Final Report

Meteorological and Dispersion Modelling Using TAPM for Wagerup

Phase 3B: HRA (Health Risk Assessment) Concentration Modelling – Expanded Refinery Scenario

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Executive Summary

The work presented in this report is part of a study entitled “Meteorological and Dispersion Modelling Using TAPM for Wagerup”.

The aspect addressed here is Phase 3B: Concentration Modelling for the Health Risk Assessment (HRA) for the Expanded Refinery (4.7 Mt of alumina per annum).

The concentration modelling was carried out using TAPM (The Air Pollution Model) with the configuration determined by the evaluations of meteorology in Phase 1 of the Study and dispersion in Phase 2, which evaluated TAPM for air quality predictions at Wagerup using a database of emissions and observed ambient air concentrations.

The following emission sources are included in the modelling:

- Oxalate Kiln Stack
- Liquor Burner Stack
- Calciner stacks 1, 2, 3, 4, 5, 6
- Boiler stacks 1, 2, 3, 4, 5
- Gas Turbine stacks 1, 2, 3
- Calciner 1, 2, 3 Vac Pump, 50B and Dorrco
- Calciner 4 Vac Pump and Dorrco
- 45K Cooling Towers 2 and 3
- 50 Cooling Towers 1 and 2
- Milling Vents
- 25A Tank Vents
- 35A Vents.

The following chemical species are included in the modelling:

- 1,2,4, trimethylbenzene
- 1,3,5 trimethylbenzene
- 2-butanone
- acetaldehyde
- acetone
- acrolein
- ammonia
- arsenic
- benzo(a)pyrene equivalents
- benzene
- cadmium
- carbon monoxide (CO)
- chromium VI
- dust
- ethylbenzene
- formaldehyde
- manganese
- mercury
- methylene chloride
- nickel
- nitrogen dioxide (NO_2)
- oxides of nitrogen(NO_x)

- selenium
- styrene
- sulphur dioxide (SO_2)
- toluene
- vinyl chloride
- xylenes.

Each of these species is released at different rates from one or more of the emission sources listed above. Modelling has been carried out for the Expanded Refinery (4.7 Mtpa) Emissions Scenarios. Two scenarios have been considered:

- Case 6, with Cogeneration using new Gas Turbines 2 and 3
- Case 7, with new Boilers 4 and 5.

Two sets of emissions have been considered for each of these scenarios– the Average emission rates and the Peak emission rates. The emission rates used have been provided by Alcoa World Alumina Australia. CSIRO has had no role in the development or verification of these emissions. The atmospheric concentrations modelled in this study are the direct consequence of the emissions included in the model. Different emission rates would produce different concentrations.

The following concentration statistics were identified by Alcoa as important for the HRA and are tabulated at 15 receptor points located around and at distances up to 7 km from the Refinery at locations specified by Alcoa:

- Annual average concentration (at average emission rates)
- Maximum 1-hour average concentrations (at peak emission rates)
- 95^{th} percentile 1-hour average concentrations (at peak emission rates)
- 95^{th} percentile 24-hour average concentrations (at peak emission rates)
- Maximum 10-minute average concentrations (at peak emission rates)
- Maximum 3-minute average concentrations (at peak emission rates).

Concentrations were obtained from the model TAPM (version 2.6), which was run with four nested grid domains at 20-km, 7-km, 2-km, and 0.5-km resolution for meteorology (31×31 grid points). Similarly four nested domains of 53×53 horizontal grid points with resolutions of 10-km, 3.5-km, 1-km and 0.25-km were used for the pollutant dispersion modelling. The lowest ten of the 25 vertical levels were 10, 25, 50, 100, 150, 200, 250, 300, 400 and 500 m. The default databases of soil properties, topography, and the monthly sea-surface temperature and deep soil parameters (with a deep-soil moisture content of 0.15) were used. The Wagerup-specific land-use database and a refinery-generated surface heat flux value of 150 W m^{-2}, both derived as part of the Phase 1 work (CSIRO, 2004b), were used. The runs included building wake effects with a total of 29 rectangular buildings included, ranging in height between 8 m and 42 m. In all the Phase 3 runs, the Lagrangian mode was used on the inner-most grid in the pollution dispersion calculations. The period modelled was one year from April 2003 to March 2004.

The uncertainty of the model predictions at the receptor sites, based on consideration of results from a range of TAPM studies as well as uncertainties in the Wagerup region, is a factor of approximately 2 (i.e. the actual values lie in the range of +100% to -50% of the listed concentrations) at the 95% confidence level.

Glossary

Simple definitions of various technical terms are given here to assist the reader. If required, the reader should look to other sources for more formal and technical definitions.

ABL	Atmospheric Boundary Layer. The ABL is the lowest 100 to 3000 m of the atmosphere modified by the earth's surface. The ABL responds to surface forcings (i.e. heating, cooling, and roughness) with a time scale of about an hour or less, and its extent is deeper in the daytime and shallower in the nighttime. It is often turbulent and is capped by a temperature inversion (see definition below).
Aerosol	A suspension of fine solid, liquid or mixed-phase particles in air.
AGL	Height Above Ground Level
ANSTO	Australian Nuclear Science and Technology Organisation (http://www.ansto.gov.au/)
AUSPLUME	A simple, steady-state, Gaussian plume dispersion model used for predicting ground-level concentrations of pollutants from a variety of sources. It is a regulatory model developed and approved by EPA Victoria and other regulatory agencies. AUSPLUME requires input, which typically contains hourly values of temperature, wind speed, wind direction, stability, and mixing height.
BaP equivalents	Benzo(a)pyrene equivalents. This species is used as a marker for a group of chemical compounds called Polycyclic Aromatic Hydrocarbons (PAH). The relative toxicities of the various PAHs have been assessed compared to BaP (e.g. Nisbet and LaGoy, 1992). Multiplying the concentration of each PAH by its relative toxicity yields a concentration for the total PAH mixture that is expressed in terms of an equivalent concentration (with regard to toxic potency) of BaP.
Buoyancy enhancement	An increase in the effective buoyancy of a plume as a result of merging with another buoyant plume. This leads to greater plume rise of the combined plume than of the individual plumes.
CALMET	A computer model providing the meteorological input for the dispersion model CALPUFF. It is driven by observed or large-scale model meteorology and is capable of calculating temporally and spatially varying wind fields.
CALPUFF	An air pollution dispersion model developed by Earth Tech Inc. (USA). It simulates the transport and diffusion of a plume via the puff approach in which a plume is described as consisting of a series of puffs. CALPUFF

	typically uses meteorological data generated by the processor CALMET. (http://www.src.com/calpuff/calpuff1.htm)
CAR	CSIRO Atmospheric Research (http://www.dar.csiro.au)
CO	Carbon monoxide
Combined source	The representation of two or more closely-spaced emission sources (usually within the same stack) which have similar emission characteristics by a single source.
Convective mixed layer	Also called the convective boundary layer, mixed layer or mixing layer. A type of atmospheric boundary layer (ABL) characterised by vigorous turbulence, generated by the solar heating of the ground, tending to stir and mix pollutants particularly in the vertical.
CSIRO	Commonwealth Scientific and Industrial Research Organisation (http://www.csiro.au)
Diffusion	In air pollution meteorology the words dispersion and diffusion are often used interchangeably. This is also the case in this report. However, strictly speaking the two words mean different things. Diffusion refers to dilution of pollutants by turbulent eddies in the atmosphere whose dimensions are smaller than that of a pollutant plume or a puff (see also Dispersion).
Dispersion	Dispersion refers to the movement or transport of pollutants horizontally or vertically by the wind field and their dilution by atmospheric turbulence. Dispersion includes both transport and diffusion of pollutants (see also Diffusion).
Emission rate	Specifies the rate at which gas or particles are emitted from a source. The quantity is expressed in units of grams per second.
EPAV	Environment Protection Authority of Victoria (Australia) (http://www.epa.vic.gov.au)
Eulerian approach	An approach to describing atmospheric diffusion in which the behaviour of species is described relative to a fixed coordinate system.
Exit temperature	The temperature of the gas released from a source.
Exit velocity	The velocity at which gases are emitted from source. For a stack, the volume flow rate from the stack is obtained by multiplying the exit velocity by the internal cross-sectional area of the top of the stack.
Exponential notation	A notation used in scientific, engineering and computing applications to represent very large and small numbers without having to use a large number of zeros. For example, the value 4.8E-06 = 4.8×10^{-6} = 0.0000048.

GASP	Global AnalySis and Prediction. A meteorological modelling system currently used by the Australian Bureau of Meteorology that can provide the large-scale (synoptic) meteorological input needed in the models TAPM and CALMET.
glc	Ground-level concentration. Refers to pollutant concentrations at a height where it is detected by people standing on the ground. In modelling it is the concentration in the lowest model level, typically 0–10 m above the ground.
Inversion	An atmospheric layer in which temperature increases with altitude (e.g. the layer above the atmospheric boundary layer). These layers are stable and resistant to vertical mixing and hence may restrict the dispersion of pollutants. Properly described as a temperature inversion.
Lagrangian approach	An approach to describing atmospheric diffusion in which concentration changes are described relative to the moving fluid.
LAPS	Limited Area Prediction System. A meteorological modelling system previously used by the Australian Bureau of Meteorology that can provide the large-scale (synoptic) meteorological input needed in the model TAPM.
mg	Milligram (1 mg = 10^{-3} gram = 0.001 gram). One thousandth of a gram
mg m^{-3}	Milligram per cubic metre. 1 mg m^{-3} = 1000 μg m^{-3}
NBL	Neutral Boundary Layer. A type of atmospheric boundary layer (ABL) that forms when winds are strong and/or when there is negligible heating or cooling of the ground (e.g. overcast conditions). The turbulence responsible for mixing under these conditions is generated by wind shear.
NO	Nitric oxide
NO_x	Oxides of nitrogen (commonly NO_x = NO + NO_2)
NO_2	Nitrogen dioxide
O_3	Ozone
OU	Odour Unit. The odour units are dimensionless and are effectively “dilutions to odour threshold.” An odour present at a concentration of 1 OU will be discerned as odourless by approximately half the population. 10 OU represents a mixture, which if diluted by 10 will then have an odour detected by 50% of the respondents and so forth.
Percentile	The p^{th} percentile is a value so that roughly p% of the data are smaller and (100-p)% of the data are larger than

	this value; the 50th percentile is called the median. Quantile is a more general definition than percentile.
pg	Picogram (1 pg = 10^{-12} gram = 0.000000000001 gram). One trillionth of a gram
pg m^{-3}	Picogram per cubic metre. 1 pg m^{-3} = 0.000001 μg m^{-3}
Pollutant	Used in this report in the non-legal sense to refer to a chemical species being modelled by air pollution dispersion models, such as TAPM.
ppb	Parts per billion (by volume): 1 ppb = 1/1000 ppm.
ppm	Parts per million (by volume): a unit for the concentration of a gas in the atmosphere based on the mixing ratio approach. A concentration of 1 ppm is equivalent to a volume of 1 cubic metre of pure undiluted gas in 1 million cubic metres of air. The expression ppm (or ppb) is without dimensions. The ppm (or ppb) unit is useful because its value is unaffected by changes in temperature and pressure, and also because many sampling techniques are based on volume concentrations. Concentrations of gaseous compounds can be converted from mixing ratio units, e.g. ppm units (volumetric), to density units, e.g. mg m^{-3} (mass/volume), using the following formula: $$C(\text{mg m}^{-3}) = \frac{273.15 \times M_w \times C}{22.4136 \times (273.15 + T)},$$ where C is the concentration (ppm), M_w is the molecular weight of the gas, and T is the ambient temperature in degrees Celsius. At a temperature of 0 degrees Celsius, the conversion factor from 1 ppm to mg m^{-3} for nitrogen dioxide (NO_2) is 2.050.
Prognostic equation	Any equation governing a system that contains change with time of a quantity, and therefore can be used to determine the value of that quantity at a later time when the other terms in the equation are known.
Quantile	The fraction (or percent) of points below the given value. That is, the 0.3 (or 30%) quantile is the point at which 30% percent of the data fall below and 70% fall above that value. Certain quantiles have special names. The 0.25-, 0.50-, and 0.75-quantiles are called the first, second and third quartiles. The 0.01-, 0.02-, 0.03-, ... , 0.98-, 0.99-quantiles are called the first, second, third, ... , ninety-eighth, and ninety-ninth percentiles.
Q-Q plot	A graphical data analysis technique for comparing the distributions of two data sets. The plot consists of the

	following: vertical axis = estimated quantiles from data set 1; horizontal axis = estimated quantiles from data set 2. However, it is common to directly plot the one data set against the other. That is, the actual quantile level is not plotted. Hence, in an air pollution model evaluation application, the Q-Q plot is essentially a plot of the sorted observed concentrations against the sorted predicted concentrations.
RDA	Residue Disposal Area
RHC	Robust Highest Concentration (Cox and Tikvart, 1990). A robust test statistic calculated using information contained in the upper end of the distribution of concentrations. It is defined as: $RHC = C(R) + \left(\overline{C} - C(R)\right)\ln\left[(3R-1)/2\right],$ where $C(R)$ is the R^{th} highest concentration and $\overline{C}$ is the mean of the top $R-1$ concentrations. A value of $R = 11$ is used in the present analysis so that $\overline{C}$ is the average of the top ten concentrations. The RHC is based on an exponential fit to the highest $R-1$ values of the cumulative frequency distribution. In air quality studies, the RHC is often preferred to the maximum value because it removes the undesirable influence of unusual (stochastic) events, while still representing the highest concentrations.
SBL	Stable Boundary Layer. A type of atmospheric boundary layer (ABL) that develops during the night when the ground is substantially cooler than the air above it, thus forming a stable temperature gradient with height in the air that opposes vertical motions of air and resulting in little ambient turbulence.
SKM	Sinclair Knight Merz (an environmental consulting company)
SO_2	Sulfur dioxide
Stack	Commonly a chimney. Also referred to in air pollution studies as a point source because the inside cross-sectional area is small compared to the size of typical eddies in the atmosphere.
Stack diameter	For air pollution studies, the inside diameter of the stack at the exit. It is used together with the exit velocity to calculate the volume flow rate of gas from the stack.
Stochastic	Stochastic is synonymous with “random”. It is used to indicate that a particular subject is seen from point of view of randomness. Stochastic is often used as counterpart of the word “deterministic”, which means

	that random phenomena are not involved.
TAPM	The Air Pollution Model. A prognostic meteorological and air pollution dispersion model developed by CSIRO Atmospheric Research (http://www.dar.csiro.au/tapm). The meteorological component of TAPM predicts the local-scale flow, such as sea breezes and terrain-induced circulations, given the larger-scale synoptic meteorology. The air pollution component uses the model-predicted three-dimensional meteorology and turbulence, and consists of a set of species conservation equations and an optional particle trajectory module.
Temperature inversion	see Inversion
TSP	Total Suspended Particulates– all particles below about 50 µm in diameter suspended in the atmosphere.
US EPA	United States Environmental Protection Agency (http://www.epa.gov)
Vent	A short chimney or stack, usually located on top of a building to vent emissions from the building.
WA	Western Australia
Wind data assimilation	A technique in which at one or more locations in a meteorological model, the wind speed and wind direction in the model are adjusted towards those observed in the atmosphere. The model adjusts its airflow at this and surrounding locations to ensure that the model wind speed and direction at the location closely follow that observed.
µg	Microgram (1 µg = 10^{-6} gram = 0.000001 gram). One millionth of a gram
µg m^{-3}	Microgram per cubic metre: a unit for the concentration of a gas or particulate matter in the atmosphere based on the density approach (mass per unit volume of air). Concentrations of gaseous compounds can be converted from density units, e.g. mg m^{-3} (mass/volume), to mixing ratio units, e.g. ppm units (volumetric), using the following formula: $$C(\text{ppm}) = \frac{22.4136 \times (273.15 + T) \times C}{273.15 \times M_w},$$ where C is the concentration (mg m^{-3}), M_w is the molecular weight of the gas, and T is the ambient temperature in degrees Celsius. At a temperature of 0 degrees Celsius, the conversion factor from 1 mg m^{-3} to ppm for nitrogen dioxide (NO_2) is 0.488.

1. Introduction

The Wagerup alumina refinery of Alcoa World Alumina Australia is located about 130 km south of Perth in Western Australia, 25 km inland from the coast and in the western foothills of the north-south Darling escarpment (Figure 1). The local communities in the proximity of the Refinery include Yarloop, a small town 15° west of south and 3 km away from the Refinery, and Hamel and Waroona, two small towns approximately 5 km and 8 km north of the Refinery (see Figure 1).

The work presented in this report forms Phase 3B of the project "Meteorological and Dispersion Modelling Using TAPM for Wagerup". The larger project consists of the components:

- *Phase 1: Meteorology* Evaluation of the capability of CSIRO's The Air Pollution Model (TAPM) to acceptably produce meteorological predictions matching available field observations at Wagerup (CSIRO, 2004b);

- *Phase 2: Dispersion* Evaluation of TAPM for air quality predictions at Wagerup using a database of emissions and observed ambient air concentrations (CSIRO, 2004c); and

- *Phase 3: Concentration Modelling* Use of TAPM to generate modelled concentrations as input for the Health Risk Assessment (HRA) and the Public Environmental Review Document concerning the Wagerup Refinery expansion plans.

The objective of Phase 3 is:

"To run TAPM with Wagerup specific input for four scenarios of emissions (Current–Average, Current–Peak, Expanded–Average, and Expanded–Peak) for agreed sources to produce selected concentration statistics at receptor points for input into the Health Risk Assessment and the Public Environmental Review Document. Investigate the temporal variation of concentration around, and mechanisms causing the modelled short-term peak concentrations."

It has been agreed that the Phase 3 study be split into two parts; Phase 3A for the Current emission scenarios, and Phase 3B for the Expanded emissions scenarios. This report presents results from the Phase 3B modelling with a total of four emission scenarios corresponding to a production rate of 4.7 million tonnes per year of alumina, namely:

- Expansion (Case 6, Cogeneration) - Average (average emission rates)
- Expansion (Case 6, Cogeneration) - Peak (peak emission rates).
- Expansion (Case 7, New Boilers) - Average (average emission rates)
- Expansion (Case 7, New Boilers) - Peak (peak emission rates).

The atmospheric concentrations modelled in this study are the direct consequence of the emissions included in the model. Different emission rates would produce different concentrations. The emissions used have been provided by Alcoa World Alumina Australia. CSIRO has had no role in the development or verification of these emissions.

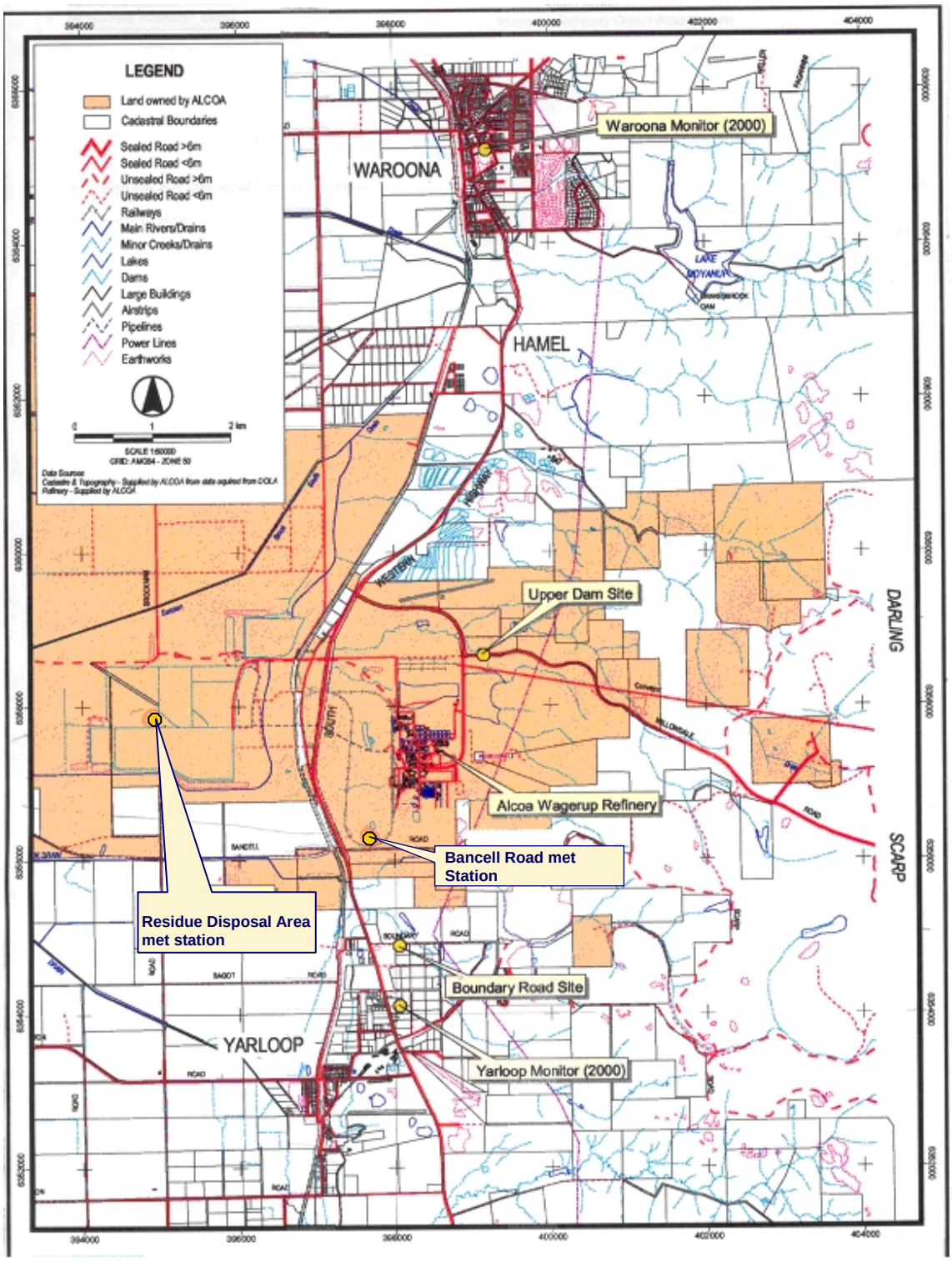

Figure 1: A map of Wagerup area showing the Alcoa Wagerup Refinery, Bancell Road meteorological station, Residue Disposal Area (RDA) meteorological station, Boundary Road air quality monitoring station, and the Upper Dam monitoring site. The Yarloop monitoring site and the Waroona Monitor are non-operative. To the east of the Refinery is the north-south Darling escarpment (adapted from SKM, 2002).

The detailed objectives of Phase 3B are:

"Run the refined TAPM (as resolved in Phases 1 and 2) for the annual meteorological file (1 April 2003 to 31 March 2004) and agreed sources to produce estimates of the following parameters for 28 pollutants at 15 receptor points:

- *Annual average concentration (at average emission rates)*
- *Maximum 1-hour average concentrations (peak emissions)*
- *95^{th} percentile 1-hour average concentrations (peak emissions)*
- *95^{th} percentile 24-hour average concentrations (peak emissions)*
- *Maximum 10-minute average concentrations (peak emissions)*
- *Maximum 3-minute average concentrations (peak emissions).*

The 28 pollutants are oxides of nitrogen(NO_x), carbon monoxide (CO), sulphur dioxide (SO_2), dust, arsenic, selenium, manganese, cadmium, chromium VI, nickel, mercury, ammonia, benzo(a)pyrene equivalents, acetone, acetaldehyde, formaldehyde, 2-butanone, benzene, toluene, xylenes, acrolein, ethylbenzene, methylene chloride, styrene, 1,2,4 trimethylbenzene, 1,3,5 trimethylbenzene, vinyl chloride, and nitrogen dioxide (NO_2).

Produce contour plots of these six statistics for three example substances (NO_x, Formaldehyde and Mercury) to indicate the different concentration distribution patterns for substances predominantly emitted from high and low level sources.

Calculate the conversion of NO_x to NO_2 using a simple titration algorithmic method.

Describe the best practice methods for deriving shorter time period (3 and 10-minute) maximum concentrations from the Wagerup hourly TAPM concentration fields.

Investigate the temporal variation of concentration around, and mechanisms causing the modelled 5 highest short-term peak concentrations for NO_x and Formaldehyde for three receptors (at sites 1, 3, and 14) for the peak emission scenario.

Undertake separate quality assurance runs for selected pollutants to confirm the accuracy of the main modelling technique. Comment on the expected accuracy/level of confidence in model predictions, based on the work performed in Phases 1 and 2."

2. TAPM

The Phase 1 report of the present project (CSIRO, 2004b) provides a brief introduction to the various classes of air pollution models, and presents the advantages offered by the prognostic approach used by CSIRO's The Air Pollution Model (TAPM) over some of the other commonly-used air pollution models. Although a brief description of TAPM has been given in the CSIRO (2004b) report, we describe TAPM here again for the sake of completeness.

TAPM is a three-dimensional, prognostic meteorological and air pollution model (see Hurley, 2002; http://www.dar.csiro.au/tapm/ for model details). The model uses a complete set of mathematical equations governing the behaviour of the atmosphere and the dispersion of pollutants. The global databases input to TAPM include terrain height (given at a resolution of about 300 m for Australia), land use, sea-surface temperature, and synoptic meteorological analyses. All input datasets, except emissions, accompany the TAPM software, and are easily transferred through a graphical user interface to nested grids for the region of interest.

The meteorological component of TAPM uses the large-scale weather information (synoptic analyses or, potentially, weather forecasts), typically obtained from the Bureau of Meteorology LAPS (Limited Area Prediction System) or GASP (Global Analysis and Prediction) analyses at a horizontal grid spacing of about 100 km at 6-hourly intervals as boundary conditions for the model outer grid. These synoptic data are for the horizontal wind components, temperature and moisture, and are obtained from the output of Bureau of Meteorology meteorological model(s) that assimilates meteorological observations from a network of stations. The vertical levels of the synoptic analyses are in a scaled pressure coordinate system. For the present application, the lowest of these correspond typically to 0, 75, 200, 425, 650, 875, 1100, 1325 and 1800 m above mean-sea level. TAPM then 'zooms-in' from the 100-km data to model local scales at a finer resolution using a one-way nested approach to improve efficiency and resolution, predicting local-scale meteorology (typically down to a resolution of 1 km), such as sea breezes and terrain induced flows.

The model solves a set of momentum equations for horizontal wind components, the incompressible continuity equation for the vertical velocity in a terrain-following coordinate system, and scalar equations for potential virtual temperature, specific humidity of water vapour, cloud water and rain water. Pressure is determined from the sum of hydrostatic and (when necessary) non-hydrostatic components, and a Poisson equation is solved for the non-hydrostatic component. Explicit cloud microphysical processes are included. Wind observations can optionally be assimilated into the momentum equations as nudging terms. The turbulence closure terms in the mean equations use a gradient diffusion approach, including a counter-gradient term for the heat flux, with eddy diffusivity determined using prognostic equations for turbulence kinetic energy and eddy dissipation rate. A weighted vegetative canopy, soil and urban land-use scheme is used to predict energy partitioning at the surface, while radiative fluxes, both at the surface and at upper levels, are also included. Boundary conditions for the turbulent fluxes are determined by Monin-Obukhov surface-layer scaling variables and parameterisations for stomatal resistance.

The air pollution component of TAPM consists of an Eulerian (fixed location) grid-based set of species conservation equations for determining a spatially explicit distribution of time varying ground-level pollutant concentrations, either using the Eulerian grid-based approach and/or a Lagrangian particle approach targeted at

important point sources. In the Lagrangian mode (where the model coordinates move with the flow), mass is represented as a puff in the horizontal direction and as a particle in the vertical direction. The Lagrangian option was used in the present work. The pollutants are transported and dispersed according to the air motions determined by the meteorological component.

Previous versions of TAPM have been used, for example, to model year-long meteorology and air pollution for the industrial area of Kwinana (Hurley et al., 2001) and the Pilbara (Physick and Blockley, 2001; Physick et al., 2002); to model year-long urban meteorology, photochemical smog and particulate matter in Melbourne (Hurley et al., 2003a); and to compare with international model validation data sets (Luhar and Hurley, 2003).

The performance of the meteorological component of TAPM is discussed in Section 10 of the Phase 1 report (CSIRO, 2004b) – for completeness, the main results are repeated here.

The Index of Agreement has been found to be the most useful measure of the degree to which the observed variable is accurately estimated by the model. It is defined as:

$$IOA = 1 - \frac{\sum_{i=1}^{N} \left(P_i - O_i\right)^2}{\sum_{i=1}^{N} \left(\left|P_i - O_{mean}\right| + \left|O_i - O_{mean}\right|\right)^2}, \qquad (1)$$

where N is the number of observations O and predictions P. An IOA value of 0 means no agreement whereas a value of 1 means perfect agreement. A value greater than 0.5 represents a good result for prediction of meteorology.

For the model comparisons presented in the Phase 1 report for Wagerup, the overall IOA for TAPM for the near-surface meteorology (with winds at 30 m AGL) at Bancell Road is 0.65 for wind speed, 0.79 for the U component, and 0.92 for the V component, 0.97 for temperature, 0.94 for net radiation, and 0.87 for relative humidity. For the winter months, when low to moderate winds are important from the point of view of point source emissions from the Refinery, the respective IOA values are 0.79, 0.86, 0.93, 0.89, and 0.81. The overall IOA for the near-surface meteorology at RDA is 0.73 for wind speed, 0.83 for the U component, and 0.90 for the V component. For the summer months, when high and variable winds are relevant from the point of view of dust emissions and management at RDA, the respective IOA values are 0.65, 0.79 and 0.84. In the summer months, the IOA values for net radiation and relative humidity at Bancell Road are 0.94 and 0.90, respectively.

The comparisons presented in the Phase 1 report indicate that TAPM's overall performance is as good as and in some cases better than some of the other internationally used prognostic meteorological models such as MM5, RAMS, and CSU. The performance of TAPM at Wagerup is comparable to its performance elsewhere for the near-surface meteorology, except that TAPM generally predicts stronger wind speeds at Wagerup than the measurements. Its performance for wind speed at Wagerup is not as good as the best of TAPM modelling for other locations. This may be due to the complexity of the area being studied.

The uncertainty of the TAPM modelling of ground-level concentrations is discussed in detail in Section 4.2 of this report. For the RHC (robust highest concentration, see Glossary) the ratio of modelled to observed values for TAPM studies in a range of locations ranges from 0.70 to 1.75 with an average value of 1.1 and an uncertainty of ±50% at the 95% confidence level.

2.1. TAPM Settings

Version 2.6 of TAPM was used for all the simulations presented in this report. This is the same version as used in Phases 1 and 2 (CSIRO, 2004b, c) of the present project. The most appropriate settings of TAPM for the Wagerup modelling have been described in Phase 1 (Meteorology) and Phase 2 (Dispersion), the latter of which evaluated TAPM using several different databases of emissions and observed ambient air concentrations at Wagerup.

The meteorological grids used here are the same as those used in Phase 2, but the pollution grids cover a larger area to include all the defined receptor points (Figure 2). Four nested domains of 31 × 31 horizontal grid points with resolutions of 20-km, 7-km, 2-km and 0.5-km are used for the meteorological modelling. Similarly four nested domains of 53 × 53 horizontal grid points with resolutions of 10-km, 3.5-km, 1-km and 0.25-km are used for the pollutant dispersion modelling. The pollution grid was selected to include all receptor points (Figure 2(d) and Figure 10) with the best possible combination of fine grid resolution and model computing time. The grids are all centred on the location 115°54′ E, 32°54.5′ S, which is equivalent to 397.133 km east and 6358.326 km north in the AMG84 (Australian Map Grid) coordinate system. The centre point is about 1 km north-west of the Refinery and was selected to optimise the locations of the grids with respect to the receptors. This centre point is situated 2 km north-northwest of the centre point used in the Phase 2 modelling and 3.8 km slightly west of north from the centre point used in the Phase 1 modelling. The lowest ten of the 25 vertical levels were 10, 25, 50, 100, 150, 200, 250, 300, 400 and 500 m, with the highest model level at 8000 m. The default databases of soil properties, topography, and the monthly sea-surface temperature and deep soil parameters (with a deep-soil moisture content of 0.15) were used. The Wagerup-specific land-use database and a refinery-generated surface heat flux value of 150 W m^{-2}, both derived as part of the Phase 1 work (CSIRO, 2004b), were used. The change in the centre of the grids compared to Phases 1 and 2 produced slight changes in the apparent pattern of land-use because of the need to map the underlying complex pattern of land-use onto a single value for each grid square of the TAPM grids. However, the sensitivity tests reported in the Phase 2 report indicate that the model results at the receptor points change by less than 10% for runs with and without the Refinery heat flux. This is indicative of the sensitivity of the model to the slight changes caused by different grid centres. In all the Phase 3 runs, the Lagrangian mode was used on the inner-most grid in the pollution dispersion calculations and the Eulerian mode was used on the outer grid pollutant calculations.

The TAPM runs included building wake effects. A total of 29 rectangular buildings were considered, ranging in height between 8 m and 42 m. The locations and horizontal size of these buildings are shown in Figure 3, based on data supplied by Pitts (pers. comm. 20 Aug 2004). The figure also shows the locations of the Wagerup Refinery point sources modelled in this work, as supplied by Coffey (pers. comm. 16 Dec 2004).

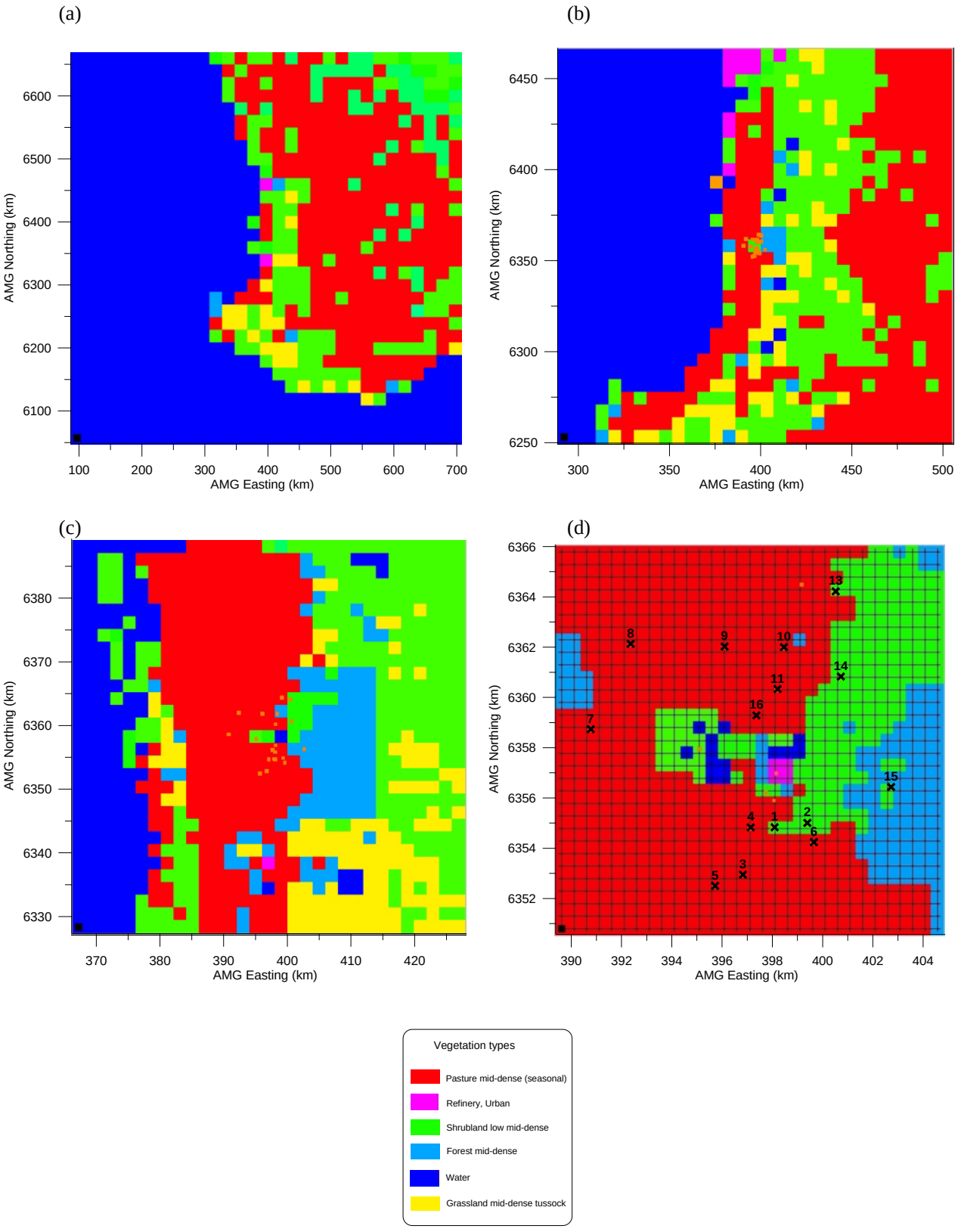

Figure 2: The horizontal grid domain used in TAPM for meteorology (31 × 31 grid points). The domains are successively nested with grid resolutions of (a) 20 km, (b) 7 km, (c) 2 km, and (d) 0.5 km. The dispersion grids are located within these grids and have higher resolutions of 53 × 53 grid points per domain. The resolutions for the dispersion grids are (a) 10 km, (b) 3.5 km, (c) 1 km, and (d) 0.25 km. The inner grid (d) shows the grid lines and the numbered receptor locations.

The period modelled was one year from 1 April 2003 to 31 March 2004. This is the same as the period used in Phases 1 and 2 and was selected for those phases because it had the best meteorological data available. This period was also used for Phase 3 to maintain consistency. In order to reduce run time for dispersion modelling of the many sources, the meteorological part of the model was only run once with the output stored at hourly intervals (in the TAPM *.m3d files) for use in all further pollution modelling runs.

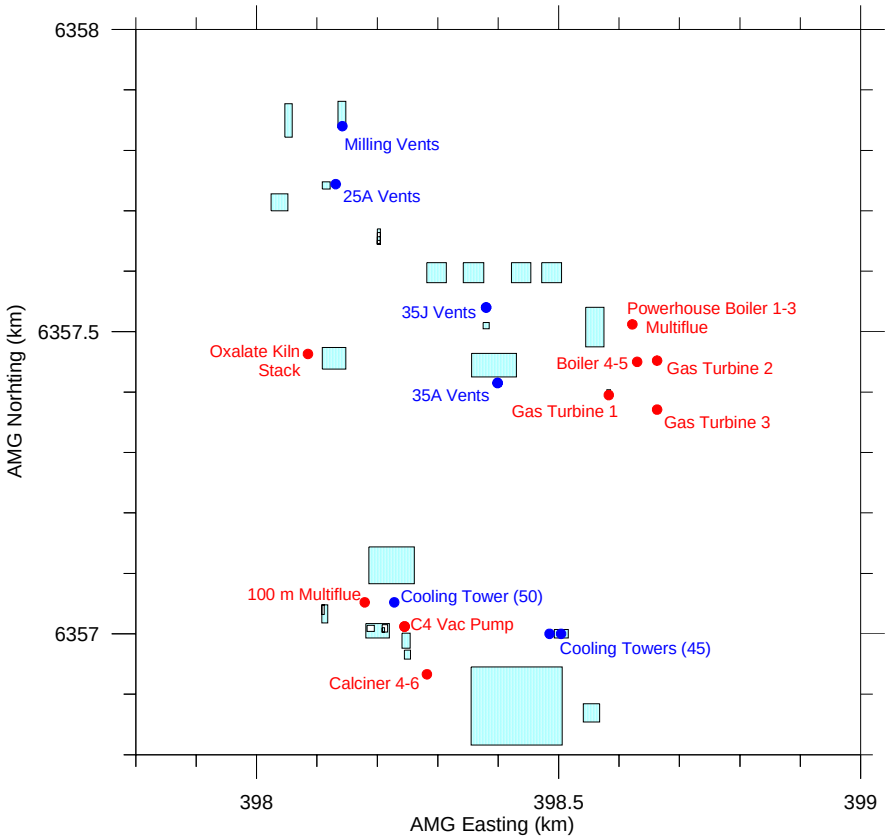

Figure 3: Locations and horizontal size of the buildings used in the TAPM runs (shown in aqua). The modelled point sources are shown – those in red are the higher stacks (40–100 m), those in blue are shorter than 25 m. Gas Turbines 2 & 3 are only included in Case 6 modelling; Boiler 4-5 is only included in the Case 7 modelling.

The TAPM runs presented here do not include wind data assimilation. The Phase 2 results on the effect of including data assimilation are mixed. There was not a complete year of wind data available for assimilation from 30 m at Bancell Road (only 18 July 2003 – 31 March 2004) and the 8 m data at the RDA (1 April 2003 – 31 March 2004) had errors in the low wind speeds. Thus a year of high quality wind data was not available for assimilation.

Comparisons with observed ground-level concentrations were limited by the available data: one year of NO_x data from Bancell Road and Upper Dam, and 13 hours of ANSTO tracer data. The Bancell Road data were "contaminated" by NO_x sources other than the Refinery (such as local traffic and Yarloop), which were not included in the TAPM modelling. While wind data assimilation will generally improve modelled concentrations close to the location where the wind data is recorded, it can worsen the accuracy of both the modelled winds and the modelled concentrations further afield. In

a topographically complex region such as Wagerup where there is significant influence of the escarpment on local wind fields, the radius of influence of 5 km for the assimilated winds means that the influence of these assimilated winds can extend into regions where the local wind fields differ from those at the wind data site, thus worsening the accuracy of the modelled winds in these regions. For example, wind direction data measured at the Bancell Road and RDA sites, which are less than 3 km apart, show that north-easterlies are much less frequent at Bancell Road than at the RDA (Phase 1 report; CSIRO, 2004b). Similarly, wind roses from Hamel and Yarloop for October/November 2003 show much more frequent easterlies and south-westerlies and much less frequent south-easterlies at Hamel than at Yarloop (WADEP, pers. comm.). As the aim of the Phase 3 modelling for the HRA is to provide the best model results for the whole 15 km × 15 km region around the Refinery (Figure 2(d), Figure **10**), the modelling presented here did not include wind data assimilation. The sensitivity of the results to changes in the wind patterns is presented in Section 4.2 as part of the discussion of model uncertainty.

All model runs were carried out on an IBM eServer Cluster 1350 using dual 3.2 GHz Xeon processors running under the Linux operating system. The TAPM code was compiled using an Intel Fortran compiler version 8.0.

3. Model Inputs

3.1. Combined Sources (buoyancy enhancement)

The stack (chimney) sources used in the modelling along with the relevant properties for the modelling were provided by Alcoa World Alumina Australia (Coffey, pers. comm. 24 Dec 2004). They are listed in Table 1 and are considered in more detail in Section 3.2. Here we consider some aspects of the way the sources are included in the modelling.

Some of the stacks (for example, the 100 m Multiflue and the 65 m and 75 m Boilerhouse stacks) contain several closely-spaced flues which release buoyant plumes, i.e. the exit temperature of the gas emitted from the flue is greater than the temperature of the surrounding air. Buoyant plumes emitted from closely-spaced flues tend to merge quickly with one another after their release (Briggs, 1984; Manins et al, 1992; Anfossi et al, 1978; Overcamp and Ku, 1988). This plume merging results in an enhancement of the plume buoyancy, thus causing a greater plume rise of the combined plume than the individual plume rises that occur when the flues are treated as separate point sources. The enhancement of the plume buoyancy (and plume rise) can be understood by noting that as the hot air rises it mixes in (entrains) cooler surrounding air, which reduces the temperature of the rising plume. Eventually the temperature of the air in the plume is reduced to that of the surrounding air and the plume stops rising. If one buoyant plume is rising close to another buoyant plume, then some of the air entrained by the first plume will be warmer air from the second plume rather than the cooler surrounding air. The consequence of this is that it takes longer for the plume to cool to the temperature of the surrounding air so that both plumes together continue to rise higher than they would individually.

The emissions from the multiflue stacks are best modelled using a single combined source with its emission characteristics (stack height, diameter, exit temperature, exit velocity) chosen such that the buoyancy flux and momentum flux (defined below) of the combined source is equal to the sum of these quantities for the individual flues.

Merging of buoyant plumes can also occur for plumes that are released from stacks separated by some tens of metres or even a hundred metres. In this case, each of the stacks is modelled separately but the buoyancy of each plume is increased by a buoyancy enhancement factor N_E. This factor can be specified as an input parameter for each source in TAPM.

For a number of stacks with the same emission geometries and exit conditions, the buoyancy enhancement factor is defined as (e.g. Manins et al, 1992):

$$N_E = \left[\frac{n+S}{1+S} \right], \tag{2}$$

where n is the number of stacks and S is the dimensionless separation factor, defined as

$$S = 6 \cdot \left[\frac{(n-1)\cdot \Delta s}{n^{1/3} \cdot \Delta z} \right]^{3/2}, \tag{3}$$

where Δs is the stack separation and Δz is the rise of an individual plume.

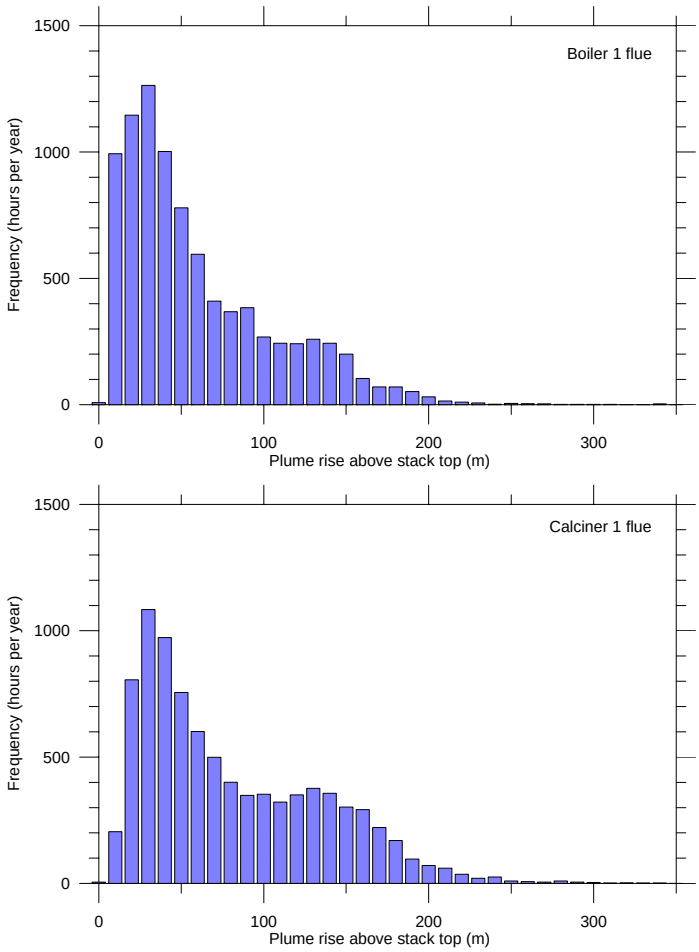

Figure 4: Histograms of plume rise modelled by TAPM for the year April 2003 to March 2004 for two separate flues, one in the 65 m Boilerhouse multiflue and one in the 100 m Multiflue stacks.

The plume rise Δz depends on wind speed and other meteorological conditions. Figure 4 shows histograms of the plume rise from the individual Boiler 1 and Calciner 1 flues as modelled by TAPM for the annual model year considered in this report (April 2003 to March 2004). In most case the plume rise lies between 20 and 200 m. The median plume rise is 45 m for the Boiler 1 flue and 65 m for the Calciner 1 flue.

Figure 5 shows the results from equation (2) for the variation of N_E with stack separation (and n = 2) for two typical values of plume rise. For two stacks, an enhancement factor of 2 is referred to as full buoyancy enhancement and is seen to occur for stacks separated by less than about 10 m. This corresponds to the case of the Wagerup multiflues where two or more flues are separated by much less than 10 m.

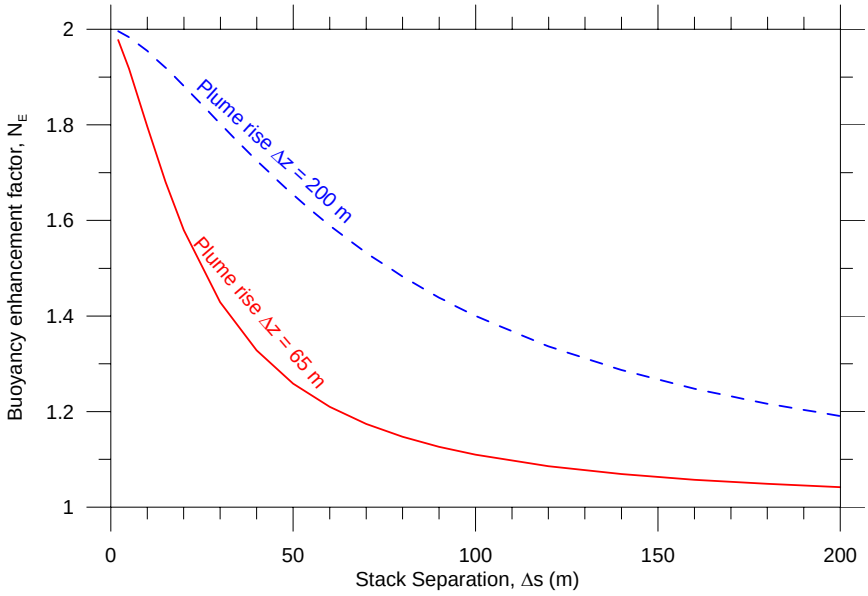

Figure 5: Buoyancy enhancement factor for two stacks as a function of stack separation for two values of plume rise Δz = 65 m and Δz = 200 m. Values for N_E calculated using equations (2) and (3).

The merging of the buoyant plumes from each of the flues in the multiflue stacks can be taken into account in the modelling either by using the buoyancy enhancement factors or, equivalently, by treating them as a combined source.

If the buoyancy enhancement factors are used, then each flue is modelled separately and the appropriate buoyancy enhancement factor is included in the modelling, which increases the individual plume buoyancy by this factor. For two flues $N_E = 2$ and for three flues $N_E = 3$. In cases where each flue has the same emission geometry and exit conditions, then each of these enhanced plumes will be modelled as having the same plume rise and dispersion behaviour. Rather than modelling the same plume three times, it is computationally more efficient to model them as a combined source (single plume) that has its buoyancy flux (F_b) and momentum flux (F_m) equal to (or as close as possible to) the sum of these quantities for the individual flues. The pollution emission rate from the combined source is set equal to the sum of the pollution emission rates from the individual flues.

The quantities F_b ($m^4\ s^{-3}$) and F_m ($m^4\ s^{-2}$) are defined as:

$$F_b = \left(1 - \frac{T_e}{T_s}\right) g\, w_s\, r_s^2 , \tag{4}$$

$$F_m = \left(\frac{T_e}{T_s}\right) w_s^2\, r_s^2 , \tag{5}$$

where T_e is the ambient temperature (K) of the environment, T_s is the stack exit temperature (K), r_s is the stack top radius (m), w_s is the stack exit velocity (m s^{-1}), and g is the acceleration due to gravity (m s^{-2}).

A common method for matching the fluxes is first to set the diameter of the combined source such that the exit area of the combined source is equal to the sum of the areas of the flues being combined. Then the combined source exit velocity and exit temperature are set equal to the averages of the values for the individual flues. Small adjustments to the exit velocity and temperature are then made to match the buoyancy and momentum fluxes of the combined source as closely as possible to the sums of these quantities for the individual flues. For cases where the buoyancy flux dominates the plume rise (such as for the Wagerup plumes), it is more important to match the buoyancy flux than the momentum flux.

For two flues with equal emission characteristics, the buoyancy flux of the combined source will be twice that from a single flue. This is equivalent to using a buoyancy enhancement factor of 2 for an individual flue. Thus the combined source approach is sometimes referred to as full plume buoyancy enhancement.

In contrast to these cases, there are some other sources such as the Milling Vents, where there are several sources with identical emission characteristics located near to each other but with very low buoyancy and not close enough for there to be any plume-rise enhancement. Within a few hundred to a thousand metres from these sources, the plumes overlap. Thus these sources can be modelled as a single source with the emission characteristics (stack height, diameter, exit temperature, exit velocity) of one of the sources and with the emission rate (in g/s) equal to the total from the sources being modelled by the single stack. The validity of this approach can be demonstrated by considering the case of two stacks, each with identical emission characteristics. If the pollutant emission rate from one stack is x g/s and this produces ground-level concentrations (glcs) of y µg/m^3 at some point, say 1 km downwind, then two such stacks will produce glcs of $2y$ µg/m^3 at the same point. The same glcs are achieved if just one stack is modelled with an emission rate of $2x$ g/s.

3.2. Sources modelled

The properties of the stack sources included in the modelling are listed in Table 1. The sources shown in italics are the individual flues that are modelled as combined sources. The properties of the combined sources are listed directly above the data for each set of individual flues. These properties were calculated using the procedure outlined in the previous section. Combined sources were used for the Calciner 1–3, Calciner 4–6, Boilerhouse 1–3, and Boilerhouse 4–5 multiflues. The shaded rows indicate sources that are used in only one of the two scenarios. Case 6 (with Cogeneration) includes the Gas Turbines 2 and 3, but not the Boilers 4 & 5. Case 7 (new Boilers) includes Boilers 4 & 5 but not the Gas Turbines 2 & 3.

Flues from the Liquor Burner and the Calciner 1, 2, 3 Vacuum Pump and Dorrco are part of the 100 m Multiflue with the Calciner 1–3 flues but the former have not been included in the combined source because of their quite different emission characteristics, which lead to different plume trajectories.

The trajectory of a plume above its release point is given by the relation (Weil, 1988):

$$z = \left(8.3 \frac{F_m}{U^2} \cdot x + 4.2 \frac{F_b}{U^3} \cdot x^2 \right)^{\frac{1}{3}}, \qquad (6)$$

where z is the height of the plume above the release point, x is the downwind distance, and U is the local wind speed at stack height.

The trajectories of the individual plumes from the 100 m Multiflue are shown in Figure **6** for a wind speed of 4 m s^{-1} and assuming no interaction between the plumes. Changes in the wind speed change the absolute heights of the plume but not the relativities between the trajectories of the plumes from the different flues. The similarity of the plume rise from the three Calciner flues reflects the similarities between their emission characteristics and justifies them being treated as a combined source. As expected, the trajectory for the combined Calciner source shows considerably more plume rise than the individual sources.

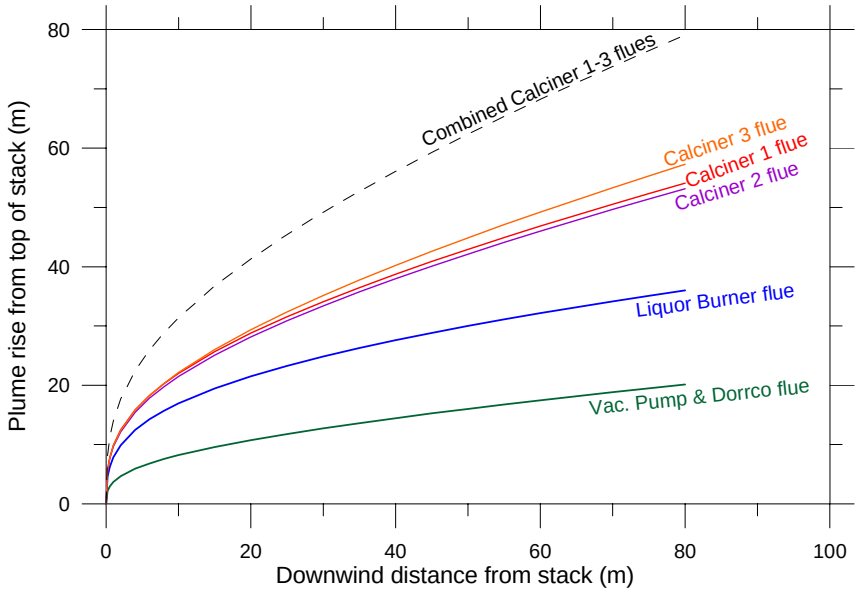

Figure 6: Plume trajectories for the plumes from the flues in the 100 m Multiflue calculated according to equation (6) for a wind speed of 4 m s^{-1} assuming no interaction between the plumes (except for the Combined Source trajectory)

On the other hand, the trajectory of the Liquor Burner (LB) plume shows only one-third of the plume rise of the combined Calciner plume, and the Vacuum Pump/Dorrco (VPD) plume shows only one-quarter of the rise of the combined Calciner plume. The large differences between these trajectories make it unlikely that there will be much interaction between these plumes and so unlikely that there will be any buoyancy enhancement between either of these two plumes or with the combined Calciner plume.

In the absence of information on the degree of such interaction, the LB and VPD plumes are modelled as separate plumes, i.e. without any buoyancy enhancement. If any buoyancy enhancement occurs, it will lead to lower ground-level concentrations from these sources.

The plumes from the proposed new Gas Turbines 2 and 3 (included in the Case 6 modelling) have large buoyancies and hence large plume rises Δz. The results of TAPM modelling of the plume rises from one of these stacks (Gas Turbine 2) show a median rise of 200 m (Figure 7). With the separation between the proposed Gas Turbines 2 and 3 being 81 m, Figure 5 indicates that a buoyancy enhancement factor of $N_E = 1.5$ should be applied to the plumes from Gas Turbines 2 and 3. This factor is used in the modelling results presented in this report.

The possibility of interaction between the plumes from the existing Gas Turbine 1 and from the proposed new units 2 and 3 is explored in Figure 8. The plume rise of the Gas Turbine 1 plume is much smaller than for the Gas Turbine 2 plume with median values of 65 m and 200 m, respectively. The separations between Gas Turbine 1 and the other two units are 83 m and 98 m. Figure 8 shows that at these downwind distances the Gas Turbine 1 plume is about 50 m lower than those from the other units and so unlikely to interact very strongly with the other plumes. In the absence of information on the degree of such interaction, the Gas Turbine 1 plume is modelled without any buoyancy enhancement, i.e. $N_E = 1$. If any buoyancy enhancement occurs, it will lead to lower ground-level concentrations from these sources.

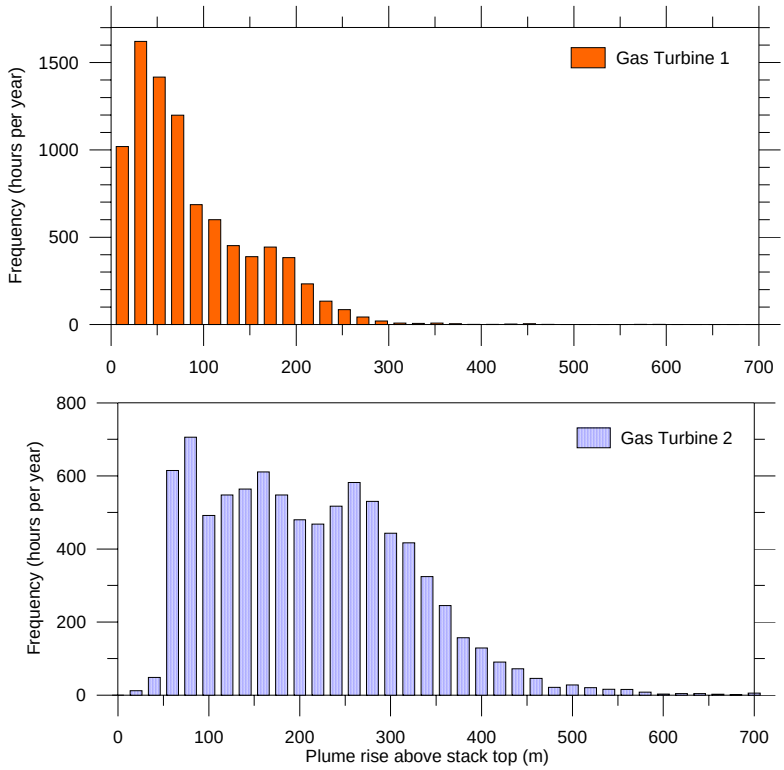

Figure 7: Histogram of plume rise modelled by TAPM for the year April 2003 to March 2004 for the Gas Turbine 1 and 2 plumes, each treated as an individual plume.

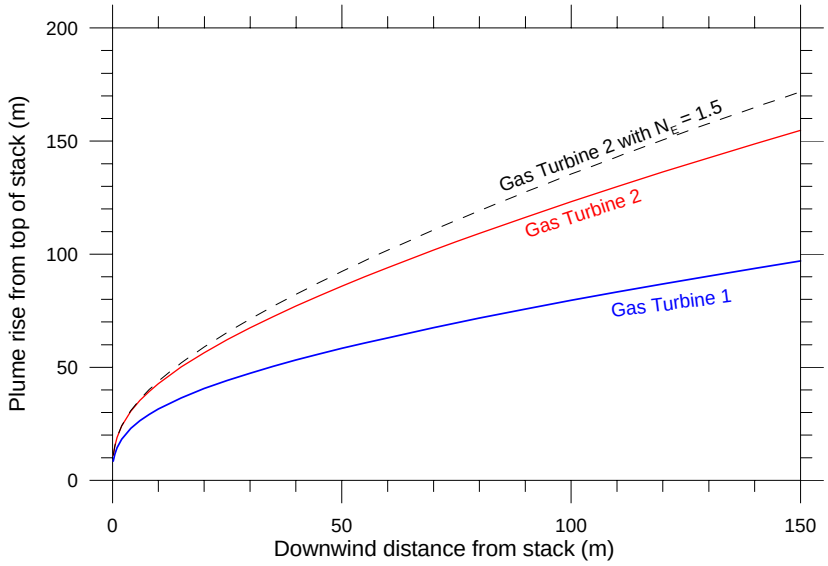

Figure 8: Plume trajectories for the plumes from the Gas Turbines calculated according to equation (6) for a wind speed of 4 m s^{-1}. The dashed line shows the trajectory for Gas Turbine 2 with a buoyancy enhancement factor N_E = 1.5.

The details of the assumptions made in modelling the other sources are listed below:

- Calciner 4 Vac Pump and Dorrco. There are two separate stacks but the emissions rates supplied by Alcoa are the total for both stacks. Because most of the volume flow (92%) occurs from the 50VAC4 stack and the stack heights are similar (40 m and 37 m), only the 50VAC4 stack is included in the modelling using the exit characteristics of this stack with the total emission rate attributed to this stack.
- Cooling Towers 1 and 2 (50CT). The two cooling towers are treated as one source with the diameter set to give the same effective area as the total of the two separate towers.
- Milling Vents. There are three separate Mill Vents, which are all low enough (12 m) to be affected by building wakes so that they rapidly effectively become volumes sources. As these are close to each other but not so close that they can be considered to produce a single plume, just one of these is modelled with the typical exit characteristics for a single vent. However, the total emission rate of the pollutants released from these vents is considered to all be discharged through the single modelled vent.
- 25A Tank Vents. There are two stacks 25A1 and 25A3. These are treated in the same way as the Milling Vent stacks with just a single stack included in the modelling at the location of 25A1.
- 35A Vents. There are two separate vent stacks. These are treated like the Milling Vents with just a single stack included in the modelling.

Table 1. Relevant properties of the sources modelled in Phase 3B (location, stack height, exit temperature, stack diameter, and both average and peak exit velocities) for the Expanded Refinery Emissions Scenario (4.7 Mtpa) as supplied by Coffey (pers. comm. 24 Dec 2004). *Gas Turbines 2 and 3 are modelled with a buoyancy enhancement factor N_E = 1.5 (see text).

Stacks modelled	**AMG84 Coordinates**					**Expanded scenario**	
	East	**North**	**Stack height**	**Stack Diamet -er**	**Temper -ature**	**Average Exit Velocity**	**Peak Exit Velocity**
	(km)	**(km)**	**(m)**	**(m)**	**(K)**	**(m/s)**	**(m/s)**
Oxalate Kiln Stack	398.085	6357.463	50	1.3	363	19.6	19.6
Liquor Burner (in Multiflue)	398.179	6357.052	100	0.925	338	27.9	33.2
Calciner 1–3 flues (modelled as combined source)	398.179	6357.052	100	3.44	450	24.9	27.0
Calciner1 flue (in Multiflue stack)	*398.179*	*6357.052*	*100*	*1.9*	*432*	*23.7*	*25.7*
Calciner2 flue (in Multiflue stack)	*398.179*	*6357.052*	*100*	*1.9*	*433*	*24.0*	*26.1*
Calciner 3 flue (in Multiflue stack)	*398.179*	*6357.052*	*100*	*2.15*	*469*	*26.9*	*29.3*
Calciner 4–6 flues (modelled as combined source)	398.282	6356.933	100	3.44	430	23.8	25.9
Calciner 4 flue (in new Multiflue)	*398.282*	*6356.933*	*100*	*2.35*	*430*	*23.8*	*25.9*
Calciner 5 flue (in new Multiflue)	*398.282*	*6356.933*	*100*	*2.35*	*430*	*23.8*	*25.9*
Calciner 6 flue (in new Multiflue)	*398.282*	*6356.933*	*100*	*2.35*	*430*	*23.8*	*25.9*
Boiler 1–3 flues (modelled as combined source)	398.622	6357.512	65	3.71	390	14.4	15.2
Boiler 1 (in Boilerhouse Multiflue)	*398.622*	*6357.512*	*65*	*2.4*	*374*	*14.1*	*15.2*
Boiler 2 (in Boilerhouse Multiflue)	*398.622*	*6357.512*	*65*	*2.0*	*397*	*15.7*	*16.4*
Boiler 3 (in Boilerhouse Multiflue)	*398.622*	*6357.512*	*65*	*2.0*	*404*	*13.5*	*14.0*
Boiler 4–5 flues (modelled as combined source) **(only included in Case 7)**	398.630	6357.450	75	3.39	374	14.1	15.2
Boiler 4 flue (in new Multiflue)	*398.630*	*6357.450*	*75*	*2.4*	*374*	*14.1*	*15.2*
Boiler 5 flue (in new Multiflue)	*398.630*	*6357.450*	*75*	*2.4*	*374*	*14.1*	*15.2*
Gas Turbine 1 stack	398.583	6357.395	40	3.03	371	22.4	22.4
Gas Turbine 2 stack **(only included in case 6)**	398.663	6357.452	50	6.2	444*	18.0*	18.0*
Gas Turbine 3 stack **(only included in Case 6)**	398.663	6357.371	50	6.2	444*	18.0*	18.0*
Calciner 1,2,3 Vac Pump, 50B and Dorrco (in Multiflue)	398.179	6357.052	100	1.1	345	7.5	8.4
Calciner 4 Vac Pump and Dorrco (combined emission), use 50VAC4 stack details	398.245	6357.012	40	0.914	345	7.5	12.6
45K Cooling Tower 2 and 3 (1 duty, 1 standby cell)	398.504	6357.000	16.3	8	323	15.3	15.3
50 Cooling Tower 1 and 2	398.228	6357.052	4	7.07	322	3.7	3.7
Milling Vents	398.142	6357.840	12	0.44	343	2.3	2.3
25A Tank Vents	398.131	6357.744	20	0.5	371	3.2	3.2
35A Vents	398.399	6357.415	19	0.6	370	1.3	1.3

3.3. Emission Rates

In a typical TAPM run, all sources of a particular pollutant are included as input to TAPM, with the output being hourly modelled ground-level concentrations of that pollutant for each hour of the period modelled (in this case a full year).

However, because of the complexity and large computing time required to use this method for the 28 pollutant species and 4 emissions scenarios to be modelled in this Phase, separate model runs are undertaken for each stack source listed in Table 1 with separate runs for average and peak exit rates when these differed from each other. This required a total of 20 annual runs of TAPM. In each case the emission rate was assumed to be 1 g/s of a notional pollutant. The TAPM runs thus produced concentration fields for a nominal pollutant from each stack. The results from these runs were scaled according to the actual emission rates of each pollutant from each stack, as listed in Table 2 and Table 3, and then combined to derive concentration fields for each pollutant for both average and peak emission rates using the relation

$$GLC_{species} = e_1 \cdot GLC_1 + e_2 \cdot GLC_2 + \ldots + e_n \cdot GLC_n, \qquad (7)$$

where $GLC_{species}$ is the ground-level concentration for the species which is emitted at a rate e_i (in g/s) from source i and GLC_i is the modelled ground-level concentration for an emission rate of 1 g/s from source i.

The validity of this approach was verified by comparison of concentrations derived in this manner with those for the same species from a "typical" TAPM run where all sources of the particular pollutant were included, as described in Section 4.3.

The NO_2 concentrations were derived from modelled NO_x and representative O_3 concentrations using the method described in Section 3.6.

Two sets of emission rates are listed. Table 2 is for Case 6 (with Cogeneration). Table 3 is for Case 7 (with Boilers 4 & 5). The emissions listed as from "Boiler 2/3 (Non-condensables)" were split 50:50 between the Boiler 2 flue and Boiler 3 flue.

These emission rates from each source are as supplied by Alcoa World Alumina Australia on 24 December 2004. CSIRO had no role in the development or verification of these emissions. The modelled concentrations are directly dependent on these emissions. If the emissions are different, then the modelled concentrations will be different.

3.4. Emission Rates for Case 6 (with Cogeneration)

Table 2. Emission rates (Case 6 – Expanded Refinery Scenario (4.7 Mtpa) with Cogeneration) as supplied by Alcoa World Alumina Australia from each of the sources for each of the 27 modelled chemical species. The 28th species (NO_2) is modelled separately, as described in Section 3.6. Both the average and peak emission rates are listed. In the modelling, the emissions listed as from "Boiler 2/3 (Non-condensables)" were split 50:50 between the Boiler 2 and Boiler 3 flues. The numbers in the table are given using exponential notation which is commonly used in computing, for example, the value 4.81E-01 = 4.81×10^{-1} = 0.481.

CHEMICAL SPECIES Case 6 (Cogeneration)	**STACK SOURCE Case 6 (Cogeneration)**	**AVERAGE EMISSION RATE (g/s)**	**PEAK EMISSION RATE (g/s)**
1. NOx	Oxalate Kiln Stack	4.81E-01	4.81E-01
	Liquor Burner	1.24E+00	4.24E+00
	Calciner 1	2.37E+00	3.41E+00
	Calciner 2	1.44E+00	4.94E+00
	Calciner 3	4.92E+00	8.74E+00
	Calciner 4	2.86E+00	5.14E+00
	Calciner 5	2.86E+00	5.14E+00
	Calciner 6	2.86E+00	5.14E+00
	Boiler 1	4.04E+00	4.80E+00
	Boiler 2	3.07E+00	3.50E+00
	Boiler 3	2.60E+00	2.97E+00
	Gas Turbine 1	3.00E+00	1.36E+01
	Gas Turbine 2	1.88E+01	3.32E+01
	Gas Turbine 3	1.88E+01	3.32E+01
2. CO	Oxalate Kiln Stack	7.34E+00	7.34E+00
	Liquor Burner	7.65E+00	2.13E+01
	Calciner 1	5.61E+00	1.06E+01
	Calciner 2	1.02E+01	2.39E+01
	Calciner 3	1.74E+00	4.66E+00
	Calciner 4	2.70E+00	5.14E+00
	Calciner 5	2.70E+00	5.14E+00
	Calciner 6	2.70E+00	5.14E+00
	Boiler 1	2.87E-01	1.76E+00
	Boiler 2	2.41E-01	1.75E+00
	Boiler 3	1.19E-01	5.69E-01
	Gas Turbine 1	2.99E+00	7.83E+00
	Gas Turbine 2	3.75E+00	3.75E+00
	Gas Turbine 3	3.75E+00	3.75E+00
3. SO2	Oxalate Kiln Stack	3.83E-01	3.83E-01
	Liquor Burner	1.04E-01	4.38E-01
	Calciner 1	3.54E-01	9.52E-01
	Calciner 2	4.67E-01	9.06E-01
	Calciner 3	3.20E-01	1.57E+00
	Calciner 4	1.47E-01	3.99E-01
	Calciner 5	1.47E-01	3.99E-01
	Calciner 6	1.47E-01	3.99E-01
	Boiler 1	1.89E-01	7.20E-01
	Boiler 2	2.06E-01	9.03E-01
	Boiler 3	1.76E-01	3.22E-01

CHEMICAL SPECIES Case 6 (Cogeneration)	STACK SOURCE Case 6 (Cogeneration)	AVERAGE EMISSION RATE (g/s)	PEAK EMISSION RATE (g/s)
	Gas Turbine 1	4.27E-01	2.56E+00
	Gas Turbine 2	1.90E-02	1.90E-02
	Gas Turbine 3	1.90E-02	1.90E-02
4. Dust	Oxalate Kiln Stack	1.12E-01	1.12E-01
	Liquor Burner	7.01E-02	5.39E-01
	Calciner 1	4.51E-01	1.64E+00
	Calciner 2	3.31E-01	1.02E+00
	Calciner 3	4.50E-01	8.74E-01
	Calciner 4	4.93E-01	9.57E-01
	Calciner 5	7.32E-02	7.97E-02
	Calciner 6	7.32E-02	7.97E-02
5. Arsenic	Oxalate Kiln Stack	9.14E-06	9.14E-06
	Liquor Burner	1.42E-04	1.68E-04
	Boiler 1	2.13E-03	2.30E-03
	Boiler 2	9.58E-05	9.98E-05
	Boiler 3	8.14E-05	8.48E-05
	Boiler 2/3 (Non-condensables)	0.00E+00	5.93E-06
	25A Vents	0.00E+00	1.04E-05
6. Selenium	Oxalate Kiln Stack	5.49E-05	5.49E-05
	Liquor Burner	8.50E-04	1.01E-03
	Boiler 2	3.45E-05	3.59E-05
	Boiler 3	2.93E-05	3.05E-05
	Boiler 2/3 (Non-condensables)	0.00E+00	5.52E-05
	Milling Vents	7.20E-06	7.66E-06
	25A Vents	1.82E-05	1.82E-05
7. Manganese	Oxalate Kiln Stack	4.57E-06	4.57E-06
	Liquor Burner	7.08E-05	8.42E-05
	Boiler 1	9.87E-04	1.07E-03
	Boiler 2	5.66E-04	5.89E-04
	Boiler 3	4.80E-04	5.01E-04
	Boiler 2/3 (Non-condensables)	0.00E+00	1.31E-03
	Milling Vents	1.44E-05	1.53E-05
	25A Vents	1.71E-03	1.71E-03
8. Cadmium	Boiler 2/3 (Non-condensables)	4.45E-07	4.45E-07
9. Chromium VI	Oxalate Kiln Stack	2.97E-08	2.97E-08
	Liquor Burner	2.67E-07	3.17E-07
	Calciner 1	1.50E-06	1.82E-06
	Calciner 2	1.50E-06	1.82E-06
	Calciner 3	1.68E-06	1.82E-06
	Calciner 4	1.68E-06	1.82E-06
	Calciner 5	1.68E-06	1.82E-06
	Calciner 6	1.68E-06	1.82E-06
	Boiler 1	4.10E-06	4.44E-06
	Boiler 2	4.26E-06	4.44E-06
	Boiler 3	4.26E-06	4.44E-06

CHEMICAL SPECIES Case 6 (Cogeneration)	STACK SOURCE Case 6 (Cogeneration)	AVERAGE EMISSION RATE (g/s)	PEAK EMISSION RATE (g/s)
10. Nickel	Boiler 2	0.00E+00	1.02E-04
	Boiler 3	0.00E+00	8.66E-05
	Boiler 2/3 (Non-condensables)	2.31E-04	2.31E-04
	25A Vents	5.38E-05	5.38E-05
11. Mercury	Oxalate Kiln Stack	1.02E-03	1.02E-03
	Liquor Burner	1.22E-04	1.22E-04
	Calciner 1	2.51E-05	2.51E-05
	Calciner 2	2.51E-05	2.51E-05
	Calciner 3	2.51E-05	2.51E-05
	Calciner 4	2.51E-05	2.51E-05
	Calciner 5	2.51E-05	2.51E-05
	Calciner 6	2.51E-05	2.51E-05
	Boiler 2/3 (Non-condensables)	1.42E-03	1.42E-03
	Milling Vents	1.27E-05	1.27E-05
	25A Vents	1.11E-04	1.11E-04
12. Ammonia	Boiler 2	1.16E-01	1.21E-01
	Boiler 3	9.86E-02	1.03E-01
	Milling Vents	4.46E-02	4.75E-02
	25A Vents	1.59E-02	1.59E-02
13. BaP Equivalents	Oxalate Kiln Stack	9.36E-08	9.36E-08
	Liquor Burner	2.61E-06	3.10E-06
	Calciner 1	5.12E-07	5.57E-07
	Calciner 2	5.12E-07	5.57E-07
	Calciner 3	8.03E-07	8.74E-07
	Calciner 4	8.79E-07	9.57E-07
	Calciner 5	8.79E-07	9.57E-07
	Calciner 6	8.79E-07	9.57E-07
	Calc1-3 VacPump&Dorrco	3.02E-10	6.75E-09
	Calciner4 VacPump&Dorrco	3.02E-10	6.75E-09
	Milling Vents	8.64E-08	9.19E-08
	25A Vents	2.03E-07	2.03E-07
	35A Vents	4.48E-06	4.48E-06
14. Acetone	Liquor Burner	1.66E-02	1.76E-02
	Calciner 1	6.79E-02	7.39E-02
	Calciner 2	8.01E-02	8.71E-02
	Calciner 3	4.51E-02	4.91E-02
	Calciner 4	1.24E-01	1.34E-01
	Calciner 5	1.24E-01	1.34E-01
	Calciner 6	1.24E-01	1.34E-01
	Boiler 1	2.95E-02	3.20E-02
	Boiler 2	3.73E-02	3.88E-02
	Boiler 3	2.76E-02	2.88E-02
	45K Cooling Tower 2&3	3.55E-01	3.55E-01
	50 Cooling Tower 1&2	4.87E-02	4.87E-02
	Milling Vents	1.35E-02	1.44E-02
	25A Vents	5.08E-03	5.08E-03

CHEMICAL SPECIES Case 6 (Cogeneration)	STACK SOURCE Case 6 (Cogeneration)	AVERAGE EMISSION RATE (g/s)	PEAK EMISSION RATE (g/s)
	35A Vents	8.61E-02	8.61E-02
15. Acetaldehyde	Liquor Burner	3.15E-03	3.35E-03
	Calciner 1	6.49E-02	7.07E-02
	Calciner 2	6.40E-02	6.97E-02
	Calciner 3	4.41E-02	4.80E-02
	Calciner 4	1.16E-01	1.26E-01
	Calciner 5	1.16E-01	1.26E-01
	Calciner 6	1.16E-01	1.26E-01
	Boiler 1	7.38E-03	8.00E-03
	Boiler 2	8.39E-03	8.74E-03
	Boiler 3	4.75E-03	4.95E-03
	Gas Turbine 2	5.83E-03	5.83E-03
	Gas Turbine 3	5.83E-03	5.83E-03
	45K Cooling Tower 2&3	4.01E-02	4.01E-02
	50 Cooling Tower 1&2	5.50E-03	5.50E-03
	Milling Vents	1.07E-02	1.14E-02
	25A Vents	1.25E-03	1.25E-03
	35A Vents	1.28E-02	1.28E-02
16. Formaldehyde	Liquor Burner	5.44E-04	5.79E-04
	Calciner 1	5.91E-02	6.44E-02
	Calciner 2	5.79E-02	6.30E-02
	Calciner 3	1.90E-01	2.07E-01
	Calciner 4	1.09E-01	1.18E-01
	Calciner 5	1.09E-01	1.18E-01
	Calciner 6	1.09E-01	1.18E-01
	Boiler 1	7.38E-03	8.00E-03
	Boiler 2	5.59E-03	5.83E-03
	Boiler 3	4.75E-03	4.95E-03
	Gas Turbine 2	2.01E-02	2.01E-02
	Gas Turbine 3	2.01E-02	2.01E-02
	45K Cooling Tower 2&3	4.01E-02	4.01E-02
	Milling Vents	1.53E-04	1.62E-04
	25A Vents	3.05E-05	3.05E-05
	35A Vents	7.46E-05	7.46E-05
17. 2-Butanone	Liquor Burner	1.22E-03	1.30E-03
	Calciner 1	5.87E-03	6.39E-03
	Calciner 2	6.40E-03	6.97E-03
	Calciner 3	8.56E-03	9.32E-03
	Calciner 4	1.28E-02	1.40E-02
	Calciner 5	1.28E-02	1.40E-02
	Calciner 6	1.28E-02	1.40E-02
	Boiler 1	7.38E-03	8.00E-03
	Boiler 2	5.59E-03	5.83E-03
	Boiler 3	4.75E-03	4.95E-03
	45K Cooling Tower 2&3	4.01E-02	4.01E-02
	Milling Vents	1.22E-03	1.30E-03
	25A Vents	3.31E-04	3.31E-04
	35A Vents	1.49E-02	1.49E-02

CHEMICAL SPECIES Case 6 (Cogeneration)	STACK SOURCE Case 6 (Cogeneration)	AVERAGE EMISSION RATE (g/s)	PEAK EMISSION RATE (g/s)
18. Benzene	Liquor Burner	6.99E-03	7.44E-03
	Calciner 1	5.12E-03	5.57E-03
	Calciner 2	5.26E-03	5.73E-03
	Calciner 3	1.34E-03	1.46E-03
	Calciner 4	7.78E-03	8.47E-03
	Calciner 5	7.78E-03	8.47E-03
	Calciner 6	7.78E-03	8.47E-03
	Boiler 1	4.61E-03	5.00E-03
	Boiler 2	3.50E-03	3.64E-03
	Boiler 3	2.97E-03	3.09E-03
	Gas Turbine 2	7.84E-04	7.84E-04
	Gas Turbine 3	7.84E-04	7.84E-04
	45K Cooling Tower 2&3	2.01E-02	2.01E-02
	50 Cooling Tower 1&2	0.00E+00	2.75E-11
	Milling Vents	1.03E-04	1.10E-04
	25A Vents	2.07E-05	2.07E-05
	35A Vents	3.25E-05	9.75E-05
19. Toluene	Liquor Burner	5.71E-04	6.07E-04
	Calciner 1	2.03E-03	2.21E-03
	Calciner 2	2.03E-03	2.21E-03
	Calciner 3	1.27E-03	1.38E-03
	Calciner 4	3.48E-03	3.79E-03
	Calciner 5	3.48E-03	3.79E-03
	Calciner 6	3.48E-03	3.79E-03
	Boiler 1	1.85E-03	2.00E-03
	Boiler 2	1.40E-03	1.46E-03
	Boiler 3	1.19E-03	1.24E-03
	Gas Turbine 2	2.67E-03	2.67E-03
	Gas Turbine 3	2.67E-03	2.67E-03
	45K Cooling Tower 2&3	2.01E-02	2.01E-02
	50 Cooling Tower 1&2	1.10E-04	1.10E-04
	Milling Vents	1.37E-04	1.46E-04
	25A Vents	1.51E-04	1.51E-04
	35A Vents	6.79E-04	6.79E-04
20. Xylenes	Liquor Burner	1.37E-04	1.46E-04
	Calciner 1	6.93E-04	7.55E-04
	Calciner 2	6.93E-04	7.55E-04
	Calciner 3	4.35E-04	4.73E-04
	Calciner 4	1.19E-03	1.30E-03
	Calciner 5	1.19E-03	1.30E-03
	Calciner 6	1.19E-03	1.30E-03
	Boiler 1	3.69E-11	4.00E-11
	Boiler 2	2.80E-11	2.91E-11
	Boiler 3	2.38E-11	2.47E-11
	Gas Turbine 2	1.69E-03	1.69E-03
	Gas Turbine 3	1.69E-03	1.69E-03
	25A Vents	2.22E-05	2.22E-05

CHEMICAL SPECIES Case 6 (Cogeneration)	STACK SOURCE Case 6 (Cogeneration)	AVERAGE EMISSION RATE (g/s)	PEAK EMISSION RATE (g/s)
21. Acrolein	Oxalate Kiln Stack	6.20E-05	6.20E-05
	Calciner 1	8.53E-03	9.29E-03
	Calciner 2	8.53E-03	9.29E-03
	Calciner 3	1.34E-02	1.46E-02
	Calciner 4	1.46E-02	1.59E-02
	Calciner 5	1.46E-02	1.59E-02
	Calciner 6	1.46E-02	1.59E-02
22. Ethylbenzene	Oxalate Kiln Stack	2.56E-05	2.56E-05
	Liquor Burner	3.97E-04	4.72E-04
	Calciner 1	2.13E-04	2.32E-04
	Calciner 2	2.13E-04	2.32E-04
	Calciner 3	3.34E-04	3.64E-04
	Calciner 4	3.66E-04	3.99E-04
	Calciner 5	3.66E-04	3.99E-04
	Calciner 6	3.66E-04	3.99E-04
	25A Vents	2.89E-05	2.89E-05
23. Methylene Chloride	Calciner 1	9.39E-03	1.02E-02
	Calciner 2	9.39E-03	1.02E-02
	Calciner 3	1.47E-02	1.60E-02
	Calciner 4	1.61E-02	1.75E-02
	Calciner 5	1.61E-02	1.75E-02
	Calciner 6	1.61E-02	1.75E-02
	Boiler 1	1.48E-02	1.60E-02
	Boiler 2	1.12E-02	1.17E-02
	Boiler 3	9.50E-03	9.90E-03
	Calc1-3 VacPump&Dorrco	5.03E-06	1.13E-04
	Calciner4 VacPump&Dorrco	5.03E-06	1.13E-04
	25A Vents	7.86E-04	7.85E-04
24. Styrene	Oxalate Kiln Stack	3.38E-05	3.38E-05
	Liquor Burner	5.24E-04	6.23E-04
	Calciner 1	3.20E-04	3.48E-04
	Calciner 2	3.20E-04	3.48E-04
	Calciner 3	5.02E-04	5.46E-04
	Calciner 4	5.49E-04	5.98E-04
	Calciner 5	5.49E-04	5.98E-04
	Calciner 6	5.49E-04	5.98E-04
	45K Cooling Tower 2&3	1.15E-03	1.15E-03
	50 Cooling Tower 1&2	9.70E-05	2.20E-04
	25A Vents	4.13E-06	4.13E-06
25. 1,2,4 Trimethylbenzene	Oxalate Kiln Stack	1.46E-05	1.46E-05
	Liquor Burner	2.27E-04	2.69E-04
	25A Vents	1.20E-04	1.20E-04
26. 1,3,5 Trimethylbenzene	Oxalate Kiln Stack	3.66E-06	3.66E-06
	Liquor Burner	5.67E-05	6.74E-05
	Calciner 1	5.33E-05	6.50E-05
	Calciner 2	5.33E-05	6.50E-05

CHEMICAL SPECIES Case 6 (Cogeneration)	**STACK SOURCE Case 6 (Cogeneration)**	**AVERAGE EMISSION RATE (g/s)**	**PEAK EMISSION RATE (g/s)**
	Calciner 3	8.36E-05	9.10E-05
	Calciner 4	9.16E-05	9.97E-05
	Calciner 5	9.16E-05	9.97E-05
	Calciner 6	9.16E-05	9.97E-05
	25A Vents	3.72E-05	3.72E-05
27. Vinyl Chloride	Calciner 1	5.33E-05	6.50E-05
	Calciner 2	5.33E-05	6.50E-05
	Calciner 3	8.36E-05	9.10E-05
	Calciner 4	9.16E-05	9.97E-05
	Calciner 5	9.16E-05	9.97E-05
	Calciner 6	9.16E-05	9.97E-05

3.5. Emission Rates for Case 7 (with new Boilers)

Table 3. Emission rates (Case 7 – Expanded Refinery Scenario (4.7 Mtpa) with Boilers 4 & 5) as supplied by Alcoa World Alumina Australia from each of the sources for each of the 27 modelled chemical species. The 28th species (NO_2) is modelled separately, as described in Section 3.6. Both the average and peak emission rates are listed. In the modelling, the emissions listed as from "Boiler 2/3 (Non-condensables)" were split 50:50 between the Boiler 2 and Boiler 3 flues.

CHEMICAL SPECIES Case 7 (New Boilers)	**STACK SOURCE Case 7 (New Boilers)**	**AVERAGE EMISSION RATE (g/s)**	**PEAK EMISSION RATE (g/s)**
1. NOx	Oxalate Kiln Stack	4.81E-01	4.81E-01
	Liquor Burner	1.24E+00	4.24E+00
	Calciner 1	2.37E+00	3.41E+00
	Calciner 2	1.44E+00	4.94E+00
	Calciner 3	4.92E+00	8.74E+00
	Calciner 4	2.86E+00	5.14E+00
	Calciner 5	2.86E+00	5.14E+00
	Calciner 6	2.86E+00	5.14E+00
	Boiler 1	4.04E+00	4.80E+00
	Boiler 2	3.07E+00	3.50E+00
	Boiler 3	2.60E+00	2.97E+00
	Boiler 4	4.04E+00	4.80E+00
	Boiler 5	4.04E+00	4.80E+00
	Gas Turbine 1	3.00E+00	1.36E+01
2. CO	Oxalate Kiln Stack	7.34E+00	7.34E+00
	Liquor Burner	7.65E+00	2.13E+01
	Calciner 1	5.61E+00	1.06E+01
	Calciner 2	1.02E+01	2.39E+01
	Calciner 3	1.74E+00	4.66E+00
	Calciner 4	2.70E+00	5.14E+00
	Calciner 5	2.70E+00	5.14E+00
	Calciner 6	2.70E+00	5.14E+00
	Boiler 1	2.87E-01	1.76E+00
	Boiler 2	2.41E-01	1.75E+00
	Boiler 3	1.19E-01	5.69E-01
	Boiler 4	2.87E-01	1.76E+00
	Boiler 5	2.87E-01	1.76E+00
	Gas Turbine 1	2.99E+00	7.83E+00
3. SO2	Oxalate Kiln Stack	3.83E-01	3.83E-01
	Liquor Burner	1.04E-01	4.38E-01
	Calciner 1	3.54E-01	9.52E-01
	Calciner 2	4.67E-01	9.06E-01
	Calciner 3	3.20E-01	1.57E+00
	Calciner 4	1.47E-01	3.99E-01
	Calciner 5	1.47E-01	3.99E-01
	Calciner 6	1.47E-01	3.99E-01
	Boiler 1	1.89E-01	7.20E-01
	Boiler 2	2.06E-01	9.03E-01
	Boiler 3	1.76E-01	3.22E-01
	Boiler 4	1.89E-01	7.20E-01

CHEMICAL SPECIES Case 7 (New Boilers)	STACK SOURCE Case 7 (New Boilers)	AVERAGE EMISSION RATE (g/s)	PEAK EMISSION RATE (g/s)
	Boiler 5	1.89E-01	7.20E-01
	Gas Turbine 1	4.27E-01	2.56E+00
4. Dust	Oxalate Kiln Stack	1.12E-01	1.12E-01
	Liquor Burner	7.01E-02	5.39E-01
	Calciner 1	4.51E-01	1.64E+00
	Calciner 2	3.31E-01	1.02E+00
	Calciner 3	4.50E-01	8.74E-01
	Calciner 4	4.93E-01	9.57E-01
	Calciner 5	7.32E-02	7.97E-02
	Calciner 6	7.32E-02	7.97E-02
5. Arsenic	Oxalate Kiln Stack	9.14E-06	9.14E-06
	Liquor Burner	1.42E-04	1.68E-04
	Boiler 1	2.13E-03	2.30E-03
	Boiler 2	9.58E-05	9.98E-05
	Boiler 3	8.14E-05	8.48E-05
	Boiler 2/3 (Non-condensables)	0.00E+00	5.93E-06
	Boiler 4	2.13E-03	2.30E-03
	Boiler 5	2.13E-03	2.30E-03
	25A Vents	0.00E+00	1.04E-05
6. Selenium	Oxalate Kiln Stack	5.49E-05	5.49E-05
	Liquor Burner	8.50E-04	1.01E-03
	Boiler 2	3.45E-05	3.59E-05
	Boiler 3	2.93E-05	3.05E-05
	Boiler 2/3 (Non-condensables)	0.00E+00	5.52E-05
	Milling Vents	7.20E-06	7.66E-06
	25A Vents	1.82E-05	1.82E-05
7. Manganese	Oxalate Kiln Stack	4.57E-06	4.57E-06
	Liquor Burner	7.08E-05	8.42E-05
	Boiler 1	9.87E-04	1.07E-03
	Boiler 2	5.66E-04	5.89E-04
	Boiler 3	4.80E-04	5.01E-04
	Boiler 2/3 (Non-condensables)	0.00E+00	1.31E-03
	Boiler 4	9.87E-04	1.07E-03
	Boiler 5	9.87E-04	1.07E-03
	Milling Vents	1.44E-05	1.53E-05
	25A Vents	1.71E-03	1.71E-03
8. Cadmium	Boiler 2/3 (Non-condensables)	4.45E-07	4.45E-07
9. Chromium VI	Oxalate Kiln Stack	2.97E-08	2.97E-08
	Liquor Burner	2.67E-07	3.17E-07
	Calciner 1	1.50E-06	1.82E-06
	Calciner 2	1.50E-06	1.82E-06
	Calciner 3	1.68E-06	1.82E-06
	Calciner 4	1.68E-06	1.82E-06
	Calciner 5	1.68E-06	1.82E-06
	Calciner 6	1.68E-06	1.82E-06

CHEMICAL SPECIES Case 7 (New Boilers)	STACK SOURCE Case 7 (New Boilers)	AVERAGE EMISSION RATE (g/s)	PEAK EMISSION RATE (g/s)
	Boiler 1	4.10E-06	4.44E-06
	Boiler 2	4.26E-06	4.44E-06
	Boiler 3	4.26E-06	4.44E-06
	Boiler 4	4.10E-06	4.44E-06
	Boiler 5	4.10E-06	4.44E-06
10. Nickel	Boiler 2	0.00E+00	1.02E-04
	Boiler 3	0.00E+00	8.66E-05
	Boiler 2/3 (Non-condensables)	2.31E-04	2.31E-04
	25A Vents	5.38E-05	5.38E-05
11. Mercury	Oxalate Kiln Stack	1.02E-03	1.02E-03
	Liquor Burner	1.22E-04	1.22E-04
	Calciner 1	2.51E-05	2.51E-05
	Calciner 2	2.51E-05	2.51E-05
	Calciner 3	2.51E-05	2.51E-05
	Calciner 4	2.51E-05	2.51E-05
	Calciner 5	2.51E-05	2.51E-05
	Calciner 6	2.51E-05	2.51E-05
	Boiler 2/3 (Non-condensables)	1.42E-03	1.42E-03
	Milling Vents	1.27E-05	1.27E-05
	25A Vents	1.11E-04	1.11E-04
12. Ammonia	Boiler 2	1.16E-01	1.21E-01
	Boiler 3	9.86E-02	1.03E-01
	Milling Vents	4.46E-02	4.75E-02
	25A Vents	1.59E-02	1.59E-02
13. BaP Equivalents	Oxalate Kiln Stack	9.36E-08	9.36E-08
	Liquor Burner	2.61E-06	3.10E-06
	Calciner 1	5.12E-07	5.57E-07
	Calciner 2	5.12E-07	5.57E-07
	Calciner 3	8.03E-07	8.74E-07
	Calciner 4	8.79E-07	9.57E-07
	Calciner 5	8.79E-07	9.57E-07
	Calciner 6	8.79E-07	9.57E-07
	Calc1-3 VacPump&Dorrco	3.02E-10	6.75E-09
	Calciner4 VacPump&Dorrco	3.02E-10	6.75E-09
	Milling Vents	8.64E-08	9.19E-08
	25A Vents	2.03E-07	2.03E-07
	35A Vents	4.48E-06	4.48E-06
14. Acetone	Liquor Burner	1.66E-02	1.76E-02
	Calciner 1	6.79E-02	7.39E-02
	Calciner 2	8.01E-02	8.71E-02
	Calciner 3	4.51E-02	4.91E-02
	Calciner 4	1.24E-01	1.34E-01
	Calciner 5	1.24E-01	1.34E-01
	Calciner 6	1.24E-01	1.34E-01
	Boiler 1	2.95E-02	3.20E-02
	Boiler 2	3.73E-02	3.88E-02

CHEMICAL SPECIES Case 7 (New Boilers)	STACK SOURCE Case 7 (New Boilers)	AVERAGE EMISSION RATE (g/s)	PEAK EMISSION RATE (g/s)
	Boiler 3	2.76E-02	2.88E-02
	Boiler 4	2.95E-02	3.20E-02
	Boiler 5	2.95E-02	3.20E-02
	45K Cooling Tower 2&3	3.55E-01	3.55E-01
	50 Cooling Tower 1&2	4.87E-02	4.87E-02
	Milling Vents	1.35E-02	1.44E-02
	25A Vents	5.08E-03	5.08E-03
	35A Vents	8.61E-02	8.61E-02
15. Acetaldehyde	Liquor Burner	3.15E-03	3.35E-03
	Calciner 1	6.49E-02	7.07E-02
	Calciner 2	6.40E-02	6.97E-02
	Calciner 3	4.41E-02	4.80E-02
	Calciner 4	1.16E-01	1.26E-01
	Calciner 5	1.16E-01	1.26E-01
	Calciner 6	1.16E-01	1.26E-01
	Boiler 1	7.38E-03	8.00E-03
	Boiler 2	8.39E-03	8.74E-03
	Boiler 3	4.75E-03	4.95E-03
	Boiler 4	7.38E-03	8.00E-03
	Boiler 5	7.38E-03	8.00E-03
	45K Cooling Tower 2&3	4.01E-02	4.01E-02
	50 Cooling Tower 1&2	5.50E-03	5.50E-03
	Milling Vents	1.07E-02	1.14E-02
	25A Vents	1.25E-03	1.25E-03
	35A Vents	1.28E-02	1.28E-02
16. Formaldehyde	Liquor Burner	5.44E-04	5.79E-04
	Calciner 1	5.91E-02	6.44E-02
	Calciner 2	5.79E-02	6.30E-02
	Calciner 3	1.90E-01	2.07E-01
	Calciner 4	1.09E-01	1.18E-01
	Calciner 5	1.09E-01	1.18E-01
	Calciner 6	1.09E-01	1.18E-01
	Boiler 1	7.38E-03	8.00E-03
	Boiler 2	5.59E-03	5.83E-03
	Boiler 3	4.75E-03	4.95E-03
	Boiler 4	7.38E-03	8.00E-03
	Boiler 5	7.38E-03	8.00E-03
	45K Cooling Tower 2&3	4.01E-02	4.01E-02
	Milling Vents	1.53E-04	1.62E-04
	25A Vents	3.05E-05	3.05E-05
	35A Vents	7.46E-05	7.46E-05
17. 2-Butanone	Liquor Burner	1.22E-03	1.30E-03
	Calciner 1	5.87E-03	6.39E-03
	Calciner 2	6.40E-03	6.97E-03
	Calciner 3	8.56E-03	9.32E-03
	Calciner 4	1.28E-02	1.40E-02
	Calciner 5	1.28E-02	1.40E-02
	Calciner 6	1.28E-02	1.40E-02

CHEMICAL SPECIES Case 7 (New Boilers)	STACK SOURCE Case 7 (New Boilers)	AVERAGE EMISSION RATE (g/s)	PEAK EMISSION RATE (g/s)
	Boiler 1	7.38E-03	8.00E-03
	Boiler 2	5.59E-03	5.83E-03
	Boiler 3	4.75E-03	4.95E-03
	Boiler 4	7.38E-03	8.00E-03
	Boiler 5	7.38E-03	8.00E-03
	45K Cooling Tower 2&3	4.01E-02	4.01E-02
	Milling Vents	1.22E-03	1.30E-03
	25A Vents	3.31E-04	3.31E-04
	35A Vents	1.49E-02	1.49E-02
18. Benzene	Liquor Burner	6.99E-03	7.44E-03
	Calciner 1	5.12E-03	5.57E-03
	Calciner 2	5.26E-03	5.73E-03
	Calciner 3	1.34E-03	1.46E-03
	Calciner 4	7.78E-03	8.47E-03
	Calciner 5	7.78E-03	8.47E-03
	Calciner 6	7.78E-03	8.47E-03
	Boiler 1	4.61E-03	5.00E-03
	Boiler 2	3.50E-03	3.64E-03
	Boiler 3	2.97E-03	3.09E-03
	Boiler 4	4.61E-03	5.00E-03
	Boiler 5	4.61E-03	5.00E-03
	45K Cooling Tower 2&3	2.01E-02	2.01E-02
	50 Cooling Tower 1&2	0.00E+00	2.75E-11
	Milling Vents	1.03E-04	1.10E-04
	25A Vents	2.07E-05	2.07E-05
	35A Vents	3.25E-05	9.75E-05
19. Toluene	Liquor Burner	5.71E-04	6.07E-04
	Calciner 1	2.03E-03	2.21E-03
	Calciner 2	2.03E-03	2.21E-03
	Calciner 3	1.27E-03	1.38E-03
	Calciner 4	3.48E-03	3.79E-03
	Calciner 5	3.48E-03	3.79E-03
	Calciner 6	3.48E-03	3.79E-03
	Boiler 1	1.85E-03	2.00E-03
	Boiler 2	1.40E-03	1.46E-03
	Boiler 3	1.19E-03	1.24E-03
	Boiler 4	1.85E-03	2.00E-03
	Boiler 5	1.85E-03	2.00E-03
	Gas Turbine 1	0.00E+00	1.09E-10
	45K Cooling Tower 2&3	2.01E-02	2.01E-02
	50 Cooling Tower 1&2	1.10E-04	1.10E-04
	Milling Vents	1.37E-04	1.46E-04
	25A Vents	1.51E-04	1.51E-04
	35A Vents	6.79E-04	6.79E-04
20. Xylenes	Liquor Burner	1.37E-04	1.46E-04
	Calciner 1	6.93E-04	7.55E-04
	Calciner 2	6.93E-04	7.55E-04
	Calciner 3	4.35E-04	4.73E-04

CHEMICAL SPECIES Case 7 (New Boilers)	STACK SOURCE Case 7 (New Boilers)	AVERAGE EMISSION RATE (g/s)	PEAK EMISSION RATE (g/s)
	Calciner 4	1.19E-03	1.30E-03
	Calciner 5	1.19E-03	1.30E-03
	Calciner 6	1.19E-03	1.30E-03
	Boiler 1	3.69E-11	4.00E-11
	Boiler 2	2.80E-11	2.91E-11
	Boiler 3	2.38E-11	2.47E-11
	Boiler 4	3.69E-11	4.00E-11
	Boiler 5	3.69E-11	4.00E-11
	25A Vents	2.22E-05	2.22E-05
21. Acrolein	Oxalate Kiln Stack	6.20E-05	6.20E-05
	Calciner 1	8.53E-03	9.29E-03
	Calciner 2	8.53E-03	9.29E-03
	Calciner 3	1.34E-02	1.46E-02
	Calciner 4	1.46E-02	1.59E-02
	Calciner 5	1.46E-02	1.59E-02
	Calciner 6	1.46E-02	1.59E-02
22. Ethylbenzene	Oxalate Kiln Stack	2.56E-05	2.56E-05
	Liquor Burner	3.97E-04	4.72E-04
	Calciner 1	2.13E-04	2.32E-04
	Calciner 2	2.13E-04	2.32E-04
	Calciner 3	3.34E-04	3.64E-04
	Calciner 4	3.66E-04	3.99E-04
	Calciner 5	3.66E-04	3.99E-04
	Calciner 6	3.66E-04	3.99E-04
	25A Vents	2.89E-05	2.89E-05
23. Methylene Chloride	Calciner 1	9.39E-03	1.02E-02
	Calciner 2	9.39E-03	1.02E-02
	Calciner 3	1.47E-02	1.60E-02
	Calciner 4	1.61E-02	1.75E-02
	Calciner 5	1.61E-02	1.75E-02
	Calciner 6	1.61E-02	1.75E-02
	Boiler 1	1.48E-02	1.60E-02
	Boiler 2	1.12E-02	1.17E-02
	Boiler 3	9.50E-03	9.90E-03
	Boiler 4	1.48E-02	1.60E-02
	Boiler 5	1.48E-02	1.60E-02
	Calc1-3 VacPump&Dorrco	5.03E-06	1.13E-04
	Calciner4 VacPump&Dorrco	5.03E-06	1.13E-04
	25A Vents	7.86E-04	7.85E-04
24. Styrene	Oxalate Kiln Stack	3.38E-05	3.38E-05
	Liquor Burner	5.24E-04	6.23E-04
	Calciner 1	3.20E-04	3.48E-04
	Calciner 2	3.20E-04	3.48E-04
	Calciner 3	5.02E-04	5.46E-04
	Calciner 4	5.49E-04	5.98E-04
	Calciner 5	5.49E-04	5.98E-04
	Calciner 6	5.49E-04	5.98E-04

CHEMICAL SPECIES Case 7 (New Boilers)	**STACK SOURCE Case 7 (New Boilers)**	**AVERAGE EMISSION RATE (g/s)**	**PEAK EMISSION RATE (g/s)**
	45K Cooling Tower 2&3	1.15E-03	1.15E-03
	50 Cooling Tower 1&2	9.70E-05	2.20E-04
	25A Vents	4.13E-06	4.13E-06
25. 1,2,4 Trimethylbenzene	Oxalate Kiln Stack	1.46E-05	1.46E-05
	Liquor Burner	2.27E-04	2.69E-04
	25A Vents	1.20E-04	1.20E-04
26. 1,3,5 Trimethylbenzene	Oxalate Kiln Stack	3.66E-06	3.66E-06
	Liquor Burner	5.67E-05	6.74E-05
	Calciner 1	5.33E-05	6.50E-05
	Calciner 2	5.33E-05	6.50E-05
	Calciner 3	8.36E-05	9.10E-05
	Calciner 4	9.16E-05	9.97E-05
	Calciner 5	9.16E-05	9.97E-05
	Calciner 6	9.16E-05	9.97E-05
	25A Vents	3.72E-05	3.72E-05
27. Vinyl Chloride	Calciner 1	5.33E-05	6.50E-05
	Calciner 2	5.33E-05	6.50E-05
	Calciner 3	8.36E-05	9.10E-05
	Calciner 4	9.16E-05	9.97E-05
	Calciner 5	9.16E-05	9.97E-05
	Calciner 6	9.16E-05	9.97E-05

3.6. NO_x to NO_2 Conversion

The NO_x (nitrogen oxides) emission rates were used to calculate NO_x concentration fields. The NO_2 (nitrogen dioxide) concentrations were derived using a simple titration algorithm for the conversion of nitric oxide (NO) to NO_2 in the presence of ozone (O_3):

$$NO + O_3 \rightarrow NO_2 + O_2, \quad (8)$$

which is approximately correct at night-time but is conservative (i.e. potentially over-estimates NO_2) in the near field (less than 1 hour downwind of the source) during daylight hours when photochemical reactions become important.

This reaction equation shows that both compounds on the left-hand side (nitric oxide and ozone) are needed to produce nitrogen dioxide, NO_2. The amount of NO_2 produced is limited by the smaller of either the NO or the O_3 concentration. If there is more O_3 than NO then all of the NO will be converted to NO_2. If, on the other hand, there is more NO than O_3, then NO_2 is only produced until all of the O_3 is used up. Thus the NO_2 concentration is taken to be the minimum of the NO_x and the ozone concentration with both expressed in ppb. The NO_x emission rates used in the TAPM modelling to generate NO_x glcs are expressed in terms of NO_2, as is standard practice in air pollution studies.

In the absence of hourly ozone data for the modelled period (April 2003 to March 2004), the average diurnal variation of ozone concentrations at the Upper Dam site for the period March 2002 to March 2003 reported by Johnson (2003) was used. These data are reproduced in Figure 9.

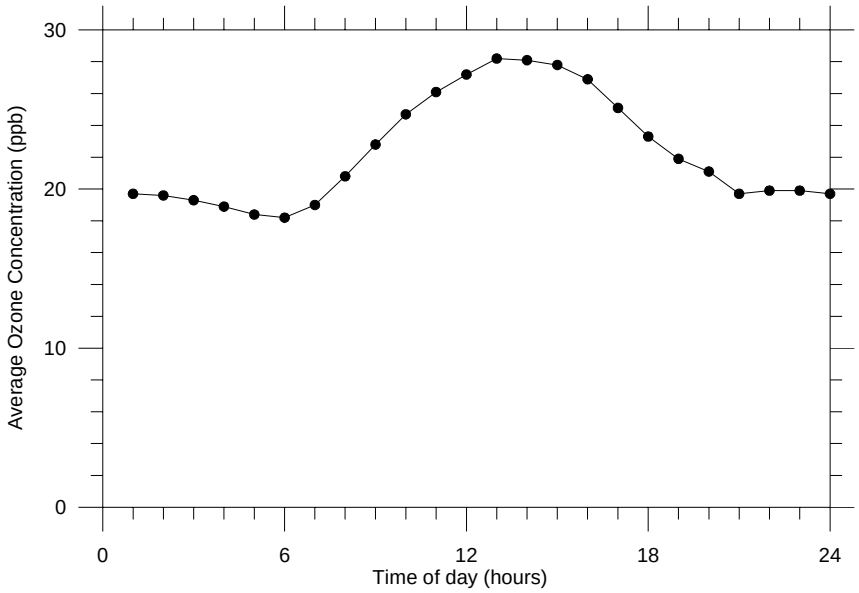

Figure 9. Average diurnal variation of ozone concentration used for deriving NO_2 concentrations from modelled NO_x concentrations (after Johnson, 2003). Concentrations are given in ppb (parts per billion).

Capping of the peak 10-minute and 3-minute averages for NO_2 due to the limited availability of ozone for titration of NO to NO_2 is discussed at the end of Section 3.7. The affected peak NO_2 concentrations are indicating by shading of the cells in the tables of concentrations at the receptor sites in Sections 5 and 6.

3.7. Modelling Short-term Peak Concentrations

It is well established in the literature that observed annual peak ground level concentrations for averaging times ranging from minutes to hours can be related through a power law expression of the form (e.g. Hibberd, 1998, NSW EPA, 2001):

$$c_{\max,2} = c_{\max,1}\left(\frac{t_1}{t_2}\right)^p, \qquad (9)$$

where $c_{max,i}$ is the maximum concentration for an averaging time t_i and the value of the exponent p typically lies in the range 0.1 to 0.4 with lower values representative of stable conditions and larger values more appropriate for highly unstable (convective) conditions. The value of p also decreases with increasing distance from the source.

Provided that an appropriate value of p is used, this equation has been found to give good estimates of the highest concentrations likely to be observed in a year. For example, knowing the highest 1-hour average concentration in a year, it is possible to predict the highest 10-minute average or highest 3-minute average concentration.

Uncertainty in these estimates arises because the value of the exponent p depends on many factors, including:

- the configuration of the source, e.g. point, area
- atmospheric stability
- the distance from the source.

Table 4 lists commonly-used values of p with an indication of the origin of data used to derive these exponents.

Table 4. Power-law exponents derived from a range of studies for different source configurations. After Katestone Scientific (1998).

Source type	**Power-law exponent *p***	**Types of studies** F – field, L – laboratory N – numerical, T – theoretical
Area	0.10 – 0.15	L, N
Line	0.25	L, N, T
Surface point	0.15 – 0.2	F, L, N, T
Tall wake-free point	0.4	F, L, N, T
Wake-affected point	0.10	F, L
Volume	0.10	T

In many cases, the maximum 1-hour average ground-level concentrations near tall stacks are observed during convective conditions and a value of $p = 0.4$ is used. This gives the peak 10-minute average as $2.0 \times c_{max,1hr}$ and the peak 3-minute average as $3.3 \times c_{max,1hr}$. In cases where the maximum ground-level concentrations are observed at night in stable conditions, for example as plume impact on nearby hills, a value of

$p = 0.2$ is more commonly applied. This gives the peak 10-minute average as $1.4 \times c_{max,1hr}$ and the peak 3-minute average as $1.8 \times c_{max,1hr}$.

Many modelling studies use a default value of $p = 0.2$, and this value is included in the commonly-used air quality models AUSPLUME and CALPUFF.

Although equation (9) is only valid for long data series such as year-long sets of data, it is often mis-applied to much shorter periods. For example, it is often applied to 1-hour average data for each hour of a year to calculate a maximum short-term peak during that hour, even though the actual "peak" may be much larger or much smaller than the calculated peak value. This discrepancy can easily be seen by considering two simple cases:

1. A pollutant concentration of 60 µg m^{-3} is observed for the first 3 minutes of an hour with a concentration of zero for the rest of the hour. The 1-hour average concentration is then 3 µg m^{-3} so that $c_{max,3\text{-}min} = 20 \times c_{max,1hr}$.

2. A pollutant concentration of 10 µg m^{-3} is observed for each 3 minutes of a full hour. Both the maximum 3-minute average concentration and the 1-hour average concentration are 10 µg m^{-3}. Thus $c_{max,3\text{-}min} = 1 \times c_{max,1hr}$.

The factors of 1 and 20 are clearly much different from the factors obtained from the power-law model with $p = 0.2$ or 0.4, as given above. This occurs because the equation is based on properties of statistical extremes – it accurately predicts extreme statistics when there are a sufficiently large number of events, but it does not apply to data in any particular hour.

A consequence of this limitation is that the power-law method cannot be used to generate a time series of, for example, 10-minute average concentrations from modelled 1-hour average concentrations. It is only the annual peak 10-minute average concentration that can be obtained.

The most uncertain aspect of the power-law method is the selection of the correct value of p for calculating the peak values. In this study we determine the value of p from the magnitude of the concentration variance (a measure of the variability in the concentrations) calculated by the model, which accounts for its variability with prevailing meteorological and dispersion conditions and hence for its variability with distance from the sources and time of day. The TAPM modelling for this study had the option switched on to calculate the concentration variance. In the processing step combining the model results from each stack source (represented by equation (7)), the variances contributed by each source is also taken into account. The larger the concentration variance, the larger the value was of p and vice versa, with values of p ranging between 0.1 and 0.4. Thus the most appropriate value of p was calculated for each hour of the day at each point on the modelled domain. Using equation (9) and the modelled 1-hour average concentration, a set of numbers was produced, from which the annual maximum 10-minute and 3-minute concentrations were derived at each point on the modelled domain. (As noted above, the individual values at each hour of the year are not realistic, but the annual maxima of these numbers do represent the extremes of the distribution.) A significant advantage of the technique is that the exponent chosen each hour more closely represents the dispersion conditions prevailing at that time. It can be more accurate than the simple AUSPLUME technique of applying a constant value of $p = 0.2$, as it correctly accounts for the larger exponent that applies for tall stack emissions into convective conditions and the smaller exponent for near-surface sources. This TAPM technique has been validated for peak 10-minute concentrations

using emissions and ground-level monitoring data in the Kwinana region (Hurley, pers. comm.).

This TAPM approach represents the current state of knowledge for statistical modelling of extreme annual events.

The results obtained in this study for the maximum 1-hour, 10-minute and 3-minute concentrations show that at the 15 receptor points, the short-term peaks are equivalent to using exponents between 0.12 and 0.24 with the value varying across the grid.

The model results can be compared with observations of 6-minute average NO_x concentrations at Upper Dam for the calendar year 2003, where the maximum observed 1-hour average concentration in 2003 was 76 µg m^{-3} and the maximum 6-minute average concentration was 102 µg m^{-3}, corresponding to an exponent $p = 0.13$. The caveat on this calculation is that the numbers were derived from single points at the extreme end of the distribution of values and so are subject to some uncertainty, which cannot be quantified without a much more detailed analysis.

The modelled TAPM results for NO_x obtained in this study for the Upper Dam site corresponds to an exponent of $p = 0.24$, which is somewhat larger than the observed value. This indicates that the results for the 10-minute and 3-minute peaks presented here may be conservative, i.e. they will tend to be over-predictions rather than under-predictions.

The peak-to-mean ratios for NO_2 are affected by the capping of the 10-minute and 3-minute averages for NO_2 due to the limited availability of ozone for titration of NO to NO_2 (as described in Section 3.6). The ozone data used in this study do not include short-term (sub-hourly) variations (which in any case are small because of the nature and extent of ozone sources in the background air). On occasions when the 1-hour average NO_x concentration exceeds the ozone concentration for that hour, then the modelled 10-minute and 3-minute NO_2 concentrations will be the same as the 1-hour average NO_2 and ozone concentration for that hour. This is equivalent to a power law exponent $p = 0$. On other occasions, just the modelled 10-minute or 3-minute NO_x concentration will exceed the 1-hour average ozone concentration, so only these shorter term NO_2 peaks will be capped (producing values of p between 0 and that for NO_x). As described above, the individual 10-minute and 3-minute concentrations calculated each hour are not realistic, but the annual peak values do represent the extreme values. The peak NO_2 concentrations that are limited by the available ozone are highlighted by shading of the cells in which they occur in the tables in Sections 5 and 6.

4. Model Outputs

4.1. Receptor Locations

Table 5 lists the coordinates of the 15 receptor sites at which the required concentration statistics of the 28 chemical species were extracted. Their locations are also shown overlaid on an aerial photograph of the site in Figure 10.

Table 5. Locations of each of the thirteen receptors used in the modelling study. (NB. Receptor 12 was not included in the selected sites.)

Receptor	AMG84 Coordinates		Location
	Eastings (km)	Northings (km)	
1	398.091	6354.834	Boundary Rd
2	399.393	6355.006	
3	396.830	6352.949	Yarloop
4	397.138	6354.827	
5	395.721	6352.503	
6	399.650	6354.240	
7	390.775	6358.733	Bremner Rd
8	392.360	6362.131	Somers/McClure Rds
9	396.099	6362.024	
10	398.460	6362.000	Hamel
11	398.207	6360.331	
13	400.520	6364.215	
14	400.727	6360.830	Escarpment
15	400.726	6356.435	
16	397.365	6359.285	

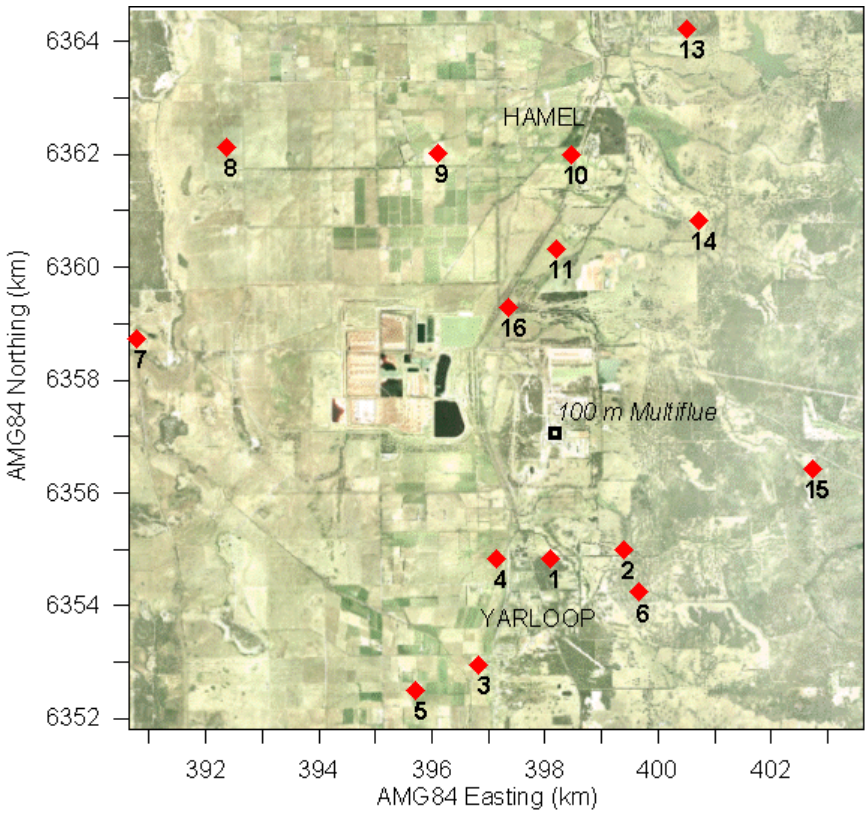

Figure 10: Location of the receptors used in this modelling study overlaid on an aerial photograph of the site.

4.2. Uncertainty in modelled concentrations

The performance statistics for the meteorological component of TAPM were presented in Section 2. The performance of the concentration (pollution) modelling component of TAPM has been evaluated using the robust highest concentration and is described here.

The robust highest concentration (Cox and Tikvart, 1990) is a robust test statistic calculated using information contained in the upper end of the distribution of concentrations. It is defined as:

$$RHC = C(R) + \left(\overline{C} - C(R)\right)\ln\left[(3R-1)/2\right], \qquad (10)$$

where $C(R)$ is the R^{th} highest concentration and $\overline{C}$ is the mean of the top $R-1$ concentrations. A value of $R = 11$ is usually used in TAPM studies, in which case $\overline{C}$ is the average of the top ten concentrations. The RHC is based on an exponential fit to the highest $R-1$ values of the cumulative frequency distribution. In air quality studies, the RHC is often preferred to the maximum value because it removes the undesirable influence of unusual (stochastic) events, while still representing the highest concentrations.

Table 6 lists the ratio of modelled-to-observed RHCs from the most recent studies undertaken using TAPM Version 2. The studies are separated into point source studies and airshed studies, the latter having many types of sources including line and diffuse sources across the airshed. The first category is more relevant for Wagerup. For these, the ratio ranges from 0.70 (a 30% underprediction) to 1.75 (a 75% over-prediction) with a mean of 1.1. For NO_x at Upper Dam, the ratio is 0.8. The results indicate that in any particular modelling study, the uncertainty in the modelled RHCs at a given site is approximately ±50% at the 95% confidence level (i.e. two standard deviations). For more extreme statistics such as the annual maximum 1-hour average, 10-minute average or 3-minute average concentration, the uncertainty will be somewhat greater, and for less extreme statistics such as the annual average or 95th percentiles the uncertainty may be smaller, but the magnitude of these uncertainties have not been evaluated. Although it should be simple to evaluate the uncertainty in modelled annual averages, this is not the case. Measured concentrations are often confounded by zero offset problems, which can be of similar magnitude to the annual average, although much smaller than peak concentrations. In addition, modelling often doesn't include all sources of the particular pollutant (such as the vehicular and Yarloop sources of NO_x in the current modelling).

Uncertainty in modelling the maximum concentration at a particular location is usually greater than the uncertainty in the maximum concentration within the modelled domain. This is because the modelled concentration at a particular location is very sensitive to small changes in wind direction. Thus in air quality studies it is common to report the maximum domain concentration. In this report, this information is available for selected pollutants in the contour plots in Sections 5.3 and 6.3 and from the detailed glc fields to be used in the Health Risk Assessment.

Factors contributing to the uncertainty in model results include the turbulent (random) nature of dispersion in the turbulent atmosphere, inaccuracies in the mathematical description of the physical processes that occur in the atmosphere, and uncertainties in the numerical solutions of the many equations in the model. A further factor is uncertainty or variability in the source emission rates. As mentioned above, the modelling of extreme events, such as annual maximum 1-hour average concentrations, has the highest level of uncertainty. The nature of the TAPM uncertainty is similar to the uncertainty in weather predictions of the timing and location of thunderstorms.

Uncertainties are inherent in any modelling of the atmosphere. TAPM incorporates the best techniques for dispersion modelling consistent with the ability to do year-long model runs, albeit using large amounts of computing resources.

Table 6. List of the ratio of modelled to observed robust highest concentrations (RHC) for a range of studies using TAPM. The point source studies are most relevant for the Wagerup modelling; the airshed studies, by contrast, include many area and diffuse sources.

Location	Species	Ratio of modelled to observed RHC	Reference
Point Source Studies			
Kwinana, site 1	SO_2	0.87	Hurley et al., 2002
Kwinana, site 2	SO_2	0.91	Hurley et al., 2002
Kwinana, site 3	SO_2	1.45	Hurley et al., 2002
Kwinana, site 4	SO_2	0.84	Hurley et al., 2002
Kwinana, site 5	SO_2	1.27	Hurley et al., 2002
Kwinana, site 6	SO_2	1.13	Hurley et al., 2002
Pilbara, site 1	NO_x	0.87	Hurley et al., 2003b
Pilbara, site 2	NO_x	1.06	Hurley et al., 2003b
Pilbara, Dampier	NO_x	0.70	Physick and Blockley, 2001
Pilbara, King Bay	NO_x	1.75	Physick et al, 2002
Anglesea, site 1	SO_2	1.01	Hill and Hurley, 2003
Anglesea, site 2	SO_2	1.29	Hill and Hurley, 2003
Kincaid (USA)	SF_6	1.18	Luhar and Hurley, 2003
Indianapolis	SF_6	0.92	Luhar and Hurley, 2003
Pilbara, site 1	NO_2	1.27	Hurley et al., 2003b
Pilbara, site 2	NO_2	1.21	Hurley et al., 2003b
Wagerup, Upper Dam	NO_x	0.80	CSIRO, 2005 (Phase 2 Report,
Average ± standard deviation		**1.09 ± 0.27**	Appendix A)
Range		**0.70 to 1.75**	
Airshed Studies			
Perth	NO_2	0.90	Hurley et al., 2002
Melbourne, site 1	NO_2	1.12	Hurley et al., 2003a
Melbourne, site 2	NO_2	1.14	Hurley et al., 2003a
Melbourne, site 3	NO_2	1.20	Hurley et al., 2003a
Melbourne, site 4	NO_2	1.21	Hurley et al., 2003a
Pilbara	O_3	1.05	Hurley et al., 2003b
Perth	O_3	1.02	Hurley et al., 2002
Melbourne, site 1	O_3	0.80	Hurley et al., 2003a
Melbourne, site 2	O_3	1.00	Hurley et al., 2003a
Melbourne, site 3	O_3	0.94	Hurley et al., 2003a
Melbourne, site 4	O_3	1.02	Hurley et al., 2003a
Average ± standard deviation		**1.04 ± 0.13**	
Range		**0.80 to 1.21**	

Two further analyses of uncertainty are undertaken. An analysis is presented of the year-to-year variation in synoptic wind directions at Wagerup and an analysis is made of the sensitivity of model results to wind data assimilation of the available wind data from Wagerup.

The annual variability in the large-scale synoptic weather pattern in the Wagerup region and the representativeness of the modelled year has been investigated by analysing the 6-hourly 10-m wind directions for the grid point closest to Wagerup in the Bureau of Meteorology's GASP (Global Analysis and Prediction) analyses, which are used as the synoptic input to TAPM. The data have been sorted into 22.5º bins centred on the directions labelled on the axis of Figure 11. (The GASP data are well suited for this analysis of inter-annual variability and are of much better quality (consistency of location, no missing data) than the data available the Wagerup meteorological tower.)

The pattern shows that the winds are in the southerly quadrants (south-east and south-west) about two-thirds of the time, and in the northerly quadrants (north-east and north-west) about one-third of the time. The annual variability in the frequency of each wind direction is represented by the shaded vertical bar; it is typically ±30% about the mean (range 12% to 49%). The modelled year is seen to be a fairly average year, with all frequencies within 20% of the median values, except for easterlies (33% less frequent than the median) and southerlies (24% more frequent than the median). Although ground-level concentrations are influenced by more meteorological conditions than just the wind directions, the inter-annual variability of ±30% in the frequency of wind in each sector would be expected to lead to similar sized variations in the annual average concentrations, but determining the effect on maximum concentrations is more complicated. In fact, a full comparison of the inter-annual variability would require repeat modelling for several years, which is currently beyond the scope of what is possible for such a complex set of modelling conditions. Even the current modelling for the Current and Expansion scenarios required more than 10,000 hours of CPU time.

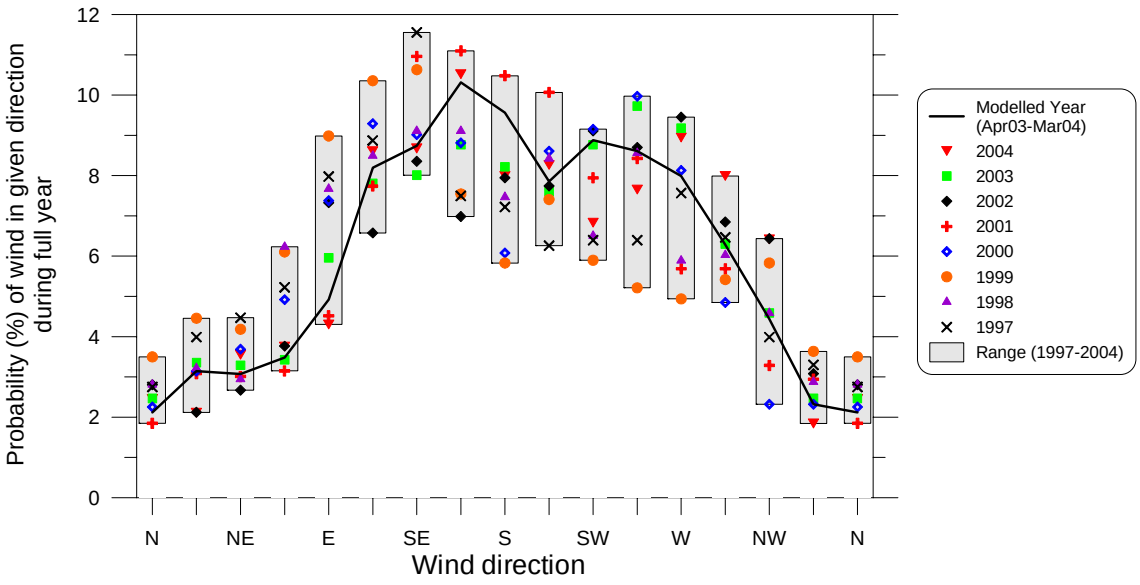

Figure 11. Probability distribution of 10-m wind directions at Wagerup for the years 1997–2004 compared with those for the modelled year (April 2003–March 2004) indicated by the solid line. Data are from the 6-hourly GASP (Global Analysis and Prediction) records that are used as the synoptic input to TAPM.

Some model runs for NO_x were undertaken using wind data assimilation, as discussed in Section 2.1. The results from these runs provide an indication of the sensitivity of the model results to uncertainties in the wind direction and speed in the meteorological input to the model. The simulations were an annual run for NO_x using the Current Scenario peak emission rates presented in Table 2 of the Phase 3A report (CSIRO, 2004d) with assimilation of available wind data from 30 m at Bancell Road and 8 m at the RDA. Table 7 lists the ratio at the receptor site of the concentration modelled with data assimilation to that without data assimilation.

For the maximum 1-hour average concentration, the bulk of the ratios are in the range from 0.4 to 2.0, with an outlier at site 3, where the ratio is 3.1. As can be seen from Figure 27 (which is similar to the contour pattern in the Phase 3A report (CSIRO, 2004d) for the Current Scenario Emissions used in this simulation), site 3 is in a region of low 1-hour average ground-level concentrations bordered by a steep concentration gradient to the west. A rotation of the modelled wind with wind data assimilation brings in the much higher ground-level concentrations from the west to receptor 3. Because the maximum 1-hour average concentration only occurs once per year, this difference between results with and without wind data assimilation at receptor 3 would not necessarily occur at that receptor if another year's meteorology was used. The extreme sensitivity of this statistic (maximum concentration) is seen when comparing its ratios with the ratios of the 10^{th} highest concentration in the table, which are all within the range 0.5 to 1.5, i.e. within ±50% of the runs without data assimilation.

These results in Table 7 and Figure 11 indicate that the TAPM model uncertainty of ±50% derived from Table 6 from a range of studies is an underestimate for the topographically complex region of Wagerup with the significant influence of the

Table 7. Ratio of modelled concentrations for NO_x (Current Scenario – Peak Emissions) when TAPM was run with data assimilation compared to the results obtained without data assimilation.

Receptor	c_{max} (1-hr avg)	RHC (1-hr avg)	10^{th} highest (1-hr avg)	Annual average
1	1.5	1.6	1.5	1.9
2	1.3	1.3	1.4	2.4
3	3.1	2.8	1.4	1.6
4	2.0	1.8	1.2	1.5
5	1.0	1.1	1.1	1.2
6	1.0	1.3	1.3	2.1
7	0.4	0.4	0.5	1.0
8	0.8	0.9	0.7	1.2
9	0.9	1.1	0.7	1.1
10	0.7	0.7	0.6	1.1
11	0.8	0.9	0.8	1.0
13	1.0	1.2	1.1	1.5
14	1.2	1.3	1.5	1.7
15	1.5	1.4	1.2	1.3
16	1.0	1.0	0.9	1.1
average	1.2 ± 0.7	1.2 ± 0.6	1.1 ± 0.3	1.4 ± 0.4

escarpment on local wind fields. As mentioned elsewhere, wind direction data measured at the Bancell Road and RDA sites, which are less than 3 km apart, show that north-easterlies are much less frequent at Bancell Road than at the RDA (Phase 1 report; CSIRO, 2004b). Similarly, wind roses from Hamel and Yarloop for October/November 2003 show much more frequent easterlies and south-westerlies and much less frequent south-easterlies at Hamel than at Yarloop (WADEP, pers. comm.). Although wind data assimilation will generally improve modelled concentrations close to the location where the wind data is recorded, this will not be the case to the north of the Refinery including at Hamel or for much of the 15 km × 15 km region considered in this modelling. The comparison of results with and without data assimilation is presented here to indicate the sensitivity of the model results to changes in the wind patterns.

Based on an analysis of all the above information, taking into account the occurrence of one outlier in Table 7, we conclude that the scenario model results for maximum 1-hour average concentrations presented in this report have an uncertainty of a factor of approximately 2 (i.e. the actual values lie in the range of +100% to -50% of the scenario model concentrations at the receptors) at the 95% confidence level. We conclude that the same level of uncertainty also applies to the other reported scenario concentrations (annual averages, 95th percentiles, maximum 10-minute and maximum 3-minute average concentrations).

4.3. Quality Assurance Run

For NO_x, TAPM was run using all sources of the pollutant in a single input file to generate a quality assurance run. That is, the QA run includes all the NO_x sources with the associated emission rates (g/s) in a single TAPM run.

These results are compared with the results obtained from the method used in the rest of the modelling presented in this report, which is described by Equation (7). This combines the TAPM results from each point source with a weighting according to the emission rates from each source. The quality assurance run was designed to test both the model and the post-processing steps.

Table 8 lists the results for the maximum 1-hour average concentrations at each of the receptor sites. (As the maximum 1-hour average concentration is a once in a year extreme event, it represents the most stringent test that can be used for this comparison. Other statistics will show smaller differences.) It compares the results obtained using the weighted sum method with those from the QA run and lists the differences as a percentage at each receptor point. The differences range from -7% to +12%. These reflect uncertainties in TAPM modelling which arise from the numerical solutions of a large number of equations and the stochastic (Lagrangian) modelling technique used on the inner grid. Comparison of contour plots of the modelled concentration fields indicate similar agreement over the whole modelled domain (not shown). These results confirm the veracity of the weighted sum approach for computing the ground-level concentrations of a large number of species emitted from a large number of separate sources.

These results differ slightly from those presented in and Table 10 for Case 6 (Cogeneration) as they were computed without buoyancy enhancement of the plumes from Gas Turbines 2 and 3, but otherwise the procedure was the same as that used in the rest of the modelling results presented in this report.

Table 8. Comparison of results from Quality Assurance (QA) run with results from the weighted sum method described in Section 3.3.

		Max. 1-hr average (μg m^{-3})		
Site	**Species**	**Results using Eq(7)**	**QA run**	**Difference**
1	NO_x	52.1	48.7	**-7%**
2	NO_x	64.7	64.9	**0%**
3	NO_x	68.9	67.9	**-1%**
4	NO_x	86.6	93.8	**+8%**
5	NO_x	100.7	105.8	**+5%**
6	NO_x	64.3	68.7	**+7%**
7	NO_x	114.6	126.8	**+11%**
8	NO_x	50.0	52.2	**+4%**
9	NO_x	42.8	44.3	**+4%**
10	NO_x	45.2	48.4	**+7%**
11	NO_x	59.2	66.5	**+12%**
13	NO_x	35.0	35.2	**+1%**
14	NO_x	67.5	68.6	**+2%**
15	NO_x	75.9	77.9	**+3%**
16	NO_x	65.2	73.1	**+12%**

5. Results for Case 6 (with Cogeneration)

5.1. Concentration Statistics by Species – Case 6 (with Cogeneration)

Table 9 lists the concentration statistics for all 28 chemical species modelled at each of the 15 receptor sites for Expansion Case 6 sorted by species. The same results are shown in Table 10 sorted by receptor site. The results are shown to one decimal place as this represents an uncertainty of at most 10% in the results. As indicated in the previous section, results of many TAPM modelling studies indicate that it is not possible to obtain better accuracy than this, particularly for peak statistics.

The 95th percentile value represents a concentration where 95% of the data are smaller and 5% of the data are larger than this concentration. For the 24-hour averages, it represents the 18th highest concentration in a year of 365 24-hour averages, whereas for the 1-hour averages it represents the 440th highest concentration in a year of 8760 1-hour averages. Although on any particular day, the 24-hour average will always be smaller than (or equal to) the maximum 1-hour average for that day, for the 95th percentiles there is no simple relation. The 95th percentile 24-hour average can be either larger or smaller than the 95th percentile 1-hour average, as is observed in Table 9.

Table 9. Selected modelled concentration statistics sorted by species for each of the 28 chemical species at each of the 15 receptor sites for Expanded Refinery Scenario (4.7 Mtpa) with Case 6 (Cogeneration). The annual averages are for the average emission rates, whereas all other statistics are for peak emission rates. The shaded NO_2 cells are values limited by the available ozone, see Section 3.7.

Chemical species *(Case 6 – Cogeneration)*	**Site**	**Annual average** ($\mu g\ m^{-3}$)	**95th % 24-hr average** ($\mu g\ m^{-3}$)	**95th % 1-hr average** ($\mu g\ m^{-3}$)	**Max. 1-hr average** ($\mu g\ m^{-3}$)	**Max. 10-min average** ($\mu g\ m^{-3}$)	**Max. 3-min average** ($\mu g\ m^{-3}$)
NOx	1	2.9E-01	3.4E+00	2.1E+00	4.2E+01	6.5E+01	8.8E+01
NOx	2	3.0E-01	3.5E+00	2.2E+00	5.5E+01	8.6E+01	1.2E+02
NOx	3	2.3E-01	3.0E+00	1.0E+00	6.0E+01	9.1E+01	1.2E+02
NOx	4	2.9E-01	3.5E+00	1.8E+00	6.8E+01	1.0E+02	1.4E+02
NOx	5	2.2E-01	2.8E+00	8.9E-01	7.8E+01	1.2E+02	1.5E+02
NOx	6	2.9E-01	3.7E+00	2.5E+00	5.9E+01	7.9E+01	9.5E+01
NOx	7	2.8E-01	3.8E+00	1.6E+00	7.9E+01	1.2E+02	1.5E+02
NOx	8	2.3E-01	2.8E+00	2.2E+00	3.8E+01	5.6E+01	7.3E+01
NOx	9	3.6E-01	3.8E+00	4.4E+00	4.1E+01	6.5E+01	8.8E+01
NOx	10	3.5E-01	3.6E+00	3.1E+00	4.2E+01	5.4E+01	6.4E+01
NOx	11	5.4E-01	6.1E+00	6.4E+00	4.4E+01	5.6E+01	6.7E+01
NOx	13	2.1E-01	2.0E+00	1.7E+00	3.1E+01	4.7E+01	6.1E+01
NOx	14	4.7E-01	4.7E+00	4.7E+00	7.5E+01	1.1E+02	1.4E+02
NOx	15	4.6E-01	5.8E+00	4.1E+00	6.2E+01	9.3E+01	1.2E+02
NOx	16	6.8E-01	8.3E+00	1.0E+01	4.5E+01	5.8E+01	6.9E+01
CO	1	5.7E-01	5.3E+00	4.2E+00	6.7E+01	9.5E+01	1.2E+02
CO	2	5.5E-01	5.4E+00	4.3E+00	7.0E+01	1.0E+02	1.3E+02
CO	3	4.1E-01	3.8E+00	2.3E+00	8.7E+01	1.2E+02	1.4E+02
CO	4	5.1E-01	4.8E+00	3.3E+00	6.0E+01	8.0E+01	9.7E+01
CO	5	3.4E-01	3.4E+00	1.3E+00	7.0E+01	9.4E+01	1.1E+02
CO	6	5.0E-01	5.5E+00	3.8E+00	7.9E+01	1.1E+02	1.3E+02
CO	7	3.3E-01	3.3E+00	1.8E+00	4.6E+01	6.8E+01	8.9E+01
CO	8	3.0E-01	3.4E+00	2.6E+00	4.1E+01	6.1E+01	8.0E+01
CO	9	5.1E-01	4.4E+00	5.5E+00	5.5E+01	8.4E+01	1.1E+02
CO	10	4.3E-01	3.5E+00	4.1E+00	6.4E+01	9.9E+01	1.3E+02
CO	11	7.0E-01	5.8E+00	8.1E+00	6.9E+01	1.1E+02	1.5E+02
CO	13	3.0E-01	2.6E+00	3.3E+00	4.0E+01	6.0E+01	7.9E+01
CO	14	6.9E-01	5.8E+00	7.3E+00	1.1E+02	1.6E+02	2.1E+02
CO	15	7.8E-01	8.5E+00	5.5E+00	1.1E+02	1.6E+02	2.2E+02
CO	16	1.1E+00	1.1E+01	1.4E+01	7.7E+01	1.2E+02	1.6E+02
SO2	1	3.3E-02	5.1E-01	3.7E-01	7.2E+00	1.1E+01	1.5E+01
SO2	2	3.1E-02	5.0E-01	3.7E-01	6.8E+00	9.3E+00	1.1E+01
SO2	3	2.4E-02	3.5E-01	1.8E-01	1.0E+01	1.5E+01	2.0E+01
SO2	4	3.1E-02	5.1E-01	2.8E-01	1.1E+01	1.7E+01	2.3E+01
SO2	5	2.1E-02	3.5E-01	1.0E-01	1.1E+01	1.6E+01	2.1E+01

Chemical species *(Case 6 – Cogeneration)*	**Site**	**Annual average** ($\mu g\ m^{-3}$)	**95th % 24-hr average** ($\mu g\ m^{-3}$)	**95th % 1-hr average** ($\mu g\ m^{-3}$)	**Max. 1-hr average** ($\mu g\ m^{-3}$)	**Max. 10-min average** ($\mu g\ m^{-3}$)	**Max. 3-min average** ($\mu g\ m^{-3}$)
SO2	6	2.9E-02	4.3E-01	3.7E-01	1.0E+01	1.4E+01	1.7E+01
SO2	7	2.4E-02	5.1E-01	1.8E-01	1.0E+01	1.5E+01	2.0E+01
SO2	8	1.9E-02	3.7E-01	2.4E-01	5.7E+00	7.9E+00	9.9E+00
SO2	9	3.1E-02	4.5E-01	5.2E-01	6.0E+00	9.0E+00	1.2E+01
SO2	10	2.6E-02	3.6E-01	3.6E-01	6.3E+00	9.6E+00	1.3E+01
SO2	11	4.2E-02	6.3E-01	7.8E-01	5.7E+00	8.9E+00	1.2E+01
SO2	13	1.7E-02	2.2E-01	2.3E-01	4.5E+00	6.6E+00	8.6E+00
SO2	14	4.0E-02	5.9E-01	5.7E-01	1.1E+01	1.7E+01	2.2E+01
SO2	15	4.5E-02	7.0E-01	5.2E-01	1.2E+01	1.7E+01	2.3E+01
SO2	16	6.8E-02	1.1E+00	1.5E+00	7.5E+00	1.1E+01	1.5E+01
Dust	1	1.2E-02	1.4E-01	8.7E-02	2.3E+00	3.6E+00	4.9E+00
Dust	2	1.3E-02	1.7E-01	9.1E-02	3.0E+00	4.6E+00	6.2E+00
Dust	3	8.5E-03	1.2E-01	6.1E-02	2.9E+00	3.9E+00	4.8E+00
Dust	4	1.1E-02	1.4E-01	7.8E-02	2.4E+00	3.7E+00	4.9E+00
Dust	5	7.2E-03	9.9E-02	4.2E-02	2.1E+00	2.8E+00	3.5E+00
Dust	6	1.1E-02	1.5E-01	8.8E-02	3.1E+00	4.7E+00	6.4E+00
Dust	7	6.8E-03	8.5E-02	6.2E-02	1.8E+00	2.7E+00	3.5E+00
Dust	8	7.5E-03	1.1E-01	8.2E-02	1.5E+00	2.2E+00	2.8E+00
Dust	9	1.3E-02	1.6E-01	1.8E-01	2.4E+00	3.7E+00	4.9E+00
Dust	10	1.2E-02	1.4E-01	1.3E-01	3.3E+00	5.2E+00	7.0E+00
Dust	11	2.0E-02	2.4E-01	2.3E-01	3.7E+00	5.8E+00	7.9E+00
Dust	13	7.5E-03	9.3E-02	9.5E-02	1.8E+00	2.7E+00	3.7E+00
Dust	14	1.7E-02	2.1E-01	2.3E-01	2.6E+00	3.9E+00	5.1E+00
Dust	15	1.7E-02	2.6E-01	1.4E-01	4.2E+00	6.6E+00	8.9E+00
Dust	16	2.9E-02	4.3E-01	4.0E-01	3.0E+00	4.6E+00	6.2E+00
Arsenic	1	1.9E-05	1.3E-04	6.6E-05	3.0E-03	4.3E-03	5.4E-03
Arsenic	2	2.2E-05	1.2E-04	6.5E-05	3.3E-03	5.1E-03	6.8E-03
Arsenic	3	1.5E-05	9.6E-05	3.7E-05	2.9E-03	4.0E-03	4.9E-03
Arsenic	4	1.8E-05	1.2E-04	6.2E-05	3.7E-03	5.6E-03	7.5E-03
Arsenic	5	1.5E-05	9.2E-05	3.0E-05	4.1E-03	6.3E-03	8.4E-03
Arsenic	6	2.2E-05	1.1E-04	7.4E-05	4.2E-03	5.8E-03	7.2E-03
Arsenic	7	1.9E-05	1.4E-04	3.3E-05	5.5E-03	8.5E-03	1.1E-02
Arsenic	8	1.3E-05	8.1E-05	4.5E-05	1.5E-03	2.3E-03	3.0E-03
Arsenic	9	2.0E-05	1.1E-04	9.9E-05	2.0E-03	3.0E-03	4.1E-03
Arsenic	10	1.9E-05	9.8E-05	9.7E-05	2.0E-03	3.2E-03	4.3E-03
Arsenic	11	3.0E-05	1.9E-04	2.0E-04	2.4E-03	4.1E-03	5.8E-03
Arsenic	13	1.1E-05	5.7E-05	4.7E-05	1.5E-03	2.3E-03	3.2E-03
Arsenic	14	2.9E-05	1.6E-04	1.4E-04	3.5E-03	5.4E-03	7.2E-03
Arsenic	15	3.2E-05	2.1E-04	1.1E-04	6.4E-03	9.7E-03	1.3E-02

Chemical species *(Case 6 – Cogeneration)*	**Site**	**Annual average** ($\mu g\ m^{-3}$)	**95th % 24-hr average** ($\mu g\ m^{-3}$)	**95th % 1-hr average** ($\mu g\ m^{-3}$)	**Max. 1-hr average** ($\mu g\ m^{-3}$)	**Max. 10-min average** ($\mu g\ m^{-3}$)	**Max. 3-min average** ($\mu g\ m^{-3}$)
Arsenic	16	4.0E-05	2.5E-04	2.9E-04	2.3E-03	3.9E-03	5.6E-03
Selenium	1	1.9E-05	1.2E-04	8.9E-05	2.5E-03	3.6E-03	4.6E-03
Selenium	2	2.1E-05	1.4E-04	7.9E-05	2.8E-03	4.2E-03	5.5E-03
Selenium	3	1.4E-05	7.6E-05	5.5E-05	2.1E-03	2.9E-03	3.5E-03
Selenium	4	1.7E-05	9.9E-05	9.0E-05	2.0E-03	2.7E-03	3.3E-03
Selenium	5	1.0E-05	6.4E-05	3.7E-05	1.8E-03	2.5E-03	3.1E-03
Selenium	6	1.9E-05	1.4E-04	6.7E-05	2.9E-03	4.1E-03	5.2E-03
Selenium	7	7.8E-06	5.1E-05	3.8E-05	8.4E-04	1.3E-03	1.8E-03
Selenium	8	8.5E-06	5.6E-05	4.5E-05	1.1E-03	1.7E-03	2.2E-03
Selenium	9	1.5E-05	7.9E-05	9.7E-05	1.3E-03	2.0E-03	2.7E-03
Selenium	10	1.5E-05	9.2E-05	9.3E-05	1.4E-03	2.2E-03	3.0E-03
Selenium	11	2.7E-05	1.3E-04	1.9E-04	2.3E-03	3.3E-03	4.1E-03
Selenium	13	1.1E-05	5.9E-05	6.3E-05	9.0E-04	1.4E-03	1.8E-03
Selenium	14	2.4E-05	1.2E-04	1.3E-04	4.1E-03	6.1E-03	8.0E-03
Selenium	15	3.0E-05	2.0E-04	8.1E-05	4.3E-03	6.8E-03	9.2E-03
Selenium	16	4.3E-05	2.1E-04	3.2E-04	3.7E-03	5.1E-03	6.4E-03
Manganese	1	2.0E-04	1.0E-03	5.5E-04	3.2E-02	4.7E-02	6.0E-02
Manganese	2	1.3E-04	7.6E-04	4.3E-04	1.7E-02	2.6E-02	3.5E-02
Manganese	3	1.6E-04	9.6E-04	3.4E-04	1.8E-02	2.6E-02	3.4E-02
Manganese	4	3.3E-04	2.4E-03	6.7E-04	6.2E-02	9.0E-02	1.2E-01
Manganese	5	1.2E-04	7.9E-04	3.7E-04	1.6E-02	2.3E-02	2.9E-02
Manganese	6	9.5E-05	6.2E-04	3.5E-04	1.4E-02	2.1E-02	2.8E-02
Manganese	7	1.1E-04	6.1E-04	2.7E-04	1.1E-02	1.7E-02	2.2E-02
Manganese	8	9.4E-05	5.8E-04	3.3E-04	1.0E-02	1.4E-02	1.8E-02
Manganese	9	2.2E-04	1.1E-03	9.4E-04	1.8E-02	2.7E-02	3.4E-02
Manganese	10	2.7E-04	1.7E-03	1.1E-03	4.7E-02	6.8E-02	8.8E-02
Manganese	11	6.9E-04	3.4E-03	2.2E-03	1.7E-01	2.4E-01	3.0E-01
Manganese	13	7.1E-05	3.2E-04	4.2E-04	5.3E-03	7.9E-03	1.0E-02
Manganese	14	1.7E-04	8.3E-04	1.1E-03	1.1E-02	1.7E-02	2.3E-02
Manganese	15	1.0E-04	6.4E-04	2.8E-04	1.4E-02	2.2E-02	2.8E-02
Manganese	16	1.1E-03	6.4E-03	3.8E-03	2.9E-01	4.0E-01	5.1E-01
Cadmium	1	3.2E-09	2.0E-08	3.4E-09	5.3E-07	7.6E-07	9.6E-07
Cadmium	2	3.6E-09	1.8E-08	3.5E-09	5.8E-07	9.1E-07	1.2E-06
Cadmium	3	2.6E-09	1.6E-08	1.8E-09	4.8E-07	6.6E-07	8.2E-07
Cadmium	4	3.1E-09	1.9E-08	3.1E-09	6.4E-07	1.0E-06	1.3E-06
Cadmium	5	2.6E-09	1.5E-08	1.9E-09	7.0E-07	1.1E-06	1.5E-06
Cadmium	6	3.8E-09	1.7E-08	4.6E-09	7.1E-07	9.8E-07	1.2E-06
Cadmium	7	3.4E-09	2.2E-08	3.9E-09	9.7E-07	1.5E-06	2.0E-06

Chemical species *(Case 6 – Cogeneration)*	**Site**	**Annual average** ($\mu g\ m^{-3}$)	**95th % 24-hr average** ($\mu g\ m^{-3}$)	**95th % 1-hr average** ($\mu g\ m^{-3}$)	**Max. 1-hr average** ($\mu g\ m^{-3}$)	**Max. 10-min average** ($\mu g\ m^{-3}$)	**Max. 3-min average** ($\mu g\ m^{-3}$)
Cadmium	8	2.2E-09	1.3E-08	5.9E-09	2.5E-07	4.0E-07	5.4E-07
Cadmium	9	3.5E-09	1.8E-08	1.4E-08	3.4E-07	5.3E-07	7.2E-07
Cadmium	10	3.2E-09	1.5E-08	1.0E-08	3.6E-07	5.6E-07	7.6E-07
Cadmium	11	5.2E-09	3.1E-08	2.3E-08	4.3E-07	7.3E-07	1.1E-06
Cadmium	13	1.9E-09	9.1E-09	5.0E-09	2.4E-07	3.9E-07	5.3E-07
Cadmium	14	4.9E-09	2.6E-08	1.8E-08	5.9E-07	9.2E-07	1.2E-06
Cadmium	15	5.3E-09	3.3E-08	6.9E-09	1.1E-06	1.7E-06	2.3E-06
Cadmium	16	6.9E-09	4.1E-08	3.4E-08	4.1E-07	7.0E-07	1.0E-06
Chromium (VI)	1	1.3E-07	7.6E-07	2.7E-07	1.6E-05	2.3E-05	2.8E-05
Chromium (VI)	2	1.5E-07	8.8E-07	3.3E-07	1.9E-05	2.8E-05	3.7E-05
Chromium (VI)	3	1.0E-07	7.1E-07	1.3E-07	1.7E-05	2.4E-05	2.9E-05
Chromium (VI)	4	1.3E-07	7.8E-07	1.9E-07	1.9E-05	2.9E-05	3.8E-05
Chromium (VI)	5	9.7E-08	6.1E-07	1.2E-07	2.2E-05	3.3E-05	4.3E-05
Chromium (VI)	6	1.5E-07	8.7E-07	4.0E-07	2.4E-05	3.3E-05	4.0E-05
Chromium (VI)	7	1.2E-07	7.7E-07	2.2E-07	2.9E-05	4.4E-05	5.7E-05
Chromium (VI)	8	9.2E-08	6.1E-07	3.4E-07	7.9E-06	1.2E-05	1.5E-05
Chromium (VI)	9	1.5E-07	8.1E-07	8.2E-07	1.0E-05	1.5E-05	2.0E-05
Chromium (VI)	10	1.4E-07	7.1E-07	5.7E-07	1.2E-05	1.8E-05	2.3E-05
Chromium (VI)	11	2.3E-07	1.5E-06	1.3E-06	1.3E-05	2.1E-05	2.9E-05
Chromium (VI)	13	8.3E-08	4.6E-07	2.6E-07	1.0E-05	1.6E-05	2.1E-05
Chromium (VI)	14	2.0E-07	1.1E-06	8.6E-07	2.1E-05	3.1E-05	4.1E-05
Chromium (VI)	15	2.1E-07	1.4E-06	6.1E-07	3.4E-05	5.0E-05	6.5E-05
Chromium (VI)	16	3.0E-07	2.0E-06	2.2E-06	1.2E-05	2.0E-05	2.7E-05
Nickel	1	7.6E-06	4.1E-05	3.7E-05	1.0E-03	1.5E-03	1.9E-03
Nickel	2	5.4E-06	3.7E-05	2.7E-05	5.5E-04	8.2E-04	1.1E-03
Nickel	3	5.8E-06	4.1E-05	2.2E-05	5.5E-04	8.2E-04	1.1E-03
Nickel	4	1.2E-05	7.5E-05	3.8E-05	2.0E-03	2.8E-03	3.6E-03
Nickel	5	4.8E-06	3.4E-05	2.0E-05	6.6E-04	9.9E-04	1.3E-03
Nickel	6	4.3E-06	3.1E-05	2.4E-05	6.7E-04	9.1E-04	1.1E-03
Nickel	7	4.6E-06	3.1E-05	1.7E-05	1.0E-03	1.5E-03	2.0E-03
Nickel	8	3.8E-06	2.5E-05	2.0E-05	3.2E-04	4.8E-04	6.2E-04
Nickel	9	8.0E-06	4.0E-05	5.0E-05	5.7E-04	8.3E-04	1.1E-03
Nickel	10	9.7E-06	6.4E-05	6.0E-05	1.5E-03	2.1E-03	2.7E-03
Nickel	11	2.3E-05	1.1E-04	1.3E-04	5.2E-03	7.4E-03	9.4E-03
Nickel	13	2.9E-06	1.7E-05	2.5E-05	2.5E-04	3.8E-04	5.0E-04
Nickel	14	7.1E-06	4.3E-05	6.5E-05	5.6E-04	8.4E-04	1.1E-03
Nickel	15	5.1E-06	4.2E-05	2.0E-05	1.2E-03	1.8E-03	2.3E-03
Nickel	16	3.8E-05	2.0E-04	1.8E-04	9.1E-03	1.3E-02	1.6E-02

Chemical species *(Case 6 – Cogeneration)*	**Site**	**Annual average** ($\mu g\ m^{-3}$)	**95th % 24-hr average** ($\mu g\ m^{-3}$)	**95th % 1-hr average** ($\mu g\ m^{-3}$)	**Max. 1-hr average** ($\mu g\ m^{-3}$)	**Max. 10-min average** ($\mu g\ m^{-3}$)	**Max. 3-min average** ($\mu g\ m^{-3}$)
Mercury	1	6.6E-05	3.9E-04	2.9E-04	6.8E-03	1.0E-02	1.4E-02
Mercury	2	5.5E-05	3.0E-04	2.7E-04	4.7E-03	7.3E-03	9.9E-03
Mercury	3	4.9E-05	2.5E-04	2.1E-04	4.7E-03	7.1E-03	9.4E-03
Mercury	4	7.0E-05	3.4E-04	2.9E-04	6.4E-03	9.8E-03	1.3E-02
Mercury	5	4.0E-05	2.2E-04	1.3E-04	6.2E-03	9.1E-03	1.2E-02
Mercury	6	4.9E-05	2.6E-04	2.3E-04	4.0E-03	5.5E-03	6.9E-03
Mercury	7	4.1E-05	2.5E-04	1.1E-04	5.5E-03	8.3E-03	1.1E-02
Mercury	8	3.3E-05	1.9E-04	1.3E-04	3.7E-03	5.1E-03	6.3E-03
Mercury	9	6.1E-05	2.7E-04	3.2E-04	5.3E-03	7.7E-03	9.8E-03
Mercury	10	5.4E-05	2.6E-04	3.1E-04	6.5E-03	9.9E-03	1.3E-02
Mercury	11	1.1E-04	4.7E-04	6.6E-04	1.2E-02	1.7E-02	2.1E-02
Mercury	13	2.9E-05	1.4E-04	1.8E-04	1.8E-03	2.7E-03	3.5E-03
Mercury	14	6.8E-05	2.9E-04	3.9E-04	4.6E-03	7.0E-03	9.3E-03
Mercury	15	6.9E-05	3.8E-04	1.8E-04	5.9E-03	8.9E-03	1.2E-02
Mercury	16	1.8E-04	8.9E-04	1.2E-03	2.0E-02	2.7E-02	3.4E-02
Ammonia	1	7.8E-03	3.9E-02	2.6E-02	1.0E+00	1.5E+00	1.9E+00
Ammonia	2	5.4E-03	3.2E-02	1.9E-02	6.3E-01	9.4E-01	1.2E+00
Ammonia	3	5.9E-03	4.1E-02	1.8E-02	5.5E-01	8.1E-01	1.1E+00
Ammonia	4	1.2E-02	8.1E-02	3.5E-02	1.5E+00	2.1E+00	2.8E+00
Ammonia	5	4.8E-03	3.1E-02	1.7E-02	4.3E-01	6.2E-01	7.9E-01
Ammonia	6	4.3E-03	2.4E-02	1.7E-02	5.0E-01	7.4E-01	9.6E-01
Ammonia	7	5.3E-03	3.1E-02	1.4E-02	5.8E-01	8.7E-01	1.1E+00
Ammonia	8	4.5E-03	2.6E-02	1.6E-02	4.6E-01	6.3E-01	7.8E-01
Ammonia	9	9.6E-03	4.3E-02	4.7E-02	7.3E-01	1.1E+00	1.3E+00
Ammonia	10	1.1E-02	6.6E-02	5.2E-02	1.7E+00	2.4E+00	3.1E+00
Ammonia	11	2.6E-02	1.3E-01	1.1E-01	5.0E+00	7.1E+00	9.0E+00
Ammonia	13	3.0E-03	1.4E-02	1.9E-02	1.9E-01	2.8E-01	3.6E-01
Ammonia	14	7.2E-03	3.0E-02	5.1E-02	3.6E-01	5.4E-01	7.1E-01
Ammonia	15	5.0E-03	2.9E-02	1.4E-02	7.5E-01	1.1E+00	1.4E+00
Ammonia	16	4.7E-02	2.3E-01	2.1E-01	8.2E+00	1.1E+01	1.4E+01
BaP Equivalents	1	6.9E-07	3.9E-06	1.8E-06	5.8E-05	8.5E-05	1.1E-04
BaP Equivalents	2	4.2E-07	2.5E-06	1.3E-06	4.6E-05	7.0E-05	9.2E-05
BaP Equivalents	3	4.1E-07	2.6E-06	1.0E-06	4.4E-05	6.3E-05	8.1E-05
BaP Equivalents	4	7.8E-07	4.8E-06	2.2E-06	1.1E-04	1.7E-04	2.2E-04
BaP Equivalents	5	3.5E-07	2.4E-06	9.1E-07	3.6E-05	5.0E-05	6.4E-05
BaP Equivalents	6	3.0E-07	1.7E-06	9.9E-07	3.5E-05	5.2E-05	6.9E-05
BaP Equivalents	7	2.8E-07	1.6E-06	7.7E-07	3.9E-05	5.7E-05	7.3E-05
BaP Equivalents	8	2.3E-07	1.3E-06	8.5E-07	2.3E-05	3.2E-05	4.1E-05
BaP Equivalents	9	5.2E-07	2.3E-06	2.3E-06	3.9E-05	5.5E-05	7.1E-05

Chemical species *(Case 6 – Cogeneration)*	**Site**	**Annual average** ($\mu g\ m^{-3}$)	**95th % 24-hr average** ($\mu g\ m^{-3}$)	**95th % 1-hr average** ($\mu g\ m^{-3}$)	**Max. 1-hr average** ($\mu g\ m^{-3}$)	**Max. 10-min average** ($\mu g\ m^{-3}$)	**Max. 3-min average** ($\mu g\ m^{-3}$)
BaP Equivalents	10	5.8E-07	3.4E-06	2.6E-06	6.4E-05	9.3E-05	1.2E-04
BaP Equivalents	11	1.2E-06	6.0E-06	5.1E-06	1.3E-04	1.9E-04	2.4E-04
BaP Equivalents	13	1.8E-07	7.9E-07	1.1E-06	1.2E-05	1.8E-05	2.4E-05
BaP Equivalents	14	4.4E-07	1.9E-06	2.7E-06	2.7E-05	4.0E-05	5.1E-05
BaP Equivalents	15	3.4E-07	2.3E-06	1.0E-06	3.3E-05	5.0E-05	6.6E-05
BaP Equivalents	16	2.2E-06	1.1E-05	9.3E-06	2.3E-04	3.3E-04	4.1E-04
Acetone	1	2.6E-02	1.2E-01	1.3E-01	1.4E+00	2.2E+00	2.8E+00
Acetone	2	1.8E-02	9.0E-02	8.9E-02	1.7E+00	2.5E+00	3.3E+00
Acetone	3	1.8E-02	9.7E-02	8.2E-02	1.4E+00	2.1E+00	2.8E+00
Acetone	4	3.2E-02	1.9E-01	1.7E-01	3.3E+00	4.6E+00	5.9E+00
Acetone	5	1.7E-02	1.0E-01	6.9E-02	1.6E+00	2.4E+00	3.1E+00
Acetone	6	1.4E-02	7.1E-02	6.9E-02	1.2E+00	1.8E+00	2.4E+00
Acetone	7	1.4E-02	8.0E-02	5.7E-02	9.5E-01	1.4E+00	1.9E+00
Acetone	8	1.1E-02	5.7E-02	5.9E-02	7.5E-01	1.1E+00	1.5E+00
Acetone	9	2.1E-02	8.3E-02	1.3E-01	1.1E+00	1.6E+00	2.0E+00
Acetone	10	2.1E-02	1.1E-01	1.3E-01	1.8E+00	2.6E+00	3.2E+00
Acetone	11	4.2E-02	2.0E-01	2.7E-01	3.0E+00	4.3E+00	5.5E+00
Acetone	13	7.6E-03	3.4E-02	5.8E-02	4.6E-01	6.9E-01	9.1E-01
Acetone	14	1.8E-02	8.3E-02	1.3E-01	9.1E-01	1.3E+00	1.7E+00
Acetone	15	1.8E-02	1.0E-01	7.7E-02	1.5E+00	2.2E+00	2.9E+00
Acetone	16	7.4E-02	3.2E-01	4.7E-01	5.7E+00	8.0E+00	1.0E+01
Acetaldehyde	1	6.0E-03	3.2E-02	3.6E-02	2.7E-01	4.5E-01	6.3E-01
Acetaldehyde	2	4.8E-03	2.3E-02	2.4E-02	3.6E-01	5.5E-01	7.4E-01
Acetaldehyde	3	4.2E-03	2.1E-02	2.5E-02	2.9E-01	4.4E-01	5.7E-01
Acetaldehyde	4	7.4E-03	3.6E-02	5.2E-02	4.2E-01	6.0E-01	7.5E-01
Acetaldehyde	5	3.7E-03	2.0E-02	2.2E-02	2.3E-01	3.5E-01	4.7E-01
Acetaldehyde	6	3.8E-03	2.0E-02	1.9E-02	3.6E-01	5.4E-01	7.2E-01
Acetaldehyde	7	3.6E-03	1.9E-02	2.2E-02	3.4E-01	5.0E-01	6.4E-01
Acetaldehyde	8	3.2E-03	1.6E-02	2.2E-02	1.6E-01	2.4E-01	3.2E-01
Acetaldehyde	9	6.1E-03	2.5E-02	4.6E-02	2.7E-01	3.9E-01	4.9E-01
Acetaldehyde	10	6.4E-03	3.4E-02	4.5E-02	5.0E-01	7.2E-01	9.1E-01
Acetaldehyde	11	1.3E-02	5.6E-02	1.0E-01	1.1E+00	1.6E+00	2.0E+00
Acetaldehyde	13	2.6E-03	1.2E-02	1.7E-02	2.0E-01	2.9E-01	3.8E-01
Acetaldehyde	14	5.8E-03	2.7E-02	4.1E-02	2.9E-01	4.5E-01	6.1E-01
Acetaldehyde	15	5.2E-03	2.8E-02	2.5E-02	5.3E-01	8.2E-01	1.1E+00
Acetaldehyde	16	2.2E-02	1.1E-01	1.5E-01	1.9E+00	2.6E+00	3.3E+00
Formaldehyde	1	3.1E-03	1.8E-02	6.3E-03	2.9E-01	4.9E-01	6.9E-01
Formaldehyde	2	3.4E-03	2.0E-02	5.1E-03	3.7E-01	5.8E-01	7.8E-01

Chemical species *(Case 6 – Cogeneration)*	**Site**	**Annual average** ($\mu g\ m^{-3}$)	**95th % 24-hr average** ($\mu g\ m^{-3}$)	**95th % 1-hr average** ($\mu g\ m^{-3}$)	**Max. 1-hr average** ($\mu g\ m^{-3}$)	**Max. 10-min average** ($\mu g\ m^{-3}$)	**Max. 3-min average** ($\mu g\ m^{-3}$)
Formaldehyde	3	2.3E-03	1.4E-02	3.9E-03	3.2E-01	4.9E-01	6.5E-01
Formaldehyde	4	3.3E-03	1.8E-02	8.0E-03	3.3E-01	5.0E-01	6.7E-01
Formaldehyde	5	2.2E-03	1.5E-02	3.7E-03	2.6E-01	4.0E-01	5.4E-01
Formaldehyde	6	2.9E-03	1.8E-02	5.1E-03	3.8E-01	5.9E-01	7.9E-01
Formaldehyde	7	2.3E-03	1.4E-02	8.4E-03	3.3E-01	4.9E-01	6.3E-01
Formaldehyde	8	2.3E-03	1.5E-02	1.0E-02	2.0E-01	2.6E-01	3.1E-01
Formaldehyde	9	3.6E-03	2.2E-02	2.0E-02	2.7E-01	3.6E-01	4.2E-01
Formaldehyde	10	3.6E-03	2.0E-02	1.3E-02	4.2E-01	6.5E-01	8.8E-01
Formaldehyde	11	5.8E-03	3.0E-02	2.7E-02	4.2E-01	6.6E-01	9.0E-01
Formaldehyde	13	2.0E-03	1.2E-02	5.7E-03	2.3E-01	3.4E-01	4.4E-01
Formaldehyde	14	4.4E-03	2.6E-02	1.7E-02	3.4E-01	5.4E-01	7.3E-01
Formaldehyde	15	4.5E-03	2.6E-02	9.1E-03	6.1E-01	9.4E-01	1.3E+00
Formaldehyde	16	8.0E-03	5.3E-02	4.9E-02	3.5E-01	5.5E-01	7.5E-01
2-Butanone	1	3.2E-03	1.6E-02	1.5E-02	1.9E-01	2.8E-01	3.6E-01
2-Butanone	2	2.1E-03	1.1E-02	9.1E-03	1.9E-01	2.9E-01	3.9E-01
2-Butanone	3	2.1E-03	1.2E-02	9.0E-03	1.6E-01	2.5E-01	3.3E-01
2-Butanone	4	3.7E-03	2.2E-02	1.9E-02	3.8E-01	5.6E-01	7.3E-01
2-Butanone	5	1.9E-03	1.1E-02	8.1E-03	1.8E-01	2.6E-01	3.4E-01
2-Butanone	6	1.6E-03	8.5E-03	7.0E-03	1.2E-01	1.8E-01	2.4E-01
2-Butanone	7	1.8E-03	9.8E-03	6.7E-03	1.4E-01	2.0E-01	2.6E-01
2-Butanone	8	1.3E-03	6.8E-03	6.7E-03	7.9E-02	1.1E-01	1.4E-01
2-Butanone	9	2.6E-03	1.1E-02	1.5E-02	1.4E-01	2.0E-01	2.5E-01
2-Butanone	10	2.6E-03	1.5E-02	1.6E-02	2.2E-01	3.2E-01	4.1E-01
2-Butanone	11	5.3E-03	2.4E-02	3.2E-02	4.5E-01	6.5E-01	8.3E-01
2-Butanone	13	9.1E-04	4.1E-03	6.8E-03	5.4E-02	8.1E-02	1.1E-01
2-Butanone	14	2.1E-03	1.0E-02	1.6E-02	1.1E-01	1.6E-01	2.1E-01
2-Butanone	15	2.1E-03	1.3E-02	8.3E-03	1.7E-01	2.6E-01	3.4E-01
2-Butanone	16	9.4E-03	4.4E-02	5.3E-02	8.3E-01	1.2E+00	1.5E+00
Benzene	1	6.8E-04	3.7E-03	2.1E-03	7.1E-02	1.1E-01	1.5E-01
Benzene	2	6.3E-04	3.0E-03	1.9E-03	7.4E-02	1.1E-01	1.5E-01
Benzene	3	5.2E-04	2.8E-03	1.0E-03	7.9E-02	1.2E-01	1.6E-01
Benzene	4	7.2E-04	3.7E-03	2.1E-03	9.4E-02	1.4E-01	1.9E-01
Benzene	5	5.2E-04	2.5E-03	8.5E-04	8.9E-02	1.3E-01	1.7E-01
Benzene	6	5.6E-04	2.8E-03	2.0E-03	5.6E-02	8.6E-02	1.1E-01
Benzene	7	5.3E-04	3.7E-03	1.4E-03	5.0E-02	7.6E-02	9.9E-02
Benzene	8	3.9E-04	2.5E-03	1.7E-03	4.3E-02	6.4E-02	8.4E-02
Benzene	9	6.1E-04	3.1E-03	3.7E-03	4.1E-02	6.0E-02	7.8E-02
Benzene	10	5.2E-04	2.8E-03	2.4E-03	4.7E-02	7.2E-02	9.5E-02
Benzene	11	8.5E-04	4.0E-03	4.9E-03	4.4E-02	6.9E-02	9.5E-02

Chemical species *(Case 6 – Cogeneration)*	**Site**	**Annual average** ($\mu g\ m^{-3}$)	**95th % 24-hr average** ($\mu g\ m^{-3}$)	**95th % 1-hr average** ($\mu g\ m^{-3}$)	**Max. 1-hr average** ($\mu g\ m^{-3}$)	**Max. 10-min average** ($\mu g\ m^{-3}$)	**Max. 3-min average** ($\mu g\ m^{-3}$)
Benzene	13	3.0E-04	1.5E-03	1.4E-03	2.9E-02	4.3E-02	5.7E-02
Benzene	14	6.8E-04	3.5E-03	3.7E-03	4.9E-02	7.2E-02	9.3E-02
Benzene	15	9.0E-04	5.4E-03	3.0E-03	8.6E-02	1.3E-01	1.7E-01
Benzene	16	1.3E-03	7.0E-03	9.4E-03	5.1E-02	7.8E-02	1.0E-01
Toluene	1	5.8E-04	3.0E-03	2.6E-03	6.5E-02	1.0E-01	1.4E-01
Toluene	2	4.4E-04	2.0E-03	1.8E-03	7.0E-02	1.1E-01	1.5E-01
Toluene	3	4.4E-04	2.1E-03	1.6E-03	6.7E-02	1.0E-01	1.4E-01
Toluene	4	6.8E-04	3.1E-03	3.4E-03	8.9E-02	1.4E-01	1.8E-01
Toluene	5	4.5E-04	1.9E-03	1.3E-03	8.5E-02	1.3E-01	1.6E-01
Toluene	6	3.7E-04	1.7E-03	1.5E-03	4.5E-02	7.0E-02	9.5E-02
Toluene	7	4.6E-04	3.2E-03	1.5E-03	4.3E-02	6.1E-02	7.8E-02
Toluene	8	3.0E-04	1.9E-03	1.6E-03	3.3E-02	5.0E-02	6.7E-02
Toluene	9	5.0E-04	2.2E-03	3.1E-03	3.5E-02	5.3E-02	6.9E-02
Toluene	10	4.3E-04	1.9E-03	2.6E-03	4.0E-02	6.1E-02	8.2E-02
Toluene	11	7.6E-04	3.6E-03	5.6E-03	4.6E-02	7.1E-02	9.4E-02
Toluene	13	1.9E-04	9.5E-04	1.0E-03	1.6E-02	2.5E-02	3.3E-02
Toluene	14	4.4E-04	2.1E-03	2.6E-03	2.9E-02	4.4E-02	5.8E-02
Toluene	15	5.8E-04	3.2E-03	1.8E-03	6.6E-02	1.0E-01	1.4E-01
Toluene	16	1.3E-03	5.5E-03	9.3E-03	6.0E-02	8.3E-02	1.0E-01
Xylenes	1	3.0E-05	1.7E-04	9.1E-05	2.9E-03	4.4E-03	5.8E-03
Xylenes	2	3.3E-05	2.0E-04	8.1E-05	3.0E-03	5.0E-03	7.0E-03
Xylenes	3	2.2E-05	1.3E-04	6.4E-05	2.8E-03	4.2E-03	5.6E-03
Xylenes	4	3.2E-05	1.7E-04	1.1E-04	3.6E-03	5.3E-03	6.9E-03
Xylenes	5	2.0E-05	1.1E-04	5.4E-05	2.5E-03	3.9E-03	5.1E-03
Xylenes	6	2.9E-05	1.8E-04	6.8E-05	3.1E-03	4.8E-03	6.5E-03
Xylenes	7	2.3E-05	1.4E-04	7.4E-05	3.2E-03	4.7E-03	6.2E-03
Xylenes	8	2.4E-05	1.6E-04	9.3E-05	2.3E-03	3.0E-03	3.6E-03
Xylenes	9	3.9E-05	2.5E-04	1.9E-04	3.0E-03	3.8E-03	4.6E-03
Xylenes	10	4.2E-05	2.5E-04	1.9E-04	3.8E-03	5.9E-03	7.9E-03
Xylenes	11	6.9E-05	3.7E-04	3.8E-04	3.6E-03	5.7E-03	7.7E-03
Xylenes	13	2.4E-05	1.3E-04	6.8E-05	2.4E-03	3.5E-03	4.6E-03
Xylenes	14	5.0E-05	3.0E-04	1.9E-04	3.8E-03	5.9E-03	8.0E-03
Xylenes	15	4.4E-05	2.5E-04	1.2E-04	5.4E-03	8.0E-03	1.0E-02
Xylenes	16	8.7E-05	5.1E-04	5.9E-04	3.7E-03	5.2E-03	6.6E-03
Acrolein	1	2.6E-04	1.5E-03	2.6E-04	3.0E-02	5.0E-02	7.1E-02
Acrolein	2	3.0E-04	1.9E-03	2.7E-04	3.6E-02	5.6E-02	7.5E-02
Acrolein	3	1.8E-04	1.3E-03	1.7E-04	3.0E-02	4.6E-02	6.2E-02
Acrolein	4	2.6E-04	1.7E-03	3.0E-04	3.4E-02	5.0E-02	6.6E-02

Chemical species *(Case 6 – Cogeneration)*	**Site**	**Annual average** ($\mu g\ m^{-3}$)	**95th % 24-hr average** ($\mu g\ m^{-3}$)	**95th % 1-hr average** ($\mu g\ m^{-3}$)	**Max. 1-hr average** ($\mu g\ m^{-3}$)	**Max. 10-min average** ($\mu g\ m^{-3}$)	**Max. 3-min average** ($\mu g\ m^{-3}$)
Acrolein	5	1.6E-04	1.1E-03	1.9E-04	2.5E-02	3.9E-02	5.2E-02
Acrolein	6	2.6E-04	1.8E-03	2.2E-04	4.1E-02	6.3E-02	8.4E-02
Acrolein	7	1.7E-04	1.1E-03	3.3E-04	3.6E-02	5.3E-02	6.9E-02
Acrolein	8	2.0E-04	1.3E-03	6.8E-04	2.1E-02	3.3E-02	4.3E-02
Acrolein	9	3.2E-04	2.1E-03	1.4E-03	2.8E-02	3.6E-02	4.3E-02
Acrolein	10	3.4E-04	2.0E-03	1.1E-03	4.5E-02	7.0E-02	9.5E-02
Acrolein	11	5.5E-04	2.9E-03	2.0E-03	4.7E-02	7.3E-02	1.0E-01
Acrolein	13	1.9E-04	1.2E-03	4.8E-04	2.4E-02	3.5E-02	4.6E-02
Acrolein	14	4.3E-04	2.6E-03	1.5E-03	3.6E-02	5.7E-02	7.8E-02
Acrolein	15	4.0E-04	2.8E-03	3.8E-04	6.7E-02	1.0E-01	1.4E-01
Acrolein	16	7.2E-04	5.0E-03	3.5E-03	3.8E-02	6.0E-02	8.1E-02
Ethylbenzene	1	1.7E-05	9.5E-05	8.1E-05	1.2E-03	1.9E-03	2.6E-03
Ethylbenzene	2	1.8E-05	9.4E-05	7.3E-05	1.5E-03	2.3E-03	3.0E-03
Ethylbenzene	3	1.2E-05	6.6E-05	6.2E-05	1.5E-03	2.0E-03	2.5E-03
Ethylbenzene	4	1.8E-05	8.7E-05	9.1E-05	1.2E-03	1.9E-03	2.7E-03
Ethylbenzene	5	9.9E-06	5.5E-05	4.5E-05	1.2E-03	1.6E-03	2.0E-03
Ethylbenzene	6	1.6E-05	9.9E-05	6.7E-05	1.5E-03	2.3E-03	3.1E-03
Ethylbenzene	7	8.4E-06	4.6E-05	4.5E-05	1.3E-03	1.9E-03	2.5E-03
Ethylbenzene	8	9.6E-06	5.6E-05	5.6E-05	8.3E-04	1.2E-03	1.6E-03
Ethylbenzene	9	1.7E-05	7.8E-05	1.2E-04	1.2E-03	1.9E-03	2.5E-03
Ethylbenzene	10	1.8E-05	8.6E-05	1.1E-04	1.6E-03	2.5E-03	3.3E-03
Ethylbenzene	11	3.3E-05	1.6E-04	2.3E-04	2.8E-03	4.0E-03	5.1E-03
Ethylbenzene	13	1.0E-05	5.2E-05	6.4E-05	8.6E-04	1.3E-03	1.7E-03
Ethylbenzene	14	2.3E-05	1.1E-04	1.4E-04	1.9E-03	2.9E-03	3.7E-03
Ethylbenzene	15	2.4E-05	1.5E-04	9.1E-05	2.2E-03	3.3E-03	4.5E-03
Ethylbenzene	16	4.8E-05	2.3E-04	3.4E-04	4.9E-03	6.8E-03	8.5E-03
Methylene Chloride	1	6.2E-04	3.5E-03	2.5E-03	4.8E-02	7.9E-02	1.1E-01
Methylene Chloride	2	6.7E-04	4.1E-03	2.3E-03	6.1E-02	9.8E-02	1.4E-01
Methylene Chloride	3	4.7E-04	3.0E-03	1.4E-03	6.4E-02	8.6E-02	1.1E-01
Methylene Chloride	4	6.8E-04	3.5E-03	2.7E-03	6.3E-02	9.3E-02	1.2E-01
Methylene Chloride	5	4.3E-04	2.5E-03	1.3E-03	6.8E-02	9.9E-02	1.3E-01
Methylene Chloride	6	6.2E-04	3.9E-03	2.0E-03	7.9E-02	1.1E-01	1.3E-01
Methylene Chloride	7	5.0E-04	2.9E-03	1.7E-03	8.4E-02	1.3E-01	1.6E-01
Methylene Chloride	8	4.4E-04	2.8E-03	2.2E-03	3.2E-02	4.2E-02	5.0E-02
Methylene Chloride	9	7.3E-04	3.9E-03	4.5E-03	4.2E-02	5.4E-02	6.4E-02
Methylene Chloride	10	7.5E-04	4.0E-03	4.0E-03	6.0E-02	9.4E-02	1.3E-01
Methylene Chloride	11	1.3E-03	6.8E-03	8.9E-03	7.6E-02	1.1E-01	1.4E-01
Methylene Chloride	13	3.9E-04	2.3E-03	1.4E-03	4.5E-02	6.7E-02	8.9E-02
Methylene Chloride	14	9.3E-04	4.9E-03	4.1E-03	7.6E-02	1.1E-01	1.4E-01

Chemical species *(Case 6 – Cogeneration)*	**Site**	**Annual average** ($\mu g\ m^{-3}$)	**95th % 24-hr average** ($\mu g\ m^{-3}$)	**95th % 1-hr average** ($\mu g\ m^{-3}$)	**Max. 1-hr average** ($\mu g\ m^{-3}$)	**Max. 10-min average** ($\mu g\ m^{-3}$)	**Max. 3-min average** ($\mu g\ m^{-3}$)
Methylene Chloride	15	9.0E-04	5.7E-03	2.5E-03	9.8E-02	1.4E-01	1.9E-01
Methylene Chloride	16	1.9E-03	9.8E-03	1.4E-02	1.3E-01	1.9E-01	2.3E-01
Styrene	1	4.6E-05	3.1E-04	2.3E-04	3.6E-03	5.5E-03	7.4E-03
Styrene	2	4.3E-05	2.4E-04	1.8E-04	5.1E-03	7.8E-03	1.0E-02
Styrene	3	3.6E-05	2.3E-04	1.7E-04	4.4E-03	6.7E-03	8.9E-03
Styrene	4	5.3E-05	3.8E-04	2.5E-04	8.8E-03	1.3E-02	1.6E-02
Styrene	5	3.4E-05	2.1E-04	1.2E-04	5.5E-03	8.1E-03	1.0E-02
Styrene	6	3.6E-05	2.2E-04	1.7E-04	4.6E-03	6.8E-03	9.0E-03
Styrene	7	3.0E-05	2.4E-04	1.2E-04	3.4E-03	5.1E-03	6.7E-03
Styrene	8	2.4E-05	1.8E-04	1.3E-04	3.0E-03	4.5E-03	5.8E-03
Styrene	9	3.9E-05	2.2E-04	2.8E-04	2.8E-03	4.1E-03	5.3E-03
Styrene	10	3.4E-05	1.8E-04	2.3E-04	3.1E-03	4.8E-03	6.3E-03
Styrene	11	5.7E-05	3.0E-04	4.7E-04	4.7E-03	6.9E-03	9.0E-03
Styrene	13	2.0E-05	1.1E-04	1.4E-04	1.8E-03	2.7E-03	3.6E-03
Styrene	14	4.4E-05	2.2E-04	3.1E-04	3.4E-03	5.0E-03	6.5E-03
Styrene	15	5.8E-05	3.5E-04	1.8E-04	6.4E-03	9.6E-03	1.3E-02
Styrene	16	9.0E-05	6.0E-04	7.5E-04	5.7E-03	8.3E-03	1.1E-02
1-2-4 Trimethylbenzene	1	1.7E-05	8.7E-05	5.1E-05	2.2E-03	3.3E-03	4.2E-03
1-2-4 Trimethylbenzene	2	1.3E-05	8.5E-05	4.2E-05	1.3E-03	1.9E-03	2.6E-03
1-2-4 Trimethylbenzene	3	1.3E-05	7.9E-05	4.0E-05	1.3E-03	1.9E-03	2.4E-03
1-2-4 Trimethylbenzene	4	2.5E-05	1.6E-04	6.0E-05	4.4E-03	6.3E-03	8.1E-03
1-2-4 Trimethylbenzene	5	9.9E-06	6.5E-05	3.4E-05	1.1E-03	1.6E-03	2.0E-03
1-2-4 Trimethylbenzene	6	9.8E-06	6.1E-05	3.6E-05	1.1E-03	1.7E-03	2.2E-03
1-2-4 Trimethylbenzene	7	7.9E-06	4.1E-05	2.5E-05	7.3E-04	1.1E-03	1.4E-03
1-2-4 Trimethylbenzene	8	7.6E-06	4.2E-05	3.1E-05	7.0E-04	1.0E-03	1.3E-03
1-2-4 Trimethylbenzene	9	1.7E-05	7.9E-05	8.2E-05	1.4E-03	2.0E-03	2.5E-03
1-2-4 Trimethylbenzene	10	2.1E-05	1.3E-04	9.6E-05	3.3E-03	4.8E-03	6.1E-03
1-2-4 Trimethylbenzene	11	5.0E-05	2.7E-04	1.8E-04	1.2E-02	1.7E-02	2.1E-02
1-2-4 Trimethylbenzene	13	6.8E-06	3.3E-05	4.5E-05	4.0E-04	5.9E-04	7.8E-04
1-2-4 Trimethylbenzene	14	1.6E-05	6.5E-05	1.1E-04	1.1E-03	1.6E-03	2.1E-03
1-2-4 Trimethylbenzene	15	1.3E-05	8.9E-05	4.2E-05	1.2E-03	1.9E-03	2.5E-03
1-2-4 Trimethylbenzene	16	8.4E-05	4.5E-04	3.1E-04	2.0E-02	2.8E-02	3.5E-02
1-3-5 Trimethylbenzene	1	6.7E-06	2.9E-05	3.0E-05	6.9E-04	1.0E-03	1.3E-03
1-3-5 Trimethylbenzene	2	5.6E-06	3.1E-05	2.7E-05	3.9E-04	5.9E-04	7.9E-04
1-3-5 Trimethylbenzene	3	4.9E-06	2.6E-05	2.5E-05	3.9E-04	5.8E-04	7.5E-04
1-3-5 Trimethylbenzene	4	9.3E-06	5.1E-05	3.5E-05	1.3E-03	2.0E-03	2.5E-03
1-3-5 Trimethylbenzene	5	4.0E-06	2.2E-05	2.1E-05	3.4E-04	4.9E-04	6.2E-04
1-3-5 Trimethylbenzene	6	4.4E-06	2.5E-05	2.3E-05	3.7E-04	5.7E-04	7.6E-04

Chemical species *(Case 6 – Cogeneration)*	**Site**	**Annual average** ($\mu g\ m^{-3}$)	**95th % 24-hr average** ($\mu g\ m^{-3}$)	**95th % 1-hr average** ($\mu g\ m^{-3}$)	**Max. 1-hr average** ($\mu g\ m^{-3}$)	**Max. 10-min average** ($\mu g\ m^{-3}$)	**Max. 3-min average** ($\mu g\ m^{-3}$)
1-3-5 Trimethylbenzene	7	3.4E-06	2.0E-05	2.0E-05	2.8E-04	4.2E-04	5.4E-04
1-3-5 Trimethylbenzene	8	3.5E-06	1.8E-05	2.3E-05	2.2E-04	3.1E-04	3.9E-04
1-3-5 Trimethylbenzene	9	7.1E-06	2.9E-05	4.9E-05	4.2E-04	6.1E-04	7.8E-04
1-3-5 Trimethylbenzene	10	8.3E-06	4.6E-05	5.4E-05	1.0E-03	1.5E-03	1.9E-03
1-3-5 Trimethylbenzene	11	1.9E-05	9.2E-05	1.0E-04	3.6E-03	5.1E-03	6.5E-03
1-3-5 Trimethylbenzene	13	3.2E-06	1.5E-05	2.5E-05	2.0E-04	3.0E-04	4.0E-04
1-3-5 Trimethylbenzene	14	7.2E-06	3.9E-05	5.5E-05	2.9E-04	4.6E-04	6.2E-04
1-3-5 Trimethylbenzene	15	6.0E-06	3.5E-05	3.2E-05	5.0E-04	7.7E-04	1.0E-03
1-3-5 Trimethylbenzene	16	3.0E-05	1.5E-04	1.6E-04	6.3E-03	8.8E-03	1.1E-02
Vinyl chloride	1	1.6E-06	9.9E-06	1.5E-06	1.9E-04	3.2E-04	4.6E-04
Vinyl chloride	2	1.9E-06	1.2E-05	1.7E-06	2.3E-04	3.6E-04	4.8E-04
Vinyl chloride	3	1.1E-06	8.3E-06	1.0E-06	2.0E-04	3.0E-04	4.0E-04
Vinyl chloride	4	1.6E-06	1.1E-05	1.8E-06	2.2E-04	3.2E-04	4.2E-04
Vinyl chloride	5	1.0E-06	6.9E-06	1.1E-06	1.6E-04	2.5E-04	3.4E-04
Vinyl chloride	6	1.6E-06	1.2E-05	1.3E-06	2.6E-04	4.0E-04	5.4E-04
Vinyl chloride	7	1.0E-06	7.4E-06	2.1E-06	2.3E-04	3.4E-04	4.4E-04
Vinyl chloride	8	1.2E-06	8.4E-06	4.3E-06	1.4E-04	2.1E-04	2.8E-04
Vinyl chloride	9	2.0E-06	1.3E-05	8.9E-06	1.8E-04	2.3E-04	2.8E-04
Vinyl chloride	10	2.1E-06	1.3E-05	6.9E-06	2.9E-04	4.5E-04	6.1E-04
Vinyl chloride	11	3.4E-06	1.9E-05	1.3E-05	3.0E-04	4.7E-04	6.4E-04
Vinyl chloride	13	1.2E-06	7.7E-06	3.1E-06	1.5E-04	2.3E-04	2.9E-04
Vinyl chloride	14	2.7E-06	1.7E-05	9.4E-06	2.3E-04	3.7E-04	5.0E-04
Vinyl chloride	15	2.5E-06	1.8E-05	2.3E-06	4.3E-04	6.7E-04	9.0E-04
Vinyl chloride	16	4.5E-06	3.2E-05	2.2E-05	2.4E-04	3.8E-04	5.2E-04
				Shaded values limited by available ozone			
NO2	1	2.9E-01	3.4E+00	2.1E+00	4.2E+01	5.4E+01	5.4E+01
NO2	2	3.0E-01	3.5E+00	2.2E+00	5.2E+01	5.3E+01	5.4E+01
NO2	3	2.3E-01	2.9E+00	1.0E+00	5.4E+01	5.4E+01	5.4E+01
NO2	4	2.9E-01	3.5E+00	1.8E+00	5.2E+01	5.4E+01	5.4E+01
NO2	5	2.2E-01	2.8E+00	8.9E-01	4.6E+01	5.0E+01	5.4E+01
NO2	6	2.9E-01	3.6E+00	2.5E+00	5.2E+01	5.3E+01	5.4E+01
NO2	7	2.8E-01	3.5E+00	1.6E+00	3.8E+01	4.3E+01	5.0E+01
NO2	8	2.3E-01	2.8E+00	2.2E+00	3.8E+01	4.4E+01	4.4E+01
NO2	9	3.6E-01	3.8E+00	4.4E+00	4.1E+01	5.0E+01	5.4E+01
NO2	10	3.5E-01	3.6E+00	3.1E+00	3.8E+01	5.3E+01	5.4E+01
NO2	11	5.4E-01	6.1E+00	6.4E+00	4.1E+01	5.4E+01	5.4E+01
NO2	13	2.1E-01	2.0E+00	1.7E+00	3.1E+01	4.7E+01	5.3E+01
NO2	14	4.7E-01	4.7E+00	4.7E+00	5.4E+01	5.4E+01	5.4E+01
NO2	15	4.6E-01	5.6E+00	4.1E+00	5.4E+01	5.4E+01	5.4E+01
NO2	16	6.8E-01	8.3E+00	1.0E+01	4.4E+01	5.4E+01	5.4E+01

5.2. Concentration Statistics by Receptor Site – Case 6 (with Cogeneration)

Table 10. Selected modelled concentration statistics sorted by receptor site for each of the 28 chemical species at each of the 15 receptor sites for Expanded Refinery Scenario (4.7 Mtpa) with Case 6 (Cogeneration). The annual averages are for the average emission rates, whereas all other statistics are for peak emission rates. The shaded NO_2 cells indicate values that are limited by the available ozone, see Section 3.7.

Site	Chemical Species *(Case 6 – Cogeneration)*	Annual average ($\mu g\ m^{-3}$)	95th % 24-hr average ($\mu g\ m^{-3}$)	95th % 1-hr average ($\mu g\ m^{-3}$)	Max. 1-hr average ($\mu g\ m^{-3}$)	Max. 10-min average ($\mu g\ m^{-3}$)	Max. 3-min average ($\mu g\ m^{-3}$)
1	NOx	2.9E-01	3.4E+00	2.1E+00	4.2E+01	6.5E+01	8.8E+01
1	CO	5.7E-01	5.3E+00	4.2E+00	6.7E+01	9.5E+01	1.2E+02
1	SO2	3.3E-02	5.1E-01	3.7E-01	7.2E+00	1.1E+01	1.5E+01
1	Dust	1.2E-02	1.4E-01	8.7E-02	2.3E+00	3.6E+00	4.9E+00
1	Arsenic	1.9E-05	1.3E-04	6.6E-05	3.0E-03	4.3E-03	5.4E-03
1	Selenium	1.9E-05	1.2E-04	8.9E-05	2.5E-03	3.6E-03	4.6E-03
1	Manganese	2.0E-04	1.0E-03	5.5E-04	3.2E-02	4.7E-02	6.0E-02
1	Cadmium	3.2E-09	2.0E-08	3.4E-09	5.3E-07	7.6E-07	9.6E-07
1	Chromium (VI)	1.3E-07	7.6E-07	2.7E-07	1.6E-05	2.3E-05	2.8E-05
1	Nickel	7.6E-06	4.1E-05	3.7E-05	1.0E-03	1.5E-03	1.9E-03
1	Mercury	6.6E-05	3.9E-04	2.9E-04	6.8E-03	1.0E-02	1.4E-02
1	Ammonia	7.8E-03	3.9E-02	2.6E-02	1.0E+00	1.5E+00	1.9E+00
1	BaP Equivalents	6.9E-07	3.9E-06	1.8E-06	5.8E-05	8.5E-05	1.1E-04
1	Acetone	2.6E-02	1.2E-01	1.3E-01	1.4E+00	2.2E+00	2.8E+00
1	Acetaldehyde	6.0E-03	3.2E-02	3.6E-02	2.7E-01	4.5E-01	6.3E-01
1	Formaldehyde	3.1E-03	1.8E-02	6.3E-03	2.9E-01	4.9E-01	6.9E-01
1	2-Butanone	3.2E-03	1.6E-02	1.5E-02	1.9E-01	2.8E-01	3.6E-01
1	Benzene	6.8E-04	3.7E-03	2.1E-03	7.1E-02	1.1E-01	1.5E-01
1	Toluene	5.8E-04	3.0E-03	2.6E-03	6.5E-02	1.0E-01	1.4E-01
1	Xylenes	3.0E-05	1.7E-04	9.1E-05	2.9E-03	4.4E-03	5.8E-03
1	Acrolein	2.6E-04	1.5E-03	2.6E-04	3.0E-02	5.0E-02	7.1E-02
1	Ethylbenzene	1.7E-05	9.5E-05	8.1E-05	1.2E-03	1.9E-03	2.6E-03
1	Methylene Chloride	6.2E-04	3.5E-03	2.5E-03	4.8E-02	7.9E-02	1.1E-01
1	Styrene	4.6E-05	3.1E-04	2.3E-04	3.6E-03	5.5E-03	7.4E-03
1	1-2-4 Trimethylbenzene	1.7E-05	8.7E-05	5.1E-05	2.2E-03	3.3E-03	4.2E-03
1	1-3-5 Trimethylbenzene	6.7E-06	2.9E-05	3.0E-05	6.9E-04	1.0E-03	1.3E-03
1	Vinyl chloride	1.6E-06	9.9E-06	1.5E-06	1.9E-04	3.2E-04	4.6E-04
1	NO2	2.9E-01	3.4E+00	2.1E+00	4.2E+01	5.4E+01	5.4E+01
2	NOx	3.0E-01	3.5E+00	2.2E+00	5.5E+01	8.6E+01	1.2E+02
2	CO	5.5E-01	5.4E+00	4.3E+00	7.0E+01	1.0E+02	1.3E+02
2	SO2	3.1E-02	5.0E-01	3.7E-01	6.8E+00	9.3E+00	1.1E+01
2	Dust	1.3E-02	1.7E-01	9.1E-02	3.0E+00	4.6E+00	6.2E+00
2	Arsenic	2.2E-05	1.2E-04	6.5E-05	3.3E-03	5.1E-03	6.8E-03

Site	Chemical Species *(Case 6 – Cogeneration)*	Annual average ($\mu g\ m^{-3}$)	95th % 24-hr average ($\mu g\ m^{-3}$)	95th % 1-hr average ($\mu g\ m^{-3}$)	Max. 1-hr average ($\mu g\ m^{-3}$)	Max. 10-min average ($\mu g\ m^{-3}$)	Max. 3-min average ($\mu g\ m^{-3}$)
2	Selenium	2.1E-05	1.4E-04	7.9E-05	2.8E-03	4.2E-03	5.5E-03
2	Manganese	1.3E-04	7.6E-04	4.3E-04	1.7E-02	2.6E-02	3.5E-02
2	Cadmium	3.6E-09	1.8E-08	3.5E-09	5.8E-07	9.1E-07	1.2E-06
2	Chromium (VI)	1.5E-07	8.8E-07	3.3E-07	1.9E-05	2.8E-05	3.7E-05
2	Nickel	5.4E-06	3.7E-05	2.7E-05	5.5E-04	8.2E-04	1.1E-03
2	Mercury	5.5E-05	3.0E-04	2.7E-04	4.7E-03	7.3E-03	9.9E-03
2	Ammonia	5.4E-03	3.2E-02	1.9E-02	6.3E-01	9.4E-01	1.2E+00
2	BaP Equivalents	4.2E-07	2.5E-06	1.3E-06	4.6E-05	7.0E-05	9.2E-05
2	Acetone	1.8E-02	9.0E-02	8.9E-02	1.7E+00	2.5E+00	3.3E+00
2	Acetaldehyde	4.8E-03	2.3E-02	2.4E-02	3.6E-01	5.5E-01	7.4E-01
2	Formaldehyde	3.4E-03	2.0E-02	5.1E-03	3.7E-01	5.8E-01	7.8E-01
2	2-Butanone	2.1E-03	1.1E-02	9.1E-03	1.9E-01	2.9E-01	3.9E-01
2	Benzene	6.3E-04	3.0E-03	1.9E-03	7.4E-02	1.1E-01	1.5E-01
2	Toluene	4.4E-04	2.0E-03	1.8E-03	7.0E-02	1.1E-01	1.5E-01
2	Xylenes	3.3E-05	2.0E-04	8.1E-05	3.0E-03	5.0E-03	7.0E-03
2	Acrolein	3.0E-04	1.9E-03	2.7E-04	3.6E-02	5.6E-02	7.5E-02
2	Ethylbenzene	1.8E-05	9.4E-05	7.3E-05	1.5E-03	2.3E-03	3.0E-03
2	Methylene Chloride	6.7E-04	4.1E-03	2.3E-03	6.1E-02	9.8E-02	1.4E-01
2	Styrene	4.3E-05	2.4E-04	1.8E-04	5.1E-03	7.8E-03	1.0E-02
2	1-2-4 Trimethylbenzene	1.3E-05	8.5E-05	4.2E-05	1.3E-03	1.9E-03	2.6E-03
2	1-3-5 Trimethylbenzene	5.6E-06	3.1E-05	2.7E-05	3.9E-04	5.9E-04	7.9E-04
2	Vinyl chloride	1.9E-06	1.2E-05	1.7E-06	2.3E-04	3.6E-04	4.8E-04
2	NO2	3.0E-01	3.5E+00	2.2E+00	5.2E+01	5.3E+01	5.4E+01
3	NOx	2.3E-01	3.0E+00	1.0E+00	6.0E+01	9.1E+01	1.2E+02
3	CO	4.1E-01	3.8E+00	2.3E+00	8.7E+01	1.2E+02	1.4E+02
3	SO2	2.4E-02	3.5E-01	1.8E-01	1.0E+01	1.5E+01	2.0E+01
3	Dust	8.5E-03	1.2E-01	6.1E-02	2.9E+00	3.9E+00	4.8E+00
3	Arsenic	1.5E-05	9.6E-05	3.7E-05	2.9E-03	4.0E-03	4.9E-03
3	Selenium	1.4E-05	7.6E-05	5.5E-05	2.1E-03	2.9E-03	3.5E-03
3	Manganese	1.6E-04	9.6E-04	3.4E-04	1.8E-02	2.6E-02	3.4E-02
3	Cadmium	2.6E-09	1.6E-08	1.8E-09	4.8E-07	6.6E-07	8.2E-07
3	Chromium (VI)	1.0E-07	7.1E-07	1.3E-07	1.7E-05	2.4E-05	2.9E-05
3	Nickel	5.8E-06	4.1E-05	2.2E-05	5.5E-04	8.2E-04	1.1E-03
3	Mercury	4.9E-05	2.5E-04	2.1E-04	4.7E-03	7.1E-03	9.4E-03
3	Ammonia	5.9E-03	4.1E-02	1.8E-02	5.5E-01	8.1E-01	1.1E+00
3	BaP Equivalents	4.1E-07	2.6E-06	1.0E-06	4.4E-05	6.3E-05	8.1E-05
3	Acetone	1.8E-02	9.7E-02	8.2E-02	1.4E+00	2.1E+00	2.8E+00
3	Acetaldehyde	4.2E-03	2.1E-02	2.5E-02	2.9E-01	4.4E-01	5.7E-01
3	Formaldehyde	2.3E-03	1.4E-02	3.9E-03	3.2E-01	4.9E-01	6.5E-01
3	2-Butanone	2.1E-03	1.2E-02	9.0E-03	1.6E-01	2.5E-01	3.3E-01

Site	Chemical Species *(Case 6 – Cogeneration)*	Annual average ($\mu g\ m^{-3}$)	95th % 24-hr average ($\mu g\ m^{-3}$)	95th % 1-hr average ($\mu g\ m^{-3}$)	Max. 1-hr average ($\mu g\ m^{-3}$)	Max. 10-min average ($\mu g\ m^{-3}$)	Max. 3-min average ($\mu g\ m^{-3}$)
3	Benzene	5.2E-04	2.8E-03	1.0E-03	7.9E-02	1.2E-01	1.6E-01
3	Toluene	4.4E-04	2.1E-03	1.6E-03	6.7E-02	1.0E-01	1.4E-01
3	Xylenes	2.2E-05	1.3E-04	6.4E-05	2.8E-03	4.2E-03	5.6E-03
3	Acrolein	1.8E-04	1.3E-03	1.7E-04	3.0E-02	4.6E-02	6.2E-02
3	Ethylbenzene	1.2E-05	6.6E-05	6.2E-05	1.5E-03	2.0E-03	2.5E-03
3	Methylene Chloride	4.7E-04	3.0E-03	1.4E-03	6.4E-02	8.6E-02	1.1E-01
3	Styrene	3.6E-05	2.3E-04	1.7E-04	4.4E-03	6.7E-03	8.9E-03
3	1-2-4 Trimethylbenzene	1.3E-05	7.9E-05	4.0E-05	1.3E-03	1.9E-03	2.4E-03
3	1-3-5 Trimethylbenzene	4.9E-06	2.6E-05	2.5E-05	3.9E-04	5.8E-04	7.5E-04
3	Vinyl chloride	1.1E-06	8.3E-06	1.0E-06	2.0E-04	3.0E-04	4.0E-04
3	NO2	2.3E-01	2.9E+00	1.0E+00	5.4E+01	5.4E+01	5.4E+01
4	NOx	2.9E-01	3.5E+00	1.8E+00	6.8E+01	1.0E+02	1.4E+02
4	CO	5.1E-01	4.8E+00	3.3E+00	6.0E+01	8.0E+01	9.7E+01
4	SO2	3.1E-02	5.1E-01	2.8E-01	1.1E+01	1.7E+01	2.3E+01
4	Dust	1.1E-02	1.4E-01	7.8E-02	2.4E+00	3.7E+00	4.9E+00
4	Arsenic	1.8E-05	1.2E-04	6.2E-05	3.7E-03	5.6E-03	7.5E-03
4	Selenium	1.7E-05	9.9E-05	9.0E-05	2.0E-03	2.7E-03	3.3E-03
4	Manganese	3.3E-04	2.4E-03	6.7E-04	6.2E-02	9.0E-02	1.2E-01
4	Cadmium	3.1E-09	1.9E-08	3.1E-09	6.4E-07	1.0E-06	1.3E-06
4	Chromium (VI)	1.3E-07	7.8E-07	1.9E-07	1.9E-05	2.9E-05	3.8E-05
4	Nickel	1.2E-05	7.5E-05	3.8E-05	2.0E-03	2.8E-03	3.6E-03
4	Mercury	7.0E-05	3.4E-04	2.9E-04	6.4E-03	9.8E-03	1.3E-02
4	Ammonia	1.2E-02	8.1E-02	3.5E-02	1.5E+00	2.1E+00	2.8E+00
4	BaP Equivalents	7.8E-07	4.8E-06	2.2E-06	1.1E-04	1.7E-04	2.2E-04
4	Acetone	3.2E-02	1.9E-01	1.7E-01	3.3E+00	4.6E+00	5.9E+00
4	Acetaldehyde	7.4E-03	3.6E-02	5.2E-02	4.2E-01	6.0E-01	7.5E-01
4	Formaldehyde	3.3E-03	1.8E-02	8.0E-03	3.3E-01	5.0E-01	6.7E-01
4	2-Butanone	3.7E-03	2.2E-02	1.9E-02	3.8E-01	5.6E-01	7.3E-01
4	Benzene	7.2E-04	3.7E-03	2.1E-03	9.4E-02	1.4E-01	1.9E-01
4	Toluene	6.8E-04	3.1E-03	3.4E-03	8.9E-02	1.4E-01	1.8E-01
4	Xylenes	3.2E-05	1.7E-04	1.1E-04	3.6E-03	5.3E-03	6.9E-03
4	Acrolein	2.6E-04	1.7E-03	3.0E-04	3.4E-02	5.0E-02	6.6E-02
4	Ethylbenzene	1.8E-05	8.7E-05	9.1E-05	1.2E-03	1.9E-03	2.7E-03
4	Methylene Chloride	6.8E-04	3.5E-03	2.7E-03	6.3E-02	9.3E-02	1.2E-01
4	Styrene	5.3E-05	3.8E-04	2.5E-04	8.8E-03	1.3E-02	1.6E-02
4	1-2-4 Trimethylbenzene	2.5E-05	1.6E-04	6.0E-05	4.4E-03	6.3E-03	8.1E-03
4	1-3-5 Trimethylbenzene	9.3E-06	5.1E-05	3.5E-05	1.3E-03	2.0E-03	2.5E-03
4	Vinyl chloride	1.6E-06	1.1E-05	1.8E-06	2.2E-04	3.2E-04	4.2E-04
4	NO2	2.9E-01	3.5E+00	1.8E+00	5.2E+01	5.4E+01	5.4E+01

Site	Chemical Species *(Case 6 – Cogeneration)*	Annual average ($\mu g\ m^{-3}$)	95th % 24-hr average ($\mu g\ m^{-3}$)	95th % 1-hr average ($\mu g\ m^{-3}$)	Max. 1-hr average ($\mu g\ m^{-3}$)	Max. 10-min average ($\mu g\ m^{-3}$)	Max. 3-min average ($\mu g\ m^{-3}$)
5	NOx	2.2E-01	2.8E+00	8.9E-01	7.8E+01	1.2E+02	1.5E+02
5	CO	3.4E-01	3.4E+00	1.3E+00	7.0E+01	9.4E+01	1.1E+02
5	SO2	2.1E-02	3.5E-01	1.0E-01	1.1E+01	1.6E+01	2.1E+01
5	Dust	7.2E-03	9.9E-02	4.2E-02	2.1E+00	2.8E+00	3.5E+00
5	Arsenic	1.5E-05	9.2E-05	3.0E-05	4.1E-03	6.3E-03	8.4E-03
5	Selenium	1.0E-05	6.4E-05	3.7E-05	1.8E-03	2.5E-03	3.1E-03
5	Manganese	1.2E-04	7.9E-04	3.7E-04	1.6E-02	2.3E-02	2.9E-02
5	Cadmium	2.6E-09	1.5E-08	1.9E-09	7.0E-07	1.1E-06	1.5E-06
5	Chromium (VI)	9.7E-08	6.1E-07	1.2E-07	2.2E-05	3.3E-05	4.3E-05
5	Nickel	4.8E-06	3.4E-05	2.0E-05	6.6E-04	9.9E-04	1.3E-03
5	Mercury	4.0E-05	2.2E-04	1.3E-04	6.2E-03	9.1E-03	1.2E-02
5	Ammonia	4.8E-03	3.1E-02	1.7E-02	4.3E-01	6.2E-01	7.9E-01
5	BaP Equivalents	3.5E-07	2.4E-06	9.1E-07	3.6E-05	5.0E-05	6.4E-05
5	Acetone	1.7E-02	1.0E-01	6.9E-02	1.6E+00	2.4E+00	3.1E+00
5	Acetaldehyde	3.7E-03	2.0E-02	2.2E-02	2.3E-01	3.5E-01	4.7E-01
5	Formaldehyde	2.2E-03	1.5E-02	3.7E-03	2.6E-01	4.0E-01	5.4E-01
5	2-Butanone	1.9E-03	1.1E-02	8.1E-03	1.8E-01	2.6E-01	3.4E-01
5	Benzene	5.2E-04	2.5E-03	8.5E-04	8.9E-02	1.3E-01	1.7E-01
5	Toluene	4.5E-04	1.9E-03	1.3E-03	8.5E-02	1.3E-01	1.6E-01
5	Xylenes	2.0E-05	1.1E-04	5.4E-05	2.5E-03	3.9E-03	5.1E-03
5	Acrolein	1.6E-04	1.1E-03	1.9E-04	2.5E-02	3.9E-02	5.2E-02
5	Ethylbenzene	9.9E-06	5.5E-05	4.5E-05	1.2E-03	1.6E-03	2.0E-03
5	Methylene Chloride	4.3E-04	2.5E-03	1.3E-03	6.8E-02	9.9E-02	1.3E-01
5	Styrene	3.4E-05	2.1E-04	1.2E-04	5.5E-03	8.1E-03	1.0E-02
5	1-2-4 Trimethylbenzene	9.9E-06	6.5E-05	3.4E-05	1.1E-03	1.6E-03	2.0E-03
5	1-3-5 Trimethylbenzene	4.0E-06	2.2E-05	2.1E-05	3.4E-04	4.9E-04	6.2E-04
5	Vinyl chloride	1.0E-06	6.9E-06	1.1E-06	1.6E-04	2.5E-04	3.4E-04
5	NO2	2.2E-01	2.8E+00	8.9E-01	4.6E+01	5.0E+01	5.4E+01
6	NOx	2.9E-01	3.7E+00	2.5E+00	5.9E+01	7.9E+01	9.5E+01
6	CO	5.0E-01	5.5E+00	3.8E+00	7.9E+01	1.1E+02	1.3E+02
6	SO2	2.9E-02	4.3E-01	3.7E-01	1.0E+01	1.4E+01	1.7E+01
6	Dust	1.1E-02	1.5E-01	8.8E-02	3.1E+00	4.7E+00	6.4E+00
6	Arsenic	2.2E-05	1.1E-04	7.4E-05	4.2E-03	5.8E-03	7.2E-03
6	Selenium	1.9E-05	1.4E-04	6.7E-05	2.9E-03	4.1E-03	5.2E-03
6	Manganese	9.5E-05	6.2E-04	3.5E-04	1.4E-02	2.1E-02	2.8E-02
6	Cadmium	3.8E-09	1.7E-08	4.6E-09	7.1E-07	9.8E-07	1.2E-06
6	Chromium (VI)	1.5E-07	8.7E-07	4.0E-07	2.4E-05	3.3E-05	4.0E-05
6	Nickel	4.3E-06	3.1E-05	2.4E-05	6.7E-04	9.1E-04	1.1E-03
6	Mercury	4.9E-05	2.6E-04	2.3E-04	4.0E-03	5.5E-03	6.9E-03
6	Ammonia	4.3E-03	2.4E-02	1.7E-02	5.0E-01	7.4E-01	9.6E-01

Site	Chemical Species *(Case 6 – Cogeneration)*	Annual average ($\mu g\ m^{-3}$)	95th % 24-hr average ($\mu g\ m^{-3}$)	95th % 1-hr average ($\mu g\ m^{-3}$)	Max. 1-hr average ($\mu g\ m^{-3}$)	Max. 10-min average ($\mu g\ m^{-3}$)	Max. 3-min average ($\mu g\ m^{-3}$)
6	BaP Equivalents	3.0E-07	1.7E-06	9.9E-07	3.5E-05	5.2E-05	6.9E-05
6	Acetone	1.4E-02	7.1E-02	6.9E-02	1.2E+00	1.8E+00	2.4E+00
6	Acetaldehyde	3.8E-03	2.0E-02	1.9E-02	3.6E-01	5.4E-01	7.2E-01
6	Formaldehyde	2.9E-03	1.8E-02	5.1E-03	3.8E-01	5.9E-01	7.9E-01
6	2-Butanone	1.6E-03	8.5E-03	7.0E-03	1.2E-01	1.8E-01	2.4E-01
6	Benzene	5.6E-04	2.8E-03	2.0E-03	5.6E-02	8.6E-02	1.1E-01
6	Toluene	3.7E-04	1.7E-03	1.5E-03	4.5E-02	7.0E-02	9.5E-02
6	Xylenes	2.9E-05	1.8E-04	6.8E-05	3.1E-03	4.8E-03	6.5E-03
6	Acrolein	2.6E-04	1.8E-03	2.2E-04	4.1E-02	6.3E-02	8.4E-02
6	Ethylbenzene	1.6E-05	9.9E-05	6.7E-05	1.5E-03	2.3E-03	3.1E-03
6	Methylene Chloride	6.2E-04	3.9E-03	2.0E-03	7.9E-02	1.1E-01	1.3E-01
6	Styrene	3.6E-05	2.2E-04	1.7E-04	4.6E-03	6.8E-03	9.0E-03
6	1-2-4 Trimethylbenzene	9.8E-06	6.1E-05	3.6E-05	1.1E-03	1.7E-03	2.2E-03
6	1-3-5 Trimethylbenzene	4.4E-06	2.5E-05	2.3E-05	3.7E-04	5.7E-04	7.6E-04
6	Vinyl chloride	1.6E-06	1.2E-05	1.3E-06	2.6E-04	4.0E-04	5.4E-04
6	NO2	2.9E-01	3.6E+00	2.5E+00	5.2E+01	5.3E+01	5.4E+01
7	NOx	2.8E-01	3.8E+00	1.6E+00	7.9E+01	1.2E+02	1.5E+02
7	CO	3.3E-01	3.3E+00	1.8E+00	4.6E+01	6.8E+01	8.9E+01
7	SO2	2.4E-02	5.1E-01	1.8E-01	1.0E+01	1.5E+01	2.0E+01
7	Dust	6.8E-03	8.5E-02	6.2E-02	1.8E+00	2.7E+00	3.5E+00
7	Arsenic	1.9E-05	1.4E-04	3.3E-05	5.5E-03	8.5E-03	1.1E-02
7	Selenium	7.8E-06	5.1E-05	3.8E-05	8.4E-04	1.3E-03	1.8E-03
7	Manganese	1.1E-04	6.1E-04	2.7E-04	1.1E-02	1.7E-02	2.2E-02
7	Cadmium	3.4E-09	2.2E-08	3.9E-09	9.7E-07	1.5E-06	2.0E-06
7	Chromium (VI)	1.2E-07	7.7E-07	2.2E-07	2.9E-05	4.4E-05	5.7E-05
7	Nickel	4.6E-06	3.1E-05	1.7E-05	1.0E-03	1.5E-03	2.0E-03
7	Mercury	4.1E-05	2.5E-04	1.1E-04	5.5E-03	8.3E-03	1.1E-02
7	Ammonia	5.3E-03	3.1E-02	1.4E-02	5.8E-01	8.7E-01	1.1E+00
7	BaP Equivalents	2.8E-07	1.6E-06	7.7E-07	3.9E-05	5.7E-05	7.3E-05
7	Acetone	1.4E-02	8.0E-02	5.7E-02	9.5E-01	1.4E+00	1.9E+00
7	Acetaldehyde	3.6E-03	1.9E-02	2.2E-02	3.4E-01	5.0E-01	6.4E-01
7	Formaldehyde	2.3E-03	1.4E-02	8.4E-03	3.3E-01	4.9E-01	6.3E-01
7	2-Butanone	1.8E-03	9.8E-03	6.7E-03	1.4E-01	2.0E-01	2.6E-01
7	Benzene	5.3E-04	3.7E-03	1.4E-03	5.0E-02	7.6E-02	9.9E-02
7	Toluene	4.6E-04	3.2E-03	1.5E-03	4.3E-02	6.1E-02	7.8E-02
7	Xylenes	2.3E-05	1.4E-04	7.4E-05	3.2E-03	4.7E-03	6.2E-03
7	Acrolein	1.7E-04	1.1E-03	3.3E-04	3.6E-02	5.3E-02	6.9E-02
7	Ethylbenzene	8.4E-06	4.6E-05	4.5E-05	1.3E-03	1.9E-03	2.5E-03
7	Methylene Chloride	5.0E-04	2.9E-03	1.7E-03	8.4E-02	1.3E-01	1.6E-01
7	Styrene	3.0E-05	2.4E-04	1.2E-04	3.4E-03	5.1E-03	6.7E-03

Site	Chemical Species *(Case 6 – Cogeneration)*	Annual average ($\mu g\ m^{-3}$)	95th % 24-hr average ($\mu g\ m^{-3}$)	95th % 1-hr average ($\mu g\ m^{-3}$)	Max. 1-hr average ($\mu g\ m^{-3}$)	Max. 10-min average ($\mu g\ m^{-3}$)	Max. 3-min average ($\mu g\ m^{-3}$)
7	1-2-4 Trimethylbenzene	7.9E-06	4.1E-05	2.5E-05	7.3E-04	1.1E-03	1.4E-03
7	1-3-5 Trimethylbenzene	3.4E-06	2.0E-05	2.0E-05	2.8E-04	4.2E-04	5.4E-04
7	Vinyl chloride	1.0E-06	7.4E-06	2.1E-06	2.3E-04	3.4E-04	4.4E-04
7	NO2	2.8E-01	3.5E+00	1.6E+00	3.8E+01	4.3E+01	5.0E+01
8	NOx	2.3E-01	2.8E+00	2.2E+00	3.8E+01	5.6E+01	7.3E+01
8	CO	3.0E-01	3.4E+00	2.6E+00	4.1E+01	6.1E+01	8.0E+01
8	SO2	1.9E-02	3.7E-01	2.4E-01	5.7E+00	7.9E+00	9.9E+00
8	Dust	7.5E-03	1.1E-01	8.2E-02	1.5E+00	2.2E+00	2.8E+00
8	Arsenic	1.3E-05	8.1E-05	4.5E-05	1.5E-03	2.3E-03	3.0E-03
8	Selenium	8.5E-06	5.6E-05	4.5E-05	1.1E-03	1.7E-03	2.2E-03
8	Manganese	9.4E-05	5.8E-04	3.3E-04	1.0E-02	1.4E-02	1.8E-02
8	Cadmium	2.2E-09	1.3E-08	5.9E-09	2.5E-07	4.0E-07	5.4E-07
8	Chromium (VI)	9.2E-08	6.1E-07	3.4E-07	7.9E-06	1.2E-05	1.5E-05
8	Nickel	3.8E-06	2.5E-05	2.0E-05	3.2E-04	4.8E-04	6.2E-04
8	Mercury	3.3E-05	1.9E-04	1.3E-04	3.7E-03	5.1E-03	6.3E-03
8	Ammonia	4.5E-03	2.6E-02	1.6E-02	4.6E-01	6.3E-01	7.8E-01
8	BaP Equivalents	2.3E-07	1.3E-06	8.5E-07	2.3E-05	3.2E-05	4.1E-05
8	Acetone	1.1E-02	5.7E-02	5.9E-02	7.5E-01	1.1E+00	1.5E+00
8	Acetaldehyde	3.2E-03	1.6E-02	2.2E-02	1.6E-01	2.4E-01	3.2E-01
8	Formaldehyde	2.3E-03	1.5E-02	1.0E-02	2.0E-01	2.6E-01	3.1E-01
8	2-Butanone	1.3E-03	6.8E-03	6.7E-03	7.9E-02	1.1E-01	1.4E-01
8	Benzene	3.9E-04	2.5E-03	1.7E-03	4.3E-02	6.4E-02	8.4E-02
8	Toluene	3.0E-04	1.9E-03	1.6E-03	3.3E-02	5.0E-02	6.7E-02
8	Xylenes	2.4E-05	1.6E-04	9.3E-05	2.3E-03	3.0E-03	3.6E-03
8	Acrolein	2.0E-04	1.3E-03	6.8E-04	2.1E-02	3.3E-02	4.3E-02
8	Ethylbenzene	9.6E-06	5.6E-05	5.6E-05	8.3E-04	1.2E-03	1.6E-03
8	Methylene Chloride	4.4E-04	2.8E-03	2.2E-03	3.2E-02	4.2E-02	5.0E-02
8	Styrene	2.4E-05	1.8E-04	1.3E-04	3.0E-03	4.5E-03	5.8E-03
8	1-2-4 Trimethylbenzene	7.6E-06	4.2E-05	3.1E-05	7.0E-04	1.0E-03	1.3E-03
8	1-3-5 Trimethylbenzene	3.5E-06	1.8E-05	2.3E-05	2.2E-04	3.1E-04	3.9E-04
8	Vinyl chloride	1.2E-06	8.4E-06	4.3E-06	1.4E-04	2.1E-04	2.8E-04
8	NO2	2.3E-01	2.8E+00	2.2E+00	3.8E+01	4.4E+01	4.4E+01
9	NOx	3.6E-01	3.8E+00	4.4E+00	4.1E+01	6.5E+01	8.8E+01
9	CO	5.1E-01	4.4E+00	5.5E+00	5.5E+01	8.4E+01	1.1E+02
9	SO2	3.1E-02	4.5E-01	5.2E-01	6.0E+00	9.0E+00	1.2E+01
9	Dust	1.3E-02	1.6E-01	1.8E-01	2.4E+00	3.7E+00	4.9E+00
9	Arsenic	2.0E-05	1.1E-04	9.9E-05	2.0E-03	3.0E-03	4.1E-03
9	Selenium	1.5E-05	7.9E-05	9.7E-05	1.3E-03	2.0E-03	2.7E-03
9	Manganese	2.2E-04	1.1E-03	9.4E-04	1.8E-02	2.7E-02	3.4E-02

Site	Chemical Species *(Case 6 – Cogeneration)*	Annual average ($\mu g\ m^{-3}$)	95th % 24-hr average ($\mu g\ m^{-3}$)	95th % 1-hr average ($\mu g\ m^{-3}$)	Max. 1-hr average ($\mu g\ m^{-3}$)	Max. 10-min average ($\mu g\ m^{-3}$)	Max. 3-min average ($\mu g\ m^{-3}$)
9	Cadmium	3.5E-09	1.8E-08	1.4E-08	3.4E-07	5.3E-07	7.2E-07
9	Chromium (VI)	1.5E-07	8.1E-07	8.2E-07	1.0E-05	1.5E-05	2.0E-05
9	Nickel	8.0E-06	4.0E-05	5.0E-05	5.7E-04	8.3E-04	1.1E-03
9	Mercury	6.1E-05	2.7E-04	3.2E-04	5.3E-03	7.7E-03	9.8E-03
9	Ammonia	9.6E-03	4.3E-02	4.7E-02	7.3E-01	1.1E+00	1.3E+00
9	BaP Equivalents	5.2E-07	2.3E-06	2.3E-06	3.9E-05	5.5E-05	7.1E-05
9	Acetone	2.1E-02	8.3E-02	1.3E-01	1.1E+00	1.6E+00	2.0E+00
9	Acetaldehyde	6.1E-03	2.5E-02	4.6E-02	2.7E-01	3.9E-01	4.9E-01
9	Formaldehyde	3.6E-03	2.2E-02	2.0E-02	2.7E-01	3.6E-01	4.2E-01
9	2-Butanone	2.6E-03	1.1E-02	1.5E-02	1.4E-01	2.0E-01	2.5E-01
9	Benzene	6.1E-04	3.1E-03	3.7E-03	4.1E-02	6.0E-02	7.8E-02
9	Toluene	5.0E-04	2.2E-03	3.1E-03	3.5E-02	5.3E-02	6.9E-02
9	Xylenes	3.9E-05	2.5E-04	1.9E-04	3.0E-03	3.8E-03	4.6E-03
9	Acrolein	3.2E-04	2.1E-03	1.4E-03	2.8E-02	3.6E-02	4.3E-02
9	Ethylbenzene	1.7E-05	7.8E-05	1.2E-04	1.2E-03	1.9E-03	2.5E-03
9	Methylene Chloride	7.3E-04	3.9E-03	4.5E-03	4.2E-02	5.4E-02	6.4E-02
9	Styrene	3.9E-05	2.2E-04	2.8E-04	2.8E-03	4.1E-03	5.3E-03
9	1-2-4 Trimethylbenzene	1.7E-05	7.9E-05	8.2E-05	1.4E-03	2.0E-03	2.5E-03
9	1-3-5 Trimethylbenzene	7.1E-06	2.9E-05	4.9E-05	4.2E-04	6.1E-04	7.8E-04
9	Vinyl chloride	2.0E-06	1.3E-05	8.9E-06	1.8E-04	2.3E-04	2.8E-04
9	NO2	3.6E-01	3.8E+00	4.4E+00	4.1E+01	5.0E+01	5.4E+01
10	NOx	3.5E-01	3.6E+00	3.1E+00	4.2E+01	5.4E+01	6.4E+01
10	CO	4.3E-01	3.5E+00	4.1E+00	6.4E+01	9.9E+01	1.3E+02
10	SO2	2.6E-02	3.6E-01	3.6E-01	6.3E+00	9.6E+00	1.3E+01
10	Dust	1.2E-02	1.4E-01	1.3E-01	3.3E+00	5.2E+00	7.0E+00
10	Arsenic	1.9E-05	9.8E-05	9.7E-05	2.0E-03	3.2E-03	4.3E-03
10	Selenium	1.5E-05	9.2E-05	9.3E-05	1.4E-03	2.2E-03	3.0E-03
10	Manganese	2.7E-04	1.7E-03	1.1E-03	4.7E-02	6.8E-02	8.8E-02
10	Cadmium	3.2E-09	1.5E-08	1.0E-08	3.6E-07	5.6E-07	7.6E-07
10	Chromium (VI)	1.4E-07	7.1E-07	5.7E-07	1.2E-05	1.8E-05	2.3E-05
10	Nickel	9.7E-06	6.4E-05	6.0E-05	1.5E-03	2.1E-03	2.7E-03
10	Mercury	5.4E-05	2.6E-04	3.1E-04	6.5E-03	9.9E-03	1.3E-02
10	Ammonia	1.1E-02	6.6E-02	5.2E-02	1.7E+00	2.4E+00	3.1E+00
10	BaP Equivalents	5.8E-07	3.4E-06	2.6E-06	6.4E-05	9.3E-05	1.2E-04
10	Acetone	2.1E-02	1.1E-01	1.3E-01	1.8E+00	2.6E+00	3.2E+00
10	Acetaldehyde	6.4E-03	3.4E-02	4.5E-02	5.0E-01	7.2E-01	9.1E-01
10	Formaldehyde	3.6E-03	2.0E-02	1.3E-02	4.2E-01	6.5E-01	8.8E-01
10	2-Butanone	2.6E-03	1.5E-02	1.6E-02	2.2E-01	3.2E-01	4.1E-01
10	Benzene	5.2E-04	2.8E-03	2.4E-03	4.7E-02	7.2E-02	9.5E-02
10	Toluene	4.3E-04	1.9E-03	2.6E-03	4.0E-02	6.1E-02	8.2E-02

Site	Chemical Species *(Case 6 – Cogeneration)*	Annual average ($\mu g\ m^{-3}$)	95th % 24-hr average ($\mu g\ m^{-3}$)	95th % 1-hr average ($\mu g\ m^{-3}$)	Max. 1-hr average ($\mu g\ m^{-3}$)	Max. 10-min average ($\mu g\ m^{-3}$)	Max. 3-min average ($\mu g\ m^{-3}$)
10	Xylenes	4.2E-05	2.5E-04	1.9E-04	3.8E-03	5.9E-03	7.9E-03
10	Acrolein	3.4E-04	2.0E-03	1.1E-03	4.5E-02	7.0E-02	9.5E-02
10	Ethylbenzene	1.8E-05	8.6E-05	1.1E-04	1.6E-03	2.5E-03	3.3E-03
10	Methylene Chloride	7.5E-04	4.0E-03	4.0E-03	6.0E-02	9.4E-02	1.3E-01
10	Styrene	3.4E-05	1.8E-04	2.3E-04	3.1E-03	4.8E-03	6.3E-03
10	1-2-4 Trimethylbenzene	2.1E-05	1.3E-04	9.6E-05	3.3E-03	4.8E-03	6.1E-03
10	1-3-5 Trimethylbenzene	8.3E-06	4.6E-05	5.4E-05	1.0E-03	1.5E-03	1.9E-03
10	Vinyl chloride	2.1E-06	1.3E-05	6.9E-06	2.9E-04	4.5E-04	6.1E-04
10	NO2	3.5E-01	3.6E+00	3.1E+00	3.8E+01	5.3E+01	5.4E+01
11	NOx	5.4E-01	6.1E+00	6.4E+00	4.4E+01	5.6E+01	6.7E+01
11	CO	7.0E-01	5.8E+00	8.1E+00	6.9E+01	1.1E+02	1.5E+02
11	SO2	4.2E-02	6.3E-01	7.8E-01	5.7E+00	8.9E+00	1.2E+01
11	Dust	2.0E-02	2.4E-01	2.3E-01	3.7E+00	5.8E+00	7.9E+00
11	Arsenic	3.0E-05	1.9E-04	2.0E-04	2.4E-03	4.1E-03	5.8E-03
11	Selenium	2.7E-05	1.3E-04	1.9E-04	2.3E-03	3.3E-03	4.1E-03
11	Manganese	6.9E-04	3.4E-03	2.2E-03	1.7E-01	2.4E-01	3.0E-01
11	Cadmium	5.2E-09	3.1E-08	2.3E-08	4.3E-07	7.3E-07	1.1E-06
11	Chromium (VI)	2.3E-07	1.5E-06	1.3E-06	1.3E-05	2.1E-05	2.9E-05
11	Nickel	2.3E-05	1.1E-04	1.3E-04	5.2E-03	7.4E-03	9.4E-03
11	Mercury	1.1E-04	4.7E-04	6.6E-04	1.2E-02	1.7E-02	2.1E-02
11	Ammonia	2.6E-02	1.3E-01	1.1E-01	5.0E+00	7.1E+00	9.0E+00
11	BaP Equivalents	1.2E-06	6.0E-06	5.1E-06	1.3E-04	1.9E-04	2.4E-04
11	Acetone	4.2E-02	2.0E-01	2.7E-01	3.0E+00	4.3E+00	5.5E+00
11	Acetaldehyde	1.3E-02	5.6E-02	1.0E-01	1.1E+00	1.6E+00	2.0E+00
11	Formaldehyde	5.8E-03	3.0E-02	2.7E-02	4.2E-01	6.6E-01	9.0E-01
11	2-Butanone	5.3E-03	2.4E-02	3.2E-02	4.5E-01	6.5E-01	8.3E-01
11	Benzene	8.5E-04	4.0E-03	4.9E-03	4.4E-02	6.9E-02	9.5E-02
11	Toluene	7.6E-04	3.6E-03	5.6E-03	4.6E-02	7.1E-02	9.4E-02
11	Xylenes	6.9E-05	3.7E-04	3.8E-04	3.6E-03	5.7E-03	7.7E-03
11	Acrolein	5.5E-04	2.9E-03	2.0E-03	4.7E-02	7.3E-02	1.0E-01
11	Ethylbenzene	3.3E-05	1.6E-04	2.3E-04	2.8E-03	4.0E-03	5.1E-03
11	Methylene Chloride	1.3E-03	6.8E-03	8.9E-03	7.6E-02	1.1E-01	1.4E-01
11	Styrene	5.7E-05	3.0E-04	4.7E-04	4.7E-03	6.9E-03	9.0E-03
11	1-2-4 Trimethylbenzene	5.0E-05	2.7E-04	1.8E-04	1.2E-02	1.7E-02	2.1E-02
11	1-3-5 Trimethylbenzene	1.9E-05	9.2E-05	1.0E-04	3.6E-03	5.1E-03	6.5E-03
11	Vinyl chloride	3.4E-06	1.9E-05	1.3E-05	3.0E-04	4.7E-04	6.4E-04
11	NO2	5.4E-01	6.1E+00	6.4E+00	4.1E+01	5.4E+01	5.4E+01
13	NOx	2.1E-01	2.0E+00	1.7E+00	3.1E+01	4.7E+01	6.1E+01
13	CO	3.0E-01	2.6E+00	3.3E+00	4.0E+01	6.0E+01	7.9E+01

Site	Chemical Species *(Case 6 – Cogeneration)*	Annual average ($\mu g\ m^{-3}$)	95th % 24-hr average ($\mu g\ m^{-3}$)	95th % 1-hr average ($\mu g\ m^{-3}$)	Max. 1-hr average ($\mu g\ m^{-3}$)	Max. 10-min average ($\mu g\ m^{-3}$)	Max. 3-min average ($\mu g\ m^{-3}$)
13	SO2	1.7E-02	2.2E-01	2.3E-01	4.5E+00	6.6E+00	8.6E+00
13	Dust	7.5E-03	9.3E-02	9.5E-02	1.8E+00	2.7E+00	3.7E+00
13	Arsenic	1.1E-05	5.7E-05	4.7E-05	1.5E-03	2.3E-03	3.2E-03
13	Selenium	1.1E-05	5.9E-05	6.3E-05	9.0E-04	1.4E-03	1.8E-03
13	Manganese	7.1E-05	3.2E-04	4.2E-04	5.3E-03	7.9E-03	1.0E-02
13	Cadmium	1.9E-09	9.1E-09	5.0E-09	2.4E-07	3.9E-07	5.3E-07
13	Chromium (VI)	8.3E-08	4.6E-07	2.6E-07	1.0E-05	1.6E-05	2.1E-05
13	Nickel	2.9E-06	1.7E-05	2.5E-05	2.5E-04	3.8E-04	5.0E-04
13	Mercury	2.9E-05	1.4E-04	1.8E-04	1.8E-03	2.7E-03	3.5E-03
13	Ammonia	3.0E-03	1.4E-02	1.9E-02	1.9E-01	2.8E-01	3.6E-01
13	BaP Equivalents	1.8E-07	7.9E-07	1.1E-06	1.2E-05	1.8E-05	2.4E-05
13	Acetone	7.6E-03	3.4E-02	5.8E-02	4.6E-01	6.9E-01	9.1E-01
13	Acetaldehyde	2.6E-03	1.2E-02	1.7E-02	2.0E-01	2.9E-01	3.8E-01
13	Formaldehyde	2.0E-03	1.2E-02	5.7E-03	2.3E-01	3.4E-01	4.4E-01
13	2-Butanone	9.1E-04	4.1E-03	6.8E-03	5.4E-02	8.1E-02	1.1E-01
13	Benzene	3.0E-04	1.5E-03	1.4E-03	2.9E-02	4.3E-02	5.7E-02
13	Toluene	1.9E-04	9.5E-04	1.0E-03	1.6E-02	2.5E-02	3.3E-02
13	Xylenes	2.4E-05	1.3E-04	6.8E-05	2.4E-03	3.5E-03	4.6E-03
13	Acrolein	1.9E-04	1.2E-03	4.8E-04	2.4E-02	3.5E-02	4.6E-02
13	Ethylbenzene	1.0E-05	5.2E-05	6.4E-05	8.6E-04	1.3E-03	1.7E-03
13	Methylene Chloride	3.9E-04	2.3E-03	1.4E-03	4.5E-02	6.7E-02	8.9E-02
13	Styrene	2.0E-05	1.1E-04	1.4E-04	1.8E-03	2.7E-03	3.6E-03
13	1-2-4 Trimethylbenzene	6.8E-06	3.3E-05	4.5E-05	4.0E-04	5.9E-04	7.8E-04
13	1-3-5 Trimethylbenzene	3.2E-06	1.5E-05	2.5E-05	2.0E-04	3.0E-04	4.0E-04
13	Vinyl chloride	1.2E-06	7.7E-06	3.1E-06	1.5E-04	2.3E-04	2.9E-04
13	NO2	2.1E-01	2.0E+00	1.7E+00	3.1E+01	4.7E+01	5.3E+01
14	NOx	4.7E-01	4.7E+00	4.7E+00	7.5E+01	1.1E+02	1.4E+02
14	CO	6.9E-01	5.8E+00	7.3E+00	1.1E+02	1.6E+02	2.1E+02
14	SO2	4.0E-02	5.9E-01	5.7E-01	1.1E+01	1.7E+01	2.2E+01
14	Dust	1.7E-02	2.1E-01	2.3E-01	2.6E+00	3.9E+00	5.1E+00
14	Arsenic	2.9E-05	1.6E-04	1.4E-04	3.5E-03	5.4E-03	7.2E-03
14	Selenium	2.4E-05	1.2E-04	1.3E-04	4.1E-03	6.1E-03	8.0E-03
14	Manganese	1.7E-04	8.3E-04	1.1E-03	1.1E-02	1.7E-02	2.3E-02
14	Cadmium	4.9E-09	2.6E-08	1.8E-08	5.9E-07	9.2E-07	1.2E-06
14	Chromium (VI)	2.0E-07	1.1E-06	8.6E-07	2.1E-05	3.1E-05	4.1E-05
14	Nickel	7.1E-06	4.3E-05	6.5E-05	5.6E-04	8.4E-04	1.1E-03
14	Mercury	6.8E-05	2.9E-04	3.9E-04	4.6E-03	7.0E-03	9.3E-03
14	Ammonia	7.2E-03	3.0E-02	5.1E-02	3.6E-01	5.4E-01	7.1E-01
14	BaP Equivalents	4.4E-07	1.9E-06	2.7E-06	2.7E-05	4.0E-05	5.1E-05
14	Acetone	1.8E-02	8.3E-02	1.3E-01	9.1E-01	1.3E+00	1.7E+00

Site	Chemical Species *(Case 6 – Cogeneration)*	Annual average ($\mu g\ m^{-3}$)	95th % 24-hr average ($\mu g\ m^{-3}$)	95th % 1-hr average ($\mu g\ m^{-3}$)	Max. 1-hr average ($\mu g\ m^{-3}$)	Max. 10-min average ($\mu g\ m^{-3}$)	Max. 3-min average ($\mu g\ m^{-3}$)
14	Acetaldehyde	5.8E-03	2.7E-02	4.1E-02	2.9E-01	4.5E-01	6.1E-01
14	Formaldehyde	4.4E-03	2.6E-02	1.7E-02	3.4E-01	5.4E-01	7.3E-01
14	2-Butanone	2.1E-03	1.0E-02	1.6E-02	1.1E-01	1.6E-01	2.1E-01
14	Benzene	6.8E-04	3.5E-03	3.7E-03	4.9E-02	7.2E-02	9.3E-02
14	Toluene	4.4E-04	2.1E-03	2.6E-03	2.9E-02	4.4E-02	5.8E-02
14	Xylenes	5.0E-05	3.0E-04	1.9E-04	3.8E-03	5.9E-03	8.0E-03
14	Acrolein	4.3E-04	2.6E-03	1.5E-03	3.6E-02	5.7E-02	7.8E-02
14	Ethylbenzene	2.3E-05	1.1E-04	1.4E-04	1.9E-03	2.9E-03	3.7E-03
14	Methylene Chloride	9.3E-04	4.9E-03	4.1E-03	7.6E-02	1.1E-01	1.4E-01
14	Styrene	4.4E-05	2.2E-04	3.1E-04	3.4E-03	5.0E-03	6.5E-03
14	1-2-4 Trimethylbenzene	1.6E-05	6.5E-05	1.1E-04	1.1E-03	1.6E-03	2.1E-03
14	1-3-5 Trimethylbenzene	7.2E-06	3.9E-05	5.5E-05	2.9E-04	4.6E-04	6.2E-04
14	Vinyl chloride	2.7E-06	1.7E-05	9.4E-06	2.3E-04	3.7E-04	5.0E-04
14	NO2	4.7E-01	4.7E+00	4.7E+00	5.4E+01	5.4E+01	5.4E+01
15	NOx	4.6E-01	5.8E+00	4.1E+00	6.2E+01	9.3E+01	1.2E+02
15	CO	7.8E-01	8.5E+00	5.5E+00	1.1E+02	1.6E+02	2.2E+02
15	SO2	4.5E-02	7.0E-01	5.2E-01	1.2E+01	1.7E+01	2.3E+01
15	Dust	1.7E-02	2.6E-01	1.4E-01	4.2E+00	6.6E+00	8.9E+00
15	Arsenic	3.2E-05	2.1E-04	1.1E-04	6.4E-03	9.7E-03	1.3E-02
15	Selenium	3.0E-05	2.0E-04	8.1E-05	4.3E-03	6.8E-03	9.2E-03
15	Manganese	1.0E-04	6.4E-04	2.8E-04	1.4E-02	2.2E-02	2.8E-02
15	Cadmium	5.3E-09	3.3E-08	6.9E-09	1.1E-06	1.7E-06	2.3E-06
15	Chromium (VI)	2.1E-07	1.4E-06	6.1E-07	3.4E-05	5.0E-05	6.5E-05
15	Nickel	5.1E-06	4.2E-05	2.0E-05	1.2E-03	1.8E-03	2.3E-03
15	Mercury	6.9E-05	3.8E-04	1.8E-04	5.9E-03	8.9E-03	1.2E-02
15	Ammonia	5.0E-03	2.9E-02	1.4E-02	7.5E-01	1.1E+00	1.4E+00
15	BaP Equivalents	3.4E-07	2.3E-06	1.0E-06	3.3E-05	5.0E-05	6.6E-05
15	Acetone	1.8E-02	1.0E-01	7.7E-02	1.5E+00	2.2E+00	2.9E+00
15	Acetaldehyde	5.2E-03	2.8E-02	2.5E-02	5.3E-01	8.2E-01	1.1E+00
15	Formaldehyde	4.5E-03	2.6E-02	9.1E-03	6.1E-01	9.4E-01	1.3E+00
15	2-Butanone	2.1E-03	1.3E-02	8.3E-03	1.7E-01	2.6E-01	3.4E-01
15	Benzene	9.0E-04	5.4E-03	3.0E-03	8.6E-02	1.3E-01	1.7E-01
15	Toluene	5.8E-04	3.2E-03	1.8E-03	6.6E-02	1.0E-01	1.4E-01
15	Xylenes	4.4E-05	2.5E-04	1.2E-04	5.4E-03	8.0E-03	1.0E-02
15	Acrolein	4.0E-04	2.8E-03	3.8E-04	6.7E-02	1.0E-01	1.4E-01
15	Ethylbenzene	2.4E-05	1.5E-04	9.1E-05	2.2E-03	3.3E-03	4.5E-03
15	Methylene Chloride	9.0E-04	5.7E-03	2.5E-03	9.8E-02	1.4E-01	1.9E-01
15	Styrene	5.8E-05	3.5E-04	1.8E-04	6.4E-03	9.6E-03	1.3E-02
15	1-2-4 Trimethylbenzene	1.3E-05	8.9E-05	4.2E-05	1.2E-03	1.9E-03	2.5E-03
15	1-3-5 Trimethylbenzene	6.0E-06	3.5E-05	3.2E-05	5.0E-04	7.7E-04	1.0E-03

Site	Chemical Species *(Case 6 – Cogeneration)*	Annual average ($\mu g\ m^{-3}$)	95th % 24-hr average ($\mu g\ m^{-3}$)	95th % 1-hr average ($\mu g\ m^{-3}$)	Max. 1-hr average ($\mu g\ m^{-3}$)	Max. 10-min average ($\mu g\ m^{-3}$)	Max. 3-min average ($\mu g\ m^{-3}$)
15	Vinyl chloride	2.5E-06	1.8E-05	2.3E-06	4.3E-04	6.7E-04	9.0E-04
15	NO2	4.6E-01	5.6E+00	4.1E+00	5.4E+01	5.4E+01	5.4E+01
16	NOx	6.8E-01	8.3E+00	1.0E+01	4.5E+01	5.8E+01	6.9E+01
16	CO	1.1E+00	1.1E+01	1.4E+01	7.7E+01	1.2E+02	1.6E+02
16	SO2	6.8E-02	1.1E+00	1.5E+00	7.5E+00	1.1E+01	1.5E+01
16	Dust	2.9E-02	4.3E-01	4.0E-01	3.0E+00	4.6E+00	6.2E+00
16	Arsenic	4.0E-05	2.5E-04	2.9E-04	2.3E-03	3.9E-03	5.6E-03
16	Selenium	4.3E-05	2.1E-04	3.2E-04	3.7E-03	5.1E-03	6.4E-03
16	Manganese	1.1E-03	6.4E-03	3.8E-03	2.9E-01	4.0E-01	5.1E-01
16	Cadmium	6.9E-09	4.1E-08	3.4E-08	4.1E-07	7.0E-07	1.0E-06
16	Chromium (VI)	3.0E-07	2.0E-06	2.2E-06	1.2E-05	2.0E-05	2.7E-05
16	Nickel	3.8E-05	2.0E-04	1.8E-04	9.1E-03	1.3E-02	1.6E-02
16	Mercury	1.8E-04	8.9E-04	1.2E-03	2.0E-02	2.7E-02	3.4E-02
16	Ammonia	4.7E-02	2.3E-01	2.1E-01	8.2E+00	1.1E+01	1.4E+01
16	BaP Equivalents	2.2E-06	1.1E-05	9.3E-06	2.3E-04	3.3E-04	4.1E-04
16	Acetone	7.4E-02	3.2E-01	4.7E-01	5.7E+00	8.0E+00	1.0E+01
16	Acetaldehyde	2.2E-02	1.1E-01	1.5E-01	1.9E+00	2.6E+00	3.3E+00
16	Formaldehyde	8.0E-03	5.3E-02	4.9E-02	3.5E-01	5.5E-01	7.5E-01
16	2-Butanone	9.4E-03	4.4E-02	5.3E-02	8.3E-01	1.2E+00	1.5E+00
16	Benzene	1.3E-03	7.0E-03	9.4E-03	5.1E-02	7.8E-02	1.0E-01
16	Toluene	1.3E-03	5.5E-03	9.3E-03	6.0E-02	8.3E-02	1.0E-01
16	Xylenes	8.7E-05	5.1E-04	5.9E-04	3.7E-03	5.2E-03	6.6E-03
16	Acrolein	7.2E-04	5.0E-03	3.5E-03	3.8E-02	6.0E-02	8.1E-02
16	Ethylbenzene	4.8E-05	2.3E-04	3.4E-04	4.9E-03	6.8E-03	8.5E-03
16	Methylene Chloride	1.9E-03	9.8E-03	1.4E-02	1.3E-01	1.9E-01	2.3E-01
16	Styrene	9.0E-05	6.0E-04	7.5E-04	5.7E-03	8.3E-03	1.1E-02
16	1-2-4 Trimethylbenzene	8.4E-05	4.5E-04	3.1E-04	2.0E-02	2.8E-02	3.5E-02
16	1-3-5 Trimethylbenzene	3.0E-05	1.5E-04	1.6E-04	6.3E-03	8.8E-03	1.1E-02
16	Vinyl chloride	4.5E-06	3.2E-05	2.2E-05	2.4E-04	3.8E-04	5.2E-04
16	NO2	6.8E-01	8.3E+00	1.0E+01	4.4E+01	5.4E+01	5.4E+01

5.3. Concentration Contours – Case 6 (with Cogeneration)

Figure 12 to Figure 29 show the modelled concentration contour patterns for Expansion Case 6 for the six statistics (annual average, 95th percentile 24-hour average, 95th percentile 1-hour average, maximum 1-hour average, maximum 10-minute average, and maximum 3-minute average) for formaldehyde, mercury, and NO_x. These were selected as representative of low-level, medium level and tall-stack releases from the Refinery for investigating the different patterns of ground-level concentrations. The mercury results presented here only include stack sources; the area source contributions are being modelled separately. The strongest mercury stack sources are the Oxalate Kiln Stack and the Boilerhouse Multiflue whereas the strongest formaldehyde stack sources are the Calciner stacks.

For the annual average and 95th percentile 24-hour average, the highest concentrations in the spatial distribution all occur within the Refinery within a few hundred metres of the 100 m Multiflue stack. The same is true for the modelled maximum 1-hour average concentrations for formaldehyde and mercury. Formaldehyde shows a very diffuse pattern with values below 0.5 µg m^{-3} at all receptors (except 15) and the maximum of 1 µg m^{-3} located 5 km south-east of the 100 m Multiflue on the escarpment. Mercury shows small peaks of up to 0.02 µg m^{-3} about 2 km east of the 100 m Multiflue and one extending about 2 km north of the 100 m Multiflue.

For NO_x, the modelled maximum 1-hour average concentrations (Figure 27) show a highest concentration in the spatial distribution of about 200 µg m^{-3} at a distance of 4 km approximately west-south-west of the 100 m Multiflue stack. There is also a local peak of 90 µg m^{-3} in the same location as the formaldehyde peak on the escarpment, 5 km south-east of the 100 m Multiflue. Modelled maximum concentrations through Yarloop are lower (from 50 to 75 µg m^{-3}) and about 50 µg m^{-3} in Hamel. The NO_x results differ from those for formaldehyde because most of the NO_x emissions occur from the taller stacks that have significant plume rise because of the high temperature and volume of flow from the Calciner and Boilerhouse stacks. The highest ground-level concentrations from these stacks occur under convective or fumigation conditions. The maximum 10-minute and 3-minute average concentrations show similar patterns but with higher concentrations.

These differences between the contour patterns for species released at different heights are in agreement with our understanding of the different dispersion processes that are dominant at different heights in the atmosphere.

These yearly maximum 1-hour average concentrations represent the most extreme hour in the year with respect to ground-level concentrations. In a different year with different meteorology the location and magnitude of these yearly maximum 1-hour average concentrations could change. This is why the 9th highest concentration (99.9th percentile) or robust highest concentration (RHC) is often chosen as the key statistic to represent the extremes, rather than the modelled or observed maximum.

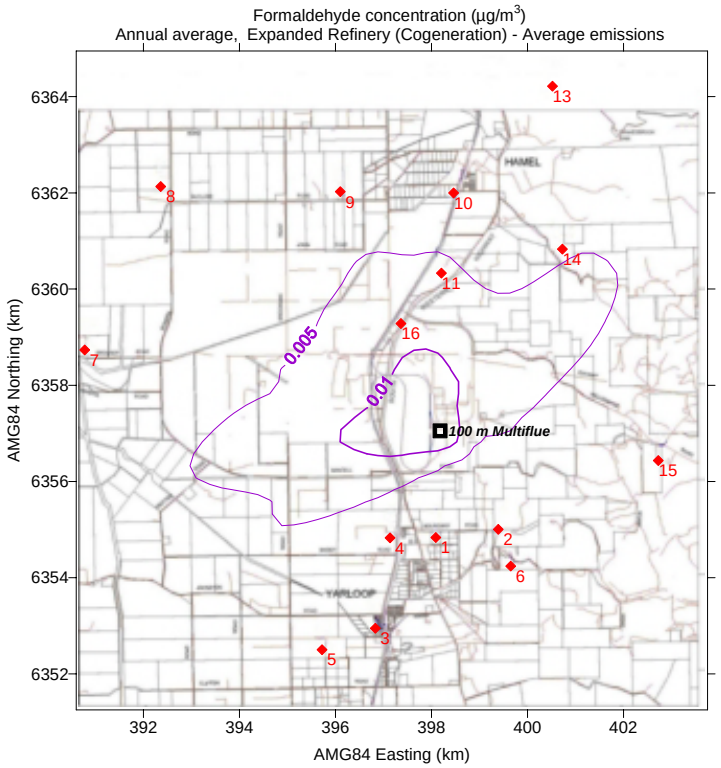

Figure 12: Annual-average modelled formaldehyde concentrations for 4.7 Mtpa Expanded Refinery Scenario Case 6 (with Cogeneration) – Average Emissions.

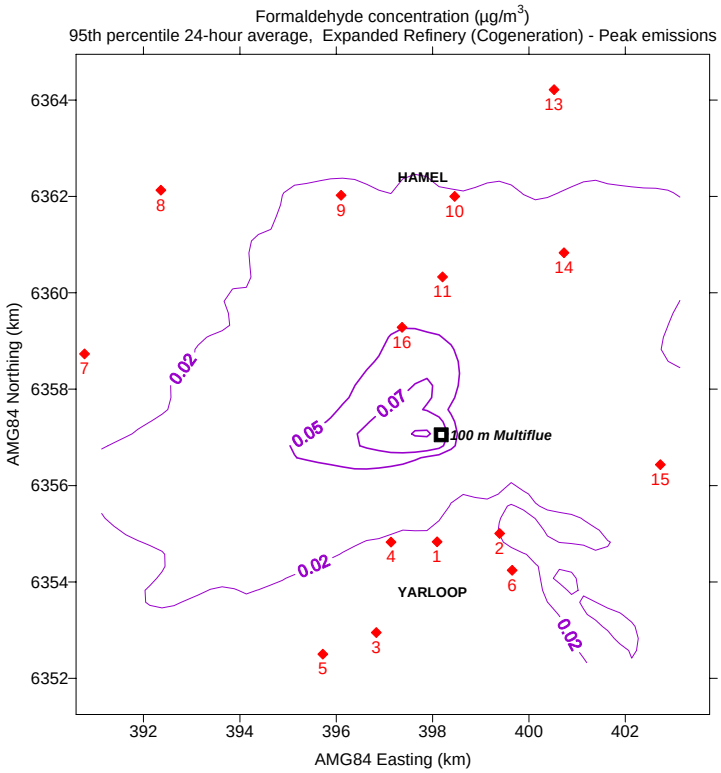

Figure 13: 95th percentile 24-hour average modelled formaldehyde concentrations for 4.7 Mtpa Expanded Refinery Scenario Case 6 (with Cogeneration) – Peak Emissions.

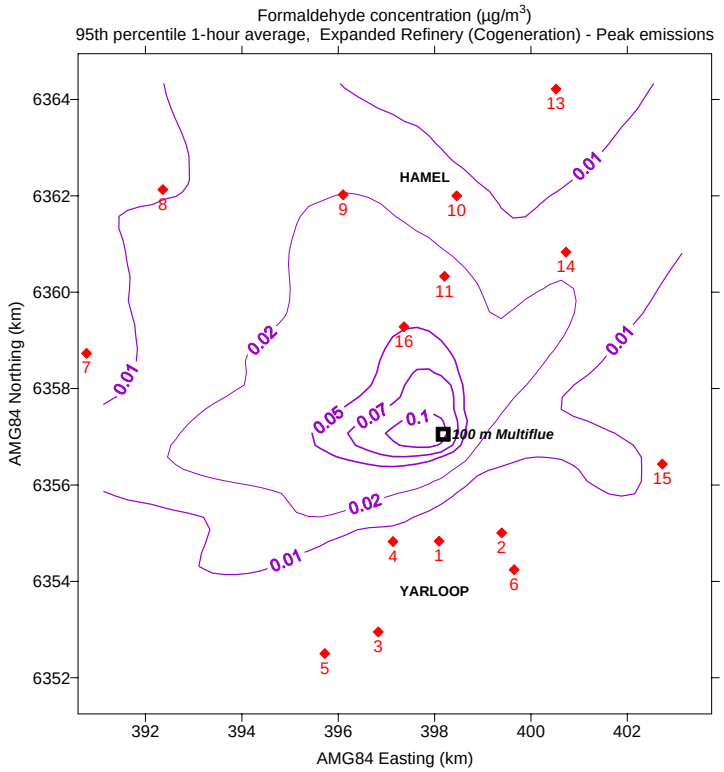

Figure 14: 95th percentile 1-hour average modelled formaldehyde concentrations for 4.7 Mtpa Expanded Refinery Scenario Case 6 (with Cogeneration) – Peak Emissions.

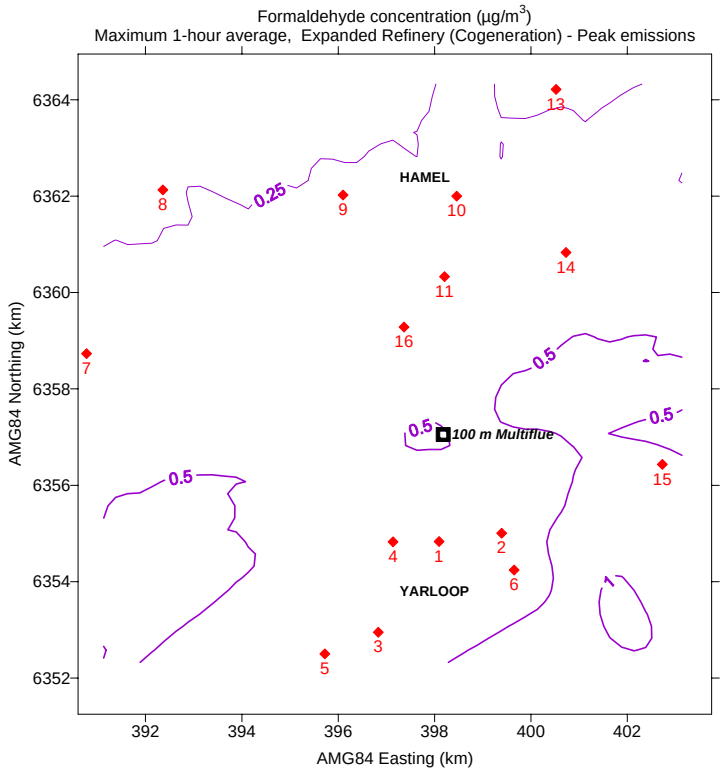

Figure 15: Maximum 1-hour average modelled formaldehyde concentrations for 4.7 Mtpa Expanded Refinery Scenario Case 6 (with Cogeneration) – Peak Emissions.

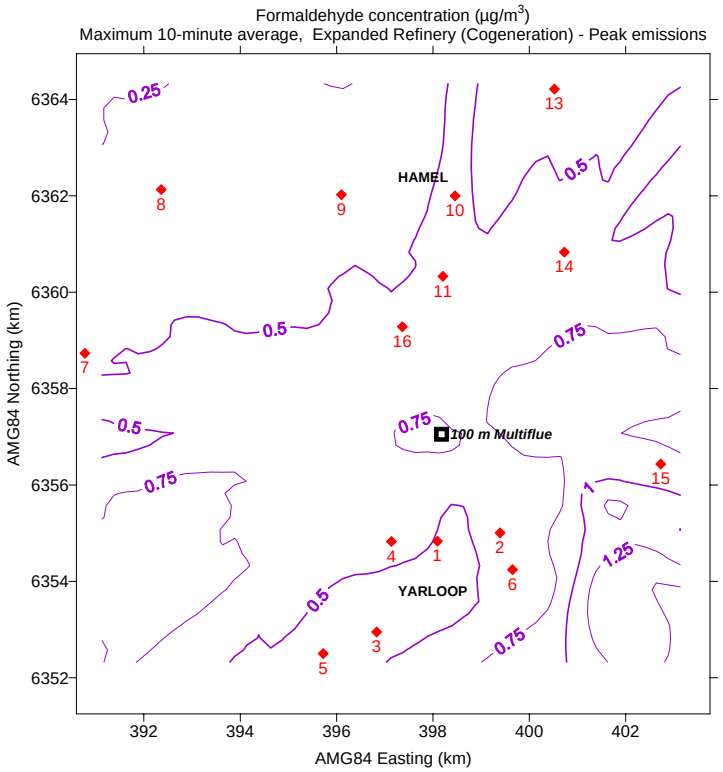

Figure 16: Maximum 10-minute average modelled formaldehyde concentrations for 4.7 Mtpa Expanded Refinery Scenario Case 6 (with Cogeneration) – Peak Emissions.

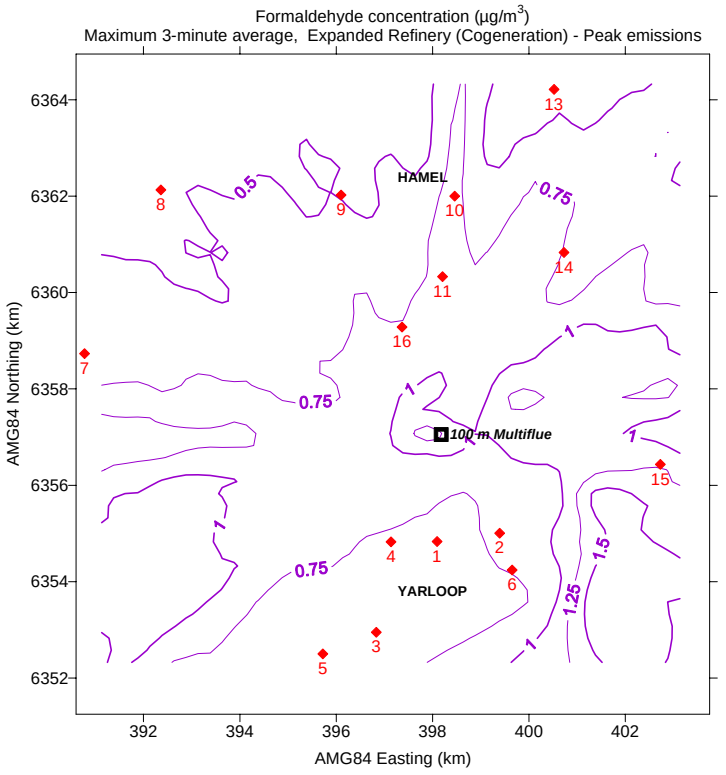

Figure 17: Maximum 3-minute average modelled formaldehyde concentrations for 4.7 Mtpa Expanded Refinery Scenario Case 6 (with Cogeneration) – Peak Emissions.

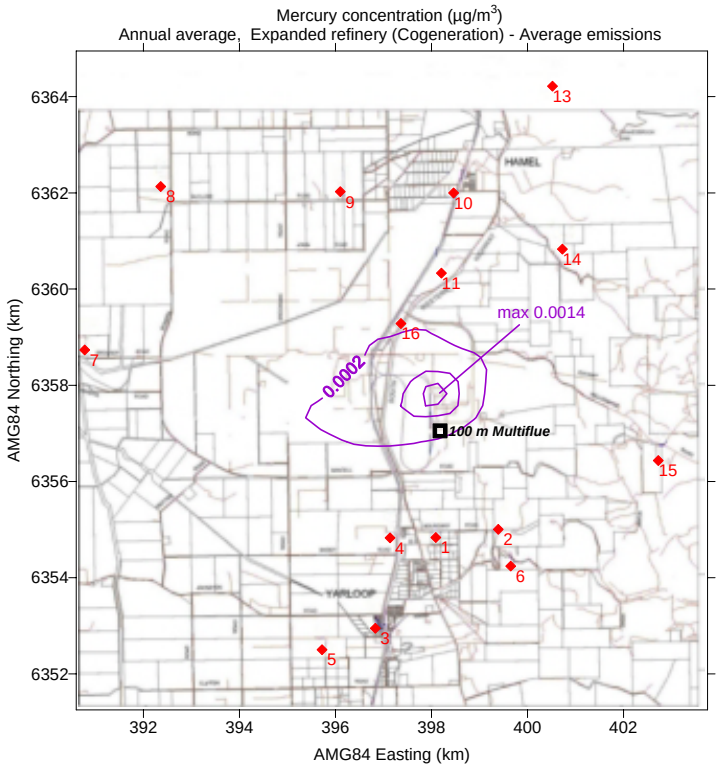

Figure 18: Annual-average modelled mercury concentrations for 4.7 Mtpa Expanded Refinery Scenario Case 6 (with Cogeneration) – Average Emissions.

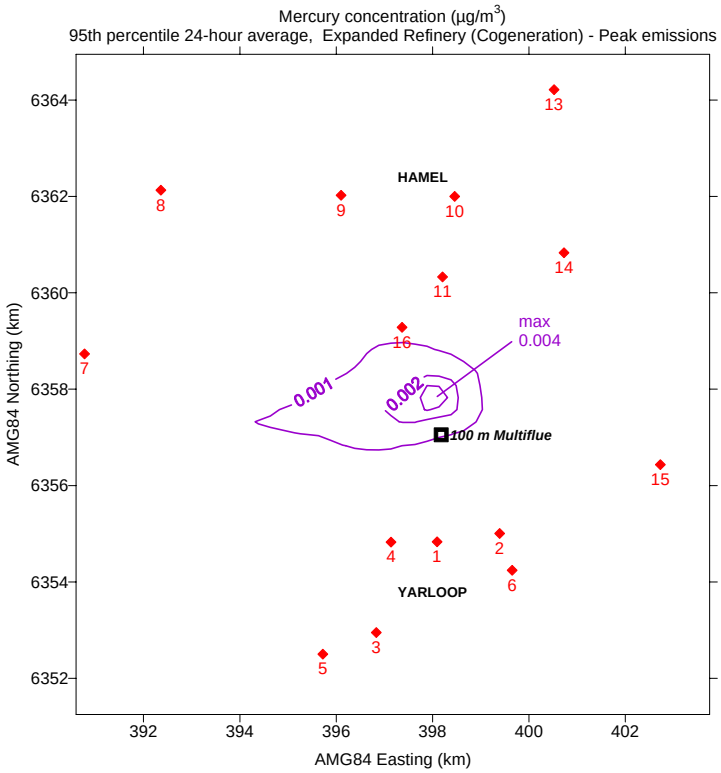

Figure 19: 95th percentile 24-hour average modelled mercury concentrations for 4.7 Mtpa Expanded Refinery Scenario Case 6 (with Cogeneration) – Peak Emissions.

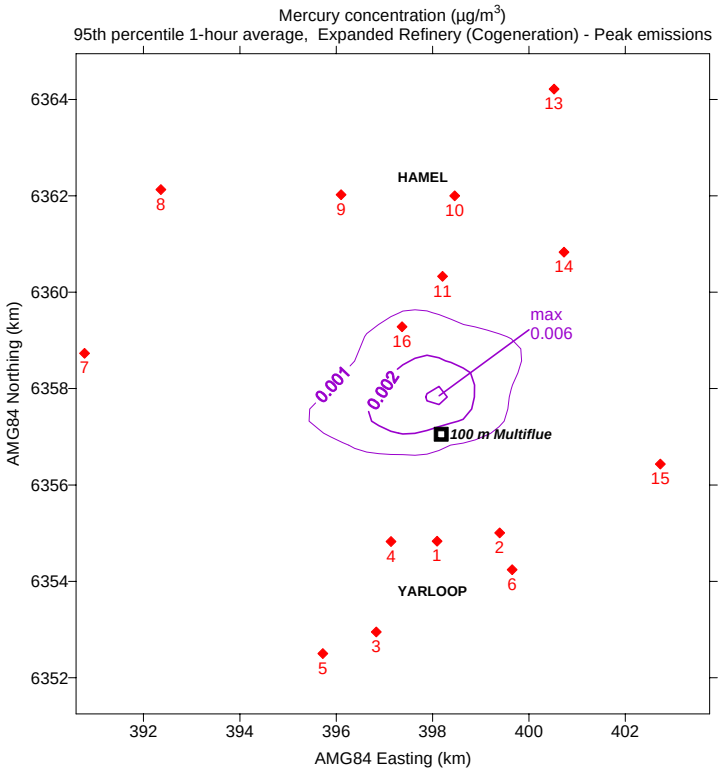

Figure 20: 95th percentile 1-hour average modelled mercury concentrations for 4.7 Mtpa Expanded Refinery Scenario Case 6 (with Cogeneration) – Peak Emissions.

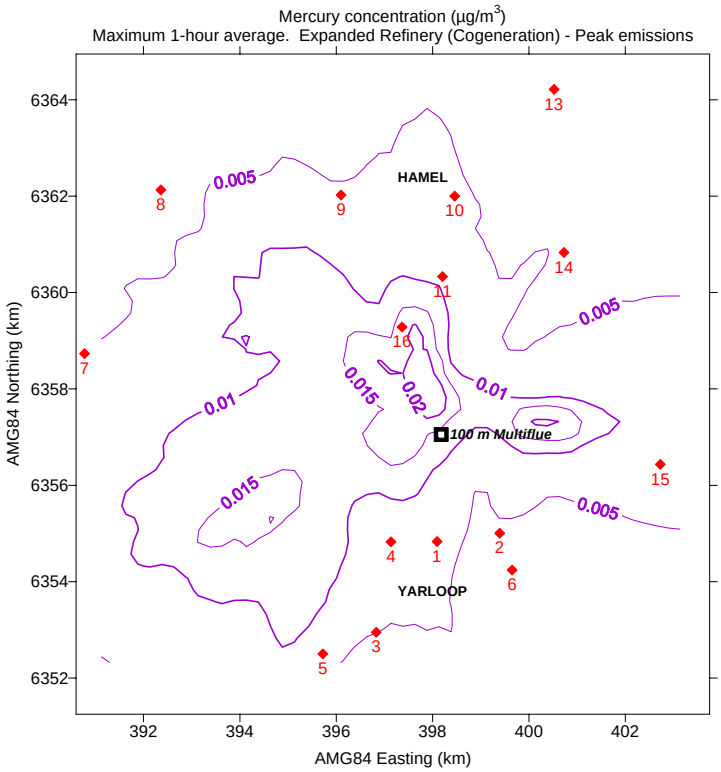

Figure 21: Maximum 1-hour average modelled mercury concentrations for 4.7 Mtpa Expanded Refinery Scenario Case 6 (with Cogeneration) – Peak Emissions.

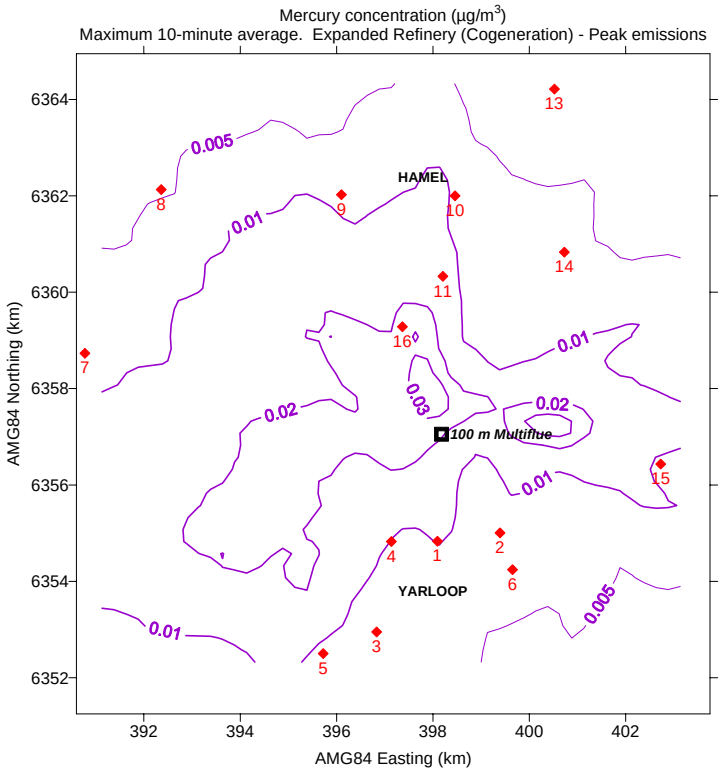

Figure 22: Maximum 10-minute average modelled mercury concentrations for 4.7 Mtpa Expanded Refinery Scenario Case 6 (with Cogeneration) – Peak Emissions.

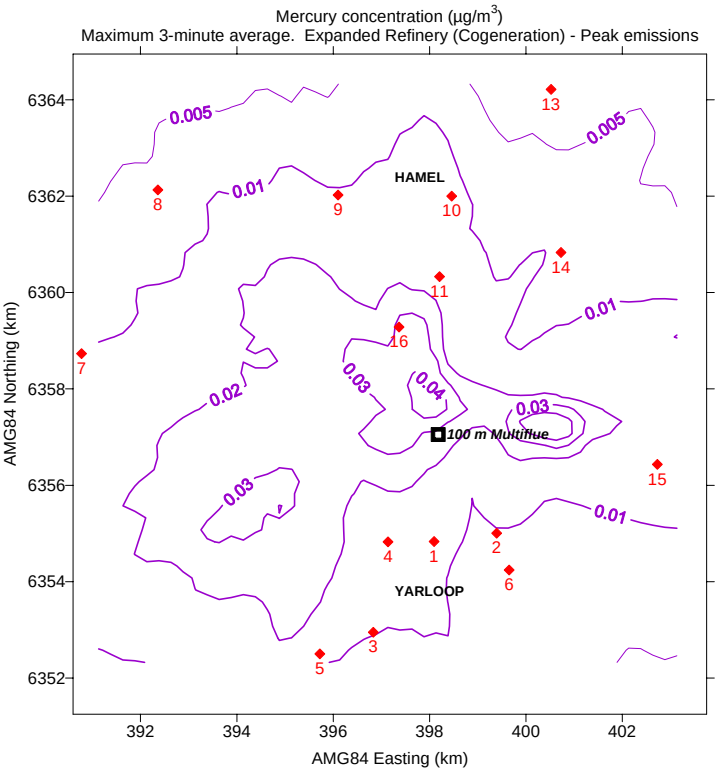

Figure 23: Maximum 3-minute average modelled mercury concentrations for 4.7 Mtpa Expanded Refinery Scenario Case 6 (with Cogeneration) – Peak Emissions.

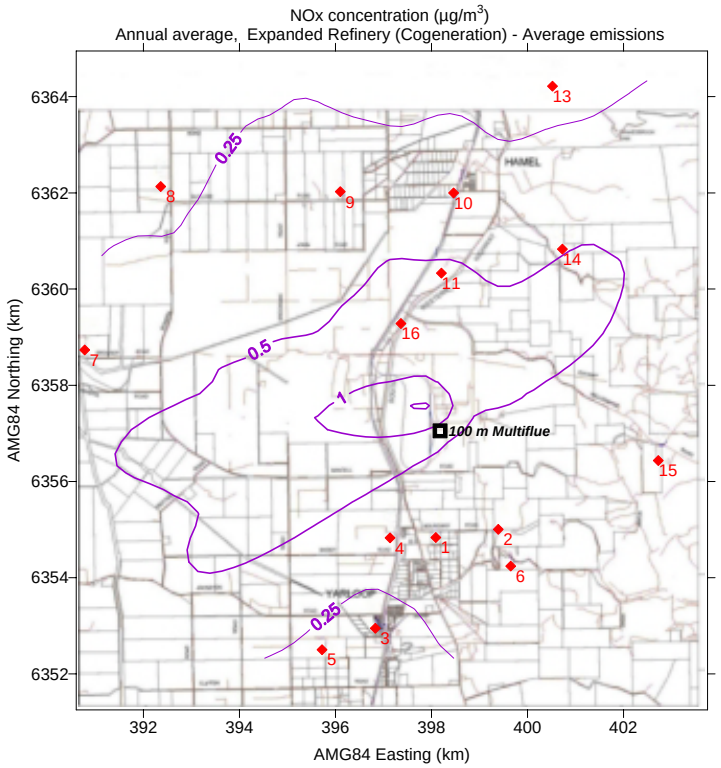

Figure 24: Annual-average modelled NO_x concentrations for 4.7 Mtpa Expanded Refinery Scenario Case 6 (with Cogeneration) – Average Emissions.

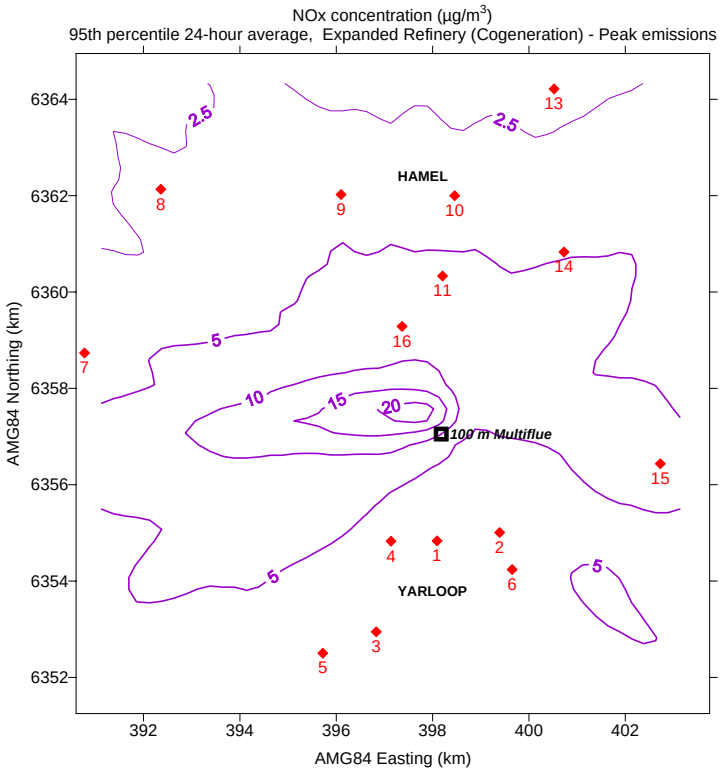

Figure 25: 95th percentile 24-hour average modelled NO_x concentrations for 4.7 Mtpa Expanded Refinery Scenario Case 6 (with Cogeneration) – Peak Emissions.

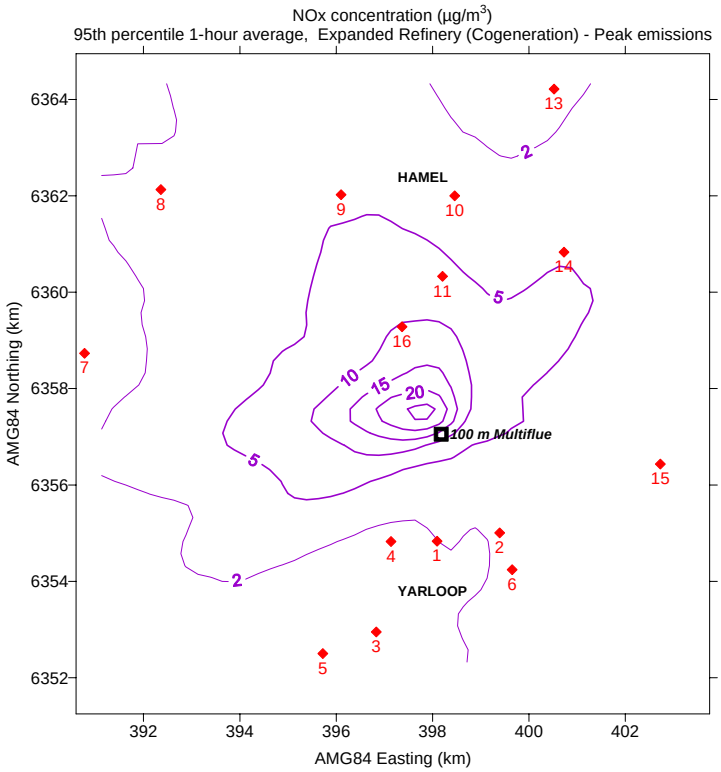

Figure 26: 95th percentile 1-hour average modelled NO_x concentrations for 4.7 Mtpa Expanded Refinery Scenario Case 6 (with Cogeneration) – Peak Emissions.

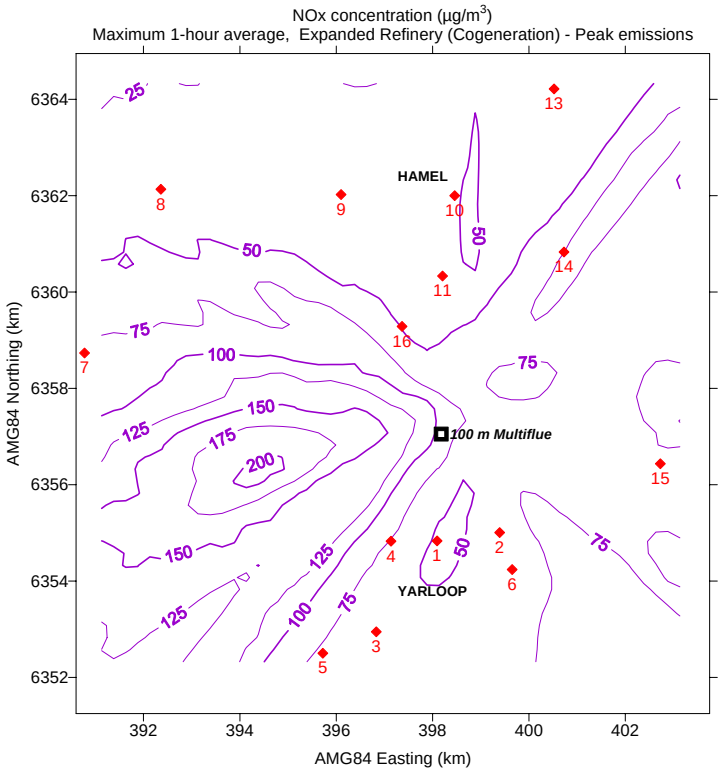

Figure 27: Maximum 1-hour average modelled NO_x concentrations for 4.7 Mtpa Expanded Refinery Scenario Case 6 (with Cogeneration) – Peak Emissions.

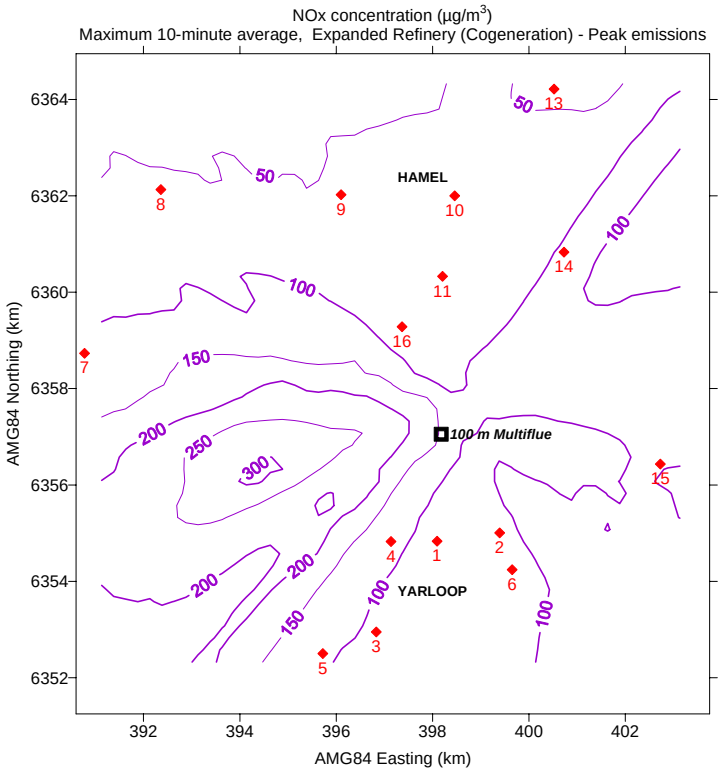

Figure 28: Maximum 10-minute average modelled NO_x concentrations for Current 4.7 Mtpa Expanded Refinery Scenario Case 6 (with Cogeneration) – Peak Emissions.

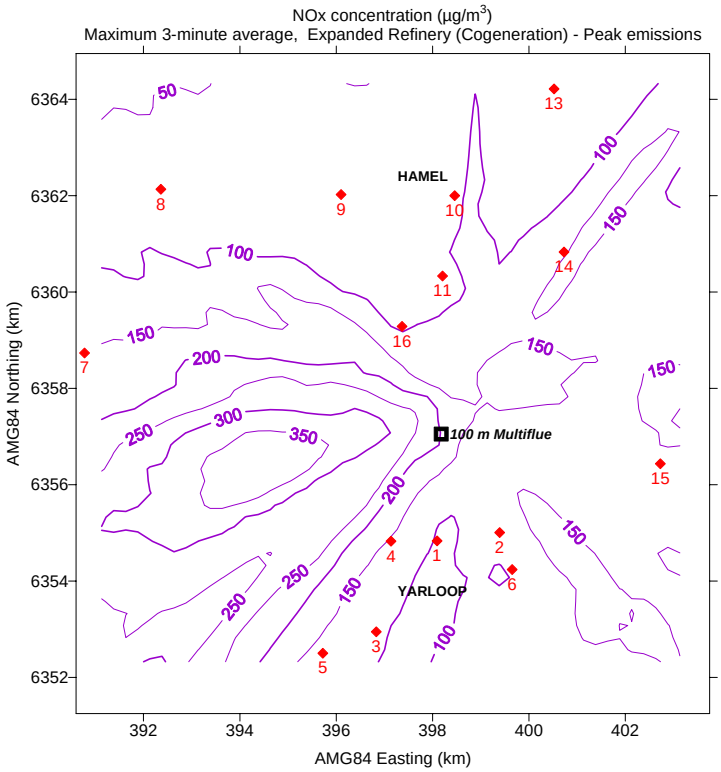

Figure 29: Maximum 3-minute average modelled NO_x concentrations for 4.7 Mtpa Expanded Refinery Scenario Case 6 (with Cogeneration) – Peak Emissions.

5.4. Peak Events – Case 6 (with Cogeneration)

Figure 30 to Figure 32 show the temporal variation of the modelled 1-hour average concentrations around the five highest concentration events for formaldehyde, NO_x and NO_2 for Expansion Case 6.

One-half of the model events occur at the same time for NO_x and formaldehyde, though not always at the same site, with most of these events during the winter months (April to September).

For both formaldehyde and NO_x the peaks at receptors 1 (Boundary Road) and 14 (Escarpment) all occur between 10:00 to 18:00, whereas at receptor 3 (Yarloop), peaks are observed both at night and during the day. All the peaks only last for one hour.

The results for NO_2 are similar to those for NO_x except for largest peak at receptor 14 (Escarpment) which is capped by the ambient ozone concentration to 53 μg m^{-3} and lasts for 3 hours on 22 August.

Figure 33 shows that the wind directions at the times of the peak concentrations correspond closely with the Refinery being directly upwind from the receptor. Wind directions corresponding to the receptor being directly downwind of the Refinery are 0º for receptor 1, 20º for receptor 3, and 215º for receptor 14. The exceptions (when these peaks occurred and the wind direction was not from the Refinery) include two cases at receptor 3 for NO_x and formaldehyde which occurred at 2100 and 0400 hours with mixing heights of 34 and 50 m and wind speeds of 2 m s^{-1} and 3 m s^{-1}). There is also one case at receptor 1 for formaldehyde, which occurred at 1000 hours with a wind speed of 1.6 m s^{-1} and a mixing height of 480 m. These indicate some turning of the wind, the former with flow from the escarpment towards the receptor, the latter from the north-west back towards the receptor. In the other cases, the wind speeds were higher, typically 4 to 11 m s^{-1}. These features are similar to those identified in the Wagerup Air Quality Review (CSIRO, 2004a) when examining the peak NO_x concentrations observed at Boundary Road and Upper Dam, except that the wind speeds in those cases tended to be lower, generally less than 4 m s^{-1}. These features also closely match those identified in Section 6 of the Phase 2 report (CSIRO, 2004c), where most model events were identified as occurring with wind speeds from 2 to 6 m s^{-1} and at lower speeds under easterly flows. Night-time model events occurred with mixing heights less than 300 m, whereas daytime model events occur in strongly convective conditions with mixing heights up to 2000 m, similar to the results shown in Figure 33.

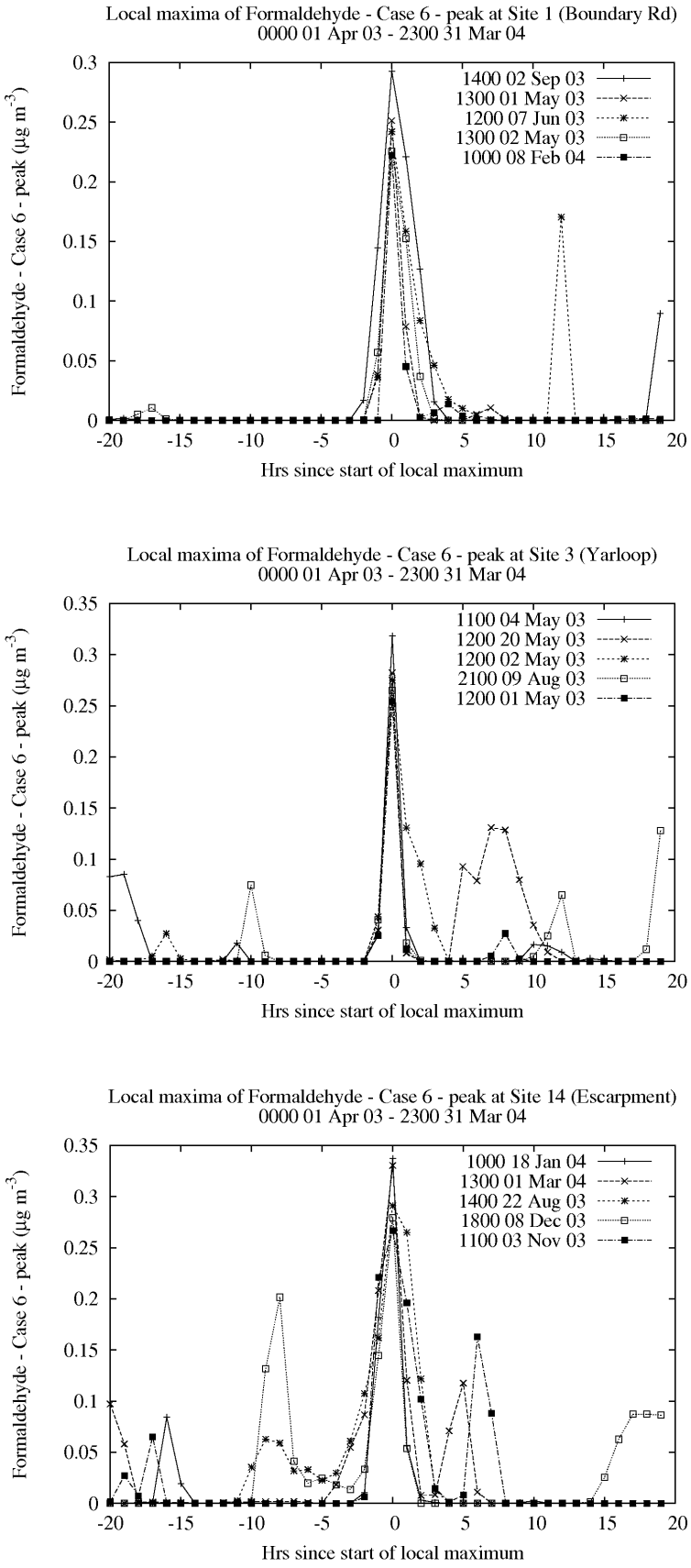

Figure 30: Time series of the five highest formaldehyde concentrations at three receptor sites.

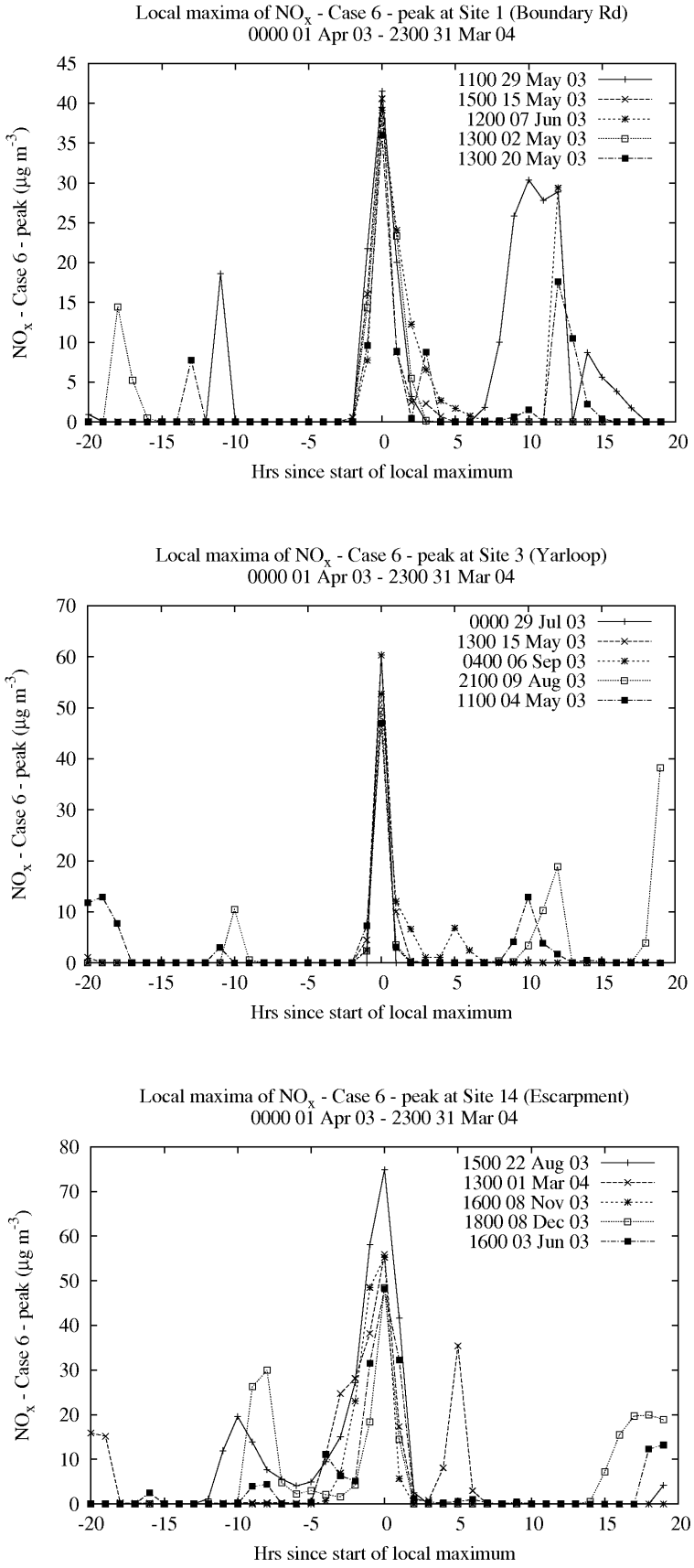

Figure 31: Time series of the five highest NO_x concentrations at three receptor sites.

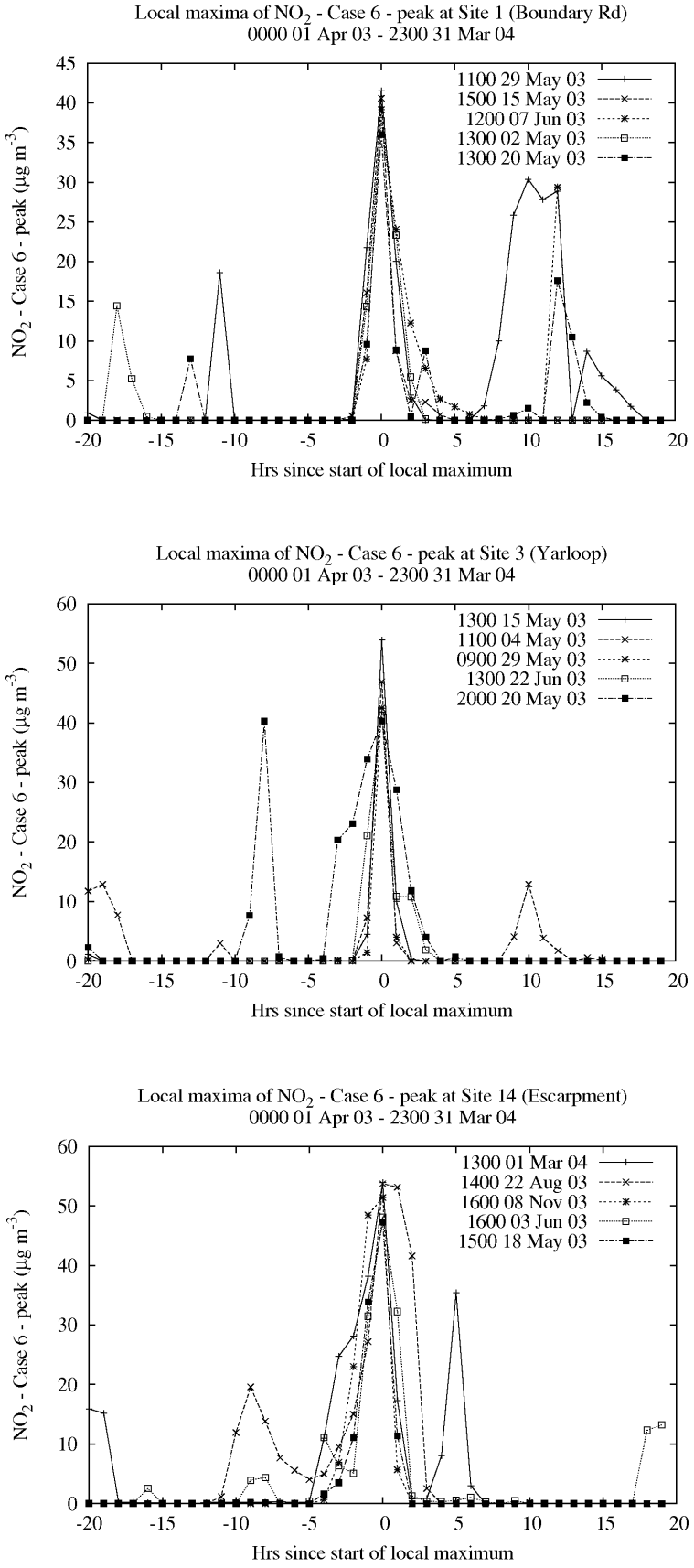

Figure 32: Time series of the five highest NO_2 concentrations at three receptor sites.

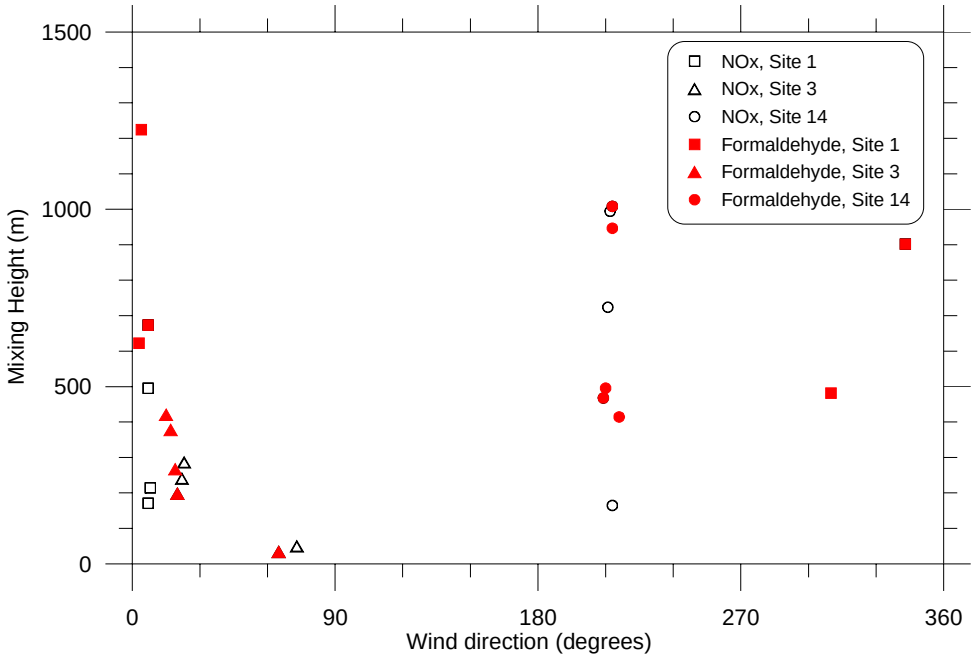

Figure 33: Modelled wind direction (at 25 m) and mixing height at Bancell Road for the five highest Case 6 peak concentrations of NO_x and formaldehyde at receptors 1, 3, and 14.

6. Results for Case 7 (with new Boilers 4 & 5)

6.1. Concentration Statistics by Species – Case 7 (with new Boilers)

Table 11 lists the concentration statistics for all 28 chemical species modelled at each of the 15 receptor sites for Expansion Case 7 sorted by species. The same results are shown in Table 12 sorted by receptor site. The results are shown to one decimal place as this represents an uncertainty of at most 10% in the results. As indicated in the previous section, results of many TAPM modelling studies indicate that it is not possible to obtain better accuracy than this, particularly for peak statistics.

The 95th percentile value represents a concentration where 95% of the data are smaller and 5% of the data are larger than this concentration. For the 24-hour averages, it represents the 18th highest concentration in a year of 365 24-hour averages, whereas for the 1-hour averages it represents the 440th highest concentration in a year of 8760 1-hour averages. Although on any particular day, the 24-hour average will always be smaller than (or equal to) the maximum 1-hour average for that day, for the 95th percentiles there is no simple relation. The 95th percentile 24-hour average can be either larger or smaller than the 95th percentile 1-hour average, as is observed in Table 11.

Table 11. Selected modelled concentration statistics sorted by species for each of the 28 chemical species at each of the 15 receptor sites for Expanded Refinery Scenario (4.7 Mtpa) with Case 7 (new Boilers 4 & 5). The annual averages are for the average emission rates, whereas all other statistics are for peak emission rates. The shaded NO_2 cells are values limited by the available ozone, see Section 3.7.

Chemical Species *(Case 7 – Boilers 4 & 5)*	**Site**	**Annual average** ($\mu g\ m^{-3}$)	**95th % 24-hr average** ($\mu g\ m^{-3}$)	**95th % 1-hr average** ($\mu g\ m^{-3}$)	**Max. 1-hr average** ($\mu g\ m^{-3}$)	**Max. 10-min average** ($\mu g\ m^{-3}$)	**Max. 3-min average** ($\mu g\ m^{-3}$)
NOx	1	2.8E-01	3.0E+00	1.7E+00	4.8E+01	7.4E+01	9.9E+01
NOx	2	3.0E-01	3.2E+00	1.9E+00	5.1E+01	7.6E+01	9.8E+01
NOx	3	2.1E-01	2.3E+00	7.6E-01	6.0E+01	9.1E+01	1.2E+02
NOx	4	2.6E-01	3.1E+00	1.4E+00	7.3E+01	1.1E+02	1.4E+02
NOx	5	2.0E-01	2.3E+00	5.8E-01	7.2E+01	1.1E+02	1.4E+02
NOx	6	2.9E-01	3.0E+00	2.1E+00	7.5E+01	9.9E+01	1.2E+02
NOx	7	2.3E-01	3.0E+00	1.2E+00	6.7E+01	1.0E+02	1.3E+02
NOx	8	1.8E-01	2.3E+00	1.6E+00	2.8E+01	3.9E+01	4.9E+01
NOx	9	2.9E-01	2.9E+00	3.2E+00	4.0E+01	6.0E+01	7.8E+01
NOx	10	2.6E-01	2.5E+00	2.1E+00	4.2E+01	6.4E+01	8.4E+01
NOx	11	4.2E-01	4.1E+00	4.6E+00	4.1E+01	6.2E+01	8.2E+01
NOx	13	1.6E-01	1.4E+00	1.2E+00	3.2E+01	4.7E+01	6.1E+01
NOx	14	4.0E-01	3.9E+00	3.5E+00	7.4E+01	1.1E+02	1.4E+02
NOx	15	4.5E-01	5.0E+00	3.5E+00	9.0E+01	1.3E+02	1.7E+02
NOx	16	6.0E-01	6.7E+00	8.7E+00	4.7E+01	7.2E+01	9.5E+01
CO	1	5.6E-01	5.3E+00	4.2E+00	6.7E+01	9.5E+01	1.2E+02
CO	2	5.4E-01	5.4E+00	4.4E+00	7.0E+01	1.0E+02	1.3E+02
CO	3	4.0E-01	3.9E+00	2.3E+00	9.1E+01	1.2E+02	1.5E+02
CO	4	5.0E-01	4.9E+00	3.3E+00	6.0E+01	8.1E+01	9.8E+01
CO	5	3.3E-01	3.4E+00	1.3E+00	7.2E+01	9.7E+01	1.2E+02
CO	6	4.9E-01	5.5E+00	3.9E+00	8.5E+01	1.1E+02	1.4E+02
CO	7	3.1E-01	3.3E+00	1.7E+00	4.9E+01	7.2E+01	9.3E+01
CO	8	2.9E-01	3.4E+00	2.5E+00	4.2E+01	6.2E+01	8.1E+01
CO	9	4.9E-01	4.4E+00	5.4E+00	5.5E+01	8.4E+01	1.1E+02
CO	10	4.1E-01	3.5E+00	4.0E+00	6.4E+01	9.9E+01	1.3E+02
CO	11	6.6E-01	5.8E+00	8.0E+00	6.9E+01	1.1E+02	1.5E+02
CO	13	2.9E-01	2.6E+00	3.3E+00	4.2E+01	6.2E+01	8.2E+01
CO	14	6.6E-01	5.9E+00	7.3E+00	1.1E+02	1.6E+02	2.1E+02
CO	15	7.7E-01	8.5E+00	5.6E+00	1.1E+02	1.6E+02	2.2E+02
CO	16	1.1E+00	1.1E+01	1.4E+01	7.7E+01	1.2E+02	1.6E+02
SO2	1	3.6E-02	5.6E-01	4.0E-01	8.3E+00	1.3E+01	1.7E+01
SO2	2	3.4E-02	5.3E-01	4.0E-01	8.8E+00	1.3E+01	1.7E+01
SO2	3	2.6E-02	3.8E-01	2.0E-01	1.1E+01	1.6E+01	2.1E+01
SO2	4	3.3E-02	5.9E-01	3.1E-01	1.3E+01	2.0E+01	2.6E+01
SO2	5	2.3E-02	4.1E-01	1.1E-01	1.2E+01	1.8E+01	2.4E+01

Chemical Species *(Case 7 – Boilers 4 & 5)*	**Site**	**Annual average** ($\mu g\ m^{-3}$)	**95th % 24-hr average** ($\mu g\ m^{-3}$)	**95th % 1-hr average** ($\mu g\ m^{-3}$)	**Max. 1-hr average** ($\mu g\ m^{-3}$)	**Max. 10-min average** ($\mu g\ m^{-3}$)	**Max. 3-min average** ($\mu g\ m^{-3}$)
SO2	6	3.2E-02	4.9E-01	4.1E-01	1.3E+01	1.7E+01	2.1E+01
SO2	7	2.6E-02	5.3E-01	2.0E-01	1.2E+01	1.8E+01	2.4E+01
SO2	8	2.1E-02	3.9E-01	2.7E-01	5.7E+00	7.9E+00	9.9E+00
SO2	9	3.4E-02	5.1E-01	5.7E-01	7.2E+00	1.1E+01	1.4E+01
SO2	10	2.9E-02	4.1E-01	4.2E-01	7.5E+00	1.1E+01	1.5E+01
SO2	11	4.6E-02	7.6E-01	8.6E-01	7.1E+00	1.1E+01	1.4E+01
SO2	13	1.8E-02	2.5E-01	2.4E-01	5.3E+00	7.8E+00	1.0E+01
SO2	14	4.4E-02	6.5E-01	6.5E-01	1.3E+01	1.9E+01	2.4E+01
SO2	15	5.0E-02	8.3E-01	5.7E-01	1.6E+01	2.3E+01	3.0E+01
SO2	16	7.4E-02	1.2E+00	1.6E+00	8.3E+00	1.3E+01	1.7E+01
Dust	1	1.2E-02	1.4E-01	8.7E-02	2.3E+00	3.6E+00	4.9E+00
Dust	2	1.3E-02	1.7E-01	9.1E-02	3.0E+00	4.6E+00	6.2E+00
Dust	3	8.5E-03	1.2E-01	6.1E-02	2.9E+00	3.9E+00	4.8E+00
Dust	4	1.1E-02	1.4E-01	7.8E-02	2.4E+00	3.7E+00	4.9E+00
Dust	5	7.2E-03	9.9E-02	4.2E-02	2.1E+00	2.8E+00	3.5E+00
Dust	6	1.1E-02	1.5E-01	8.8E-02	3.1E+00	4.7E+00	6.4E+00
Dust	7	6.8E-03	8.5E-02	6.2E-02	1.8E+00	2.7E+00	3.5E+00
Dust	8	7.5E-03	1.1E-01	8.2E-02	1.5E+00	2.2E+00	2.8E+00
Dust	9	1.3E-02	1.6E-01	1.8E-01	2.4E+00	3.7E+00	4.9E+00
Dust	10	1.2E-02	1.4E-01	1.3E-01	3.3E+00	5.2E+00	7.0E+00
Dust	11	2.0E-02	2.4E-01	2.3E-01	3.7E+00	5.8E+00	7.9E+00
Dust	13	7.5E-03	9.3E-02	9.5E-02	1.8E+00	2.7E+00	3.7E+00
Dust	14	1.7E-02	2.1E-01	2.3E-01	2.6E+00	3.9E+00	5.1E+00
Dust	15	1.7E-02	2.6E-01	1.4E-01	4.2E+00	6.6E+00	8.9E+00
Dust	16	2.9E-02	4.3E-01	4.0E-01	3.0E+00	4.6E+00	6.2E+00
Arsenic	1	5.2E-05	3.5E-04	1.1E-04	8.7E-03	1.2E-02	1.5E-02
Arsenic	2	5.9E-05	3.4E-04	1.2E-04	1.0E-02	1.5E-02	2.0E-02
Arsenic	3	4.0E-05	2.6E-04	6.0E-05	8.3E-03	1.1E-02	1.4E-02
Arsenic	4	4.8E-05	3.4E-04	1.0E-04	9.2E-03	1.4E-02	1.8E-02
Arsenic	5	3.9E-05	2.5E-04	4.8E-05	9.8E-03	1.5E-02	1.9E-02
Arsenic	6	6.1E-05	2.9E-04	1.4E-04	1.2E-02	1.7E-02	2.0E-02
Arsenic	7	4.3E-05	2.9E-04	6.3E-05	1.2E-02	1.8E-02	2.4E-02
Arsenic	8	3.2E-05	2.0E-04	1.0E-04	4.2E-03	6.3E-03	8.2E-03
Arsenic	9	5.4E-05	2.9E-04	2.3E-04	6.0E-03	8.9E-03	1.2E-02
Arsenic	10	5.1E-05	2.7E-04	1.9E-04	6.1E-03	9.1E-03	1.2E-02
Arsenic	11	8.0E-05	5.2E-04	4.4E-04	6.7E-03	1.0E-02	1.3E-02
Arsenic	13	3.1E-05	1.5E-04	1.0E-04	4.3E-03	6.4E-03	8.4E-03
Arsenic	14	7.9E-05	4.2E-04	3.3E-04	8.5E-03	1.3E-02	1.7E-02
Arsenic	15	8.8E-05	5.8E-04	2.1E-04	2.0E-02	2.9E-02	3.8E-02

Chemical Species *(Case 7 – Boilers 4 & 5)*	**Site**	**Annual average** ($\mu g\ m^{-3}$)	**95th % 24-hr average** ($\mu g\ m^{-3}$)	**95th % 1-hr average** ($\mu g\ m^{-3}$)	**Max. 1-hr average** ($\mu g\ m^{-3}$)	**Max. 10-min average** ($\mu g\ m^{-3}$)	**Max. 3-min average** ($\mu g\ m^{-3}$)
Arsenic	16	1.1E-04	6.9E-04	6.1E-04	6.6E-03	1.0E-02	1.4E-02
Selenium	1	1.9E-05	1.2E-04	8.9E-05	2.5E-03	3.6E-03	4.6E-03
Selenium	2	2.1E-05	1.4E-04	7.9E-05	2.8E-03	4.2E-03	5.5E-03
Selenium	3	1.4E-05	7.6E-05	5.5E-05	2.1E-03	2.9E-03	3.5E-03
Selenium	4	1.7E-05	9.9E-05	9.0E-05	2.0E-03	2.7E-03	3.3E-03
Selenium	5	1.0E-05	6.4E-05	3.7E-05	1.8E-03	2.5E-03	3.1E-03
Selenium	6	1.9E-05	1.4E-04	6.7E-05	2.9E-03	4.1E-03	5.2E-03
Selenium	7	7.8E-06	5.1E-05	3.8E-05	8.4E-04	1.3E-03	1.8E-03
Selenium	8	8.5E-06	5.6E-05	4.5E-05	1.1E-03	1.7E-03	2.2E-03
Selenium	9	1.5E-05	7.9E-05	9.7E-05	1.3E-03	2.0E-03	2.7E-03
Selenium	10	1.5E-05	9.2E-05	9.3E-05	1.4E-03	2.2E-03	3.0E-03
Selenium	11	2.7E-05	1.3E-04	1.9E-04	2.3E-03	3.3E-03	4.1E-03
Selenium	13	1.1E-05	5.9E-05	6.3E-05	9.0E-04	1.4E-03	1.8E-03
Selenium	14	2.4E-05	1.2E-04	1.3E-04	4.1E-03	6.1E-03	8.0E-03
Selenium	15	3.0E-05	2.0E-04	8.1E-05	4.3E-03	6.8E-03	9.2E-03
Selenium	16	4.3E-05	2.1E-04	3.2E-04	3.7E-03	5.1E-03	6.4E-03
Manganese	1	2.2E-04	1.1E-03	7.2E-04	3.2E-02	4.7E-02	6.0E-02
Manganese	2	1.5E-04	8.8E-04	5.7E-04	1.7E-02	2.6E-02	3.5E-02
Manganese	3	1.7E-04	1.1E-03	4.6E-04	1.8E-02	2.6E-02	3.4E-02
Manganese	4	3.5E-04	2.4E-03	8.4E-04	6.2E-02	9.0E-02	1.2E-01
Manganese	5	1.3E-04	8.4E-04	4.4E-04	1.6E-02	2.3E-02	2.9E-02
Manganese	6	1.1E-04	6.6E-04	4.8E-04	1.4E-02	2.1E-02	2.8E-02
Manganese	7	1.2E-04	7.1E-04	3.5E-04	1.4E-02	2.1E-02	2.7E-02
Manganese	8	1.0E-04	6.2E-04	4.0E-04	1.0E-02	1.4E-02	1.8E-02
Manganese	9	2.3E-04	1.1E-03	1.1E-03	1.8E-02	2.7E-02	3.4E-02
Manganese	10	2.9E-04	1.8E-03	1.4E-03	4.7E-02	6.8E-02	8.8E-02
Manganese	11	7.1E-04	3.5E-03	2.7E-03	1.7E-01	2.4E-01	3.0E-01
Manganese	13	8.0E-05	3.8E-04	5.2E-04	5.3E-03	7.9E-03	1.0E-02
Manganese	14	1.9E-04	8.8E-04	1.4E-03	1.1E-02	1.8E-02	2.4E-02
Manganese	15	1.3E-04	7.8E-04	3.7E-04	2.0E-02	2.9E-02	3.7E-02
Manganese	16	1.2E-03	6.4E-03	4.2E-03	2.9E-01	4.0E-01	5.1E-01
Cadmium	1	3.2E-09	2.0E-08	3.4E-09	5.3E-07	7.6E-07	9.6E-07
Cadmium	2	3.6E-09	1.8E-08	3.5E-09	5.8E-07	9.1E-07	1.2E-06
Cadmium	3	2.6E-09	1.6E-08	1.8E-09	4.8E-07	6.6E-07	8.2E-07
Cadmium	4	3.1E-09	1.9E-08	3.1E-09	6.4E-07	1.0E-06	1.3E-06
Cadmium	5	2.6E-09	1.5E-08	1.9E-09	7.0E-07	1.1E-06	1.5E-06
Cadmium	6	3.8E-09	1.7E-08	4.6E-09	7.1E-07	9.8E-07	1.2E-06
Cadmium	7	3.4E-09	2.2E-08	3.9E-09	9.7E-07	1.5E-06	2.0E-06

Chemical Species *(Case 7 – Boilers 4 & 5)*	**Site**	**Annual average** ($\mu g\ m^{-3}$)	**95th % 24-hr average** ($\mu g\ m^{-3}$)	**95th % 1-hr average** ($\mu g\ m^{-3}$)	**Max. 1-hr average** ($\mu g\ m^{-3}$)	**Max. 10-min average** ($\mu g\ m^{-3}$)	**Max. 3-min average** ($\mu g\ m^{-3}$)
Cadmium	8	2.2E-09	1.3E-08	5.9E-09	2.5E-07	4.0E-07	5.4E-07
Cadmium	9	3.5E-09	1.8E-08	1.4E-08	3.4E-07	5.3E-07	7.2E-07
Cadmium	10	3.2E-09	1.5E-08	1.0E-08	3.6E-07	5.6E-07	7.6E-07
Cadmium	11	5.2E-09	3.1E-08	2.3E-08	4.3E-07	7.3E-07	1.1E-06
Cadmium	13	1.9E-09	9.1E-09	5.0E-09	2.4E-07	3.9E-07	5.3E-07
Cadmium	14	4.9E-09	2.6E-08	1.8E-08	5.9E-07	9.2E-07	1.2E-06
Cadmium	15	5.3E-09	3.3E-08	6.9E-09	1.1E-06	1.7E-06	2.3E-06
Cadmium	16	6.9E-09	4.1E-08	3.4E-08	4.1E-07	7.0E-07	1.0E-06
Chromium (VI)	1	1.9E-07	1.2E-06	3.2E-07	2.7E-05	3.7E-05	4.6E-05
Chromium (VI)	2	2.2E-07	1.3E-06	4.6E-07	3.2E-05	4.7E-05	6.1E-05
Chromium (VI)	3	1.5E-07	9.7E-07	1.6E-07	2.8E-05	3.8E-05	4.6E-05
Chromium (VI)	4	1.8E-07	1.2E-06	2.6E-07	3.0E-05	4.4E-05	5.7E-05
Chromium (VI)	5	1.4E-07	9.9E-07	1.6E-07	3.3E-05	4.8E-05	6.2E-05
Chromium (VI)	6	2.2E-07	1.2E-06	5.3E-07	4.0E-05	5.3E-05	6.4E-05
Chromium (VI)	7	1.7E-07	1.1E-06	3.0E-07	4.2E-05	6.1E-05	7.9E-05
Chromium (VI)	8	1.3E-07	8.9E-07	4.7E-07	1.3E-05	1.9E-05	2.5E-05
Chromium (VI)	9	2.1E-07	1.2E-06	1.1E-06	1.8E-05	2.6E-05	3.4E-05
Chromium (VI)	10	2.0E-07	1.0E-06	8.0E-07	1.9E-05	2.8E-05	3.6E-05
Chromium (VI)	11	3.2E-07	2.1E-06	1.9E-06	2.1E-05	3.1E-05	4.1E-05
Chromium (VI)	13	1.2E-07	6.4E-07	3.7E-07	1.6E-05	2.3E-05	3.0E-05
Chromium (VI)	14	3.0E-07	1.7E-06	1.3E-06	3.1E-05	4.5E-05	5.8E-05
Chromium (VI)	15	3.2E-07	2.1E-06	7.9E-07	6.0E-05	8.7E-05	1.1E-04
Chromium (VI)	16	4.3E-07	2.6E-06	2.9E-06	2.0E-05	3.1E-05	4.2E-05
Nickel	1	7.6E-06	4.1E-05	3.7E-05	1.0E-03	1.5E-03	1.9E-03
Nickel	2	5.4E-06	3.7E-05	2.7E-05	5.5E-04	8.2E-04	1.1E-03
Nickel	3	5.8E-06	4.1E-05	2.2E-05	5.5E-04	8.2E-04	1.1E-03
Nickel	4	1.2E-05	7.5E-05	3.8E-05	2.0E-03	2.8E-03	3.6E-03
Nickel	5	4.8E-06	3.4E-05	2.0E-05	6.6E-04	9.9E-04	1.3E-03
Nickel	6	4.3E-06	3.1E-05	2.4E-05	6.7E-04	9.1E-04	1.1E-03
Nickel	7	4.6E-06	3.1E-05	1.7E-05	1.0E-03	1.5E-03	2.0E-03
Nickel	8	3.8E-06	2.5E-05	2.0E-05	3.2E-04	4.8E-04	6.2E-04
Nickel	9	8.0E-06	4.0E-05	5.0E-05	5.7E-04	8.3E-04	1.1E-03
Nickel	10	9.7E-06	6.4E-05	6.0E-05	1.5E-03	2.1E-03	2.7E-03
Nickel	11	2.3E-05	1.1E-04	1.3E-04	5.2E-03	7.4E-03	9.4E-03
Nickel	13	2.9E-06	1.7E-05	2.5E-05	2.5E-04	3.8E-04	5.0E-04
Nickel	14	7.1E-06	4.3E-05	6.5E-05	5.6E-04	8.4E-04	1.1E-03
Nickel	15	5.1E-06	4.2E-05	2.0E-05	1.2E-03	1.8E-03	2.3E-03
Nickel	16	3.8E-05	2.0E-04	1.8E-04	9.1E-03	1.3E-02	1.6E-02

Chemical Species *(Case 7 – Boilers 4 & 5)*	**Site**	**Annual average** ($\mu g\ m^{-3}$)	**95th % 24-hr average** ($\mu g\ m^{-3}$)	**95th % 1-hr average** ($\mu g\ m^{-3}$)	**Max. 1-hr average** ($\mu g\ m^{-3}$)	**Max. 10-min average** ($\mu g\ m^{-3}$)	**Max. 3-min average** ($\mu g\ m^{-3}$)
Mercury	1	6.6E-05	3.9E-04	2.9E-04	6.8E-03	1.0E-02	1.4E-02
Mercury	2	5.5E-05	3.0E-04	2.7E-04	4.7E-03	7.3E-03	9.9E-03
Mercury	3	4.9E-05	2.5E-04	2.1E-04	4.7E-03	7.1E-03	9.4E-03
Mercury	4	7.0E-05	3.4E-04	2.9E-04	6.4E-03	9.8E-03	1.3E-02
Mercury	5	4.0E-05	2.2E-04	1.3E-04	6.2E-03	9.1E-03	1.2E-02
Mercury	6	4.9E-05	2.6E-04	2.3E-04	4.0E-03	5.5E-03	6.9E-03
Mercury	7	4.1E-05	2.5E-04	1.1E-04	5.5E-03	8.3E-03	1.1E-02
Mercury	8	3.3E-05	1.9E-04	1.3E-04	3.7E-03	5.1E-03	6.3E-03
Mercury	9	6.1E-05	2.7E-04	3.2E-04	5.3E-03	7.7E-03	9.8E-03
Mercury	10	5.4E-05	2.6E-04	3.1E-04	6.5E-03	9.9E-03	1.3E-02
Mercury	11	1.1E-04	4.7E-04	6.6E-04	1.2E-02	1.7E-02	2.1E-02
Mercury	13	2.9E-05	1.4E-04	1.8E-04	1.8E-03	2.7E-03	3.5E-03
Mercury	14	6.8E-05	2.9E-04	3.9E-04	4.6E-03	7.0E-03	9.3E-03
Mercury	15	6.9E-05	3.8E-04	1.8E-04	5.9E-03	8.9E-03	1.2E-02
Mercury	16	1.8E-04	8.9E-04	1.2E-03	2.0E-02	2.7E-02	3.4E-02
Ammonia	1	7.8E-03	3.9E-02	2.6E-02	1.0E+00	1.5E+00	1.9E+00
Ammonia	2	5.4E-03	3.2E-02	1.9E-02	6.3E-01	9.4E-01	1.2E+00
Ammonia	3	5.9E-03	4.1E-02	1.8E-02	5.5E-01	8.1E-01	1.1E+00
Ammonia	4	1.2E-02	8.1E-02	3.5E-02	1.5E+00	2.1E+00	2.8E+00
Ammonia	5	4.8E-03	3.1E-02	1.7E-02	4.3E-01	6.2E-01	7.9E-01
Ammonia	6	4.3E-03	2.4E-02	1.7E-02	5.0E-01	7.4E-01	9.6E-01
Ammonia	7	5.3E-03	3.1E-02	1.4E-02	5.8E-01	8.7E-01	1.1E+00
Ammonia	8	4.5E-03	2.6E-02	1.6E-02	4.6E-01	6.3E-01	7.8E-01
Ammonia	9	9.6E-03	4.3E-02	4.7E-02	7.3E-01	1.1E+00	1.3E+00
Ammonia	10	1.1E-02	6.6E-02	5.2E-02	1.7E+00	2.4E+00	3.1E+00
Ammonia	11	2.6E-02	1.3E-01	1.1E-01	5.0E+00	7.1E+00	9.0E+00
Ammonia	13	3.0E-03	1.4E-02	1.9E-02	1.9E-01	2.8E-01	3.6E-01
Ammonia	14	7.2E-03	3.0E-02	5.1E-02	3.6E-01	5.4E-01	7.1E-01
Ammonia	15	5.0E-03	2.9E-02	1.4E-02	7.5E-01	1.1E+00	1.4E+00
Ammonia	16	4.7E-02	2.3E-01	2.1E-01	8.2E+00	1.1E+01	1.4E+01
BaP Equivalents	1	6.9E-07	3.9E-06	1.8E-06	5.8E-05	8.5E-05	1.1E-04
BaP Equivalents	2	4.2E-07	2.5E-06	1.3E-06	4.6E-05	7.0E-05	9.2E-05
BaP Equivalents	3	4.1E-07	2.6E-06	1.0E-06	4.4E-05	6.3E-05	8.1E-05
BaP Equivalents	4	7.8E-07	4.8E-06	2.2E-06	1.1E-04	1.7E-04	2.2E-04
BaP Equivalents	5	3.5E-07	2.4E-06	9.1E-07	3.6E-05	5.0E-05	6.4E-05
BaP Equivalents	6	3.0E-07	1.7E-06	9.9E-07	3.5E-05	5.2E-05	6.9E-05
BaP Equivalents	7	2.8E-07	1.6E-06	7.7E-07	3.9E-05	5.7E-05	7.3E-05
BaP Equivalents	8	2.3E-07	1.3E-06	8.5E-07	2.3E-05	3.2E-05	4.1E-05
BaP Equivalents	9	5.2E-07	2.3E-06	2.3E-06	3.9E-05	5.5E-05	7.1E-05

Chemical Species *(Case 7 – Boilers 4 & 5)*	**Site**	**Annual average** ($\mu g\ m^{-3}$)	**95th % 24-hr average** ($\mu g\ m^{-3}$)	**95th % 1-hr average** ($\mu g\ m^{-3}$)	**Max. 1-hr average** ($\mu g\ m^{-3}$)	**Max. 10-min average** ($\mu g\ m^{-3}$)	**Max. 3-min average** ($\mu g\ m^{-3}$)
BaP Equivalents	10	5.8E-07	3.4E-06	2.6E-06	6.4E-05	9.3E-05	1.2E-04
BaP Equivalents	11	1.2E-06	6.0E-06	5.1E-06	1.3E-04	1.9E-04	2.4E-04
BaP Equivalents	13	1.8E-07	7.9E-07	1.1E-06	1.2E-05	1.8E-05	2.4E-05
BaP Equivalents	14	4.4E-07	1.9E-06	2.7E-06	2.7E-05	4.0E-05	5.1E-05
BaP Equivalents	15	3.4E-07	2.3E-06	1.0E-06	3.3E-05	5.0E-05	6.6E-05
BaP Equivalents	16	2.2E-06	1.1E-05	9.3E-06	2.3E-04	3.3E-04	4.1E-04
Acetone	1	2.6E-02	1.3E-01	1.4E-01	1.4E+00	2.2E+00	2.8E+00
Acetone	2	1.8E-02	9.1E-02	9.3E-02	1.7E+00	2.5E+00	3.3E+00
Acetone	3	1.8E-02	9.7E-02	8.5E-02	1.4E+00	2.1E+00	2.8E+00
Acetone	4	3.2E-02	1.9E-01	1.7E-01	3.3E+00	4.6E+00	5.9E+00
Acetone	5	1.7E-02	1.0E-01	7.1E-02	1.6E+00	2.4E+00	3.1E+00
Acetone	6	1.4E-02	7.3E-02	7.2E-02	1.2E+00	1.8E+00	2.4E+00
Acetone	7	1.5E-02	8.3E-02	5.9E-02	9.5E-01	1.4E+00	1.9E+00
Acetone	8	1.1E-02	6.0E-02	6.1E-02	7.7E-01	1.1E+00	1.5E+00
Acetone	9	2.2E-02	8.4E-02	1.3E-01	1.1E+00	1.6E+00	2.0E+00
Acetone	10	2.1E-02	1.2E-01	1.3E-01	1.8E+00	2.6E+00	3.2E+00
Acetone	11	4.3E-02	2.1E-01	2.8E-01	3.0E+00	4.3E+00	5.5E+00
Acetone	13	7.8E-03	3.6E-02	6.0E-02	4.9E-01	7.4E-01	9.8E-01
Acetone	14	1.8E-02	8.9E-02	1.3E-01	9.8E-01	1.4E+00	1.9E+00
Acetone	15	1.9E-02	1.1E-01	8.3E-02	1.5E+00	2.2E+00	2.9E+00
Acetone	16	7.5E-02	3.3E-01	4.8E-01	5.7E+00	8.0E+00	1.0E+01
Acetaldehyde	1	6.1E-03	3.3E-02	3.7E-02	2.8E-01	4.6E-01	6.4E-01
Acetaldehyde	2	4.9E-03	2.4E-02	2.6E-02	3.6E-01	5.5E-01	7.4E-01
Acetaldehyde	3	4.2E-03	2.1E-02	2.5E-02	3.0E-01	4.5E-01	5.9E-01
Acetaldehyde	4	7.5E-03	3.6E-02	5.2E-02	4.2E-01	6.0E-01	7.5E-01
Acetaldehyde	5	3.8E-03	2.1E-02	2.2E-02	2.3E-01	3.6E-01	4.8E-01
Acetaldehyde	6	3.9E-03	2.1E-02	1.9E-02	3.6E-01	5.5E-01	7.2E-01
Acetaldehyde	7	3.6E-03	1.9E-02	2.2E-02	3.4E-01	5.0E-01	6.5E-01
Acetaldehyde	8	3.3E-03	1.6E-02	2.3E-02	1.7E-01	2.4E-01	3.2E-01
Acetaldehyde	9	6.2E-03	2.5E-02	4.7E-02	2.7E-01	3.9E-01	4.9E-01
Acetaldehyde	10	6.5E-03	3.4E-02	4.6E-02	5.0E-01	7.2E-01	9.1E-01
Acetaldehyde	11	1.3E-02	5.6E-02	1.0E-01	1.1E+00	1.6E+00	2.0E+00
Acetaldehyde	13	2.6E-03	1.3E-02	1.7E-02	2.0E-01	3.0E-01	3.8E-01
Acetaldehyde	14	5.9E-03	2.7E-02	4.3E-02	3.0E-01	4.3E-01	5.5E-01
Acetaldehyde	15	5.4E-03	3.1E-02	2.6E-02	5.3E-01	8.2E-01	1.1E+00
Acetaldehyde	16	2.2E-02	1.1E-01	1.5E-01	1.9E+00	2.6E+00	3.3E+00
Formaldehyde	1	3.2E-03	1.9E-02	6.6E-03	2.9E-01	4.9E-01	6.9E-01
Formaldehyde	2	3.4E-03	2.0E-02	5.6E-03	3.7E-01	5.8E-01	7.8E-01

Chemical Species *(Case 7 – Boilers 4 & 5)*	**Site**	**Annual average** ($\mu g\ m^{-3}$)	**95th % 24-hr average** ($\mu g\ m^{-3}$)	**95th % 1-hr average** ($\mu g\ m^{-3}$)	**Max. 1-hr average** ($\mu g\ m^{-3}$)	**Max. 10-min average** ($\mu g\ m^{-3}$)	**Max. 3-min average** ($\mu g\ m^{-3}$)
Formaldehyde	3	2.3E-03	1.4E-02	3.8E-03	3.2E-01	4.9E-01	6.6E-01
Formaldehyde	4	3.3E-03	1.8E-02	7.8E-03	3.4E-01	5.1E-01	6.8E-01
Formaldehyde	5	2.2E-03	1.4E-02	3.6E-03	2.6E-01	4.1E-01	5.5E-01
Formaldehyde	6	3.0E-03	1.8E-02	5.6E-03	3.8E-01	5.9E-01	7.9E-01
Formaldehyde	7	2.3E-03	1.4E-02	8.4E-03	3.3E-01	4.9E-01	6.3E-01
Formaldehyde	8	2.2E-03	1.5E-02	1.0E-02	1.9E-01	2.5E-01	3.0E-01
Formaldehyde	9	3.6E-03	2.1E-02	2.0E-02	2.7E-01	3.5E-01	4.2E-01
Formaldehyde	10	3.5E-03	1.9E-02	1.3E-02	4.2E-01	6.5E-01	8.8E-01
Formaldehyde	11	5.7E-03	2.9E-02	2.7E-02	4.2E-01	6.6E-01	9.0E-01
Formaldehyde	13	2.0E-03	1.2E-02	5.6E-03	2.3E-01	3.3E-01	4.3E-01
Formaldehyde	14	4.4E-03	2.6E-02	1.7E-02	3.3E-01	5.3E-01	7.2E-01
Formaldehyde	15	4.6E-03	2.7E-02	9.8E-03	6.1E-01	9.4E-01	1.3E+00
Formaldehyde	16	8.0E-03	5.4E-02	4.9E-02	3.5E-01	5.5E-01	7.5E-01
2-Butanone	1	3.3E-03	1.6E-02	1.6E-02	1.9E-01	2.8E-01	3.6E-01
2-Butanone	2	2.2E-03	1.2E-02	1.0E-02	1.9E-01	2.9E-01	3.9E-01
2-Butanone	3	2.2E-03	1.2E-02	9.3E-03	1.7E-01	2.6E-01	3.4E-01
2-Butanone	4	3.8E-03	2.3E-02	2.0E-02	3.8E-01	5.6E-01	7.3E-01
2-Butanone	5	2.0E-03	1.1E-02	8.5E-03	1.8E-01	2.6E-01	3.4E-01
2-Butanone	6	1.7E-03	9.1E-03	8.0E-03	1.2E-01	1.8E-01	2.4E-01
2-Butanone	7	1.9E-03	1.0E-02	7.0E-03	1.4E-01	2.0E-01	2.6E-01
2-Butanone	8	1.4E-03	7.2E-03	7.3E-03	8.3E-02	1.2E-01	1.6E-01
2-Butanone	9	2.7E-03	1.1E-02	1.6E-02	1.4E-01	2.0E-01	2.5E-01
2-Butanone	10	2.7E-03	1.5E-02	1.7E-02	2.2E-01	3.2E-01	4.1E-01
2-Butanone	11	5.5E-03	2.5E-02	3.4E-02	4.5E-01	6.5E-01	8.3E-01
2-Butanone	13	9.7E-04	4.5E-03	7.3E-03	6.3E-02	9.5E-02	1.2E-01
2-Butanone	14	2.3E-03	1.1E-02	1.7E-02	1.3E-01	1.9E-01	2.4E-01
2-Butanone	15	2.3E-03	1.3E-02	9.3E-03	1.7E-01	2.6E-01	3.4E-01
2-Butanone	16	9.6E-03	4.5E-02	5.7E-02	8.3E-01	1.2E+00	1.5E+00
Benzene	1	7.5E-04	3.8E-03	2.2E-03	7.6E-02	1.2E-01	1.6E-01
Benzene	2	7.1E-04	3.4E-03	2.2E-03	7.4E-02	1.1E-01	1.5E-01
Benzene	3	5.7E-04	3.2E-03	1.1E-03	8.4E-02	1.3E-01	1.7E-01
Benzene	4	7.8E-04	4.2E-03	2.2E-03	9.9E-02	1.5E-01	2.0E-01
Benzene	5	5.7E-04	2.8E-03	8.8E-04	9.5E-02	1.4E-01	1.8E-01
Benzene	6	6.4E-04	3.1E-03	2.3E-03	7.2E-02	9.7E-02	1.2E-01
Benzene	7	5.8E-04	3.8E-03	1.6E-03	5.1E-02	7.6E-02	9.9E-02
Benzene	8	4.3E-04	2.8E-03	1.9E-03	4.6E-02	6.8E-02	8.9E-02
Benzene	9	6.8E-04	3.6E-03	4.0E-03	4.6E-02	6.7E-02	8.7E-02
Benzene	10	5.8E-04	3.1E-03	2.7E-03	5.5E-02	8.2E-02	1.1E-01
Benzene	11	9.5E-04	4.5E-03	5.5E-03	4.9E-02	7.7E-02	1.0E-01

Chemical Species *(Case 7 – Boilers 4 & 5)*	**Site**	**Annual average** ($\mu g\ m^{-3}$)	**95th % 24-hr average** ($\mu g\ m^{-3}$)	**95th % 1-hr average** ($\mu g\ m^{-3}$)	**Max. 1-hr average** ($\mu g\ m^{-3}$)	**Max. 10-min average** ($\mu g\ m^{-3}$)	**Max. 3-min average** ($\mu g\ m^{-3}$)
Benzene	13	3.4E-04	1.7E-03	1.5E-03	3.5E-02	5.2E-02	6.8E-02
Benzene	14	7.8E-04	3.9E-03	4.2E-03	6.0E-02	8.7E-02	1.1E-01
Benzene	15	1.0E-03	6.1E-03	3.7E-03	8.6E-02	1.3E-01	1.7E-01
Benzene	16	1.5E-03	8.1E-03	1.1E-02	5.1E-02	7.8E-02	1.0E-01
Toluene	1	6.0E-04	3.2E-03	2.6E-03	6.7E-02	1.0E-01	1.4E-01
Toluene	2	4.6E-04	2.2E-03	1.8E-03	7.0E-02	1.1E-01	1.5E-01
Toluene	3	4.5E-04	2.3E-03	1.6E-03	6.9E-02	1.1E-01	1.4E-01
Toluene	4	6.9E-04	3.3E-03	3.4E-03	9.1E-02	1.4E-01	1.9E-01
Toluene	5	4.6E-04	2.1E-03	1.3E-03	8.5E-02	1.3E-01	1.6E-01
Toluene	6	3.9E-04	1.8E-03	1.6E-03	4.5E-02	7.0E-02	9.5E-02
Toluene	7	4.6E-04	3.3E-03	1.5E-03	4.3E-02	6.1E-02	7.8E-02
Toluene	8	3.1E-04	1.9E-03	1.6E-03	3.4E-02	5.2E-02	6.8E-02
Toluene	9	5.1E-04	2.3E-03	3.1E-03	3.7E-02	5.5E-02	7.2E-02
Toluene	10	4.3E-04	2.0E-03	2.6E-03	4.2E-02	6.5E-02	8.7E-02
Toluene	11	7.8E-04	3.6E-03	5.6E-03	4.7E-02	7.2E-02	9.6E-02
Toluene	13	2.0E-04	9.5E-04	1.0E-03	1.8E-02	2.8E-02	3.7E-02
Toluene	14	4.6E-04	2.2E-03	2.7E-03	3.3E-02	4.9E-02	6.4E-02
Toluene	15	6.1E-04	3.4E-03	1.9E-03	6.6E-02	1.0E-01	1.4E-01
Toluene	16	1.3E-03	5.5E-03	9.4E-03	6.0E-02	8.3E-02	1.0E-01
Xylenes	1	2.3E-05	1.2E-04	7.4E-05	2.3E-03	3.8E-03	5.4E-03
Xylenes	2	2.6E-05	1.6E-04	6.3E-05	2.7E-03	4.3E-03	5.7E-03
Xylenes	3	1.6E-05	9.8E-05	5.3E-05	2.3E-03	3.5E-03	4.6E-03
Xylenes	4	2.4E-05	1.3E-04	9.0E-05	2.5E-03	3.7E-03	4.9E-03
Xylenes	5	1.4E-05	8.3E-05	4.5E-05	1.8E-03	2.9E-03	3.9E-03
Xylenes	6	2.2E-05	1.4E-04	5.4E-05	3.1E-03	4.8E-03	6.4E-03
Xylenes	7	1.4E-05	9.0E-05	4.8E-05	2.9E-03	4.4E-03	5.7E-03
Xylenes	8	1.7E-05	1.0E-04	6.9E-05	1.6E-03	2.4E-03	3.2E-03
Xylenes	9	2.7E-05	1.6E-04	1.4E-04	2.0E-03	3.1E-03	4.1E-03
Xylenes	10	2.9E-05	1.6E-04	1.3E-04	3.4E-03	5.3E-03	7.1E-03
Xylenes	11	5.0E-05	2.4E-04	2.6E-04	3.5E-03	5.5E-03	7.4E-03
Xylenes	13	1.6E-05	9.0E-05	5.3E-05	1.8E-03	2.6E-03	3.4E-03
Xylenes	14	3.5E-05	2.0E-04	1.4E-04	2.7E-03	4.2E-03	5.8E-03
Xylenes	15	3.4E-05	2.2E-04	8.5E-05	5.1E-03	7.9E-03	1.1E-02
Xylenes	16	6.9E-05	4.0E-04	4.5E-04	3.7E-03	5.2E-03	6.6E-03
Acrolein	1	2.6E-04	1.5E-03	2.6E-04	3.0E-02	5.0E-02	7.1E-02
Acrolein	2	3.0E-04	1.9E-03	2.7E-04	3.6E-02	5.6E-02	7.5E-02
Acrolein	3	1.8E-04	1.3E-03	1.7E-04	3.0E-02	4.6E-02	6.2E-02
Acrolein	4	2.6E-04	1.7E-03	3.0E-04	3.4E-02	5.0E-02	6.6E-02

Chemical Species *(Case 7 – Boilers 4 & 5)*	**Site**	**Annual average** ($\mu g\ m^{-3}$)	**95th % 24-hr average** ($\mu g\ m^{-3}$)	**95th % 1-hr average** ($\mu g\ m^{-3}$)	**Max. 1-hr average** ($\mu g\ m^{-3}$)	**Max. 10-min average** ($\mu g\ m^{-3}$)	**Max. 3-min average** ($\mu g\ m^{-3}$)
Acrolein	5	1.6E-04	1.1E-03	1.9E-04	2.5E-02	3.9E-02	5.2E-02
Acrolein	6	2.6E-04	1.8E-03	2.2E-04	4.1E-02	6.3E-02	8.4E-02
Acrolein	7	1.7E-04	1.1E-03	3.3E-04	3.6E-02	5.3E-02	6.9E-02
Acrolein	8	2.0E-04	1.3E-03	6.8E-04	2.1E-02	3.3E-02	4.3E-02
Acrolein	9	3.2E-04	2.1E-03	1.4E-03	2.8E-02	3.6E-02	4.3E-02
Acrolein	10	3.4E-04	2.0E-03	1.1E-03	4.5E-02	7.0E-02	9.5E-02
Acrolein	11	5.5E-04	2.9E-03	2.0E-03	4.7E-02	7.3E-02	1.0E-01
Acrolein	13	1.9E-04	1.2E-03	4.8E-04	2.4E-02	3.5E-02	4.6E-02
Acrolein	14	4.3E-04	2.6E-03	1.5E-03	3.6E-02	5.7E-02	7.8E-02
Acrolein	15	4.0E-04	2.8E-03	3.8E-04	6.7E-02	1.0E-01	1.4E-01
Acrolein	16	7.2E-04	5.0E-03	3.5E-03	3.8E-02	6.0E-02	8.1E-02
Ethylbenzene	1	1.7E-05	9.5E-05	8.1E-05	1.2E-03	1.9E-03	2.6E-03
Ethylbenzene	2	1.8E-05	9.4E-05	7.3E-05	1.5E-03	2.3E-03	3.0E-03
Ethylbenzene	3	1.2E-05	6.6E-05	6.2E-05	1.5E-03	2.0E-03	2.5E-03
Ethylbenzene	4	1.8E-05	8.7E-05	9.1E-05	1.2E-03	1.9E-03	2.7E-03
Ethylbenzene	5	9.9E-06	5.5E-05	4.5E-05	1.2E-03	1.6E-03	2.0E-03
Ethylbenzene	6	1.6E-05	9.9E-05	6.7E-05	1.5E-03	2.3E-03	3.1E-03
Ethylbenzene	7	8.4E-06	4.6E-05	4.5E-05	1.3E-03	1.9E-03	2.5E-03
Ethylbenzene	8	9.6E-06	5.6E-05	5.6E-05	8.3E-04	1.2E-03	1.6E-03
Ethylbenzene	9	1.7E-05	7.8E-05	1.2E-04	1.2E-03	1.9E-03	2.5E-03
Ethylbenzene	10	1.8E-05	8.6E-05	1.1E-04	1.6E-03	2.5E-03	3.3E-03
Ethylbenzene	11	3.3E-05	1.6E-04	2.3E-04	2.8E-03	4.0E-03	5.1E-03
Ethylbenzene	13	1.0E-05	5.2E-05	6.4E-05	8.6E-04	1.3E-03	1.7E-03
Ethylbenzene	14	2.3E-05	1.1E-04	1.4E-04	1.9E-03	2.9E-03	3.7E-03
Ethylbenzene	15	2.4E-05	1.5E-04	9.1E-05	2.2E-03	3.3E-03	4.5E-03
Ethylbenzene	16	4.8E-05	2.3E-04	3.4E-04	4.9E-03	6.8E-03	8.5E-03
Methylene Chloride	1	8.5E-04	5.0E-03	3.0E-03	8.8E-02	1.2E-01	1.5E-01
Methylene Chloride	2	9.3E-04	5.6E-03	2.8E-03	1.1E-01	1.6E-01	2.0E-01
Methylene Chloride	3	6.3E-04	4.2E-03	1.7E-03	1.0E-01	1.4E-01	1.7E-01
Methylene Chloride	4	8.9E-04	4.6E-03	3.3E-03	9.4E-02	1.4E-01	1.8E-01
Methylene Chloride	5	6.0E-04	3.6E-03	1.6E-03	1.1E-01	1.6E-01	2.0E-01
Methylene Chloride	6	8.9E-04	5.4E-03	2.6E-03	1.4E-01	1.8E-01	2.2E-01
Methylene Chloride	7	6.7E-04	4.1E-03	2.0E-03	1.3E-01	1.9E-01	2.5E-01
Methylene Chloride	8	5.7E-04	3.6E-03	2.6E-03	4.4E-02	6.5E-02	8.4E-02
Methylene Chloride	9	9.7E-04	5.1E-03	5.6E-03	6.0E-02	8.8E-02	1.1E-01
Methylene Chloride	10	9.7E-04	5.3E-03	4.7E-03	6.8E-02	1.1E-01	1.4E-01
Methylene Chloride	11	1.7E-03	8.9E-03	1.1E-02	7.6E-02	1.1E-01	1.4E-01
Methylene Chloride	13	5.3E-04	2.9E-03	1.8E-03	6.4E-02	9.5E-02	1.2E-01
Methylene Chloride	14	1.3E-03	7.0E-03	5.5E-03	1.1E-01	1.6E-01	2.1E-01

Chemical Species *(Case 7 – Boilers 4 & 5)*	**Site**	**Annual average** ($\mu g\ m^{-3}$)	**95th % 24-hr average** ($\mu g\ m^{-3}$)	**95th % 1-hr average** ($\mu g\ m^{-3}$)	**Max. 1-hr average** ($\mu g\ m^{-3}$)	**Max. 10-min average** ($\mu g\ m^{-3}$)	**Max. 3-min average** ($\mu g\ m^{-3}$)
Methylene Chloride	15	1.3E-03	8.2E-03	3.2E-03	1.9E-01	2.8E-01	3.6E-01
Methylene Chloride	16	2.3E-03	1.2E-02	1.8E-02	1.3E-01	1.9E-01	2.3E-01
Styrene	1	4.6E-05	3.1E-04	2.3E-04	3.6E-03	5.5E-03	7.4E-03
Styrene	2	4.3E-05	2.4E-04	1.8E-04	5.1E-03	7.8E-03	1.0E-02
Styrene	3	3.6E-05	2.3E-04	1.7E-04	4.4E-03	6.7E-03	8.9E-03
Styrene	4	5.3E-05	3.8E-04	2.5E-04	8.8E-03	1.3E-02	1.6E-02
Styrene	5	3.4E-05	2.1E-04	1.2E-04	5.5E-03	8.1E-03	1.0E-02
Styrene	6	3.6E-05	2.2E-04	1.7E-04	4.6E-03	6.8E-03	9.0E-03
Styrene	7	3.0E-05	2.4E-04	1.2E-04	3.4E-03	5.1E-03	6.7E-03
Styrene	8	2.4E-05	1.8E-04	1.3E-04	3.0E-03	4.5E-03	5.8E-03
Styrene	9	3.9E-05	2.2E-04	2.8E-04	2.8E-03	4.1E-03	5.3E-03
Styrene	10	3.4E-05	1.8E-04	2.3E-04	3.1E-03	4.8E-03	6.3E-03
Styrene	11	5.7E-05	3.0E-04	4.7E-04	4.7E-03	6.9E-03	9.0E-03
Styrene	13	2.0E-05	1.1E-04	1.4E-04	1.8E-03	2.7E-03	3.6E-03
Styrene	14	4.4E-05	2.2E-04	3.1E-04	3.4E-03	5.0E-03	6.5E-03
Styrene	15	5.8E-05	3.5E-04	1.8E-04	6.4E-03	9.6E-03	1.3E-02
Styrene	16	9.0E-05	6.0E-04	7.5E-04	5.7E-03	8.3E-03	1.1E-02
1-2-4 Trimethylbenzene	1	1.7E-05	8.7E-05	5.1E-05	2.2E-03	3.3E-03	4.2E-03
1-2-4 Trimethylbenzene	2	1.3E-05	8.5E-05	4.2E-05	1.3E-03	1.9E-03	2.6E-03
1-2-4 Trimethylbenzene	3	1.3E-05	7.9E-05	4.0E-05	1.3E-03	1.9E-03	2.4E-03
1-2-4 Trimethylbenzene	4	2.5E-05	1.6E-04	6.0E-05	4.4E-03	6.3E-03	8.1E-03
1-2-4 Trimethylbenzene	5	9.9E-06	6.5E-05	3.4E-05	1.1E-03	1.6E-03	2.0E-03
1-2-4 Trimethylbenzene	6	9.8E-06	6.1E-05	3.6E-05	1.1E-03	1.7E-03	2.2E-03
1-2-4 Trimethylbenzene	7	7.9E-06	4.1E-05	2.5E-05	7.3E-04	1.1E-03	1.4E-03
1-2-4 Trimethylbenzene	8	7.6E-06	4.2E-05	3.1E-05	7.0E-04	1.0E-03	1.3E-03
1-2-4 Trimethylbenzene	9	1.7E-05	7.9E-05	8.2E-05	1.4E-03	2.0E-03	2.5E-03
1-2-4 Trimethylbenzene	10	2.1E-05	1.3E-04	9.6E-05	3.3E-03	4.8E-03	6.1E-03
1-2-4 Trimethylbenzene	11	5.0E-05	2.7E-04	1.8E-04	1.2E-02	1.7E-02	2.1E-02
1-2-4 Trimethylbenzene	13	6.8E-06	3.3E-05	4.5E-05	4.0E-04	5.9E-04	7.8E-04
1-2-4 Trimethylbenzene	14	1.6E-05	6.5E-05	1.1E-04	1.1E-03	1.6E-03	2.1E-03
1-2-4 Trimethylbenzene	15	1.3E-05	8.9E-05	4.2E-05	1.2E-03	1.9E-03	2.5E-03
1-2-4 Trimethylbenzene	16	8.4E-05	4.5E-04	3.1E-04	2.0E-02	2.8E-02	3.5E-02
1-3-5 Trimethylbenzene	1	6.7E-06	2.9E-05	3.0E-05	6.9E-04	1.0E-03	1.3E-03
1-3-5 Trimethylbenzene	2	5.6E-06	3.1E-05	2.7E-05	3.9E-04	5.9E-04	7.9E-04
1-3-5 Trimethylbenzene	3	4.9E-06	2.6E-05	2.5E-05	3.9E-04	5.8E-04	7.5E-04
1-3-5 Trimethylbenzene	4	9.3E-06	5.1E-05	3.5E-05	1.3E-03	2.0E-03	2.5E-03
1-3-5 Trimethylbenzene	5	4.0E-06	2.2E-05	2.1E-05	3.4E-04	4.9E-04	6.2E-04
1-3-5 Trimethylbenzene	6	4.4E-06	2.5E-05	2.3E-05	3.7E-04	5.7E-04	7.6E-04

Chemical Species *(Case 7 – Boilers 4 & 5)*	**Site**	**Annual average** ($\mu g\ m^{-3}$)	**95th % 24-hr average** ($\mu g\ m^{-3}$)	**95th % 1-hr average** ($\mu g\ m^{-3}$)	**Max. 1-hr average** ($\mu g\ m^{-3}$)	**Max. 10-min average** ($\mu g\ m^{-3}$)	**Max. 3-min average** ($\mu g\ m^{-3}$)
1-3-5 Trimethylbenzene	7	3.4E-06	2.0E-05	2.0E-05	2.8E-04	4.2E-04	5.4E-04
1-3-5 Trimethylbenzene	8	3.5E-06	1.8E-05	2.3E-05	2.2E-04	3.1E-04	3.9E-04
1-3-5 Trimethylbenzene	9	7.1E-06	2.9E-05	4.9E-05	4.2E-04	6.1E-04	7.8E-04
1-3-5 Trimethylbenzene	10	8.3E-06	4.6E-05	5.4E-05	1.0E-03	1.5E-03	1.9E-03
1-3-5 Trimethylbenzene	11	1.9E-05	9.2E-05	1.0E-04	3.6E-03	5.1E-03	6.5E-03
1-3-5 Trimethylbenzene	13	3.2E-06	1.5E-05	2.5E-05	2.0E-04	3.0E-04	4.0E-04
1-3-5 Trimethylbenzene	14	7.2E-06	3.9E-05	5.5E-05	2.9E-04	4.6E-04	6.2E-04
1-3-5 Trimethylbenzene	15	6.0E-06	3.5E-05	3.2E-05	5.0E-04	7.7E-04	1.0E-03
1-3-5 Trimethylbenzene	16	3.0E-05	1.5E-04	1.6E-04	6.3E-03	8.8E-03	1.1E-02
Vinyl chloride	1	1.6E-06	9.9E-06	1.5E-06	1.9E-04	3.2E-04	4.6E-04
Vinyl chloride	2	1.9E-06	1.2E-05	1.7E-06	2.3E-04	3.6E-04	4.8E-04
Vinyl chloride	3	1.1E-06	8.3E-06	1.0E-06	2.0E-04	3.0E-04	4.0E-04
Vinyl chloride	4	1.6E-06	1.1E-05	1.8E-06	2.2E-04	3.2E-04	4.2E-04
Vinyl chloride	5	1.0E-06	6.9E-06	1.1E-06	1.6E-04	2.5E-04	3.4E-04
Vinyl chloride	6	1.6E-06	1.2E-05	1.3E-06	2.6E-04	4.0E-04	5.4E-04
Vinyl chloride	7	1.0E-06	7.4E-06	2.1E-06	2.3E-04	3.4E-04	4.4E-04
Vinyl chloride	8	1.2E-06	8.4E-06	4.3E-06	1.4E-04	2.1E-04	2.8E-04
Vinyl chloride	9	2.0E-06	1.3E-05	8.9E-06	1.8E-04	2.3E-04	2.8E-04
Vinyl chloride	10	2.1E-06	1.3E-05	6.9E-06	2.9E-04	4.5E-04	6.1E-04
Vinyl chloride	11	3.4E-06	1.9E-05	1.3E-05	3.0E-04	4.7E-04	6.4E-04
Vinyl chloride	13	1.2E-06	7.7E-06	3.1E-06	1.5E-04	2.3E-04	2.9E-04
Vinyl chloride	14	2.7E-06	1.7E-05	9.4E-06	2.3E-04	3.7E-04	5.0E-04
Vinyl chloride	15	2.5E-06	1.8E-05	2.3E-06	4.3E-04	6.7E-04	9.0E-04
Vinyl chloride	16	4.5E-06	3.2E-05	2.2E-05	2.4E-04	3.8E-04	5.2E-04
				Shaded values limited by available ozone			
NO2	1	2.8E-01	3.0E+00	1.7E+00	4.8E+01	5.4E+01	5.4E+01
NO2	2	3.0E-01	3.2E+00	1.9E+00	4.7E+01	5.3E+01	5.4E+01
NO2	3	2.1E-01	2.3E+00	7.6E-01	5.2E+01	5.4E+01	5.4E+01
NO2	4	2.6E-01	3.1E+00	1.4E+00	5.2E+01	5.4E+01	5.4E+01
NO2	5	2.0E-01	2.2E+00	5.8E-01	4.5E+01	5.0E+01	5.4E+01
NO2	6	2.9E-01	3.0E+00	2.1E+00	4.7E+01	5.3E+01	5.4E+01
NO2	7	2.3E-01	3.0E+00	1.2E+00	3.8E+01	3.8E+01	4.2E+01
NO2	8	1.8E-01	2.3E+00	1.6E+00	2.8E+01	3.8E+01	4.0E+01
NO2	9	2.9E-01	2.9E+00	3.2E+00	4.0E+01	4.5E+01	4.8E+01
NO2	10	2.6E-01	2.5E+00	2.1E+00	4.2E+01	5.1E+01	5.3E+01
NO2	11	4.2E-01	4.1E+00	4.6E+00	4.1E+01	5.2E+01	5.4E+01
NO2	13	1.6E-01	1.4E+00	1.2E+00	3.2E+01	4.7E+01	4.7E+01
NO2	14	4.0E-01	3.9E+00	3.5E+00	5.4E+01	5.4E+01	5.4E+01
NO2	15	4.5E-01	4.8E+00	3.5E+00	5.4E+01	5.4E+01	5.4E+01
NO2	16	6.0E-01	6.7E+00	8.7E+00	4.4E+01	5.0E+01	5.4E+01

6.2. Concentration Statistics by Receptor Site – Case 7 (with new Boilers)

Table 12. Selected modelled concentration statistics sorted by receptor site for each of the 28 chemical species at each of the 15 receptor sites for Expanded Refinery Scenario (4.7 Mtpa) with Case 7 (new Boilers 4 & 5). The annual averages are for the average emission rates, whereas all other statistics are for peak emission rates. The shaded NO_2 cells indicate values that are limited by the available ozone, see Section 3.7.

Site	Chemical Species *(Case 7 – Boilers 4 & 5)*	Annual average ($\mu g\ m^{-3}$)	95th % 24-hr average ($\mu g\ m^{-3}$)	95th % 1-hr average ($\mu g\ m^{-3}$)	Max. 1-hr average ($\mu g\ m^{-3}$)	Max. 10-min average ($\mu g\ m^{-3}$)	Max. 3-min average ($\mu g\ m^{-3}$)
1	NOx	2.8E-01	3.0E+00	1.7E+00	4.8E+01	7.4E+01	9.9E+01
1	CO	5.6E-01	5.3E+00	4.2E+00	6.7E+01	9.5E+01	1.2E+02
1	SO2	3.6E-02	5.6E-01	4.0E-01	8.3E+00	1.3E+01	1.7E+01
1	Dust	1.2E-02	1.4E-01	8.7E-02	2.3E+00	3.6E+00	4.9E+00
1	Arsenic	5.2E-05	3.5E-04	1.1E-04	8.7E-03	1.2E-02	1.5E-02
1	Selenium	1.9E-05	1.2E-04	8.9E-05	2.5E-03	3.6E-03	4.6E-03
1	Manganese	2.2E-04	1.1E-03	7.2E-04	3.2E-02	4.7E-02	6.0E-02
1	Cadmium	3.2E-09	2.0E-08	3.4E-09	5.3E-07	7.6E-07	9.6E-07
1	Chromium (VI)	1.9E-07	1.2E-06	3.2E-07	2.7E-05	3.7E-05	4.6E-05
1	Nickel	7.6E-06	4.1E-05	3.7E-05	1.0E-03	1.5E-03	1.9E-03
1	Mercury	6.6E-05	3.9E-04	2.9E-04	6.8E-03	1.0E-02	1.4E-02
1	Ammonia	7.8E-03	3.9E-02	2.6E-02	1.0E+00	1.5E+00	1.9E+00
1	BaP Equivalents	6.9E-07	3.9E-06	1.8E-06	5.8E-05	8.5E-05	1.1E-04
1	Acetone	2.6E-02	1.3E-01	1.4E-01	1.4E+00	2.2E+00	2.8E+00
1	Acetaldehyde	6.1E-03	3.3E-02	3.7E-02	2.8E-01	4.6E-01	6.4E-01
1	Formaldehyde	3.2E-03	1.9E-02	6.6E-03	2.9E-01	4.9E-01	6.9E-01
1	2-Butanone	3.3E-03	1.6E-02	1.6E-02	1.9E-01	2.8E-01	3.6E-01
1	Benzene	7.5E-04	3.8E-03	2.2E-03	7.6E-02	1.2E-01	1.6E-01
1	Toluene	6.0E-04	3.2E-03	2.6E-03	6.7E-02	1.0E-01	1.4E-01
1	Xylenes	2.3E-05	1.2E-04	7.4E-05	2.3E-03	3.8E-03	5.4E-03
1	Acrolein	2.6E-04	1.5E-03	2.6E-04	3.0E-02	5.0E-02	7.1E-02
1	Ethylbenzene	1.7E-05	9.5E-05	8.1E-05	1.2E-03	1.9E-03	2.6E-03
1	Methylene Chloride	8.5E-04	5.0E-03	3.0E-03	8.8E-02	1.2E-01	1.5E-01
1	Styrene	4.6E-05	3.1E-04	2.3E-04	3.6E-03	5.5E-03	7.4E-03
1	1-2-4 Trimethylbenzene	1.7E-05	8.7E-05	5.1E-05	2.2E-03	3.3E-03	4.2E-03
1	1-3-5 Trimethylbenzene	6.7E-06	2.9E-05	3.0E-05	6.9E-04	1.0E-03	1.3E-03
1	Vinyl chloride	1.6E-06	9.9E-06	1.5E-06	1.9E-04	3.2E-04	4.6E-04
1	NO2	2.8E-01	3.0E+00	1.7E+00	4.8E+01	5.4E+01	5.4E+01
2	NOx	3.0E-01	3.2E+00	1.9E+00	5.1E+01	7.6E+01	9.8E+01
2	CO	5.4E-01	5.4E+00	4.4E+00	7.0E+01	1.0E+02	1.3E+02
2	SO2	3.4E-02	5.3E-01	4.0E-01	8.8E+00	1.3E+01	1.7E+01
2	Dust	1.3E-02	1.7E-01	9.1E-02	3.0E+00	4.6E+00	6.2E+00
2	Arsenic	5.9E-05	3.4E-04	1.2E-04	1.0E-02	1.5E-02	2.0E-02

Site	Chemical Species *(Case 7 – Boilers 4 & 5)*	Annual average ($\mu g\ m^{-3}$)	95th % 24-hr average ($\mu g\ m^{-3}$)	95th % 1-hr average ($\mu g\ m^{-3}$)	Max. 1-hr average ($\mu g\ m^{-3}$)	Max. 10-min average ($\mu g\ m^{-3}$)	Max. 3-min average ($\mu g\ m^{-3}$)
2	Selenium	2.1E-05	1.4E-04	7.9E-05	2.8E-03	4.2E-03	5.5E-03
2	Manganese	1.5E-04	8.8E-04	5.7E-04	1.7E-02	2.6E-02	3.5E-02
2	Cadmium	3.6E-09	1.8E-08	3.5E-09	5.8E-07	9.1E-07	1.2E-06
2	Chromium (VI)	2.2E-07	1.3E-06	4.6E-07	3.2E-05	4.7E-05	6.1E-05
2	Nickel	5.4E-06	3.7E-05	2.7E-05	5.5E-04	8.2E-04	1.1E-03
2	Mercury	5.5E-05	3.0E-04	2.7E-04	4.7E-03	7.3E-03	9.9E-03
2	Ammonia	5.4E-03	3.2E-02	1.9E-02	6.3E-01	9.4E-01	1.2E+00
2	BaP Equivalents	4.2E-07	2.5E-06	1.3E-06	4.6E-05	7.0E-05	9.2E-05
2	Acetone	1.8E-02	9.1E-02	9.3E-02	1.7E+00	2.5E+00	3.3E+00
2	Acetaldehyde	4.9E-03	2.4E-02	2.6E-02	3.6E-01	5.5E-01	7.4E-01
2	Formaldehyde	3.4E-03	2.0E-02	5.6E-03	3.7E-01	5.8E-01	7.8E-01
2	2-Butanone	2.2E-03	1.2E-02	1.0E-02	1.9E-01	2.9E-01	3.9E-01
2	Benzene	7.1E-04	3.4E-03	2.2E-03	7.4E-02	1.1E-01	1.5E-01
2	Toluene	4.6E-04	2.2E-03	1.8E-03	7.0E-02	1.1E-01	1.5E-01
2	Xylenes	2.6E-05	1.6E-04	6.3E-05	2.7E-03	4.3E-03	5.7E-03
2	Acrolein	3.0E-04	1.9E-03	2.7E-04	3.6E-02	5.6E-02	7.5E-02
2	Ethylbenzene	1.8E-05	9.4E-05	7.3E-05	1.5E-03	2.3E-03	3.0E-03
2	Methylene Chloride	9.3E-04	5.6E-03	2.8E-03	1.1E-01	1.6E-01	2.0E-01
2	Styrene	4.3E-05	2.4E-04	1.8E-04	5.1E-03	7.8E-03	1.0E-02
2	1-2-4 Trimethylbenzene	1.3E-05	8.5E-05	4.2E-05	1.3E-03	1.9E-03	2.6E-03
2	1-3-5 Trimethylbenzene	5.6E-06	3.1E-05	2.7E-05	3.9E-04	5.9E-04	7.9E-04
2	Vinyl chloride	1.9E-06	1.2E-05	1.7E-06	2.3E-04	3.6E-04	4.8E-04
2	NO2	3.0E-01	3.2E+00	1.9E+00	4.7E+01	5.3E+01	5.4E+01
3	NOx	2.1E-01	2.3E+00	7.6E-01	6.0E+01	9.1E+01	1.2E+02
3	CO	4.0E-01	3.9E+00	2.3E+00	9.1E+01	1.2E+02	1.5E+02
3	SO2	2.6E-02	3.8E-01	2.0E-01	1.1E+01	1.6E+01	2.1E+01
3	Dust	8.5E-03	1.2E-01	6.1E-02	2.9E+00	3.9E+00	4.8E+00
3	Arsenic	4.0E-05	2.6E-04	6.0E-05	8.3E-03	1.1E-02	1.4E-02
3	Selenium	1.4E-05	7.6E-05	5.5E-05	2.1E-03	2.9E-03	3.5E-03
3	Manganese	1.7E-04	1.1E-03	4.6E-04	1.8E-02	2.6E-02	3.4E-02
3	Cadmium	2.6E-09	1.6E-08	1.8E-09	4.8E-07	6.6E-07	8.2E-07
3	Chromium (VI)	1.5E-07	9.7E-07	1.6E-07	2.8E-05	3.8E-05	4.6E-05
3	Nickel	5.8E-06	4.1E-05	2.2E-05	5.5E-04	8.2E-04	1.1E-03
3	Mercury	4.9E-05	2.5E-04	2.1E-04	4.7E-03	7.1E-03	9.4E-03
3	Ammonia	5.9E-03	4.1E-02	1.8E-02	5.5E-01	8.1E-01	1.1E+00
3	BaP Equivalents	4.1E-07	2.6E-06	1.0E-06	4.4E-05	6.3E-05	8.1E-05
3	Acetone	1.8E-02	9.7E-02	8.5E-02	1.4E+00	2.1E+00	2.8E+00
3	Acetaldehyde	4.2E-03	2.1E-02	2.5E-02	3.0E-01	4.5E-01	5.9E-01
3	Formaldehyde	2.3E-03	1.4E-02	3.8E-03	3.2E-01	4.9E-01	6.6E-01
3	2-Butanone	2.2E-03	1.2E-02	9.3E-03	1.7E-01	2.6E-01	3.4E-01

Site	Chemical Species *(Case 7 – Boilers 4 & 5)*	Annual average ($\mu g\ m^{-3}$)	95th % 24-hr average ($\mu g\ m^{-3}$)	95th % 1-hr average ($\mu g\ m^{-3}$)	Max. 1-hr average ($\mu g\ m^{-3}$)	Max. 10-min average ($\mu g\ m^{-3}$)	Max. 3-min average ($\mu g\ m^{-3}$)
3	Benzene	5.7E-04	3.2E-03	1.1E-03	8.4E-02	1.3E-01	1.7E-01
3	Toluene	4.5E-04	2.3E-03	1.6E-03	6.9E-02	1.1E-01	1.4E-01
3	Xylenes	1.6E-05	9.8E-05	5.3E-05	2.3E-03	3.5E-03	4.6E-03
3	Acrolein	1.8E-04	1.3E-03	1.7E-04	3.0E-02	4.6E-02	6.2E-02
3	Ethylbenzene	1.2E-05	6.6E-05	6.2E-05	1.5E-03	2.0E-03	2.5E-03
3	Methylene Chloride	6.3E-04	4.2E-03	1.7E-03	1.0E-01	1.4E-01	1.7E-01
3	Styrene	3.6E-05	2.3E-04	1.7E-04	4.4E-03	6.7E-03	8.9E-03
3	1-2-4 Trimethylbenzene	1.3E-05	7.9E-05	4.0E-05	1.3E-03	1.9E-03	2.4E-03
3	1-3-5 Trimethylbenzene	4.9E-06	2.6E-05	2.5E-05	3.9E-04	5.8E-04	7.5E-04
3	Vinyl chloride	1.1E-06	8.3E-06	1.0E-06	2.0E-04	3.0E-04	4.0E-04
3	NO2	2.1E-01	2.3E+00	7.6E-01	5.2E+01	5.4E+01	5.4E+01
4	NOx	2.6E-01	3.1E+00	1.4E+00	7.3E+01	1.1E+02	1.4E+02
4	CO	5.0E-01	4.9E+00	3.3E+00	6.0E+01	8.1E+01	9.8E+01
4	SO2	3.3E-02	5.9E-01	3.1E-01	1.3E+01	2.0E+01	2.6E+01
4	Dust	1.1E-02	1.4E-01	7.8E-02	2.4E+00	3.7E+00	4.9E+00
4	Arsenic	4.8E-05	3.4E-04	1.0E-04	9.2E-03	1.4E-02	1.8E-02
4	Selenium	1.7E-05	9.9E-05	9.0E-05	2.0E-03	2.7E-03	3.3E-03
4	Manganese	3.5E-04	2.4E-03	8.4E-04	6.2E-02	9.0E-02	1.2E-01
4	Cadmium	3.1E-09	1.9E-08	3.1E-09	6.4E-07	1.0E-06	1.3E-06
4	Chromium (VI)	1.8E-07	1.2E-06	2.6E-07	3.0E-05	4.4E-05	5.7E-05
4	Nickel	1.2E-05	7.5E-05	3.8E-05	2.0E-03	2.8E-03	3.6E-03
4	Mercury	7.0E-05	3.4E-04	2.9E-04	6.4E-03	9.8E-03	1.3E-02
4	Ammonia	1.2E-02	8.1E-02	3.5E-02	1.5E+00	2.1E+00	2.8E+00
4	BaP Equivalents	7.8E-07	4.8E-06	2.2E-06	1.1E-04	1.7E-04	2.2E-04
4	Acetone	3.2E-02	1.9E-01	1.7E-01	3.3E+00	4.6E+00	5.9E+00
4	Acetaldehyde	7.5E-03	3.6E-02	5.2E-02	4.2E-01	6.0E-01	7.5E-01
4	Formaldehyde	3.3E-03	1.8E-02	7.8E-03	3.4E-01	5.1E-01	6.8E-01
4	2-Butanone	3.8E-03	2.3E-02	2.0E-02	3.8E-01	5.6E-01	7.3E-01
4	Benzene	7.8E-04	4.2E-03	2.2E-03	9.9E-02	1.5E-01	2.0E-01
4	Toluene	6.9E-04	3.3E-03	3.4E-03	9.1E-02	1.4E-01	1.9E-01
4	Xylenes	2.4E-05	1.3E-04	9.0E-05	2.5E-03	3.7E-03	4.9E-03
4	Acrolein	2.6E-04	1.7E-03	3.0E-04	3.4E-02	5.0E-02	6.6E-02
4	Ethylbenzene	1.8E-05	8.7E-05	9.1E-05	1.2E-03	1.9E-03	2.7E-03
4	Methylene Chloride	8.9E-04	4.6E-03	3.3E-03	9.4E-02	1.4E-01	1.8E-01
4	Styrene	5.3E-05	3.8E-04	2.5E-04	8.8E-03	1.3E-02	1.6E-02
4	1-2-4 Trimethylbenzene	2.5E-05	1.6E-04	6.0E-05	4.4E-03	6.3E-03	8.1E-03
4	1-3-5 Trimethylbenzene	9.3E-06	5.1E-05	3.5E-05	1.3E-03	2.0E-03	2.5E-03
4	Vinyl chloride	1.6E-06	1.1E-05	1.8E-06	2.2E-04	3.2E-04	4.2E-04
4	NO2	2.6E-01	3.1E+00	1.4E+00	5.2E+01	5.4E+01	5.4E+01

Site	Chemical Species *(Case 7 – Boilers 4 & 5)*	Annual average ($\mu g\ m^{-3}$)	95th % 24-hr average ($\mu g\ m^{-3}$)	95th % 1-hr average ($\mu g\ m^{-3}$)	Max. 1-hr average ($\mu g\ m^{-3}$)	Max. 10-min average ($\mu g\ m^{-3}$)	Max. 3-min average ($\mu g\ m^{-3}$)
5	NOx	2.0E-01	2.3E+00	5.8E-01	7.2E+01	1.1E+02	1.4E+02
5	CO	3.3E-01	3.4E+00	1.3E+00	7.2E+01	9.7E+01	1.2E+02
5	SO2	2.3E-02	4.1E-01	1.1E-01	1.2E+01	1.8E+01	2.4E+01
5	Dust	7.2E-03	9.9E-02	4.2E-02	2.1E+00	2.8E+00	3.5E+00
5	Arsenic	3.9E-05	2.5E-04	4.8E-05	9.8E-03	1.5E-02	1.9E-02
5	Selenium	1.0E-05	6.4E-05	3.7E-05	1.8E-03	2.5E-03	3.1E-03
5	Manganese	1.3E-04	8.4E-04	4.4E-04	1.6E-02	2.3E-02	2.9E-02
5	Cadmium	2.6E-09	1.5E-08	1.9E-09	7.0E-07	1.1E-06	1.5E-06
5	Chromium (VI)	1.4E-07	9.9E-07	1.6E-07	3.3E-05	4.8E-05	6.2E-05
5	Nickel	4.8E-06	3.4E-05	2.0E-05	6.6E-04	9.9E-04	1.3E-03
5	Mercury	4.0E-05	2.2E-04	1.3E-04	6.2E-03	9.1E-03	1.2E-02
5	Ammonia	4.8E-03	3.1E-02	1.7E-02	4.3E-01	6.2E-01	7.9E-01
5	BaP Equivalents	3.5E-07	2.4E-06	9.1E-07	3.6E-05	5.0E-05	6.4E-05
5	Acetone	1.7E-02	1.0E-01	7.1E-02	1.6E+00	2.4E+00	3.1E+00
5	Acetaldehyde	3.8E-03	2.1E-02	2.2E-02	2.3E-01	3.6E-01	4.8E-01
5	Formaldehyde	2.2E-03	1.4E-02	3.6E-03	2.6E-01	4.1E-01	5.5E-01
5	2-Butanone	2.0E-03	1.1E-02	8.5E-03	1.8E-01	2.6E-01	3.4E-01
5	Benzene	5.7E-04	2.8E-03	8.8E-04	9.5E-02	1.4E-01	1.8E-01
5	Toluene	4.6E-04	2.1E-03	1.3E-03	8.5E-02	1.3E-01	1.6E-01
5	Xylenes	1.4E-05	8.3E-05	4.5E-05	1.8E-03	2.9E-03	3.9E-03
5	Acrolein	1.6E-04	1.1E-03	1.9E-04	2.5E-02	3.9E-02	5.2E-02
5	Ethylbenzene	9.9E-06	5.5E-05	4.5E-05	1.2E-03	1.6E-03	2.0E-03
5	Methylene Chloride	6.0E-04	3.6E-03	1.6E-03	1.1E-01	1.6E-01	2.0E-01
5	Styrene	3.4E-05	2.1E-04	1.2E-04	5.5E-03	8.1E-03	1.0E-02
5	1-2-4 Trimethylbenzene	9.9E-06	6.5E-05	3.4E-05	1.1E-03	1.6E-03	2.0E-03
5	1-3-5 Trimethylbenzene	4.0E-06	2.2E-05	2.1E-05	3.4E-04	4.9E-04	6.2E-04
5	Vinyl chloride	1.0E-06	6.9E-06	1.1E-06	1.6E-04	2.5E-04	3.4E-04
5	NO2	2.0E-01	2.2E+00	5.8E-01	4.5E+01	5.0E+01	5.1E+01
6	NOx	2.9E-01	3.0E+00	2.1E+00	7.5E+01	9.9E+01	1.2E+02
6	CO	4.9E-01	5.5E+00	3.9E+00	8.5E+01	1.1E+02	1.4E+02
6	SO2	3.2E-02	4.9E-01	4.1E-01	1.3E+01	1.7E+01	2.1E+01
6	Dust	1.1E-02	1.5E-01	8.8E-02	3.1E+00	4.7E+00	6.4E+00
6	Arsenic	6.1E-05	2.9E-04	1.4E-04	1.2E-02	1.7E-02	2.0E-02
6	Selenium	1.9E-05	1.4E-04	6.7E-05	2.9E-03	4.1E-03	5.2E-03
6	Manganese	1.1E-04	6.6E-04	4.8E-04	1.4E-02	2.1E-02	2.8E-02
6	Cadmium	3.8E-09	1.7E-08	4.6E-09	7.1E-07	9.8E-07	1.2E-06
6	Chromium (VI)	2.2E-07	1.2E-06	5.3E-07	4.0E-05	5.3E-05	6.4E-05
6	Nickel	4.3E-06	3.1E-05	2.4E-05	6.7E-04	9.1E-04	1.1E-03
6	Mercury	4.9E-05	2.6E-04	2.3E-04	4.0E-03	5.5E-03	6.9E-03
6	Ammonia	4.3E-03	2.4E-02	1.7E-02	5.0E-01	7.4E-01	9.6E-01

Site	Chemical Species *(Case 7 – Boilers 4 & 5)*	Annual average ($\mu g\ m^{-3}$)	95th % 24-hr average ($\mu g\ m^{-3}$)	95th % 1-hr average ($\mu g\ m^{-3}$)	Max. 1-hr average ($\mu g\ m^{-3}$)	Max. 10-min average ($\mu g\ m^{-3}$)	Max. 3-min average ($\mu g\ m^{-3}$)
6	BaP Equivalents	3.0E-07	1.7E-06	9.9E-07	3.5E-05	5.2E-05	6.9E-05
6	Acetone	1.4E-02	7.3E-02	7.2E-02	1.2E+00	1.8E+00	2.4E+00
6	Acetaldehyde	3.9E-03	2.1E-02	1.9E-02	3.6E-01	5.5E-01	7.2E-01
6	Formaldehyde	3.0E-03	1.8E-02	5.6E-03	3.8E-01	5.9E-01	7.9E-01
6	2-Butanone	1.7E-03	9.1E-03	8.0E-03	1.2E-01	1.8E-01	2.4E-01
6	Benzene	6.4E-04	3.1E-03	2.3E-03	7.2E-02	9.7E-02	1.2E-01
6	Toluene	3.9E-04	1.8E-03	1.6E-03	4.5E-02	7.0E-02	9.5E-02
6	Xylenes	2.2E-05	1.4E-04	5.4E-05	3.1E-03	4.8E-03	6.4E-03
6	Acrolein	2.6E-04	1.8E-03	2.2E-04	4.1E-02	6.3E-02	8.4E-02
6	Ethylbenzene	1.6E-05	9.9E-05	6.7E-05	1.5E-03	2.3E-03	3.1E-03
6	Methylene Chloride	8.9E-04	5.4E-03	2.6E-03	1.4E-01	1.8E-01	2.2E-01
6	Styrene	3.6E-05	2.2E-04	1.7E-04	4.6E-03	6.8E-03	9.0E-03
6	1-2-4 Trimethylbenzene	9.8E-06	6.1E-05	3.6E-05	1.1E-03	1.7E-03	2.2E-03
6	1-3-5 Trimethylbenzene	4.4E-06	2.5E-05	2.3E-05	3.7E-04	5.7E-04	7.6E-04
6	Vinyl chloride	1.6E-06	1.2E-05	1.3E-06	2.6E-04	4.0E-04	5.4E-04
6	NO2	2.9E-01	3.0E+00	2.1E+00	4.7E+01	5.3E+01	5.3E+01
7	NOx	2.3E-01	3.0E+00	1.2E+00	6.7E+01	1.0E+02	1.3E+02
7	CO	3.1E-01	3.3E+00	1.7E+00	4.9E+01	7.2E+01	9.3E+01
7	SO2	2.6E-02	5.3E-01	2.0E-01	1.2E+01	1.8E+01	2.4E+01
7	Dust	6.8E-03	8.5E-02	6.2E-02	1.8E+00	2.7E+00	3.5E+00
7	Arsenic	4.3E-05	2.9E-04	6.3E-05	1.2E-02	1.8E-02	2.4E-02
7	Selenium	7.8E-06	5.1E-05	3.8E-05	8.4E-04	1.3E-03	1.8E-03
7	Manganese	1.2E-04	7.1E-04	3.5E-04	1.4E-02	2.1E-02	2.7E-02
7	Cadmium	3.4E-09	2.2E-08	3.9E-09	9.7E-07	1.5E-06	2.0E-06
7	Chromium (VI)	1.7E-07	1.1E-06	3.0E-07	4.2E-05	6.1E-05	7.9E-05
7	Nickel	4.6E-06	3.1E-05	1.7E-05	1.0E-03	1.5E-03	2.0E-03
7	Mercury	4.1E-05	2.5E-04	1.1E-04	5.5E-03	8.3E-03	1.1E-02
7	Ammonia	5.3E-03	3.1E-02	1.4E-02	5.8E-01	8.7E-01	1.1E+00
7	BaP Equivalents	2.8E-07	1.6E-06	7.7E-07	3.9E-05	5.7E-05	7.3E-05
7	Acetone	1.5E-02	8.3E-02	5.9E-02	9.5E-01	1.4E+00	1.9E+00
7	Acetaldehyde	3.6E-03	1.9E-02	2.2E-02	3.4E-01	5.0E-01	6.5E-01
7	Formaldehyde	2.3E-03	1.4E-02	8.4E-03	3.3E-01	4.9E-01	6.3E-01
7	2-Butanone	1.9E-03	1.0E-02	7.0E-03	1.4E-01	2.0E-01	2.6E-01
7	Benzene	5.8E-04	3.8E-03	1.6E-03	5.1E-02	7.6E-02	9.9E-02
7	Toluene	4.6E-04	3.3E-03	1.5E-03	4.3E-02	6.1E-02	7.8E-02
7	Xylenes	1.4E-05	9.0E-05	4.8E-05	2.9E-03	4.4E-03	5.7E-03
7	Acrolein	1.7E-04	1.1E-03	3.3E-04	3.6E-02	5.3E-02	6.9E-02
7	Ethylbenzene	8.4E-06	4.6E-05	4.5E-05	1.3E-03	1.9E-03	2.5E-03
7	Methylene Chloride	6.7E-04	4.1E-03	2.0E-03	1.3E-01	1.9E-01	2.5E-01
7	Styrene	3.0E-05	2.4E-04	1.2E-04	3.4E-03	5.1E-03	6.7E-03

Site	Chemical Species *(Case 7 – Boilers 4 & 5)*	Annual average ($\mu g\ m^{-3}$)	95th % 24-hr average ($\mu g\ m^{-3}$)	95th % 1-hr average ($\mu g\ m^{-3}$)	Max. 1-hr average ($\mu g\ m^{-3}$)	Max. 10-min average ($\mu g\ m^{-3}$)	Max. 3-min average ($\mu g\ m^{-3}$)
7	1-2-4 Trimethylbenzene	7.9E-06	4.1E-05	2.5E-05	7.3E-04	1.1E-03	1.4E-03
7	1-3-5 Trimethylbenzene	3.4E-06	2.0E-05	2.0E-05	2.8E-04	4.2E-04	5.4E-04
7	Vinyl chloride	1.0E-06	7.4E-06	2.1E-06	2.3E-04	3.4E-04	4.4E-04
7	NO2	2.3E-01	3.0E+00	1.2E+00	3.8E+01	3.8E+01	4.2E+01
8	NOx	1.8E-01	2.3E+00	1.6E+00	2.8E+01	3.9E+01	4.9E+01
8	CO	2.9E-01	3.4E+00	2.5E+00	4.2E+01	6.2E+01	8.1E+01
8	SO2	2.1E-02	3.9E-01	2.7E-01	5.7E+00	7.9E+00	9.9E+00
8	Dust	7.5E-03	1.1E-01	8.2E-02	1.5E+00	2.2E+00	2.8E+00
8	Arsenic	3.2E-05	2.0E-04	1.0E-04	4.2E-03	6.3E-03	8.2E-03
8	Selenium	8.5E-06	5.6E-05	4.5E-05	1.1E-03	1.7E-03	2.2E-03
8	Manganese	1.0E-04	6.2E-04	4.0E-04	1.0E-02	1.4E-02	1.8E-02
8	Cadmium	2.2E-09	1.3E-08	5.9E-09	2.5E-07	4.0E-07	5.4E-07
8	Chromium (VI)	1.3E-07	8.9E-07	4.7E-07	1.3E-05	1.9E-05	2.5E-05
8	Nickel	3.8E-06	2.5E-05	2.0E-05	3.2E-04	4.8E-04	6.2E-04
8	Mercury	3.3E-05	1.9E-04	1.3E-04	3.7E-03	5.1E-03	6.3E-03
8	Ammonia	4.5E-03	2.6E-02	1.6E-02	4.6E-01	6.3E-01	7.8E-01
8	BaP Equivalents	2.3E-07	1.3E-06	8.5E-07	2.3E-05	3.2E-05	4.1E-05
8	Acetone	1.1E-02	6.0E-02	6.1E-02	7.7E-01	1.1E+00	1.5E+00
8	Acetaldehyde	3.3E-03	1.6E-02	2.3E-02	1.7E-01	2.4E-01	3.2E-01
8	Formaldehyde	2.2E-03	1.5E-02	1.0E-02	1.9E-01	2.5E-01	3.0E-01
8	2-Butanone	1.4E-03	7.2E-03	7.3E-03	8.3E-02	1.2E-01	1.6E-01
8	Benzene	4.3E-04	2.8E-03	1.9E-03	4.6E-02	6.8E-02	8.9E-02
8	Toluene	3.1E-04	1.9E-03	1.6E-03	3.4E-02	5.2E-02	6.8E-02
8	Xylenes	1.7E-05	1.0E-04	6.9E-05	1.6E-03	2.4E-03	3.2E-03
8	Acrolein	2.0E-04	1.3E-03	6.8E-04	2.1E-02	3.3E-02	4.3E-02
8	Ethylbenzene	9.6E-06	5.6E-05	5.6E-05	8.3E-04	1.2E-03	1.6E-03
8	Methylene Chloride	5.7E-04	3.6E-03	2.6E-03	4.4E-02	6.5E-02	8.4E-02
8	Styrene	2.4E-05	1.8E-04	1.3E-04	3.0E-03	4.5E-03	5.8E-03
8	1-2-4 Trimethylbenzene	7.6E-06	4.2E-05	3.1E-05	7.0E-04	1.0E-03	1.3E-03
8	1-3-5 Trimethylbenzene	3.5E-06	1.8E-05	2.3E-05	2.2E-04	3.1E-04	3.9E-04
8	Vinyl chloride	1.2E-06	8.4E-06	4.3E-06	1.4E-04	2.1E-04	2.8E-04
8	NO2	1.8E-01	2.3E+00	1.6E+00	2.8E+01	3.8E+01	4.0E+01
9	NOx	2.9E-01	2.9E+00	3.2E+00	4.0E+01	6.0E+01	7.8E+01
9	CO	4.9E-01	4.4E+00	5.4E+00	5.5E+01	8.4E+01	1.1E+02
9	SO2	3.4E-02	5.1E-01	5.7E-01	7.2E+00	1.1E+01	1.4E+01
9	Dust	1.3E-02	1.6E-01	1.8E-01	2.4E+00	3.7E+00	4.9E+00
9	Arsenic	5.4E-05	2.9E-04	2.3E-04	6.0E-03	8.9E-03	1.2E-02
9	Selenium	1.5E-05	7.9E-05	9.7E-05	1.3E-03	2.0E-03	2.7E-03
9	Manganese	2.3E-04	1.1E-03	1.1E-03	1.8E-02	2.7E-02	3.4E-02

Site	Chemical Species *(Case 7 – Boilers 4 & 5)*	Annual average ($\mu g\ m^{-3}$)	95th % 24-hr average ($\mu g\ m^{-3}$)	95th % 1-hr average ($\mu g\ m^{-3}$)	Max. 1-hr average ($\mu g\ m^{-3}$)	Max. 10-min average ($\mu g\ m^{-3}$)	Max. 3-min average ($\mu g\ m^{-3}$)
9	Cadmium	3.5E-09	1.8E-08	1.4E-08	3.4E-07	5.3E-07	7.2E-07
9	Chromium (VI)	2.1E-07	1.2E-06	1.1E-06	1.8E-05	2.6E-05	3.4E-05
9	Nickel	8.0E-06	4.0E-05	5.0E-05	5.7E-04	8.3E-04	1.1E-03
9	Mercury	6.1E-05	2.7E-04	3.2E-04	5.3E-03	7.7E-03	9.8E-03
9	Ammonia	9.6E-03	4.3E-02	4.7E-02	7.3E-01	1.1E+00	1.3E+00
9	BaP Equivalents	5.2E-07	2.3E-06	2.3E-06	3.9E-05	5.5E-05	7.1E-05
9	Acetone	2.2E-02	8.4E-02	1.3E-01	1.1E+00	1.6E+00	2.0E+00
9	Acetaldehyde	6.2E-03	2.5E-02	4.7E-02	2.7E-01	3.9E-01	4.9E-01
9	Formaldehyde	3.6E-03	2.1E-02	2.0E-02	2.7E-01	3.5E-01	4.2E-01
9	2-Butanone	2.7E-03	1.1E-02	1.6E-02	1.4E-01	2.0E-01	2.5E-01
9	Benzene	6.8E-04	3.6E-03	4.0E-03	4.6E-02	6.7E-02	8.7E-02
9	Toluene	5.1E-04	2.3E-03	3.1E-03	3.7E-02	5.5E-02	7.2E-02
9	Xylenes	2.7E-05	1.6E-04	1.4E-04	2.0E-03	3.1E-03	4.1E-03
9	Acrolein	3.2E-04	2.1E-03	1.4E-03	2.8E-02	3.6E-02	4.3E-02
9	Ethylbenzene	1.7E-05	7.8E-05	1.2E-04	1.2E-03	1.9E-03	2.5E-03
9	Methylene Chloride	9.7E-04	5.1E-03	5.6E-03	6.0E-02	8.8E-02	1.1E-01
9	Styrene	3.9E-05	2.2E-04	2.8E-04	2.8E-03	4.1E-03	5.3E-03
9	1-2-4 Trimethylbenzene	1.7E-05	7.9E-05	8.2E-05	1.4E-03	2.0E-03	2.5E-03
9	1-3-5 Trimethylbenzene	7.1E-06	2.9E-05	4.9E-05	4.2E-04	6.1E-04	7.8E-04
9	Vinyl chloride	2.0E-06	1.3E-05	8.9E-06	1.8E-04	2.3E-04	2.8E-04
9	NO2	2.9E-01	2.9E+00	3.2E+00	4.0E+01	4.5E+01	4.8E+01
10	NOx	2.6E-01	2.5E+00	2.1E+00	4.2E+01	6.4E+01	8.4E+01
10	CO	4.1E-01	3.5E+00	4.0E+00	6.4E+01	9.9E+01	1.3E+02
10	SO2	2.9E-02	4.1E-01	4.2E-01	7.5E+00	1.1E+01	1.5E+01
10	Dust	1.2E-02	1.4E-01	1.3E-01	3.3E+00	5.2E+00	7.0E+00
10	Arsenic	5.1E-05	2.7E-04	1.9E-04	6.1E-03	9.1E-03	1.2E-02
10	Selenium	1.5E-05	9.2E-05	9.3E-05	1.4E-03	2.2E-03	3.0E-03
10	Manganese	2.9E-04	1.8E-03	1.4E-03	4.7E-02	6.8E-02	8.8E-02
10	Cadmium	3.2E-09	1.5E-08	1.0E-08	3.6E-07	5.6E-07	7.6E-07
10	Chromium (VI)	2.0E-07	1.0E-06	8.0E-07	1.9E-05	2.8E-05	3.6E-05
10	Nickel	9.7E-06	6.4E-05	6.0E-05	1.5E-03	2.1E-03	2.7E-03
10	Mercury	5.4E-05	2.6E-04	3.1E-04	6.5E-03	9.9E-03	1.3E-02
10	Ammonia	1.1E-02	6.6E-02	5.2E-02	1.7E+00	2.4E+00	3.1E+00
10	BaP Equivalents	5.8E-07	3.4E-06	2.6E-06	6.4E-05	9.3E-05	1.2E-04
10	Acetone	2.1E-02	1.2E-01	1.3E-01	1.8E+00	2.6E+00	3.2E+00
10	Acetaldehyde	6.5E-03	3.4E-02	4.6E-02	5.0E-01	7.2E-01	9.1E-01
10	Formaldehyde	3.5E-03	1.9E-02	1.3E-02	4.2E-01	6.5E-01	8.8E-01
10	2-Butanone	2.7E-03	1.5E-02	1.7E-02	2.2E-01	3.2E-01	4.1E-01
10	Benzene	5.8E-04	3.1E-03	2.7E-03	5.5E-02	8.2E-02	1.1E-01
10	Toluene	4.3E-04	2.0E-03	2.6E-03	4.2E-02	6.5E-02	8.7E-02

Site	Chemical Species *(Case 7 – Boilers 4 & 5)*	Annual average ($\mu g\ m^{-3}$)	95th % 24-hr average ($\mu g\ m^{-3}$)	95th % 1-hr average ($\mu g\ m^{-3}$)	Max. 1-hr average ($\mu g\ m^{-3}$)	Max. 10-min average ($\mu g\ m^{-3}$)	Max. 3-min average ($\mu g\ m^{-3}$)
10	Xylenes	2.9E-05	1.6E-04	1.3E-04	3.4E-03	5.3E-03	7.1E-03
10	Acrolein	3.4E-04	2.0E-03	1.1E-03	4.5E-02	7.0E-02	9.5E-02
10	Ethylbenzene	1.8E-05	8.6E-05	1.1E-04	1.6E-03	2.5E-03	3.3E-03
10	Methylene Chloride	9.7E-04	5.3E-03	4.7E-03	6.8E-02	1.1E-01	1.4E-01
10	Styrene	3.4E-05	1.8E-04	2.3E-04	3.1E-03	4.8E-03	6.3E-03
10	1-2-4 Trimethylbenzene	2.1E-05	1.3E-04	9.6E-05	3.3E-03	4.8E-03	6.1E-03
10	1-3-5 Trimethylbenzene	8.3E-06	4.6E-05	5.4E-05	1.0E-03	1.5E-03	1.9E-03
10	Vinyl chloride	2.1E-06	1.3E-05	6.9E-06	2.9E-04	4.5E-04	6.1E-04
10	NO2	2.6E-01	2.5E+00	2.1E+00	4.2E+01	5.1E+01	5.3E+01
11	NOx	4.2E-01	4.1E+00	4.6E+00	4.1E+01	6.2E+01	8.2E+01
11	CO	6.6E-01	5.8E+00	8.0E+00	6.9E+01	1.1E+02	1.5E+02
11	SO2	4.6E-02	7.6E-01	8.6E-01	7.1E+00	1.1E+01	1.4E+01
11	Dust	2.0E-02	2.4E-01	2.3E-01	3.7E+00	5.8E+00	7.9E+00
11	Arsenic	8.0E-05	5.2E-04	4.4E-04	6.7E-03	1.0E-02	1.3E-02
11	Selenium	2.7E-05	1.3E-04	1.9E-04	2.3E-03	3.3E-03	4.1E-03
11	Manganese	7.1E-04	3.5E-03	2.7E-03	1.7E-01	2.4E-01	3.0E-01
11	Cadmium	5.2E-09	3.1E-08	2.3E-08	4.3E-07	7.3E-07	1.1E-06
11	Chromium (VI)	3.2E-07	2.1E-06	1.9E-06	2.1E-05	3.1E-05	4.1E-05
11	Nickel	2.3E-05	1.1E-04	1.3E-04	5.2E-03	7.4E-03	9.4E-03
11	Mercury	1.1E-04	4.7E-04	6.6E-04	1.2E-02	1.7E-02	2.1E-02
11	Ammonia	2.6E-02	1.3E-01	1.1E-01	5.0E+00	7.1E+00	9.0E+00
11	BaP Equivalents	1.2E-06	6.0E-06	5.1E-06	1.3E-04	1.9E-04	2.4E-04
11	Acetone	4.3E-02	2.1E-01	2.8E-01	3.0E+00	4.3E+00	5.5E+00
11	Acetaldehyde	1.3E-02	5.6E-02	1.0E-01	1.1E+00	1.6E+00	2.0E+00
11	Formaldehyde	5.7E-03	2.9E-02	2.7E-02	4.2E-01	6.6E-01	9.0E-01
11	2-Butanone	5.5E-03	2.5E-02	3.4E-02	4.5E-01	6.5E-01	8.3E-01
11	Benzene	9.5E-04	4.5E-03	5.5E-03	4.9E-02	7.7E-02	1.0E-01
11	Toluene	7.8E-04	3.6E-03	5.6E-03	4.7E-02	7.2E-02	9.6E-02
11	Xylenes	5.0E-05	2.4E-04	2.6E-04	3.5E-03	5.5E-03	7.4E-03
11	Acrolein	5.5E-04	2.9E-03	2.0E-03	4.7E-02	7.3E-02	1.0E-01
11	Ethylbenzene	3.3E-05	1.6E-04	2.3E-04	2.8E-03	4.0E-03	5.1E-03
11	Methylene Chloride	1.7E-03	8.9E-03	1.1E-02	7.6E-02	1.1E-01	1.4E-01
11	Styrene	5.7E-05	3.0E-04	4.7E-04	4.7E-03	6.9E-03	9.0E-03
11	1-2-4 Trimethylbenzene	5.0E-05	2.7E-04	1.8E-04	1.2E-02	1.7E-02	2.1E-02
11	1-3-5 Trimethylbenzene	1.9E-05	9.2E-05	1.0E-04	3.6E-03	5.1E-03	6.5E-03
11	Vinyl chloride	3.4E-06	1.9E-05	1.3E-05	3.0E-04	4.7E-04	6.4E-04
11	NO2	4.2E-01	4.1E+00	4.6E+00	4.1E+01	5.2E+01	5.4E+01
13	NOx	1.6E-01	1.4E+00	1.2E+00	3.2E+01	4.7E+01	6.1E+01
13	CO	2.9E-01	2.6E+00	3.3E+00	4.2E+01	6.2E+01	8.2E+01

Site	Chemical Species *(Case 7 – Boilers 4 & 5)*	Annual average ($\mu g\ m^{-3}$)	95th % 24-hr average ($\mu g\ m^{-3}$)	95th % 1-hr average ($\mu g\ m^{-3}$)	Max. 1-hr average ($\mu g\ m^{-3}$)	Max. 10-min average ($\mu g\ m^{-3}$)	Max. 3-min average ($\mu g\ m^{-3}$)
13	SO2	1.8E-02	2.5E-01	2.4E-01	5.3E+00	7.8E+00	1.0E+01
13	Dust	7.5E-03	9.3E-02	9.5E-02	1.8E+00	2.7E+00	3.7E+00
13	Arsenic	3.1E-05	1.5E-04	1.0E-04	4.3E-03	6.4E-03	8.4E-03
13	Selenium	1.1E-05	5.9E-05	6.3E-05	9.0E-04	1.4E-03	1.8E-03
13	Manganese	8.0E-05	3.8E-04	5.2E-04	5.3E-03	7.9E-03	1.0E-02
13	Cadmium	1.9E-09	9.1E-09	5.0E-09	2.4E-07	3.9E-07	5.3E-07
13	Chromium (VI)	1.2E-07	6.4E-07	3.7E-07	1.6E-05	2.3E-05	3.0E-05
13	Nickel	2.9E-06	1.7E-05	2.5E-05	2.5E-04	3.8E-04	5.0E-04
13	Mercury	2.9E-05	1.4E-04	1.8E-04	1.8E-03	2.7E-03	3.5E-03
13	Ammonia	3.0E-03	1.4E-02	1.9E-02	1.9E-01	2.8E-01	3.6E-01
13	BaP Equivalents	1.8E-07	7.9E-07	1.1E-06	1.2E-05	1.8E-05	2.4E-05
13	Acetone	7.8E-03	3.6E-02	6.0E-02	4.9E-01	7.4E-01	9.8E-01
13	Acetaldehyde	2.6E-03	1.3E-02	1.7E-02	2.0E-01	3.0E-01	3.8E-01
13	Formaldehyde	2.0E-03	1.2E-02	5.6E-03	2.3E-01	3.3E-01	4.3E-01
13	2-Butanone	9.7E-04	4.5E-03	7.3E-03	6.3E-02	9.5E-02	1.2E-01
13	Benzene	3.4E-04	1.7E-03	1.5E-03	3.5E-02	5.2E-02	6.8E-02
13	Toluene	2.0E-04	9.5E-04	1.0E-03	1.8E-02	2.8E-02	3.7E-02
13	Xylenes	1.6E-05	9.0E-05	5.3E-05	1.8E-03	2.6E-03	3.4E-03
13	Acrolein	1.9E-04	1.2E-03	4.8E-04	2.4E-02	3.5E-02	4.6E-02
13	Ethylbenzene	1.0E-05	5.2E-05	6.4E-05	8.6E-04	1.3E-03	1.7E-03
13	Methylene Chloride	5.3E-04	2.9E-03	1.8E-03	6.4E-02	9.5E-02	1.2E-01
13	Styrene	2.0E-05	1.1E-04	1.4E-04	1.8E-03	2.7E-03	3.6E-03
13	1-2-4 Trimethylbenzene	6.8E-06	3.3E-05	4.5E-05	4.0E-04	5.9E-04	7.8E-04
13	1-3-5 Trimethylbenzene	3.2E-06	1.5E-05	2.5E-05	2.0E-04	3.0E-04	4.0E-04
13	Vinyl chloride	1.2E-06	7.7E-06	3.1E-06	1.5E-04	2.3E-04	2.9E-04
13	NO2	1.6E-01	1.4E+00	1.2E+00	3.2E+01	4.7E+01	4.7E+01
14	NOx	4.0E-01	3.9E+00	3.5E+00	7.4E+01	1.1E+02	1.4E+02
14	CO	6.6E-01	5.9E+00	7.3E+00	1.1E+02	1.6E+02	2.1E+02
14	SO2	4.4E-02	6.5E-01	6.5E-01	1.3E+01	1.9E+01	2.4E+01
14	Dust	1.7E-02	2.1E-01	2.3E-01	2.6E+00	3.9E+00	5.1E+00
14	Arsenic	7.9E-05	4.2E-04	3.3E-04	8.5E-03	1.3E-02	1.7E-02
14	Selenium	2.4E-05	1.2E-04	1.3E-04	4.1E-03	6.1E-03	8.0E-03
14	Manganese	1.9E-04	8.8E-04	1.4E-03	1.1E-02	1.8E-02	2.4E-02
14	Cadmium	4.9E-09	2.6E-08	1.8E-08	5.9E-07	9.2E-07	1.2E-06
14	Chromium (VI)	3.0E-07	1.7E-06	1.3E-06	3.1E-05	4.5E-05	5.8E-05
14	Nickel	7.1E-06	4.3E-05	6.5E-05	5.6E-04	8.4E-04	1.1E-03
14	Mercury	6.8E-05	2.9E-04	3.9E-04	4.6E-03	7.0E-03	9.3E-03
14	Ammonia	7.2E-03	3.0E-02	5.1E-02	3.6E-01	5.4E-01	7.1E-01
14	BaP Equivalents	4.4E-07	1.9E-06	2.7E-06	2.7E-05	4.0E-05	5.1E-05
14	Acetone	1.8E-02	8.9E-02	1.3E-01	9.8E-01	1.4E+00	1.9E+00

Site	Chemical Species *(Case 7 – Boilers 4 & 5)*	Annual average ($\mu g\ m^{-3}$)	95th % 24-hr average ($\mu g\ m^{-3}$)	95th % 1-hr average ($\mu g\ m^{-3}$)	Max. 1-hr average ($\mu g\ m^{-3}$)	Max. 10-min average ($\mu g\ m^{-3}$)	Max. 3-min average ($\mu g\ m^{-3}$)
14	Acetaldehyde	5.9E-03	2.7E-02	4.3E-02	3.0E-01	4.3E-01	5.5E-01
14	Formaldehyde	4.4E-03	2.6E-02	1.7E-02	3.3E-01	5.3E-01	7.2E-01
14	2-Butanone	2.3E-03	1.1E-02	1.7E-02	1.3E-01	1.9E-01	2.4E-01
14	Benzene	7.8E-04	3.9E-03	4.2E-03	6.0E-02	8.7E-02	1.1E-01
14	Toluene	4.6E-04	2.2E-03	2.7E-03	3.3E-02	4.9E-02	6.4E-02
14	Xylenes	3.5E-05	2.0E-04	1.4E-04	2.7E-03	4.2E-03	5.8E-03
14	Acrolein	4.3E-04	2.6E-03	1.5E-03	3.6E-02	5.7E-02	7.8E-02
14	Ethylbenzene	2.3E-05	1.1E-04	1.4E-04	1.9E-03	2.9E-03	3.7E-03
14	Methylene Chloride	1.3E-03	7.0E-03	5.5E-03	1.1E-01	1.6E-01	2.1E-01
14	Styrene	4.4E-05	2.2E-04	3.1E-04	3.4E-03	5.0E-03	6.5E-03
14	1-2-4 Trimethylbenzene	1.6E-05	6.5E-05	1.1E-04	1.1E-03	1.6E-03	2.1E-03
14	1-3-5 Trimethylbenzene	7.2E-06	3.9E-05	5.5E-05	2.9E-04	4.6E-04	6.2E-04
14	Vinyl chloride	2.7E-06	1.7E-05	9.4E-06	2.3E-04	3.7E-04	5.0E-04
14	NO2	4.0E-01	3.9E+00	3.5E+00	5.4E+01	5.4E+01	5.4E+01
15	NOx	4.5E-01	5.0E+00	3.5E+00	9.0E+01	1.3E+02	1.7E+02
15	CO	7.7E-01	8.5E+00	5.6E+00	1.1E+02	1.6E+02	2.2E+02
15	SO2	5.0E-02	8.3E-01	5.7E-01	1.6E+01	2.3E+01	3.0E+01
15	Dust	1.7E-02	2.6E-01	1.4E-01	4.2E+00	6.6E+00	8.9E+00
15	Arsenic	8.8E-05	5.8E-04	2.1E-04	2.0E-02	2.9E-02	3.8E-02
15	Selenium	3.0E-05	2.0E-04	8.1E-05	4.3E-03	6.8E-03	9.2E-03
15	Manganese	1.3E-04	7.8E-04	3.7E-04	2.0E-02	2.9E-02	3.7E-02
15	Cadmium	5.3E-09	3.3E-08	6.9E-09	1.1E-06	1.7E-06	2.3E-06
15	Chromium (VI)	3.2E-07	2.1E-06	7.9E-07	6.0E-05	8.7E-05	1.1E-04
15	Nickel	5.1E-06	4.2E-05	2.0E-05	1.2E-03	1.8E-03	2.3E-03
15	Mercury	6.9E-05	3.8E-04	1.8E-04	5.9E-03	8.9E-03	1.2E-02
15	Ammonia	5.0E-03	2.9E-02	1.4E-02	7.5E-01	1.1E+00	1.4E+00
15	BaP Equivalents	3.4E-07	2.3E-06	1.0E-06	3.3E-05	5.0E-05	6.6E-05
15	Acetone	1.9E-02	1.1E-01	8.3E-02	1.5E+00	2.2E+00	2.9E+00
15	Acetaldehyde	5.4E-03	3.1E-02	2.6E-02	5.3E-01	8.2E-01	1.1E+00
15	Formaldehyde	4.6E-03	2.7E-02	9.8E-03	6.1E-01	9.4E-01	1.3E+00
15	2-Butanone	2.3E-03	1.3E-02	9.3E-03	1.7E-01	2.6E-01	3.4E-01
15	Benzene	1.0E-03	6.1E-03	3.7E-03	8.6E-02	1.3E-01	1.7E-01
15	Toluene	6.1E-04	3.4E-03	1.9E-03	6.6E-02	1.0E-01	1.4E-01
15	Xylenes	3.4E-05	2.2E-04	8.5E-05	5.1E-03	7.9E-03	1.1E-02
15	Acrolein	4.0E-04	2.8E-03	3.8E-04	6.7E-02	1.0E-01	1.4E-01
15	Ethylbenzene	2.4E-05	1.5E-04	9.1E-05	2.2E-03	3.3E-03	4.5E-03
15	Methylene Chloride	1.3E-03	8.2E-03	3.2E-03	1.9E-01	2.8E-01	3.6E-01
15	Styrene	5.8E-05	3.5E-04	1.8E-04	6.4E-03	9.6E-03	1.3E-02
15	1-2-4 Trimethylbenzene	1.3E-05	8.9E-05	4.2E-05	1.2E-03	1.9E-03	2.5E-03
15	1-3-5 Trimethylbenzene	6.0E-06	3.5E-05	3.2E-05	5.0E-04	7.7E-04	1.0E-03

Site	Chemical Species *(Case 7 – Boilers 4 & 5)*	Annual average ($\mu g\ m^{-3}$)	95th % 24-hr average ($\mu g\ m^{-3}$)	95th % 1-hr average ($\mu g\ m^{-3}$)	Max. 1-hr average ($\mu g\ m^{-3}$)	Max. 10-min average ($\mu g\ m^{-3}$)	Max. 3-min average ($\mu g\ m^{-3}$)
15	Vinyl chloride	2.5E-06	1.8E-05	2.3E-06	4.3E-04	6.7E-04	9.0E-04
15	NO2	4.5E-01	4.8E+00	3.5E+00	5.4E+01	5.4E+01	5.4E+01
16	NOx	6.0E-01	6.7E+00	8.7E+00	4.7E+01	7.2E+01	9.5E+01
16	CO	1.1E+00	1.1E+01	1.4E+01	7.7E+01	1.2E+02	1.6E+02
16	SO2	7.4E-02	1.2E+00	1.6E+00	8.3E+00	1.3E+01	1.7E+01
16	Dust	2.9E-02	4.3E-01	4.0E-01	3.0E+00	4.6E+00	6.2E+00
16	Arsenic	1.1E-04	6.9E-04	6.1E-04	6.6E-03	1.0E-02	1.4E-02
16	Selenium	4.3E-05	2.1E-04	3.2E-04	3.7E-03	5.1E-03	6.4E-03
16	Manganese	1.2E-03	6.4E-03	4.2E-03	2.9E-01	4.0E-01	5.1E-01
16	Cadmium	6.9E-09	4.1E-08	3.4E-08	4.1E-07	7.0E-07	1.0E-06
16	Chromium (VI)	4.3E-07	2.6E-06	2.9E-06	2.0E-05	3.1E-05	4.2E-05
16	Nickel	3.8E-05	2.0E-04	1.8E-04	9.1E-03	1.3E-02	1.6E-02
16	Mercury	1.8E-04	8.9E-04	1.2E-03	2.0E-02	2.7E-02	3.4E-02
16	Ammonia	4.7E-02	2.3E-01	2.1E-01	8.2E+00	1.1E+01	1.4E+01
16	BaP Equivalents	2.2E-06	1.1E-05	9.3E-06	2.3E-04	3.3E-04	4.1E-04
16	Acetone	7.5E-02	3.3E-01	4.8E-01	5.7E+00	8.0E+00	1.0E+01
16	Acetaldehyde	2.2E-02	1.1E-01	1.5E-01	1.9E+00	2.6E+00	3.3E+00
16	Formaldehyde	8.0E-03	5.4E-02	4.9E-02	3.5E-01	5.5E-01	7.5E-01
16	2-Butanone	9.6E-03	4.5E-02	5.7E-02	8.3E-01	1.2E+00	1.5E+00
16	Benzene	1.5E-03	8.1E-03	1.1E-02	5.1E-02	7.8E-02	1.0E-01
16	Toluene	1.3E-03	5.5E-03	9.4E-03	6.0E-02	8.3E-02	1.0E-01
16	Xylenes	6.9E-05	4.0E-04	4.5E-04	3.7E-03	5.2E-03	6.6E-03
16	Acrolein	7.2E-04	5.0E-03	3.5E-03	3.8E-02	6.0E-02	8.1E-02
16	Ethylbenzene	4.8E-05	2.3E-04	3.4E-04	4.9E-03	6.8E-03	8.5E-03
16	Methylene Chloride	2.3E-03	1.2E-02	1.8E-02	1.3E-01	1.9E-01	2.3E-01
16	Styrene	9.0E-05	6.0E-04	7.5E-04	5.7E-03	8.3E-03	1.1E-02
16	1-2-4 Trimethylbenzene	8.4E-05	4.5E-04	3.1E-04	2.0E-02	2.8E-02	3.5E-02
16	1-3-5 Trimethylbenzene	3.0E-05	1.5E-04	1.6E-04	6.3E-03	8.8E-03	1.1E-02
16	Vinyl chloride	4.5E-06	3.2E-05	2.2E-05	2.4E-04	3.8E-04	5.2E-04
16	NO2	6.0E-01	6.7E+00	8.7E+00	4.4E+01	5.0E+01	5.4E+01

6.3. Concentration Contours – Case 7 (with new Boilers)

Figure 34 to Figure 51 show the modelled concentration contour patterns for Expansion Case 7 for the six statistics (annual average, 95th percentile 24-hour average, 95th percentile 1-hour average, maximum 1-hour average, maximum 10-minute average, and maximum 3-minute average) for mercury, formaldehyde, and NO_x. These were selected as representative of low-level, medium level and tall-stack releases from the Refinery for investigating the different patterns of ground-level concentrations. However, the mercury results presented here only include stack sources; the area source contributions are being modelled separately. The strongest mercury stack sources are the Oxalate Kiln Stack and the Boilerhouse Multiflue whereas the strongest formaldehyde stack sources are the Calciner stacks.

For the annual average and 95th percentile 24-hour average, the highest concentrations in the spatial distribution all occur within the Refinery within a few hundred metres of the 100 m Multiflue stack. The same is true for the modelled maximum 1-hour average concentrations for formaldehyde and mercury. Formaldehyde shows a very diffuse pattern with values below 0.5 µg m^{-3} at all receptors (except 15) and the maximum of 1 µg m^{-3} located 5 km south-east of the 100 m Multiflue on the escarpment. Mercury shows small peaks of up to 0.02 µg m^{-3} about 2 km east of the 100 m Multiflue and one extending about 2 km north of the 100 m Multiflue.

For NO_x, the modelled maximum 1-hour average concentrations (Figure 49) show a highest concentration in the spatial distribution of about 160 µg m^{-3} at a distance of 4 km approximately west-south-west of the 100 m Multiflue stack. There is also a local peak of 100 µg m^{-3} in the same location as the formaldehyde peak on the escarpment, 5 km south-east of the 100 m Multiflue. Modelled maximum concentrations through Yarloop are lower (from 50 to 75 µg m^{-3}) and less than 50 µg m^{-3} in Hamel. The NO_x results differ from those for formaldehyde because most of the NO_x emissions occur from the taller stacks that have significant plume rise because of the high temperature and volume of flow from the Calciner and Boilerhouse stacks. The highest ground-level concentrations from these stacks occur under convective or fumigation conditions. The maximum 10-minute and 3-minute average concentrations show similar patterns but with higher concentrations.

These differences between the contour patterns for species released at different heights are in agreement with our understanding of the different dispersion processes that are dominant at different heights in the atmosphere.

These yearly maximum 1-hour average concentrations represent the most extreme hour in the year with respect to ground-level concentrations. In a different year with different meteorology the location and magnitude of these yearly maximum 1-hour average concentrations could change. This is why the 9th highest concentration (99.9th percentile) or robust highest concentration (RHC) is often chosen as the key statistic to represent the extremes, rather than the modelled or observed maximum.

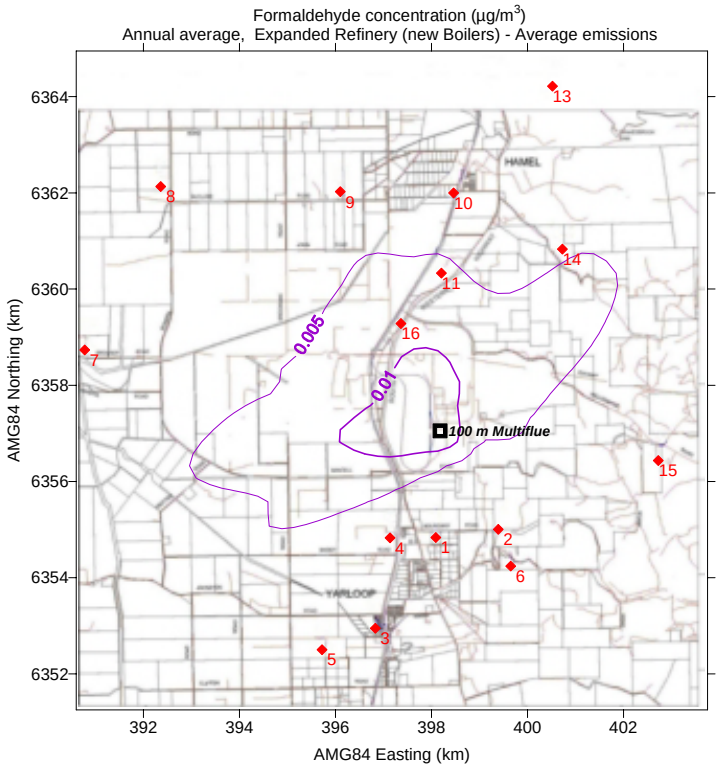

Figure 34: Annual-average modelled formaldehyde concentrations for 4.7 Mtpa Expanded Refinery Scenario Case 7 (with new Boilers 4 & 5) – Average Emissions.

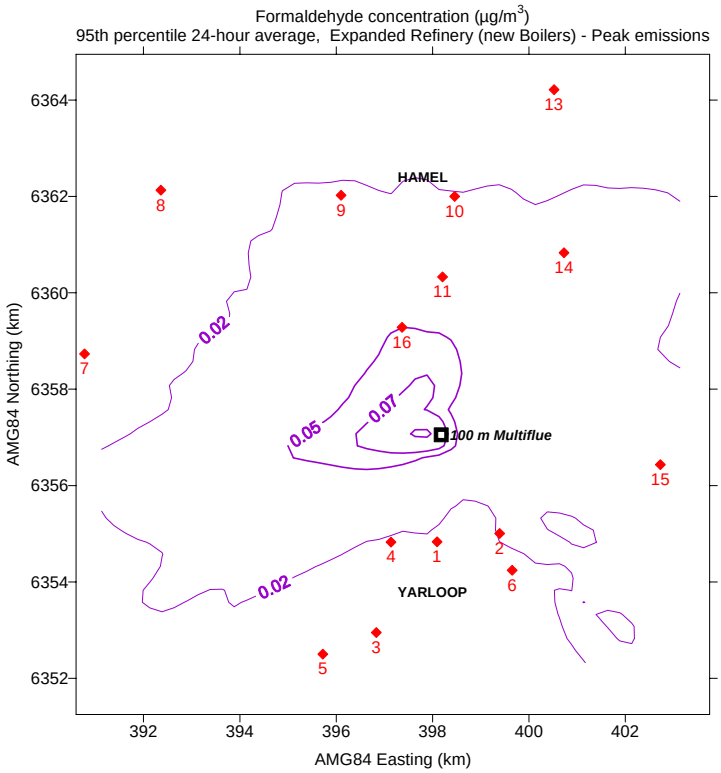

Figure 35: 95th percentile 24-hour average modelled formaldehyde concentrations for 4.7 Mtpa Expanded Refinery Scenario Case 7 (with new Boilers 4 & 5) – Peak Emissions.

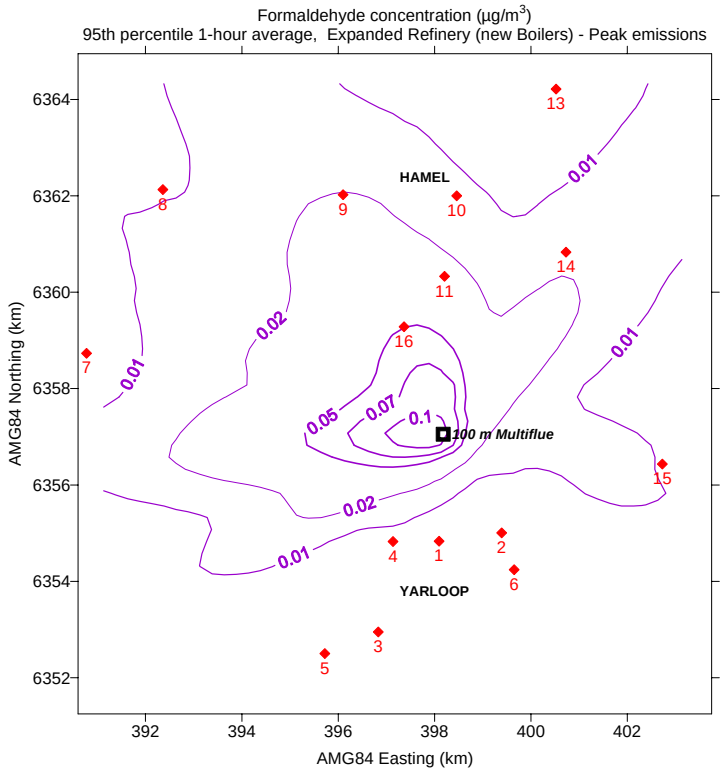

Figure 36: 95th percentile 1-hour average modelled formaldehyde concentrations for 4.7 Mtpa Expanded Refinery Scenario Case 7 (with new Boilers 4 & 5) – Peak Emissions.

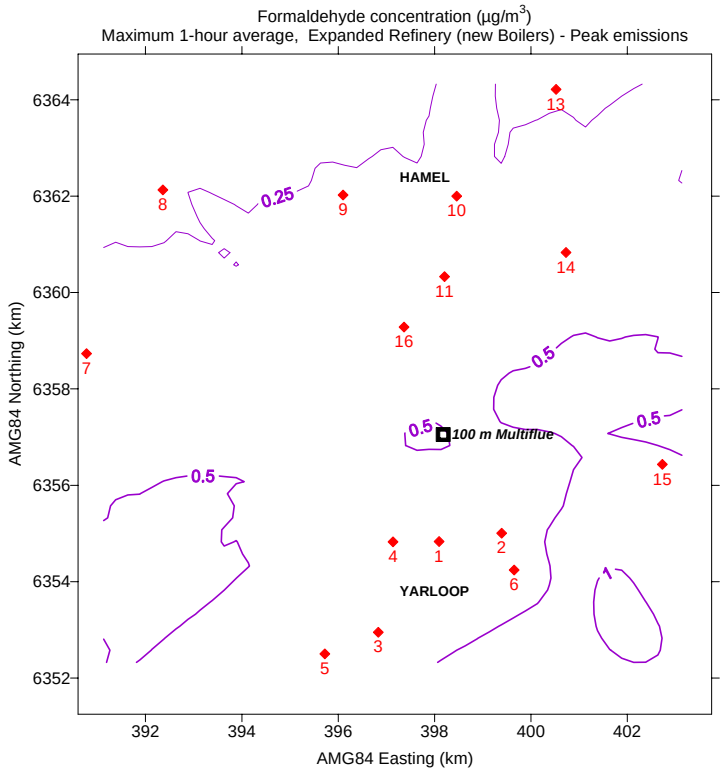

Figure 37: Maximum 1-hour average modelled formaldehyde concentrations for 4.7 Mtpa Expanded Refinery Scenario Case 7 (with new Boilers 4 & 5) – Peak Emissions.

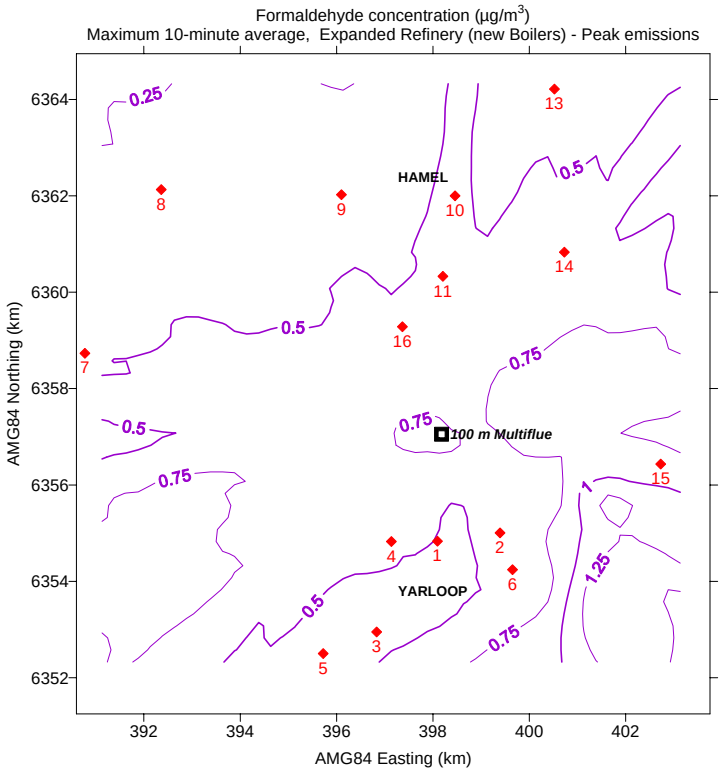

Figure 38: Maximum 10-minute average modelled formaldehyde concentrations for 4.7 Mtpa Expanded Refinery Scenario Case 7 (with new Boilers 4 & 5) – Peak Emissions.

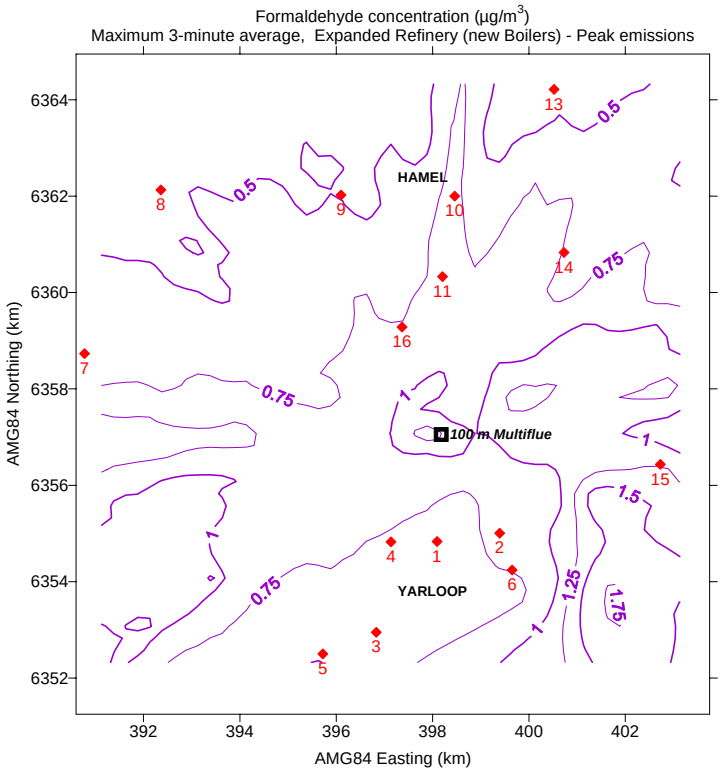

Figure 39: Maximum 3-minute average modelled formaldehyde concentrations for 4.7 Mtpa Expanded Refinery Scenario Case 7 (with new Boilers 4 & 5) – Peak Emissions.

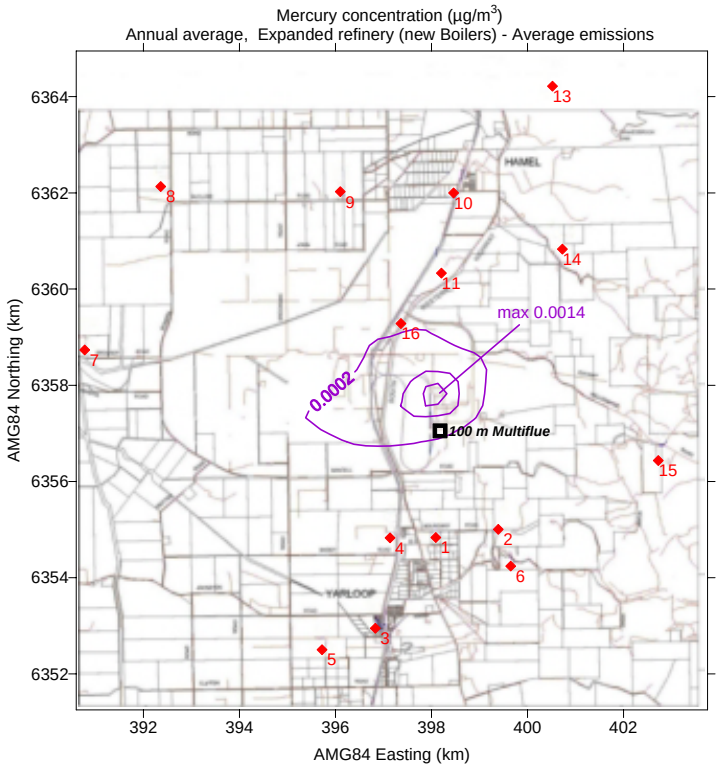

Figure 40: Annual-average modelled mercury concentrations for 4.7 Mtpa Expanded Refinery Scenario Case 7 (with new Boilers 4 & 5) – Average Emissions.

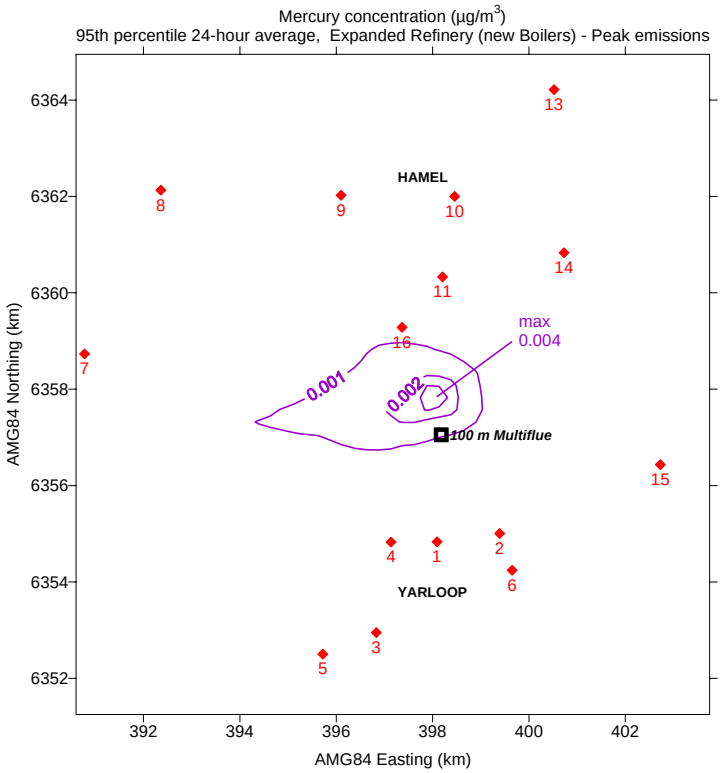

Figure 41: 95th percentile 24-hour average modelled mercury concentrations for 4.7 Mtpa Expanded Refinery Scenario Case 7 (with new Boilers 4 & 5) – Peak Emissions.

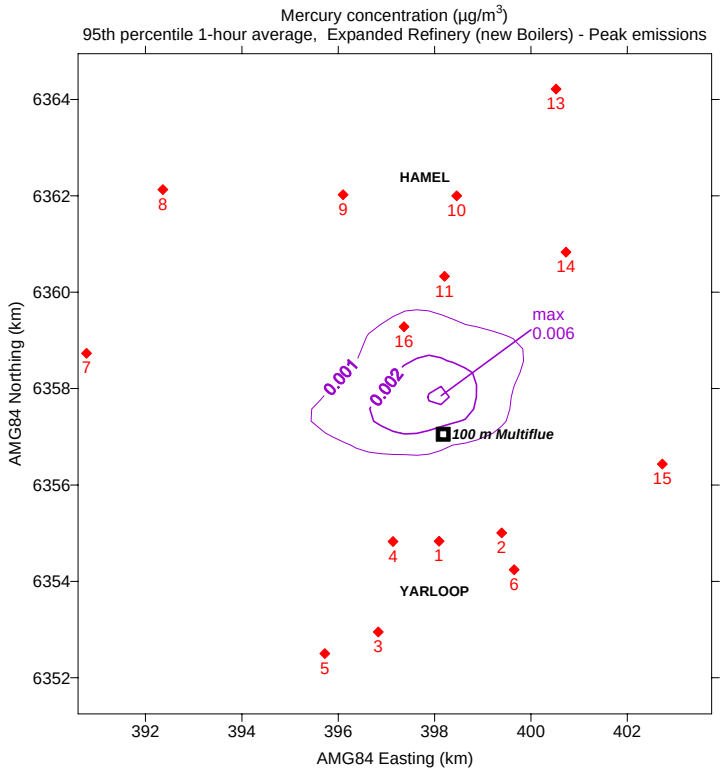

Figure 42: 95th percentile 1-hour average modelled mercury concentrations for 4.7 Mtpa Expanded Refinery Scenario Case 7 (with new Boilers 4 & 5) – Peak Emissions.

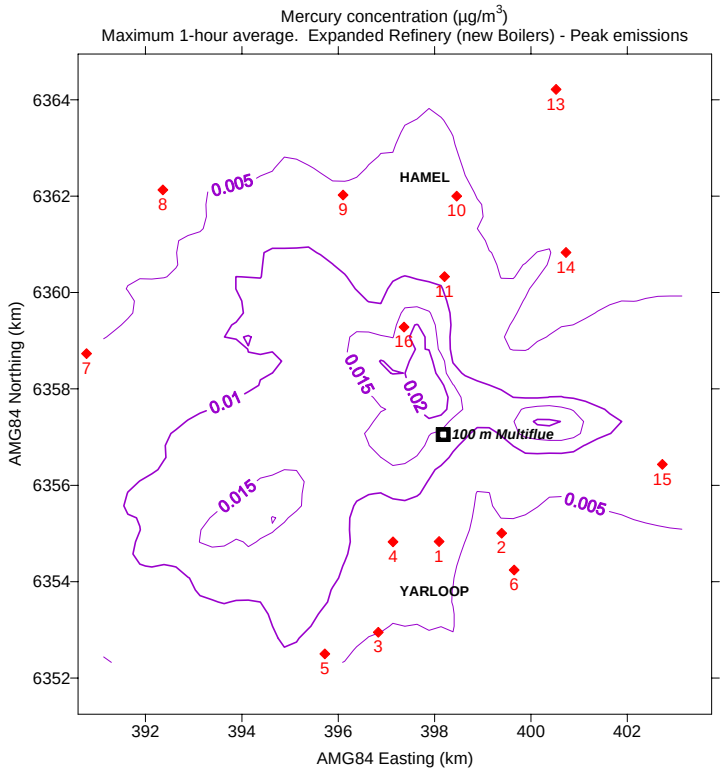

Figure 43: Maximum 1-hour average modelled mercury concentrations for 4.7 Mtpa Expanded Refinery Scenario Case 7 (with new Boilers 4 & 5) – Peak Emissions.

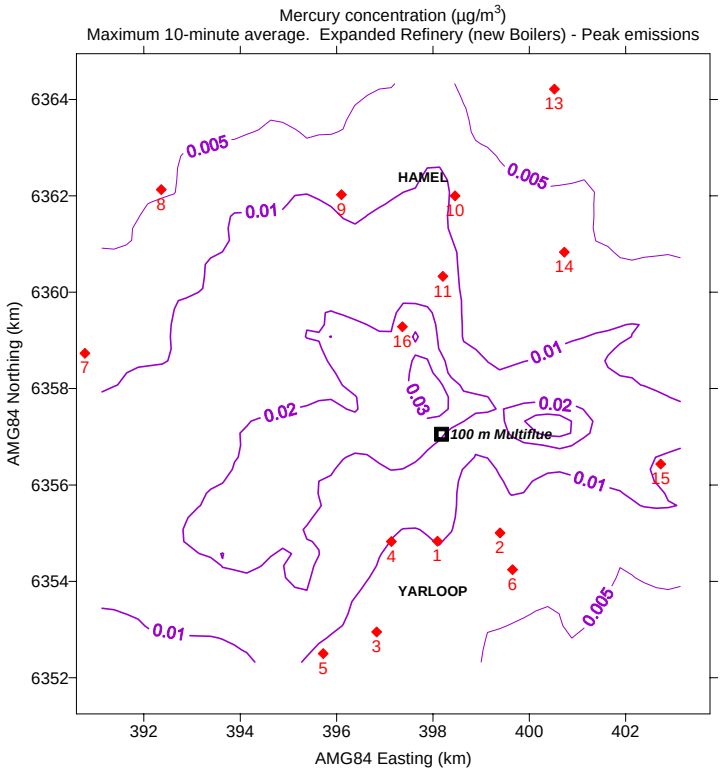

Figure 44: Maximum 10-minute average modelled mercury concentrations for 4.7 Mtpa Expanded Refinery Scenario Case 7 (with new Boilers 4 & 5) – Peak Emissions.

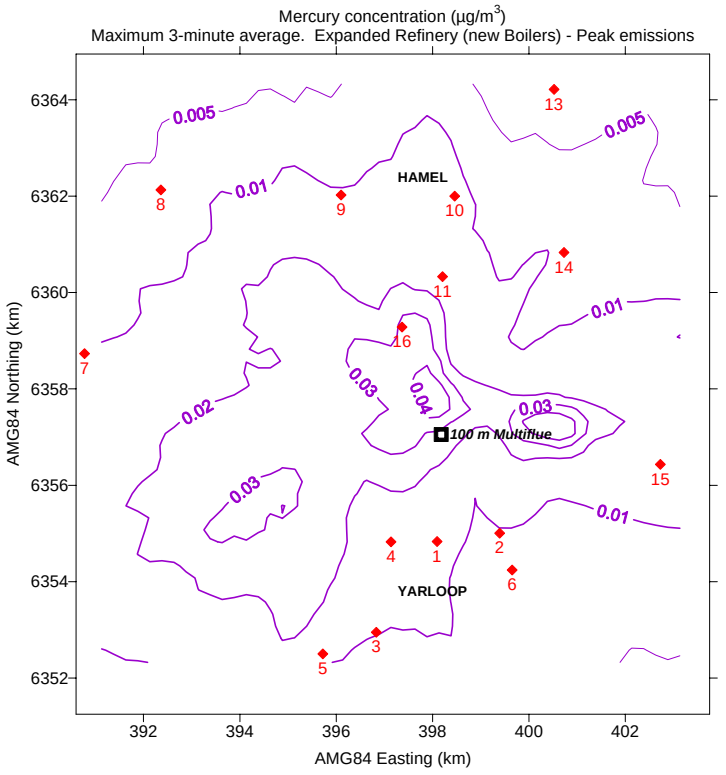

Figure 45: Maximum 3-minute average modelled mercury concentrations for 4.7 Mtpa Expanded Refinery Scenario Case 7 (with new Boilers 4 & 5) – Peak Emissions.

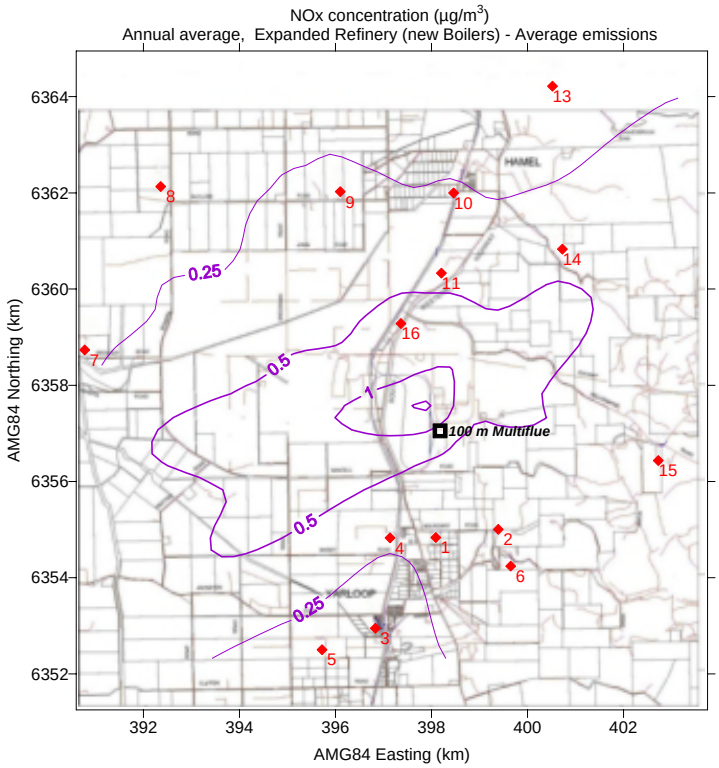

Figure 46: Annual-average modelled NO_x concentrations for 4.7 Mtpa Expanded Refinery Scenario Case 7 (with new Boilers 4 & 5) – Average Emissions.

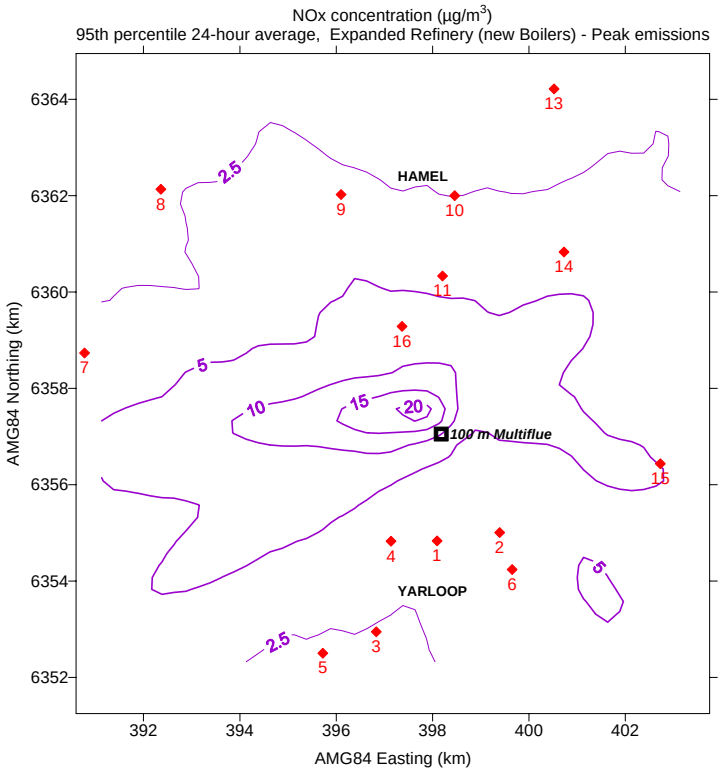

Figure 47: 95th percentile 24-hour average modelled NO_x concentrations for 4.7 Mtpa Expanded Refinery Scenario Case 7 (with new Boilers 4 & 5) – Peak Emissions.

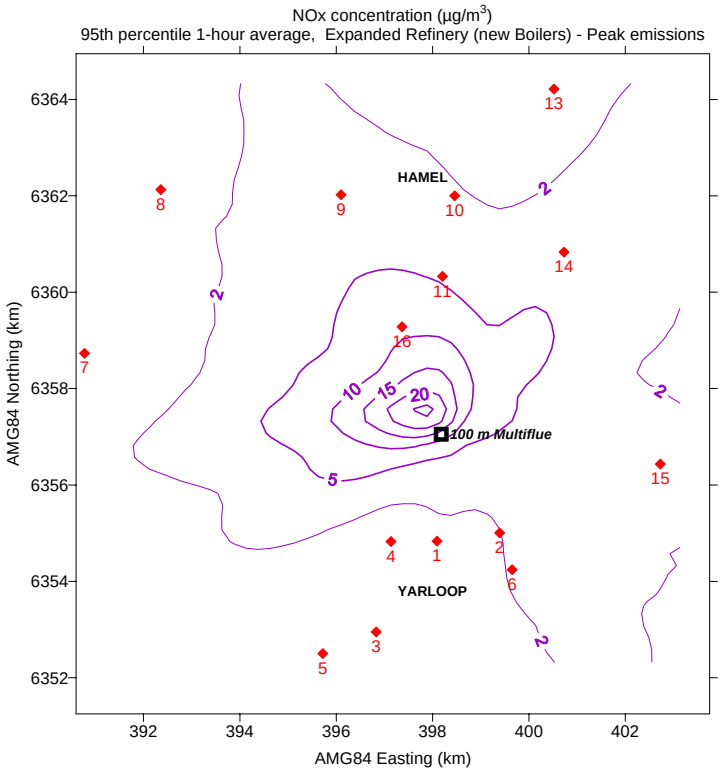

Figure 48: 95th percentile 1-hour average modelled NO_x concentrations for 4.7 Mtpa Expanded Refinery Scenario Case 7 (with new Boilers 4 & 5) – Peak Emissions.

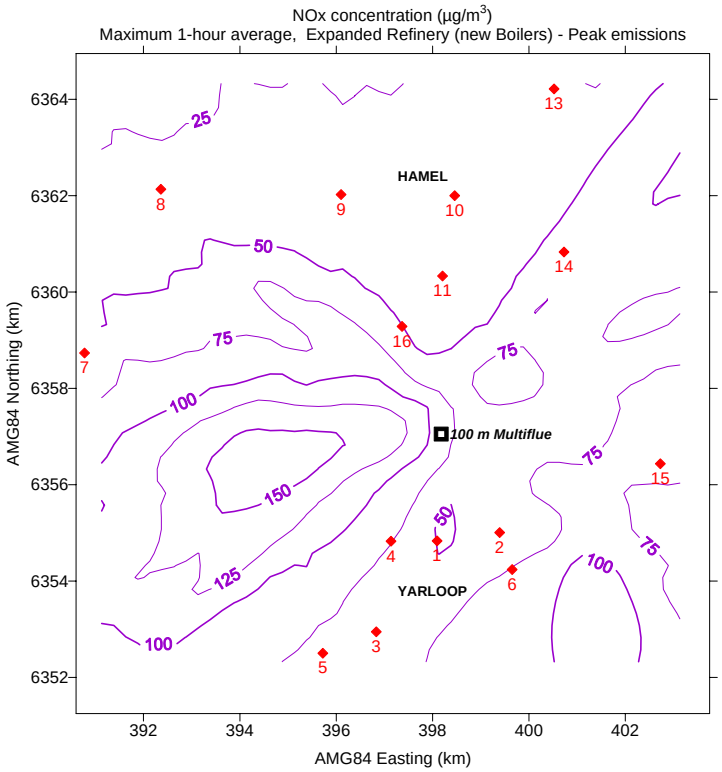

Figure 49: Maximum 1-hour average modelled NO_x concentrations for 4.7 Mtpa Expanded Refinery Scenario Case 7 (with new Boilers 4 & 5) – Peak Emissions.

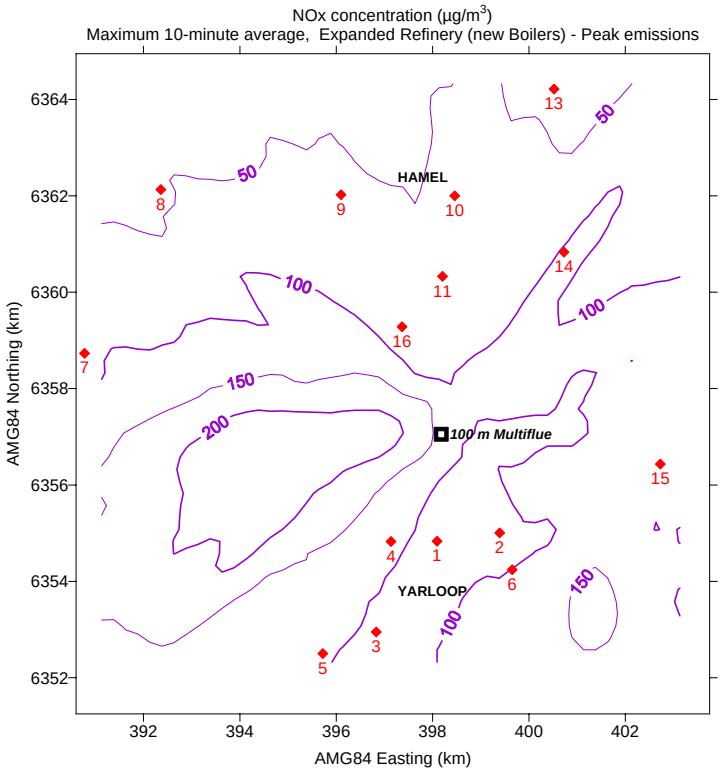

Figure 50: Maximum 10-minute average modelled NO_x concentrations for 4.7 Mtpa Expanded Refinery Scenario Case 7 (with new Boilers 4 & 5) – Peak Emissions.

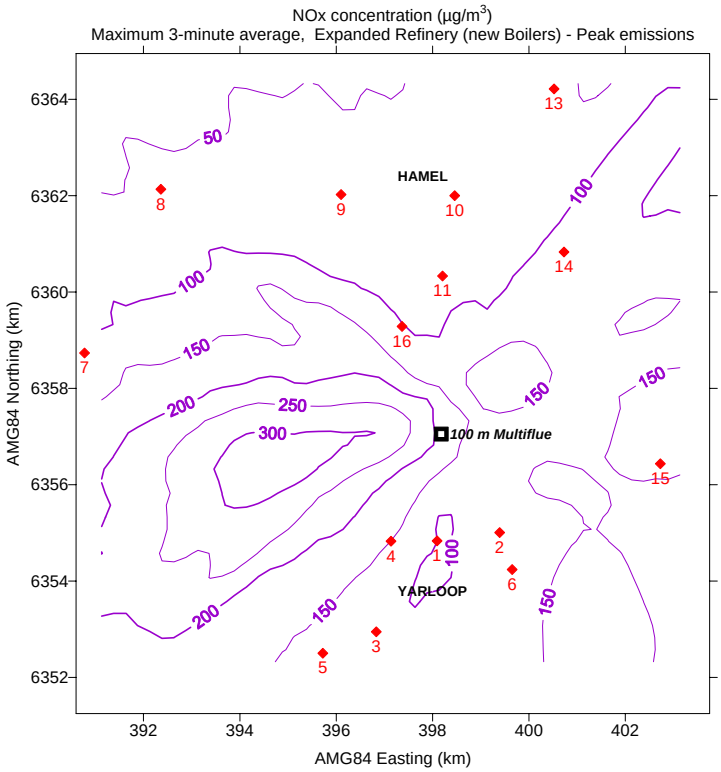

Figure 51: Maximum 3-minute average modelled NO_x concentrations for 4.7 Mtpa Expanded Refinery Scenario Case 7 (with new Boilers 4 & 5) – Peak Emissions.

6.4. Peak Events – Case 7 (with new Boilers)

Figure 52 to Figure 54 the temporal variation of the modelled 1-hour average concentrations around the five highest concentration events for formaldehyde, NO_x and NO_2 for Expansion Case 7

One-half of the model events occur at the same time for NO_x and formaldehyde, though not always at the same site, with most of these events during the winter months (April to September).

For formaldehyde the peaks at receptors 1 (Boundary Road) and 14 (Escarpment) all occur between 10:00 to 18:00, whereas at receptor 3 (Yarloop), peaks are observed both at night and during the day. All except one of the peaks only last for one hour. The exception is on 22 August at 1400 and 1500 hours with a 2-hour peak.

The timing of the NO_x peaks are similar to those for formaldehyde NO_x but there is one event from 0400 to 0900 hours with elevated NO_x concentrations (above 30 µg m^{-3}) at receptor 3 (Yarloop) on 7 August.

The NO_2 peaks are similar except for one example at each of receptors 3 and 14 of capping due to the ambient ozone concentration to 53 µg m^{-3} at 1400 hours and 45 µg m^{-3} at 1800 hours.

Figure 55 shows that the wind directions at the times of the peak concentrations correspond closely with the Refinery being directly upwind from the receptor. Wind directions corresponding to the receptor being directly downwind of the Refinery are 0º for receptor 1, 20º for receptor 3, and 215º for receptor 14. The exceptions (when these peaks occurred and the wind direction was not from the Refinery) include two case at receptor 1 with NO_x and formaldehyde, which occurred at 0900 and 1000 hours with mixing heights of 90 m and 480 m and wind speeds of 1.5 m s^{-1} and 1.6 m s^{-1}. There are also two cases at receptor 3 for formaldehyde, which occurred at 0400 and 2100 hours with wind speeds of 3 m s^{-1} and 2 m s^{-1} and mixing heights of 50 m and 35 m. These cases all indicate some turning of the wind, three with flow from the escarpment towards the receptor, and one from the north-west back towards the receptor. In the other cases, the wind speeds were higher, typically 4 to 11 m s^{-1}. These features are similar to those identified in the Wagerup Air Quality Review (CSIRO, 2004a) when examining the peak NO_x concentrations observed at Boundary Road and Upper Dam, except that the wind speeds in those cases tended to be lower, generally less than 4 m s^{-1}. These features also closely match those identified in Section 6 of the Phase 2 report (CSIRO, 2004c), where most model events were identified as occurring with wind speeds from 2 to 6 m s^{-1} and at lower speeds under easterly flows. Night-time model events occurred with mixing heights less than 300 m, whereas daytime model events occur in strongly convective conditions with mixing heights up to 2000 m, similar to the results shown in Figure 55.

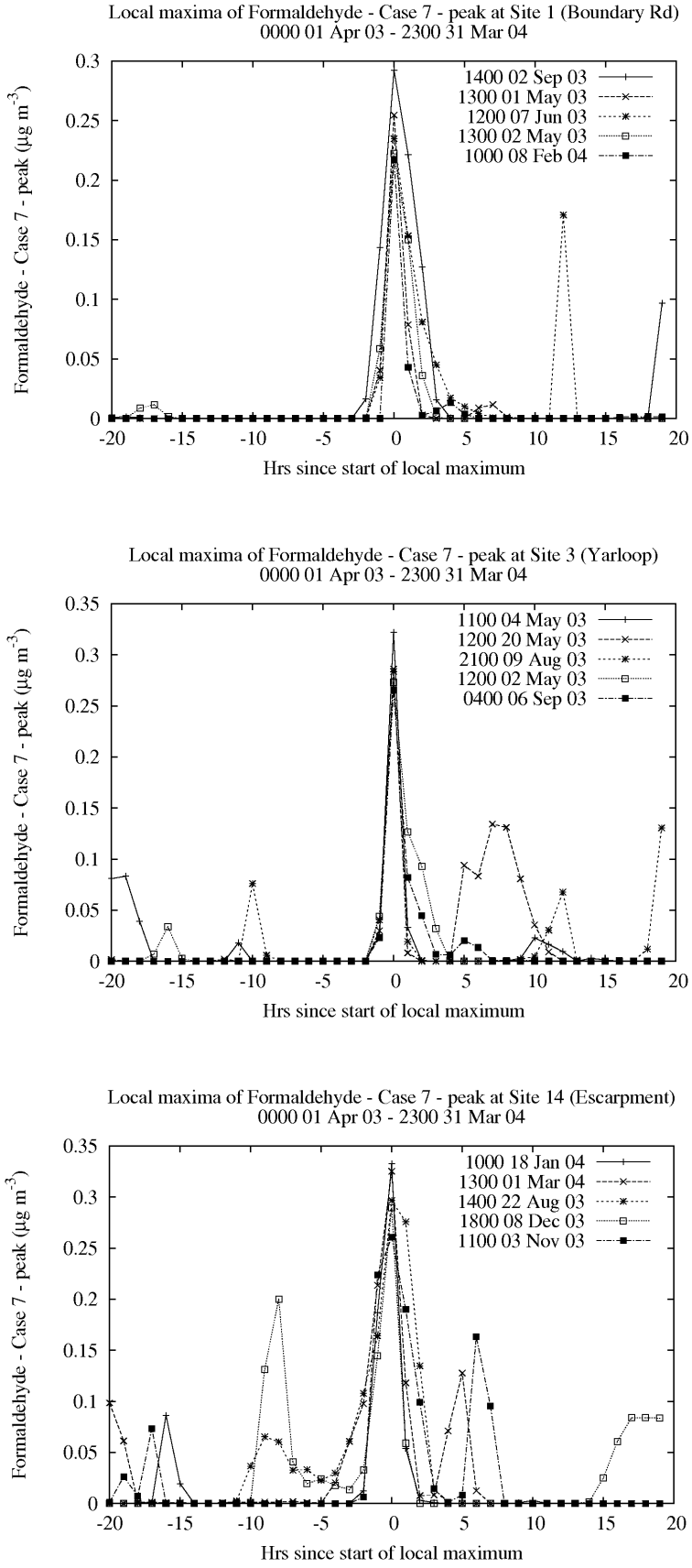

Figure 52: Time series of the five highest formaldehyde concentrations at three receptor sites.

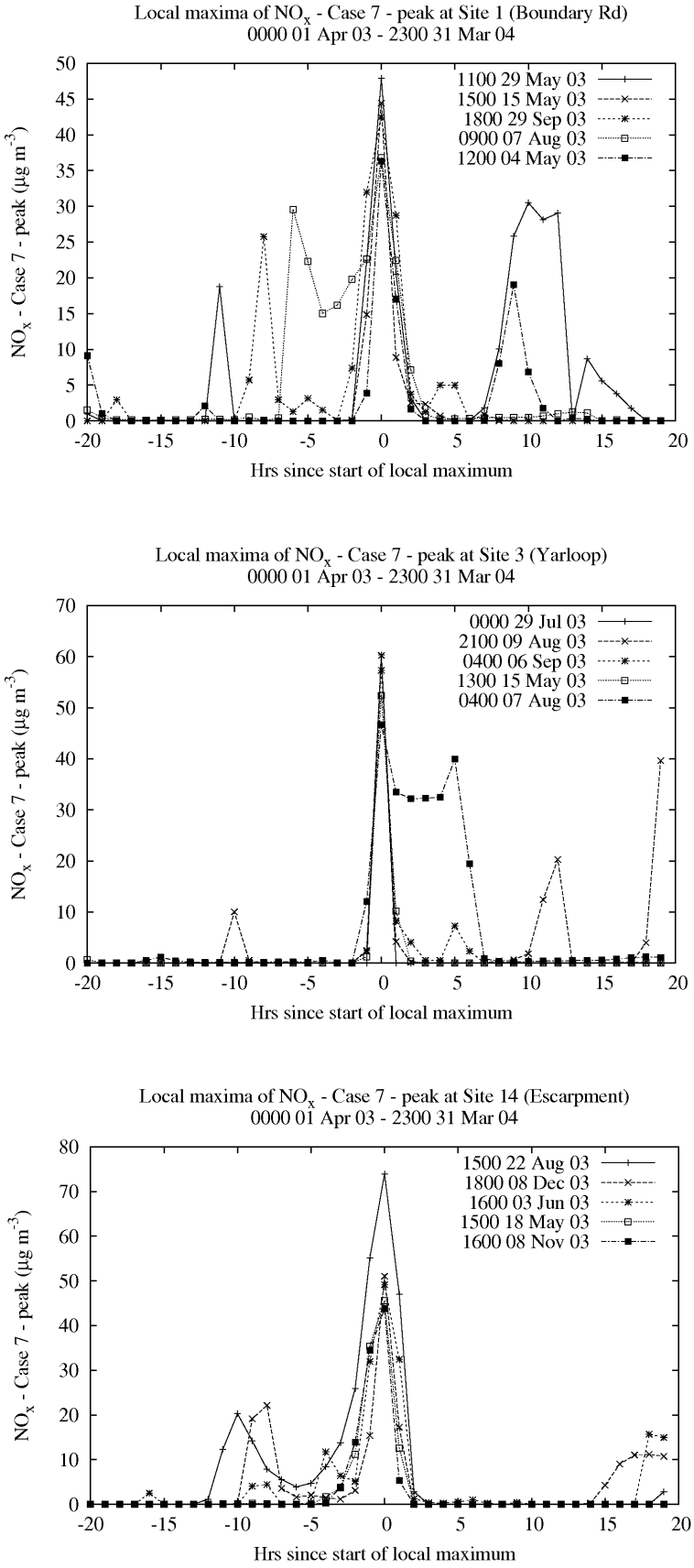

Figure 53: Time series of the five highest NO_x concentrations at three receptor sites.

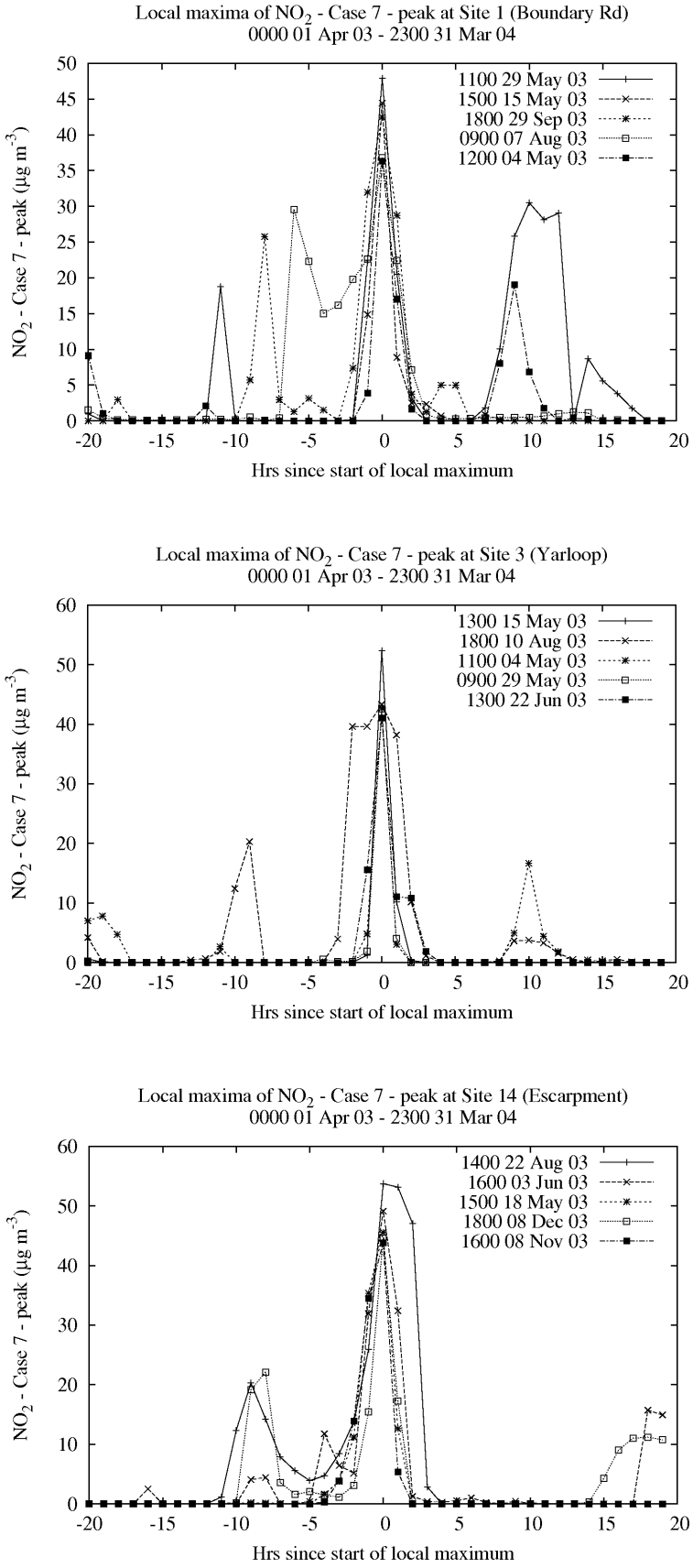

Figure 54: Time series of the five highest NO_2 concentrations at three receptor sites.

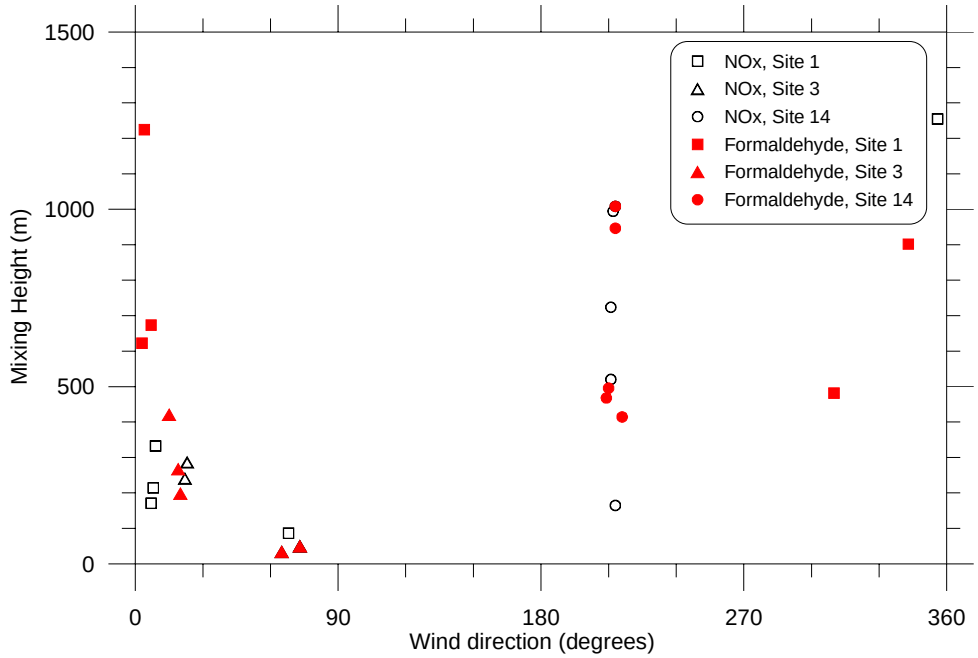

Figure 55: Modelled wind direction (at 25 m) and mixing height at Bancell Road for the five highest Case 7 peak concentrations of NO_x and formaldehyde at receptors 1, 3, and 14.

7. Summary

The work presented in this report is part of a study entitled "Meteorological and Dispersion Modelling Using TAPM for Wagerup", consisting of three closely defined objectives.

This report deals with the third objective for the Expanded Refinery scenarios (Phase 3B: HRA Concentration Modelling), with the following objectives completed:

1. The refined TAPM (as resolved in Phases 1 and 2) has been run for the annual meteorological file (1 April 2003 to 31 March 2004) and the agreed sources listed in dot point 2 to produce estimates of the following parameters for 28 pollutants at 15 receptor points:
   - Annual average concentration (at average emission rates)
   - Maximum 1-hour average concentrations (peak emissions)
   - 95th percentile 1-hour average concentrations (peak emissions)
   - 95th percentile 24-hour average concentrations (peak emissions)
   - Maximum 10-minute average concentrations (peak emissions)
   - Maximum 3-minute average concentrations (peak emissions).

2. The 28 pollutants are oxides of nitrogen, carbon monoxide, sulphur dioxide, dust, arsenic, selenium, manganese, cadmium, chromium VI, nickel, mercury, ammonia, benzo(a)pyrene equivalents, acetone, acetaldehyde, formaldehyde, 2-butanone, benzene, toluene, xylenes, acrolein, ethylbenzene, methylene chloride, styrene, 1,2,4, trimethylbenzene, 1,3,5 trimethylbenzene, vinyl chloride, and nitrogen dioxide.

3. Contour plots have been produced of these six statistics for three example substances (NO_x, Formaldehyde and Mercury) to indicate the different concentration distribution patterns for substances predominantly emitted from high and low level sources.

4. A simple titration algorithmic method has been described and used to calculate the conversion of NO_x to NO_2 using available data on the diurnal variation in ozone concentrations at Wagerup.

5. The best practice method has been used for deriving shorter time period (3 and 10-minute) maximum concentrations from the Wagerup hourly TAPM concentration fields. A detailed description of this method has been presented.

6. The temporal variation of concentration around, and mechanisms causing, the modelled five highest short-term peak concentrations has been investigated for NO_x and formaldehyde for the peak emission scenario at three receptors (sites 1, 3, and 14). The mechanisms identified as responsible for the highest short-term peak concentrations match those identified in Phase 2 of this work (CSIRO, 2004c) and in the Wagerup Air Quality review (CSIRO, 2004a).

7. Separate quality assurance runs have been undertaken for NO_x and formaldehyde to confirm the accuracy of the main modelling technique.

8. The uncertainty of the model predictions has been determined from consideration of results from a range of TAPM studies and an analysis of the sensitivity of model results to wind data assimilation. We conclude that the results for the model concentrations

presented in this report have an uncertainty of a factor of approximately 2 (i.e. the actual values lie in the range of +100% to -50% of the listed concentrations) at the 95% confidence level.

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