Pinnacle Risk Management Pty Ltd

PRELIMINARY HAZARD ANALYSIS, QUANTEM, SITE A, SECOND COMBUSTOR, PORT BOTANY, NSW

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Rev	Date	Description	Reviewed By
A	14/11/20	Draft for Comment	Quantem

CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

Quantem owns and operates three bulk liquid storage and handling facilities at Port Botany, NSW, i.e. Sites A, B and C. Site A is the original site which was built in 1978 and extended in the early 1980's. This area is adjacent to Friendship Road and is used to store flammable, combustible and corrosive liquids.

Quantem are proposing to install a second combustor or thermal oxidiser. As part of the project requirements, a Preliminary Hazard Analysis (PHA) is required.

The risks associated with the proposed second combustor at Quantem's Site A have been assessed and compared against the DoP risk criteria. The results are as follows and show compliance with all risk criteria.

Description	Risk Criteria	Risk Acceptable?
Fatality risk to sensitive uses, including hospitals, schools, aged care	0.5 x 10^{-6} per year	Yes
Fatality risk to residential and hotels	1 x 10^{-6} per year	Yes
Fatality risk to commercial areas, including offices, retail centres, warehouses	5 x 10^{-6} per year	Yes
Fatality risk to sporting complexes and active open spaces	10 x 10^{-6} per year	Yes
Fatality risk to be contained within the boundary of an industrial site	50 x 10^{-6} per year	Yes
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 x 10^{-6} per year	Yes
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 x 10^{-6} per year	Yes
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 x 10^{-6} per year	Yes
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 x 10^{-6} per year	Yes

Societal risk, area cumulative risk and environmental risk is also concluded to be acceptable.

The primary reasons for the low risk levels from the second combustor are that significant levels of radiant heat from potential fires are contained on-site and the likelihood of catastrophic equipment failures is acceptably low. As the proposed combustor feed pipes and equipment have already been reviewed via the HAZOP technique then there are no further recommendations from this PHA.

GLOSSARY

ALARP	As Low As Reasonably Practicable
API	American Petroleum Institute
AS	Australian Standard
ASME	American Society of Mechanical Engineers
BTX	Benzene Toluene Xylene
CCTV	Closed Circuit Television
DG	Dangerous Good
DoP	Department of Planning
EPA	Environmental Protection Authority
ESD	Emergency Shutdown
GHS	Globally Harmonized System
HAZOP	Hazard and Operability Study
HIPAP	Hazardous Industry Planning Advisory Paper
IBC	Intermediate Bulk Containers
LEL	Lower Explosive Limit
LPG	Liquefied Petroleum Gas
PHA	Preliminary Hazard Analysis
QRA	Quantitative Risk Analysis
SPC	Sydney Ports Corporation
UK HSE	United Kingdom Health and Safety Executive
VCS	Vapour Combustion System
VECS	Vapour Emission Control System
VIE	Vacuum Insulated Expander

REPORT

1 BACKGROUND AND OBJECTIVES

Quantem owns and operates three bulk liquid storage and handling facilities at Port Botany, NSW, i.e. Sites A, B and C. Site A is the original site which was built in 1978 and extended in the early 1980's. This area is adjacent to Friendship Road and is used to store flammable, combustible and corrosive liquids.

Quantem are proposing to install a second combustor or thermal oxidiser. As part of the project requirements, a Preliminary Hazard Analysis (PHA) is required.

Quantem requested that Pinnacle Risk Management prepare the PHA for the proposed modification. This PHA has been prepared in accordance with the guidelines published by the Department of Planning (DoP) Hazardous Industry Planning Advisory Paper (HIPAP) No 6 (Ref 1).

1.1 OBJECTIVES

The main aims of this PHA study are to:

- Identify the credible, potential hazardous events associated with the proposed second combustor;
- Evaluate the level of risk associated with the identified potential hazardous events to surrounding land users and compare the calculated risk levels with the risk criteria published by the DoP in HIPAP No 4 (Ref 2);
- Evaluate the potential for propagation events;
- Review the adequacy of the proposed safeguards to prevent and mitigate the potential hazardous events; and
- Where necessary, submit recommendations to Quantem to ensure that the proposed second combustor is operated and maintained at acceptable levels of safety and effective safety management systems are used.

1.2 SCOPE

This PHA assesses the credible, potential hazardous events and corresponding risks associated with the proposed second combustor only with the potential for off-site impacts.

1.3 METHODOLOGY

In accordance with the approach recommended by the DoP 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 proposed second combustor was reviewed to identify credible, potential hazardous events, their causes and consequences. Proposed safeguards were also included in this review;
- As the potential hazardous events are located at a significant distance from other sensitive land users, the consequences (or likelihoods, as appropriate) of each potential hazardous event were estimated to determine if there are any possible unacceptable off-site impacts or risks;
- Included in the analysis is the risk of propagation between the proposed combustor equipment and piping and the adjacent processes; and
- If adverse off-site impacts could occur, assess the risk levels to check if they are within the criteria in HIPAP 4 (Ref 2).

2 SITE AND PROCESS DESCRIPTION

2.1 SITE LOCATION AND LAYOUT

Site A is located on the Quantem 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 residential area is 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 for transport by pipeline to Botany Industrial Park manufacturing site at Botany.

Vopak (Sites B and C): This terminal stores and distributes hydrocarbon products such as unleaded petrol, diesel and jet fuel. Vopak's Site A was sold to Quantem and is now known as Quantem Site C.

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.

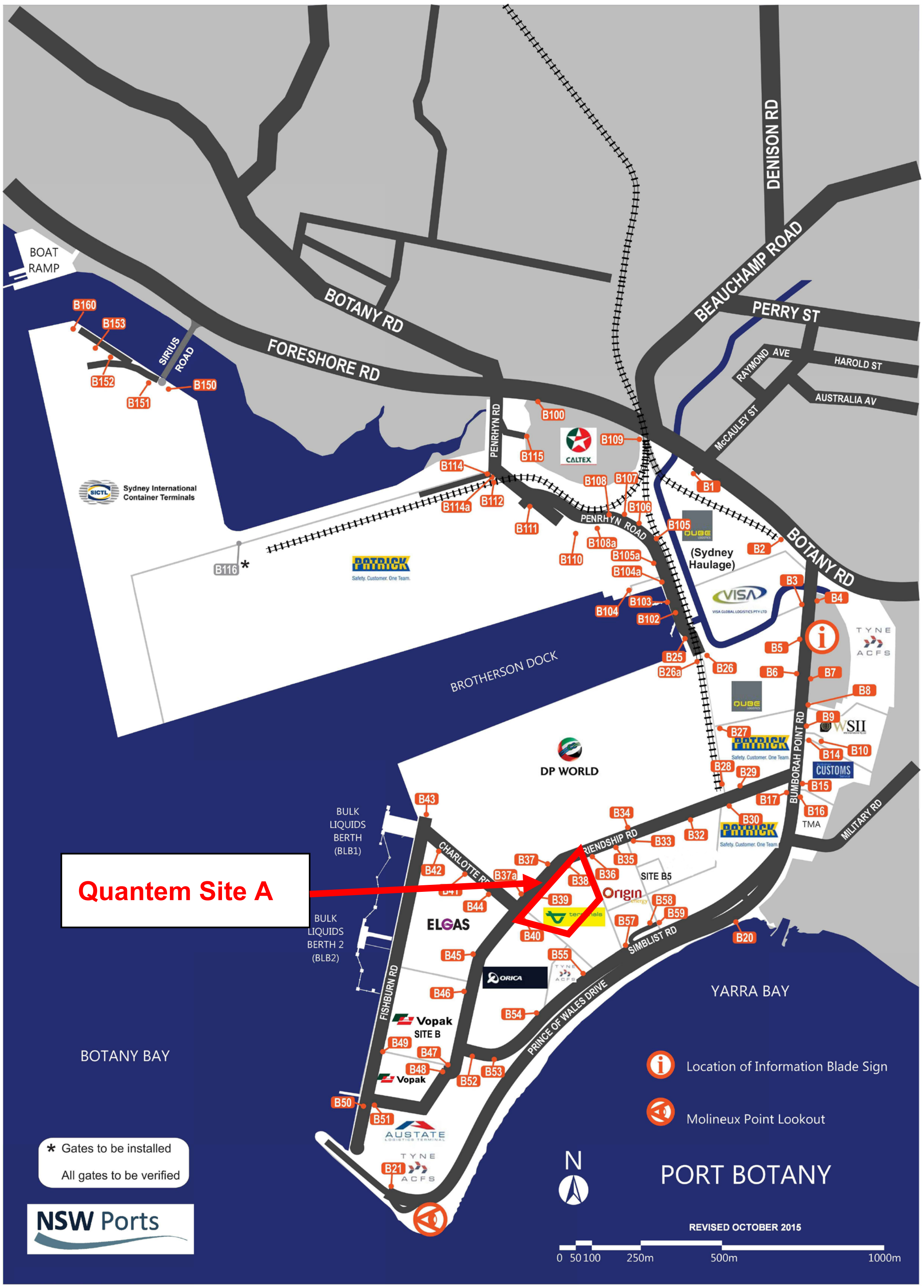
P&O Ports, Molineaux Point: A facility for storing and distributing shipping containers.

Construction of the Quantem site began in 1978 and has expanded in five major stages to date. Site A has 64 tanks of various sizes with a total storage capacity of 48,000 m^3 of bulk liquids. 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 and IBCs (intermediate bulk containers);
- 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 (vacuum insulated expander) for tank blanketing etc.

Figure 1 - Site Location



The site layout is shown in Figure 2.

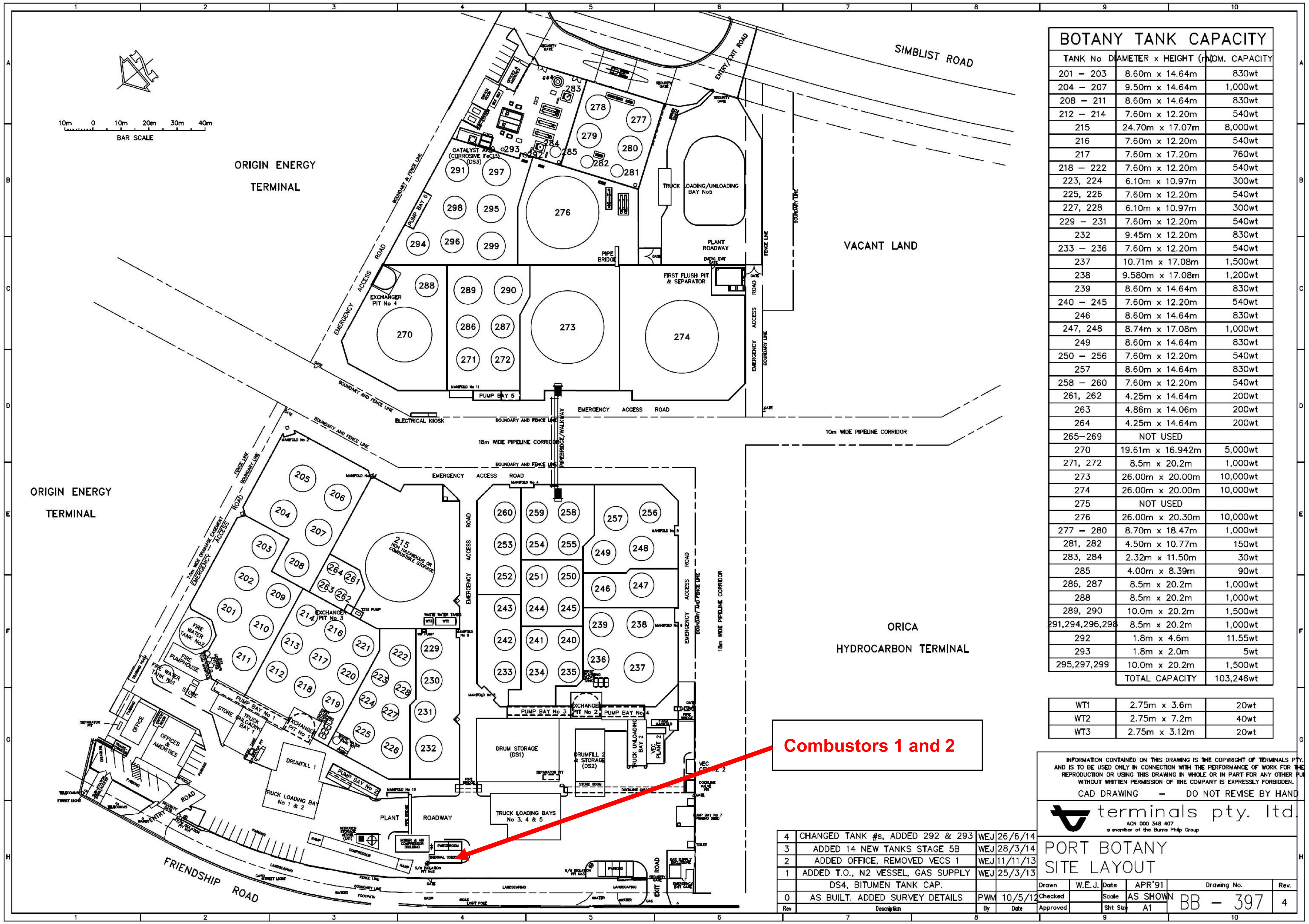
Security of the site is achieved by a number of means. This includes site personnel who are present 24/7. Also, the site is fully fenced and non-operating gates are locked (e.g. to the pipeline corridor). The main entrance and exit gates are normally closed. A security swipe card is required to open them. Security cameras (CCTV) are installed around the perimeter of the site and for staff to view visitors prior to entry as well as observe selected areas of the site.

Staff are on-site to inspect the facility, are trained to accept alarms and act on unusual incidents.

There are approximately 26 people on-site during shift-changeovers in normal working hours (plus drivers, visitors and contractors).

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



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
265–269	NOT USED	
270	19.61m x 16.942m	5,000wt
271, 272	8.5m x 20.2m	1,000wt
273	26.00m x 20.00m	10,000wt
274	26.00m x 20.00m	10,000wt
275	NOT USED	
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
286, 287	8.5m x 20.2m	1,000wt
288	8.5m x 20.2m	1,000wt
289, 290	10.0m x 20.2m	1,500wt
291,294,296,298	8.5m x 20.2m	1,000wt
292	1.8m x 4.6m	11.55wt
293	1.8m x 2.0m	5wt
295,297,299	10.0m x 20.2m	1,500wt
	TOTAL CAPACITY	103,246wt

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

2.2 PROCESS DESCRIPTION

2.2.1 Site Summary

There are 64 major storage tanks on the Site A for storing products. The products are transferred into the terminal by sea-going parcel tankers or via road tanker. The products are stored in the tanks until being loaded into road tankers for delivery to customers or exported by ship.

Site A includes the following main components:

- A total of 48,000 m^3 of bulk chemical product can be stored on the site including:
  - 12 ethanol (fuel / industrial / food grade) tanks. Total ethanol stored on Site A is up to 7,800 m^3;
  - 14 fixed roof methanol tanks with a capacity of 9,071 m^3;
  - One 8,000 m^3 jet fuel tank;
  - Remainder consisting of flammable, combustible or corrosive chemicals;
- Two road tanker gantries:
  - A two-bay road tanker loading gantry (bays 1 and 2);
  - A three-bay road tanker loading gantry (bays 3, 4 and 5);

  The tanker loading bays 3 and 5 are bottom loading, bays 2 and 4 are top loading while bay 1 is a mixture of top and bottom loading. There is currently a project to convert most tanker loading operations to bottom loading for enhanced safety.
- Two road tanker unloading bays:
  - Truck unloading bay 1. This is currently used for the transfer of monoethylene glycol. This bay is rarely used;
  - Truck unloading bay 2. This is currently used for the transfer of Iso-hexane;
- Fire protection including:
  - Foam system suppling foam pourers on the flammable tanks;
  - Spray cooling on tank shells and roofs as per AS1940;

Note: For some tanks this is not the case. Temporary portable fire water monitors are being used until fixed systems can be installed;

- Gantry foam deluge system for flammable loading bays including fire detection and automated foam deluge;
- Foam deluge system for the flammable pump bays including automated foam deluge;
- Site firewater ring main and associated hydrants and monitors;

➢ Two x 100% diesel firewater pumps (18,000 litres per minute);

➢ Tank compounds and bunds as per AS1940 (Australian Standard for the Storage and Handling of Flammable and Combustible Liquids);

➢ Drainage system including API (American Petroleum Institute) triple interceptor;

➢ Electrical and control systems;

➢ Tank gauging / stock controls:

- Tank gauging currently only exists on a few tanks;
- The inventory in most tanks is by manually dipping a tank;
- High level switches / alarms are provided on each tank;

➢ Emergency Shutdown Systems (ESD);

➢ 205 L drums are filled in the Drumfill 1 building. The drums are then stored in the Drum Storage (DS1) building (up to a capacity of 400 m^3). The Drumfill 2 and Storage (DS2) operations will cease in 2017;

➢ Product pipework and pumps:

- Ship discharge / loading and transfer piping;
- Tanker loading and unloading facilities;
- Drum fill piping as required;
- A vapour collection system for collecting and processing vapours from:
    - Storage tanks; and
    - Road tankers when being filled;

➢ Vapour emission control systems:

- Vapour combustion system (VCS). The second combustor will be identical in operation and located in the same area as the existing vapour combustion system; and

- Vapour emission control system (VECS); and

➢ Slops handling facilities.

2.2.2 Vapour Emission Control

Tank vents during ship discharge and truck vents are connected to the Vapour Combustion System (VCS) or Vapour Control System (VECS) for the following chemicals:

➢ Carcinogens Category 1 (A and B) and 2 as per the GHS (Globally Harmonised System) classification scheme;

➢ Highly odorous chemicals;

➢ Those with a vapour pressure of higher than 1 kPa at a temperature of 20°C; and

➢ Those classed as hazardous taking into account vapour pressure and exposure limits.

Existing Vapour Combustion System (VCS)

The vapour combustion system processes displaced vapours from designated storage tanks (e.g. BTX, benzene and hexene operations) in a thermal oxidiser (combustor). All vapours generated during tank filling, tank breathing and ship loading are directed to the thermal oxidiser via a vapour collection line and fan.

Vapours from the tanks are directed as an inert stream (mostly nitrogen with the volatile organic compounds) into the thermal oxidiser. The nitrogen ensures the stream composition is below the lower explosive limit (LEL) and hence internal explosions within the piping system are prevented.

In the case of the storage tanks, nitrogen inerting takes place via the existing nitrogen blanketing system. In the case of ship loading, nitrogen is injected into the vapour collection line.

Oxygen sensors are in the vapour ducting to the thermal oxidiser. High oxygen levels will trip the thermal oxidiser. This causes the system to divert to the carbon bed adsorption system (VECS).

Vapours are also diverted to the carbon adsorption system whenever the thermal oxidiser is not available or shutdown and whenever the system requires purging of the vapour collection line (e.g. initial start-up and the high oxygen trip activated).

Proposed Second Combustor

Quantem propose to install an additional larger combustor (thermal oxidiser) at Site A with the existing combustor to remain to allow for redundancy and peak loads. The existing combustor burns waste vapours. The proposed second combustor will burn waste liquids as well as vapours. See Figure 3 for the process schematic.

The objectives to install a second combustor at Site A are to comply with EPA regulations as well as support the site during peak thermal load scenarios. The existing combustor is operating near to the design capacity and therefore Site A has no vapour destruction redundancy. The existing design relies on the VECS (vapour emission control system) carbon beds to temporarily handle any shutdown of the existing combustor which results in a restriction to Site A activities.

The second combustor will be larger in capacity along with added liquid waste burning capability. It will be used in normal operations with the existing combustor remaining as the back-up combustor for 100% redundancy and also used in conjunction with the second combustor for site thermal peak load scenarios.

The project has the potential value-added benefit of liquid waste burning to reduce export waste disposal from the site.

The vapour supply to the new combustor will be from the existing vapour header to the current VECS and combustor systems. The supply piping design and controls to the new combustor will be identical to the existing combustor.

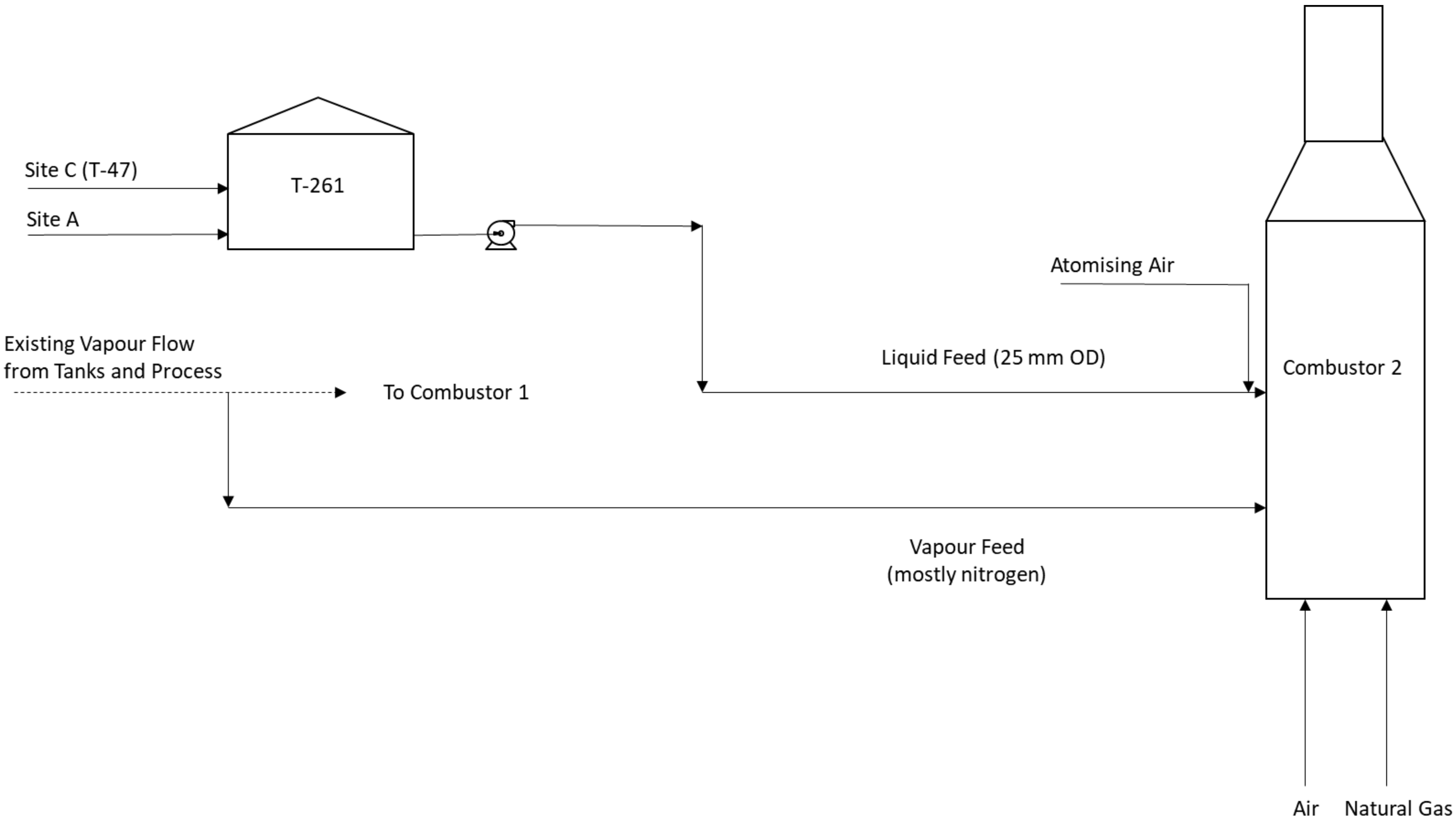
Waste liquid will be sourced from a number of locations as follows:

- Site A; and
- Transfers from waste tank T-47 at Site C.

As part of this project, Waste Tank 1 and its associated equipment at Site A will be removed. Existing tank, T-261, will be re-purposed as a new waste tank. This is a fixed-roof tank with approximately 200 m^3 capacity. It has redundant high level protection and fire protection (foam injection and exterior cooling water via sprays).

Waste liquid from T-261 will be pumped to the proposed second combustor for treatment. If this combustor is not available, the waste liquid can be transferred via the existing piping systems to a road tanker, or Waste Tanks 2 and/or 3. When the waste liquid enters the proposed combustor, instrument air will be used to spray the waste liquid through a nozzle into the combustor to facilitate the combustion process.

Figure 3 – Second Combustor Schematic



Vapour Emission Control System (VECS)

All other vapours are directed through the vapour emission control system (VECS). The VECS will process displaced vapour from the road tanker loading gantries and storage tanks as a dilute stream. The displaced vapour is passed through vessels of activated carbon that adsorb the volatile organic compounds.

The VECS is fitted with an emissions monitoring device. The monitor has two purposes which are as follows:

1. To switch carbon beds when the on-line carbon bed is fully saturated;
2. Initiate steam regeneration / drying sequence for the saturated bed, and
3. To provide a log of the emissions.

LEL meters are located in the ducting to the VECS. These will trip the VECS and vent to atmosphere on high LEL.

3 HAZARD IDENTIFICATION

3.1 HAZARDOUS MATERIALS

Site A stores and handles the following chemicals:

1. Combustible liquids such as base oils, monoethylene glycol and jet fuel;
2. Flammable liquids such as ethanol, methanol, BTX (benzene, toluene and xylene), acetone and hexene;
3. The only Dangerous Good (DG) Class 6 (i.e. toxic material) the site has recently stored and handled is methanol. The DG Class for methanol is 3 with a subsidiary risk of 6.1;
4. Corrosive liquids such as sodium hydroxide; and
5. Natural gas, e.g. to the combustors.

The hazards of the combustible liquids, flammable liquids and natural gas include fires and explosions. Releases of natural gas, if ignited, include jet fires, flash fires and explosions (if confined).

In a fire, the products include smoke, carbon dioxide and carbon monoxide.

Combustible liquids are generally difficult to ignite in normal operation. However, sprays are more easily ignited.

Some products, e.g. ethanol, are soluble in water. Ethanol and methanol also burn with a near colourless flame. Fires involving these types of materials are normally extinguished with alcohol resistant foam.

All petroleum products are potentially injurious to humans, e.g. carcinogenic properties, and aquatic organisms.

3.2 HAZARDOUS EVENTS

The credible, significant fire and/or explosion incidents identified for the proposed second combustor are summarised in the hazard identification word diagram following (Table 1). Events involving tank T-261 are existing as this tank currently holds flammable or combustible liquids and therefore are not included in Table 1.

The hazardous event word diagram presents the causes and consequences of the events, together with major preventative and protective features that are included as part of the design.

Table 1 – Hazard Identification Word Diagram

Event ID No.	Hazardous Event	Causes	Possible Consequences	Proposed Prevention and Mitigation Control Measures
1.	Pipe failure, i.e. the pipe conveying flammable and/or combustible liquids to the second combustor	Corrosion Impact Maintenance work Pressure surge	Spillage of product. Fire if ignition occurs for the flammable and combustible materials. Impact to people (radiant heat and/or exposure to products), property and the environment (products of combustion)	Regular maintenance and inspection procedures Firefighting system (including foam) Pipe within bunded or contained 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 The pipe is relatively small, i.e. only 25 mm diameter
2.	Leak at new transfer pump	Pump seal, shaft or casing failures	Leak of product in pump bund Local pump fire if ignition occurs for the flammable and combustible materials 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 Firefighting as above Pump within contained area

Event ID No.	Hazardous Event	Causes	Possible Consequences	Proposed Prevention and Mitigation Control Measures
3.	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 / carbon steel and at low pressure. Piping is designed and constructed to AS4041 or AS5601. 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 includes the required isolation procedures when fire fighting

Event ID No.	Hazardous Event	Causes	Possible Consequences	Proposed Prevention and Mitigation Control Measures
4.	Internal explosion within the thermal oxidiser (combustor)	Gas or vapour 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 units (e.g. the thermal oxidiser is an open-ended burner in a vertical chamber)	Loss-of-flame shutdown via double isolation valves. Pre-purge before start up sequence. Testing of shutdown and pre-purge sequence as part of regular maintenance and inspection procedures. Combustor control system compliant with the Australian Standards (e.g. AS3814) to achieve the required integrity level
5.	Internal explosion within the vapour feed line to the second combustor	Gas or vapour mixture is in the flammable region and a source of ignition is present, e.g. flashback from the combustor	Internal pipe explosions leading to the pipe failing, i.e. damage to local equipment and injury to nearby people	The vapour feed stream to the combustor is mostly nitrogen. Redundant gas detectors in the vapour feed stream with alarms and trips. Detonation arrester in the vapour line

4 RISK ANALYSIS

The assessment of risks to both the public as well as to operating personnel for the proposed modifications 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. Risk analysis could be qualitative, semi-quantitative or quantitative.

The typical risk analysis methodology attempts to take account of all credible hazardous situations that may arise from the operation of processing plants etc.

Having identified all credible, significant incidents, risk analysis requires the following general approach for individual incidents:

Risk = Likelihood x Consequence

The risks from all individual potential events are then summated to get cumulative risk.

For QRA (quantitative risk analysis) 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 reason for this approach is the distances from the proposed modifications to residential and other sensitive land users are large and hence it is unlikely that any significant consequential impacts, e.g. due to radiant heat from fires, from the facility will have any significant contribution to off-site risk.

The risk criteria applying to developments in NSW are summarised in Table 2 on the following page (from Ref 2).

Table 2 - 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

From a review of potential hazardous events listed in Table 1, there are local events, e.g. partially confined explosions in the proposed combustor, that do not credibly pose any significant off-site risks and also ignitions of natural gas, and flammable and/or combustible liquids releases. The latter are assessed in the next section to determine the risk levels.

4.1 Natural Gas, and Flammable and Combustible Liquids Releases

Failures associated with the natural gas feed line to the proposed combustor will release the natural gas to atmosphere and hence the possibility of ignition. This can lead to jet and/or flash fires and possibly an explosion if the vapours are confined (the latter is less likely given the terminal layout). Similar releases for the waste flammable and/or combustible liquids pipe to the proposed combustor, if ignited, can result in pool fires.

The natural gas line is installed both above and below ground throughout the site. The mains supply pressure is 10.5 barg and is reduced to 2.75 barg at the site boundary. The gas pipe is 80 mm nominal diameter. 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 existing and proposed combustors is shown in Table 3. From above, the natural gas pressure is taken as 2.75 barg (at ambient temperature).

Table 3 –Natural Gas Jet Fires

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

As expected for these size jet fires, no adverse radiant heat levels will be imposed off-site or onto the storage tanks. However, propagation to adjacent equipment could be expected if there is direct flame contact.

The waste liquids pipe to the proposed combustor will be 25 mm diameter.

The estimated likelihoods for loss of containment events from piping systems are shown in the following table (Ref: UK HSE (Ref 3).

Table 4 – Piping Failure Frequencies

Failure Rates (per m per year) for Pipework Diameter (mm)					
Hole Size:	0 - 49	50 - 149	150 - 299	300 - 499	500 – 1,000
3 mm diameter	1×10^{-5}	2×10^{-6}			
4 mm diameter			1×10^{-6}	8×10^{-7}	7×10^{-7}
25 mm diameter	5×10^{-6}	1×10^{-6}	7×10^{-7}	5×10^{-7}	4×10^{-7}
1/3 pipework diameter			4×10^{-7}	2×10^{-7}	1×10^{-7}
Guillotine	1×10^{-6}	5×10^{-7}	2×10^{-7}	7×10^{-8}	4×10^{-8}

Typical probabilities of gas and flammable liquids ignition are shown in the following table (Ref 4).

Table 5 – Ignition Probabilities

Leak	Probability of Ignition	
	Gas	Liquid
Minor (<1 kg/s)	0.01	0.01
Major (1 to 50 kg/s)	0.07	0.03
Massive (>50 kg/s)	0.3	0.08

For example, the likelihood of catastrophic (guillotine) pipe failure for an 80 mm natural gas pipe is 5×10^{-7} / m per year. If a probability of ignition of 0.07 is used, i.e. a major leak, then the combined fire and explosion likelihood is:

$$0.07 \times 5 \times 10^{-7} \text{ / m per year} = 3.5 \times 10^{-8} \text{ / m per year.}$$

Similarly, the likelihood of catastrophic pipe failure for a 25 mm flammable and/or combustible liquids pipe is 1×10^{-6} / m per year. If a probability of ignition of 0.03 is used, i.e. a major leak, then the fire likelihood is:

$$0.03 \times 1 \times 10^{-6} \text{ / m per year} = 3 \times 10^{-8} \text{ / m per year.}$$

As these are low likelihoods (and correspondingly the risk is low) and they are below the risk criteria shown in Table 2 then they are not considered intolerable. The ALARP (As Low As Reasonably Practicable) principle is achieved; primarily due to compliance with the Australian Standards for piping.

4.2 CUMULATIVE AND PROPAGATION RISK

The proposed combustor is to be located away from the storage tanks and tanker transfer areas as shown in Figure 2. The estimated release and ignition likelihoods from the above Section, e.g. 3.5×10^{-8} / m per year for catastrophic failures of the natural gas pipe, are low. As only some of the ignition events will impinge on adjacent equipment, e.g. a jet fire could be vertically upwards, then the propagation likelihood will be lower than these values. Correspondingly, the likelihood of propagation is deemed to be acceptably low.

Given that significant levels of radiant heat from potential fires remain on-site, e.g. the natural gas jet fires are up to an estimated 9 m, and that the likelihoods of a catastrophic failures with ignition are acceptably low then it is reasonable to conclude that the proposed combustor does not make a significant contribution to the existing cumulative risk in the area.

4.3 SOCIETAL RISK

The criteria in HIPAP 4 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 proposed combustor, the risk of off-site fatality is below the HIPAP 4 risk criteria. As the nearest house is approximately 1,000 m away and the adjacent area at Port Botany has a low population density, the concept of societal risk applying to populated areas is therefore not applicable for this project.

4.4 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 proposed combustor, there are no solid or gaseous effluents that could significantly impact the environment.

Spills of flammable and/or combustible liquids at the site are contained either via the existing bunded areas, e.g. Tank 261, or via the stormwater pits with isolation valves (normally closed). The latter will mitigate the environmental risk of liquid releases from the combustor waste liquid line in the combustor area (not part of a tank or transfer bay bunded area).

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.

5 CONCLUSION AND RECOMMENDATIONS

The risks associated with the proposed second combustor at Quantem's Site A have been assessed and compared against the DoP risk criteria.

The results are as follows and show compliance with all risk criteria.

Description	Risk Criteria	Risk Acceptable?
Fatality risk to sensitive uses, including hospitals, schools, aged care	0.5×10^{-6} per year	Yes
Fatality risk to residential and hotels	1×10^{-6} per year	Yes
Fatality risk to commercial areas, including offices, retail centres, warehouses	5×10^{-6} per year	Yes
Fatality risk to sporting complexes and active open spaces	10×10^{-6} per year	Yes
Fatality risk to be contained within the boundary of an industrial site	50×10^{-6} per year	Yes
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	Yes
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	Yes
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	Yes
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	Yes

Societal risk, area cumulative risk and environmental risk is also concluded to be acceptable.

The primary reasons for the low risk levels from the second combustor are that significant levels of radiant heat from potential fires are contained on-site and the likelihood of catastrophic equipment failures is acceptably low. As the proposed combustor feed pipes and equipment have already been reviewed via the HAZOP technique then there are no further recommendations from this PHA.

6 REFERENCES

1 Department of Planning and Infrastructure (NSW) *Hazardous Industry Planning Advisory Paper No 6 – Hazard Analysis,* January, 2011

2 Department of Planning and Infrastructure (NSW) *Hazardous Industry Planning Advisory Paper No 4 – Risk Criteria for Land Use Safety Planning,* January, 2011

3 UK HSE, *Failure Rate and Event Data for use within Risk Assessments*, 28/06/2012

4 Cox, Lees and Ang, *Classification of Hazardous Locations*, January 2000