared by CSIRO and comments on amendments to the draft reports and additional information prepared by CSIRO in response to issues raised in our initial review (Katestone Environmental 2005). Based on feedback from the community on the initial review, the report aims to present the issues in an easy to understand language and identify the significance of the findings of the previous technical review report.

The revised reports prepared by CSIRO have addressed either directly or indirectly the significant issues identified in our initial review. Some of the additional information requested in our review has not been supplied. The question "is the model predicting the right answer for the right reason" remains unanswered. It would give more confidence in the results if this question was answered but due to the limited monitoring information available for the region it may not be possible.

Generally the modelling undertaken for the Wagerup 3 Refinery expansion adequately assesses the potential impacts on the local atmospheric environment so long as a degree of conservatism is taken into account when applying the uncertainty factors from the modelling results presented by CSIRO in the HRA.

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Key issues that are highlighted in the desktop review and that are critical for credible assessment of air quality impacts of the refinery expansion are:

1. The model validation study (Phase 2 Appendix A) has shown that the model can provide reasonable predictions of ground-level concentrations of nitrogen oxides provided that daily average emission rates are used. The validated model setup should be used for subsequent HRA modelling work and has been used in the Phase 3 modelling scenarios as requested in our initial review.

2. The model validation study has shown that coupling the meteorological model with surface meteorological measurements (i.e. called data assimilation in CSIRO reports) provides a more realistic characterisation of wind conditions at Yarloop and consequently a better understanding of the air quality impacts of the refinery. Whilst there may be practical reasons why data assimilation cannot be used explicitly in the HRA modelling work, the impact on predictions of air quality is significant and needs to be accounted for by some alternative means.

3. To reduce uncertainty due to year-to-year variability in wind patterns the modelling results should be presented for the maximum exposed location as well as at the key receptors as listed in Phase 3 reports.

4. The peak emission scenario used to predict the short-term impacts is conservative as all sources are assumed to be operating at peak emissions at the same time and during the worst meteorological conditions. However, individual sources can operate at higher emission rates than those modelled, though there is likely to be a low risk that these short-term peaks will coincide. Therefore it is likely that the actual impacts will be lower than those presented if actual emission rates were used.

5. Whilst there appears to be substantial uncertainty in the predictions of the air quality impacts that are presented in the CSIRO reports, these uncertainties can be minimised through the experience gained in CSIRO's various studies for this project and by accounting for known uncertainties in a reasonable way, as discussed above. It is important to recognise that any modelling or measurement process will have associated errors and uncertainties, particularly where complex processes such as meteorology are at work. For the refinery expansion, the errors and uncertainties inherent in the modelling will be the same for the existing refinery and the expanded refinery and therefore, the relative changes in impacts will be as important as the magnitude of impacts

If you have any questions about the review please contact me directly.

Yours sincerely

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Katestone Environmental

**REPORT FROM KATESTONE ENVIRONMENTAL
TO ALCOA WORLD ALUMINA AUSTRALIA**

**DESKTOP REVIEW OF THE CSIRO PHASE 2, 3A AND 3B
(FINAL REPORTS) FOR ASSESSMENT OF THE ALCOA
WAGERUP REFINERY EXPANSION**

March 2005

KATESTONE ENVIRONMENTAL PTY. LTD.

DOCUMENT DETAILS

Job Number: KE0501316	*Date:* 17/03/2005
Title: Desktop Review Of The CSIRO Phase 2, 3A and 3B (Final Reports) For Assessment Of The Alcoa Wagerup Refinery expansion	
Client: Alcoa World Alumina Australia	
Document reference: Katestone review of CSIRO Phase 1-3 final reports.doc	

Revision No.	*Prepared by:*	*Reviewed by:*	*Approved by:*	*Date*
Draft	*Christine Killip*	*Simon Welchman*	*Christine Killip*	*16/3/05*

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1.   Scope of Expert Review

Katestone Environmental has been commissioned by Alcoa to prepare independent expert advice, in the form of a desktop review of project studies related to Alcoa's Wagerup 3 Refinery expansion, in order to assist the Emissions and Health Working Group. In addition the desktop review may be used by Alcoa to provide additional information to regulatory agencies and the public.

This report presents a review of the final air dispersion modelling reports for the Wagerup 3 Refinery expansion prepared by CSIRO and comments on amendments to the draft reports and additional information prepared by CSIRO in response to issues raised in our initial review (Katestone Environmental 2005). Based on feedback from the community on the initial review, this report aims to present the issues in an easy to understand language and identify the significance of the findings of the previous technical review report. This report has benefited from feedback from the community given in response to the initial review.

The project reports to be reviewed in this report are:

"Meteorological and dispersion Modelling Using TAPM for Wagerup Phase 1: Meteorology" Prepared for Alcoa World Alumina Australia by CSIRO Atmospheric Research, November 2004. – Final report Appendix

 "Meteorological and dispersion Modelling Using TAPM for Wagerup Phase 2: Dispersion" Prepared for Alcoa World Alumina Australia by CSIRO Atmospheric Research, February 2005. – Final report

 "Meteorological and dispersion Modelling Using TAPM for Wagerup Phase 3A: HRA (Health Risk Assessment) Concentration Modelling – Current Emissions Scenario" Prepared for Alcoa World Alumina Australia by CSIRO Atmospheric Research, 14 February 2005. – Final report

"Meteorological and dispersion Modelling Using TAPM for Wagerup Phase 3B: HRA (Health Risk Assessment) Concentration Modelling – Expanded Refinery Scenario" Prepared for Alcoa World Alumina Australia by CSIRO Atmospheric Research, 11 February 2005. – Draft Final report

This desktop review is intended to evaluate the air quality assessment prepared by CSIRO and presented in the reports listed above to determine if the information is adequate, whether the methodologies used are appropriate to determine the impacts on air quality due to the refinery and whether the conclusions drawn from the work are appropriate. This review is not intended as an audit of the provided input information (eg. the completeness of the emissions inventory), an evaluation of the process or technology, or an assessment of the air quality impacts of the project; these tasks are for the proponent and the governing environmental authorities. This review focuses on the robustness and reliability of the modelling methodology and the conclusions drawn from it.

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2.   Review of reports

2.1   Phase 1 report – Meteorological assessment

As this report was finalised when reviewed, an Appendix was added to address some of the issues identified in our previous review. These issues can be summarised as follows:

(a)   Inter-annual variability of wind direction

CSIRO's previous reports found that there is significant inter-annual variability in wind direction frequency at Wagerup. Our review requested that the impact of inter-annual variability in meteorological conditions should be investigated and the implications for ground-level concentrations (and HRA outcomes) should be considered.

The inter-annual variability was presented in the Appendix of the Phase 1 report (and repeated in both Phase 3 reports). The variability was investigated over the years 1997 to 2004 from 6-hourly synoptic analyses used as input into TAPM. It would have been better to investigate the variability using hourly measurements taken in the region, rather than a model output. However, given that it is difficult to obtain good quality and consistent data for such a long period for the region, the analysis presented by CSIRO in the Appendix is adequate. The analysis indicates that the variability is typically ±30% about the mean (up to 49%). The year chosen for modelling is within 20% of the average wind year, except for easterlies that are 33% less frequent for the year chosen than a typical year and southerlies are 24% more frequent.

CSIRO conclude that the inter-annual variability would result in the same variability in the annual average concentrations predicted by the model. Therefore the annual averages presented in the Phase 3 reports could be expected to be either 30% higher or 30% lower at a particular location depending on the year.

(b)   Wind speed and direction frequency distribution predicted by TAPM

Our previous review identified the importance of adequately predicting the actual local frequency of wind direction and wind speed. CSIRO were requested to show that the differences in the frequency of winds (direction and speed) predicted by TAPM compared with actual measurements do not adversely impact on ground-level concentrations (particularly annual averages) and hence the validation of air quality impacts. In particular, it was evident that the model under-predicted the frequency of light to moderate wind speeds and the frequency of winds in the northerly sector during the time of maximum odour complaints (8 – 11 am).

These issues were not directly addressed in the revised reports but were indirectly addressed through the use of data assimilation in the modelling. By including data assimilation the winds generated by the model better reflect those measured and hence display a more representative frequency distribution of light winds and northerly winds. The results of modelling with data assimilation were presented in the Phase 3.

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The results of modelling with data assimilation indicate that the predicted concentrations are quite sensitive to the wind speed and frequency of wind direction. The peak short-term concentrations (presented as maximum, RHC (robust highest concentration) and 10th highest 1-hour average) are higher at most receptors, particularly in the south on the western side of Yarloop. The annual averages are predicted to be either the same or higher (over twice as high in some areas of Yarloop) with the inclusion of data assimilation. As the frequency of northerly winds was significantly under-predicted by the model it is understandable that the annual averages in this area are higher with the inclusion of data assimilation. However, as most areas receive higher annual averages this would indicate that the results are also sensitive to the frequency of light winds. More details are presented in Section 2.3 on the uncertainty in modelling.

2.2   Phase 2 report – Dispersion

Substantial additions have been made to the Phase 2 final report addressing most of the issues raised in our previous review. Most of the new work has been presented in Appendix A, which presents the results of remodelling with daily emission rates, rather than a constant rate for the year long run. The justification of combining closely located stacks to take into account the enhanced buoyancy is also presented in the new Appendix A. The revised modelling results and the two recommendations identified in our previous review for the Phase 2 report (reproduced below) are discussed in the following section.

(a)   Detailed testing of model performance

Recommendation: Using techniques described in ASTM (2000), test the model's performance for key meteorological regimes, particularly those important to the transport of emissions to sensitive residential areas.

Testing the models performance in more detail would be beneficial as the difference in the performance of the model between night and day and summer and winter is significant. More information regarding the reason the model under-predicts during the winter and nighttime and over-predicts during the summer and daytime would help CSIRO and the reviewer to assess the model's performance (this type of analysis could also be undertaken for the new modelling results presented in Appendix A).

Due to the limited ambient pollution monitoring data available for verification and possible contamination of the data by other sources, it can be justified that further testing is not likely to produce a reliable outcome. CSIRO have used both Upper Dam and Boundary Road sites for verification of the models performance with only minor scrutiny of the data to separate out the signature from the refinery operations. In Appendix A, only data from Upper Dam was selected for model verification due to the significant influence of other sources at the Boundary Road site. It was stated in our previous review that the data from the Boundary Road site is significantly influenced by other sources and therefore more weight should be given to the Upper Dam site or more analysis of the Boundary Road site is required to better identify the refinery signature at this site.

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Due to the significant number of complaints from residents (perhaps indicating a sensitised population) in the vicinity of the Boundary Road site a more in-depth analysis and justification of refinery signature at this site may be warranted. The revised report included additional analysis in Section 6, which sumarised the important meteorological conditions under which the model predicted adverse impacts at sensitive receptors. Validation of the modelled pathways by analysis of actual measurements is advisable to provide additional support for these findings.

(b)   Buoyancy enhancement

Recommendation: Test the model's performance at Upper Dam using buoyancy enhancement for the multiflue stacks, as used in the Phase 3a modelling.

This recommendation was addressed and presented in Appendix A of the Phase 2 report. It has been assumed that the scenario presented in Appendix A of the Phase 2 report is for the model without wind data assimilation, however, this is not stated.

The use of buoyancy enhancement for multiflue stacks is appropriate and the results presented in the Phase 2 report are closer to the measurements at Upper Dam than those without buoyancy enhancement. The model tends to under-predict the top few measurements and concentrations in the 2-10 ppb range. The apparent under-prediction of the maximum concentrations has been discussed earlier and could be caused by the modelled flow rates from the GT being high compared to actual flow rates of the GT during peak emissions. The under-prediction in the 2-10 ppb range is probably a result of modelling the refinery emissions and not other sources that could also contribute to measured levels at the site.

(c)   Daily emission rates

The validation study undertaken by CSIRO in the original Phase 2 report used a constant emission rate for all the refinery sources. Due to changes in operating conditions throughout the year, the emission rates for each source can vary significantly from day to day and probably also from hour to hour. Our initial review recommended the use of detailed hourly emission rates for a more robust model verification process due to the likely significant variability. This has been presented in Appendix A of the Phase 2 report.

It is unfortunate that CSIRO has gone to the trouble of modelling daily emission rates (of which there is significant variability) but has not also modelled the corresponding daily flow rates. The flow rates will change as the operating conditions of the equipment change. Typically, for higher equipment loads the flow rates are also higher resulting in more buoyant plumes and hence relatively lower ground-level impacts. The most significant changes in emission rates are for Boiler 1 and the Gas Turbine these two sources are discussed separately below.

The emissions of NO_x from Boiler 1 were high during October and November (up to three times higher than the level modelled as the average emission rate in the main section of the Phase 2 report). During the peak operating conditions of the boiler the flow rates would also be higher resulting in a more buoyant plume and hence lower ground level concentrations. Therefore the modelling of this source is conservative and the actual ground-level concentrations during peak operating conditions would be lower than the model predictions.

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The opposite is the case for the Gas Turbine. During September and November the Gas Turbine emissions were four times higher than typical operations. This is presumably due to the turbines operating in the critical peak NO_x regime of between 60-75% turbine load. During this regime not only are the NO_x emissions significantly higher than at peak turbine loads but the flow rates are also lower resulting in a less buoyant plume and worse dispersion (i.e. higher ground-level concentrations) than during peak operating conditions. This may be the reason for the under-prediction of the peak impacts by the model.

Analysis of the conditions during which the peak impacts are predicted and the corresponding operating conditions for each stack could help resolve this issue. Alternatively, modelling the actual daily flow rates for the stacks should eliminate the apparent under-prediction of the peak impacts by the model (Table 1A indicates that the RHC ratio is 0.8, which means the highest concentrations predicted by the model are lower than measurements by 20%).

2.3   Phase 3A report – Concentration Modelling of Current Operations for HRA

The final version of the Phase 3A report presents additional information on the method used to combine closely located plumes into a single plume to account for enhanced plume buoyancy and more detail on model uncertainty.

(a)   Model uncertainty

Uncertainty in model results can be broken into uncertainty in meteorological fluctuations and model uncertainty. The uncertainty in modelling results depends on what you are trying to predict. Annual averages across a wide area may be quite accurately estimated, whilst short-term peak concentrations at a specific location may be poorly estimated. Therefore to get a better understanding of uncertainty that is important to this project we need to break down the modelling results and determine the uncertainty in meteorological fluctuations (e.g. location or change in conditions from year-to-year) and model uncertainty, which should be fairly consistent from run to run for a particular location and model setup.

There is a much higher uncertainty in the modelling results if trying to predict the right concentration at the right location for the right time. This means that the predicted impact may vary significantly at a particular receptor (such as those selected in the CSIRO report). The uncertainty can be reduced by considering the maximum impact irrespective of location. At the maximum exposed location the peak impacts should not vary significantly. This is generally why a full year (or more) of meteorological conditions is included in an air quality assessment and impacts are presented as the maximum predicted concentration over the modelling domain. Extreme statistics, such as maximum 1 hour average predicted over an entire year, are very difficult to predict and have a large uncertainty. For this reason modelling results are quite often assessed by the 9th highest concentration (or 99.9[th] percentile) or the robust highest concentration (RHC) rather than the maximum.

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The annual average at a particular location will also vary, particularly from year to year and is generally dependent on the frequency of winds that occur in a particular direction. The uncertainty from year to year due to variation in wind patterns at Wagerup has been shown by CSIRO to result in a variation of ±30% for annual average concentrations at a selected receptor location. Generally if one location, say Hamlet, receives a higher annual average in a typical year due to a significant percentage of winds directing emissions from the refinery towards that location, another location, say Yarloop, will receive a lower annual average as there may be less winds than average that take emissions from the refinery to Yarloop. Therefore it is important to select the maximum exposed location for longer-term averages.

The inclusion of data assimilation in the model has a significant affect on short-term impacts (maximum 1-hour average and RHC) and the annual average. Short-term concentrations decreased in some areas, such as the receptors to the west. In most areas the inclusion of data assimilation resulted in higher concentrations, with concentrations 20-50% higher. One location (Receptor 3) on the south-western corner of Yarloop had predicted impacts that are three times higher with the inclusion of data assimilation.

Table 1 presents the predicted impacts for the current operations with and without the inclusion of data assimilation in the modelling. This shows the sensitivity of impacts at selected locations to the inclusion of data assimilation. We have contacted CSIRO and requested a contour plot showing the predicted impacts for the data assimilation scenario; this is presented in Figure 1. This can be compared directly to Figure 25 in the Phase 3A report to see the difference that data assimilation makes to the overall contours. From inspection of the contour plot Receptor 3 represents almost the maximum exposed receptor, a very small area further to the west received a concentration above 250 $\mu g/m^3$. Therefore the inclusion of data assimilation increases the maximum on the model domain by about 50% for short-term impacts.

Table 1: **Summary of predicted maximum 1-hour average concentrations of NO_x for current operations of the Wagerup Refinery with and without data assimilation ($\mu g/m^3$)**

Receptor	Predicted maximum 1-hour average concentration of NO_x ($\mu g/m^3$) for peak emission scenarios		
	Current operations	**Current operations with wind data assimilation**	**Ratio**
1	55	83	1.5
2	69	90	1.3
3	75	233	3.1
4	84	168	2.0
5	95	95	1.0
6	89	89	1.0
7	84	33	0.4
8	36	29	0.8
9	41	37	0.9
10	42	29	0.7
11	48	38	0.8
13	34	34	1.0
14	85	102	1.2
15	75	112	1.5
16	52	52	1.0
Maximum on grid	>150 <200	250	1.25-1.7

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The figure indicates the plumes are very narrow and demonstrates the large variability in impacts for a particular location. Therefore to reduce model uncertainty it is advisable to present the maximum exposed location as well as the individual receptors.

Figure 2 presents the contour plots for annual average concentrations with and without data assimilation. Predicted concentrations at all locations remain the same or increase by as much as 100% at a particular location. The maximum on the model domain is also increased by 100% with the inclusion of data assimilation, as are most locations in Yarloop. This is probably due to the assimilated data slowing down the TAPM winds and increasing the frequency of northerly winds and hence predicting higher concentrations particularly in Yarloop.

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Figure 1: **Contour plot of predicted maximum 1-hour average concentrations of NO$_x$ for current operating scenario (6600tpd) of Wagerup Refinery predicted by TAPM with data assimilation.**

NOx concentration (µg/m^3) with data assimilation
Maximum 1-hour average, Current scenario (6600 tpd) - Peak emissions
No smoothing, contour interval 50 µg/m^3

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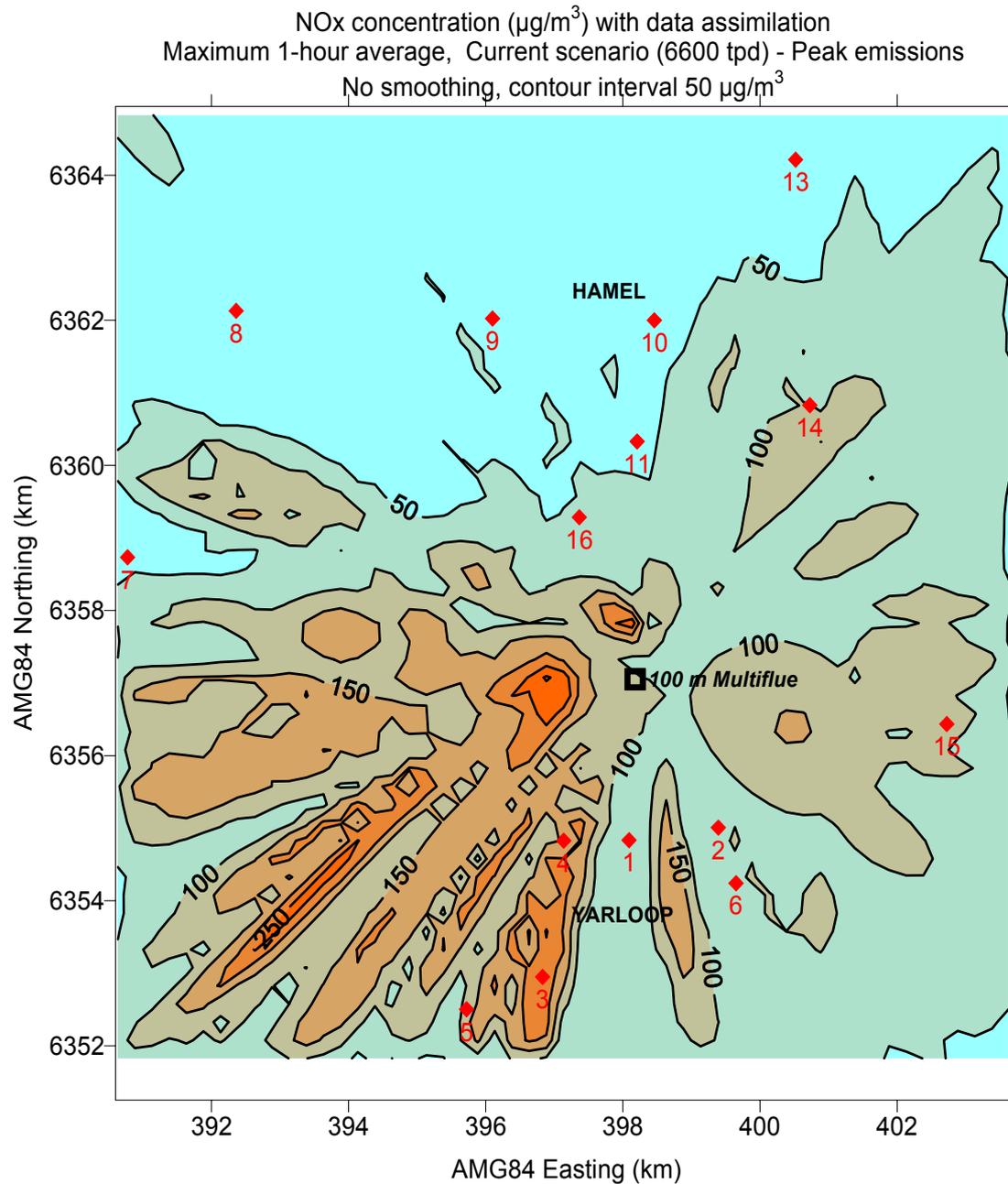
Figure 2: **Contour plot of predicted annual average concentrations of NO_x for current operating scenario and peak emissions (6600tpd) of Wagerup Refinery predicted by TAPM (a) without and (b) with data assimilation.**

(a)
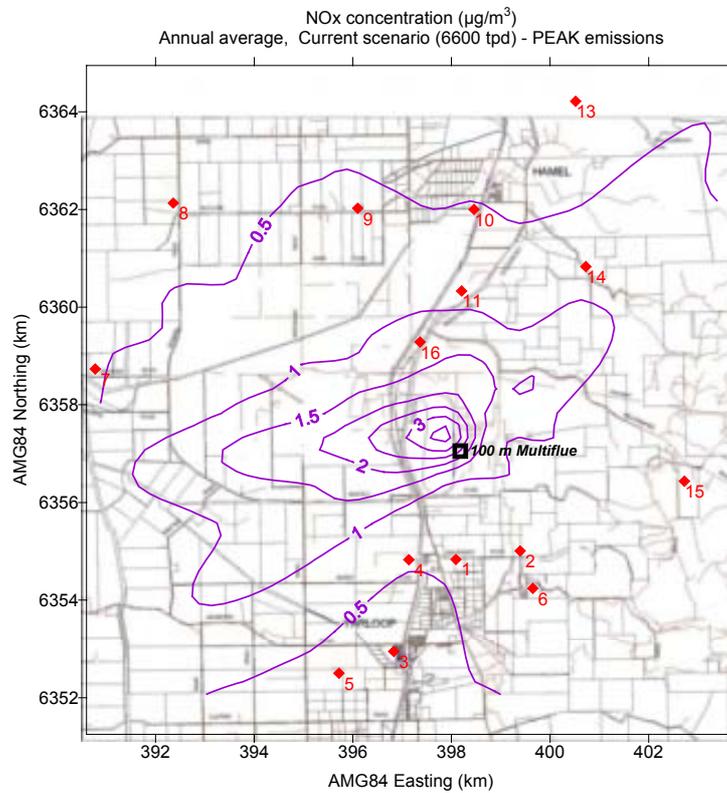
(b)
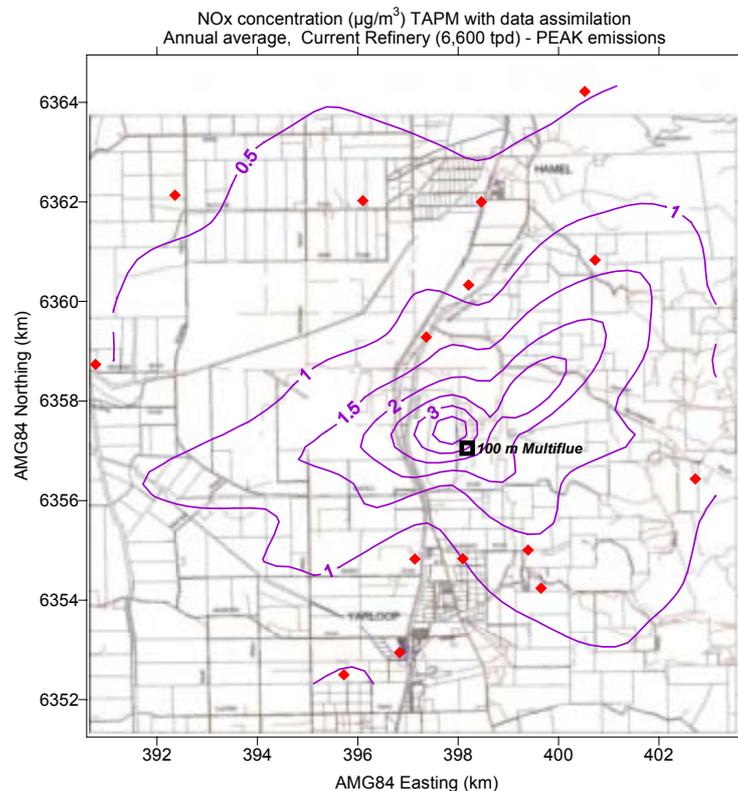
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Table 5 of the Phase 3 reports should be replaced with the TAPM results presented in Table 7 of Phase 2 report. Table 5 incorrectly presents an average of the modelled RHC ratios, which is not suitable because of the effect of averaging is to under-represent the errors (the positive and negative errors cancel out). As noted in our previous review, studies not relevant to the Wagerup study should also be removed. The RHC ratio for the final configuration tested in the Phase 2 report and used in the Phase 3 modelling should also be presented, which is 0.8 (from Table A1 in Phase 2 report). The range in RHC ratios for TAPM presented in the Phase 2 report is 0.7 to 1.75 (i.e. a 30% under-prediction to a 75% over-prediction).

It would be useful to include a receptor at the Upper Dam site in Table 6 of Phase 3 reports as it may be shown that with data assimilation the under-prediction of RHC at Upper Dam is corrected (based on receptor 14 showing RHC 30% higher with data assimilation, this is also confirmed by inspection of the contour plots).

From inspection of contour plots (e.g. Figure 25, 26 and 27) it can be seen that the receptors chosen for detailed analysis do not include the maximum exposed location outside the plant boundary. An area approximately 2 km to the west of Yarloop (west of receptor 6) receives the highest short-term concentrations and should be included in the HRA as the maximum exposed location.

CSIRO draw the conclusion that the level of uncertainty in the modelling results presented in the Phase 3 reports is a factor of 2 (i.e. the actual value lies in the range –50% to +100%) for both short-term impacts and annual averages. This may be the case for each individual receptor location but may be overstated for the maximum exposed receptor. Recent model validation studies undertaken by CSIRO (Hurley et al, 2005) for TAPM V3 (which is closer to Version 2.6 used in the Wagerup studies compared to TAPM V2) showed that the RHC ratio was in the range 0.89 – 1.39 for maximum concentrations at selected distances from the source. The ratios of mean concentrations were in the range 0.88 – 1.64. Based on these results and those for the final configuration of the model predictions at the Upper Dam site (RHC ratio of 0.8), the peak impacts are more likely in the range 0.8 to 1.5 (i.e. results presented in the CSIRO reports 3A and B are actually in the range –20% to + 50%) for the maximum exposed location.

In Yarloop the modelling may have underestimated the maximum impacts (both short-term and long-term), as data assimilation was not included. At Yarloop the short-term maximums and long-term averages are more likely to be double those presented in the CSIRO reports.

We recommend that the modelling is redone to include data assimilation and an analysis of the sensitivity of impacts is undertaken particularly in Yarloop, when more data are available for the 30 m tower at Bancell Road. This will enable better data assimilation for a longer period of time.

It should also be noted that as long as the expansion scenarios do not contain any significantly different source types (such as 200 m stacks or buoyant line sources) the model uncertainty would be inherent in both current and expanded scenarios. Therefore it is important to look at the change in impacts rather than the absolute magnitude of predicted ground-level concentrations.

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2.4   Phase 3B report – Concentration Modelling of Proposed Expansion for HRA

The scope of this review does not cover verification of emission rates, however, it does cover the ground level concentration predictions. Therefore we have presented a summary of a selection of results for current and expanded operations for comparison. We have also commented on the appropriateness of the emission rates used in the modelling based on the information provided in the Appendix A of Phase 2 reports for daily average emissions.

(a)   Emission rates

The modelling results presented in Phase 3A and 3B use peak emission rates for short-term averages and average emissions for annual average concentrations. For the short-term averages, this should be a conservative assumption as all sources are modelled with peak emissions at the same time. The total emissions of NO_x from the current refinery operation are modelled as 32 g/s for average emissions and 75 g/s for peak emissions. From inspection of the daily emission rates (Figure A2 (j) Phase 2 report) the total emissions from the refinery are in the approximate range of 30 to 50 g/s. Therefore the total peak emission from the refinery are typically much less than that assumed in the modelling.

The most significant sources of NO_x from the current operation of the refinery (peak emissions as modelled) are Boilers 1 (24%) and 2 (22%) and Gas Turbine (18%). The daily emission rates reported for Boiler 1 can be up to 35% higher than the peak emission rate that is used in the modelling (approximately 15 days out of 365). It should be noted that this is also a daily average emission rate and that on a shorter averaging period, such as hourly average, the emission variability may be even higher. This source will be fitted with low NO_x burners for the expansion and as such the emission rates will decrease significantly, therefore the under estimation of the peak emissions is not a significant issue.

The Gas Turbine is modelled with peak emissions of 13.6 g/s, up to 70% lower than the peak daily emission rate for the 2003-2004 period. This may be due to the peak emissions only representing the Gas Turbine operating at full load when emissions are actually lower than the turbine operating at 50-75% load. At lower load the emissions from gas turbines are higher than at full load and the flow rates are lower, and hence plume rise and dispersion, are lower resulting in potentially higher ground level concentrations than operations during full load. The current operations have included the low load for a significant period (all of September) this should also be modelled as a potential scenario for the future operations.

Generally the peak emission scenario is conservative as all sources are assumed to be operating at peak emissions at the same time and during the worst meteorological conditions. However, individual sources may operate at higher emission rates than those modelled but this is likely to occur very infrequently and is unlikely to coincide with peak emissions from other sources or worst case meteorological conditions.

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(b)   Impacts

NO_x was selected to show the difference in short-term impacts due to the proposed expansions. The results for current operations, Case 6 and Case 7, are summarised in Table 2. At most locations the impacts are lower then the current operations. For the expansion (Case 6), two new gas turbines are included with significant emission rates of NOx (18 g/s/source) compared to the existing sources. The NO_x emissions from the calciners are slightly increased, as is the exit velocity and there are two new calciners with similar emissions to the existing Calciner 4. The only significant change in emission rates and characteristics for the existing sources that could result in a decrease in NO_x impacts is the increase in the height of the Calciner 4 stack from 49 m to 100 m multiflue and a significant decrease in emissions from the existing boilers (due to retrofit of low NO_x burners to the existing boilers). The only area that receives higher impacts for Case 6 expansion is to the west of the plant (where there are no receptors identified). A receptor should be chosen in this area at a location outside of the land owned by Alcoa to show the maximum exposed location.

The Case 7 expansion scenario involves two additional boilers that are similar to the existing boilers but with a slightly taller stack. From inspection of Table 2, the only location to receive an increase in impacts is Receptor 15. From inspection of the contour maps for each modelling scenario there appears to be little difference in the impacts. This shows the sensitivity of predictions to the receptors selected and therefore we recommend that the maximum prediction at all off-site locations also be presented.

Table 2:   Summary of predicted maximum 1 hour average concentrations of NO_x for current and expanded operations of the Wagerup Refinery ($\mu g/m^3$)

Receptor	Predicted maximum 1 hour average concentration of NO_x ($\mu g/m^3$) for Peak emission scenarios		
	Current operations	**Expansion Case 6**	**Expansion Case 7**
1	55	42	48
2	69	55	51
3	75	60	60
4	84	68	73
5	95	78	72
6	89	59	75
7	84	79	67
8	36	38	28
9	41	41	40
10	42	42	42
11	48	44	41
13	34	31	32
14	85	75	74
15	75	62	90
16	52	45	47

Note: shaded cells represent an increase in impacts for the expanded operations.

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In order to determine the pollutant that is most critical for the HRA we have used the CAPCOA HRA96 program as a screening tool. This HRA methodology is accepted in most states in Australia, but not Western Australia. Consequently the detailed results are not presented here but the results have been used to determine the most critical pollutant based on the relative toxicities of each pollutant that is emitted. The most critical pollutant for the HRA is Acrolein, followed by Mercury, Acetaldehyde, Formaldehyde and Manganese. Table 3 presents the modelling results for current operations and expanded operating scenarios for Acrolein for short-term and long-term averages.

Table 3: **Summary of predicted ground level concentrations of Acrolein for current and expanded operations of the Wagerup Refinery**

Receptor	Predicted maximum 1 hour average concentration of Acrolein ($\times 10^{-2}$ µg/m^3)			Predicted annual average concentration of Acrolein ($\times 10^{-4}$ µg/m^3)		
	Current operations	Expansion Case 6	Expansion Case 7	Current operations	Expansion Case 6	Expansion Case 7
1	3.2	3.0	3.0	2.8	2.6	2.6
2	4.5	3.6	3.6	3.8	3.0	3.0
3	3.3	3.0	3.0	2.0	1.8	1.8
4	4.2	3.4	3.4	2.6	2.6	2.6
5	3.7	2.4	2.5	1.9	1.6	1.6
6	4.7	4.1	4.1	3.1	2.6	2.6
7	3.2	3.6	3.6	2.4	1.7	1.7
8	2.3	2.1	2.1	1.9	2.0	2.0
9	2.6	2.8	2.8	3.0	3.2	3.2
10	2.9	4.5	4.5	2.4	3.4	3.4
11	3.0	4.7	4.7	4.0	5.5	5.5
13	1.9	2.4	2.4	1.5	1.9	1.9
14	3.6	3.6	3.6	3.6	4.3	4.3
15	6.2	6.7	6.7	4.9	4.0	4.0
16	3.4	3.8	3.8	6.3	7.2	7.2

Note: shaded cells represent an increase in impacts for the expanded operations.

The calciners are the only stack sources with Acrolein emissions at the Wagerup refinery. During the expansion two additional calciners will be installed and the stack height for Calciner 4 will increase and be combined with the new 100 m multiflue Calciner stack. The significant decrease in impacts in some areas (mainly south of the plant) is likely to be due to the improved dispersion of Calciner 4 after the expansion when it is combined with the exhausts from Calciner 5 and 6 in a 100 m multiflued stack.

Due to the changes in emission rates and stack characteristics (e.g. increased stack height for Calciner 4) for the proposed expanded refinery it is difficult to check the validity of the predicted impacts for the refinery expansion. However, based on the changes noted above in emission rates and stack characteristics the changes in impacts seem reasonable.

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3.   Summary of review

Generally the use of TAPM for modelling the Wagerup Refinery plumes should be suitable, and is probably the best available model. It is commendable that CSIRO has tested the TAPM scheme against many data sets and are constantly upgrading the model. However, the performance of TAPM can be quite mixed and depends on the situation being modelled and the performance measures required for a particular situation. The model appears to be more useful than many comparable models and the recent upgrades to the model have been shown to improve the model's performance. It has been recognised by the developers that there are circumstances in which the model over-predicts surface wind speeds and may have problems with dispersion in complex terrain. We point out that any model or measurement process has associated errors for which it is important to estimate the likely influence on the conclusion of a given study, however, keeping this in mind the errors of a particular model will be the same for the current scenario as for the expansion and therefore the relative difference in impacts can be as important as the magnitude of impacts.

The revised reports prepared by CSIRO have addressed either directly or indirectly the significant issues identified in our previous review. Some of the additional information requested in our review has not been supplied. The question "is the model predicting the right answer for the right reason" remains unanswered. It would give more confidence in the results if this question was answered but due to the limited monitoring information available for the region it may not be possible.

The model setup verified in the model validation study presented in Phase 2 (Appendix A) has been shown with daily average emission rates to be a suitable configuration of the model. The peak few concentrations are slightly under predicted by the model which may be a result of not using the actual daily average operating conditions (e.g. flow rates and exit velocities) for each source or not including data assimilation.

We still recommend that the model use data assimilation as the more appropriate meteorological scenario for the region. This is shown to increase the impacts in the Yarloop area particularly, for both short-term and long-term ground-level concentrations. Overall the most exposed location is higher with data assimilation for peak 1-hour average concentrations and annual averages.

Modelling results should be presented for the maximum exposed location as well as at the discrete receptors. This will reduce the uncertainty due to year to year variability in wind patterns.

The peak emission scenario used to predict the short-term impacts is conservative as all sources are assumed to be operating at peak emissions at the same time and during the worst meteorological conditions, however, individual sources can operate at higher emission rates than those modeled, though there is likely to be a low risk that these short-term peaks will coincide. Therefore it is likely that the actual impacts will be lower than those presented if actual emission rates were used.

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The uncertainty in the predicted modelling results presented in the Phase 3A and B reports for peak short-term impacts are likely to be in the range 0.8 to 1.5 (i.e. results presented in the CSIRO reports 3A and B are actually in the range –20% to + 50%) for the maximum exposed location. The uncertainty is slightly higher at Yarloop where the modelling may be an under prediction of the peak and annual average concentrations by a factor of 2 (i.e. results presented in the CSIRO reports 3A and B are actually + 100%).

It should also be noted that as long as the expansion scenarios do not contain any significantly different source types that are not similar to the range of source types modelled for the current operations (such as buoyant line sources), the model uncertainty would be inherent to and similar in magnitude for both current and expanded scenarios. Therefore it is important to look at the change in impacts as well as the absolute magnitude of predicted ground-level concentrations.

For the Refinery Expansion scenarios the impacts decrease and increase depending on the pollutant and location. Due to the changes in emission rates and stack characteristics for the proposed expanded refinery it is difficult to check the validity of the predicted impacts for the refinery expansion. However, based on the reduced emissions for some sources and better dispersion for others with the inclusion of a new multiflue source, the changes in impacts seem reasonable.

Generally the modelling undertaken for the Wagerup 3 Refinery expansion adequately assesses the potential impacts on the local atmospheric environment so long as a degree of conservatism is taken into account when applying the uncertainty factors from the modelling results presented by CSIRO in the HRA. We also strongly recommend that the maximum exposed location outside the Alcoa lease boundary is also presented and the change in impacts for the expansion assessed at this location.