Winter 2006 Study: Intensive Air Quality Investigations at Wagerup

Department of Environment and Conservation, October 2008
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1. Background

The Department of Environment and Conservation (DEC) plays a leading role in ensuring that Alcoa and the communities of Wagerup, Hamel, Yarloop, Waroona and Cookernup can understand and address air quality issues as they arise.

Over the last five years, DEC has undertaken a series of air quality measurements in the vicinity of the Alcoa Wagerup alumina refinery. This latest study focuses on the results obtained during the winter period of 2006.

In 2006, the former Minister for the Environment conditionally approved Alcoa’s proposal to expand its Wagerup alumina refinery, subject to the company:

- undertaking further studies of local weather conditions;
- verifying that the computer modelling used in its Environmental Review and Management Program (ERMP) for the proposal could accurately predict ground level concentrations of refinery air emissions; and
- ensuring that the impacts of emissions on the local environment do not increase.

In its assessment of the proposal to expand the refinery, the Environmental Protection Authority (EPA) referred to previous DEC investigations which raised the possibility that under certain meteorological conditions, there was a chance of short-term elevated ground level concentrations of refinery emissions to the south and south-west of the refinery during winter months. The EPA concluded that although not considered a health risk to the general community, periodic short-term ground level concentrations of refinery emissions could contribute to adverse health symptoms in individuals with sensitivities to chemicals.

To complement the former Minister’s conditional approval of the refinery expansion, DEC was given the task of conducting additional studies in the Wagerup area, including:

- undertaking field studies during winter 2006 and augmenting Alcoa’s field measurements;
- engaging CSIRO specialists to advise on the performance of Alcoa’s computer modelling of refinery emissions;
- coordinating the integration and independent analysis of field data from multiple sources; and
- advising the EPA and the Minister for the Environment on Alcoa’s fulfilment of Ministerial Conditions for expanding the refinery.

DEC was also able to undertake part of this work by consulting with Alcoa in an open, professional environment, which included sharing data to enhance overall understanding of Wagerup’s meteorology and air quality.

DEC’s commitment to transparent dealings with all stakeholders extended to regular communication with the local community through the Wagerup Tripartite Group and other forums, such as a community open day in Yarloop in June 2007.

This latest study provides information on the current status of the DEC work program, the key findings to date and the actions to be implemented by DEC and Alcoa as a result of the findings. DEC has also considered the outcomes of targeted investigations undertaken by Arizona State University and CSIRO as part of this project. The final reports of these investigations, including a peer review of the Arizona State University document by the United States National Oceanic and Atmospheric Administration, are available on the DEC website www.dec.wa.gov.au/wagerup.
2. Overview of measurement program and analysis

2.1 Measurement program

2.2 Analysis methods
A large amount of data was collected during the winter 2006 study. Air quality experts from DEC, CSIRO and Arizona State University collaborated for 18 months processing, analysing and integrating the data using a variety of tools.

The data analysis undertaken by DEC and CSIRO focused on two main areas:

- building understanding of the conditions under which community members experience and report air quality impacts (this work is largely complete); and
- the ability of the computer model used in Alcoa’s ERMP to simulate important meteorological and dispersion processes that occur in the Wagerup region (this work is well advanced and ongoing).

The approach adopted by DEC scientists was to select days for analysis based on the community observations, targeted meteorology and field measurements. A number of days from the 2006 winter study period were analysed in detail. These days represent a broad cross section of the conditions experienced in the area.

An example of DEC’s analysis of community complaints for 14 August 2006 is shown in Figures 1 to 3. Figure 1 is taken from visualisation software developed by DEC, which shows two complaints, illustrated with light blue cone and circle, in Yarloop during a period of winds from the north. Figure 2 contains results from a light detection and ranging laser radar (LIDAR) scan showing a refinery plume or plumes moving to the south and Figure 3 is a LIDAR scan of the uniform wind flow from north to south up to 200m above ground level.

Figure 1. Visualisation of wind data and community observations at 8am on Monday 14 August 2006, looking down from the south-west. The blue cone represents a reported odour effect and the blue circle a reported health effect. Refinery emission sources are shown in red and the yellow arrows are wind vectors from the various wind measurement locations. Wind direction is from the north to south as per the arrow direction and wind speed is indicated by arrow length (moderate in this case). The vertically-stacked arrows up to 125m above the ground are derived from acoustic radar.
Figure 2. LIDAR scan in Plan Position Indicator or ‘map view’ mode, showing enhanced backscatter (light blue strip) in the region of the refinery sources, representing a plume or plumes traveling to the south.

Figure 3. LIDAR scan in ‘map view’ mode showing the uniform wind flow from north to south (blue to red) up to 200m above ground level.
3. Summary of study findings

3.1 Community observations and complaints

Community observations and complaints about air quality were compiled from DEC-issued logbooks maintained by the community, DEC’s Kwinana office and from Alcoa. The air quality observations made by community members involved in DEC’s community air sampling program provided very useful information and their assistance was critical to the study’s success.

Community observations ranged from a single person detecting weak odour to multiple reports of strong odours and reported health concerns.

The community data analysed covered the period June to October 2006 when field monitoring instruments were operating. There were a total of 216 observations from 32 individuals in Yarloop, Cookernup, Hamel, Wagerup and Waroona. These observations were tabulated and cross-checked to remove instances of double-counting where, for example, a community member made a logbook entry and also called DEC to register a complaint. The observations were then cross-checked with meteorological measurements and other information to assess whether the reported impact was reasonably attributable to refinery emissions.

The analysis suggests that for most community members, a high percentage of observations were reasonably attributable to the refinery. For a few community members, a significant portion of observations appear to be related to other sources or effects. Consideration of plume-height wind data was an important part of this assessment. Only those observations that were assessed as being attributable to the refinery were used in the subsequent analysis described below.

Figure 4 shows a graphical representation of the meteorological conditions under which community observations were made. These meteorological conditions strongly influence the dispersion of emissions. Field measurements show that the meteorology of the Wagerup area can vary between simple to complex. As an example of the latter, there are times when wind close to the escarpment has different speed and direction compared to wind over the plain. Also, winds at different heights can have very different speed and direction. This complexity means that transport of refinery emissions can also be complex. Figure 4 includes a summary description of the range of meteorological conditions. There are four broad classes of meteorological conditions, ranging from light wind conditions through to fresh breezes.

<table>
<thead>
<tr>
<th>Dispersion type vs % Community observations</th>
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<tbody>
<tr>
<td>Light wind stable conditions - low wind speed, stable, directions varying; plumes may not mix to ground or mix down sporadically.</td>
</tr>
<tr>
<td>Other non-uniform surface wind conditions - for example, strong easterly wind near the escarpment with a light westerly wind over the plain.</td>
</tr>
<tr>
<td>Post-stable conditions with shallow convective mixing - occurs during mid-morning after stable conditions; plumes are engulfed and mixed within a shallow convective layer which deepens with time</td>
</tr>
<tr>
<td>Near neutral conditions - fresh winds, possibly cloudy; plumes travel in a generally uniform direction</td>
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Figure 4. Summary of meteorological conditions under which community observations were made. The legend describes the main features of the meteorological conditions occurring at the time of community observations. The majority of observations occurred under near neutral conditions.
3.2 Linking the meteorology with the reported level of impact

DEC grouped community observations that were linked in time and space to the same meteorological conditions, and called these groups of observations ‘events’. The events were then ranked in terms of the magnitude of overall impact, accounting for the number of community observations and the reported severity of effects. This analysis indicates that the most significant odour impacts occurred as a result of post-stable conditions. A graphical representation of this event based analysis is presented in Figure 5.

Figure 5. Summary of event based analysis of community observations and associated meteorological conditions. The columns show the percentage of meteorological conditions within each event magnitude class (low, medium, high). The number of events and the number of community observations comprising the events are detailed above each column.

Figure 5 indicates that the two highest impact events occurred in post-stable conditions. There were 15 community observations associated with these events. Overall, most events occurred in near-neutral (uniform wind) conditions.

3.3 Significant odour impact event on Sunday 27 August 2006

DEC’s analysis identified event days where impacts were reported by a number of community members. The most significant event over the study period occurred on the morning of Sunday 27 August 2006, which resulted in multiple complaints across a broad area of Yarloop. Descriptions of the event included: ‘worst smell that has been detected in a long time’, ‘rated the odour as being 6/6’, and ‘worst pollution event for years’. Most complaints occurred between 9am and 10am.

Figure 6 shows the community observations made on this day up to 9.45am. The community observations were made over a broad area of Yarloop.
The analysis provides clear evidence of how this event occurred:

- An elevated layer of refinery emission was formed during the early morning under persistent light wind stable conditions. The light winds at the height of this layer transported the emissions southward. Figure 7 shows the very light wind conditions at 7am on this day, and Figure 8 is a horizontal LIDAR scan at 8.10am showing complex wind patterns with northerly winds at the height of the emissions layer. Figure 9 is a horizontal LIDAR scan at 8.39am showing the presence of the emissions layer (see the light blue ring at height of 70m) that is clearly linked to the refinery. Figure 10 is a vertical LIDAR scan that also shows the presence of this layer above the ground.

- From 9am onwards, refinery odours were detected across a wide area to the south of the refinery as the layer of emissions was mixed to ground level in post-stable conditions with shallow convective mixing. Evidence for the plume mixing to ground level is presented in Figure 11, where the elevated layer of emissions is moving downwards (see the light blue areas of the figure).

DEC has determined that Alcoa’s existing complaint management procedures, which include assessment of wind direction at a single measurement station on Bancell Road, are not adequate for understanding the complexity of this type of event.
Figure 7. Wind conditions at 7am on Sunday 27 August 2006. Viewpoint is looking down on the Wagerup area from the south-west.

Near surface winds very light, direction variable in space and time

Upper winds from the SE

Figure 8. LIDAR scan in Plan Position Indicator or ‘map view’ mode, showing very complex winds with directions spiraling clockwise as height increases at 8.10am on Sunday 27 August 2006. Wind direction is indicated by the black arrows.
Figure 9. LIDAR scan in Plan Position Indicator or ‘map view’ mode, showing the elevated layer of emissions at 8.39am on Sunday 27 August 2006.

Layer of emissions concentrated at ~ 70 metres

Figure 10. Vertical LIDAR scan at 8.16am on Sunday 27 August 2006 showing the elevated layer of emissions.
Figure 11. Vertical LIDAR scan at 8.55am on Sunday 27 August 2006 showing mixing of the elevated layer of emissions to ground level.

3.4 Issues requiring further consideration

Investigations by DEC and CSIRO provide evidence of significant sources of odour in the southern part of the refinery, which have not been properly identified or quantified to date by Alcoa in their current emissions inventory. This will be the subject of further investigations by DEC as it works with Alcoa to identify the location and nature of these odour sources.

Assessment of the performance of the computer model TAPM undertaken to date by CSIRO and DEC indicates that the model performs well under near neutral and some post-stable conditions (see Figure 4). On the other hand, the model is unable to adequately simulate light wind stable, other non-uniform surface wind and some post-stable conditions.

A key finding of the investigation is that the plumes from the 100m multi-flue stack do not appear to significantly contribute to community observations. The height and buoyancy of these plumes generally ensures that they are transported well away from where the highest concentrations of other refinery emissions occur. DEC notes that the liquor burner was not operating during the study period.

Lower level sources located in both the northern and southern parts of the refinery appear to be important contributors to reported odour impacts.
4. What do these findings mean for current operations at the refinery?

The winter 2006 study has significantly improved our understanding of the complex Wagerup environment, and provides opportunities for additional improvements in environmental management.

The winter 2006 data provides evidence of significant odour impacts in local communities. DEC will direct Alcoa to take initiatives – within an acceptable timeframe – that will minimise the likelihood of incidents of this magnitude in the future. Furthermore, there appear to be odour sources which may not be accounted for in the current emission inventory. Accordingly, Alcoa will be required to advise how it will change the environmental management of its operation to:

- improve odour management of key refinery sources;
- in light of the reports review refinery odour sources in order to ensure that all significant odour sources are included in the emissions inventory;
- expand its meteorological network, with additional surface stations and measurement of winds at different heights; and
- change its complaints management and response procedures to accommodate the new understanding of meteorological conditions from these studies.

DEC will liaise with Alcoa to ensure they meet these essential requirements, which will benefit the community and contribute to the refinery’s goal of working towards positive environmental outcomes.

5. What do these findings mean for the proposed expansion of the refinery?

The winter 2006 study indicates that low-level emission sources are the most significant contributors to odour impacts. The modelling provided as part of the assessment of the Wagerup III expansion will need to be reconsidered as part of Alcoa’s undertakings to address the Ministerial Conditions for the expansion.

DEC’s investigations are ongoing and will be considered further when Alcoa presents the work it has undertaken to address the Ministerial Conditions attached to the refinery’s expansion.