Air Quality Management Assessment

Aurecon

Appendix V

WESTERN SYDNEY STADIUM

Wind Engineering – Air Quality Report

Lend Lease

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Bringing ideas to life

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1 Introduction

Figure 1: Internal view within the stadium

1.1 Project Understanding

Project involves the demolition of the existing stadium and construction of a new stadium to seat 30,000. Structure of the stadium is relatively simple with regularly spaced trusses supporting the seating platforms and a cantilevered truss with a tensioned membrane to the underside. Openings at ground level and to the rear of the seating platform.

1.2 Assessment Background

This report provides an assessment of air quality and odour emissions for the proposed Western Sydney Stadium.

There are two emissions of primary concern; odour emissions from kitchen exhaust fans and air quality/toxicity from flare release within the stadium. Both of these sources are assessed with regard to the patrons within the stadium and the nearby properties.

1.3 Assessment Scope

Assessment of kitchen exhaust odour and flare air pollution emissions was based on the following scope of works:

- Determine the worst-case background wind conditions
- Determine kitchen exhaust odour levels
- Determine flare air pollutant content and emission rates
- Simulate background wind conditions
- Simulate the release of kitchen exhaust from exhaust locations into the atmosphere
- Simulate the release of flare emissions within the stadium at a plausible location
- Assess air quality and odour pollutant levels within the stadium and in the vicinity of neighbouring properties.

1.4 Architectural and Mechanical Sources

A simplified model of the proposed Western Sydney Stadium was developed using an architectural Revit model and drawings provided by Populous (Populous, 2016/17).

Alterations to this design were made for the roof leading edge (eyebrow), specifically the area between the roof and the leading edge was opened, the leading edge angle increased to 7 degrees and the angle between the trailing edge of the eyebrow and the leading edge of the roof membrane was set to 45 degrees.

The design of the curved display screen on the North Eastern corner of the stadium was unknown at the time of modelling and is expected to have little impact on the odour and air quality results.

A ‘plinth’ was necessary for modelling the lower bowl (below ground/concourse level). This feature provides an approximation to terrain effects near the stadium.

Kitchen exhaust locations, flow rate and velocities were provided by A.G.Coombs (2017).

Figure 2: Plaza surrounding the stadium where pedestrian impacts are important

2 Environmental and Emission Source Conditions

2.1 Climatic Wind Conditions

Climatic wind conditions near the Western Sydney Stadium were obtained by statistical analysis of the nearby Bankstown Airport weather station. The full analysis is found in the accompanying meteorological report (Aurecon, 2017). The annual wind rose from the meteorological report is shown in Figure 3 below. Here it is evident that south westerly and westerly winds are most prevalent. The overall 90^{th} and 95^{th} percentile wind speeds are 6.45m/s and 7.43 m/s respectively. Air pollutant dispersion is expected to increase with increased velocity as there will be stronger shearing and higher turbulent mixing in the atmospheric boundary layer. Therefore worst-case conditions for this report are taken at low speeds 0-2m/s for which the South Westerly direction is most dominant. Furthermore, the neighbouring buildings are on the East and North Eastern side (downwind) of the stadium (see Figure 4) and are therefore most likely to be impacted by emissions from the stadium under South Westerly wind conditions.

Figure 3: Bankstown Airport AWS wind rose for annual data across years 1998 to 2016

Figure 4: Aerial image of Western Sydney Stadium and surroundings (source: Google Earth). Yellow circle indicates a radius of 400m.

2.2 Kitchen Exhaust Emissions

Kitchen exhaust fans extract airborne grease, combustion products, fumes, smoke, odours, heat and steam. Two emission components are of primary concern, airborne grease and odours. Airborne grease poses a potential for unsightly deposition on the stretched fabric roof structure.

Odour transmission poses a risk to comfortability and enjoyment of the new Western Sydney Stadium and the nearby environment. Odour concentration is measured in odour units (OU), where 1 OU is the concentration of odour containing air that can be detected by 50% of the average population. Definition of odour units for a particular source type is determined by dynamic olfactometry as specified in the Australian Standard AS 4323.3:2001. Odour unit (OU) peak concentration per second for a typical commercial kitchen exhaust is estimated to range between 1134 OU/s at $1.62 m^3/s$ (SLR, 2013) and 3849 OU/s at $1.27 m^3/s$ (Heggies, 2010). These emission rates corresponds to emission concentrations of 700 OU/m^3 and 3031 OU/m^3, respectively. Since the SLR (2013) report determined odour emission rates from site monitoring, the lower emission rate of 700 OU/m^3 is used in this report. While the current investigation is instructive, the odour control design for Western Sydney Stadium should be subject to further investigation by monitoring kitchen exhaust odour emission and modelling with these values.

2.3 Flare Emissions

There are three types of marine distress flares available in Australia; orange smoke hand-held, red hand-held and red star parachute rocket. All flares must comply with AMSA Marine Orders Part 25 and Australian Standard AS 2092-2004. The composition and products of these flares is not specified in the standard and given the emergency nature of flare usage the only reference to air pollution or toxicity is AS 2092-2004 Section 5.7 “Neither the composition nor the decomposition products of a store shall include highly toxic compounds”.

It is more likely the hand held orange or red flares could be ignited inside the stadium rather than rocket propelled parachute flares. Old versions of orange flares in may have contained p-nitroaniline and orange oil 7078V which have significant toxicological ratings (McHale, 1977) however Section 5.7 of the AS 2092-2004 prohibits such toxic components in Australian flares.

Safety data sheets available from various international flare manufacturers and providers (Hansson PyroTech 2007, CIL 2012, Drew Marine Signal and Safety 2012) list flares as containing

- strontium nitrate
- magnesium powder
- linseed oil
- potassium nitrate
- potassium perchlorate
- potassium chlorate
- sulphur
- fuel oil

However, the exact percentage of ingredients is often unreported due to Confidential Business Information (Trade Secrets) (Orion, 2015). No information is listed in these safety data sheets for flare combustion products.

There is no known documentation of the combustion products from Australian Standard compliant hand-held flares. In the absence of further information the emissions from a green star parachute (rocket) signal flare are used for this investigation as the emissions are stated in USA EPA AP-42 Chapter 15, “Ordinance Detonation” (EPA, 2009). It is expected that the emissions from a rocket propelled flare will exceed those produced by a hand-held flare.

For the green star parachute (rocket) flare the “primary emissions [are] particulate matter (PM_{10}) and CO_2. Other hazardous air pollutants [defined in USA legislation] are emitted at very low levels” (EPA, 2009). Total flare emissions are listed in Table 1 below. A release time of 15 minutes is assumed, leading to the corresponding emission rates in milligrams per second below.

Table 1: Flare primary pollutant emission rates

Pollutant	Total emissions (lb)	Emission rate (mg/s)
PM_{10}	8.8×10^{-2}	44.35
CO_2	1.2×10^{-1}	60.48

3 Assessment Criteria

Ambient air pollution is assessed according to the National Environmental Protection Measures (NAPMs), created by the National Environmental Protection Council (NEPC). Two NAPMs exist for ambient air quality control, namely the Ambient Air Quality NEPM and the Air Toxics NEPM. These air quality measures are assessed on an 8 or 24 hour time period over large spatial scales.

For near field and short duration exposure the National Occupational Health and Safety Commission standards for air quality NOHSC:1003(1995) are used as assessment criteria. There are two time-weighted average criteria, Time Weighted Average (TWA) and Short Term Exposure Limit (STEL), where pollutant levels are averaged over an 8 hour or 15 minute period, respectively. Not all possible pollutants are listed in each standard and specific assessment criteria for missing items are formed from other sources.

Kitchen exhaust odour criteria is taken from the NSW DECCW document “Technical Framework – Assessment and Management of Odour from Stationary Sources in NSW”. Here the odour assessment criteria for urban areas such as that located to the North and East of Western Sydney Stadium is 2.0 OU/m^3. No criteria is available for airborne grease deposition on surfaces, however assessment is made in a qualitative manner in Section 5.1.

Carbon dioxide is listed in the NOHSC:1003(1995) standard. Here the TWA limit is 9000mg/m^3 while the STEL is 54,000mg/m^3.

While NEPM does include a 24 hour average for safe particulate matter levels in the far-field environment, there are no current NOHSC guidelines for safe levels of particulate matter applicable to short term or near field results. An extensive discussion on the topic is available from the Australian Institute of Occupational Hygienists (AIOH, 2016) where a literature review is conducted of relevant criteria across different countries. A final recommendation of 5mg/m^3 for the inhalable fraction and 1mg/m^3 for the respirable fraction is made over an 8 hour TWA averaging period. The more stringent 1mg/m^3 criteria is chosen for the current assessment criteria.

4 Modelling Methods

The NSW approved methods for the Modelling and Assessment of Air Pollutants (NSW EPA, 2005) stipulates which methods should be used for odour and other pollutant modelling. The models listed in this document, such as AERMOD, do not take into account the local wake effects of buildings, instead assuming the exhaust locations are higher than surrounding buildings and therefore dissipation is dominated by atmospheric effects. In the current investigation the kitchen exhaust locations are below the roofline of the stadium and the near-field flow has a significant effect on the motion and dissipation of kitchen exhaust emissions. For this reason Computational Fluid Dynamic (CFD) methods have been used which do take into account these critical effects.

4.1 Environmental Wind

The proposed Western Sydney Stadium geometry was modelled from provided architectural models (Populous 2016) as described in Section 1.4 above.

CFD analysis is used to predict the environmental winds around the stadium. A suitable mesh was created and environmental wind simulated across the stadium structure (see Figure 5). Here the Atmospheric Boundary Layer (ABL) must be modelled such that the basic characteristics of the natural wind are captured. Aurecon has implemented a suitable model of the atmospheric boundary layer based on the Deaves and Harris ABL model in OpenFOAM, closely following all recommendations of Richards and Hoxey (1993) including upper boundary shear stress. Further details on the wind modelling method description can be found in the environmental wind report (Aurecon, 2017b).

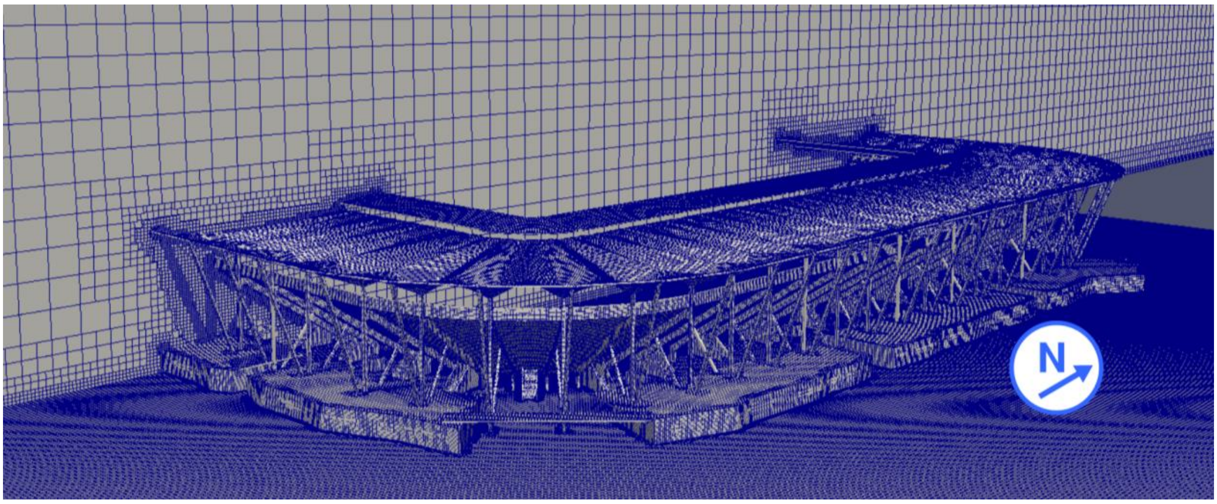

Figure 5: Cutting plane and wall surfaces displaying mesh resolution

4.2 Emissions

As kitchen exhaust or flare smoke mixes with the atmosphere there are a number of physical mechanisms that influence mixing and dissipation including particle size, exhaust temperature and velocity and local atmospheric flow. CFD methods have been chosen for this analysis since it takes into account the local flow features near the stadium geometry and provides an instructive result at this early stage of development.

Both kitchen exhaust and flare smoke contains fine particulate matter. As particles increase in size they begin to slip relative to the surrounding fluid motion in proportion to the Stokes number, which can impact on the dissipation of the particulate matter to the surrounding atmosphere. Stokes number is defined as

$$Stk = \frac{t_0 u_0}{l_0}$$

Where t_0 is the relaxation time, u_0 is the fluid velocity and l_0 is the characteristic length (diameter) of the particle. Assuming a particle Reynolds number of approximately unity the relaxation time is given by

$$t_0 = \frac{d_d^2}{18\nu_g}$$

Where d_d is the particle diameter and ν_g is the kinematic viscosity of the atmosphere ($1.5x10^5$). Assuming airborne kitchen grease and combustion particulates are a similar size to particulate matter from flare smoke, the particle diameter can be assumed to be of the order PM_{10} (10µm). For these particles the relaxation time is $t_0 = 3.707x10^{-7}$ and the Stokes number is Stk << 0.1. Hence tracing errors will be less than 1% (Tropea, 2007 and Hinds, 1999) and the particles can be considered to move with no slip relative to the surrounding atmosphere. Particulate matter dissipation can therefore be modelled in the same manner as a gas.

Separate investigations were conducted for kitchen exhaust and flare emissions. For the kitchen exhaust simulation, the mesh and atmospheric boundary layer settings were reused from previous work (Aurecon 2017b) and a number of faces were selected on the western stand of the stadium. These faces were converted to inlets, where a velocity of 15m/s was applied at an upward angle of 45 degrees away from the stadium. A steady Reynolds Averaged simulation was completed and used as the frozen flow conditions for odour dissipation. The odour dissipation simulation consisted of injecting a scalar variable at 100% concentration at the exhaust outlet faces. A contour of 1:300 dilution (0.333% concentration) was then calculated and the extent of the plume assessed.

Similarly for the flare release simulation a steady background wind calculation was first completed and the velocity field frozen in time. A scalar variable was then introduced across a $1m^3$ volume in the South Eastern corner of the lower seating area. The release was sustained for 15 minutes, increasing the local concentration while the environmental wind convected and dissipated the field across the surrounding regions. This field was scaled for each pollutant release rate listed in Table 1 and assessed against the criteria listed in the above section by taking a contour of the field values at the criteria level.

5 Results and Assessment

5.1 Kitchen Exhaust Emissions

Contours of 1:300 dilution of kitchen exhaust plumes is shown in Figures 6, 7 and 8 below. A 1:300 dilution corresponds to odour concentration of approximately 2 OU/m^3 for a 700 OU/m^3 source emission. The South Westerly atmospheric wind can be seen to convect the exhaust gasses predominantly above and across the stadium roof structure. No plume components can be seen recirculating within the stadium, meaning odour due to kitchen exhaust is not expected to cause issues for patrons.

The kitchen exhaust plume can be seen to travel down in the wake of the stadium near neighbouring buildings to the North East (refer Figure 4). For comparison, a contour of 1:100 (representing odour concentration of 7 OU/m^3) is illustrated in Figure 9 which indicates higher odour concentrations are likely to occur much higher in the atmospheric boundary layer and dissipate closer to the stadium. Given the conservative nature of this CFD model, these results indicate odour is likely close to the 2 OU/m^3 criteria for neighbouring residents, with higher odour concentrations passing over the neighbouring residents.

Based on these results airborne odour reduction is likely not required, however more detailed kitchen exhaust odour monitoring and modelling is required. It is recommended that provision be made for odour and grease control units in the kitchen ventilation system in order to mitigate risk in the event of detrimental odour effects.

Grease deposition is not expected to be an issue for surrounding residents and further investigation into possible deposition on the fabric roof above the Western stand is recommended during the detailed design phase.

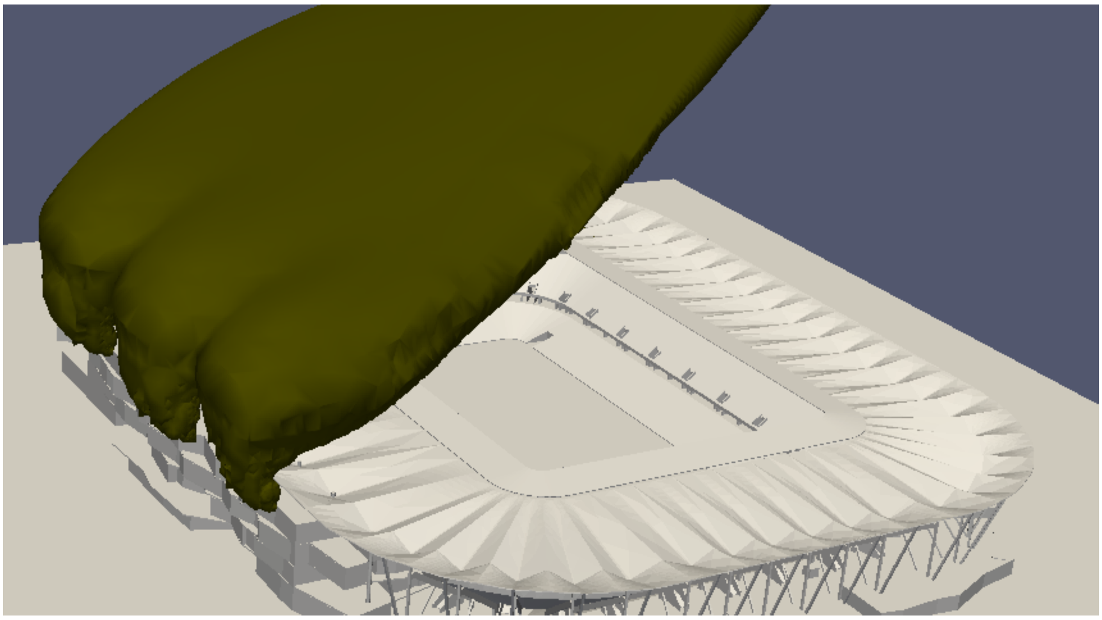

Figure 6: Kitchen exhaust plume at 1:300 dilution viewed from the South West

Figure 7: Kitchen exhaust plume at 1:300 dilution viewed from West-North-West

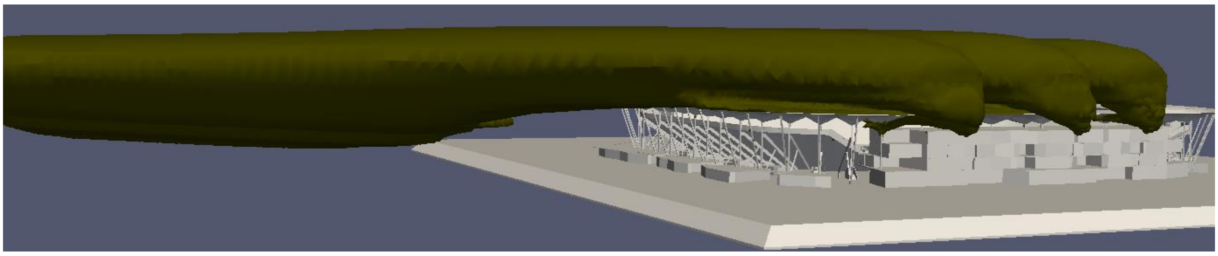

Figure 8: Kitchen exhaust plume at 1:300 dilution viewed from West-North-West showing 2 OU/m^3 plume.

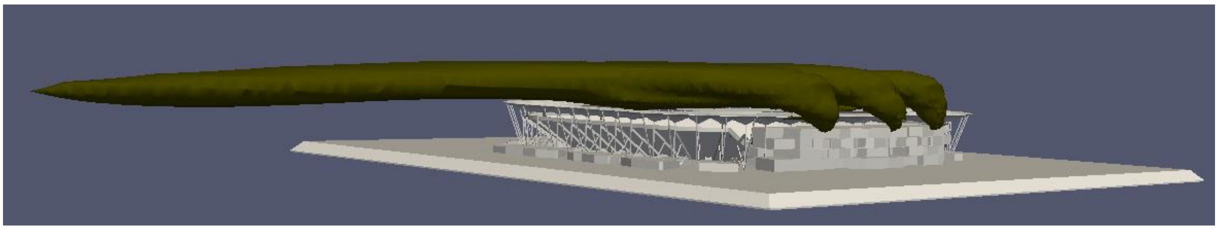

Figure 9: Kitchen exhaust plume at 1:100 dilution viewed from West-North-West showing plume of 7 OU/m^3 occurring higher in the atmosphere.

5.2 Flare Emissions

Contours of CO_2 and PM_{10} were taken at criteria levels of 54,000mg/m3 and 1mg/m^3, respectively after the 15 minute release period. Predicted results indicate that carbon dioxide emissions for a flare do not pose a health risk to any patrons as the 54,000mg/m^3 level was not reached. The contour of particulate matter criteria level is shown in Figure 10 where higher concentrations can be seen through the seating area surrounding the flare release location. However these contours shown are instantaneous results and if averaged over an 8 hour period (as is specified by AIOH 2016) the exposure levels will be negligible.

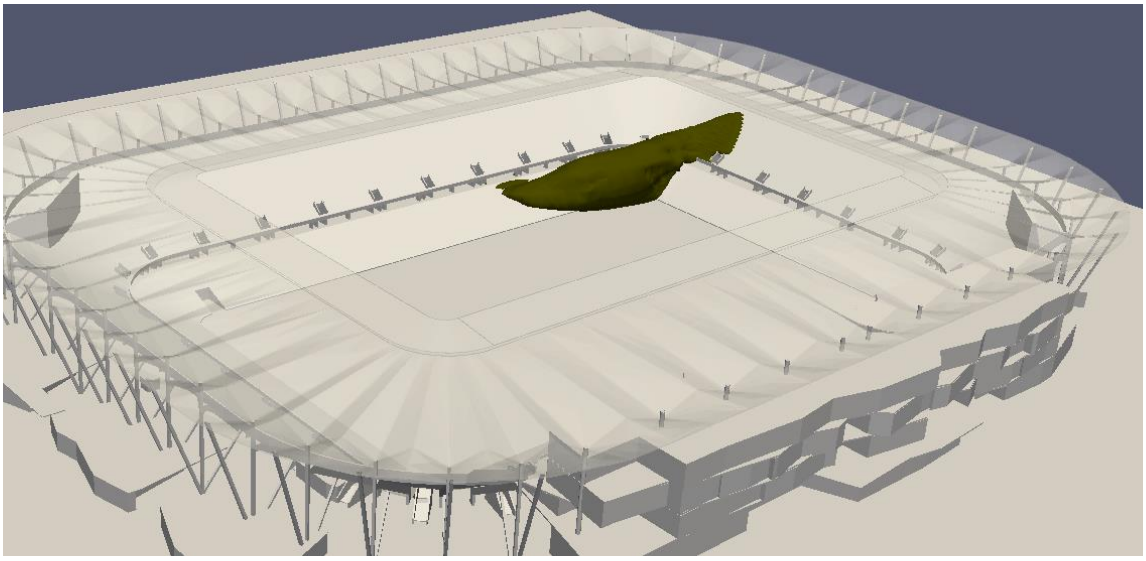

Figure 10: Instantaneous contour of PM_{10} after complete release of flare pollutants

6 Conclusion

A study was conducted of the environmental wind for the proposed Western Sydney Stadium. Local meteorological conditions were obtained from the nearest BOM station and steady South Westerly winds were simulated at 1m/s (at 10m reference height).

Scalar transport equations were solved for the motion of kitchen exhaust gasses and flare pollutant release. Flare pollutant release was not predicted to pose a health risk within the stadium. Kitchen odours were not predicted to cause issues for stadium patrons. Odour impact on neighbouring residents was determined to be within the acceptable 2 OU/m^3 criteria given the assumed kitchen exhaust odour emission rate. Further monitoring and modelling of site exhaust odour emissions are required for confidence in the design. It is recommended that spatial provision be made in the kitchen ventilation system should filtration systems be required.

Grease deposition is not expected to be an issue for surrounding residents and further investigation into possible deposition on the fabric roof above the Western stand is recommended during the detailed design phase.

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