Energy from Waste Facility (SSD 6236)
Honeycomb Drive, Eastern Creek

The Next Generation NSW Pty Ltd
Honeycomb Drive, Eastern Creek

20 March 2015 | Issued Final | Report No. sr13032_TNG_PHAFRA_20Mar15_Rev(3)

# Preliminary Hazard Analysis & Fire Risk Assessment

## The Next Generation

## Honeycomb Drive, Eastern Creek

RAWRISK Engineering



RAW Risk Engineering Pty Ltd
ABN 69 164 877 276

## Report Details

Project: Energy from Waste Facility (SSD 6236), Honeycomb Drive, Eastern Creek

Document: Preliminary Hazard Analysis & Fire Risk Assessment

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# EXECUTIVE SUMMARY

## INTRODUCTION

The Next Generation NSW Pty Ltd (TNG) has proposed the construction of an Energy from Waste (EfW) electricity generation plant to be developed at Eastern Creek, NSW. The proposal is considered a State Significant Development (SSD) and a request has been submitted to the Minister for Planning to prepare Director General Requirements (DGRs) in relation to the SSD. The DGRs received for the SSD indicate that a Preliminary Hazard Analysis (PHA) and a Fire Risk Assessment (FRA) be completed for the site. Urbis, acting on behalf of TNG has contracted RAWRiSK Engineering (RRE) to complete the PHA and FRA for the development. This document details the findings of the studies.

## METHODOLOGY

The methodology used for the PHA and FRA study used a combined approach whereby all risks associated with the facility were assessed (e.g. environmental, fire, toxic gas, etc.) and the fire risks were reported in a separate chapter within the PHA study.

The following approach was used;

### PHA Study

<u>*Hazard Analysis*</u> – A detailed hazard identification was conducted for the site facilities and operations. Where an incident was identified to have potential off site impact, it was included in the recorded hazard identification word diagram (**Appendix A**). The hazard identification word diagram lists incident type, causes, consequences and safeguards. This was performed using the word diagram format suggested in HIPAP No. 6 (Ref. 1). Each postulated hazardous incident was assessed qualitatively in light of proposed safeguards (technical and management controls). Where a potential offsite impact was identified, the incident was carried into the main report for further analysis. Where the qualitative review in the main report determined that the safeguards were adequate to control the hazard, or that the consequence would obviously have no offsite impact, no further analysis was performed.

<u>*Consequence Analysis*</u> – For those incidents qualitatively identified in the hazard analysis to have a potential offsite impact, a detailed consequence analysis was conducted. The analysis modelled the various postulated hazardous incidents and determined impact distances from the incident source. The results were compared to the consequence criteria listed in HIPAP No. 4 (Ref. 2). Where an incident was identified to result in an offsite impact, it was carried forward for frequency analysis. Where an incident was identified to not have an offsite impact, and a simple solution was evident (i.e. move the proposed equipment further away from the boundary), the solution was recommended and no further analysis was performed.

<u>*Frequency Analysis*</u> – In the event a simple solution for managing consequence impacts was not evident, each incident identified to have potential offsite impact was subjected to a frequency analysis. The analysis considers the initiating event and probability of failure of the safeguards (both hardware and software). The results of the frequency analysis were then carried forward to the risk assessment for combination with the consequence analysis results.

<u>*Risk Assessment and Reduction*</u> – The study was conducted using the Level 2 analysis detailed in the Multi-Level Risk Assessment approach, recommended by the Department of Planning and Infrastructure (DPI). As the selected approach for this analysis was a level 2 assessment, where incidents were identified to impact offsite and where a consequence and frequency analysis was conducted, the consequence and frequency analysis for each incident were combined and compared to the risk criteria published in HIPAP No.4. Where

the criteria were exceeded, a review of the major risk contributions was performed and the risks reassessed incorporating the recommended risk reduction measures. Recommendations were then made regarding risk reduction measures.

Reporting – on completion of the study a draft report was developed for review and comment by TNG. A final report was then developed incorporating the comments received by TNG.

**FRA Study**

As part of the PHA study, it was necessary to assess fire risks, including fire scenarios, incident frequency, probability of failure of the safety systems at the site and risk of fire (as a result of the combination of the fire impacts and frequency).

The fire risks identified at the site were used to determine the fire protection required at the site. This was reported in a separate chapter within the PHA study.

The conclusions and recommendations for both the general and fire hazards and risks were reported within the same section of the document.

**HAZARD IDENTIFICATION**

A hazard identification table was developed for operations and storages at the site. This table was used to develop scenarios which may occur and result in offsite impacts. The following scenarios were identified at the site;

- Ammonium hydroxide tank leak, spill and release to environment;
- Diesel tank leak, spill and release to environment;
- Diesel tank leak, spill, immediate ignition and pool fire;
- Diesel tank leak, spill, unconfined, delayed ignition and flash fire;
- Diesel tank leak, spill, confined, delayed ignition and vapour cloud explosion;
- PAC dust cloud, ignition and dust cloud explosion;
- Ignition of waste in bunker and full bunker fire;
- Emission of combustion by-products;
- Transformer oil spill, ignition and pool fire;
- PAC dust cloud explosion within residue silo;
- Turbine fire;
- Release of calcium hydroxide; and
- Ignition of waste in truck and truck fire.

A detailed qualitative review of each scenario was performed to assess the potential for offsite impacts. Following the qualitative review, scenarios that still had potential to impact offsite were carried forwards for consequence analysis.

**CONSEQUENCE ANLAYSIS**

Scenarios carried forwards for consequence analysis were subject to a detailed assessment of the potential impacts. The following scenarios were carried forwards for consequence analysis;

- Diesel tank leak, spill, immediate ignition and pool fire;
- PAC dust cloud, ignition and dust cloud explosion;
- Ignition of waste in bunker and full bunker fire; and
- Transformer Oil Spill, Ignition and Pool Fire.

The impacts estimated for each of the scenarios were overlaid on the site layout diagram to assess offsite impacts. No scenarios were identified to impact over the site boundary and so no further analysis was conducted.

**FIRE RISK ASSESSMENT**

The fire scenarios identified in the PHA were used to assess the requirements for fire protection for each scenario location at the site.

**CONCLUSIONS**

A hazard identification table was developed for the energy from waste (EfW) facility to identify potential hazards that may be present at the site as a result of operations or storage of materials. Based on the identified hazards, scenarios were postulated that may result in an incident with a potential for offsite impacts. Postulated scenarios were discussed qualitatively and any scenarios that would not impact offsite were eliminated from further assessment. Scenarios not eliminated were then carried forwards for consequence analysis.

Incidents carried forwards for consequence analysis were assessed in detail to estimate the impact distances. Impact distances were developed into scenario contours and overlaid onto the site layout diagram to determine if an offsite impact would occur. The consequence analysis showed that none of the scenarios would impact over the site boundary and so a fatality would not occur at the site boundary and therefore the cumulative risk at the site boundary would be less than 50 pmpy.

Based on the analysis conducted, the risks at the site boundary are not considered to be exceeded.

In addition to the preliminary hazard analysis (PHA) a fire risk assessment (FRA) was conducted to ensure adequate fire services would be available to combat the identified scenarios.

**RECOMMENDATIONS**

The following recommendations from the PHA have been made regarding the EfW facility;

- Development of a work permit system, including hot work permits;
- Development of hazardous area diagrams in accordance with AS60079.10.2 be conducted;
- Ignition sources within the hazardous area should be controlled according to AS60079.14;
- Installation of monitor(s) in the waste bunker (further monitor recommendations below); and
- Investigate the feasibility of installing explosion venting or nitrogen blanketing in the PAC silos.

The following recommendations from the FRA for fire protection have been made regarding the EfW facility;

*Diesel Bund*

- 1 powder type fire extinguisher per bunded area;
- 1 hose reel with foam making capabilities per bunded area; and
- 1 hydrant with foam making capabilities per bunded area.

Waste Bunker

- Monitors should be installed to provide complete coverage of the waste bunker;

- Two 1900 L/min monitors are recommended for installation to provide complete coverage within the fuel bunker as shown in Figure E-1**;**
- Monitors are recommended for installation such that access is provided externally from the fuel bunker; and
- Monitors are recommended for installation on raised platforms to prevent trucks from colliding with the monitors.

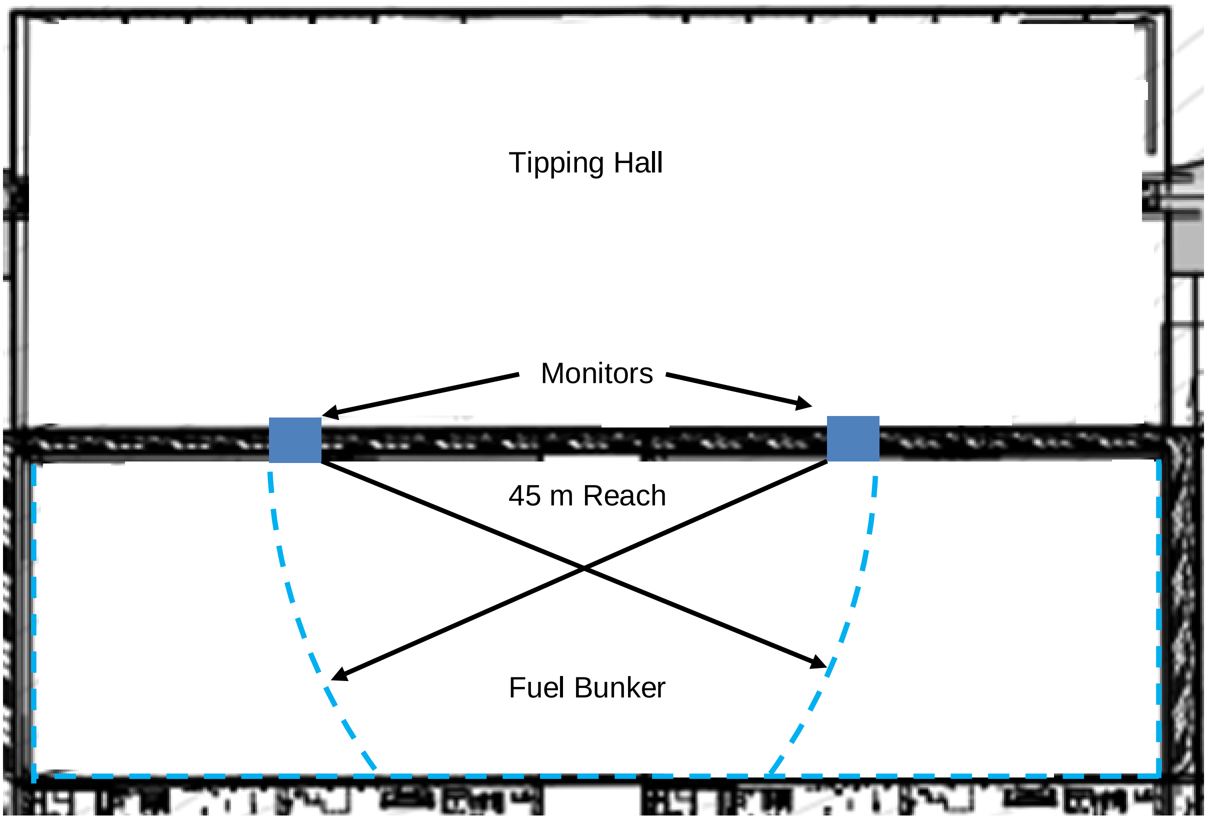


**Figure E-1: Monitor Spray Distances**

<u>PAC Silo</u>

- Investigate the potential of nitrogen blanketing for the purpose of fire protection (via oxygen exclusion).

<u>Transformers</u>

- 1 powder-type fire extinguisher per transformer.

<u>Pumping and Water Availability</u>

- A pump set is recommended for installation to provide adequate water pressure for the monitors (two pumps one of which is driven by a compression ignition engine); and
- At least 546,000 L of firewater is recommended to be stored at the site.

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## ABBREVIATIONS

| ABBREVIATION | DESCRIPTION |
|---|---|
| ACC | Air Cooled Condenser |
| ADG | Australia Dangerous Goods Code |
| ALARP | As Low As Reasonably Practicable |
| CBD | Central Business District |
| CEMS | Continuous Emission Monitor System |
| DG | Dangerous Goods |
| DGR | Director-Generals Requirements |
| DPI | Department of Planning and Infrastructure |
| EfW | Energy from Waste |
| EPA | Environment Protection Agency |
| FGT | Flue Gas Treatment |
| FRA | Fire Risk Assessment |
| HIPAP | Hazardous Industry Planning Advisory Paper |
| LEL | Lower Explosive Limit |
| LPG | Liquefied Petroleum Gas |
| MPC | Material Processing Centre |
| NCV | Net Calorific Value |

| ABBREVIATION | DESCRIPTION |
|---|---|
| NDG | Non-Dangerous Good |
| $NO_X$ | Oxides of Nitrogen |
| PAC | Powdered Activated Carbon |
| PHA | Preliminary Hazard Analysis |
| Pmpy | Per million per year |
| RRE | RAWRiSK Engineering |
| SEP | Surface Emissive Power |
| SEPP | State Environment Planning Policy |
| SNCR | Selective Non-Catalytic Reduction |
| SSC | Spread Sheet Calculator |
| SSD | State Significant Development |
| TNG | The Next Generation |
| TNT | Trinitrotoluene |
| VOC | Volatile Organic Compounds |
| WSEA | Western Sydney Employment Area |
| WTS | Waste Transfer Station |

# 1 INTRODUCTION

## 1.1 BACKGROUND

The Next Generation NSW Pty Ltd (TNG) has proposed the construction of an energy from waste (EfW) electricity generation plant to be developed at Eastern Creek, NSW. The proposal is considered a State Significant Development (SSD) and a request has been submitted to the Minister for Planning to prepare Director General Requirements (DGRs) in relation to the SSD. The DGRs received for the SSD indicate that a preliminary hazard analysis (PHA) and a fire risk assessment (FRA) be completed for the site. Urbis, acting on behalf of TNG has commissioned RAWRiSK Engineering (RRE) to complete the PHA and FRA for the development. This document details the findings of the studies.

## 1.2 OBJECTIVES

The objectives of the study are to;

- Assess the nature of materials delivered to the site and the operations of the EfW plant;
- Identify potential incidents that may occur during the operation of the plant including storage of combustible waste and incineration;
- Develop scenarios for each of the incidents identified;
- Determine the consequences of identified scenarios;
- Determine the frequency and risk of identified scenarios that have the potential to impact offsite;
- Compare the results of the analysis with the acceptable risk criteria;
- Report recommendations (if any) to be included in the design and operation;
- Determine the locations of required fire services on the site such as extinguishers, hose reels, hydrants or monitors for identified scenarios;
- Develop a report detailing the PHA and FRA

## 1.3 SCOPE OF WORK

The scope of work is to produce a PHA and FRA for the EfW plant to be developed by TNG at Eastern Creek. No other sites are included in this assessment.

It is noted that the scope of a PHA study does not take into account emergency response planning or management of equipment failures/systems. These contingency plans are assessed in other risk studies such as a Safety Management System (SMS) or an Emergency Response Plan (ERP).

The preparation of these studies is dictated by the Secretary of the Department of Planning and Environment (DPE) following review of the EIS, the Work Health and Safety Regulations or both.

In addition, contingency plans in the ERP and SMS are reviewed during a Hazard Audit (this requirement is also dictated by the Secretary) which is generally conducted after the first year of operation and every three years thereafter (although a different frequency maybe requested by the Secretary).

# 2 METHODOLOGY

## 2.1 METHODOLOGY

The methodology used for the PHA and FRA study used a combined approach whereby all risks associated with the facility were assessed (e.g. environmental, fire, toxic gas, etc.) and the fire risks were reported in a separate chapter within the PHA study.

The following approach was used:

### 2.1.1 PHA Study

**Hazard Analysis** – A detailed hazard identification was conducted for the site facilities and operations. Where an incident was identified to have potential off site impact, it was included in the recorded hazard identification word diagram (**Appendix A**). The hazard identification word diagram lists incident type, causes, consequences and safeguards. This was performed using the word diagram format suggested in HIPAP No. 6 (Ref. 1). Each postulated hazardous incident was assessed qualitatively in light of proposed safeguards (technical and management controls). Where a potential offsite impact was identified, the incident was carried into the main report for further analysis. Where the qualitative review in the main report determined that the safeguards were adequate to control the hazard, or that the consequence would obviously have no offsite impact, no further analysis was performed.

**Consequence Analysis** – For those incidents qualitatively identified in the hazard analysis to have a potential offsite impact, a detailed consequence analysis was conducted. The analysis modelled the various postulated hazardous incidents and determined impact distances from the incident source. The results were compared to the consequence criteria listed in HIPAP No. 4 (Ref. 2). Where an incident was identified to result in an offsite impact, it was carried forward for frequency analysis. Where an incident was identified to not have an offsite impact, and a simple solution was evident (i.e. move the proposed equipment further away from the boundary), the solution was recommended and no further analysis was performed.

**Frequency Analysis** – In the event a simple solution for managing consequence impacts was not evident, each incident identified to have potential offsite impact was subjected to a frequency analysis. The analysis considers the initiating event and probability of failure of the safeguards (both hardware and software). The results of the frequency analysis were then carried forward to the risk assessment for combination with the consequence analysis results.

**Risk Assessment and Reduction –** Based on the type of materials stored and handled, and the operations conducted at the proposed site, the study was conducted using the Level 2 analysis detailed in the Multi-Level Risk Assessment approach, recommended by the Department of Planning and Infrastructure (DPI). As the selected approach for this analysis was a level 2 assessment, where incidents were identified to impact offsite and where a consequence and frequency analysis was conducted, the consequence and frequency analysis for each incident were combined and compared to the risk criteria published in HIPAP No.4. Where the criteria were exceeded, a review of the major risk contributors was performed and the risks reassessed incorporating the recommended risk reduction measures. Recommendations were then made regarding risk reduction measures.

**Reporting** – on completion of the study a draft report was developed for review and comment by TNG. A final report was then developed, incorporating the comments received by TNG, for submission to the regulators.

### 2.1.2 FRA Study

As part of the PHA study, it was necessary to assess fire risks, including fire scenarios, incident frequency, probability of failure of the safety systems at the site and risk of fire (as a result of the combination of the fire impacts and frequency).

The fire risks identified at the site were used to determine the fire protection required at the site. This was reported in a separate chapter within the PHA study.

The conclusions and recommendations for both the general and fire hazards and risks were reported within the same section of the document.

# 3 SITE DESCRIPTION

## 3.1 SITE LOCATION AND SURROUNDING LAND USES

The proposed development involves the construction of an Energy from Waste (EFW) Electricity Generation Plant for The Next Generation NSW Pty Ltd (TNG) in Eastern Creek, approximately 36km west of the Sydney CBD. The regional location is shown in **Figure 3-1**.

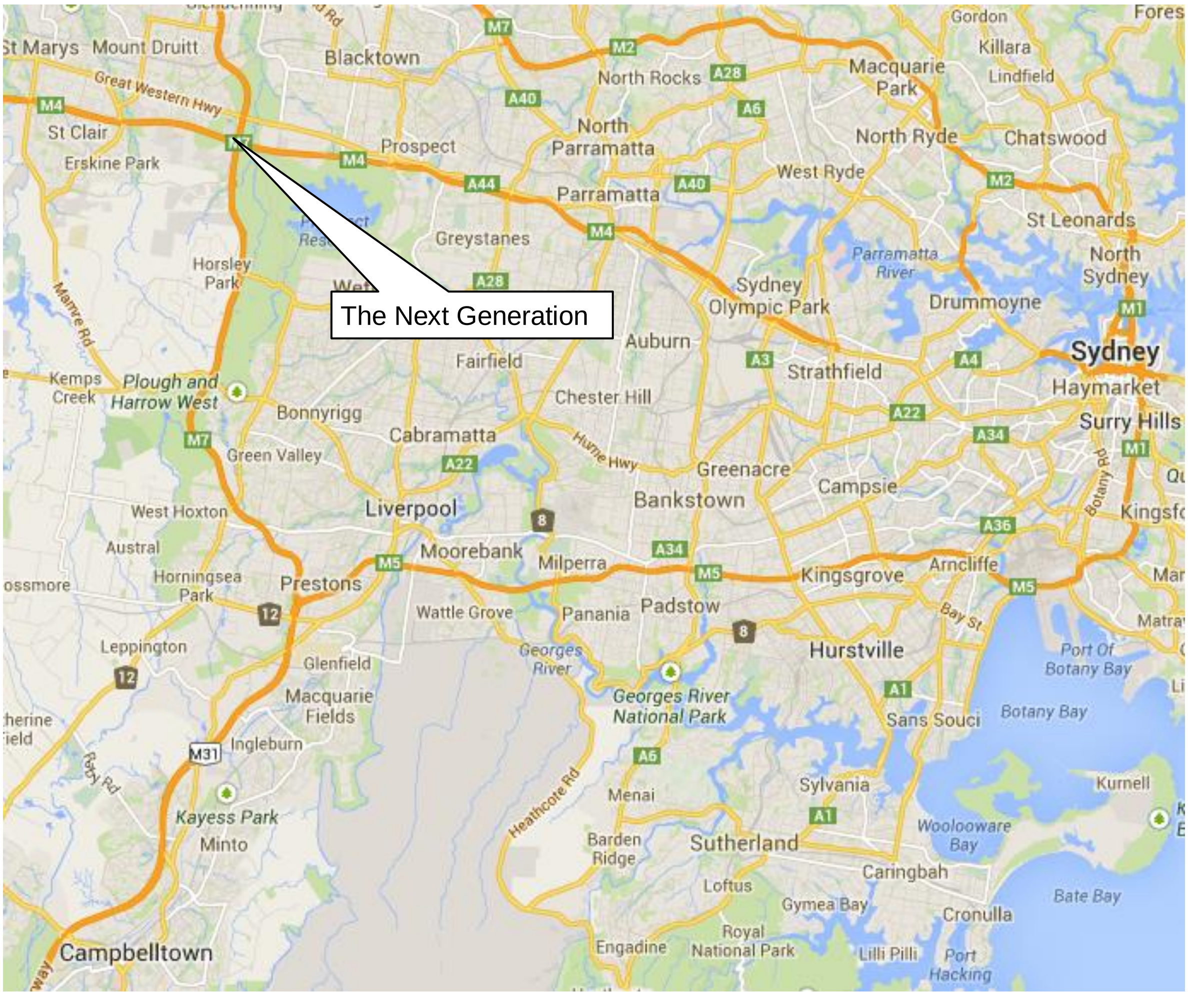


**Figure 3-1: Location of the EFW Facility**

## 3.2 SITE DETAILS

The subject site is described as Lots 2 and 3 in DP 1145808. The site covers an area of approximately 56 hectares.

The Site is accessed via Honeycomb Drive at Eastern Creek. An aerial photograph of the site and surrounding area is presented in **Figure 3-2**.

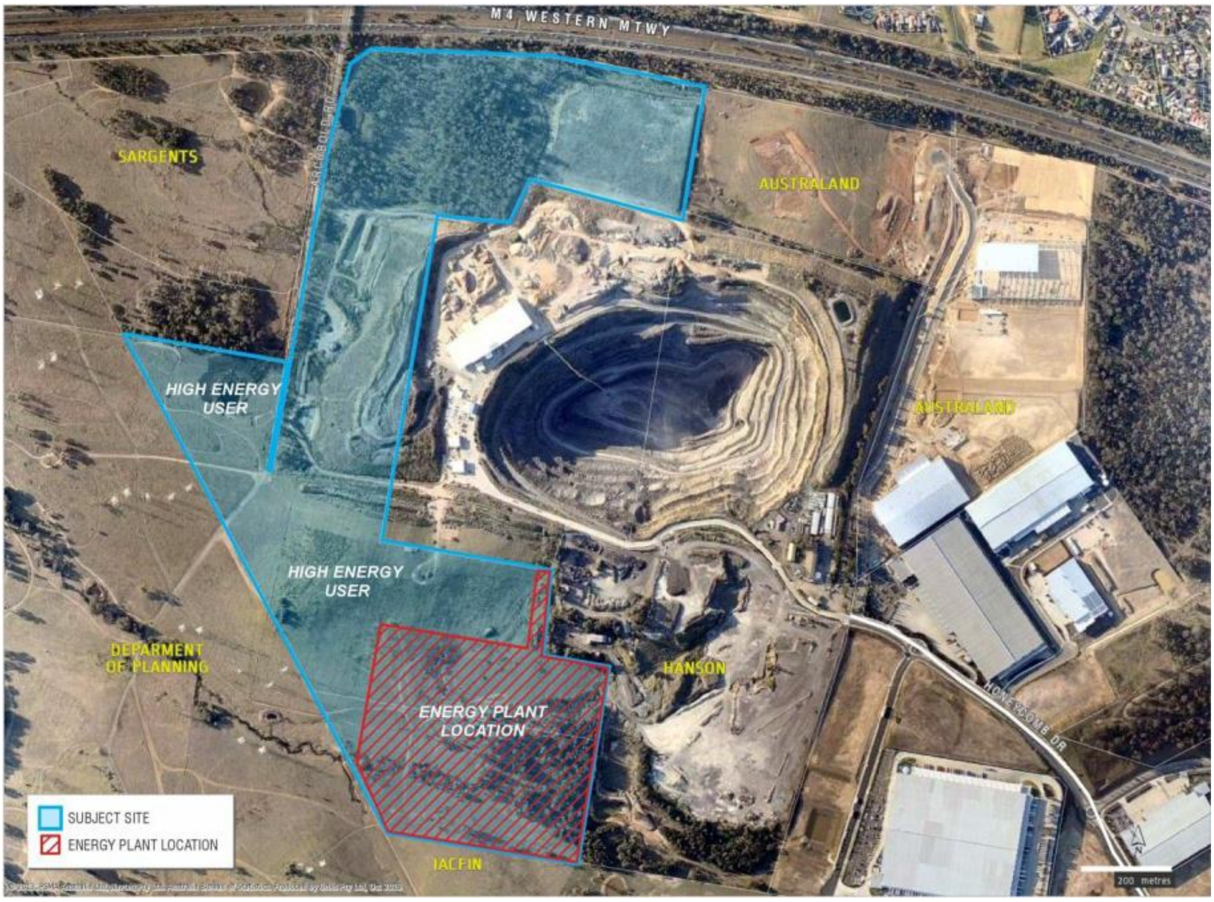


**Figure 3-2: Site Aerial Image**

## 3.3 PROJECT DESCRIPTION

The proposed development involves the construction of an Energy from Waste (EFW) Electricity Generation Plant for The Next Generation NSW Pty Ltd (TNG) in Eastern Creek, approximately 36km west of the Sydney CBD.

The development involves the construction and operation of an Electricity Generation Plant, which will allow for unsalvageable and uneconomic residue waste from the Genesis Xero Material Processing Centre (MPC) and Waste Transfer Station (WTS) to be used for generation of electrical power. The EFW Plant is proposed to be located on Lots 2 and 3, DP 1145808.

This development site is part of a proposal to construct and operate NSW's largest Energy from Waste Plant using as fuel, residual waste which would otherwise be land filled, to allow for a "green" electricity generation facility. The plant, powered by burning non-recyclable combustible waste material, will have a capacity for up to 1.35 million tonnes of waste material per annum.

The proposed EFW Facility will employment of a total of up to 55 staff upon operation, working over 3 shifts (i.e. not on site at any one time).

The project is identified as State Significant Development (SSD) under Schedule 1 of the State Environmental Planning Policy (State and Regional Development) 2011 being:

*Cl. 20 Electricity generating works and heat or co-generation:*

*Development for the purpose of electricity generating works or heat or their co-generation (using any energy source, including gas, coal, biofuel, distillate, waste, hydro, wave, solar or wind power) that:*

*(a) has a capital investment value of more than $30 million; or*

*(b) has a capital investment value of more than $10 million and is located in an environmentally sensitive area of State significance*

The proposal has a capital investment value of greater than $30 million and therefore is classified as a State Significant Development.

The site which is accessed off Honeycomb Drive at Eastern Creek is surrounded by land owned by the Corporate Group Alexandria Landfill Pty Ltd, ThaQuarry Pty Ltd, Australand, Hanson, Jacfin, the Department of Planning and Infrastructure and Sargents. The site and surrounding land is identified as part of the '*State Environmental Planning Policy (Western Sydney Employment Area) 2009 (WSEA SEPP)*' to be redeveloped for higher end industrial and employment uses over the next decade. The site has a total area of approximately 56 Ha including the Riparian Corridor, with a specific development area circa 9 Ha.

The proposed works will, in addition to the Energy from Waste Electricity Generation Facility, include the adoption of a plan of subdivision and the following ancillary works:

- Earthworks associated with the balance of the site;
- Internal roadways;
- Provision of a direct underpass connection (Precast Arch and Conveyor Culvert) between TNG Facility and the Genesis Xero Waste Facility;
- Staff amenities and ablutions;
- Staff car parking facilities;
- Water detention and treatment basins;
- Services (Sewerage, Water Supply, Communications, Power Supply).

Further to the above physical works associated with the proposed Energy from Waste Facility, this application seeks approval for the subdivision Lot 1, 2 and 3 in DP 1145805 in order to create a separate lot of 10,000 m² for the Transgrid Switching or Substation and additional lots to allow for future development of land not associated with the Energy from Waste Facility and the Genesis Xero Material Processing Plant.

## 3.4 ADJACENT LAND USES

The closest residential areas to the proposed development are located at Minchinbury, about 1000 metres from the Northern boundary of Lot 2, DP 1145808 and residential dwellings about 1,200 metres from the Northern boundary of Lot 2, and 800 metres to the west of the site at Erskine Park. Land use in the region is variable and includes residential, commercial and industrial development, remnant vegetation, waterways and associated riparian vegetation corridors and transport and utilities infrastructure. The land form is gently undulating.

## 3.5 MATERIALS USED IN THE PROCESS

**Table 3-1** details the materials and maximum quantities to be used at the site during operation. The indication in brackets denotes whether the material is a Dangerous Goods (DG) or non-Dangerous Good (NDG).

**Table 3-1: Process Materials and Quantities Stored at the Site**

| MATERIAL | QUANTITY ($M^3$) |
|---|---|
| Ammonium Hydroxide (DG) | 80 |
| Diesel (NDG) | 320 |
| Powdered Activated Carbon (PAC) (DG) | 208 |
| Transformer Oil (NDG) | 85 |
| Calcium Hydroxide (NDG) | 1052 |
| Residue (NDG) | 1518 |

## 3.6 PROCESS DESCRIPTION

A process description for the EfW facility has been provided in the following sub-sections.

### 3.6.1 Combustion System

The combustion system will utilise a moving grate system which move fuel through the combustion chamber by vibrating, reciprocating or traveling.

Primary air for combustion will be fed to the underside of the grate by fans. Secondary air will also be admitted above the grate to create turbulence and ensure complete combustion, minimising the potential for the development of oxides of nitrogen (NOx) during the combustion process. The volume of both primary and secondary air will be regulated by a combustion control system.

The combustion control system will regulate the combustion conditions, and thereby minimise the levels of pollutants and particulates in the flue gas before flue treatment. The furnaces will also be fitted with auxiliary burners, fired on low sulphur gas-oil, which will automatically, if required, maintain the combustion chamber temperature above 850°C to ensure the destruction of dioxins, furans and other undesirable combustion products. Combustion chambers, casings, ducts, and ancillary equipment will be maintained under slight negative pressure to prevent the release of gases other than through the flue system.

The combustion control system will be an automated system, including monitoring of the steam flow, oxygen content, temperature conditions of the grate, modification of the fuel feed rates and the control of primary and secondary air.

The hot flue gases will be used to generate steam via a tube boiler whereby water will be heated and turned to steam, which is collected in a steam drum at the top of the boiler. The steam will then be fed to the steam turbine to generate electricity (see **Section 3.5.4**).

### 3.6.2 Flue Gas Treatment

The flue gas treatment system will consist of selective non-catalytic reduction (SNCR) of $NO_x$, activated carbon injection, dry lime scrubbing and fabric filters. $NO_x$ levels will primarily be controlled by careful control of the combustion air. SNCR will also be installed to reduce $NO_x$. SNCR involves the injection of a 25% ammonium hydroxide solution into the boiler which converts both nitrogen oxide (NO) and nitrogen dioxide ($NO_2$) to nitrogen and water.

Acid gases produced during the combustion process will be removed by a scrubbing system using hydrated lime as a reagent. Neutralisation of the acid gases will take place as they react with the lime.

The residual material will be recovered at the outlet of the flue gas scrubbing system.

Activated carbon will also be injected into the flue gas duct to minimise the emissions of dioxins, mercury and other heavy metals. Some of the residual material will be recirculated to improve the gas clean up and reduce the amount of hydrated lime used.

After flowing through the gas scrubber, the gases will be drawn through a fabric bag filter to remove particulates, including lime and activated carbon particles. Each fabric filter will be divided into compartments. The treated flue gas will pass through an induced draught fan into the stack for release. Regular bag filter cleaning will be performed on-line by pulsing compressed air through the filter bags. The residues will be collected in fully enclosed hoppers beneath the filters. Bag failure, albeit an infrequent occurrence would be identified by a sudden increase in particular concentration at particulate meters installed immediately downstream of the bag filter or by a change in the pressure differential across the bag filter.

Following cleaning, the combustion gases from the combustion process will be released into the atmosphere via a gas flue within a chimney stack.

### 3.6.3 Gas Analysis System

Emissions from the stack will be monitored continuously by an automatic computerised system and reported.

The following parameters at the stack will be monitored and recorded continuously using a continuous emissions monitoring system (CEMS);

- Oxygen;
- Carbon monoxide;
- Hydrogen chloride;
- Sulphur dioxide;
- Nitrogen oxides;
- Ammonia;
- Volatile organic compounds (VOCs); and
- Particulates.

### 3.6.4 Steam Turbine

Steam generated in the waste boiler will be passed to the steam turbine to generate electricity. The facility will be capable of generating approximately 140 MW of electricity, amounting to 1,130,000 MWh per annum of electricity.

### 3.6.5 Cooling system

Once the steam has passed through the turbine, it is condensed, and cooled, by passing through air cooled condensers (ACC), which do not require water and, hence, no discharge is generated during the cooling. As a result, there will be no visual impacts for the ACCs.

### 3.6.6 Export of Heat

Export heat generated from the combustion of waste in the facility will be exported to nearby consumers for space heating, hot water or for cooling. Heat can be exported as either hot water or steam for specific use by the consumers.

### 3.6.7 By-Product Handling and Disposal

Two types of solid by-products and one type of liquid by-product will be produced during operations, these include;

- Bottom ash;

- Flue gas treatment (FGT) residue; and
- Liquid effluents.

*Bottom Ash* – Bottom ash is the burnt-out reside from the combustion process. The facility is expected to generate approximately 321,000 tpa of wet bottom ash for the design waste composition (8,000 hours operation at net calorific value (NCV) 10 MJ/kg and ash content of 20%). This will decrease to 184,000 tpa for the design waste composition (8,000 hours operation at NCV of 12.34 MJ/kg and ash content of 11.53%).

The bottom ash will be discharged onto a conveyor system from the boiler. The conveyor passes under a magnetic separator to remove ferrous materials, which will be discharged to a dedicated storage area. The ash will then be discharged and transported to a storage area prior to further processing and to be recycled as a secondary aggregate.

*FGT Residue* – FGT residues comprise fine particles of ash and residues from the flue gas treatment process, which are collected in the bag filters. It is estimated that the facility will generated approximately 45,000 tpa at the design waste composition. The FGT residue will be stored in sealed silos adjacent to the flue gas treatment facility. Due to the alkaline nature of the FGT residues, they are classified as hazardous waste. As a result, the residues will be transported by road in a sealed tanker to an appropriate treatment facility.

*Liquid Effluents* – Liquid effluents will be produced from the boiler water treatment system and from the boiler blow-down. All boiler blow-down and liquid effluent produced are fed to the ash discharger via the process water system. Under normal operating conditions, no effluents are disposed of to drain but are returned to the facility for reuse. In this way, the majority of liquid effluent produced on site will be evaporated.

### 3.6.8 Auxiliary Equipment and Facilities

The facility will require various auxiliary equipment and components to operate. The main auxiliary equipment required is as follows;

- Site entrance;
- Weigh bridges;
- Security;
- Fuel reception and storage;
- Compressed air;
- Demineralised water;
- Diesel system;
- Fire detection and suppression system;
- Cooling system; and
- Stack.

### 3.6.9 Buildings

The main buildings in the facility are;

- Tipping hall and fuel storage;
- Boiler hall;
- Turbine hall;
- Substation;
- Ash collection bay;
- Workshop;
- Stack; and
- Control room, offices and amenities.

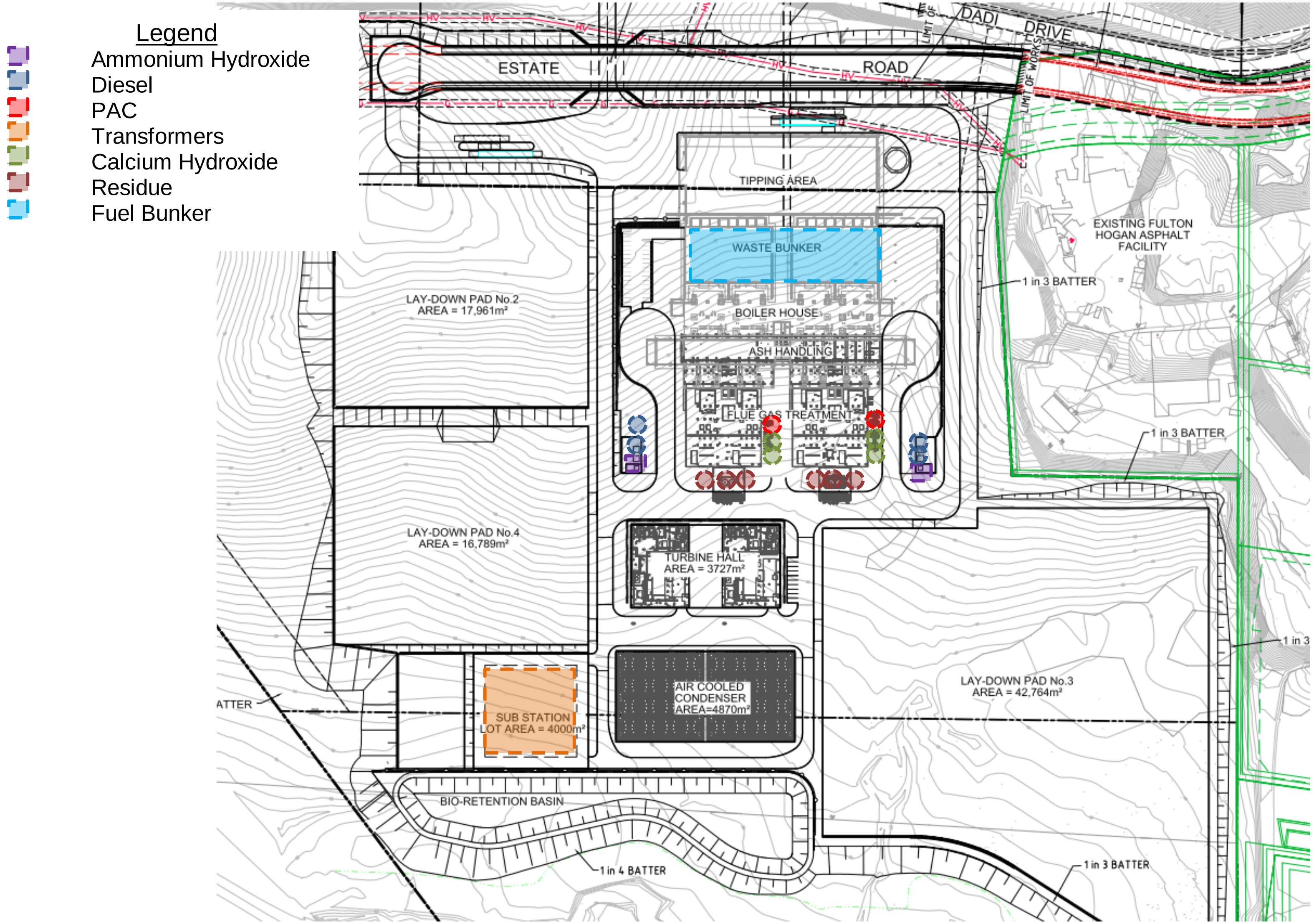


**Figure 3-3: Site Layout**

# 4 HAZARD ANALYSIS

## 4.1 INTRODUCTION

A hazard identification table has been developed and is presented at **Appendix A**. This table has been developed following the recommended approach in Hazardous Industry Planning Advisory Paper No.6, Hazard Analysis Guidelines. The Hazard Identification Table provides a summary of the potential hazards, consequences and safeguards at the site. The table has been used to identify the hazards for further assessment in this section of the study. Each hazard is identified in detail and no hazards have been eliminated from assessment by qualitative risk assessment prior to detailed hazard assessment in this section of the study.

In order to determine acceptable impact criteria for incidents that would not be considered for further analysis, due to limited impact offsite, the following approach has been applied:

- *Fire Impacts* - It is noted in Hazardous Industry Planning Advisory Paper (HIPAP) No.4 (Ref. 2) that a criterion is provided for the maximum permissible heat radiation at the site boundary (4.7 kW/m$^2$) above which the risk of injury may occur and therefore the risk must be assessed. Hence, to assist in screening those incidents that do not pose a significant risk, for this study, incidents that result in a heat radiation heat radiation less that at 4.7 kW/m$^2$, at the site boundary, are screened from further assessment. Those incidents exceeding 4.7 kW/m$^2$, at the site boundary, are carried forward for further assessment (i.e. frequency and risk). This is a conservative approach, as HIPAP No.4 indicates that values of heat radiation of 4.7 kW/m$^2$ should not exceed 50 chances per million per year at sensitive land uses (e.g. residential). It is noted that the closest residential area is over 1 km from the site, hence, by selecting 4.7 kW/m$^2$ as the consequence impact criteria (at the adjacent industrial site boundary) the assessment is considered conservative.
- *Explosion* - It is noted in HIPAP No.4 (Ref. 2) that a criterion is provided for the maximum permissible explosion over pressure at the site boundary (7 kPa) above which the risk of injury may occur and therefore the risk must be assessed. Hence, to assist in screening those incidents that do not pose a significant risk, for this study, incidents that result in an explosion overpressure less that 7 kPa, at the site boundary, are screened from further assessment. Those incidents exceeding 7 kPa, at the site boundary, are carried forward for further assessment (i.e. frequency and risk). Similar to the heat radiation impact discussed above, this is conservative as the 7 kPa value listed in HIPA No.4 relates to residential areas, which are over 1 km from the site (noting that only industrial areas adjoin the proposed facility).
- *Toxicity* – It is noted that toxic materials are not planned for storage at the proposed facility. Hence, toxic impacts are not considered in this study.
- *Property Damage and Accident Propagation* - It is noted in HIPAP No.4 (Ref. 2) that a criterion is provided for the maximum permissible heat radiation/explosion overpressure at the site boundary (23 kW/m$^2$/14 kPa) above which the risk of property damage and accident propagation to neighbouring sites must be assessed. Hence, to assist in screening those incidents that do not pose a significant risk to incident propagation, for this study, incidents that result in a heat radiation heat radiation less that 23 kW/m$^2$ and explosion over pressure less than 14 kPa, at the site boundary, are screened from further assessment. Those incidents exceeding 23 kW/m$^2$, at the site boundary, are carried forward for further assessment with respect to incident propagation (i.e. frequency and risk).
- *Societal Risk* – HIPAP No.4 (Ref. 2) discusses the application of societal risk to populations surrounding the proposed potentially hazardous facility. It is noted that HIPAP

No.4 indicates that where a development proposal involves a significant intensification of population, in the vicinity of such a facility, the change in societal risk needs to be taken into account. In the case of The Next Generation facility, there is no significant intensification of population around the proposed site. The site is located in an industrial area, with minimal population surrounding the site. Hence, societal risk has not been considered in this study.

## 4.2 PROPERTIES OF DANGEROUS GOODS

The type of DGs and quantities stored and used at the site has been described in **Section 3**. **Table 4-1** provides a description of the DGs stored and handles at the site, including the DG name, the Class and Packaging Group (*PG) and the hazardous material properties of the DG.

**Table 4-1: Properties of the Dangerous Goods and Materials Stored at the Site**

| MATERIAL | CLASS/PG | HAZARDOUS PROPERTIES |
|---|---|---|
| Ammonium Hydroxide | 8/III | Ammonium hydroxide is a classified as a Class 8 PGIII corrosive substance. When dissolved in water it forms basic solutions and is the main constituent in household ammonia. It is used in a range of industries including; rubber, fertilizers, refrigeration, detergents among others. Contact with ammonium hydroxide may result in chemical burns. It may also pose an environmental hazard. |
| Diesel | C1 | Diesel is classified as a combustible liquid 1. The SDS for the material indicates it has a flash point of approximately $63^oC$. Hence, the liquid does not readily vaporise and the formation of a vapour cloud does not occur at ambient conditions. However, ignition of a leak may occur resulting in a pool fire. |
| Powdered Activated Carbon (PAC) | 4.2/III | Activated Carbon is classified as a Class 4.2 PGIII DG under the ADG* code (UN No. 1362). It poses an explosive hazard as it is stored as a fine combustible dust, which under the right conditions and an ignition source of sufficient magnitude, the dust may ignite resulting in a dust cloud explosion |
| Transformer Oil | - | Transformer oil is not classified as a DG by the ADG, however, it is classified as a combustible liquid under the provisions of AS1940 (Ref. 4). A combustible liquid may burn after sustained heating and contact with an ignition source. |
| Calcium Hydroxide | - | Calcium hydroxide is not classified as a DG by the ADG. It is used heavily within the cement industry. |

* The Australian Code for the Transport of Dangerous Goods by Road and Rail

## 4.3 HAZARD IDENTIFICATION

A detailed hazard identification table has been developed in **Appendix A** to identify those facilities and operations that pose a hazard and risk to offsite areas. A review of **Table 4-1** and the hazard identification table indicates that there may be risks present at the site. The following scenarios were identified to have potential to impact over the site boundary;

- Ammonium hydroxide tank leak, spill and release to environment;
- Diesel tank leak, spill and release to environment;

- Diesel tank leak, spill, immediate ignition and bund fire;
- Diesel tank leak, spill, unconfined, delayed ignition and flash fire;
- Diesel tank leak, spill, confined, delayed ignition and vapour cloud explosion;
- PAC dust liberation, ignition and explosion (storage silo and residue silo);
- Ignition of waste in bunker and full bunker fire;
- Emission of combustion by-products;
- Transformer oil spill, ignition and bund fire;
- PAC dust cloud explosion within residue silo;
- Turbine fire;
- Release of calcium hydroxide and
- Ignition of waste in truck and truck fire.

Each identified scenario is discussed in further detail in the following subsections.

### 4.3.1 Ammonium Hydroxide Tank Leak, Spill and Release to Environment

The ammonium hydroxide tank could be damaged either through physical impact (vehicular movements, vandalism, etc.) or by deterioration (e.g. corrosion) which may result in the structural integrity of the tank being compromised enabling ammonium hydroxide to leak from the tank. If the ammonium hydroxide entered the drainage system it could enter the public water course (offsite) causing an environmental hazard. Several safety systems are included in the design of the DG store, the site and operations, which prevent an ammonium hydroxide leak causing an environmental hazard. These include;

- Tank bunding;
- Isolation of site waterways;
- Spill kits; and
- Regular deliveries which would identify a leak.

The bund will be designed to comply with the requirements of AS3780 (Ref. 3) and will be capable of containing the full volume of the ammonium hydroxide tank. If the bund is damaged an ammonium hydroxide leak would be contained within the site waste water system preventing release to the environment. In addition to the safety systems, regular deliveries will occur (approximately 2 per week) to refill the tank. If a leak were to occur, it would be identified by operators during tank refilling or by identification of liquid in the bund.

Based on the designed safety systems, operations, the low likelihood of a leak occurring, and the spill retention systems, the risk associated with a release to the environment are considered to be As Low As Reasonably Practicable (ALARP) and, hence, this incident has not been carried forward for further analysis.

### 4.3.2 Diesel Tank Leak, Spill and Release to Environment

Similar to the ammonium hydroxide incident described in **Section 4.3.1**, the diesel tank could be damaged or deteriorate (corrode) resulting in a leak which may result in an environmental hazard. The tank storage location will be designed in to meet the requirements of AS1940 (Ref. 4) and will be located within a bunded area, which will be designed to contain the full volume of the tank. In addition to the tank bunding, the site is designed with a drainage containment system which would prevent any onsite release from escaping into the public water course (i.e. offsite). Based on the designed safety systems, operations, the low likelihood of a leak occurring and the spill retention systems, the risk associated with a release to the environment are considered to be ALARP and, hence, this incident has not been carried forward for further analysis.

### 4.3.3 Diesel Tank Leak, Spill, Immediate Ignition and Bund Fire

If a leak occurred in the diesel tank it would be contained within the bund which may pose a fire hazard as it is classified as a flammable liquid, although its flash point is around 63°C and therefore highly unlikely to ignite in ambient conditions. If the spill ignited immediately, a pool fire could occur which may generate sufficient heat radiation to impact over the site boundary. This incident has therefore been carried forward for consequence analysis.

The potential for a fire to occur can be reduced by the control of ignition sources, in this case maintenance work such as welding, cutting and grinding in the vicinity of the storage without work permit control. ***Therefore it is recommended that a work permit system including hot work permits be developed for the site.***

### 4.3.4 Diesel Tank Leak, Spill, Unconfined, Delayed Ignition and Flash Fire

As stated in **Section 4.2** the diesel has a flash point of 63°C and so it would not generate vapours at atmospheric conditions. As no vapours would be generated from a spill, there is no potential for a flash fire. This incident has not been carried forward for further analysis.

### 4.3.5 Diesel Tank Leak, Spill, Confined, Delayed Ignition and Vapour Cloud Explosion

As stated in **Section 4.2** the diesel has a flash point of 63°C and so it would not generate vapours at atmospheric conditions. As no vapours would be generated from a spill, there is no potential for a vapour cloud explosion. This incident has not been carried forward for further analysis.

### 4.3.6 PAC Dust Storage, Ignition and Explosion within the Storage Silo

PAC is classified as a dangerous good; Class 4.2 PGIII, which has the potential to spontaneously combust, causing a smouldering fire, in specific conditions. Activated carbon is a combustible dust and is stored as a fine dust which may burn on the surface of equipment/components or in the form of a dust cloud. However, several requirements must be met for a combustible dust to be involved in a dust cloud explosion. These are;

- Fuel;
- Oxygen;
- Confinement;
- Dispersion; and
- Ignition

As noted above, PAC is combustible and oxygen is present in the atmosphere. The dust is stored in 2 silos with a 104 $m^3$ capacity which may provide necessary confinement of the dust. Dispersion of the dust may occur during delivery of activated carbon into the silo. In addition to the other 4 requirements, an ignition source must be present for the dust to ignite and escalate into an explosion.

The nature of a dust explosion is that if there is an accumulation of dust on surfaces (or dust pile within silo), an initial explosion may eject this layer into the air which may ignite from residual heat from the primary explosion resulting in a potentially larger secondary explosion (Ref. 7). Either explosion (primary or secondary) may impact over the site boundary; therefore, this incident has been carried forward for consequence analysis.

Several recommendations have been made for the PAC silo;

- ***Development of hazardous area diagrams in accordance with AS60079.10.2 (Ref.16);***
- ***Ignition sources within the hazardous areas should be controlled according to AS60079.14 (Ref. 5); and***
- ***Investigate the feasibility of installing explosion venting panels or nitrogen blanketing in the PAC silos, this would prevent a dust explosion within the silo and vent the rapidly burning dust vertically from the silo into a safe location and without catastrophic destruction of the silo.***

#### *4.3.7* Ignition of Waste in Bunker and Full Bunker Fire

Waste delivered to the site is processed either within the Genesis facility or by an external company prior to delivery to the TNG facility, which removes prohibited items such as; flammable liquids and aerosols which may pose an increased fire hazard due to the greater volatility of these products.

Notwithstanding this, there is potential that these materials may enter the waste storage bunker. If an ignition source came into contact with a flammable liquid spill or LPG release (from an aerosol) within the bunker a fire may occur. If the fire seat develops deep within the bunker, combat efforts may be inhibited by the waste overburden above the fire seat. The potential inhibition of combatting abilities may allow the fire to spread which may grow to consume the entire waste bunker. A fire in the bunker may generate sufficient heat radiation to impact over the site boundary and so this incident has been carried forward for consequence analysis.

Based on the potential for a deep seated fire to occur the following recommendations have been made;

- ***monitor(s) should be installed to provide complete coverage of the bunker.***
- ***Continuous scanning of the waste bunker with IR scanners/cameras; and***
- ***Investigate the feasibility of remotely controlled monitors controlled by the IR scanners/cameras***

#### 4.3.8 Emission of Combustion By-Products

Under normal combustion a number of undesirable by-products are produced that could be released to the atmosphere. The technology used in TNG plant has been designed to minimise, control and monitor the emission of by-product released to the atmosphere. The products that may be released are;

- Carbon monoxide;
- Hydrogen chloride;
- Sulphur dioxide;
- Volatile organic compounds (VOCs);
- $NO_x$;
- Ammonia;
- Furans and dioxins; and
- Particulates.

Each of the gases or particles produced in the plant is discussed below with regards to the relevant technology used to reduce the emission from the plant.

*Carbon Monoxide* – Carbon monoxide (CO) is a by-product of incomplete combustion, i.e. insufficient oxygen available during combustion. To ensure complete combustion occurs in the furnaces, a primary combustion air stream is introduced below the grate system. A secondary air stream is introduced from above the grate system to create high turbulence of the interacting air streams producing more efficient combustion within the furnace, ultimately reducing the production of carbon monoxide.

*Hydrogen Chloride* – Hydrogen chloride (HCl) is a gas which forms hydrochloric acid upon contact with atmospheric humidity. To control the amount released from the TNG plant, hydrated lime (calcium hydroxide $Ca(OH)_2$) is injected into the flue stream neutralising the acid into water and aqueous calcium chloride ($CaCl_2$).

*Sulphur Dioxide* – Sulphur dioxide ($SO_2$) will be produced in low quantities as the fuels burnt only contain low concentrations of sulphur and therefore insufficient $SO_2$ would be generated to impact off site.

*Volatile Organic Compounds* – VOC are combustion by-products which may pose a hazard to human health and the environment. VOC emissions are controlled by the injection of PAC dust into the flue stream that absorbs VOCs onto the surface of the carbon, which is then collected and removed by the bag filters.

*$NO_x$* – $NO_x$ compounds are produced during combustion by reaction of nitrogen with oxygen and may form several oxides of nitrogen such as NO, $NO_2$, $NO_3$, $N_2O_3$. etc. These emissions are controlled by injecting ammonia into the flue gas which reacts with the $NO_x$ forming nitrogen and oxygen.

*Ammonia* – Ammonia is injected into the flue gas, in the form of ammonium hydroxide, to control $NO_x$, however, unreacted ammonia may escape to the atmosphere. The ammonia discharge concentration is continuously monitored and if concentrations begin to rise, the amount of ammonium hydroxide injected into the flue gas stream is reduced.

*Furans and Dioxins* – Furans and dioxins are by-products of combustion which may be harmful to the environment and human health. The products are controlled in the combustions stage by ensuring that combustion occurs at a temperature above which these compounds decompose. The furnaces are operated at 850$^{o}$C, which ensures the complete destruction of these compounds. If the temperature within the furnace area falls, low sulphur diesel is burned to increase the temperature to 850$^{o}$C.

*Particulates* – Particulates are primarily produced during the combustion stage, but are also increased by the addition of PAC for the control of VOCs. These particles are removed from the flue gas by bag filters which trap the particles while allowing the gas to pass through.

In addition to the controls mentioned above, the flue gas stream is continuously monitored and reported to ensure that the emissions are below the required concentrations. Furthermore, the emissions from the plant occur from a stack which will be designed to release the gases at height, allowing the gases to disperse before they reach ground level so that human exposure at ground level is negligible.

Based on the control systems, monitoring and reporting included in the design of the plant to reduce the emissions below those required by the regulators, it has been concluded that the risks associated with the flue gas system are ALARP and so this incident has not been carried forward for consequence analysis.

### 4.3.9 Transformer Internal Arcing, Oil Spill, Ignition and Bund Fire

Transformers contain oil which is used to cool the units during operation. If arcing occurs within the transformer (e.g. due to a low oil level), the high energy passing through the coolant vaporises the oil into light hydrocarbons (methane, ethane, acetylene, etc.) resulting in rapid pressurisation within the reservoir. To minimise the likelihood of such occurrence, transformers are fitted with a low oil pressure switches and a pressure surge switch

(Buckholtz relay). These devices identify potential oil and pressure events within the transformer, isolating power and alarming operators.

Notwithstanding the protection systems, if the pressure rise exceeds the structural integrity of the reservoir, and the installed pressure relief devices, the reservoir can rupture allowing the release of oil into the bund. The rupture also allows oxygen to enter the reservoir. The temperature of the gases is above the auto ignition point, but this does not occur until oxygen is present. When oxygen enters the reservoir, the gases auto ignite which generates sufficient heat to ignite the oil in the bund.

The transformers at the site each hold 42,500 L of oil and the bunds have approximate dimensions of 13.5 m by 10 m. The radiant heat generated from this fire may be sufficient to impact over the site boundary. Therefore, this incident has been carried forward for consequence analysis.

### 4.3.10 PAC Dust Explosion within Residue Silo

PAC is input into the flue gas streams to remove VOCs and is collected in bag filters prior to emission of the flue gases from the stack. Also collected in the bag filters are non-combustible particulates generated from the combustion of the waste within the furnaces. A review of Dust Explosion Prevention and Protection (Ref. 8) indicates that diluting the combustible contents in a dust stream will prevent the generation of a dust explosion by reducing the propagation of a flame within the dust stream. The non-combustible dust forms the majority of the residue within the silos and acts as a dilutent which would prevent a dust concentration in air achieving the lower explosive limit (LEL) and therefore eliminating the potential for a dust explosion.

As the potential to achieve the LEL has been eliminated by dilution of the combustible dust with non-combustible dust, the risks associated with the PAC in the residue silo are considered ALARP. This incident has not been carried forward for consequence analysis.

### 4.3.11 Turbine Fire

Turbines spin at considerable speed which requires constant lubrication to prevent metal on metal contact between the shaft and the bearings. If there is insufficient lubrication, the metal will contact resulting in considerable increase in temperature which may vapourise the lubricant and ignite the resultant vapour resulting in a turbine fire.

The fire would occur where fuel is available (i.e. lubricant oil). The lubricant oil is under pressure and may result in a spray fire which could extend the potential fuel source area. The turbines are located in turbine oil which is centrally located within the site. The closest boundary to the site is 190 m; hence, it is considered radiant heat from a turbine fire would be insufficient to impact across this considerable distance; hence, this incident has not been carried forward for further analysis.

### 4.3.12 Release of Calcium Hydroxide

As stated in **Section 4.2**, calcium hydroxide is not classified as a DG and so there would be minimal impact if a release occurred. Furthermore, the calcium hydroxide is in a solid form and so any spill would be localised to the immediate area of a release unless it were raining, in which instance the site is fully isolated and so any rain dispersed spill would be retained on site. This incident has not been carried forward for further analysis.

### 4.3.13 Ignition of Waste in Truck and Truck Fire

Due to the uncontrolled nature of the waste that will be delivered to the site (i.e. waste may contain aerosols or flammable liquids) there is the increased potential for a fire to occur due to the volatility of these materials which can be readily ignited (i.e. by cigarette, sparks). In the event a truck fire does occur, the fire is likely to be localised within the truck tray.

Notwithstanding this, the delivery road way is located near the site boundary; hence, there is the potential for offsite impact. Therefore, this incident has been carried forward for further analysis.

# 5 CONSEQUENCE ANALYSIS

## 5.1 INCIDENTS CARRIED FORWARD FOR CONSEQUENCE ANALYSIS

The following incidents have been carried forwards for consequence analysis:

- Diesel tank leak, spill, immediate ignition and bund fire;
- PAC dust storage, ignition and dust explosion within the storage silo;
- Ignition of waste in bunker and full bunker fire;
- Transformer internal arcing, oil spill, ignition and bund fire; and
- Ignition of waste in truck and truck fire.

Each incident is assessed in the following sections.

## 5.2 DIESEL TANK LEAK, SPILL, IMMEDIATE IGNITION AND BUND FIRE

There is potential that the diesel tanks may leak resulting in a flammable liquid spill contained within the dimensions of the bund. If the spill is ignited, a pool fire with the dimensions of the bund will occur. A detailed analysis has been conducted in **Appendix B** and the radiant heat impact distances estimated for this scenario are shown in **Table 5-1**.

**Table 5-1: Radiant Heat Impact Distances from a Diesel Bund Fire**

| HEAT RADIATION (KW/M$^2$) | DISTANCE (M) |
|---|---|
| 35 | 6.1 |
| 23 | 7.6 |
| 12.6 | 10.4 |
| 4.7 | 17.5 |
| 2.1 | 26.0 |

As shown in **Figure 5-1**, the radiant heat impacts at 4.7 kW/m$^2$ do not extend over the site boundary and, hence, it is unlikely that a fatality would occur at the site boundary, therefore the risk of a fatality from this incident would be below the 50 per million per year (pmpy), the acceptable risk at the adjacent industrial property (Ref.2). This incident has not been carried forward for further analysis.

## 5.3 PAC DUST LIBERATION, IGNITION AND DUST EXPLOSION

As discussed in **Section 4.3.6**, a PAC dust explosion may occur within the storage silo provided several criteria are met. Several of these criteria may exist during a delivery of the PAC into the silo and if an ignition source is present a dust explosion could occur within the silo. A detailed analysis has been conducted in **Appendix B** and the results are presented in **Table 5-2**. It is noted that the analysis conducted for the silo explosion has been performed without the constriction of the silo enclosure. This will provide a conservative result as the initial confinement of the silo enclosure will reduce the overall overpressure. Hence, as the analysis has been conducted as a free air explosion, the results shown in **Table 5-2** would be expected to be higher than the actual overpressures at the stated distances.

**Table 5-2: Explosion over Pressure Distances for a Dust Cloud Explosion**

| EXPLOSION OVERPRESSURE (KPA) | DISTANCE (M) |
|---|---|
| 70 | 11.4 |
| 35 | 15.7 |
| 14 | 28.5 |
| 7 | 45.6 |

As shown in **Figure 5-1**, the over pressure impacts at 7 kPa do not extend over the site boundary and therefore it is unlikely that a fatality would occur at the site boundary, hence, the risk of a fatality from this incident at the site boundary would be below the 50 per million per year (pmpy), the acceptable risk at the adjacent industrial property (Ref.2). This incident has not been carried forward for frequency analysis.

## 5.4 IGNITION OF WASTE IN BUNKER AND FULL BUNKER FIRE

There is potential that a fire could develop within the waste bunker. A fire in this location may be difficult to combat as the fire seat may be shielded by waste overburden. All the materials within the bunker are combustible and so there is potential that a fire may grow to consume the entire waste storage. A detailed analysis has been conducted in **Appendix B** and the radiant heat impact distances estimated for this scenario are presented in **Table 5-3**.

**Table 5-3: Radiant Heat Impact Distances from a Full Bunker Fire**

| HEAT RADIATION ($KW/M^2$) | DISTANCE (M) |
|---|---|
| 35 | Maximum heat flux is 22.6 $kW/m^2$ |
| 23 | Maximum heat flux is 22.6 $kW/m^2$ |
| 12.6 | 14.0 |
| 4.7 | 24.0 |
| 2.1 | 37.0 |

As shown in **Figure 5-1**, the radiant heat impacts at 4.7 $kW/m^2$ do not extend over the site boundary, therefore it is unlikely that a fatality would occur at the site boundary, hence, the risk of a fatality from this incident at the site boundary would be below the 50 per million per year (pmpy), the acceptable risk at the adjacent industrial property (Ref.2). This incident has not been carried forward for frequency analysis.

## 5.5 TRANSFORMER INTERNAL ARCING, OIL SPILL, IGNITION AND BUND FIRE

There is potential that arcing may occur within the transformers which may lead to generation of gases and pressure above the structural integrity of the oil reservoir which may rupture leaking oil into the bund. As a result of the arcing and rupture, the oil may ignite leading to a bund fire within the dimensions of the bund. A detailed analysis has been conducted in **Appendix B** and the radiant heat impact distances estimated for this scenario are shown in **Table 5-4**.

**Table 5-4: Radiant Heat Impact Distances from a Transformer Bund Fire**

| HEAT RADIATION (KW/M$^2$) | DISTANCE (M) |
|---|---|
| 35 | 6.0 |
| 23 | 7.5 |
| 12.6 | 10.3 |
| 4.7 | 17.5 |
| 2.1 | 26.0 |

As shown in **Figure 5-1**, the radiant heat impacts at 4.7 kW/m$^2$ do not extend over the site boundary, therefore it is unlikely that a fatality would occur at the site boundary, hence, the risk of a fatality from this incident at the site boundary would be below the 50 per million per year (pmpy), the acceptable risk at the adjacent industrial property (Ref.2). This incident has not been carried forward for frequency analysis.

## 5.6 IGNITION OF WASTE IN TRUCK AND TRUCK FIRE

Products inside the truck trailers may catch on fire due to damaged packages which are exposed to an ignition source (i.e. Cigarette). The fire could grow to consume all the products within the truck as the stock loaded within the truck may be shielded from sprinkler discharge. A detailed analysis has been conducted in **Appendix B**. The results of the analysis are displayed in **Table 5-5**.

**Table 5-5: Radiant Heat Impact Distances from a Truck Fire**

| HEAT RADIATION (kW/m$^2$) | DISTANCE |
|---|---|
| 35 | 2.9 |
| 23 | 3.5 |
| 12.6 | 4.8 |
| 4.7 | 7.9 |
| 2.1 | 11.7 |

As shown in **Figure 5-1**, the radiant heat impacts at 4.7 kW/m$^2$ do not extend over the site boundary, therefore it is unlikely that a fatality would occur at the site boundary, hence, the risk of a fatality from this incident at the site boundary would be below the 50 per million per year (pmpy), the acceptable risk at the adjacent industrial property (Ref.2). This incident has not been carried forward for frequency analysis.

## 5.7 HEAT RADIATION AND OVERPRESSURE CONTOURS

**Figure 5-1** shows the contours representative of the radiant heat and overpressures estimated for the identified scenarios.

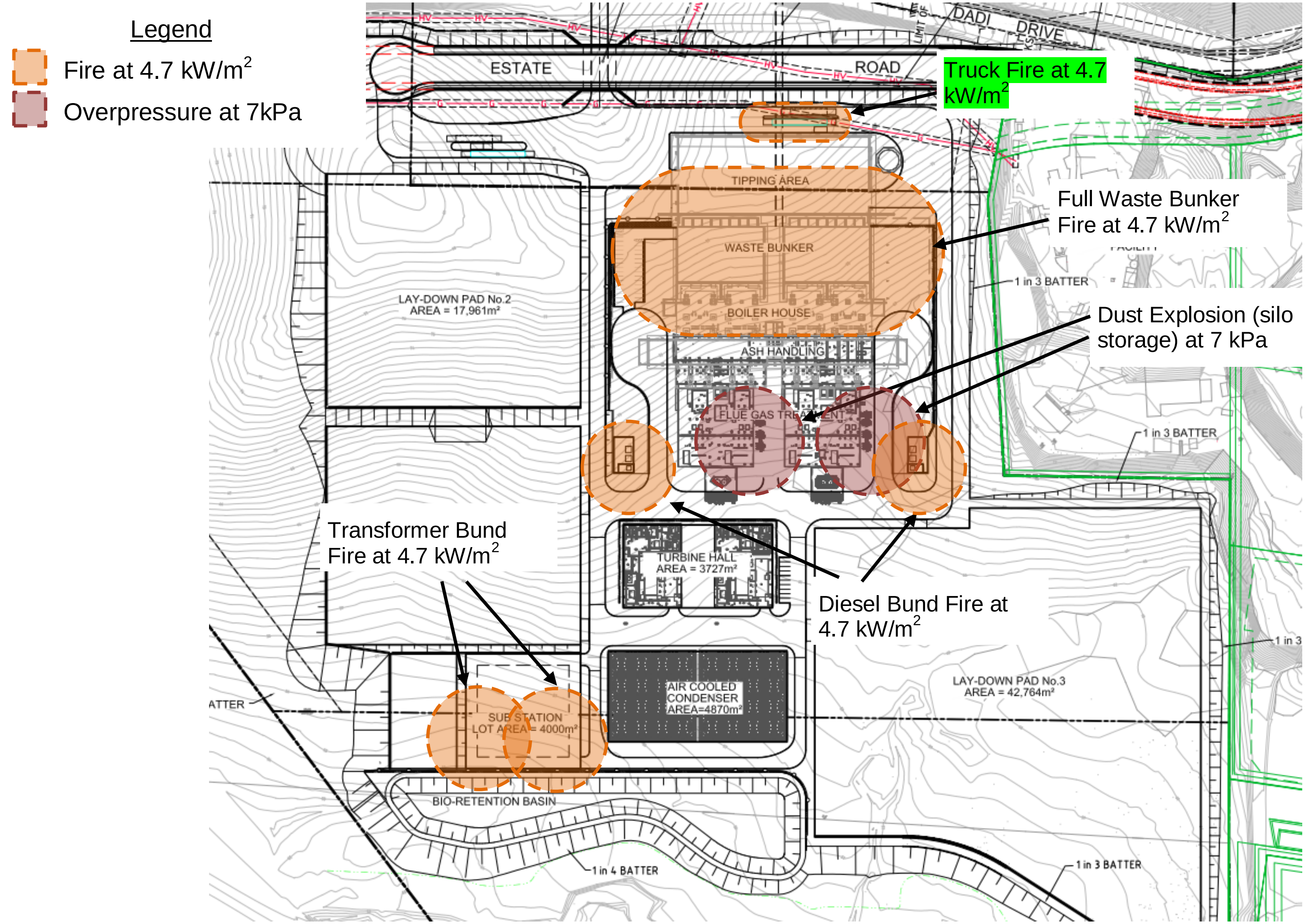


**Figure 5-1: Radiant Heat and Overpressure Contours**

# 6 FIRE RISK ASSESSMENT

## 6.1 FIRE RISK ASSESSMENT

It was identified in **Section 4** and **Section 5** that the following fire scenarios may occur at the EfW facility;

- Diesel bund fire;
- Waste bunker fire;
- PAC silo fire; and
- Transformer bund fire.

These incidents were identified to have the potential to impact over the site boundary in the hazard identification; however, a follow-up consequence analysis showed that radiant heat at the site boundary would be below 4.7 kW/m$^2$ and so it is unlikely that a fatality would occur at the boundary. In addition, radiant heat at 23 kW/m$^2$ from these scenarios would be contained within the site and; hence, fire propagation across the site boundary would be unlikely to occur.

## 6.2 FIRE SAFETY SERVICES

To ensure that the correct fire protection is available to combat the identified fires at the site, an analysis of the required fire protection based on standards or best practice was conducted. The analysis is shown in the following sub-sections.

### 6.2.1 Diesel Bund Fire

There will be a total of 320 m$^3$ of diesel stored across 2 bunded areas (160 m$^3$ in each bund). Clause 11.12 of AS1940-2004 (Ref. 4) has been used to determine the fire protection required for each bunded area. It is noted that the diesel is classified as a flammable liquid (Class 3 PGIII), with a flash point of around 63$^o$C. Hence, the flammable liquid provisions of Clause 11.12 are considered to apply. This is conservative, as the flash point of the diesel is 63$^o$C, therefore vaporisation of the diesel would not be expected at ambient conditions. Notwithstanding this, the fire protection requirements for flammable liquids are displayed in **Table 6-1**.

**Table 6-1: Diesel Bund Fire Protection**

| EQUIPMENT | QUANTITY |
|---|---|
| Powder-type extinguisher | 1 |
| Hose reel with foam capabilities able to reach all parts of the storage | 1 |
| Fire hydrant (fog nozzle and foam-making branch pipe with pick-up tube operating at minimum pressure of 400 kPa) | 1 |

The preliminary bund design gives dimensions of 14 m by 10.4 m. AS2419-2005 (Ref. 9) assumes a hose stream of 4 m, however, for car parks the stream is based on the arc length plus 4 m. As the diesel tanks are in a large open area similar to a car park, the diesel tank area has been treated as a car park for this assessment. The total flow distance has been assumed to be 8 m (arc length taken to be 4 m adding 4 m for car parks). It has been assumed that the hose installed will be 36 m long as per the maximum requirements of AS2419-2005. A hose reel located mid-way along the bund wall and set back by 5 m would be capable of reaching the whole bund area. Therefore, only 1 hose reel would be required for each diesel bunds.

### 6.2.2 Waste Bunker Fire

As noted in **Section 4.3.7**, a fire in the waste bunker may be difficult to combat as the fire seat may be protected from intervention by waste over burden. To combat a fire in the bunker it may be necessary to remove the over burden to directly combat the fire seat.

To provide sufficient firewater to the fire seat and displace overburden, it was recommended that fire monitors could be used as monitors operate at high pressure and can deliver large volumes of water directly to a fire seat. Monitors operating at 1900 L/min have a spray reach of approximately 45 m (Ref. 4). The following recommendations have been made regarding the installation of monitors in the fuel bunker;

- ***It is recommended that two 1900 L/min monitors be installed as shown in Figure 6-1;***
- ***Monitors should be installed on raised platforms above the heights of the delivery trucks to ensure a collision between trucks and the platform doesn't occur; and***
- ***Access to the monitors should be external to the fuel bunker so that monitor operators can evacuate the platform without traversing through the fire impact zone*.**

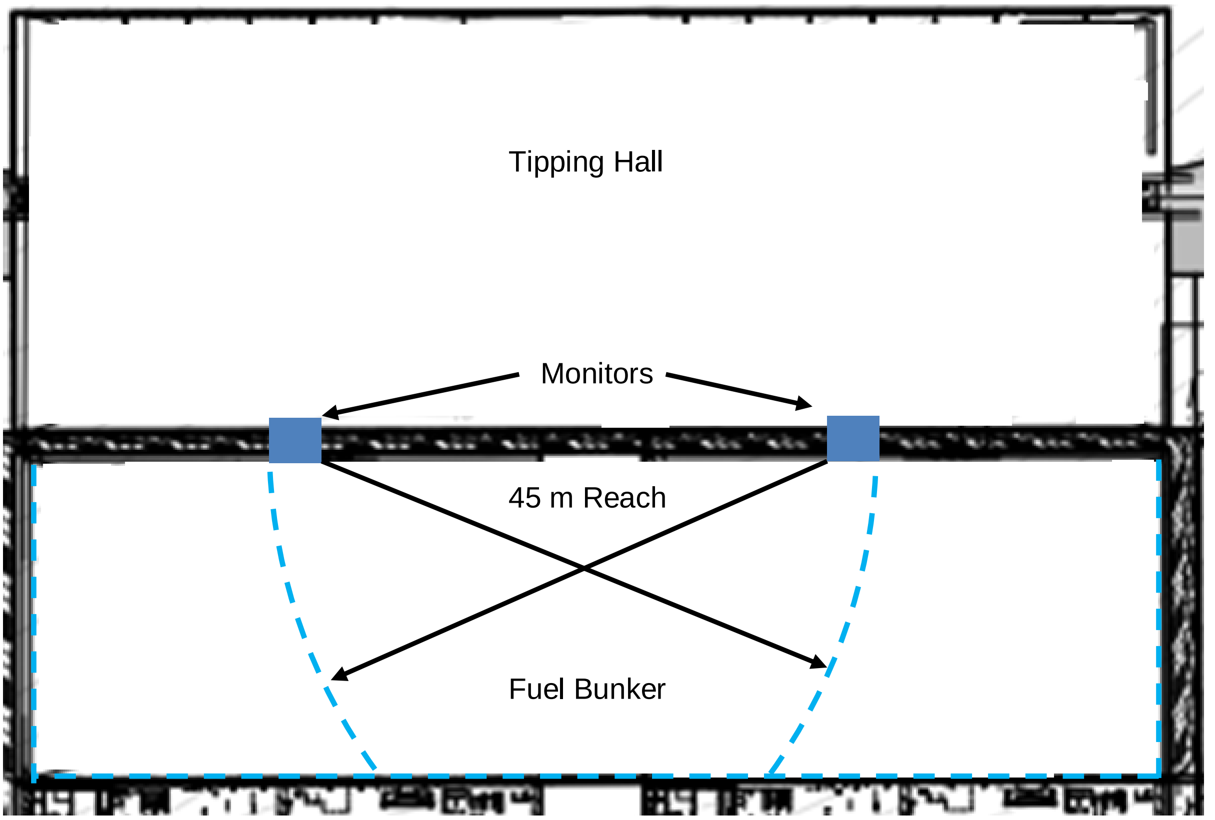


Figure 6-1: Monitor Spray Distances

### 6.2.3 PAC Silo Fire

Activated carbon is difficult to ignite and general will burn slowly as a smouldering fire as noted in **Section 4.3.6**. To combat a fire several methods could be used;

- Deluge system
- Hydrants hose application; and

- Oxygen exclusion (nitrogen blanketing).

As the fire would eb slow burning and smouldering, it is likely that a fire would not damage the full contents of the silo. However, the application of water to the fire would damage the product resulting in significant delays to in replacing the product and cleaning/drying the silo. Therefore, alternative methods may be more appropriate to extinguish this type of fire.

Nitrogen blanketing has been recommended for investigation for controlling the hazardous zones within the PAC silo. ***It is recommended that nitrogen blanketing protection systems should be further investigated for the purpose of extinguishing a potential fire within the PAC silo (i.e. exclusion of oxygen).***

### 6.2.4 Transformer Bund Fire

There will be a total of 42.5 $m^3$ of oil stored in each transformer. Clause 11.11 of AS1940 (Ref. 4) has been used to determine the fire protection required for each transformer installed at the site. It is noted that transformer oil is classified as a combustible liquid and so the combustible liquid provisions of Clause 11.11 apply. The fire protection requirements are displayed in **Table 6-2**.

**Table 6-2: Transformer Oil Bund Fire Protection**

| EQUIPMENT | QUANTITY |
|---|---|
| Powder-type extinguisher | 1 |

*Note: If the transformers are stored together in the same bund, 2 powder-type extinguishers will be required.*

## 6.3 PUMP SET

The recommended installation of monitors will require a pressure of 700kPa (minimum) for each monitor. The pressure provided by the water mains will be insufficient to meet the requirements for the monitors. ***Therefore, it is recommended that a pump set be installed to provide adequate water pressure for the monitors***. To comply with AS2419, Clause 6 the pump set should include two pumps with at least one driven by a compression ignition engine.

## 6.4 FIRE WATER REQUIREMENTS

The amount of firewater required by the monitors and the hoses at the site is discussed in the following sub-sections to ensure that there is sufficient firewater available should the protection systems be required.

### 6.4.1 Fire Hoses

Table 2.1 of AS2419 (Ref. 9) would require that 3 hydrant outlets be operating simultaneously with each outlet capable of delivery 600 L/min. This would be commensurate with the assessed fire hazards detailed above, whereby a hose for foam application would be used and two hoses for cooling adjacent areas to the fire would be applied.

Allowing for 4 hours of operation, the total amount of water required by the hydrants would be:

$$Fire\ Hose_{water} = 3 \times 600 \times 60 \times 4 = 432{,}000\ L$$

### 6.4.2 Monitors

The fire brigade would be expected to arrive within half an hour of the fire being detected. Therefore, it would be necessary for the monitors to have sufficient water for half an hour of operation. A monitor has a volumetric flow rate of 1200 L/min. The total amount of water required by the monitors during this time would be:

$$Monitor_{water} = 2 \times 1900 \times 30 = 114{,}000$$

### 6.4.3 Total

The total amount of water required to be stored at the site is the sum of the monitor and hydrant water requirements. This is 432,000 + 114,000 = 546,000 L. ***Therefore, it is recommended that provisions be made to store at least 546,000 L at the site***.

# 7 CONCLUSIONS AND RECOMMENDATIONS

## 7.1 CONCLUSIONS

A hazard identification table was developed for the energy from waste (EfW) facility to identify potential hazards that may be present at the site as a result of operations or storage of materials. Based on the identified hazards, scenarios were postulated that may result in an incident with a potential for offsite impacts. Postulated scenarios were discussed qualitatively and any scenarios that would not impact offsite were eliminated from further assessment. Scenarios not eliminated were then carried forwards for consequence analysis.

Incidents carried forwards for consequence analysis were assessed in detail to estimate the impact distances. Impact distances were developed into scenario contours and overlaid onto the site layout diagram to determine if an offsite impact would occur. The consequence analysis showed that none of the scenarios would impact over the site boundary and so a fatality would not occur at the site boundary and therefore the cumulative risk at the site boundary would be less than 50 chances pmpy.

Based on the analysis conducted, the risks at the site boundary are not considered to be exceeded.

In addition to the preliminary hazard analysis (PHA) a fire risk assessment (FRA) was conducted to ensure adequate fire services would be available to combat the identified scenarios.

## 7.2 RECOMMENDATIONS

The following recommendations from the PHA have been made regarding the EfW facility;

- Development of a work permit system, including hot work permits;
- Development of hazardous area diagrams in accordance with AS60079.10.2 be conducted;
- Ignition sources within the hazardous area should be controlled according to AS60079.14;
- Installation of monitor(s) in the waste bunker (further monitor recommendations below); and
- Investigate the feasibility of installing explosion venting in the PAC silos.

The following recommendations from the FRA for fire protection have been made regarding the EfW facility;

*Diesel Bund*

- 1 powder type fire extinguisher per bunded area;
- 1 hose reel with foam making capabilities per bunded area; and
- 1 hydrant with foam making capabilities per bunded area.

Waste Bunker

- Monitors should be installed to provide complete coverage of the waste bunker;
- Two 1900 L/min monitors are recommended for installation to provide complete coverage within the fuel bunker as shown in **Figure 7-1**;
- Monitors are recommended for installation such that access is provided externally from the fuel bunker; and

- Monitors are recommended for installation on raised platforms to prevent trucks from colliding with the monitors.

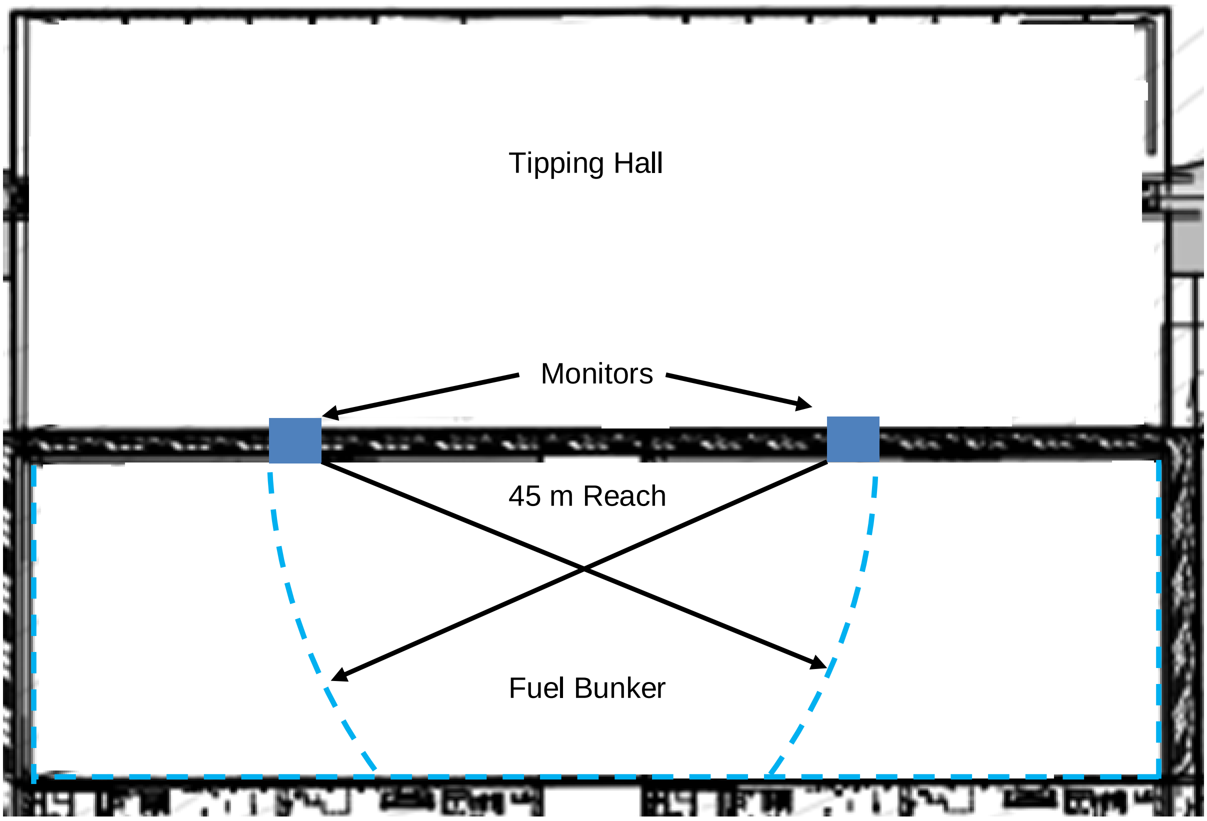


**Figure 7-1: Monitor Spray Distances**

PAC Silo

- Investigate the potential of nitrogen blanketing for the purpose of fire protection (via oxygen exclusion).

Transformers

- 1 powder-type fire extinguisher per transformer.

Pumping and Water Availability

- A pump set is recommended for installation to provide adequate water pressure for the monitors (two pumps one of which is driven by a compression ignition engine); and
- At least 546,000 L of firewater is recommended to be stored at the site.

# 8 REFERENCES

## 8.1 REFERENCES


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# APPENDIX A HAZARD IDENTIFICATION TABLE

| AREA/OPERATION | HAZARD CAUSE | HAZARD CONSEQUENCE | SAFEGUARD |
|---|---|---|---|
| Ammonium Hydroxide Store | ▪ Physical impact with tank or deterioration of tank resulting in a leak | ▪ Spill of ammonium hydroxide to adjacent area with potential for offsite impacts washed into drains | ▪ Tank bunding<br>▪ Regular deliveries so any leaks would be identified<br>▪ Bollards around bund<br>▪ Spill kits<br>▪ Site stormwater retention system |
| Low Sulphur Diesel | ▪ Physical impact with tank or deterioration of tank resulting in a leak | ▪ Spill of diesel to adjacent area with potential for offsite impacts if washed into drains<br>▪ Ignition of spill and pool fire<br>▪ Delayed ignition of unconfined vapours and flash fire<br>▪ Delayed ignition of confined vapours and vapour cloud explosion | ▪ Tank bunding<br>▪ Regular deliveries so any leaks would be identified<br>▪ No ignition sources in diesel store as per AS1940<br>▪ No smoking on the site premises<br>▪ Fire protection (hydrants, extinguishers)<br>▪ Site stormwater retention system |
| PAC | ▪ Dust is liberated within the silo<br>▪ Ignition source present within the hazardous area zone<br>▪ Sufficient confinement within the silo | ▪ Ignition of dust resulting in a dust explosion within the silo | ▪ No smoking on the site premises<br>▪ Fire protection (hydrants, extinguishers)<br>▪ Controlled ignition sources within the silo (Hazardous Area) |

| | | | |
|---|---|---|---|
| Waste Storage Bunker | ▪ Prohibited waste (DGs) unintentionally delivered to site | ▪ Ignition of waste and fire within the waste bunker | ▪ Bunker contained within a concrete pit within a building<br>▪ Waste is processed prior to delivery to site – reduced likelihood of prohibited waste being delivered into the bunker |
| Stack emissions | ▪ Bi-products of combustion | ▪ Release of gases/particles to atmosphere such as;<br>• Carbon monoxide<br>• Hydrogen chloride<br>• Sulphur dioxide<br>• Volatile organic compounds (VOC)<br>• Particulates<br>• Ammonia<br>• Nitrogen oxides<br>• Furans and dioxins | ▪ Emission monitored continuously by an automatic computerised system<br>▪ Regular reporting of emission concentrations<br>▪ Ammonia injection to break down NOx compounds into nitrogen and oxygen<br>▪ Injection of hydrated lime to remove hydrogen chloride<br>▪ Injection of PAC to absorb (VOC)<br>▪ Combustion temperature maintained at 850$^{o}$C to ensure thermal destruction of dioxins, furans and other undesirable combustion products<br>▪ Fabric filters to capture particulate<br>▪ Two counter current oxygen input streams to create turbulence and provide complete combustion to minimise carbon monoxide generation<br>▪ Emission from a stack to allow dispersion of products at ground level<br>▪ Low sulphur diesel used in combustion |

| | | | |
|---|---|---|---|
| Transformer | ▪ Arcing within transformer, vaporisation of oil and rupture of oil reservoir | ▪ Transformer oil spill in to bund and bund fire | ▪ Bunded<br>▪ Fire protection (hydrants, extinguishers)<br>▪ Fire walls |
| Residue Silo | ▪ PAC ejected within silo | ▪ Ignition of dust cloud resulting in a dust cloud explosion | ▪ Dilutent present (ash from combustion) |
| Calcium Hydroxide | ▪ Damaged silo | ▪ Release of calcium hydroxide | ▪ Solid form - limit spread of release<br>▪ Isolated stormwater system at the site<br>▪ Not classified as a DG |
| Turbine | ▪ Failed bearing and heating | ▪ Vapourisation of turbine lubricant and ignition and turbine fire | ▪ Regular vibrational analysis turbine |
| Truck | ▪ Uncontrolled waste within delivery truck | ▪ Ignition and truck fire | ▪ Hydrants<br>▪ Hose reels<br>▪ Procedures |

# APPENDIX B CONSEQUENCE ANALYSIS

## B1. INCIDENTS ASSESSED IN DETAILED CONSEQUENCE ANALYSIS

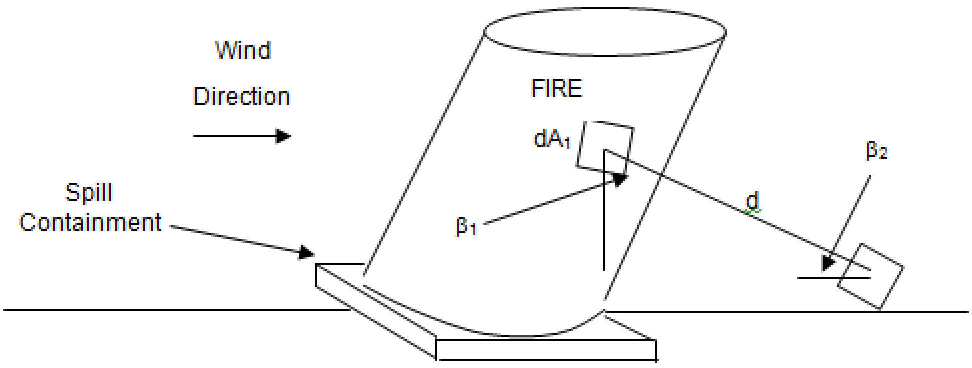
The following incidents are assessed for consequence impacts.

- Diesel tank leak, spill, immediate ignition and pool fire;
- PAC dust cloud, ignition and dust cloud explosion;
- Ignition of waste in bunker and full bunker fire;
- Transformer Oil Spill, Ignition and Pool Fire; and
- Ignition of waste in truck and truck fire.

## B2. SPREADSHEET CALCULATOR (SSC)

The SSC is designed on the basis of finite elements. The liquid flame area is calculated as if it is a circle to find the radius for input into the SSC model.

The SSC is designed on the basis of finite elements. The liquid flame area is calculated as if it is a circle to find the radius for input into the SSC model. **Appendix Figure B-1** shows a typical pool fire, indicating the target and fire impact details.




**Appendix Figure B-1: Heat Radiation on a Target from a Cylindrical Flame**

A fire in a bund or at a tank roof will act as a cylinder with the heat from the cylindrical flame radiating to the surrounding area. A number of mathematical models may be used for estimating the heat radiation impacts at various distances from the fire. The point source method is adequate for assessing impacts in the far field; however, a more effective approach is the view factor method, which uses the flame shape to determine the fraction of heat radiated from the flame to a target. The radiated heat is also reduced by the presence of water vapour and the amount of carbon dioxide in air. The formula for estimating the heat radiation impact at a set distance is shown in **Equation B-1**.

$Q = EF\tau$ **Equation B-1**

Where:

- Q = incident heat flux at the receiver (kW/m$^2$)
- E = surface emissive power of the flame (kW/m$^2$)
- F = view factor between the flame and the receiver
- $\tau$ = atmospheric transmissivity

The calculation of the view factor (F) in Equation 1 depends upon the shape of the flame and the location of the flame to the receiver. F is calculated using an integral over the surface of the flame, S. The formula can be shown as:

$$F = \int\int_s \frac{\cos\beta_1 \cos\beta_2}{\pi d^2}$$ **Equation B-2**

**Equation B-2** may be solved using the double integral or using a numerical integration method in spread sheet form. This is explained below.

For the assessment of pool fires, a Spread Sheet Calculator (SCC) has been developed, which is designed on the basis of finite elements. The liquid flame area is calculated as if the fire is a vertical cylinder, for which the flame diameter is estimated based on the fire characteristics (e.g. contained within a bund). Once the flame cylindrical diameter is estimated, it is input into the SSC model. The model then estimates the flame height, based on diameter, and develops a flame geometric shape (cylinder) on which is performed the finite element analysis to estimate the view factor of the flame. **Appendix Figure B-1** shows a typical pool fire, indicating the target and fire impact details.

The SSC integrates the element $dA_1$ by varying the angle theta $\theta$ (the angle from the centre of the circle to the element) from zero to 90$^o$ in intervals of 2.5 degrees. Zero degrees. represents the straight line joining the centre of the cylinder to the target (x0, x1, x2) while 90$^o$ is the point at the extreme left hand side of the fire base. In this way the fire surface is divided up into elements of the same angular displacement. Note the tangent to the circle in plan. This tangent lies at an angle, gamma, with the line joining the target to where the tangent touches the circle (x4). This angle varies from 90$^o$ at the closest distance between the liquid flame (circle) and the target (x0) and gets progressively smaller as $\theta$ increases. As $\theta$ increases, the line x4 subtends an angle phi $\Phi$ with x0. By similar triangles we see that the angle gamma $\gamma$ is equal to 90- $\theta$ - $\Phi$ . This angle is important because the sine of the angle give us the proportion of the projected area of the plane. When $\gamma$ is 90$^o$, sin($\gamma$) is 1.0, meaning that the projected area is 100% of the actual area.

Before the value of $\theta$ reaches 90$^o$ the line x4 becomes tangential to the circle. The fire cannot be seen from the rear and negative values appear in the view factors to reflect this. The SSC filters out all negative contributions.

For the simple case, where the fire is of unit height, the view factor of an element is simply given by the expression in **Equation B-3**:

$$VF = \Delta A \frac{\sin\gamma}{\pi \times X4 \times X4}$$ **Equation B-3**

Where $\Delta$A is the area of an individual element at ground level.

*Note: the denominator (π. x4. x4) is a term that describes the inverse square law for radiation assumed to be distributed evenly over the surface of a sphere.*

Applying the above approach, we see the value of x4 increase as $\theta$ increase, and the value of sin($\gamma$) decreases as $\theta$ increase. This means that the contribution of the radiation from the edge of the circular fire drops off quite suddenly compared to a view normal to the fire. Note that the SSC adds up the separate contributions of **Equation B-3** for values of $\theta$ between zero until x4 makes a tangent to the circle.

It is now necessary to do two things: (i) to regard the actual fire as occurring on top of a fire wall (store) and (ii) to calculate and sum all of the view factors over the surface of the fire from its base to its top. The overall height of the flame is divided into 10 equal segments. The same geometric technique is used. The value of x4 is used as the base of the triangle and the height of the flame, as the height. The hypotenuse is the distance from target to the face of the flame (called X4'). The angle of elevation to the element of the fire (alpha $\alpha$) is the arctangent of the height over the ground distance. From the cos($\alpha$) we get the projected area for radiation. Thus there is a new combined distance and an overall equation becomes in **Equation B-4**:

$$VF = \Delta A \frac{\sin\gamma \times \cos\alpha}{\pi \times X4 \times X4}$$ **Equation B-4**

The SCC now turns three dimensional. The vertical axis represents the variation in $\theta$ from 0 to 90$^o$ representing half a projected circle. The horizontal axis represents increasing values of flame height in increments of 10%. The average of the extremes is used (e.g. if the fire were 10 m high then the first point would be the average of 0 and 1 i.e. 0.5 m), the next point would be 1.5 m and so on).

Thus the surface of the flame is divided into 360 equal area increments per half cylinder making 720 increments for the whole cylinder. Some of these go negative as described above and are not counted because they are not visible. Negative values are removed automatically.

The sum is taken of the View Factors in **Equation B-3**. Actually the sum is taken without the ΔA term. This sum is then multiplied by ΔA which is constant. The value is then multiplied by 2 to give both sides of the cylinder. This is now the integral of the incremental view factors. It is dimensionless so when we multiply by the emissivity at the "face" of the flame (or surface emissive power, SEP), which occurs at the same diameter as the fire base (pool), we get the radiation flux at the target.

The SEP is calculated using the work by Mudan & Croche (Ref. 10 & Ref. 11) which uses a weighted value based on the luminous and non-luminous parts of the flame. The weighting is based on the diameter and uses the flame optical thickness ratio where the flame has a propensity to extinguish the radiation within the flame itself. The formula is shown in **Equation B-5**.

$$SEP = E_{max}e^{-sD} + E_s(1 - e^{-sD})$$ **Equation B-5**

Where;

$E_{max}$ = 140

S = 0.12

$E_s$ = 20

D = pool diameter

The only input that is required is the diameter of the pool fire and then estimation for the SEP is produced for input into the SSC.

The flame height is estimated using the Thomas Correlation (Ref. 12) which is shown in **Equation B-6**.

$$H = 42d_p\left[\frac{\dot{m}}{\rho_a\sqrt{gd_p}}\right]^{0.61}$$ **Equation B-6**

Where;

$d_p$ = pool diameter (m)

$\rho_a$ = density of air (1.2 kg/m$^3$ at 20$^o$C)

$\dot{m}$ = burning rate (kg/m$^2$.s)

$g = 9.81\ m/s^2$

**Appendix Table B-1** provides noteworthy heat radiation values and the corresponding physical effects of an observer exposed to these values (Ref. 2).

**Appendix Table B-1: Heat Radiation and Associated Physical Impacts**

| HEAT RADIATION (KW/M$^2$) | IMPACT |
|---|---|
| 35 | ▪ Cellulosic material will pilot ignite within one minute's exposure<br>▪ Significant chance of a fatality for people exposed instantaneously |
| 23 | ▪ Likely fatality for extended exposure and chance of a fatality for instantaneous exposure<br>▪ Spontaneous ignition of wood after long exposure<br>▪ Unprotected steel will reach thermal stress temperatures which can cause failure<br>▪ Pressure vessel needs to be relieved or failure would occur |
| 12.6 | ▪ Significant chance of a fatality for extended exposure. High chance of injury<br>▪ Causes the temperature of wood to rise to a point where it can be ignited by a naked flame after long exposure<br>▪ Thin steel with insulation on the side away from the fire may reach a thermal stress level high enough to cause structural failure |
| 4.7 | ▪ Will cause pain in 15-20 seconds and injury after 30 seconds exposure (at least second degree burns will occur) |
| 2.1 | ▪ Minimum to cause pain after 1 minute |

**Appendix Table B-2** provides the noteworthy overpressure values and the corresponding physical effects of an observer exposed to these values (Ref. 2).

**Appendix Table B-2: Overpressure and Associated Physical Impacts**

| HEAT RADIATION (KW/M$^2$) | IMPACT |
|---|---|
| 70 | ▪ Threshold of lung damage<br>▪ 100% chance of fatality for a person in a building or in the open<br>▪ Complete demolition of houses |
| 35 | ▪ House uninhabitable<br>▪ Wagons and plant items overturned<br>▪ Threshold of eardrum damage<br>▪ 50% chance of fatality for a person in a building and 15% chance of fatality for a person in the open |

| HEAT RADIATION ($KW/M^2$) | IMPACT |
|---|---|
| 21 | ▪ Reinforced structures distort<br>▪ Storage tanks fail<br>▪ 20% chance of fatality to a person in a building |
| 14 | ▪ House uninhabitable and badly cracked |
| 7 | ▪ Damage to internal partitions and joinery but can be repaired<br>▪ Probability of injury is 10%. No fatality |
| 3.5 | ▪ 90% glass breakage<br>▪ No fatality and very low probability of injury |

## B3. DIESEL TANK LEAK, SPILL, IMMEDIATE IGNITION AND BUND FIRE

Diesel tanks are stored in a bund with dimensions 10.4 m by 14 m. If a large enough leak occurred, a pool would form within the bund with dimensions of the bund. If ignited a bund fire could developed across the surface of the pool. The dimensions of the bund have been used to estimate a circular diameter of a fire in the diesel bund for input into the SEP and SSC models.

$$A = L \times W = 14 \times 10.4 = 145.6\, m^2$$

$$D = \sqrt{\frac{4 \times 145.6}{\pi}} = 13.5\, m$$

The following data was input into the SSC;

- Fire diameter – 13.5 m
- SEP – 43.7 $kW/m^2$
- Burning rate – 0.022 $kg/m^2.s$ (combustible liquid, Ref. 10)

The results of the analysis are shown in **Appendix Table B-3.**

**Appendix Table B-3: Heat Radiation Impacts from Diesel Bund Fire**

| HEAT RADIATION ($KW/M^2$) | DISTANCE (M) |
|---|---|
| 35 | 6.1 |
| 23 | 7.6 |
| 12.6 | 10.4 |
| 4.7 | 17.5 |
| 2.1 | 26.0 |

## B4. PAC DUST CLOUD, IGNITION AND DUST CLOUD EXPLOSION

If PAC dust is ejected into the air with sufficient dispersion, containment, oxygen and an ignition source, a dust cloud explosion could occur. Similarly to vapour cloud explosions, dust clouds have a lower explosive limit based on the concentration and the strength of the ignition source for which it won't ignite. Unlike vapour clouds, dust clouds don't have a well-defined upper explosive limit although it is estimated that above 2-3 $kg/m^3$ an explosion won't occur (Ref. 7).

There exists a variant of the TNT equivalent model discussed in **Section B5** to estimate the over pressure of a dust cloud explosion. To estimate the amount of dust that can contribute to the explosion the stoichiometry of the reaction must be reviewed as the carbon can only react with the total concentration of oxygen in the air. The reaction between carbon and oxygen is;

$$C + O_2 \rightarrow CO_2$$

Therefore, for everyone 1 mole of carbon, 1 mole of oxygen is required. The dust cloud explosion has been modelled as if a delivery has just occurred (resulting in dust in the air space in the silo) and has been filled to 75%. The silo has a volume of 104 $m^3$ and at 75% full leaving an air space of 26 $m^3$. To estimate the amount of oxygen available in this air space, the ideal gas law has been used which is shown in **Equation B-7**.

$$PV = nRT \qquad \textbf{Equation B-7}$$

The following information has been used:

- P = Pressure (1 atm)
- V = Volume (26,000 L)
- n = moles
- R = 0.08206 $L.atm.K^{-1}.mol^{-1}$
- T = Temperature (298 K)

Rearranging **Equation B-7** to make n the subject and using the information above, the number of moles of oxygen available in the air space to participate in the explosion can be estimated. The results of this calculation show that there is 1063 moles of oxygen present. Using the stoichiometry ratio, 1063 moles of carbon could participate in the explosion which gives a carbon in air mass of 12.75 kg or 0.5 kg/$m^3$.

To estimate the explosion overpressure, the TNT equivalent method is used. This method equates the quantity of dust in the cloud to an equivalent quantity of TNT by **Equation B-8**.

$$W_{TNT} = \alpha \left( \frac{WH_c}{H_{TNT}} \right) \qquad \textbf{Equation B-8}$$

The other parameters required in this equation are;

- W = mass of fuel in the dust cloud (12.75 kg)
- $H_c$ = heat of combustion of the fuel (32,800 kJ/kg for carbon Ref. 13)
- $H_{TNT}$= TNT blast energy (5420 kj/kg) (Ref. 12)
- $\alpha$ = explosion efficiency (conservatively estimated to be 0.3 for dusts, Ref. 7)

Inputting the above information into **Equation B-8** gives an equivalent mass of TNT of 23 kg.

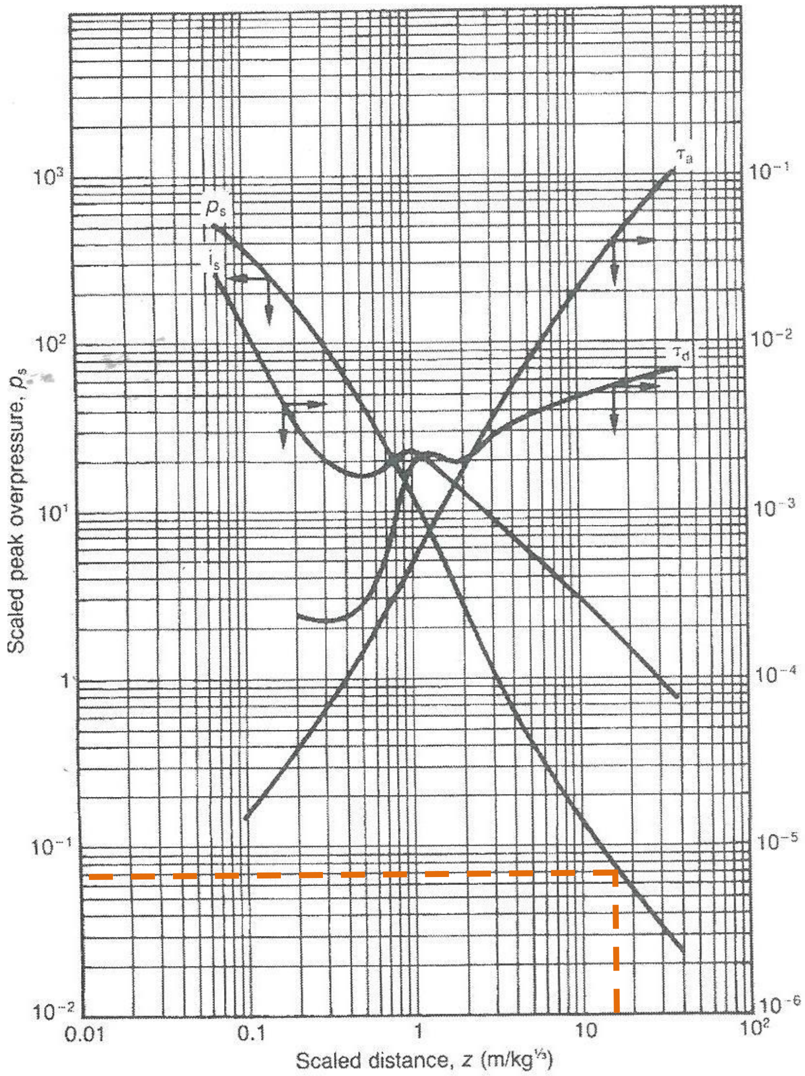
Overpressure is now calculated using a scaled distance curve, based on actual distance from the blast and the TNT equivalent, this is given **Equation B-9**.

$$Z = \frac{R}{(W_{TNT})^{\frac{1}{3}}} \qquad \textbf{Equation B-9}$$

Where:

- Z = scaled distance (unit less)
- R = distance from the blast (m)
- $W_{TNT}$= kg equivalent of TNT

HIPAP No.4 (Ref.3) indicates that the maximum permissible overpressure at the site boundary is 7 kPa, pressures exceeding this value would require additional assessment. Hence, from **Appendix Figure B-2,** for an over pressure of 7kPa, Z = 16, therefore R is calculated to be 33.5 m.




**Appendix Figure B-2: Scaled Parameter plots for TNT Explosions (Ref. 21)**

Repeating this procedure for over pressure values shown in **Appendix Table B-2** the impact distances can be estimated.

Overpressure impact distances are shown in **Appendix Table B-4**.

**Appendix Table B-4: Explosion Overpressure Distances for Dust Cloud Explosion**

| EXPLOSION OVERPRESSURE (KPA) | DISTANCE (M) |
|---|---|
| 70 | 11.4 |
| 35 | 15.7 |
| 14 | 28.5 |
| 7 | 45.6 |

## B5. IGNITION OF WASTE IN BUNKER AND FULL BUNKER FIRE

There is potential that a fire could develop within the waste bunker. A fire in this location may be difficult to combat as the fire seat may be shielded by waste overburden. All the materials within the bunker are combustible and so there is potential that a fire may grow to consume the entire waste storage.

The dimensions of the bunker are 107 m x 30 m which has a high aspect ratio which reduces the accuracy of the modelling which is based on circular fires. Therefore, to model the heat radiation of a fire in the waste bunker, the bunker has been broken down into 4 segments each with dimensions of 26.75 m x 30 m. These dimensions have been used to calculate a circular diameter to input into the SEP and SSC models.

$$A = L \times W = 26.75 \times 30 = 802.5\ m^2$$

$$D = \sqrt{\frac{4 \times 802.5}{\pi}} = 32\ m$$

The following data was input into the SSC;

- Fire diameter – 32 m
- SEP – 22.6 kW/m$^2$
- Burning rate – 0.022 kg/m$^2$.s (combustible liquid, Ref. 10).

A combustible liquid would burn faster than the fuel in the bunker which is solid. Solid fuel burning rates were not available so the combustible liquid burning rate has been adopted which is considered to be conservative.

The results of the analysis are shown in **Appendix Table B-5.**

**Appendix Table B-5: Heat Radiation Impacts from Waste Bunker Fire**

| HEAT RADIATION (KW/M$^2$) | DISTANCE (M) |
|---|---|
| 35 | Maximum heat flux is 22.6 kW/m$^2$ |
| 23 | Maximum heat flux is 22.6 kW/m$^2$ |
| 12.6 | 14.0 |
| 4.7 | 24.0 |
| 2.1 | 37.0 |

## B6. TRANSFORMER OIL SPILL, IGNITION AND BUND FIRE

Transformers contain oil to provide cooling and insulation. If arcing occurs within the transformer, the oil will rapidly heat generating gases above their auto ignition point. The pressure of the gases may rupture the reservoir allowing oxygen to enter resulting in the gases auto igniting. The oil is released from the reservoir and is ignited by the burning gases.

The transformer has dimensions of 9.21 m x 5.61 m x 4.14 m and contains 42,500 L of oil. To comply with AS1940 (Ref. 4) and NFPA 15 (Ref. 14) the bund would have approximate dimensions of 13.5 m by 10 m.

If the oil spill were ignited, a pool fire with the dimensions of the bund would occur. These dimensions have been used to calculate a circular diameter to input into the SEP and SSC models.

$$A = L \times W = 13.5 \times 10 = 135\ m^2$$

$$D = \sqrt{\frac{4 \times 135}{\pi}} = 13.11\ m$$

The following data was input into the SSC;

- Fire diameter – 13.1 m

- SEP – 44.9 kW/m$^2$
- Burning rate – 0.022 kg/m$^2$.s (combustible liquid, Ref. 10)

The results of the analysis are shown in **Appendix Table B-6.**

**Appendix Table B-6: Heat Radiation Impacts from a Transformer Bund Fire**

| HEAT RADIATION (KW/M$^2$) | DISTANCE (M) |
|---|---|
| 35 | 6.0 |
| 23 | 7.5 |
| 12.6 | 10.3 |
| 4.7 | 17.5 |
| 2.1 | 26.0 |

## B7. TRUCK FIRE

Products inside the truck trailers may catch on fire due to damaged packages which are exposed to an ignition source (i.e. Cigarette). The fire could grow to consume all the waste within the truck. A truck fire has been modelled based on the full trailer burning which has dimensions of approximately 14.63 m by 2.5 m (Ref. 17). The aspect ratio of a truck trailer is greater than the limit of the model (L/W = 2.5) hence this scenario has been modelled as smaller fires and the overall contour presented. The trailer length has been broken down into 6 segments each with dimensions of 2.44 m by 2.5 m.

These dimensions have been used to calculate a circular diameter to input into the SEP and SSC models.

$$A = L \times W = 2.44 \times 2.5 = 6.1\, m^2$$

$$D = \sqrt{\frac{4 \times 6.1}{\pi}} = 2.8\, m$$

The following data was input into the SSC;

- Fire diameter – 2.8 m
- SEP – 105.9 kW/m$^2$
- Burning rate – 0.022 kg/m$^2$.s (burning rate for combustible liquid hence selection of this figure is considered conservative as the burning rate of solid waste would be less Ref. 10)

The information in Error! Reference source not found. was input into the SSC to provide the esults of the modelling listed in **Appendix Table B-7**.

**Appendix Table B-7: Radiant Heat Impact Distances for a Truck Fire**

| HEAT RADIATION (kW/m$^2$) | EXPANDED WAREHOUSE OFFICE (m) |
|---|---|
| 35 | 2.9 |
| 23 | 3.5 |
| 12.6 | 4.8 |
| 4.7 | 7.9 |
| 2.1 | 11.7 |