PRELIMINARY HAZARD ANALYSIS,

STAGE 5B EXPANSION PROJECT,

TERMINALS PTY LTD, PORT BOTANY, NSW

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Stage 5B Expansion

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Rev	Date	Description	Reviewed By
A	22/7/13	Draft for Comment	Terminals
B	30/7/13	Comments on Rev A Included	Terminals
C	13/8/13	Stage 3 Pipebridge Details Added	Terminals
D	18/8/13	14 to 12 Tanks	Terminals
E	20/8/13	New Stage 5B Pump Bund Added	Terminals

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EXECUTIVE SUMMARY

Terminals Pty Ltd (Terminals) is proposing to install an additional 12 storage tanks within the existing Stage 5B area at the Port Botany terminal. This area is adjacent to Simblist Road and currently contains bulk liquid storage tanks, a bitumen processing facility and diesel / bitumen road tanker loadout facilities.

These tanks will store a range of general combustible liquids (C1 or C2) ranging from hydrocarbon oils, biodiesels and base oils for a range of chemical customers.

As part of the project requirements, a Preliminary Hazard Analysis (PHA) is required. This report details the results from the analysis.

The risks associated with the Stage 5B combustible liquids tanks and associated equipment at the Terminals site, Port Botany, have been assessed and compared against the DoPI risk criteria.

In summary:

1. Fires:

- No risk of injury or fatality at residential areas or other sensitive land uses as the separation distance is large, i.e. 1 km or larger to residential areas;

- As the estimated radiant heat levels from potential fire events are approximately 12.6 kW/m^2 or lower at neighbouring industrial facilities and the ignition probability of any spills is low for combustible liquids, the likelihood of fatality at these locations is acceptably low and there exists a high probability of escape; and

- Propagation to neighbouring industrial facilities is not expected given that the significant levels of radiant heat are largely contained on-site.

2. Vapour explosions:

- These are considered rare events for these types of facilities and materials, and hence the risk of injury, fatality and/or propagation at residential areas or other sensitive land uses (i.e. more than 1 km away) or at neighbouring facilities is not considered intolerable.

3. The shipping and off-site road transport activities associated with this project are commensurate with the zoning for the Port Botany area and are not considered intolerable. There are no changes to shipping transfers as a result of this project.

4. Societal risk is qualitatively concluded to be acceptable given:

- Few events analysed in the study have the potential for off-site impact and, for the ones that do, their likelihood is acceptably low; and

- The population density in the Port Botany area is relatively low.

Therefore, the results of this PHA show that the risks associated with the proposed changes comply with the DoPI guidelines for tolerable fatality, injury, irritation, propagation and societal risk. Also, risks to the biophysical environment from potential hazardous events are broadly acceptable.

Additionally, the proposed new tanks and equipment have no significant impact to the cumulative individual risk contours (for future development planning) as presented in the Port Botany Land Use Safety Study by DUAP in 1996.

The primary reason for the low risk levels from the proposed changes is that significant consequential impacts from potential hazardous events (mainly radiant heat from fires) do not extend far from the relevant storage areas.

The following recommendations are made from this review:

1. Perform a HAZOP study and a construction safety study on the proposed changes;

2. Check the existing fire prevention, detection and protection facilities for the proposed new tanks;

3. Update the existing safety management system, including the emergency response plan, for the proposed new tanks and equipment; and

4. Perform a SIL study on the proposed storage tanks and associated equipment to ensure the instrumented protective loops are suitably designed and are of adequate reliability for the potential hazardous events that can occur.

GLOSSARY

API	American Petroleum Institute
AS	Australian Standard
ASME	American Society for Mechanical Engineers
BLB	Bulk Liquids Berth
CCTV	Closed circuit television
DoPI	NSW Department of Planning and Infrastructure
DUAP	Department of Urban Affairs and Planning
EPA	Environmental Protection Authority
HAZAN	Hazard analysis
HAZOP	Hazard and operability study
HIPAP	Hazardous Industry Planning Advisory Paper
ISO	International Standards Organisation
LEL	Lower explosion limit
LPG	Liquefied petroleum gas
LNG	Liquefied natural gas
PHA	Preliminary hazard analysis
PPE	Personnel protective equipment
QRA	Quantitative risk assessment
ROSOV	Remotely operated shut-off valves
ROV	Remotely operated valves
SEP	Surface emissive power
SIL	Safety Integrity Level
SPC	Sydney Ports Corporation
TNO	The Netherlands Organisation of Applied Scientific Research
UEL	Upper explosive limit
VIE	Vacuum insulated expander

REPORT

1 INTRODUCTION

1.1 BACKGROUND

Terminals Pty Ltd (Terminals) is proposing to install an additional 12 storage tanks within the existing Stage 5B area at the Port Botany terminal. This area is adjacent to Simblist Road and currently contains bulk liquid storage tanks, a bitumen processing facility and diesel / bitumen road tanker loadout facilities.

The main features of the proposal are summarised as follows:

- An additional 12 storage tanks totalling 14,500 cubic metres;
- Two new interconnecting pipelines to the existing docklines exchanger pit stage 3, located on the other side of the pipeline corridor; means no new docklines to the wharf will be required;
- Increase the number of gantries for filling road tankers at the existing Stage 3 loading bay from two to three;
- New road tanker loading pumps for all new tanks located in two pump bunds: one next to the existing Stage 5 pumps and the other on the eastern Stage 5 bund wall;
- A new exchanger pit area for the 12 additional tanks; and
- Two small slops tanks for testing product quality during ship discharge.

These tanks will store a range of general combustible liquids (C1 or C2) such as hydrocarbon oils, biodiesels and base oils for a range of chemical customers.

The bunded area at Stage 5 will be modified with sub bunds. This will be designed to meet the legislated requirements as well as good industry practice by complying with AS1940 to contain 100 per cent of the contents of the largest tank plus an allowance for fire water.

The net Port Botany shipping and truck movements for these types of products will decrease. The reason is this increased storage capacity at Terminals is to replace a major part of the existing chemical storage at Vopak Site A as the latter is being shut down at the end of 2013. Throughputs and movements associated with the additional 12 tanks at Stage 5B have been estimated at 30-40,000 tonnes per annum. This equates to an additional 6 to 10 road tankers per day for this site and 5 to 8 additional ships per year (for Terminals) depending on the product breakdown and parcel sizes (as some of these products may share existing ship arrivals).

As part of the project requirements, a Preliminary Hazard Analysis (PHA) is required. This PHA has been prepared in accordance with the guidelines published by the NSW Department of Planning and Infrastructure (DoPI) Hazardous Industry Planning Advisory Paper (HIPAP) No 6 (Ref 1). Terminals have appointed Pinnacle Risk Management Pty Ltd (Pinnacle Risk Management) to prepare this Preliminary Hazard Analysis report.

As a revised PHA was prepared for the existing storage and handling equipment in the Stage 5B area in 2011 (Ref 2) then this analysis is an update of this report, i.e. all Stage 5B tanks and processes are included.

1.2 OBJECTIVES

The main aims of this PHA study are to:

- Identify the credible, potential hazardous events associated with the existing and proposed Stage 5B expansion equipment;
- Evaluate the level of risk associated with the identified potential hazardous events to surrounding land users, including other Port Botany companies and their operations, and compare the calculated risk levels with the risk criteria published by the DoPI in HIPAP No 4 (Ref 3);
- Review the adequacy of the proposed safeguards to prevent and mitigate the potential hazardous events; and
- Where necessary, submit recommendations to Terminals to ensure that the proposed modifications are operated and maintained at acceptable levels of safety and effective safety management systems are used.

1.3 SCOPE

This PHA assesses the credible, potential hazardous events and corresponding risks associated with the Stage 5B equipment at the Terminals Port Botany facility with the potential for off-site impacts. Both the existing and proposed equipment is assessed to allow a propagation analysis to be performed.

In summary, the assessment includes:

- The new equipment and operations associated with the proposed additional 12 tanks;
- The existing tanks, e.g. 270 (currently used to store diesel), and their associated equipment;
- The existing bitumen processing facilities (as assessed in Ref 2); and
- The modified Stage 3 road tanker loading bay that will be used for the combustible liquids stored within the additional new 12 tanks.

Off-site transport risk is not included in this PHA as the products are currently loaded into road tankers at the neighbouring Vopak Site A, i.e. no net change for the products of interest.

As the berth operations, shipping activities and pipeline corridor transfers do not require changes as a result of the additional tanks then these areas are also not included in this assessment.

1.4 METHODOLOGY

In accordance with the approach recommended by the DoPI in HIPAP 6 (Ref 1) the underlying methodology of the PHA is risk-based, that is, the risk of a particular potentially hazardous event is assessed as the outcome of its consequences and likelihood.

The PHA has been conducted as follows:

- Initially, the Stage 5B equipment and its location were reviewed to identify credible, potential hazardous events, their causes and consequences. Proposed safeguards were also included in this review;
- As the equipment is located at a significant distance from other land users, the consequences of each potential hazardous event were estimated to determine if there is any possible unacceptable off-site impacts;
- Included in the analysis is the risk of propagation between the Stage 5B equipment and the existing equipment (both onsite and off-site);
- Where adverse off-site impacts can occur, the likelihood of each potential hazardous event was reviewed, using appropriate techniques / methods, to check if there is any significant increase to existing risk levels and if the risk levels are within the criteria in HIPAP 4 (Ref 3); and
- A comparison is made to the existing Port Botany regional study (Ref 4) to determine if there is any impact on cumulative risk.

1.5 FINDINGS AND RECOMMENDATIONS

The risks associated with the Stage 5B combustible liquids tanks and associated equipment at the Terminals site, Port Botany, have been assessed and compared against the DoPI risk criteria.

In summary:

1. Fires:

- No risk of injury or fatality at residential areas or other sensitive land uses as the separation distance is large, i.e. 1 km or larger to residential areas;

- As the estimated radiant heat levels from potential fire events are approximately 12.6 kW/m^2 or lower at neighbouring industrial facilities and the ignition probability of any spills is low for combustible liquids, the likelihood of fatality at these locations is acceptably low and there exists a high probability of escape; and
- Propagation to neighbouring industrial facilities is not expected given that the significant levels of radiant heat are largely contained on-site.

2. Vapour explosions:

- These are considered rare events for these types of facilities and materials, and hence the risk of injury, fatality and/or propagation at residential areas or other sensitive land uses (i.e. more than 1 km away) or at neighbouring facilities is not considered intolerable.

3. The shipping and off-site road transport activities associated with this project are commensurate with the zoning for the Port Botany area and are not considered intolerable. There are no changes to shipping transfers as a result of this project.

4. Societal risk is qualitatively concluded to be acceptable given:

- Few events analysed in the study have the potential for off-site impact and, for the ones that do, their likelihood is acceptably low; and
- The population density in the Port Botany area is relatively low.

Therefore, the results of this PHA show that the risks associated with the proposed changes comply with the DoPI guidelines for tolerable fatality, injury, irritation, propagation and societal risk. Also, risks to the biophysical environment from potential hazardous events are broadly acceptable.

Additionally, the proposed new tanks and equipment have no significant impact to the cumulative individual risk contours (for future development planning) as presented in the Port Botany Land Use Safety Study by DUAP in 1996.

The primary reason for the low risk levels from the proposed changes is that significant consequential impacts from potential hazardous events (mainly radiant heat from fires) do not extend far from the relevant storage areas.

The following recommendations are made from this review:

1. Perform a HAZOP study and a construction safety study on the proposed changes;

2. Check the existing fire prevention, detection and protection facilities for the proposed new tanks;

3. Update the existing safety management system, including the emergency response plan, for the proposed new tanks and equipment; and

4. Perform a SIL study on the proposed storage tanks and associated equipment to ensure the instrumented protective loops are suitably designed and are of adequate reliability for the potential hazardous events that can occur.

2 SITE DESCRIPTION

The proposed expansion is to be located on the Terminals leased land at 45 Friendship Road, Port Botany. The land is part of the Port Botany reclamation area owned by SPC (leased to operator NSW Ports) and is devoted to port and associated activities. The nearest residents are over 1 kilometre away. See Figure 1 for details of the site location.

Port Botany is one of the major ports in New South Wales with trade including petroleum products, liquefied petroleum gas (LPG), and liquid chemicals. The majority of industries in the Port Botany industrial region are involved in the storage and distribution of these products and are located on Friendship Road in the vicinity of the site. These industries include:

Hydrocarbons: The terminal imports and stores ethylene, propane and butane for transport by pipeline to Botany Industrial Park manufacturing site at Botany.

Vopak (Sites A and B): These terminals store and distribute products similar to those at Terminals Pty Ltd although the chemical storage at Site A is due to cease operations at the end of 2013.

Origin Energy: The site imports LPG by sea tankers and stores it for distribution by road tankers.

Elgas Pty Ltd: An underground storage cavern and above-ground facilities for storing and distributing LPG.

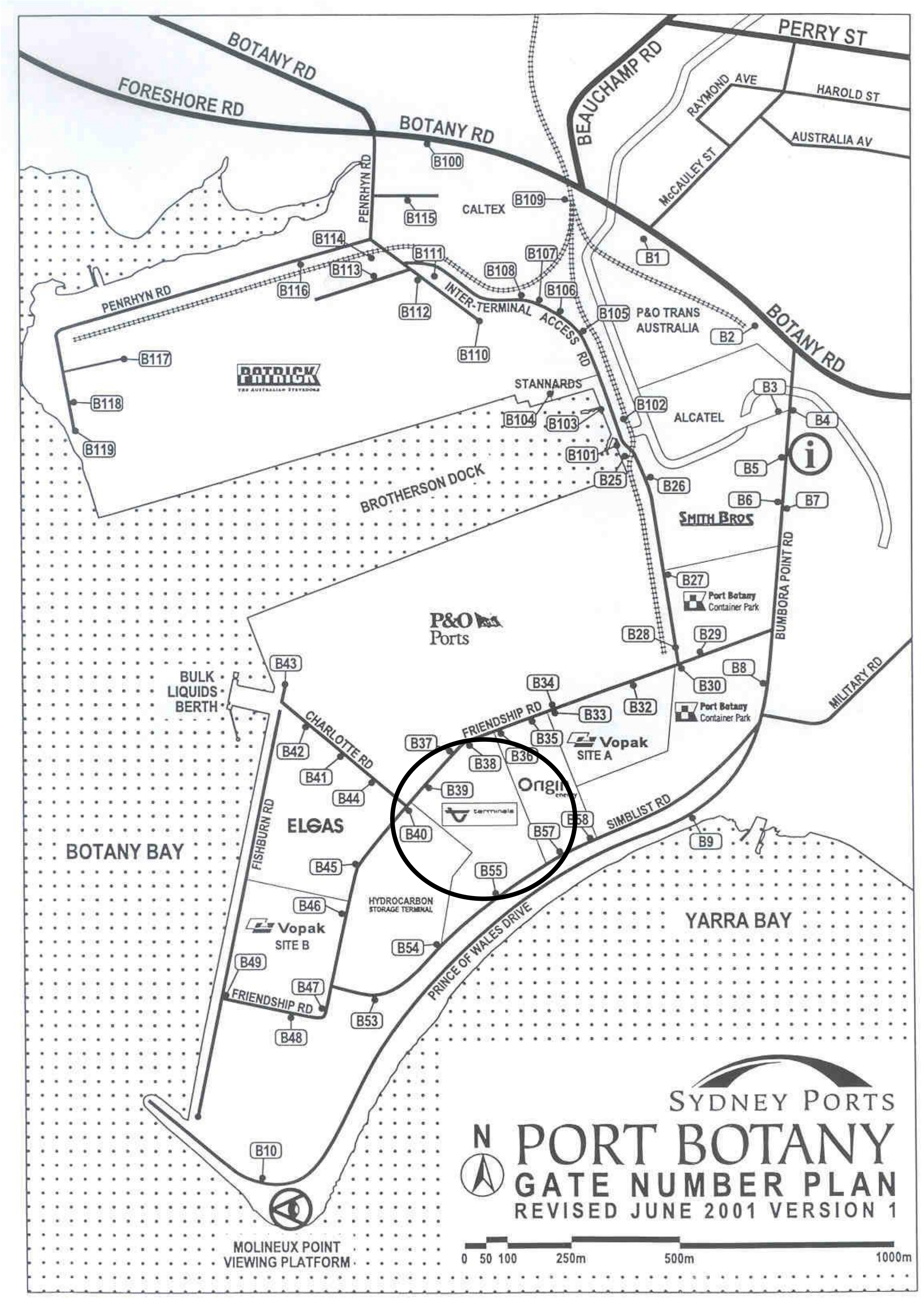
P&O Ports, Molineaux Point: A facility for storing and distributing shipping containers.

Construction of the Terminals site began in 1978 and has expanded in five major stages to date. The terminal has 74 tanks of various sizes with a total storage capacity of 87,000 m^3 of bulk liquids ranging from animal fats, vegetable oils, industrial chemicals, petrochemicals, bitumen and petroleum products. These products are handled into and out of the terminal by:

- Sea-going parcel tankers from the Bulk Liquids Berth at the end of Charlotte Road;
- Road tankers;
- Drums;
- Pipeline from the Orica petrochemical complex at Botany; and
- Iso-tank containers.

The dangerous goods stored at the site are Classes 3, 6, 8 and 9. Combustibles (C1 and C2) are also stored in bulk. Liquid nitrogen is stored in a VIE for tank blanketing etc.

Figure 1 - Site Location



The site layout, including the proposed bitumen facilities, is shown in Figure 2.

Security of the site is achieved by a number of means. This includes site personnel and security patrols by an external security company (weekends and night patrols). The site normally operates 5 days per week (day shift only, depending on whether a ship is in or not). Also, the site is fully fenced (adequate construction) and non-operating gates are locked (e.g. to the pipeline corridor). The main entrance and exit gates are normally closed. A security swipe card is required to open them. Security cameras (CCTV) are installed for staff to view visitors prior to entry as well as observe selected areas of the site.

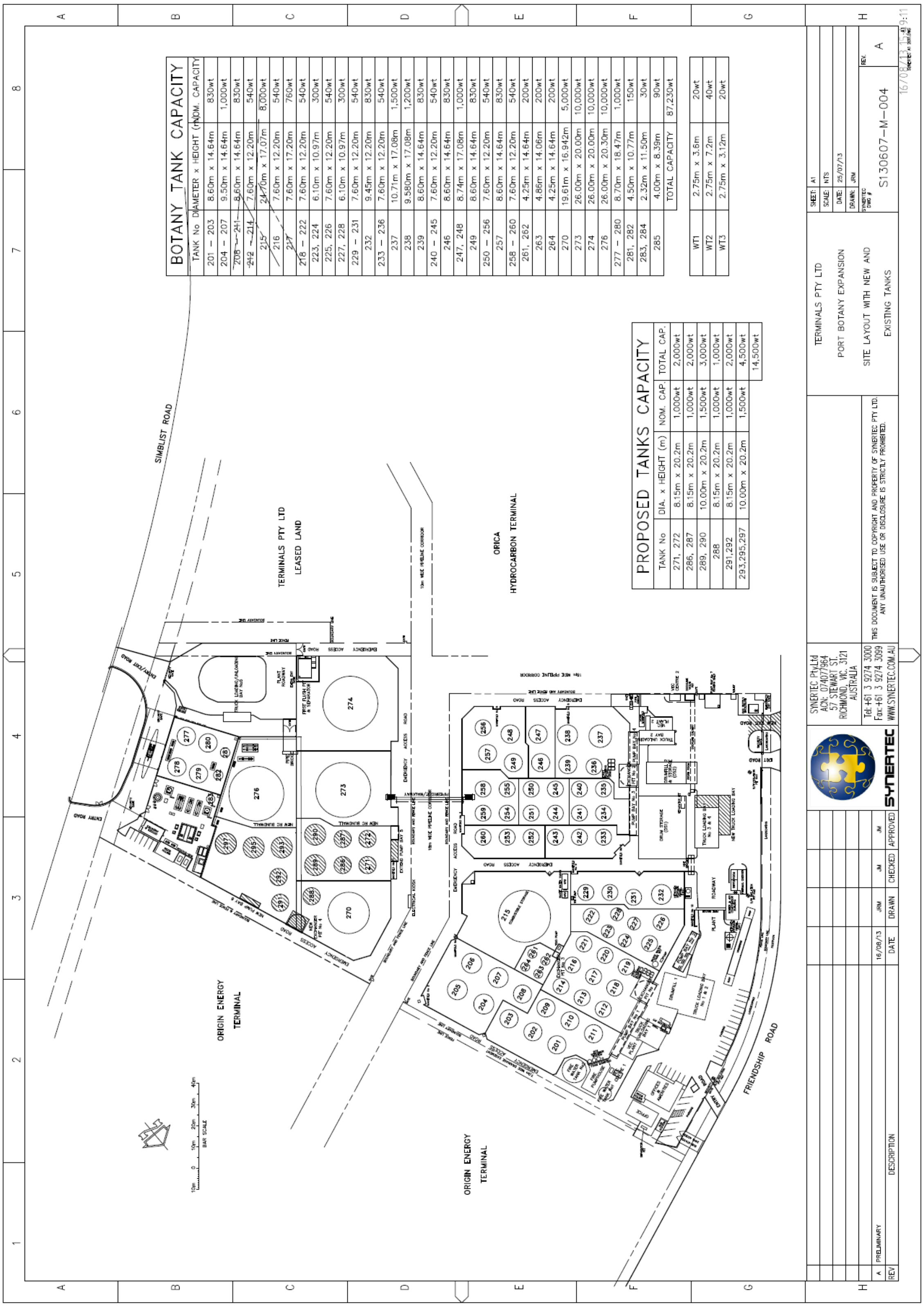
Security personnel are site inducted, have a checklist of areas to inspect (e.g. the fire water jacking pump and the main diesel fire water pumps), are trained to accept alarms and report (to the Terminals staff) on unusual incidents.

For the bitumen area, the operators also provide additional security as this process operates 24/7.

There are approximately 25 people on site (plus drivers, visitors etc) during normal working hours.

Depending on weather conditions, the site may lie under the flight path to /from Sydney Airport. There are no known natural hazards associated with this location that pose unacceptable levels of risk.

Figure 2 – Site Layout



BOTANY TANK CAPACITY

TANK No	DIAMETER x HEIGHT (m)	NOM. CAPACITY
201 – 203	8.60m x 14.64m	830wt
204 – 207	9.50m x 14.64m	1,000wt
208 – 211	8.60m x 14.64m	830wt
212 – 214	7.60m x 12.20m	540wt
215	24.70m x 17.07m	8,000wt
216	7.60m x 12.20m	540wt
217	7.60m x 17.20m	760wt
218 – 222	7.60m x 12.20m	540wt
223, 224	6.10m x 10.97m	300wt
225, 226	7.60m x 12.20m	540wt
227, 228	6.10m x 10.97m	300wt
229 – 231	7.60m x 12.20m	540wt
232	9.45m x 12.20m	830wt
233 – 236	7.60m x 12.20m	540wt
237	10.71m x 17.08m	1,500wt
238	9.580m x 17.08m	1,200wt
239	8.60m x 14.64m	830wt
240 – 245	7.60m x 12.20m	540wt
246	8.60m x 14.64m	830wt
247, 248	8.74m x 17.08m	1,000wt
249	8.60m x 14.64m	830wt
250 – 256	7.60m x 12.20m	540wt
257	8.60m x 14.64m	830wt
258 – 260	7.60m x 12.20m	540wt
261, 262	4.25m x 14.64m	200wt
263	4.86m x 14.06m	200wt
264	4.25m x 14.64m	200wt
270	19.61m x 16.942m	5,000wt
273	26.00m x 20.00m	10,000wt
274	26.00m x 20.00m	10,000wt
276	26.00m x 20.30m	10,000wt
277 – 280	8.70m x 18.47m	1,000wt
281, 282	4.50m x 10.77m	150wt
283, 284	2.32m x 11.50m	30wt
285	4.00m x 8.39m	90wt
	TOTAL CAPACITY	87,230wt

WT1	2.75m x 3.6m	20wt
WT2	2.75m x 7.2m	40wt
WT3	2.75m x 3.12m	20wt

PROPOSED TANKS CAPACITY

TANK No	DIA. x HEIGHT (m)	NOM. CAP.	TOTAL CAP.
271, 272	8.15m x 20.2m	1,000wt	2,000wt
286, 287	8.15m x 20.2m	1,000wt	2,000wt
289, 290	10.00m x 20.2m	1,500wt	3,000wt
288	8.15m x 20.2m	1,000wt	1,000wt
291,292	8.15m x 20.2m	1,000wt	2,000wt
293,295,297	10.00m x 20.2m	1,500wt	4,500wt
			14,500wt

3 DESCRIPTION OF THE PROPOSED MODIFICATIONS

The proposed new combustible liquids import, storage and road tanker loadout facilities are described as follows. The previous Stage 5 changes and equipment were described in Refs 5, 6 and 7 are not reiterated here.

In summary, the combustible liquids to be stored in the new tanks will be transferred from a ship at the Bulk Liquids Berth as per the current procedure for flammable liquids, combustible liquids and chemicals. The combustible liquids will be transferred to site via the existing docklines. That is, there is no change in the operations associated with shipping.

The docklines terminate at the existing exchanger pit number 3. There will be two new pipes from this exchanger pit to the Stage 5B area. These will run in the existing piperacks over the pipeline corridor. These two pipes will terminate at a new exchange pit south of tank 270 (exchanger pit number 4). From this exchanger pit, the products will be lined-up to the required tanks as per the existing exchanger pit operations on the site.

The 12 new tanks will be either 1,000 m^3 or 1,500 m^3 capacity within the existing Stage 5B area.

From the tanks, the combustible liquids will be pumped to the modified truck loading bays 3 and 4. The new pumps are to be located in either a bund to the east of the existing Stage 5 diesel load-out pumps or in a bund adjacent to the eastern Stage 5 bund wall. It is envisaged that two products (from separate tanks) can be transferred to road tankers at the same time. To facilitate the road tanker loading, there will be an additional 12 pump loading lines, installed on the existing piperacks over the pipeline corridor, to the road tanker bays.

The road tanker loading operation will be similar to the existing Stage 5 road tanker load-out design, i.e. bottom filling only, metered loading with automatic isolation valves to stop the flow and a Scully system for overfill / static protection.

3.1 PROPOSED TANKS

It is proposed to construct an additional 14,500 m^3 storage capacity within the Stage 5B area of the site; five tanks with 1,500 m^3 each and seven tanks with 1,000 m^3 each. The tanks are to be either 8.15 m or 10.0 m diameter and have an overall height of 20.2 metres. These tanks will be fixed roof, carbon steel tanks and used to store a range of hydrocarbon oils of a combustible (not flammable) nature, i.e. C1 or C2, including base oils, biodiesels and lubricating oils.

Protection systems on the storage tanks will include:

- Procedures for liquid transfers, stormwater management, regular maintenance and inspection (as per the existing tanks on site);

- Tank high level instruments to help protect against overfilling;
- Fully welded and tested carbon steel plate construction;
- Remote emergency shutdown valves on outlet (only open when loading trucks) includes a fusible link;
- Stainless steel piping interconnecting these tanks to filling lines from the Stage 3 exchanger pit and transfer lines to road tanker filling gantry (to minimise the risk of corrosion);
- Fire management plan and radiation protection systems for potential adjacent tank fire source suitable for combustible liquid storage as per AS1940;
- Emergency response plan including communication with site control centre;
- Structural integrity tests conducted every 10 years in accordance with AS1940;
- Non-return valves in pipelines at the Bulk Liquids Berth and all new tank inlet lines to prevent backflow, e.g. in case a ship breaks free of the berth;
- Containment of liquid within the existing Stage 5B bunds;
- Tank foundations will have an impervious membrane with 'tell-tale' drains installed for leak detection of the tank base;
- CCTV surveillance of new tanks from the existing site B (bitumen) control room; and
- Emergency alarms.

3.2 ROAD TANKER LOADING PROCEDURES

The loading of combustible liquids will be conducted from the existing but extended Stage 3 loading gantry. This will be undertaken using bottom metered automated loading systems. Loading interlock systems will be in-place to ensure that earth bonding connection and compartment overfill protection is active before loading can commence. Automatic bottom loading will be via purpose built tanker loading hoses. The trucks will load at a rate of up to 1,600 litres per minute into each truck compartment.

There are a number of protection features already in operation at the Stage 3 loading / unloading bay including:

- Procedures for operations, operator training, maintenance, training of maintenance employees, contractor safety training and emergencies;
- Specific liquid transfers and stormwater management;

- Requirement that the driver must be present during loading operations;
- Operator to be in attendance while loading (as well as the driver);
- Local Emergency Stop stations have been installed that initiate pump shutdowns and tank isolations;
- Substantial roofed area to minimise the potential contamination of stormwater;
- Facilities to contain spills or contaminated rainwater and to return this material to the existing liquid effluent tank and/or alternative storage tank;
- Fire water hose points;
- Foam supplies for foam attachment points;
- Foam and dry powder fire extinguishers;
- Existing adjacent road tanker loading operations for flammable liquids will continue to have foam protection;
- Loading ceases if air line breaks or supply fails as the automatic valves will fail closed;
- CCTV monitoring in place;
- Safety air brakes to ensure the truck's wheels remain in the locked position and hence to ensure that the truck cannot leave with the loading hose attached, i.e. drive-away protection;
- Truck electric's isolations switch;
- The Scully system is designed to dissipate any static electricity build-up and to prevent overflow by shutting down the loading system upon detecting a high level in any compartment;
- Dry break couplings to avoid leaks and spills while connecting and disconnecting hoses; and
- A containment system for any spills consistent with AS1940.

For safety reasons, there will be no queuing of trucks permitted within the site; consistent with existing site protocols along Friendship road. There is no potential for congestion or queuing along Simblist Road as truck gantry access is at Friendship Road.

3.3 SPILL MANAGEMENT

Specific operating and emergency procedures currently exist for the management of spills at the site and vary according to the magnitude of the spill as outlined below.

3.3.1 Very Minor Spill (<20 Litres)

- Contain the spill within the bunded area and/or by isolation of stormwater discharge from the site and/or local containment;
- Add appropriate absorbent; and
- Dispose of absorbent to an approved Environment Protection Authority (EPA) facility.

3.3.2 Minor Spill (<500 Litres)

- Contain the spill within the bunded area and/or by isolation of stormwater discharge from the site and/or local containment;
- Pump the contained liquid to the liquid effluent storage tanks; and
- Transport liquid to an approved EPA waste treatment facility.

3.3.3 Major Spill (>500 Litres)

- Contain the spill within the bunded area or by isolation of stormwater discharge from the site;
- Pump the liquid to the liquid effluent storage tanks and/or separate, clean, storage tank on site;
- Check the quality of the liquid by analyses; and
- Pending the results of the analysis:

  Return the liquid to the original tank

  Return the liquid to the client for reprocessing

  Classify the liquid for another use

  Treat the liquid

  Transport the liquid to the EPA's approved aqueous waste management facility at Lidcombe.

The bunded area at Stage 5B will be modified with sub-bunds. The final design will meet the legislated requirements as well as good industry practice by complying with the requirements of AS1940 to contain 100 per cent of the contents of the largest tank plus the required allowance for fire water.

The new combustible liquids tanks will be surrounded by both existing and new bund walls. The new walls are intermediate bund walls only. The wall height is yet to be finalised but as they will be lower than the perimeter bund walls then total containment for the existing tanks 273 and 276 will still be provided.

3.4 FIRE PREVENTION AND CONTROL

Fire protection for the proposed storage tanks is via the existing fire water ring main supplied by two diesel operated fire water pumps. There is 1,400 m^3 of water in storage with continuous replenishment from Sydney Water reticulation as required. These pumps are automatic upon opening up a hydrant due to low pressure activation. If the fire water systems are activated an alarm is raised to Fire and Rescue NSW.

An automatic foam deluge delivery system at the truck loading gantries for flammable liquids already exists. This system is activated by infrared detectors located in the truck bay which are inspected and checked every six months. The extended additional bay for combustible liquid loading / unloading will have fire water protection from the nearby existing fire water hydrants as well as portable fire extinguishers installed. At the exit of the existing loading bay is a manual fire call point. There will be an automatic emergency stop for the Stage 5B pumps and, in turn, the stage 5B tank outlet ROVs (remotely operated valves).

4 HAZARD IDENTIFICATION

4.1 HAZARDOUS MATERIALS

The combined stage 5B equipment will handle and store the following chemicals:

1. Combustible liquids such as diesel / biodiesel;
2. Bitumen;
3. Natural gas;
4. Hot oil; and
5. Catalyst (for the bitumen oxidation towers).

The hazards of bitumen, natural gas, hot oil and catalyst (i.e. the materials associated with the existing equipment) have been described and assessed in Ref 7 and are not reproduced here. The properties associated with the new combustible liquids are summarised in Table 1. This table contains a representative selection of the potential combustible liquids that may be stored in the new 12 tanks. The properties listed in Table 1 are understood to be representative of all possible combustible liquids to be stored in the new tanks.

Table 1 – Combustible Liquids Properties Summary

Product Name	C1 or C2	Flash Point (C)	Density kg/m^3
Chevron Neutral Oil	C2	192	860
Yubase 3	C2	>190	830
Group II 150N	C2	>204	860
Group II 500N	C2	>232	880
Brightstock	C2	>315	900

Fire fighting media includes water fog, foam, dry chemical and carbon dioxide. In a fire, the products include smoke, carbon dioxide and carbon monoxide.

As with all combustible liquids, they are generally difficult to ignite in normal operation. However, sprays are more easily ignited.

4.2 POTENTIAL HAZARDOUS INCIDENTS REVIEW

In accordance with the requirements of *Guidelines for Hazard Analysis*, (Ref 1), it is necessary to identify hazardous events associated with the tank operations. As recommended in HIPAP 6, the PHA focuses on “atypical and abnormal events and conditions. It is not intended to apply to continuous or normal operating emissions to air or water”.

A search of available literature and information was conducted to review the types of historical events that can occur with bulk fuel terminals and bitumen facilities. The search included the following references:

1. Frank Lees, Loss Prevention in the Process Industries (Ref 8);
2. Australian, US and UK Departments of Transport records;
3. US National Transport Safety Board statistics;
4. US Occupational Health and Safety Administration statistics;
5. US Chemical Safety and Hazard Investigation Board statistics;
6. UK Health and Safety Executive statistics; and
7. Previous risk studies for terminals.

4.3 HAZARDOUS EVENTS

In keeping with the principles of risk assessments, credible, hazardous events with the potential for off-site effects have been identified. That is, “slips, trips and falls” type events are not included nor are non-credible situations such as an aircraft crash occurring at the same time as an earthquake. The large majority of the specific release scenarios are generic equipment failures, e.g. failures of tanks, pipes etc, from previous industrial incidents. These are supplemented by process incidents due to other abnormal modes of operation, control system failure and human error.

The credible, significant incidents identified for the two existing diesel tanks (270 and 273) and the new 12 combustible liquids tanks in the Stage 5B area are summarised in the first Hazard Identification Word Diagram following (Table 2).

The credible, significant incidents identified for proposed bitumen facility at Stage 5 are summarised in the second Hazard Identification Word Diagram following (Table 3). This is reproduced from Ref 7 so that cumulative and propagation risk analysis can be performed in the following sections of this report.

These two hazardous event word diagrams present the causes and consequences of the events, together with major preventative and protective features that are included as part of the design.

Table 2 – Hazard Identification Word Diagram – Stage 5 Combustible Liquid Bulk Storage Tanks

Event ID No.	Hazardous Event	Causes	Possible Consequences	Proposed Prevention and Mitigation Control Measures
1.	Major mechanical failure of tanks	Metal fatigue Faulty fabrication Corrosion of tank base / weld Tank explosion due to lightning strike / breach of hazardous area ignition source controls Adjacent tank on fire Blocked vent	Large spillage of combustible materials in bund. Fire if ignited For historical tank explosions, some tanks have rocketed away from the foundations Impact to people (radiant heat and/or exposure to products), property and the environment (products of combustion)	Tanks designed to API 650 Regular maintenance and inspection procedures Tank and site fire protection facilities available Explosions only occur when ullage vapour is between LEL and UEL. For combustible liquids, the vapour concentration is expected to be below the LEL. Design conforms to AS1940 requirements
2.	Tank roof failure	Ignition, e.g. by lightning, of atmosphere within the roof space Vents blocked during filling procedure High speed filling	Tank top fire Initial explosion possible leading to a tank top fire Potential for spill into the bund with a fire if ignition occurs Boil over possible if water layer exists Impact to people (radiant heat and/or exposure to products), property and the environment (products of combustion)	Fire fighting system Regular maintenance and inspection procedures Level alarms, controlled tank filling Explosions prevention as per Item 1

Event ID No.	Hazardous Event	Causes	Possible Consequences	Proposed Prevention and Mitigation Control Measures
3.	Pipe failure (i.e. new piping within the terminal)	Corrosion Impact Maintenance work Pressure surge	Spillage of combustible material. Fire if ignited. Impact to people (radiant heat and/or exposure to products), property and the environment (products of combustion)	Regular maintenance and inspection procedures Emergency isolation valves on all tank outlet lines and non-return valves on tank inlet lines. Fire fighting system (including foam) Pipes sometimes in bunded areas Pipelines surge study The piping is designed to ASME 31.3 / AS 4041 to resist the combined effects on internal pressure due to contents, wind loads, earthquake forces and hydrostatic test loads
4.	Spillage of combustible material to the bunds	Tank overfilled during transfer Tank drain valve left open or tank sampling valve left open, e.g. human error	Spill into bund Bund fire if ignited Possible tank fire and boil over Impact to people (radiant heat and/or exposure to products), property and the environment (products of combustion)	Fire fighting as above One independent level device installed in conjunction with strict ullage monitoring protocols and tank filling infrequent at 2-4 times pa. Emergency shutdown system Operating procedures Sampling and inspection procedures prior to disposing of waste bund water

Event ID No.	Hazardous Event	Causes	Possible Consequences	Proposed Prevention and Mitigation Control Measures
5.	Leak during filling of road tanker	Failure of loading hose Leak from valves or fittings Road tanker overfill	Leak of combustible liquid in the loading area Fire if ignited Impact to people (radiant heat and/or exposure to products), property and the environment (products of combustion)	High level of surveillance and shutdown systems Drivers are well trained so as to minimise chance of operator error and ensure quick response to leaks Fire fighting as above Ignition sources controlled Scully truck overfill shutdown system
6.	Road tanker drive-away incident (i.e. driver does not disconnect the hose and drives away from the loading bay)	Failure of procedures and hardware interlocks	Leak of combustible liquid in the loading area Fire if ignited Impact to people (radiant heat and/or exposure to products), property and the environment (products of combustion) Ignition source present (road tanker engine), hence fire more likely	Driver training Driver not in cab during filling Brakes interlocked prior to connection and until disconnection Fire fighting as above "Dry-break" hose couplings
7.	Leak at product pumps	Pump seal, shaft or casing failures	Leak of combustible liquid in pump bund Fire if ignited Impact to people (radiant heat and/or exposure to products), property and the environment (products of combustion)	Single mechanical seal Condition monitoring and preventative maintenance of pumps Fire fighting as above Pumps in contained area

Event ID No.	Hazardous Event	Causes	Possible Consequences	Proposed Prevention and Mitigation Control Measures
8.	Road accident (off-site)	Bad road or traffic conditions	Most likely outcome is no loss of load Leak may occur, leading to fire Impact to people (radiant heat and/or exposure to products), property and the environment (products of combustion)	Design of road tankers to survive accident without a loss of containment - pipes and running gear designed to shear off without product loss Driver training and choice of routes to reduce accident potential
9.	Aircraft crash	Pilot error Bad weather Plane fault	Propagation to tank / bund fires Impact to people (radiant heat and/or exposure to products), property and the environment (products of combustion)	As per aviation standards
10.	Strong winds, earthquakes	Strong winds cause equipment damage etc	Loss of containment leading to a fire if ignited (as above)	The tanks are designed API 650 / AS 1692 / AS 1170 to resist the combined effects on internal pressure due to contents, weight of platforms, ladders, live loads, wind loads, earthquake forces and hydrostatic test loads Operations stopped in adverse weather conditions
11.	Breach of Security / Sabotage	Disgruntled employee or intruder	Possible release of product with consequences as per above	Security measures include fencing, CCTV, security patrols, operator / driver vigilance Pressure tests prior to commissioning transfer Pipe inspections prior to commissioning transfer; regularly during ship discharge and otherwise on a periodic basis

Table 3 – Hazard Identification Word Diagram – Bitumen Facility

Event ID No.	Hazardous Event	Causes	Possible Consequences	Proposed Prevention and Mitigation Control Measures
12.	Explosion within a bitumen tank or vessel	Buildup of flammable gases from the bitumen with subsequent source of ignition. Welding on a tank with bitumen still present. Unblocking pipes or vents with direct flames. Low level in the bitumen tanks with exposure of the heating tubes. This can lead to temperatures above the autoignition point for the vapours in the tank. Overheating a tank and hence the potential for greater flammable vapour generation. Smouldering of deposits on the underside of the roof can lead to high enough temperatures (if sufficient oxygen is present) for the flammable vapours to autoignite	Damage to the tank and possible injury to people nearby, e.g. by ejected bitumen. Potential for missile generation and propagation to nearby equipment, e.g. the bulk liquid tanks in the Stage 5 area. Explosions can result in a bitumen fire. For historical tank explosions, some tanks have rocketed away from the foundations	Bitumen tanks have frangible roofs to prevent excessive explosion overpressures developing. Bitumen tanks have 600 mm diameter emergency vents. Control of ignition sources throughout the terminal. All equipment is to be earthed. Hot work permits for maintenance. Unblocking procedures are based on the storage and handling of bitumen products standard (DR 07435 CP; previously AIP CP 20). Large storage tank temperatures are automatically controlled at about 145 C and smaller day storage tanks at about 190 C. Heating is by coils via hot oil and no direct flame heating. Hot oil high temperature is limited with alarms and trips. Storage tanks designed to maintain minimum level above heating floor coils.

Event ID No.	Hazardous Event	Causes	Possible Consequences	Proposed Prevention and Mitigation Control Measures
				Fire protection facilities available, e.g. ring main with hydrants
13.	Self-ignition of bitumen. Note that when oxygen levels fall below 3%, the tank condition favours the formation of pyrophoric materials. Smouldering of deposits can lower the oxygen levels to below 3%	Bitumen heated and exposed to air. Deposits can build-up, e.g. under tank roofs due to the condensation of hot vapours, which can auto-ignite around 190^{o}C or at lower temperatures if iron sulphide is present. Deposits can also self-heat if their thickness exceeds critical values. Deposit formation will increase with overheating, i.e. excessive vapour generation	Tank fire (typically slow burning) with toxic products of combustion and radiant heat emitted. Potential for injury to people nearby and environmental impact	Large storage tank temperatures are automatically controlled at about 145 C and smaller day storage tanks at about 190 C. Heating is by coils and no direct flame heating. Hot oil high temperature is limited with alarms and trips. Storage tanks are balanced with atmospheric air in breathing (21% oxygen). Storage tank roofs are not heated but they are insulated. Deposits within tanks are to be removed during ten year tank shutdowns when the tank is cool and high pressure water jetting or mechanical cutting tools are used
14.	Burns or exposure to hydrogen sulphide. Note that these events will not contribute to off-site risk but are included for completeness	People exposed to hot bitumen from losses of containment. People exposed to hydrogen sulphide from losses of containment or entering confined spaces	Burn injuries. Potential for toxic impact from hydrogen sulphide. This may result in fatality if the dose is high enough. Note that people may suffer loss of smell at high concentrations of hydrogen sulphide, e.g. 300 ppm	The piping design is to comply with existing Terminals and Australian Standards, e.g. AS4041, to minimise the likelihood of losses of containment. Trained first aiders on site for elevated temperature bitumen burns. Safety showers are to be located throughout the bitumen processing facility for quick

Event ID No.	Hazardous Event	Causes	Possible Consequences	Proposed Prevention and Mitigation Control Measures
				quenching of any hot bitumen that may be stuck on people's skin or for cooling of any burns. Road tanker loading is enabled by driver being in a protected booth and fumes extracted from area. Confined space entries, risk assessments and permits are included in the Terminals safety management system. The bitumen will not be heated above 200^{o}C in the storage tanks nor road tankers to avoid generating too much fumes. Fumes / vapours are handled by extracting / treating or returned to source tanks and are not free vented to limit exposure potential. Emergency response including ringing 000 to get an ambulance for the affected people to get to hospitals for further treatment
15.	Tank boilover	Water entering a tank and being heated	Steam will be generated with the potential to overpressure the tank, causing failure, and resulting in a loss of containment	All tanks to be kept above 100^{o}C to prevent water condensation. Tanks have 600 mm diameter emergency vents as well as open goose neck vents

Event ID No.	Hazardous Event	Causes	Possible Consequences	Proposed Prevention and Mitigation Control Measures
16.	Overflowing a bitumen tank	Incorrect conversion factors for changes in bitumen temperature. Failure of the level instruments	Potential for burns. Potential for a fire if exposed to source of ignition with injury to people, damage to equipment and environmental impact from products of combustion	Bitumen tanks safefill level to be nominated and included in the level monitoring and alarming system. Internal transfers to be done through a computer driven checking and monitoring system; in effect doubles the level gauging. Level instrumentation to be included in the existing Terminals preventative maintenance systems. Redundant independent level systems on all tanks with additional alarms. Tanks are bunded. Control of ignition sources in the bunded areas
17.	Major mechanical failure of tanks	Metal fatigue Faulty fabrication Corrosion of tank base / weld Adjacent tank on fire Blocked vent	Large spillage of bitumen in bund. Fire if ignited. Impact to people (radiant heat and/or exposure to products), property and the environment (products of combustion)	Tanks designed to API 650. Bitumen solidifies quickly when heating removed. Regular maintenance and inspection procedures. Tank and site fire protection facilities available

Event ID No.	Hazardous Event	Causes	Possible Consequences	Proposed Prevention and Mitigation Control Measures
18.	Loss of containment from piping systems	Pipe failures, e.g. due to corrosion, valves left open, hose failures, pump seal, shaft or casing failures	Potential for burns. Potential for a fire if exposed to source of ignition with injury to people, damage to equipment and environmental impact from products of combustion	Regular maintenance and inspection procedures. Emergency isolation valves on the outlet lines of the new tanks. Fire fighting system. Most pipes in bunded areas; all pumps are bunded. Pipelines surge study. The piping is designed to ASME 31.3 / AS 4041 to resist the combined effects on internal pressure due to contents, wind loads, earthquake forces and hydrostatic test loads. Trained first aiders on site for elevated temperature bitumen burns. Safety showers are to be located throughout the bitumen processing facility for quick quenching of any hot bitumen that may be stuck on people's skin or for cooling of any burns. Operators to wear additional appropriate PPE for handling bitumen if they have potential for exposure; i.e. heat resistant gauntlet gloves, face shield and hood (all skin protected). Bitumen hoses to be included in the existing

Event ID No.	Hazardous Event	Causes	Possible Consequences	Proposed Prevention and Mitigation Control Measures
				Terminals Hose Register with routine inspection, testing and replacement
19.	Loss of containment at the berth	Pipe failures, e.g. due to corrosion, valves left open, hose failures	Potential for burns. Potential for a fire if exposed to source of ignition with injury to people, damage to equipment and environmental impact from products of combustion. Potential for bitumen to enter the water and hence environmental impact	The piping design is to comply with existing Terminals and Australian Standards, e.g. AS4041, to minimise the likelihood of losses of containment. Operators to wear additional appropriate PPE for handling bitumen if they have potential for exposure; i.e. heat resistant gauntlet gloves, face shield and hood (all skin protected). Safety showers are located at the BLB for quick quenching of any hot bitumen that may be stuck on people's skin or for cooling of any burns. Trained first aiders on site for elevated temperature bitumen burns. Bitumen hoses to be included in the existing Terminals Hose Register with routine inspection, testing and replacement. The main processing areas are bunded

Event ID No.	Hazardous Event	Causes	Possible Consequences	Proposed Prevention and Mitigation Control Measures
20.	Loss of containment in the Pipeline Corridor	Pipe failures, e.g. due to corrosion, thermal overpressure or third party activity / malicious act	Most likely outcome is a spill onto the ground with subsequent cooling and solidification. Few sources of ignition exist in the Pipeline Corridor. Note, however, when solid deposits are heated, there is the risk of flammable vapours being evolved with subsequent ignition and burning of the bitumen	Regular maintenance and inspection procedures. Emergency isolation valves. Fire fighting system. Pipelines surge study. Routine inspections during transfers
21.	Insulation fires	Loss of containment of bitumen into the piping, tank or vessel insulation	Potential for fires, i.e. from burning of the bitumen and/or flammable vapours, and hence propagation to the adjoining system	Small amount of bitumen adsorbed as limited to about 50 mm thick insulation around tanks. Flammable vapours are limited and H_2S is readily noticeable at low odour levels of 0.005 ppm well before LEL. Combustible product. Fire fighting systems
22.	Failure of a hot oil heater coil	High temperature induced failure, cycling of the metal temperature, corrosion, material of construction failure	Potential for bitumen and flammable vapours to enter the heating circuit. The flammable vapours could ignite, e.g. when exiting the hot oil head tank	Hot oil piping designed to suit conditions. Hot oil piping system is higher pressure (usually 5 to 10 bar) than bitumen storage so leaks are into bitumen system. Top of bitumen tanks are designed for Zone 1 so no immediate ignition sources. Regular testing and monitoring of hot oil for degradation and in turn contamination. Fire fighting systems

Event ID No.	Hazardous Event	Causes	Possible Consequences	Proposed Prevention and Mitigation Control Measures
23.	Hot oil fires	Loss of containment of hot oil with subsequent ignition, e.g. pump seal failures	Hot oil fire with the potential to burn people and/or damage nearby equipment. Products of combustion, e.g. smoke, will have an environmental impact. Any fire in the bitumen processing area also has the potential to involve the oxidation catalyst (ferrous chloride). In this case, there is the potential for toxic products to be emitted, e.g. hydrogen chloride	Hot oil is combustible product at maximum temperature. Fire fighting systems
24.	Loss of containment of natural gas	Pipe failure, e.g. corrosion, flange failure or impact. Valve left open	Potential for a jet fire, flash fire or vapour cloud explosion (particularly if some degree of confinement exists), if ignited. These events can lead to injury and/or radiant heat / explosion overpressure damage to equipment. In the absence of confinement, most probable outcome will be jet or flash fires if ignited	Piping is copper and at low pressure. Piping is designed and constructed to AS 2885, Gas Pipelines code. Fully welded pipeline with no flanges in the natural gas pipeline except at regulator; metering and control valve stations / areas. All drain and vent valves are plugged. Annual pipeline inspection as part of the regular maintenance and inspection procedures. Piping is located in open areas promoting good dispersion of buoyant gas. Gas is odorous and periodically patrolling enables easy detection if leaking. Emergency Plan of isolation procedures when fire fighting

Event ID No.	Hazardous Event	Causes	Possible Consequences	Proposed Prevention and Mitigation Control Measures
25.	Internal explosion within the oil heaters	Passing natural gas isolation valves during a shutdown and the heaters are not adequately purged at startup	Potential for an internal explosion within the heater which can result in injuries to nearby personnel and/or damage to equipment. Historically, the effects of these types of incidents are generally local to the heaters	Double isolation valves as automatic shutdown. Pre-purge before start up sequence. Testing of shutdown and pre-purge sequence on a regular basis to AS 3788 as part of regular maintenance and inspection procedures
26.	Internal explosion within the combustor	Gas mixture is in the flammable region, e.g. during a startup, and a source of ignition is present, e.g. flame igniter	Potential for an internal explosion within the combustor which can result in injuries to nearby personnel and/or damage to equipment. Historically, the effects of these types of incidents are generally local to the combustors (the combustor is an open ended burner in a vertical chamber)	No flame shutdown of double isolation valves. Pre-purge before start up sequence. Testing of shutdown and pre-purge sequence on a regular basis to AS 3788 as part of regular maintenance and inspection procedures
27.	Transformer fires	Short circuiting, build-up of flammable gas (hydrogen) in the oil with subsequent ignition, loss of containment of oil with subsequent ignition	Potential for an initial explosion followed by a fire involving the transformer oil. Potential to damage nearby equipment and/or injure people	Low load, sealed 11KV transformer. Testing schedule for transformers and oil degradation. Separated from plant and people activity areas. Emergency Response Plan includes fire events

Event ID No.	Hazardous Event	Causes	Possible Consequences	Proposed Prevention and Mitigation Control Measures
28.	Leak during filling of road tanker	Failure of loading arm. Leak from valves or fittings. Road tanker overfill	Leak of bitumen in loading area. Fire if ignited. Impact to people (radiant heat and/or exposure to products), property and the environment (products of combustion)	High level of surveillance and immediate access button to shutdown systems. Drivers are well trained so as to minimise chance of operator error and ensure quick response to leaks. Ignition sources controlled at top of road tanker. Road tanker overfill shutdown system. Fire fighting systems
29.	Road tanker drive-away incident (i.e. driver does not disconnect the hose and drives away from the loading bay)	Failure of procedures and hardware interlocks	Leak of bitumen in loading area. Fire if ignited. Impact to people (radiant heat and/or exposure to products), property and the environment (products of combustion)	Driver training. Driver not in cab during filling but monitoring at same elevation as loading arm. Automatic loading system instructs driver on actions required. Ignition sources controlled at top of road tanker. Fire fighting systems

4.4 SAFETY MANAGEMENT SYSTEMS

Safety management systems are intended to minimise the risk from potentially hazardous installations by a combination of hardware (i.e. equipment) and software factors (managements systems such as procedures, policies, plans, training etc). To ensure safe operation of the terminal, both the hardware and the software systems must be of high standard.

The proposed terminal modifications will necessitate changes to the existing safety management system.

Terminals' operations and safety management systems at Port Botany have been previously reviewed during hazard audits by Pinnacle Risk Management. These hazard audits have found that the safety management systems in use at the time of the audits are generally adequate for the nature of the hazards present.

4.4.1 Safety Software in Risk Assessment

In risk assessments, incidents are assessed in terms of consequences and frequencies (where necessary), leading to a measure of risk. Where possible, frequency data comes from actual experience. However, in many cases, the frequencies used are generic, based on historical information from a variety of plants and processes with different standards and designs.

The quality of the management systems (known as "safety software") in place in these historical plants will vary. Some will have little or no software, such as work permits and modification procedures, in place. Others will have exemplary systems covering all issues of safe operation. Clearly, the generic frequencies derived from a wide sample represent the failure rates of an "average plant". This hypothetical average plant would have average hardware and software safety systems in place.

If an installation with below average safety software is assessed using generic frequencies, it is likely that risk will be underestimated. Conversely, if a plant is above average, the risk will probably be overestimated. However, it is extremely difficult to quantify the effect of software on plant safety.

Therefore, Pinnacle Risk Management adopts a policy which does not attempt to quantitatively account for the presence of and quality of software safety systems. It is assumed that the generic failure frequencies used apply to installations which have safety software corresponding to accepted industry practice. It is believed that this assumption will be conservative in that it will overstate the risk from well managed installations such as the Terminals' site. Therefore, any quantitative approach is valid (i.e. conservative) only if safety management within the operation being assessed is of a high standard. For this site, the safety management system is ISO accredited.

5 RISK ANALYSIS

The assessment of risks to both the public as well as to operating personnel around this industrial development requires the application of the basic steps outlined in Section 1. As per HIPAP 6 (Ref 1), the chosen analysis technique should be commensurate with the nature of the risks involved.

The typical risk analysis methodology attempts to take account of all credible hazardous situations that may arise from the operation of processing plants etc. For quantitative risk analysis (QRA), this is done by first taking a probabilistic approach to vessel and pipe failures for all vessels containing hazardous materials. Specific incidents, identified by a variety of techniques, are then added and the combined data used to generate composite risk contours which can be used for both the public and plant personnel.

Having assembled data on possible incidents, risk analysis requires the following general approach for individual incidents (which are then summated for all potential recognised incidents to get cumulative risk):

Risk = Likelihood x Consequence

For QRA and hazard analysis, the consequences of an incident are calculated using standard correlations and probit-type methods which assess the effect of fire radiation, explosion overpressure and toxicity to an individual, depending on the type of hazard.

In this PHA, however, the approach adopted to assess the risk of the identified hazardous events is scenario based risk assessment. The reasons for this approach are:

1. The distance to residential and other sensitive land users is large for the Port Botany area and hence it is unlikely that any significant consequential impacts, e.g. due to radiant heat from fires, from the Stage 5B equipment will have any significant contribution to off-site risk; and

2. The distance between the on-site tanks and other equipment to the neighbouring industrial facilities is relatively large, hence, the consequential impacts may not have any significant contribution to off-site industrial risk.

Therefore, appropriate analysis of credible scenarios is performed in this PHA. Initially, the consequences of the potential events with off-site impact are assessed. For the events which do not contribute to off-site risk (as determined by the risk criteria in HIPAP No. 4 (Ref 3) then no further risk analysis is warranted. When the consequence of an event does contribute to off-site, the likelihood and hence risk is then analysed as required.

The risk criteria applying to developments in NSW are summarised in Table 4 below (from Ref 3).

Table 4 - Risk Criteria, New Plants

Description	Risk Criteria
Fatality risk to sensitive uses, including hospitals, schools, aged care	0.5×10^{-6} per year
Fatality risk to residential and hotels	1×10^{-6} per year
Fatality risk to commercial areas, including offices, retail centres, warehouses	5×10^{-6} per year
Fatality risk to sporting complexes and active open spaces	10×10^{-6} per year
Fatality risk to be contained within the boundary of an industrial site	50×10^{-6} per year
Injury risk – incident heat flux radiation at residential areas should not exceed 4.7 kW/m^2 at frequencies of more than 50 chances in a million per year or incident explosion overpressure at residential areas should not exceed 7 kPa at frequencies of more than 50 chances in a million per year	50×10^{-6} per year
Toxic exposure - Toxic concentrations in residential areas which would be seriously injurious to sensitive members of the community following a relatively short period of exposure	10×10^{-6} per year
Toxic exposure - Toxic concentrations in residential areas which should cause irritation to eyes or throat, coughing or other acute physiological responses in sensitive members of the community	50×10^{-6} per year
Propagation due to Fire and Explosion – exceed radiant heat levels of 23 kW/m^2 or explosion overpressures of 14 kPa in adjacent industrial facilities	50×10^{-6} per year

As discussed above, the consequences of the potential hazardous events are initially analysed to determine if any events have the potential to contribute to the above-listed criteria and hence worthy of further analysis.

5.1 POOL FIRE MODELLING

The credible hazardous events associated with the Stage 5B terminal and bitumen operations are largely pool fires due to potential losses of containment being ignited. The potential fire events associated with all the Stage 5B area tanks and bunds are detailed in Table 6 (all events are included for cumulative and propagation risk assessment purposes). This data is used in the fire modelling. A discussion on burndown rates and surface emissive powers (SEP) is given below.

Burndown Rates:

For burning liquid pools (Ref 9), heat is transferred to the liquid via conduction, radiation and from the pool rim. For pool fires less than 1 m diameter, the radiative heat transfer and the resulting burning rate increases with pool diameter. For pool diameters greater than 1 m, radiative heat transfer dominates, thus a constant burning rate is expected.

Wind can affect the burning rate (experiments have shown both an increase and decrease in burning rates due to the effects wind) but also can affect flame stability (and hence average flame emissive power) (Ref 10). Therefore, average reported values for burndown rates are used in this study.

For very large pool fires with diameters greater than 5 to 10 m, there is some evidence of a slight decrease in burning rate. This is believed to be due to poor mixing with air and is unlikely to reduce the burning rate by more than 20%.

Typical burndown rates for diesel are 4 to 6 mm/min (Refs 8 and 11). Therefore, an average value of 5 mm/min is taken as the fire scenarios typically involve large diameters for this material. Due to the heavy nature of bitumen, the burndown rate is taken to be 2 mm/min (Ref 8). The combustible liquids to be stored in the additional tanks are heavy oils. Typical burndown rates for these types of materials are 2 to 3 mm/min (Ref 8). A value of 3 mm/min is used in this study for these combustible liquids.

The burning rate is used in the determination of flame height. Normally, the higher the burning rate, the higher the estimated flame height.

Surface Emissive Power:

Surface emissive power can be either derived by calculation or by experimentation. Unfortunately, experimental values for surface emissive powers are limited.

When calculated, the results can be overly conservative, particularly for large diameter fires, as it is assumed that the entire flame is at the same surface emissive power. This is not the case for large diameter fires as air entrainment to the centre of the flame is limited and hence inefficient combustion occurs.

The combustible liquids to be stored in the new tanks are all heavy oils where the molecular ratio of carbon to hydrogen is high and therefore significant smoke generation is expected. This is also true for diesel and bitumen.

A surface emissive power correlation that fits experimental data well for products that produce smokey flames is as follows (Ref 9):

SEP (average) = $140 \times e^{(-0.12xD)} + 20 \times (1 - e^{(-0.12xD)})$

Where D = the pool fire diameter.

The constant, 140 kW/m^2, is the maximum emissive power of luminous spots and the constant, 20 kW/m^2, is the emissive power of smoke.

The values in the following table are derived from this equation.

Table 5 – Predicted SEP

Diameter, m	**SEP Average, kW/m^2**
1	126
5	86
10	56
15	40
20	31
25	26
30	23
35	22
40	21
45	21
50	20

Note that materials such as propane, ethane, LNG, ethanol and other low molecular weight materials do not produce sooty flames.

The distances to specified radiant heat levels for the potential fire scenarios are shown in Table 6. The distances were calculated using the View Factor model for pool fires (Refs 8 and 11). This model was used as it better approximates the square / rectangular shapes of the potential bund fires. It will be slightly conservative for the tank top fires. Graphical representations of the estimated radiant heat contours are shown in Appendix 1.

Table 6 – Fire Scenarios Calculation Data and Results

Note that "Eq. D" is the equivalent diameter of the fire (4 x the fire area / the fire perimeter) and "SEP" is the surface emissive power (i.e. the radiant heat level of the flames). Where bund fires width is significantly different to the length, the top row results corresponds to the radiant heat predicted for an object perpendicular to the width and the bottom row results corresponds to the radiant heat predicted for an object perpendicular to the length.

Item No.	Item Description	Width, m	Length, m	Eq. D, m	Tank Height, m	Liquid Density, kg/m^3	SEP, kW/m^2	Distance to Specified Radiant Heat Level, m (from base of flame)				
								35 kW/m^2	23 kW/m^2	12.6 kW/m^2	4.7 kW/m^2	2.1 kW/m^2
1	Tanks 270 and 288 bund fire (diesel)	31	45	37	-	840	21	- -	- -	4 4	23 29	44 55
2	Tanks 271, 272, 286, 287, 289 and 290 bund fire (combustible liquids)	25	45	32	-	860	23	- -	- -	5 6	20 28	37 51
3	Tank 273 bund fire (diesel)	35	45	39	-	840	21	- -	- -	4 5	25 29	49 57
4	Tanks 271, 272, 273, 286, 287, 289 and 290 combined bund fire (diesel)	61	45	52	-	840	20	- -	- -	4 4	36 33	70 64
5	Tank 274 bund fire (bitumen)	45	45	45	-	970	21	-	-	5	26	49
6	Tanks 291, 292, 293, 295 and 297 bund fire (combustible liquids)	36	41	38	-	860	21	-	-	4	24	46
7	Tank 276 bund fire (bitumen)	43	33	37	-	970	21	- -	- -	4 4	24 21	46 40

Item No.	Item Description	Width, m	Length, m	Eq. D, m	Tank Height, m	Liquid Density, kg/m^3	SEP, kW/m^2	Distance to Specified Radiant Heat Level, m (from base of flame)				
								35 kW/m^2	23 kW/m^2	12.6 kW/m^2	4.7 kW/m^2	2.1 kW/m^2
8	Tanks 291, 292, 293, 295, 297 and 276 combined bund fire (bitumen)	79	38	38	-	970	21	-	-	4	23	43
9	Tanks 277 to 282 bund fire (bitumen)	26	32	29	-	970	24	- -	- -	5 6	19 22	36 40
10a	Pump Bay 5 bund fire	3	17	3	-	860	104	2	3	5	11	17
10b	Pump Bay 6 bund fire	2.3	11	2.3	-	860	111	2	3	4	8	12
11	Existing Stage 5 road tanker bay fire	8	8	8	-	840	66	3	5	8	18	29
12	Bitumen road tanker bay fire	8	8	8	-	970	66	3	5	8	15	24
13	Stage 3 road tanker bay fire (combustible liquids)	5	20	5	-	860	86	3	4	7	13	20
14	Exchanger pit No. 4 fire (combustible liquids)	7	9	8	-	860	66	3	5	8	16	26
15	Tank 270 – tank top fire	-	-	19.6	17	840	31	-	<1	8	21	38
16	Tank 273 – tank top fire	-	-	26.5	20	840	25	-	<1	7	23	43
17	Tanks 274 and 276 – tank top fire	-	-	26	21	970	25	-	<1	6	20	35
18	Tanks 271, 272, 286, 287, 288, 291 and 292 – tank top fire	-	-	8.15	20.2	860	65	3	5	8	16	26

Item No.	Item Description	Width, m	Length, m	Eq. D, m	Tank Height, m	Liquid Density, kg/m^3	SEP, kW/m^2	Distance to Specified Radiant Heat Level, m (from base of flame)				
								35 kW/m^2	23 kW/m^2	12.6 kW/m^2	4.7 kW/m^2	2.1 kW/m^2
19	Tanks 289, 290, 293, 295 and 297 – tank top fire	-	-	10	20.2	860	56	2	5	8	17	28
20	Tanks 277 to 280 – tank top fire	-	-	8.7	19	970	62	2	5	8	16	25
21	Tanks 281 and 282 – tank top fire	-	-	4.5	11	970	90	3	4	6	11	18

Notes for Table 6:

1. The individual tank bund fires are for moderate releases, including piping leaks, which ignite. If a large loss of containment occurs, e.g. 10,000 m^3 of diesel from Tank 270, then the liquid can flow to the adjacent bund causing a larger combined bund fire if ignited (as modelled in the above table).

2. Note that Scenario Numbers 8, 10 and 13 are modelled as a ‘channel fires’, i.e. the equivalent diameter is taken as the width (to estimate the flame height) along the entire length of the channel.

3. The fire dimensions for a road tanker bay fire are based on typical conditions expected once the fire is established.

4. Fires in the bitumen processing bunded area, e.g. hot oil pump fire, will be comparatively smaller than the corresponding tank and bund fires and equivalent to Scenario Numbers 10 and 12. Given the results in Table 6, off-site impact is not expected. Therefore, these cases are not modelled.

The maximum ***ground level*** radiant heat values for the tank top fires are typically much lower due to the angle from the base of the flames (approximately the tank top height) to the ground. Representative ground level radiant heat levels are as follows.

1 Tank 270, 19.6 m diameter, tank height being approximately 17 metres - a maximum ground level radiant heat value of 5.2 kW/m^2 at 9 metres from the tank wall is estimated.

2 Tank 273, 26.5 m diameter, tank height being approximately 20 metres - a maximum ground level radiant heat value of 4.5 kW/m^2 at 12 metres from the tank wall is estimated.

3 Tanks 274 and 276, 26 m diameter, tank height being approximately 21 metres - a maximum ground level radiant heat value of 4.0 kW/m^2 at 10 metres from the tank wall is estimated.

4 Tanks 277 to 280, 8.7 m diameter, tank height being approximately 19 metres - a maximum ground level radiant heat value of 5.3 kW/m^2 at 5 metres from the tank wall is estimated.

5 Tanks 281 and 282, 4.5 m diameter, tank height being approximately 11 metres - a maximum ground level radiant heat value of 7.1 kW/m^2 at 3 metres from the tank wall is estimated.

6 Tanks 271, 272, 286, 287, 288, 291 and 292, 8.15 m diameter, tank height being approximately 20.2 metres - a maximum ground level radiant heat value of 4.7 kW/m^2 at 5 metres from the tank wall is estimated.

7 Tanks 289, 290, 293, 295 and 297, 10.0 m diameter, tank height being approximately 20.2 metres - a maximum ground level radiant heat value of 4.7 kW/m^2 at 6 metres from the tank wall is estimated.

The values of interest for radiant heat (DoPI, HIPAP No. 4 and ICI HAZAN Course notes) are shown in Table 7.

Table 7 - Radiant Heat Impact

HEAT FLUX (kW/m^2)	EFFECT
1.2	Received from the sun at noon in summer
2.1	Minimum to cause pain after 1 minute
4.7	Will cause pain in 15-30 seconds and second degree burns after 30 seconds. Glass breaks
12.6	30% chance of fatality for continuous exposure. High chance of injury Wood can be ignited by a naked flame after long exposure
23	100% chance of fatality for continuous exposure to people and 10% chance of fatality for instantaneous exposure Spontaneous ignition of wood after long exposure Unprotected steel will reach thermal stress temperatures to cause failure

HEAT FLUX (kW/m^2)	EFFECT
35	25% chance of fatality if people are exposed instantaneously. Storage tanks fail
60	100% chance of fatality for instantaneous exposure

For information, further data on tolerable radiant heat levels is shown in Table 8.

Table 8 – Layout Considerations – Tolerable Radiant Heat Levels

Plant Item	Tolerable Radiant Heat Level, kW/m^2	Source
Drenched Storage Tanks	38	Ref 8
Special Buildings (Protected)	25	Ref 8
Cable Insulation Degrades	18-20	Ref 8
Normal Buildings	14	Ref 8
Vegetation	12	Ref 8
Plastic Melts	12	Ref 8
Escape Routes	6	Ref 8
Glass Breakage	4	Ref 12
Personnel in Emergencies	3	Ref 8
Plastic Cables	2	Ref 8
Stationary Personnel	1.5	Ref 8

The results in Table 6 are analysed as follows to check compliance with HIPAP 4 (Ref 3) risk criteria.

For assessment of the effects of radiant heat, it is generally assumed that if a person is subjected to 4.7 kW/m^2 of radiant heat and they can take cover within approximately 20 seconds then no serious injury, and hence fatality, is expected. However, exposure to a radiant heat level of 12.6 kW/m^2 can result in fatality for some people for limited exposure durations. Therefore, for the larger spills, appropriate emergency response actions are required to minimise the potential for harm to people. This should include moving people away from such releases to a safe distance.

With regards to the likelihood of the potential fire events involving combustible liquids such as diesel and the heavy oils that are proposed to be stored in the new tanks, the following ignition analysis shows a lower risk, as expected, than flammable liquids.

From Lees (Ref 8), the following data shows the difficulty of ignition for higher boiling point materials:

Event:	**Ignition Probability**
Massive LPG leak	0.1
Flammable liquid, flash point < 43^{o}C or operated above its flash point	0.01
Flammable liquid, flash point 43 to 93^{o}C	0.001

Hence, for diesel, the probability of ignition is approximately one order of magnitude below that of a flammable liquid as the flash point is above 60^{o}C. For the proposed heavy oils that have flash points of approximately 200^{o}C, the probability of ignition is lower. Correspondingly, the reported likelihood of fires for installations storing flammable liquids will be higher than that expected for combustible liquids (by one order of magnitude or more). This is taken into consideration in any likelihood analysis in the following sections.

5.2 Comparison to the DoPI Risk Criteria

Given the large distance to the nearest residential area (approximately 1 km to the east) and the estimated radiant heat levels from the potential fire events shown in Table 6 then there is no credible risk of injury or fatality in residential areas or to other sensitive land users.

Correspondingly, the risk criteria for fatality and injury (Table 4) in residential areas are satisfied for radiant heat from fires.

There is only one event where the estimated level of radiant heat at a neighbouring industrial area is approximately 12.6 kW/m^2 (event number 14) and hence theoretically can lead to fatality. The 12.6 kW/m^2 contour extends approximately 2 m into the Origin Energy site. At this location, there is no equipment or occupied buildings. It is more probable that should a pool fire occur in the new exchanger pit No. 4, people on the Origin Energy site will be evacuated as per the established Port Botany emergency response procedures.

Given a probability of ignition of combustible liquids with flash points of approximately 200^{o}C of 0.001 or lower then the likelihood for this event is low (no such fire has occurred to date at the site since 1978 for flammable or combustible liquids) as is the risk of fatality off-site. For example, if a large leak frequency of 1 in 100 years is chosen for the exchanger pit then the large fire likelihood becomes 1 x 10^{-5} / yr which is below the DoPI 50 x 10^{-5} / yr criterion for industrial areas.

Correspondingly, the risk criteria for fatality (Table 4) in industrial areas is satisfied for radiant heat from fires.

The risk of propagation due to fires to neighbouring industrial areas (i.e. exceeding 23 kW/m^2) is not expected given the predicted results in Table 6 as the 23 kW/m^2 contour remains on the site.

Therefore, the criterion of 50 x 10^{-6}/year for industrial propagation risk for exceeding 23 kW/m^2 (Table 4) is satisfied for fire events.

However, should a large loss of containment occur from the tanks and be ignited then, as per the current bund designs, the other intact tanks in the larger pit are at risk of failure. This is a common business risk for pit designs where the intermediate bund walls within the pit are lower than the outer bund walls. It is also possible for a road tanker fire at the bitumen loading bay could propagate to the nearby tanks (i.e. Scenario 12) or a fire in the new exchanger pit No. 4 (Scenario 14) could lead to propagation to the adjacent tanks. The results shown in Appendix 1 show the significant levels of radiant heat due to the propagation to the tanks will still be contained on-site.

Should a loss of containment of combustible liquid occur at the new Stage 3 road tanker bay occur and be ignited, it is possible that propagation could occur to an adjacent road tanker in the existing Stage 3 road tanker bay. The significant levels of radiant heat would still be contained on-site though. As the existing Stage 3 road tanker bay has an installed foam spray system (heat activated) then this is expected to be used in such an event (assuming the adjacent road tanker cannot be driven away).

Given the limited radiant heat impact as above, no further risk analysis of the identified pool fire scenarios is warranted in this study as compliance with the DoPI criteria (Table 4) has been shown.

5.3 PRODUCTS OF COMBUSTION

There is a potential risk to those attending a fire emergency (and possibly off-site) of effects from toxic products of combustion, e.g. carbon oxides and smoke, as well as vaporised product (i.e. not combusted).

Impact from toxic products of combustion will only be significant, generally, local to the fire. As stated in Lees (Ref 8):

"The hot products of combustion rising from a fire typically have a temperature in the range 800-1200^{o}C and a density a quarter that of air."

Hence, a buoyant plume is formed (as seen when smoke is emitted from a chimney) and the combustion products rise and are dispersed as per the prevailing wind / weather conditions.

Several runs of the Brigg's Plume Model (Ref 10) for various combinations of weather / wind conditions and fire temperatures for a tank top fire and a bund fire for the proposed modifications were performed. The results are shown in Table 9. An efflux velocity of 5 m/s for the products of combustion is taken for the fire event.

Table 9 – Fire Plume Rise Modelling

Scenario	Wind (m/s) / Weather	Initial Height of Plume, m	Initial Plume Radius, m	Comments
Storage tank fire Diameter = 10 m Height = 20.2 m	F2 D5 D15	100 52 31	37 16 6	As the height of this release is the tank height, i.e. 20.2 m, it is predicted that the main plume flow will not reach ground level (including further in the downwind direction). It will be relatively close to the ground for up to 50 m though
Tanks 291 to 297 bund fire	F2 D5 D15	285 114 38	133 57 21	For the F2 condition, the plume is predicted to be always above ground level. The distances to achieve a plume height more than 10 m above the ground for the D5 and D15 conditions are 90 and 300 m, respectively

The results in Table 9 are indicative of previous industrial fires. Ref 13 also quotes modelled hazard ranges up to 400 m unless smouldering combustion (i.e. cooler combustion products) is taking place.

Therefore, unless a temperature inversion exists where reverse atmospheric currents can occur (i.e. air slumps to the ground as opposed to air eddies that rise), emergency response will be required for the area around the facility, i.e. evacuation of people downwind, for some weather / wind combinations for distances up to several hundred metres. *This is typical for all industrial fire events.*

5.4 VAPOUR EXPLOSIONS

Whilst it is proposed to only store and handle combustible liquids in the Stage 5B area, it is noted that explosions involving the vapours from petroleum products are possible and are acknowledged in Table 2. There are two notable incidents involving releases of *flammable* liquids that have resulted in unconfined vapour explosions. Given that Terminals proposed to only store and handle combustible liquids in the Stage 5B area, the risk of the following events will be even lower than that for flammable liquids.

A recent significant incident occurred at the fuel storage facility at Buncefield, UK. In the early hours of Sunday 11th December 2005, a number of explosions occurred at Buncefield Oil Storage Depot, Hemel Hempstead, Hertfordshire. At least one of the initial explosions was of massive proportions and there was a large fire, which engulfed a high proportion of the site. Over 40 people were injured; fortunately there were no fatalities. The explosion was the result of a large loss of containment of flammable liquid.

Another similar incident occurred at the Texaco Newark storage facility, January 7 (i.e. during winter again), 1983. The tanks involved here had little level protective instrumentation; tank level was primarily achieved via frequent dipping with subsequent checklist completion. The material was super unleaded gasoline. During a transfer operation, one tank overflowed at approximately midnight and a vapour cloud formed. It travelled approximately 300 metres towards an incinerator (most likely source of ignition given eye-witness reports) and then exploded. There was one fatality and twenty four people injured.

Issues in common with two events are:

- Overflow from height, spraying of the flammable liquid causing a mist;
- Cold ambient temperatures (Buncefield approximately -2 deg Cel, similarly for Newark);
- Low wind speeds (e.g. Buncefield - Pasquill stability class F);
- Rolling mist (e.g. Buncefield - 5 to 7 metres high mist with confinement, i.e. between buildings);
- Delayed ignition; and
- Large amounts lost - Buncefield approximately 300 tes and Newark approximately 450 tes.

The following, summarised recommendations are from the Buncefield Safety Task Group's investigation. Comment is included on their applicability to the Terminals site at Port Botany.

- The overall systems for tank filling control need to be of high integrity, with sufficient independence to ensure timely and safe shutdown to prevent tank overflow and the overall systems for tank filling control meet AS 61511. *This is achieved via tank radar level monitoring for large diesel and bitumen tanks while the combustible liquid tanks (proposed 14) undergo strict ullage monitoring and an independent high level switch on the new tanks which are linked to the operator's radios*.
- Management systems for maintenance of equipment and systems to ensure their continuing integrity in operation. *Terminals have an established safety management system which includes equipment item maintenance, including instrumentation testing, requirements*.
- Fire-safe shut-off valves should be used and remotely operated shut-off valves (ROSOVs) should be installed on tank outlets. *Terminals plan to use fire-safe valves and install ROSOVs on the new tanks outlet lines and overhead or non-return valves on the inlet lines*.

- Safe management of fuel transfer. *Terminals have established procedures for product transfers including compliance with the International Shipping Guide for Oil Tankers and Terminals*.

- Bunds are to be leak tight, bund wall joints are to be fire resistant and the bund capacity is to be at least 110% of the maximum tank capacity. *These recommendations are consistent with the Terminals bund designs*.

- Site-specific planning of firewater management and control measures should be undertaken. *Firewater containment is afforded by the tank bunds, the ability to transfer water from bund-to-bund and on-site waste water containment facilities. Beyond these measures, further emergency response is required.*

- Procedures exist for defining roles, responsibilities and competence, staffing and shift work arrangements (e.g. managing fatigue), shift handover, organisational change and management of contractors, performance evaluation and process safety performance measurement including procedures for investigation of incidents and near misses, and auditing. *Terminals have an established safety management system which includes these requirements*.

- Emergency procedures exist inclusive of fire fighting requirements. T*erminals have an existing site emergency response plan which includes actions to take in a fire event. This is planned to be updated for the current project*.

In summary, unconfined vapour cloud explosions resulting from the spillage of a hydrocarbon at ambient temperature and below its boiling point are rare (Ref 14). If enough hydrocarbon is spilt, particularly from height with low wind speeds to minimise dilution, then a vapour cloud is possible.

Given the measures employed at the Terminals site and that only combustible liquids are to be stored in the Stage 5B area, the expected likelihoods for these types of events are still rare and therefore do not pose significant off-site risks.

Therefore, given the historically low frequency of petroleum products vapour explosions associated with these types of tanks then the risk to people off-site or adjacent industrial facilities is not considered intolerable.

As identified in Table 3, it is also possible to have confined explosions within the bitumen tanks. These events have occurred, however, the anecdotal evidence indicates the impacts are confined to the plant area around the tanks. In these cases, the energy of the explosions is largely spent in causing damage to the tanks. Therefore, propagation to other nearby tanks and equipment is possible with a potential outcome of pool fires. As per the preceding pool fire analyses, the risk of adverse consequential impacts from pool fires in the Stage 5B area is deemed acceptable and no further safeguarding is recommended.

5.5 NATURAL GAS FIRES AND EXPLOSIONS

This Section is copied from the bitumen expansion PHA (Ref 7). The reason is to conduct a propagation risk analysis on the proposed new combustible liquids tanks (see the end of this Section for specific comment).

Failures associated with the natural gas feed line to the hot oil heaters or combustor will release the natural gas to atmosphere and, if ignited, it can form a jet fire, a flash fire and/or an explosion.

The natural gas line is installed aboveground in the pipeline corridor from Friendship Road. The mains supply pressure is 10.5 barg and is let down to 2.75 barg at the terminal boundary. The gas pipe is 80 mm nominal diameter as it runs through the pipeline corridor for a distance of about 500m. The pipe has welded joints where possible. All flanged joints have a hazardous atmosphere zone around them.

The analysis of the potential jet fires from the natural gas feed line to the hot oil heaters / combustor is shown in Table 10. From above, the natural gas pressure is taken as 2.75 barg (at ambient temperature).

Table 10 –Natural Gas Jet Fires

Stream	Estimated Release Rate, kg/s	Estimated Length of Jet, m
Full bore failure (80 mm)	0.71	9
50 mm hole	0.55	8
13 mm hole	0.053	3

Notes: Jet flames modelled using methane.

As expected for these size jet fires, no adverse radiant heat levels will be imposed off-site.

Potential vapour cloud explosions and flash fires can occur from the natural gas line failures, i.e. delayed ignition.

The effects from explosion overpressures (Ref 3) are summarised in Table 11.

Table 11 – Effects of Explosion Overpressure

OVERPRESSURE, kPa	PHYSICAL EFFECT
3.5	90% glass breakage No fatality, very low probability of injury
7	Damage to internal partitions & Joinery 10% probability of injury, no fatality
14	Houses uninhabitable and badly cracked
21	Reinforced structures distort, storage tanks fail 20% chance of fatality to person in building
35	Houses uninhabitable, rail wagons & plant items overturned. Threshold of eardrum damage, 50% chance of fatality for a person in a building, 15% in the open
70	Complete demolition of houses Threshold of lung damage, 100% chance of fatality for a person in a building or in the open

For flash fires, any person inside the flash fire cloud is assumed to be fatally injured. As flash fires are of limited duration (typically burning velocity is 1 m/s, Ref 15) then those outside the flash fire cloud have a high probability of survival without serious injury.

The analysis of the potential vapour cloud explosions and flash fires from the natural gas pipe failures is shown in Table 12. The mass calculated in the flammable range is assumed to be 100% confined, i.e. all this gas is involved in the explosion calculations. As methane is not a high reactive flammable gas and the quantities involved are relatively small then a weak deflagration is assumed in the explosion calculations (multi-energy method – TNO).

Table 12 – Natural Gas Vapour Cloud Explosions and Flash Fires

Stream	Mass of Natural Gas in the Flammable Range, kg	Radius of Flash Fire, m	Distance (m) to 14 kPa Explosion Overpressure	Distance (m) to 7 kPa Explosion Overpressure
Full bore failure (80 mm)	7.5	36 m	< 10 m	16 m
50 mm hole	5	30 m	< 10 m	14 m

Notes: 1. Pipeline failures assumed to be isolated within 30 minutes.

2. Radius of flash fires calculated to be the distance to LEL at F weather stability and 2 m/s wind speed.

3. 13 mm holes not modelled as they are too small to generate gas clouds of any significant size.

For these releases of natural gas, choked flow exists and rapid jet mixing with air occurs. The result is a relatively small vapour cloud size with limited consequential impacts if ignited. The 30 minute release duration also has no significant impact on the release. Steady state conditions are reached soon after the release occurs (i.e. after approximately 4 minutes, the distance to the LEL does not change at steady state dispersion conditions).

Given these results for the natural gas vapour cloud explosions and flash fires, no adverse consequential impacts will be imposed off-site. The low likelihoods for these events are supported by the following data.

For piping failures, frequencies have been estimated either from data compiled and published by ICI (Ref 16) or from frequency estimates published by the Institution of Chemical Engineers (Ref 17).

Table 13 - Piping Failure Frequencies

Type of Failure	**Failure Rate per year**
Pipelines	
13 mm hole	3×10^{-6} / m
50 mm hole	0.3×10^{-6} / m
3 mm gasket (13 mm hole equivalent)	5×10^{-6} / joint
Guillotine fracture (full bore):	
< 50 mm	0.6×10^{-6} / m
> 50 mm but < 100 mm	0.3×10^{-6} / m
> 100 mm	0.1×10^{-6} / m

For example, the frequency of catastrophic pipe failure for an 80 mm pipe is 3×10^{-7} / m. This is a low level of risk and not considered intolerable.

Given the low likelihoods for the potential natural gas releases, the propagation risk to the new combustible tanks is correspondingly low and is also considered to be tolerable.

5.6 AIRCRAFT IMPACT AND OTHER EXTERNAL EVENTS

Frequencies associated with aircraft crashes (Ref 7) are typically in the order of 1×10^{-8}/year to 4×10^{-7}/year.

The outcomes of any aircraft crash on this site will be dominated by larger hazardous events in other storage and handling areas as well as the ensuing fire from the plane wreckage. This is an existing risk for the site and the proposed changes to the site have negligible effect. The likelihood of this type of event is acceptably low for a site of this size and location.

Other external events that may lead to propagation of incidents on any site include:

Subsidence	Landslide
Burst Dam	Vermin/insect infestation
Storm and high winds	Forest fire
Storm surge	Rising water courses
Flood	Storm water runoff
Breach of security	Lightning
Tidal waves	Earthquake

These events were reviewed and none of them were found to pose any significant risk to the new bitumen facility given the proposed safeguards.

5.7 CUMULATIVE RISK

Cumulative risk for the Port Botany area was considered by the Department of Urban Affairs and Planning (now the DoPI) in 1996 (Ref 4). The estimated risk contours extended well beyond the Terminal's site and largely over the water. As shown in this PHA, the proposed changes to the Terminals site will have negligible impact on the cumulative risk results for the Port Botany area as the significant radiant heat levels are retained on the site.

Therefore it is reasonable to conclude that the modified development does not make a significant contribution to the existing cumulative Port Botany risk.

The recommendations from the 1996 study have been reviewed to determine if the proposed changes are consistent with the intent of these recommendations. In summary, all current proposed changes to the Terminals site have been found to be consistent with the intent of the recommendations and do not contribute to unacceptable cumulative risk in the Port Botany area.

5.8 SOCIETAL RISK

The above criteria for individual risk do not necessarily reflect the overall risk associated with any proposal. In some cases for instance, where the 1 pmpy contour approaches closely to residential areas or sensitive land uses, the potential may exist for multiple fatalities as the result of a single accident. One attempt to make comparative assessments of such cases involves the calculation of societal risk.

Societal risk results are usually presented as F-N curves, which show the frequency of events (F) resulting in N or more fatalities. To determine societal risk, it is necessary to quantify the population within each zone of risk surrounding a facility. By combining the results for different risk levels, a societal risk curve can be produced.

In this study of the modified Terminals site at Port Botany, the risk of fatality does not extend significantly off the site and is therefore well away from the residential areas. In fact, the nearest house is approximately 1 kilometre away. The concept of societal risk applying to residential population is therefore not applicable for the terminal.

5.9 RISK TO THE BIOPHYSICAL ENVIRONMENT

The main concern for risk to the biophysical environment is generally with effects on whole systems or populations. For the expanded terminal, it is suitably located away from residential areas. However, due to the nature of the activities, there are operations, e.g. ship transfers and road tanker filling, where losses of containment can potentially impact the environment. Major fires can also effect the environment (combustion products).

Whereas any adverse effect on the environment is obviously undesirable, the results of this study show that the risk of losses of containment is broadly acceptable.

For completeness, risks to the biophysical environment due to loss of containment events are summarised below.

5.9.1 Escape of Materials to Atmosphere

Combustion of the stored products, caused by ignition following a spillage or leak, will release products of combustion (e.g. carbon dioxide, carbon monoxide, soot, vaporised product [unburnt] and water vapour). As shown in Section 5.3, for typical wind / weather conditions, the products of combustion from a fire will rise due to momentum and buoyancy. Local impact can be expected for very still conditions only (in which case, emergency response is required for evacuation). The products of combustion are unlikely to include any materials which present a long-term risk to the biosphere.

Hydrocarbons vapour emissions whilst tanker filling are limited as the combustible liquids have very low vapour pressures.

5.9.2 Escape of Materials to Soil or Waterways

Products Stored in Bunded Areas

Spillages of products from the tanks and adjacent piping are contained in the bunds. The bunded areas are sized to contain the entire contents of the single tank so that a total loss of contents does not spill over the bund, plus an allowance for rainwater, fire water, hosing down etc.

Drainage Systems and Site Grades

These have been designed so that in the event of fire, fire water run off containing any materials is held on site. All open processing areas are paved.

On spillage or other loss of containment on paved areas associated with the new tanks and equipment, the products will be captured in the site's existing waste water pit and disposed of off-site via a licensed contractor (as per current procedure).

If a spill was to occur on a general paved site area then equipment such as absorbents and booms are available for use to minimise the spread of the liquid.

Bulk Liquids Berth

For small spills at the Bulk Liquids Berth No. 1, containment is provided by catchment trays. Terminals have installed further matting to help prevent any potential spills flowing into the bay. Larger releases are designed to be contained by a bunded wharf with a collection sump providing 100,000 litres containment. Any liquid spills entering the sea water involve emergency response from personnel from Terminals, NSW Ports and the ship's crew. Given there are no changes in the shipping activities for this project then there are no new causes for potential losses of containment at the berth.

5.9.3 Solid Wastes

There will be a small amount of solid wastes, similar to the existing operations (e.g. pigs and rags), requiring disposal associated with the new tanks.

From the analysis in this report, no incident scenarios were identified where the risk of whole systems or populations being affected by a release to the atmosphere, waterways or soil is intolerable.

6 CONCLUSION AND RECOMMENDATIONS

The risks associated with the Stage 5B combustible liquids tanks and associated equipment at the Terminals site, Port Botany, have been assessed and compared against the DoPI risk criteria.

In summary:

1. Fires:

- No risk of injury or fatality at residential areas or other sensitive land uses as the separation distance is large, i.e. 1 km or larger to residential areas;

- As the estimated radiant heat levels from potential fire events are approximately 12.6 kW/m^2 or lower at neighbouring industrial facilities and the ignition probability of any spills is low for combustible liquids, the likelihood of fatality at these locations is acceptably low and there exists a high probability of escape; and

- Propagation to neighbouring industrial facilities is not expected given that the significant levels of radiant heat are largely contained on-site.

2. Vapour explosions:

- These are considered rare events for these types of facilities and materials, and hence the risk of injury, fatality and/or propagation at residential areas or other sensitive land uses (i.e. more than 1 km away) or at neighbouring facilities is not considered intolerable.

3. The shipping and off-site road transport activities associated with this project are commensurate with the zoning for the Port Botany area and are not considered intolerable. There are no changes to shipping transfers as a result of this project.

4. Societal risk is qualitatively concluded to be acceptable given:

- Few events analysed in the study have the potential for off-site impact and, for the ones that do, their likelihood is acceptably low; and

- The population density in the Port Botany area is relatively low.

Therefore, the results of this PHA show that the risks associated with the proposed changes comply with the DoPI guidelines for tolerable fatality, injury, irritation, propagation and societal risk. Also, risks to the biophysical environment from potential hazardous events are broadly acceptable.

Additionally, the proposed new tanks and equipment have no significant impact to the cumulative individual risk contours (for future development planning) as presented in the Port Botany Land Use Safety Study by DUAP in 1996.

The primary reason for the low risk levels from the proposed changes is that significant consequential impacts from potential hazardous events (mainly radiant heat from fires) do not extend far from the relevant storage areas.

The following recommendations are made from this review:

1. Perform a HAZOP study and a construction safety study on the proposed changes;

2. Check the existing fire prevention, detection and protection facilities for the proposed new tanks;

3. Update the existing safety management system, including the emergency response plan, for the proposed new tanks and equipment; and

4. Perform a SIL study on the proposed storage tanks and associated equipment to ensure the instrumented protective loops are suitably designed and are of adequate reliability for the potential hazardous events that can occur.

Appendix 1

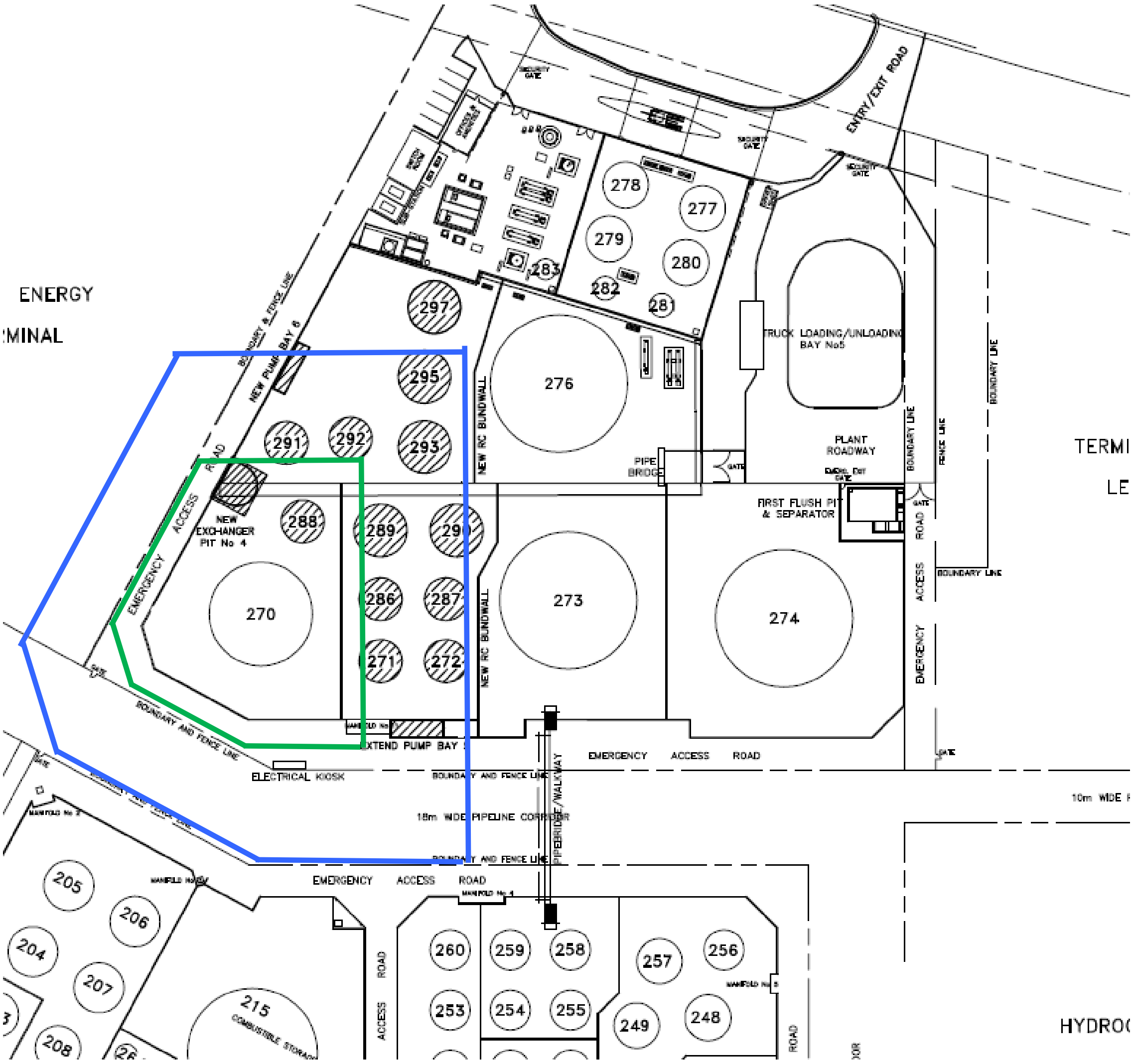
Radiant Heat Contours

Preliminary Hazard Analysis, Terminals Pty Ltd,

Stage 5B Expansion

Appendix 1 – Radiant Heat Contours.

Scenario 1 – Tanks 270 and 288 Bund Fire (diesel)

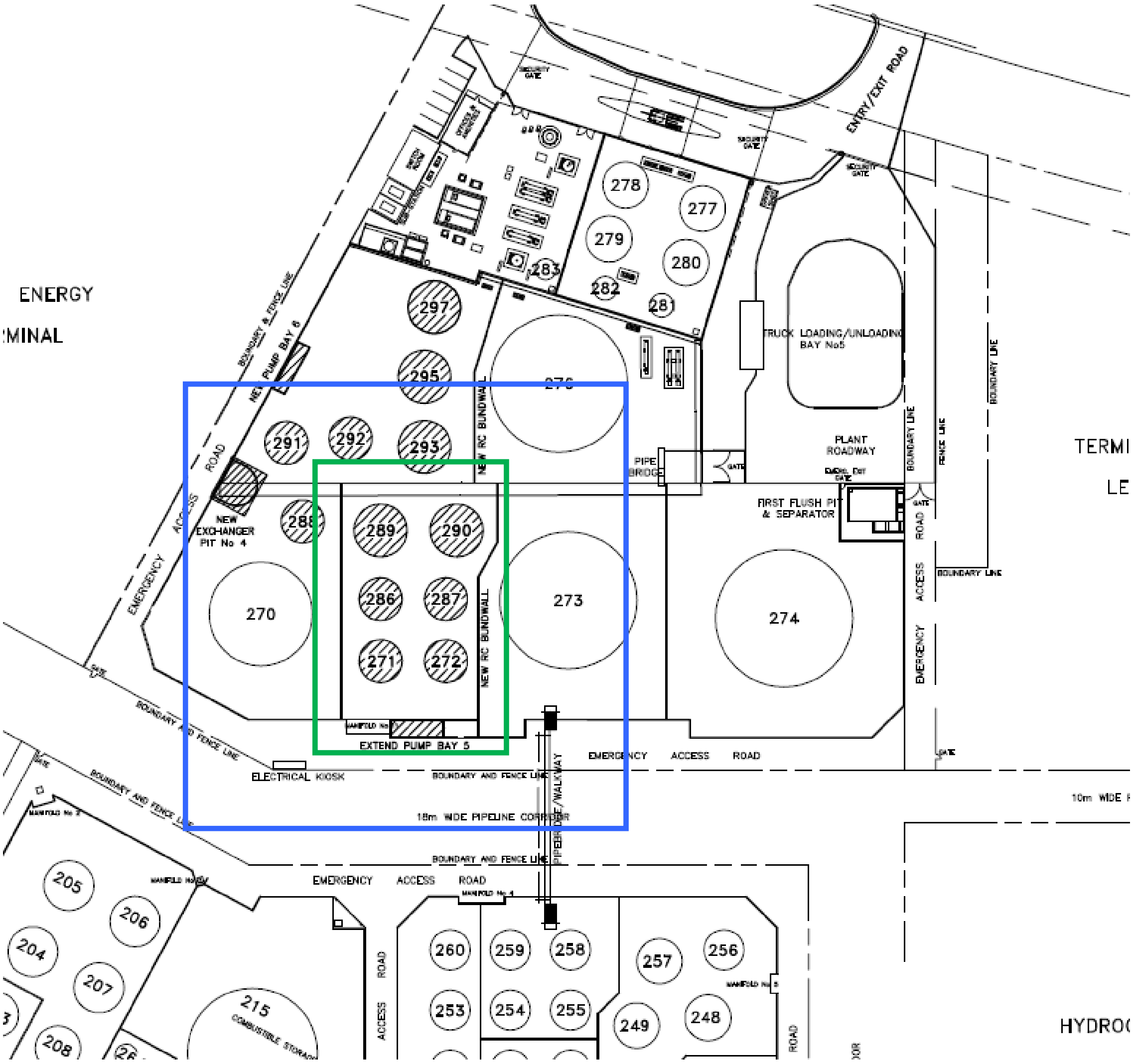


Note: Contours are an approximation given the irregular shape of the bund.

Key:

- 12.6 kW/m^2 (green)
- 4.7 kW/m^2 (blue)

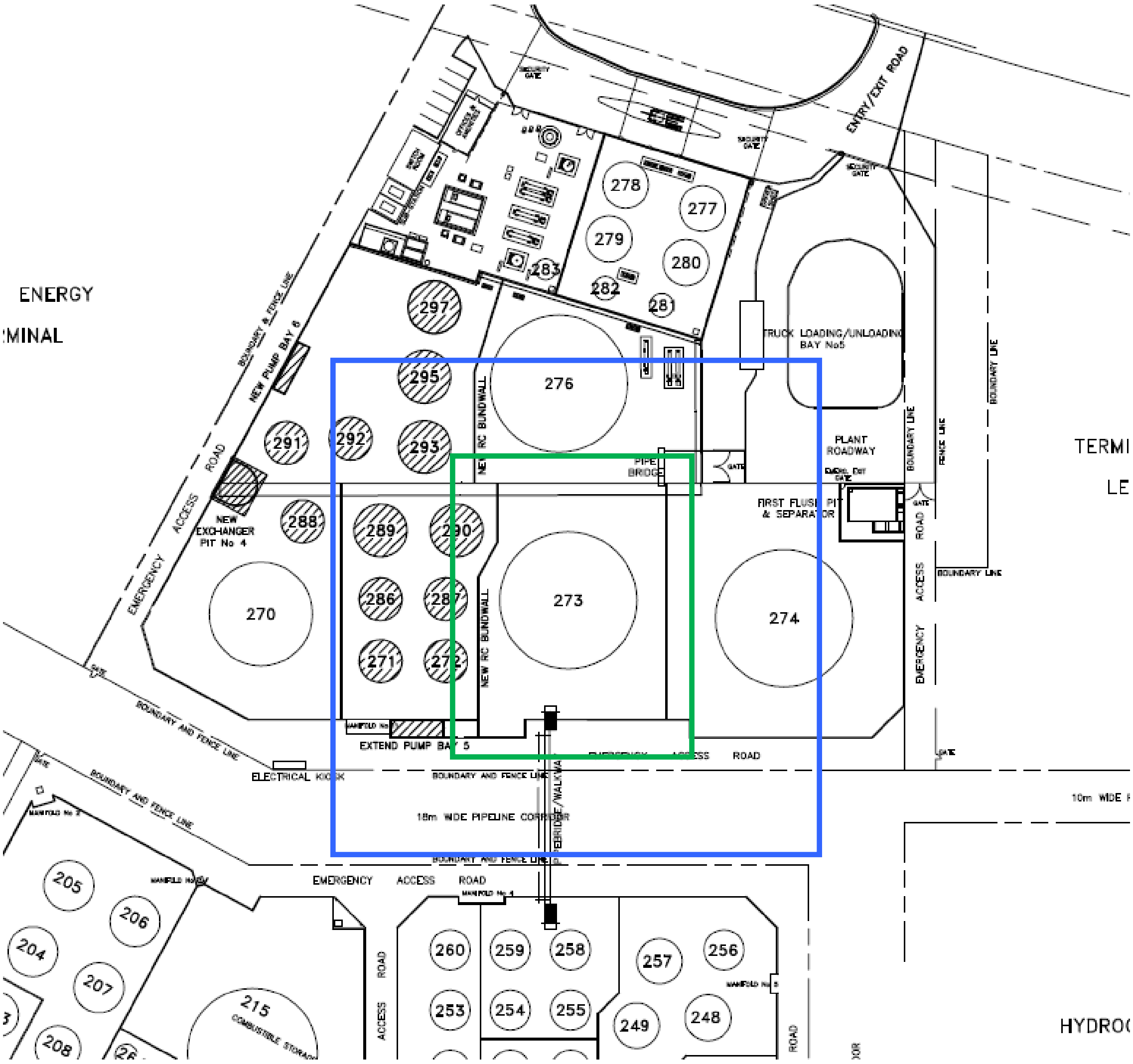
Scenario 2 – Tanks 271, 272 and 284 to 287 Bund Fire (combustible liquids)



Key:

- **12.6 kW/m^2** (green line)
- **4.7 kW/m^2** (blue line)

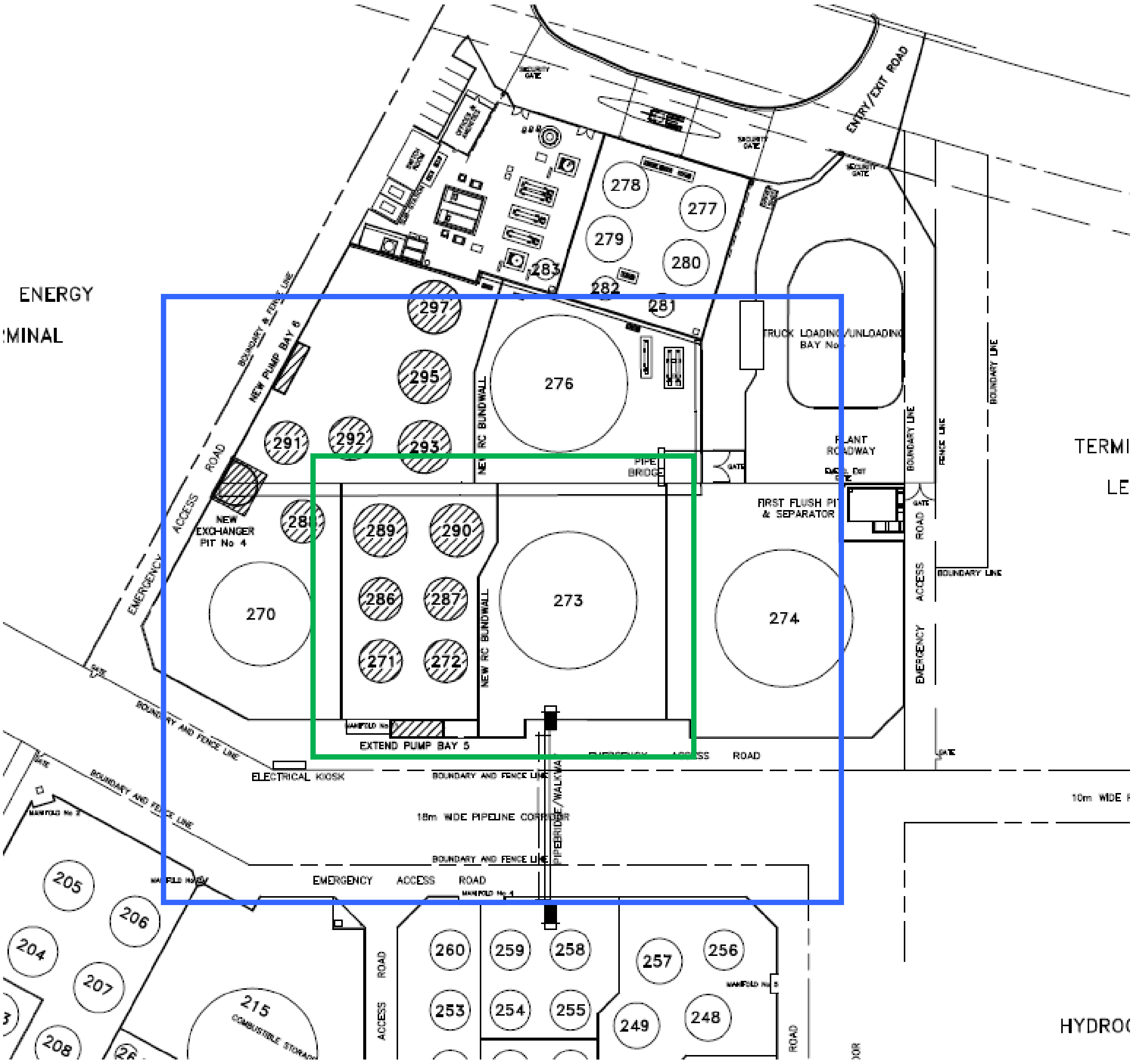
Scenario 3 – Tank 273 Bund Fire (diesel)



Key:

- 12.6 kW/m^2 (green)
- 4.7 kW/m^2 (blue)

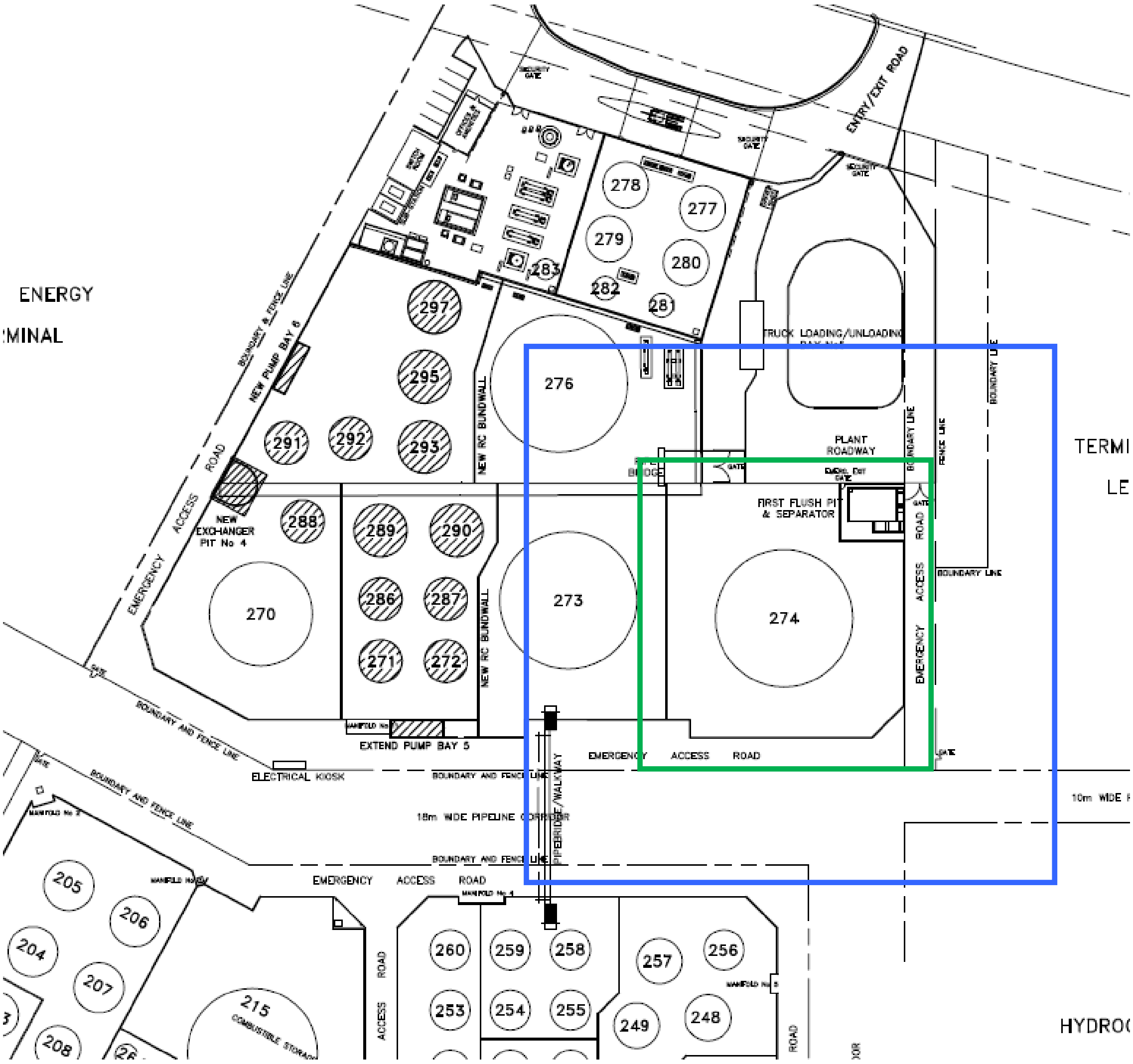
Scenario 4 – Tanks 271 to 273 and 284 to 287 Combined Bund Fire (diesel)



Key:

- 12.6 kW/m²
- 4.7 kW/m²

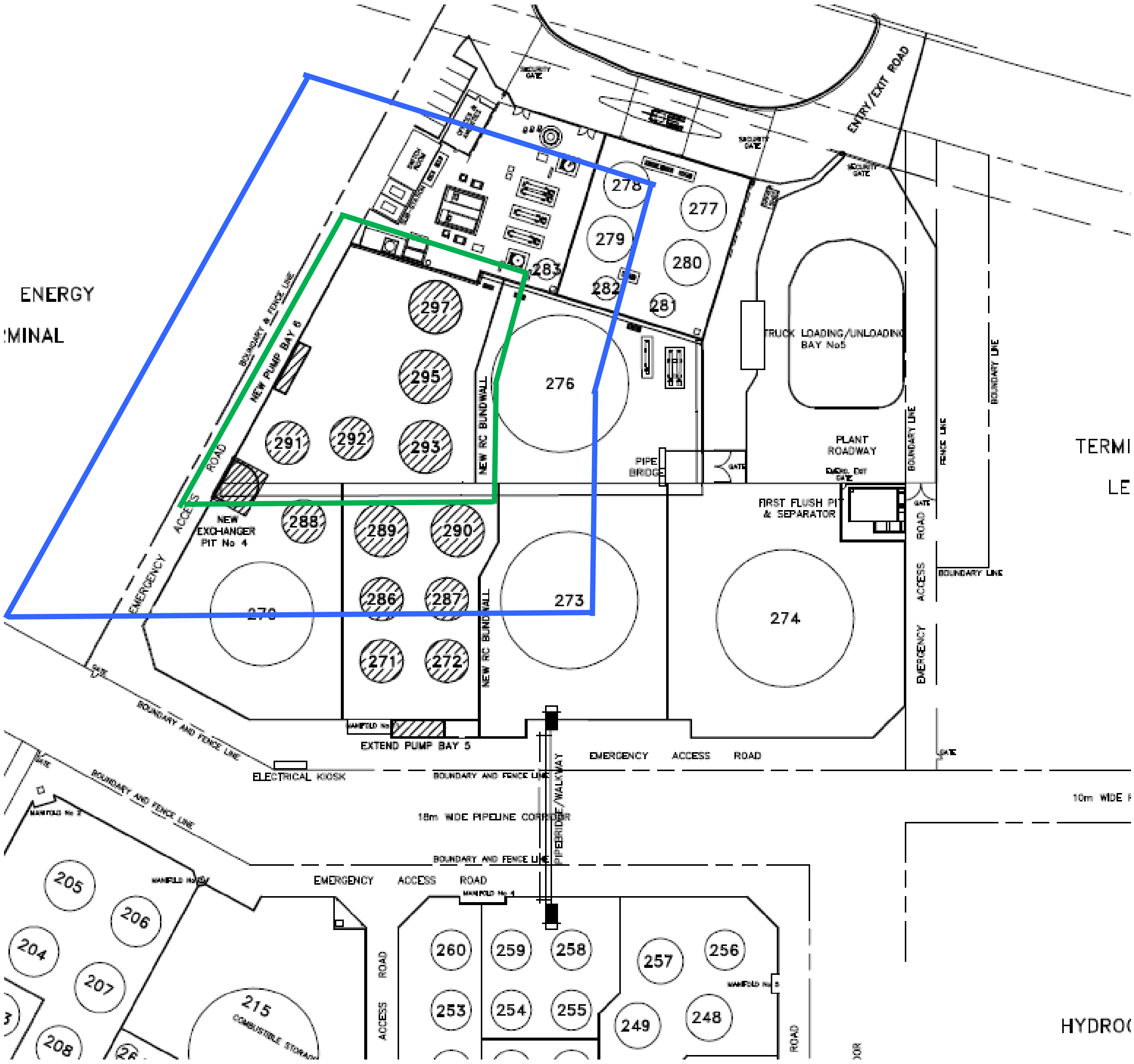
Scenario 5 – Tank 274 Bund Fire (bitumen)



Key:

- 12.6 kW/m²
- 4.7 kW/m²

Scenario 6 – Tanks 289 to 295 Bund Fire (combustible liquids)

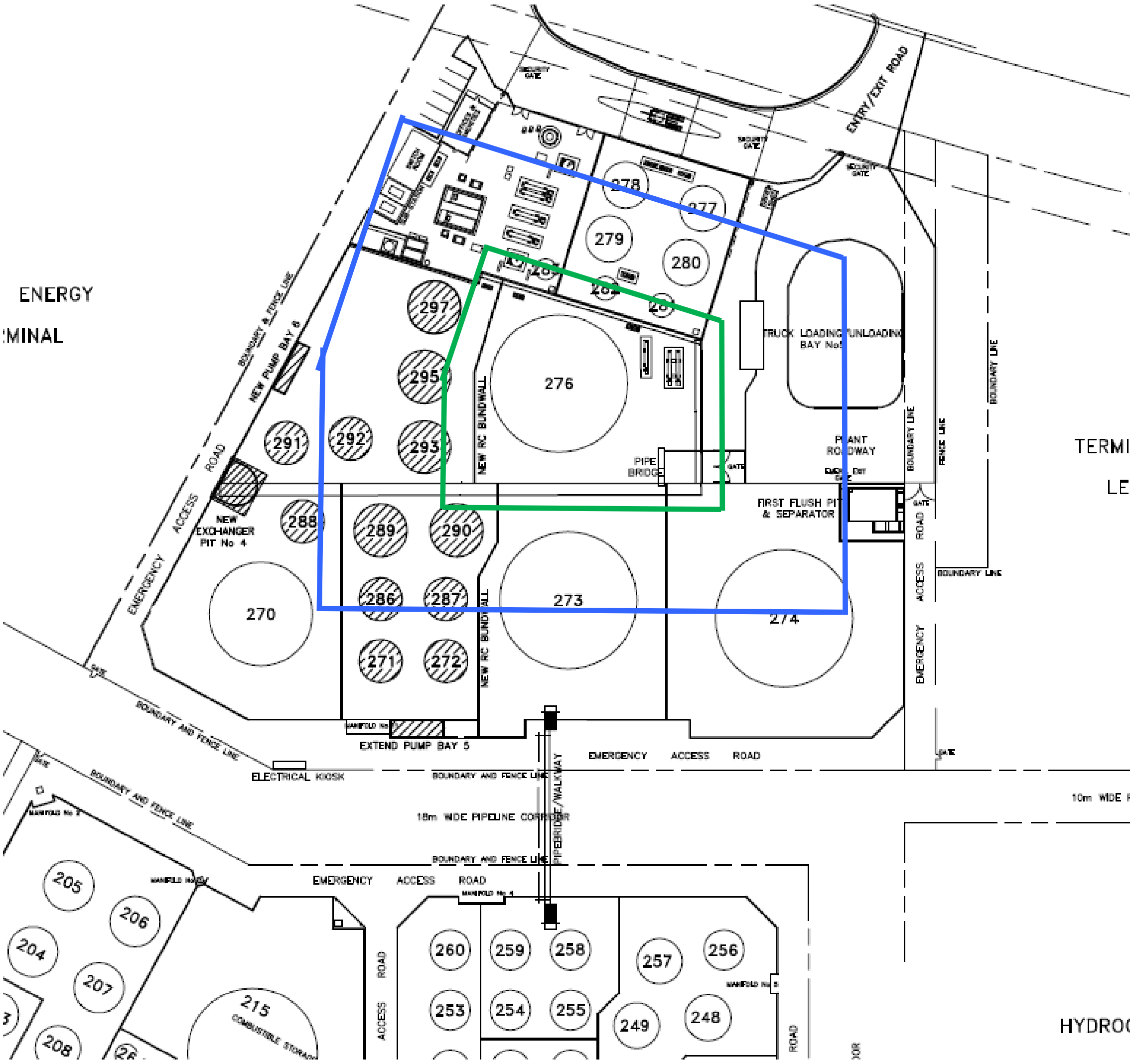


Note: Contours are an approximation given the irregular shape of the bund.

Key:

- 12.6 kW/m^2 (green)
- 4.7 kW/m^2 (blue)

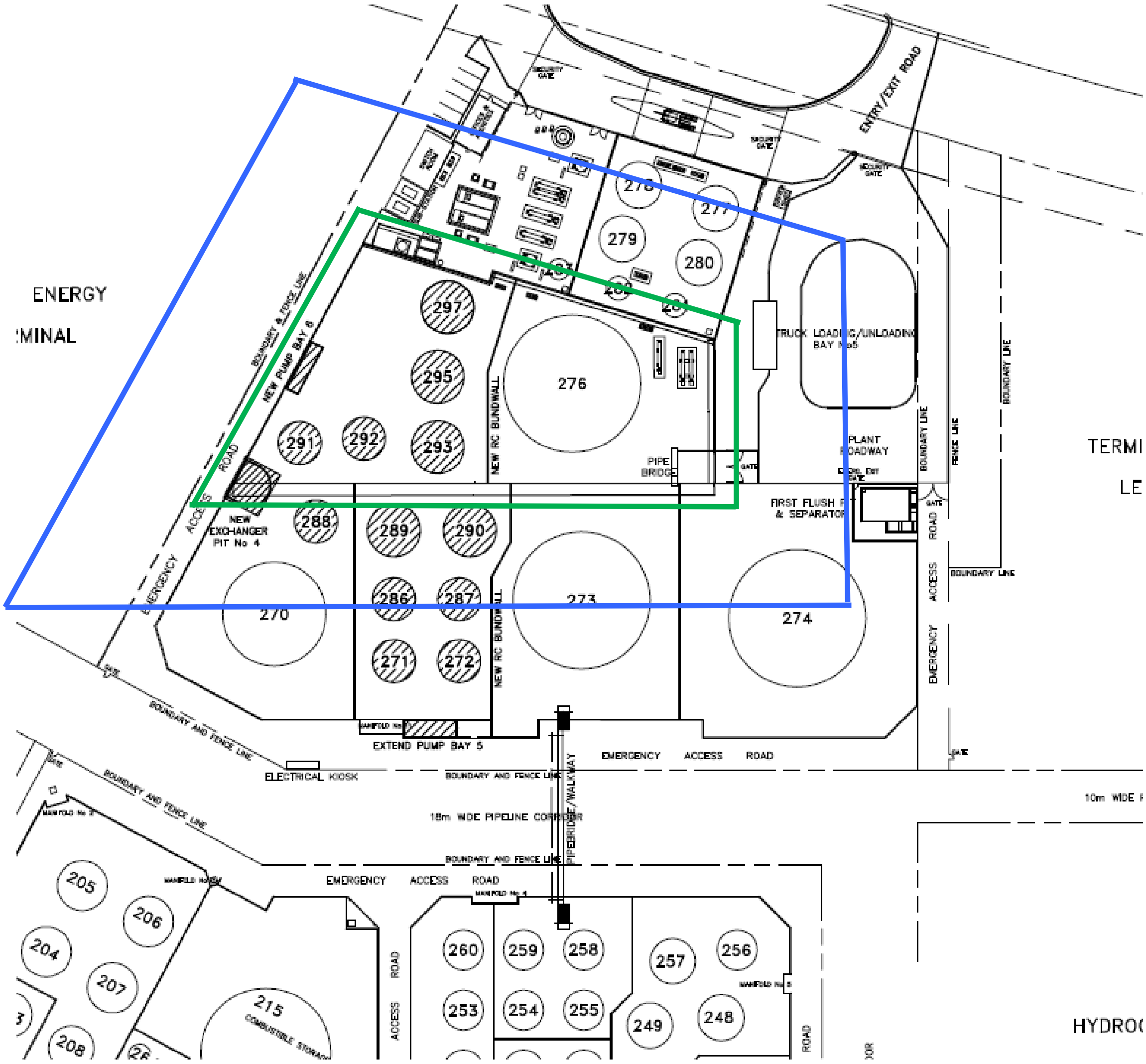
Scenario 7 – Tank 276 Bund Fire (bitumen)



Note: Contours are an approximation given the irregular shape of the bund.

Key:	
green line	12.6 kW/m^2
blue line	4.7 kW/m^2

Scenario 8 – Tanks 289 to 295 and 276 Combined Bund Fire (bitumen)

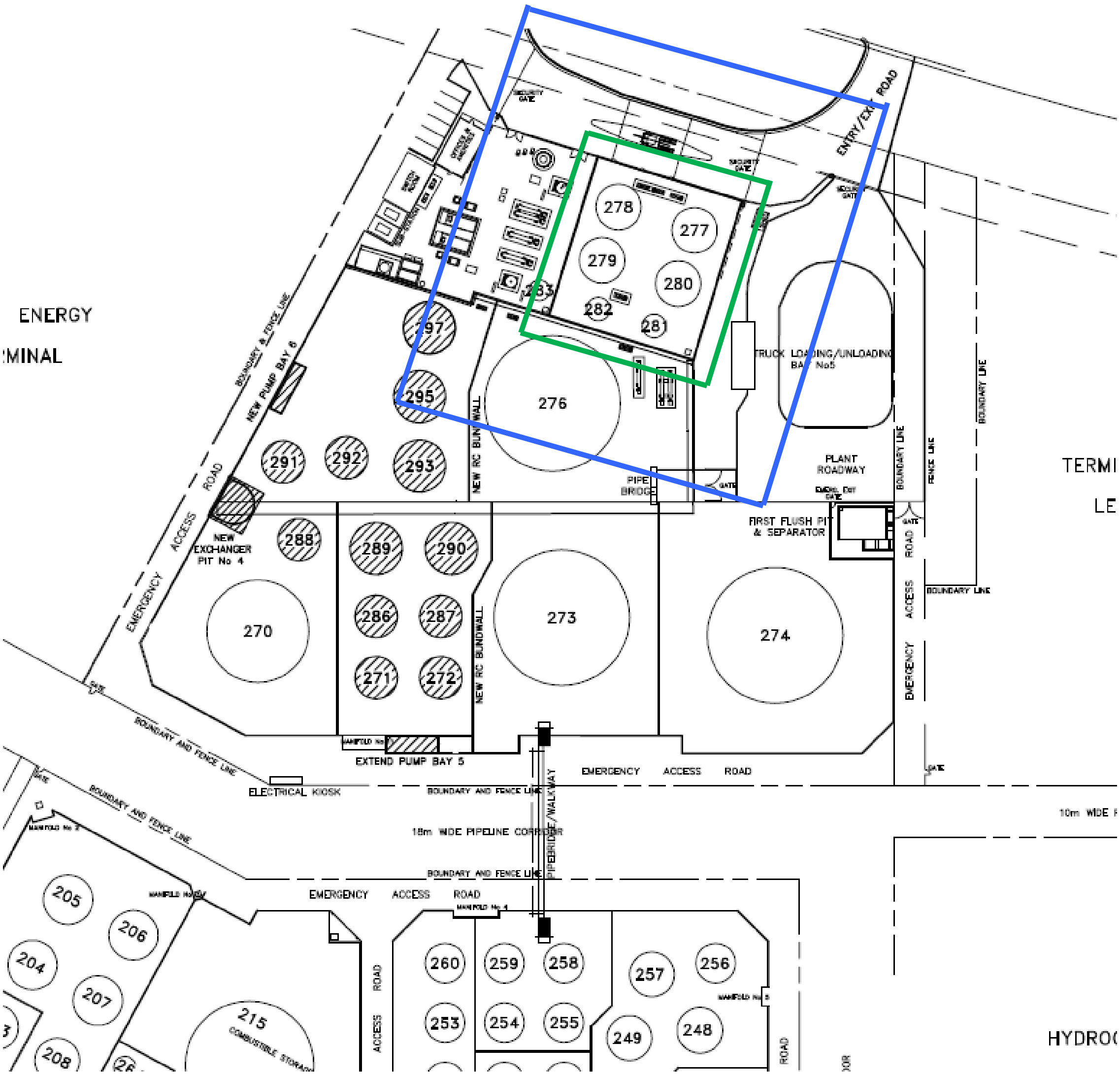


Note: Contours are an approximation given the irregular shape of the bund.

Key:

- 12.6 kW/m^2 (green)
- 4.7 kW/m^2 (blue)

Scenario 9 – Tanks 277 to 282 Bund Fire (bitumen)

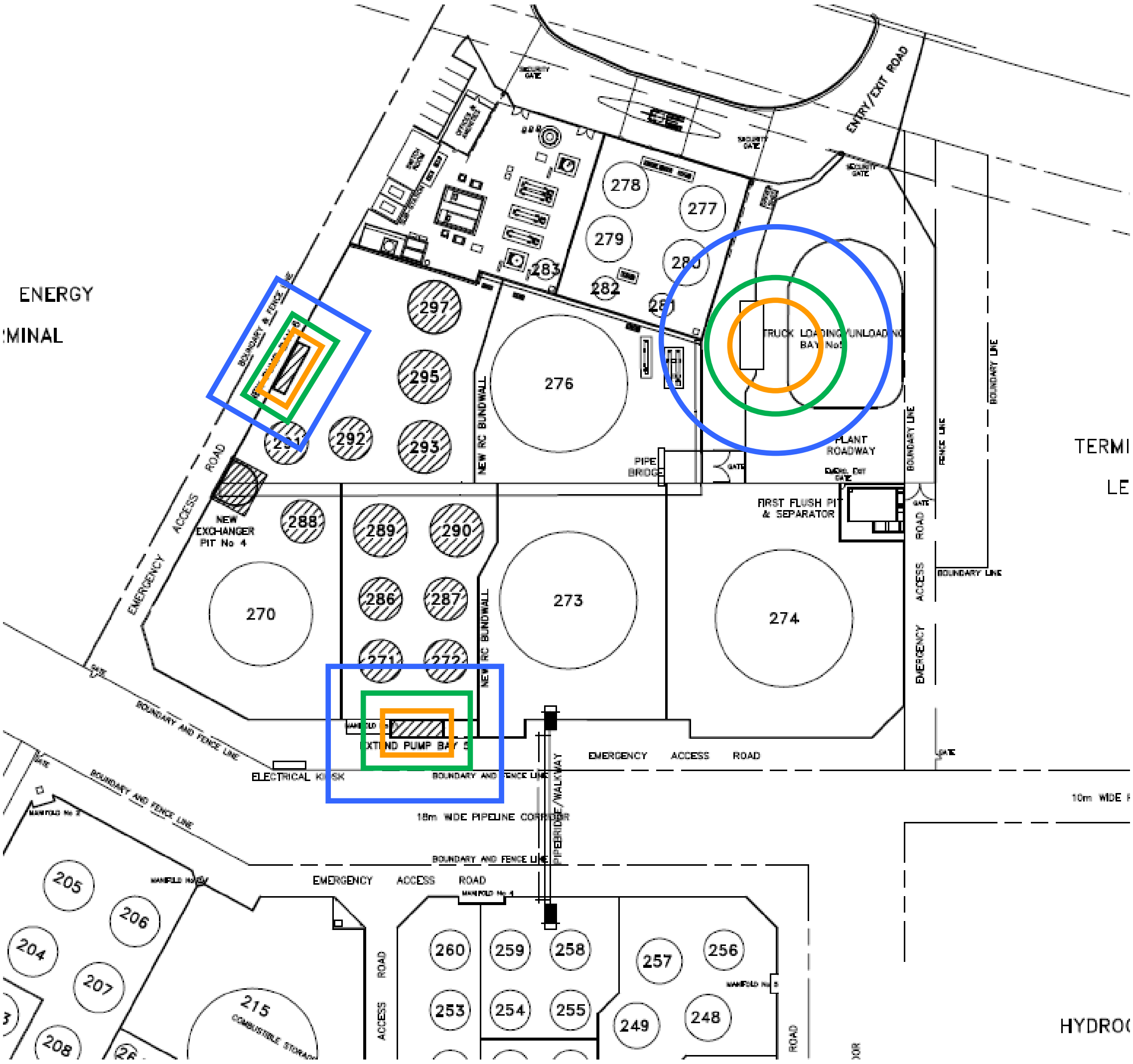


Note: Contours are an approximation given the irregular shape of the bund.

Key:

- 12.6 kW/m^2 (green line)
- 4.7 kW/m^2 (blue line)

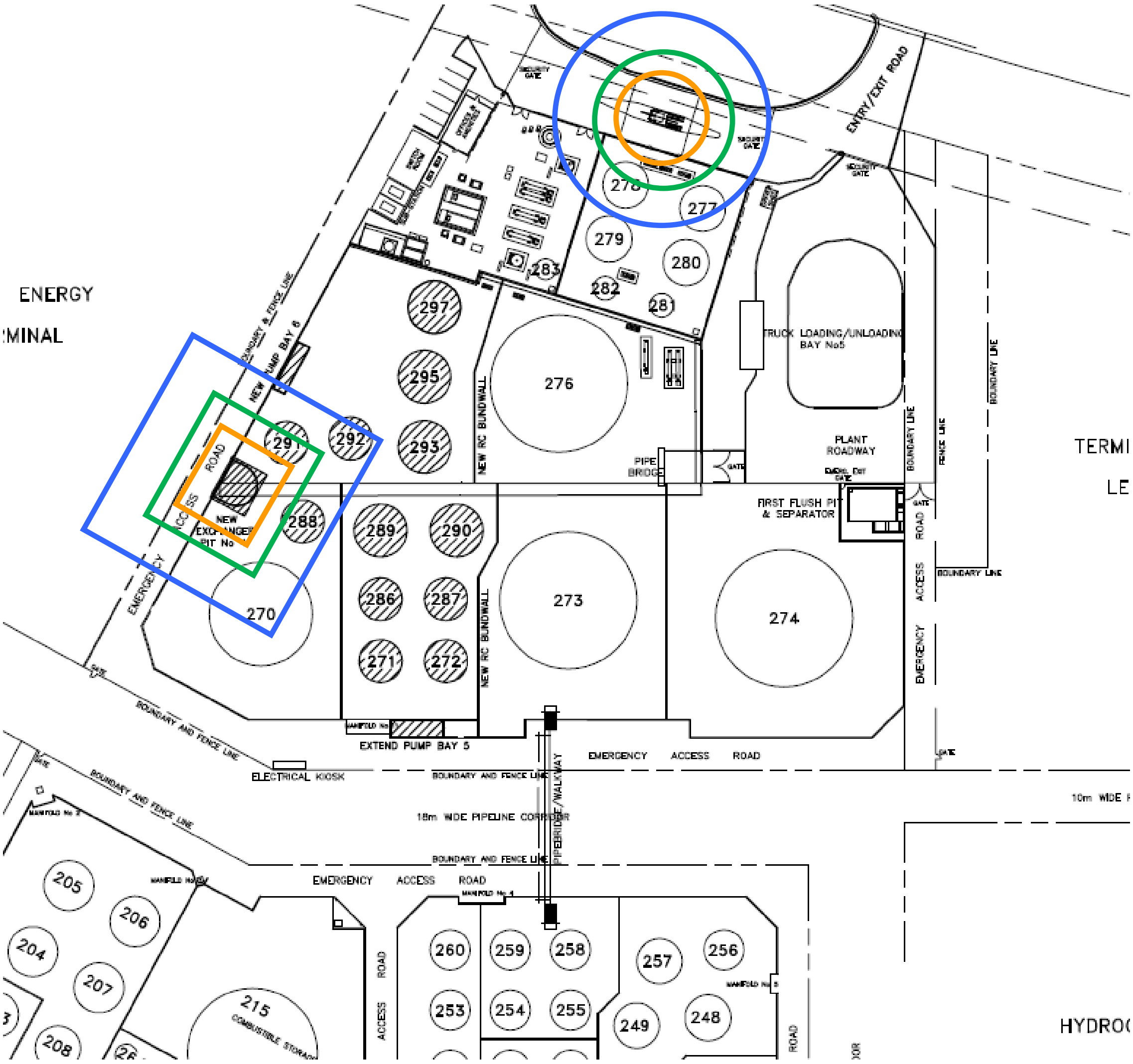
Scenarios 10a, 10b and 11– Pump Bunds and Existing Diesel Road Tanker Loading Bay Fires



Key:

- 23 kW/m²
- 12.6 kW/m²
- 4.7 kW/m²

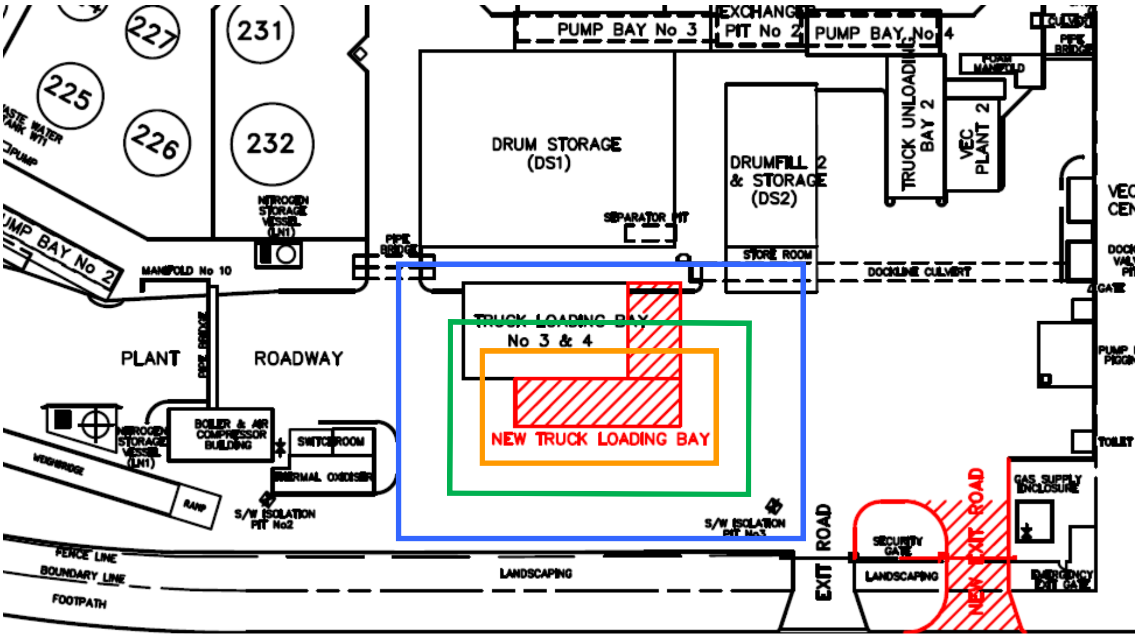
Scenarios 12 and 14– Existing Bitumen Road Tanker Loading Bay and Exchanger Pit No. 4 Fires



Key:

- 23 kW/m^2 (orange)
- 12.6 kW/m^2 (green)
- 4.7 kW/m^2 (blue)

Scenario 13– Stage 3 Road Tanker Loading Bay Fire



Key:

- Orange: 23 kW/m²
- Green: 12.6 kW/m²
- Blue: 4.7 kW/m²

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