Appendix D

Noise

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CALTEX REFINERY, KURNELL

CONSTRUCTION NOISE & VIBRATION

ASSESSMENT OF JET FUEL PIPELINE

TE992-02F02 (REV 3) CN&V ASSESSMENT.DOC

12 APRIL 2011

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DOCUMENT CONTROL

Date	Revision History	Non-Issued Revision	Issued Revision	Prepared By (initials)	Instructed By (initials)	Reviewed & Authorised by (initials)
22/12/2010	Generation of report	-	0	MCH	-	MCH
11/01/2011	Revise report	-	1	MCH	-	MCH
09/03/2011	Further update of report	-	2	MCH	-	MCH
12/03/2011	Finalise report	-	3	MCH	-	MCH

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1 INTRODUCTION

1.1 Background Information

Renzo Tonin & Associates were engaged to undertake a desktop environmental noise and vibration assessment associated with the construction of the jet fuel pipeline from the Caltex refinery at Kurnell to the Banksmeadow Terminal in Banksmeadow. More specifically, this report quantifies the noise and vibration impact from construction activity associated with the jet fuel pipeline and assesses the potential impact on neighbouring premises close to the site.

The issues addressed in this study include noise and vibration emissions during construction of the pipeline and identifies sensitive locations to assess potential noise and vibration impacts against noise and vibration criteria stipulated by the NSW Department of Environment, Climate Change and Water (DECCW).

The existing ambient noise environment was previously measured at locations near the proposed construction site at Kurnell and has been used for the establishment of construction noise criteria for nearby affected residential receivers in Kurnell. Construction noise emissions from the jet fuel pipeline were then calculated at the potentially most affected neighbouring premises at Kurnell and Banksmeadow during the construction works of the project.

The work documented in this report was carried out in accordance with the Renzo Tonin & Associates Quality Assurance System, which is based on Australian Standard / NZS ISO 9001

1.2 Study Area

This study concentrates on two areas associated with the proposed jet fuel pipeline:

<u>Kurnell</u>

The proposed construction in Kurnell will include the area along Road 7 located on the north western side of the Caltex refinery and along the pipeline easement from Road 7 through to the refinery wharf at Kurnell.

<u>Banksmeadow</u>

The proposed construction in Banksmeadow will include a small area on the northern side of the Banksmeadow Terminal.

Specifically, this study investigates construction noise and vibration impacts at sensitive receivers near these study areas.

An assessment of construction noise impacts was completed at the nearest affected sensitive receivers. For the purpose of construction noise assessment the nearest and potentially worst affected sensitive receivers were identified as follows:

Kurnell

- **Receiver R1 – 44-64 Cook Street (Industrial Premises)**
  Industrial premises adjacent to the Caltex refinery to the west and sharing a common boundary. Potentially impacted by construction noise from within the refinery and along the pipeline easement.
- **Receiver R2 – 30D Cook Street (Residential)**
  Residential property adjacent to the Caltex refinery to the west and sharing a common boundary. Potentially impacted by construction noise from within the refinery and along the pipeline easement.
- **Receiver R3 – 21 Cook Street (Residential)**
  Residential property west of the refinery and potentially impacted by construction noise along the pipeline easement.
- **Receiver R4 – 48 Prince Charles Parade (Residential)**
  Residential property south of the refinery wharf and potentially impacted by construction noise along the pipeline easement.

Banksmeadow

- **Receiver R5 – EGL Eagle Global Logistics (Industrial / Commercial Premises)**
  Industrial and commercial premises to the north of the Banksmeadow Terminal, across Botany Road. Potentially impacted by noise from construction activities on the northern side or the Banksmeadow Terminal. For a conservative assessment, this receiver will be assessed as a commercial type receiver.

Detailed maps showing the study areas and the receiver locations are shown in Figure 1 and Figure 2.

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Title : Figure 1 - Kurnell Site,Surrounds & Reciever Locations	**Date :** 22/12/10	**Scale:** NTS
Project : Caltex Jet Fuel Pumps	**Ref:** TE992-02P01 (rev 0)	

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Title : Figure 1 - Banksmeadow Terminal Site,Surrounds & Reciever Location	**Date :** 12/04/11 — **Scale:** NTS
Project : Caltex Jet Fuel Pumps	**Ref:** TE992-02P02 (rev 0)

2 EXISTING NOISE ENVIRONMENT

Background noise varies over the course of any 24 hour period, typically from a minimum at 3am in the morning to a maximum during morning and afternoon traffic peak hours. Therefore, the NSW 'Industrial Noise Policy' (INP) requires that the level of background and ambient noise be assessed separately for the daytime, evening and night-time periods. The INP defines these periods as follows:

- **Day** is defined as 7:00am to 6:00pm, Monday to Saturday and 8:00am to 6:00pm Sundays & Public Holidays.
- **Evening** is defined as 6:00pm to 10:00pm, Monday to Sunday & Public Holidays.
- **Night** is defined as 10:00pm to 7:00am, Monday to Saturday and 10:00pm to 8:00am Sundays & Public Holidays.

To determine background L_{90} noise levels used for the construction noise assessment, previous long-term unattended noise monitoring carried out between 27th April and 4th May 2006 at the following locations were obtained:

- **Location M1 – 15 Cook Street, Kurnell**
  Noise monitoring undertaken in the rear yard. Noise environment is considered to be representative of residences potentially impacted by the proposed construction activities.

The results of the background noise measurements are presented in Table 2.1 below.

Table 2.1 – Previously Monitored Background (L_{90}) Noise Levels, dB(A)

Noise Monitoring Location	L_{90} Background Noise Levels		
	Day	Evening	Night
Location M1 – 15 Cook Street	41	43	39

3 CONSTRUCTION NOISE ASSESSMENT

3.1 Construction Noise Criteria

3.1.1 Interim Construction Noise Guideline

Chapter 171 of the NSW *Environmental Noise Control Manual* (ENCM, Environment Protection Authority 1994) provides guidelines for assessing noise generated during the construction phase. However, the Department of Environment, Climate Change and Water (DECCW – formerly DECC) has recently released its *NSW Interim Construction Noise Guideline* (ICNG). This document is the DECCW's standard policy for assessing construction noise. This new guideline supersedes Chapter 171 of the ENCM.

The key components of the guideline that could be incorporated into this assessment include:

1. Use of L_{Aeq} as the descriptor for measuring and assessing construction noise.

   In recent years NSW noise policies including DECCW's NSW Industrial Noise Policy (INP) and the NSW Environmental Criteria for Road Traffic Noise (ECRTN) have moved to the primary use of L_{Aeq} over any other descriptor. As an energy average, L_{Aeq} provides ease of use when measuring or calculating noise levels since a full statistical analysis is not required as when using, for example, the L_{A10} descriptor.

   Consistent with the ICNG we recommend the use of L_{Aeq} as the key descriptor for measuring and assessing construction noise.

2. Application of reasonable and feasible noise mitigation measures

   As stated in the ICNG, a noise mitigation measure is feasible if it is capable of being put into practice, and is practical to build given the project constraints.

   Selecting reasonable mitigation measures from those that are feasible involves making a judgement to determine whether the overall noise benefit outweighs the overall social, economic and environmental effects.

3. Quantitative and qualitative assessment

   The ICNG provides two methods for assessment of construction noise, being either a quantitative or a qualitative assessment.

   A quantitative assessment is recommended for major construction projects of significant duration, and involves the measurement and prediction of noise levels, and assessment against set criteria.

   A qualitative assessment is recommended for small projects with a duration of less than three weeks and focuses on minimising noise disturbance through the implementation of reasonable and feasible work practices, and community notification.

It is anticipated that construction works proposed for the jet fuel pipeline will occur for more than three weeks; therefore, a quantitative assessment is carried out herein, consistent with the ICNG's requirements.

Management Levels

Table 3.1 below (reproduced from Table 2 of the ICNG) sets out the noise management levels and how they are to be applied for residential receivers. The guidelines intend to provide respite for residents exposed to excessive construction noise outside the recommended standard hours whilst allowing construction during the recommended standard hours without undue constraints.

In Table 3.1 below, the rating background level (RBL) is used when determining the management level. The RBL is the overall single-figure background noise level measured in each relevant assessment period (during or outside the recommended standard hours).

Table 3.1 – Noise at Residences Using Quantitative Assessment

Time of Day	Management Level $L_{Aeq\ (15\ min)}$*	How to Apply
Recommended standard hours: Monday to Friday 7 am to 6 pm Saturday 8 am to 1 pm No work on Sundays or public holidays	Noise affected RBL + 10dB(A)	The noise affected level represents the point above which there may be some community reaction to noise. • Where the predicted or measured $L_{Aeq\ (15\ min)}$ is greater than the noise affected level, the proponent should apply all feasible and reasonable work practices to meet the noise affected level. • The proponent should also inform all potentially impacted residents of the nature of works to be carried out, the expected noise levels and duration, as well as contact details.
	Highly noise affected 75dB(A)	The highly noise affected level represents the point above which there may be strong community reaction to noise. • Where noise is above this level, the relevant authority (consent, determining or regulatory) may require respite periods by restricting the hours that the very noisy activities can occur, taking into account: 1. times identified by the community when they are less sensitive to noise (such as before and after school for works near schools, or mid-morning or mid-afternoon for works near residences) 2. if the community is prepared to accept a longer period of construction in exchange for restrictions on construction times.
Outside recommended standard hours	Noise affected RBL + 5dB(A)	• A strong justification would typically be required for works outside the recommended standard hours. • The proponent should apply all feasible and reasonable work practices to meet the noise affected level. • Where all feasible and reasonable practices have been applied and noise is more than 5dB(A) above the noise affected level, the proponent should negotiate with the community. • For guidance on negotiating agreements see section 7.2.2 of the *NSW Interim Construction Noise Guideline*.

** Noise levels apply at the property boundary that is most exposed to construction noise, and at a height of 1.5 m above ground level. If the property boundary is more than 30 m from the residence, the location for measuring or predicting noise levels is at the most noise-affected point within 30 m of the residence. Noise levels may be higher at upper floors of the noise affected residence.*

The measured background noise levels at the monitoring location (M1) were considered to be representative of the RBL for residences potentially impacted upon by construction works associated with the jet fuel pipeline. Therefore, measured background noise levels are suitable for setting construction noise criteria, consistent with a conservative assessment. Based on the background noise levels measured and the construction work proposed for the day time period only, the construction noise criteria for the day period are summarised below.

Table 3.2 – Summary of Construction Noise Management Levels

Receiver	Time of Day	Base Management Level $L_{Aeq(15min)}$
Receiver R2 – 30D Cook St	During recommended standard hours (day period)	41 + 10 = **51**
Receiver R3 – 21 Cook St		
Receiver R4 – 48 Prince Charles Pde		

Industrial and Commercial Premises

Industrial and commercial premises located near the proposed Kurnell and Banksmeadow construction sites may potentially be impacted by construction noise. Therefore, in accordance with Section 4.1.3 of the ICNG, industrial and commercial properties should be assessed for construction noise impacts. The noise management levels presented in the ICNG for industrial and commercial premises are reproduced in Table 3.3 below.

Table 3.3 – Noise at Commercial Premises Using Quantitative Assessment

Type of Premises	Management level, $L_{Aeq\ (15\ min)}$
Industrial (Receiver R1)	External noise level = 75 dB(A)
Commercial (Receiver R5)	External noise level = 70 dB(A)

3.2 Construction Noise Sources

The following table lists construction plant and equipment that are considered to be noisy and likely to be used for the construction activities associated with the jet fuel pipeline at Kurnell and Banksmeadow. It is noted that the list does not include quieter plant and equipment that are expected to not contribute to noise impacts to the nearby sensitive receivers.

Table 3.4 – Typical Construction Equipment & Sound Power Levels, dB(A) re. 1pW

Plant Item	Plant Description	L_{Aeq} Sound Power Levels
	Equipment used at Caltex Refinery	
1	Jack Hammer	110
2	Mobile Crane	110
4	Bevelling Machine (pneumatic)	110
3	Hand Held Grinders	108
5	De-watering Equipment	107
6	Tip Truck	105
7	Welder	102

Plant Item	Plant Description	L_{Aeq} Sound Power Levels
8	Backhoe	101
9	Bobcat	101
10	Power Generator	100
11	Compressor	95
	Equipment used along Pipeline Easement	
12	Mobile Crane	110
13	Bevelling Machine (pneumatic)	110
14	Hand Held Grinders	108
15	De-watering Equipment	107
16	Tip Truck	105
17	Welder	102
18	Backhoe	101
19	Bobcat	101
20	Power Generator	100
	Equipment used at Banksmeadow Terminal	
21	Jack Hammer	110
22	Mobile Crane	110
23	Bevelling Machine (pneumatic)	110
24	Hand Held Grinders	108
25	Tip Truck	105
26	Concrete Pump	102
27	Welder	102
28	Backhoe	101
29	Bobcat	101
30	Power Generator	100
31	Compressor	95

Note: *Only plant and equipment items that are expected to contribute to noise impacts to nearby sensitive receivers have been included in this table*

The sound power levels for the majority of plant items presented in the above table are based on Table D2 of Australian Standard 2436 - 1981 "Guide to Noise Control on Construction, Maintenance and Demolition Sites", information from past projects and information held in our library files.

3.3 Predicted Construction Noise

Table 3.5 presents predicted external construction noise levels at the nominated receiver locations for each individual plant item, where the item is operating at the closest point to the receiver location. The total noise for a 'worse case' scenario where all plant and equipment are operating concurrently at the closest point to the receiver location is also presented. Noise levels were calculated by taking into consideration attenuation due to distance only. Due to the close proximity of the works and the nature of the topography, it was assumed that there were no intervening structures between construction activity and the nearest affected receivers.

As mentioned previously, Receivers R1 and R2 will be impacted by construction activities within the Caltex refinery site and the pipeline easement, Receivers R2 and R4 are only impacted by construction activities along the pipeline easement and Receiver R5 is only impacted by construction activities within the Banksmeadow Terminal.

Table 3.5 – Predicted L_{eq} Construction Noise Levels, dB(A)

Plant Item	Plant Description	Receiver Locations				
		R1	R2	R3	R4	R5
	Criteria	*75*	*51*	*51*	*51*	*70*
Equipment used at Caltex Refinery						
1	Jack Hammer	82	68	-	-	-
2	Mobile Crane	82	68	-	-	-
3	Bevelling Machine (pneumatic)	82	68	-	-	-
4	Hand Held Grinders	80	67	-	-	-
5	De-watering Equipment	79	66	-	-	-
6	Tip Truck	77	63	-	-	-
7	Welder	74	61	-	-	-
8	Backhoe	73	60	-	-	-
9	Bobcat	73	60	-	-	-
10	Power Generator	72	59	-	-	-
11	Compressor	67	53	-	-	-
Worse Case Scenario – All plant operating concurrently		**89**	**76**	-	-	-
Equipment used along Pipeline Easement						
12	Mobile Crane	78	71	77	82	-
13	Bevelling Machine (pneumatic)	78	71	77	82	-
14	Hand Held Grinders	76	69	75	80	-
15	De-watering Equipment	75	68	74	79	-
16	Tip Truck	73	66	72	77	-
17	Welder	70	63	69	74	-
18	Backhoe	69	62	68	73	-
19	Bobcat	69	62	68	73	-
20	Power Generator	68	61	67	72	-
Worse Case Scenario – All plant operating concurrently		**84**	**77**	**83**	**88**	-
Equipment used at Banksmeadow Terminal						
21	Jack Hammer	-	-	-	-	63
22	Mobile Crane	-	-	-	-	63
23	Bevelling Machine (pneumatic)	-	-	-	-	63
24	Hand Held Grinders	-	-	-	-	62
25	Tip Truck	-	-	-	-	58
26	Concrete Pump	-	-	-	-	55
27	Welder	-	-	-	-	56

Plant Item	Plant Description	Receiver Locations				
		R1	R2	R3	R4	R5
28	Backhoe	-	-	-	-	55
29	Bobcat	-	-	-	-	55
30	Power Generator	-	-	-	-	54
31	Compressor	-	-	-	-	48
Worse Case Scenario – All plant operating concurrently		**-**	**-**	**-**	**-**	**70**

Noise levels at any receptors resulting from construction would depend on the location of the receptor with respect to the area of construction, shielding from intervening topography and structures (eg. boundary fences) and the type and duration of construction being undertaken. Furthermore, noise levels at receivers will vary significantly over the total construction program due to the transient nature and range of plant and equipment that could be used.

Based on the construction noise levels predicted above, the construction noise criteria will generally be exceeded at the nearest sensitive receiver locations in Kurnell by most plant when operating near the receiver, while construction noise from construction activities within the Banksmeadow Terminal will comply with the noise criteria at Receiver R5.

Therefore, a reasonable and feasible approach towards noise management measures will be required to reduce noise levels as much as possible to manage the impact from construction noise as result of construction activities at Kurnell. It should also be noted that noise levels could exceed those shown if two or more items of plant are operating concurrently in close proximity.

4 CONSTRUCTION VIBRATION ASSESSMENT

4.1 Construction Vibration Criteria

Disturbance to Buildings Occupants

For disturbance to human occupants of buildings, we refer to DECCW's 'Assessing Vibration; a technical guideline', published in February 2006. This document provides criteria which are based on the British Standard BS 6472-1992, *'Evaluation of human exposure to vibration in buildings (1-80Hz)'*.

Vibration sources are defined as C*ontinuous, Impulsive or Intermittent.* Section 2 of the technical guideline defines each type of vibration as follows:

> *'**Continuous** vibration continues uninterrupted for a defined period (usually throughout the day-time and/or night-time).*
>
> ***Impulsive** vibration is a rapid build up to a peak followed by a damped decay that may or may not involve several cycles of vibration (depending on frequency and damping). It can also consist of a sudden application of several cycles at approximately the same amplitude, providing that the duration is short, typically less than 2 seconds.*
>
> ***Intermittent** vibration can be defined as interrupted periods of continuous or repeated periods of impulsive vibration that varies significantly in magnitude'.*

The criteria are to be applied to a single weighted root mean square (rms) acceleration source level in each orthogonal axis. Section 2.3 of the guideline states:

> *'Evidence from research suggests that there are summation effects for vibrations at different frequencies. Therefore, for evaluation of vibration in relation to annoyance and comfort, overall weighted rms acceleration values of the vibration in each orthogonal axis are preferred (BS 6472).'*

Preferred and maximum values for continuous and impulsive vibration are defined in Table 2.2 of the guideline and are reproduced below. It is noted that only values applicable to residential, industrial (workshop) and commercial (offices) receivers have been reproduced.

Table 4.1 – Preferred and maximum weighted rms values for continuous and impulsive vibration acceleration (m/s^2) 1-80Hz

Location	Assessment period[1]	Preferred values		Maximum values	
		z-axis	x & y-axis	z-axis	x & y-axis
Continuous vibration					
Residences	Daytime	0.010	0.0071	0.020	0.014
	Night-time	0.007	0.005	0.014	0.010
Offices	Day- or night-time	0.020	0.014	0.040	0.028

Location	Assessment period[1]	Preferred values		Maximum values	
		z-axis	x & y-axis	z-axis	x & y-axis
Workshops	Day- or night-time	0.04	0.029	0.080	0.058
Impulsive vibration					
Residences	Daytime	0.30	0.21	0.60	0.42
	Night-time	0.10	0.071	0.20	0.14
Offices	Day- or night-time	0.64	0.46	1.28	0.92
Workshops	Day- or night-time	0.64	0.46	1.28	0.92

Notes: 1. Daytime is 7.00 am to 10.00 pm and night-time is 10.00pm to 7.00 am

Intermittent vibration is to be assessed using vibration dose values (VDVs). The VDV method is a fourth power approach which is more sensitive to peaks in the acceleration waveform and makes corrections to the criteria based on the duration of the source's operation. The VDV can be calculated using the overall weighted rms acceleration of the vibrating source in each orthogonal axis and the total period during which the vibration may occur. Weighting curves are provided in each orthogonal axis in the guideline. Preferred and maximum VDV values for residential, industrial (workshop) and commercial (offices) receivers are defined in Table 2.4 of the guideline and are reproduced below.

Table 4.2 – Acceptable vibration dose values for intermittent vibration ($m/s^{1.75}$)

Location	Daytime [1]		Night-time [1]	
	Preferred values	Maximum values	Preferred values	Maximum values
Residences	0.20	0.40	0.13	0.26
Offices	0.40	0.80	0.40	0.80
Workshops	0.80	1.60	0.80	1.60

Notes: 1. Daytime is 7.00 am to 10.00 pm and night-time is 10.00pm to 7.00 am

Structural Damage to Buildings

Currently there exists no Australian Standard for assessment of structural building damage caused by vibrational energy. Therefore, reference is made to both the British and German standards below which are relevant to the assessment of structural damage.

British Standard

British Standard 7385: Part 2 "Evaluation and measurement of vibration in buildings", can be used as a guide to assess the likelihood of building damage from ground vibration. BS7385 suggests levels at which 'cosmetic', 'minor' and 'major' categories of damage might occur.

BS7385 recommends that the peak particle velocity is used to quantify vibration and specifies damage criteria for frequencies within the range 4Hz to 250Hz, which is the range usually encountered in buildings. At frequencies below 4Hz, a maximum displacement value is recommended. The levels from the standard are given below in Table 4.3.

Table 4.3 – BS 7385 Structural Damage Criteria

Group	Type of Structure	Peak component particle velocity, mm/s		
		4Hz to 15Hz	15Hz to 40Hz	40Hz and above
1	Reinforced or framed structures. Industrial and heavy commercial buildings		50	
2	Un-reinforced or light framed structures. Residential or light commercial type buildings	15 to 20	20 to 50	50

The peak vibration limits set for minimal risk of 'cosmetic' damage are: 15mm/s for un-reinforced or light framed structures, for example residential or light commercial buildings (Group 2; increasing as the frequency content of the vibration increases) and 50mm/s for reinforced or framed structures, for example industrial and heavy commercial buildings (Group 1; constant across all frequencies). 'Minor' damage is considered possible at vibration magnitudes which are twice those given and 'major' damage to a building structure may occur at levels greater than four times those values.

These values relate to transient vibrations and to low rise buildings. Continuous vibration can give rise to dynamic magnifications due to resonances and may need to be reduced by up to 50%.

The levels set by this standard are considered 'safe limits' up to which no damage due to vibration effects has been observed for certain particular types of buildings. Damage comprises minor non-structural effects such as hairline cracks on drywall surfaces, hairline cracks in mortar joints and cement render, enlargement of existing cracks and separation of partitions or intermediate walls from load bearing walls.

This standard states that it considers sources of vibration including blasting, demolition, piling, ground treatments, compaction, construction equipment, tunnelling, road and rail traffic and industrial machinery.

As stated in the standard, it sets guide values for building vibration based on the lowest levels above which damage has been credibly demonstrated. That is, it gives guidance on the levels of vibration above which building structures could be damaged.

German Standard

The German standard DIN 4150 - Part 3 - "Structural vibration in buildings - Effects on Structures", also provides recommended maximum levels of vibration that reduce the likelihood of building damage caused by vibration. This standard too, presents recommended maximum limits over a range of frequencies measured in any direction at the foundation or in the plane of the uppermost floor.

The minimum 'safe limit' of vibration at low frequencies for commercial and industrial buildings is 20mm/s. For dwellings it is 5mm/s and for particularly sensitive structures (eg historical with preservation orders etc), it is 3mm/s. These limits increase as the frequency content of the vibration increases. These values are presented in Table 4.4 below and are generally recognised to be conservative.

Table 4.4 – DIN 4150-3 Structural Damage Criteria

Group	Type of Structure	Vibration Velocity, mm/s			
		At Foundation at Frequency of			Plane of Floor Uppermost Storey
		Less than 10Hz	10Hz to 50Hz	50Hz to 100Hz	All Frequencies
1	Buildings used for commercial purposes, industrial buildings and buildings of similar design	20	20 to 40	40 to 50	40
2	Dwellings and buildings of similar design and/or use	5	5 to 15	15 to 20	15
3	Structures that because of their particular sensitivity to vibration, do not correspond to those listed in Group 1 or 2 and have intrinsic value (eg buildings under a preservation order)	3	3 to 8	8 to 10	8

4.2 Construction Vibration Sources

Typical vibration levels from construction equipment most likely to cause significant vibration are summarised below. The information was sourced from a variety of reference materials available in the Renzo Tonin & Associates library.

Table 4.5 – Typical Ground Vibration Generated by Construction Plant

Activity	Typical ground vibration
Jackhammers	Typical ground vibration levels from jackhammers range from 1 mm/s to 2mm/s at distances of approximately 5m. At distances greater than 20m, vibration levels are usually below 0.2 mm/s.
Backhoe / Bulldozer	Typical ground vibration from backhoes and bulldozers range from 1mm/s to 2mm/s at distances of approximately 5m and at distances greater than 20m, vibration levels are usually below 0.2mm/s.
Truck traffic	Typical vibration from heavy trucks passing over normal (smooth) road surfaces generate relatively low vibration levels in the range of 0.01 - 0.2mm/s at the footings of buildings located 10 - 20m from a roadway. Very large surface irregularities can cause levels up to five to ten times higher. In general, ground vibration from trucks is usually imperceptible in nearby buildings. The rattling of windows and other loose fittings that is sometimes reported is more likely to be caused by airborne acoustic excitation from very low frequency (infrasonic) noise radiated by truck exhausts and truck bodies. While this may cause concern to the occupants, the phenomenon is no different from the rattling caused by wind or people walking or jumping on the floor and fears of structural damage or even accelerated ageing are usually unfounded.

4.3 Safe Working Distances

The relationship between vibration and the probability of causing human annoyance or damage to structures is complex. This complexity is mostly due to the magnitude of the vibration source, the particular ground conditions between the source and receiver, the foundation-to-footing interaction and the large range of structures that exist in terms of design (eg dimensions, materials, type and quality of construction and footing conditions). The intensity, duration, frequency content and number of occurrences of vibration, are all important aspects in both the annoyances caused and the strains induced in structures.

The pattern of vibration radiation is very different to the pattern of airborne noise radiation, and is very site specific. As a guide, safe working distances to avoid human discomfort for typical items of vibration intensive plant are listed in Table 4.6 below.

Table 4.6 – Recommended safe working distances for vibration intensive plant

Plant Item	Safe Working Distance
Jackhammer[1]	5m
Backhoe / Bulldozer[2]	5m
Truck Movements[2]	10m

Notes: 1. TIDC Construction Noise Strategy (Rail Projects) November 2007
2. Renzo Tonin & Associates project files, databases & library

Vibration levels are unlikely to exceed the criteria for human comfort at all the nearest receivers as all the receivers are at least 10m away which is equal to or more than the recommended minimum safe working distances for each plant item shown in Table 4.6. However, these are indicative distances only and more detailed site specific safe working distances should be determined once vibration emission levels are measured from each plant item prior to the commencement of their regular use on site.

Furthermore, since the above safe working distances were determined based on the requirements for human comfort, safe working distances to avoid structural damage would significantly be lower as the requirements for human comfort are more stringent than those for structural damage.

5 CONSTRUCTION NOISE AND VIBRATION MITIGATION

The following recommendations provide reasonable and feasible in-principle noise control solutions to reduce noise impacts to sensitive receivers in Kurnell. Where actual construction activities differ from those assessed in this report, more detailed design of noise control measures may be required once specific items of plant and construction methods have been chosen and assessed on site.

The advice provided here is in respect of acoustics only. Supplementary professional advice may need to be sought in respect of fire ratings, structural design, buildability, fitness for purpose and the like.

Implementation of noise control measures, such as those suggested in Australian Standard 2436-1981 "Guide to Noise Control on Construction, Maintenance and Demolition Sites", are expected to reduce predicted construction noise levels. Reference to Australian Standard 2436-1981, Appendix E, Table E1 suggests possible remedies and alternatives to reduce noise emission levels from typical construction equipment. Table E2 in Appendix E presents typical examples of noise reductions achievable after treatment of various noise sources. Table E3 in Appendix E presents the relative effectiveness of various forms of noise control treatment.

Table 5.1 below presents noise control methods, practical examples and expected noise reductions according to AS2436 and according to Renzo Tonin & Associates' opinion based on experience with past projects.

Table 5.1 – Relative Effectiveness of Various Forms of Noise Control, dB(A)

Noise Control Method	Practical Examples	Typical noise reduction possible in practice		Maximum noise reduction possible in practice	
		AS 2436	Renzo Tonin & Assoc.	AS 2436	Renzo Tonin & Assoc.
Screening	Acoustic barriers such as earth mounds, temporary or permanent noise barriers	7 to 10	5 to 10	15	15
Acoustic Enclosures	Engine casing lagged with acoustic insulation and plywood	15 to 30	10 to 20	50	30
Engine Silencing	Residential class mufflers	5 to 10	5 to 10	20	20
Substitution by alternative process	Use electric motors in preference to diesel or petrol	15 to 25	15 to 25	60	40

The Renzo Tonin & Associates' listed noise reductions are conservatively low and should be referred to in preference to those of AS2436, for this assessment.

Table 5.2 below identifies possible noise control measures, which are applicable on the construction plant likely to be used on site.

Table 5.2 – Noise Control Measures for Likely Construction Plant

Plant Description	Screening	Acoustic Enclosures	Silencing	Alternative Process
Light commercial vehicles	✔	x	x	x
Dump Trucks	✔	x	✔	x
Concrete Truck	✔	x	✔	x
Water Cart	✔	x	✔	x
Truck (> 20 tonne)	✔	x	✔	x
Power Generator	✔	✔	✔	x
Silenced Air Compressor	✔	✔	✔	✔
Rock Breaker	✔	x	✔	x
Pneumatic Jack Hammer	✔	x	✔	x
Excavators	✔	x	✔	x
Bulldozer	✔	x	✔	x
Concrete Truck	✔	x	✔	x

To ensure efficient noise attenuation performance is achieved using any of the methods listed above, it is recommended acoustic engineers work closely with the construction contractors and carry out preliminary testing prior to commencement of works.

A construction noise and vibration management plan should be implemented to avoid adverse noise and vibration disturbance to affected residences.

Table 5.3 below summarises various techniques for controlling construction noise and vibration.

Table 5.3 – Construction Noise and Vibration Management Options

Construction Noise and Vibration Management Options	
Source controls	
Time constraints	Limit work to daylight hours. Consider implementing respite periods with low noise/vibration-producing construction activities.
Scheduling	Perform noisy work during less sensitive time periods.
Equipment restrictions	Select low-noise plant and equipment. Ensure equipment has quality mufflers installed.
Emission restrictions	Establish stringent noise emission limits for specified plant and equipment. Implement noise monitoring audit program to ensure equipment remains within specified limits.
Substitute methods	Use quieter and less vibration emitting construction methods where possible.
Limit equipment on site	Only have necessary equipment on site.
Limit activity duration	Where possible, concentrate noisy activities at one location and move to another as quickly as possible. Any equipment not in use for extended periods during construction work should be switched off.
Equipment location	Noisy plant and equipment should be located as far as possible from noise sensitive areas, optimising attenuation effects from topography, natural and purpose built barriers and materials stockpiles.

Site access	Vehicle movements outside construction hours, including loading and unloading operations, should be minimised and avoided where possible.
Equipment maintenance	Ensure equipment is well maintained and fitted with adequately maintained silencers which meet the design specifications.
Reduced equipment power	Use only necessary size and power.
Quieter work practices	For example, implement worksite induction training, educating staff on noise sensitive issues and the need to make as little noise as possible.
Reversing alarms	Consider alternatives, such as manually adjustable or ambient noise sensitive types ("smart" reversing alarms) and closed circuit TV systems. Alternative site management strategies can be developed, in accordance with the *Occupational Health and Safety Plan*, with the concurrence of the Occupational Health and Safety Officer.
Path controls	
Noise barriers / hoarding	Consider installing temporary construction noise barriers / hoarding. Locate equipment to take advantage of the noise screening provided by existing site features and structures, such as embankments, storage sheds and/or boundary fences.
Enclosures	Install noise-control kits for noisy mobile equipment and shrouds around stationary plant, as necessary.
Increased distance	Locate noisy plant as far away from noise-sensitive receptors as possible.
Site access	Select and locate site access roads as far away as possible from noise-sensitive areas.
Receptor controls	
Structural surveys and vibration monitoring	Pre-construction surveys of the structural integrity of vibration sensitive buildings may be warranted (ie. dilapidation reports) At locations where there are high-risk receptors, vibration monitoring should be conducted during the activities which cause vibration.
Temporary relocation	In extreme cases.
Consultation	Community consultation, information, participation and complaint responses are essential aspects of all construction noise management programs. They typically involve: • A community information program before construction and/or high risk activities are commenced. This usually involves a leaflet distribution and direct discussions and negotiations with affected residents, explaining the type, time and duration of expected noise emissions. • The involvement of affected residents in the development of acceptable noise management strategies. • A nominated community liaison officer with a contact telephone number. • A complaints hotline. • Timely responses to complaints, providing information on planned actions and progress towards the resolution of concerns.
Noise / Vibration Monitoring	Noise and vibration compliance monitoring for all major equipment and activities on site should be undertaken.

6 ROAD TRAFFIC NOISE ASSESSMENT

6.1 Road Traffic Noise Criteria

The L_{eq} noise level or the "equivalent continuous noise level" correlates best with the human perception of annoyance associated with traffic noise. The NSW *Environmental Criteria for Road Traffic Noise* (ECRTN) uses the $L_{Aeq(15hr)}$, $L_{Aeq(9hr)}$ and $L_{Aeq(1hr)}$ to assess traffic noise impact. The ECRTN is used to assess the potential traffic noise impact from construction traffic travelling on public roads onto residential receivers only. Construction traffic in Kurnell are likely to travel along Captain Cook Drive, Cook Street and/or Prince Charles Parade, while construction traffic at Banksmeadow are likely to travel along Foreshore Road. Residential receivers are located in Kurnell along the roads where construction traffic are likely to travel along and therefore will be assessed against the ECRTN accordingly. However, there are no residential receivers along Foreshore Road where construction traffic associated with the Banksmeadow Terminal are to travel and therefore, construction traffic associated with the Banksmeadow Terminal travelling along Foreshore Road will not be assessed from herein.

Table 1 in the ECRTN, 'Road Traffic Noise Criteria for Proposed Road or Residential Land Use Developments', divides land use developments into different categories and lists the respective noise criteria for each case. Captain Cook Drive is categorised as a 'collector' road, while Cook Street and Prince Charles Parade are classified as 'local' roads. Therefore, the applicable road traffic noise criteria at residential receivers for the day and night periods are summarised in Table 6.1 below.

Table 6.1 – Applicable Road Traffic Noise Criteria, dB(A)

Type of Development	Day (7am-10pm)	Night (10pm-7am)	Where Criteria are Already Exceeded
8. Land use developments with potential to create additional traffic on collector road	$L_{Aeq(1hr)}$ 60	$L_{Aeq(1hr)}$ 55	Where feasible and reasonable, existing noise levels should be mitigated to meet the noise criteria. Examples of applicable strategies include appropriate location of private access roads; regulating time of use; using clustering; using 'quiet' vehicles; and using barriers and acoustic treatments. In all cases, traffic arising from the development should not lead to an increase in existing noise levels of more than 2 dB
13. Land use developments with potential to create additional traffic on local roads	$L_{Aeq(1hr)}$ 55	$L_{Aeq(1hr)}$ 50	

Note: 1. Table reproduced from Table 1 of ECRTN

Given that construction activities are to only occur during the day time period, only the day period (7.00am to 10.00pm) will be assessed for traffic noise from herein.

6.2 Predicted Road Traffic Noise

As a 'worst case' scenario, it is proposed that there will be up to 20 construction truck movements per day (from 10 construction trucks) plus 20 delivery truck movements per day (from 10 delivery trucks), resulting in a total of up to 40 truck movements per day servicing the construction sites in Kurnell that may potentially utilise Captain Cook Drive, Cook Street and/or Prince Charles Parade. This will result in a maximum of four (4) truck movements over a one hour period travelling along Captain Cook Drive, Cook Street and/or Prince Charles Parade.

The following predicted road traffic noise levels based on the maximum number of construction related truck movements over a one hour period have been determined for the nearest residences along Captain Cook Drive, Cook Street and Prince Charles Parade.

Table 6.2 – Predicted Traffic Noise Levels from Proposed Construction Trucks, dB(A)

Road	Distance of Nearest Dwelling to Road	$L_{Aeq, 1hr}$ Criteria	Traffic Noise Level from Construction Traffic	Complies?
Captain Cook Drive	5m	*60*	56	Yes
Cook Street	9m	*55*	54	Yes
Prince Charles Parade	5m	*55*	55	Yes

From Table 6.2 above, the predicted traffic noise levels at residential receivers along Captain Cook Drive, Cook Street and Prince Charles Parade due to construction traffic from the proposed construction sites at Kurnell, comply with the applicable criteria during the day period.

7 CONCLUSION

A desktop assessment of the construction noise and vibration emissions from the proposed construction of the jet fuel pipeline at the Caltex refinery site in Kurnell and the Banksmeadow Terminal site in Banksmeadow has been undertaken. Specifically, this report aims to minimise noise and vibration impacts during the construction works through a combination of physical noise controls and noise management measures.

Reasonable and feasible in-principle noise and vibration mitigation measures are provided in Section 5 to aid in reducing construction noise and vibration levels at nearby receivers.

Furthermore, noise from construction traffic travelling along public roads were also assessed and were predicted to comply with the applicable criteria stipulated in the ECRTN.

APPENDIX A - GLOSSARY OF ACOUSTIC TERMS

The following is a brief description of the technical terms used to describe noise to assist in understanding the technical issues presented.

Adverse Weather — Weather effects that enhance noise (that is, wind and temperature inversions) that occur at a site for a significant period of time (that is, wind occurring more than 30% of the time in any assessment period in any season and/or temperature inversions occurring more than 30% of the nights in winter).

Ambient Noise — The all-encompassing noise associated within a given environment at a given time, usually composed of sound from all sources near and far.

Assessment Period — The period in a day over which assessments are made.

Assessment Point — A point at which noise measurements are taken or estimated. A point at which noise measurements are taken or estimated.

Background Noise — Background noise is the term used to describe the underlying level of noise present in the ambient noise, measured in the absence of the noise under investigation, when extraneous noise is removed. It is described as the average of the minimum noise levels measured on a sound level meter and is measured statistically as the A-weighted noise level exceeded for ninety percent of a sample period. This is represented as the $\mathbf{L_{90}}$ noise level (see below).

Decibel [dB] — The units that sound is measured in. The following are examples of the decibel readings of every day sounds:

0dB	The faintest sound we can hear
30dB	A quiet library or in a quiet location in the country
45dB	Typical office space. Ambience in the city at night
60dB	Martin Place at lunch time
70dB	The sound of a car passing on the street
80dB	Loud music played at home

	90dB The sound of a truck passing on the street
	100dB The sound of a rock band
	115dB Limit of sound permitted in industry
	120dB Deafening
dB(A):	A-weighted decibels The ear is not as effective in hearing low frequency sounds as it is hearing high frequency sounds. That is, low frequency sounds of the same dB level are not heard as loud as high frequency sounds. The sound level meter replicates the human response of the ear by using an electronic filter which is called the "A" filter. A sound level measured with this filter switched on is denoted as dB(A). Practically all noise is measured using the A filter.
Frequency	Frequency is synonymous to pitch. Sounds have a pitch which is peculiar to the nature of the sound generator. For example, the sound of a tiny bell has a high pitch and the sound of a bass drum has a low pitch. Frequency or pitch can be measured on a scale in units of Hertz or Hz.
Impulsive noise	Having a high peak of short duration or a sequence of such peaks. A sequence of impulses in rapid succession is termed repetitive impulsive noise.
Intermittent noise	The level suddenly drops to that of the background noise several times during the period of observation. The time during which the noise remains at levels different from that of the ambient is one second or more.
L_{max}	The maximum sound pressure level measured over a given period.
L_{min}	The minimum sound pressure level measured over a given period.
L_1	The sound pressure level that is exceeded for 1% of the time for which the given sound is measured.
L_{10}	The sound pressure level that is exceeded for 10% of the time for which the given sound is measured.
L_{90}	The level of noise exceeded for 90% of the time. The bottom 10% of the sample is the L_{90} noise level expressed in units of dB(A).

L_{eq}	The "equivalent noise level" is the summation of noise events and integrated over a selected period of time.
Reflection	Sound wave changed in direction of propagation due to a solid object obscuring its path.
SEL	Sound Exposure Level (SEL) is the constant sound level which, if maintained for a period of 1 second would have the same acoustic energy as the measured noise event. SEL noise measurements are useful as they can be converted to obtain Leq sound levels over any period of time and can be used for predicting noise at various locations.
Sound	A fluctuation of air pressure which is propagated as a wave through air.
Sound Absorption	The ability of a material to absorb sound energy through its conversion into thermal energy.
Sound Level Meter	An instrument consisting of a microphone, amplifier and indicating device, having a declared performance and designed to measure sound pressure levels.
Sound Pressure Level	The level of noise, usually expressed in decibels, as measured by a standard sound level meter with a microphone.
Sound Power Level	Ten times the logarithm to the base 10 of the ratio of the sound power of the source to the reference sound power.
Tonal noise	Containing a prominent frequency and characterised by a definite pitch.

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Doc Ref: TE992-01F02 (rev 2) Noise Assessment.doc

Date: 10 January 2011

To: ICD (Asia Pacific) Pty Ltd

Attn: MS HELEN BACHAS Email: HelenB@icdasiapacific.com.au

From: Michael Chung

RE: CALTEX REFINERY, KURNELL – NOISE ASSESSMENT OF PROPOSED JET FUEL PUMPS & CONTROL VALVE

1 INTRODUCTION

Renzo Tonin & Associates were engaged to assess noise impact from the proposed jet fuel pumps and control valve to be installed at the Caltex Refinery, Kurnell. The proposed jet fuel pumps and control valve will be assessed against relevant noise criteria from the Environmental Protection Licence issued to Caltex for the operation of the refinery. The pumps and valve will also be assessed to determine if they will cause a perceptible increase in total noise emission from the refinery to the nearest affected residential receivers and proposed new Caltex office buildings.

The proposed jet fuel pumps and control valve will be installed on the north western boundary of the Caltex refinery site and adjacent to the storage tank number 166. Noise predictions are to be conducted by introducing the proposed jet fuel pumps and control valve to an existing noise model set up for the refinery and evaluating site noise at the nearest affected receivers and the proposed new Caltex office buildings and assessing against the relevant criteria.

Furthermore, other ancillary equipment will also be installed at the Banksmeadow Terminal, in Banksmeadow as part of the jet fuel pumping system. However, given the location of the proposed equipment there are no sensitive receivers within the vicinity of the Banksmeadow Terminal and therefore, no further assessment will be required for equipment to be installed at the Banksmeadow Terminal.

The work documented in this report was carried out in accordance with the Renzo Tonin & Associates Quality Assurance system, which is based on Australian Standard / NZS ISO 9001.

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2 ASSESSMENT CRITERIA

An Environmental Protection Licence (Licence no. 837) issued by the Department of Environment, Climate Change and Water (DECCW, formerly EPA) stipulates noise limits from the operation of the Caltex Refinery site. Condition L6 of the licence states the following:

*"**L6 Noise Limits***

L6.1 Noise from the premise must not exceed:

(a) An LA10(15 minute) noise emission criterion of 70 dB(A) (0700 to 2200) seven days a week; and

(b) An LA10(15 minute) noise emission criterion of 65 dB(A) at all other times, except as expressly provided by this licence.

L6.2 Noise from the premises is to be measured or computed at any point within one metre of any affected residence to determine compliance with condition L6.1. 5 dB(A) must be added if the noise is tonal or impulsive in character."

Based on the above DECCW Licence conditions and the assumption that the proposed pumps may operate at any time, the following criterion will be used:

$$L_{A10\ (15\ minute)} \leq 65dB(A)$$

Although the proposed new Caltex office buildings are not residential type receivers, for a conservative assessment the above criterion will also be used to assess noise impacts to the office buildings.

Furthermore, with the installation of the proposed jet fuel pumps and control valve, the 'perceptible' change in total noise emission from the refinery is also assessed.

A change that is 'perceptible' to the human ear would imply that there is a sound pressure level increase of at least 2dB(A). By ensuring that site noise levels do not increase by 2dB(A) at the nearest affected residential receivers, it can be deemed that there is no 'perceptible' change in the total noise emission from the site at the nearest affected receivers.

3 MODELLING ASSUMPTIONS

The following assumptions were made with regard to the proposed jet fuel pumps and control valve when modelling:

- There will be two (2) jet fuel pumps installed. However, only one (1) pump will be operating at any one time, with the second pump used as a 'back up' pump.
- A control valve will be located adjacent to the jet fuel pumps

- The main noise source of each jet fuel pump will be a 425kW motor with an acoustic enclosure.

- The jet fuel pumps and control valve were modelled on noise data provided by the manufacturer and used in the established noise model.

- The modelling scenarios were set to be under calm weather conditions.

- The proposed jet fuel pumps and control valve were modelled as point sources with noise radiating equally in all directions.

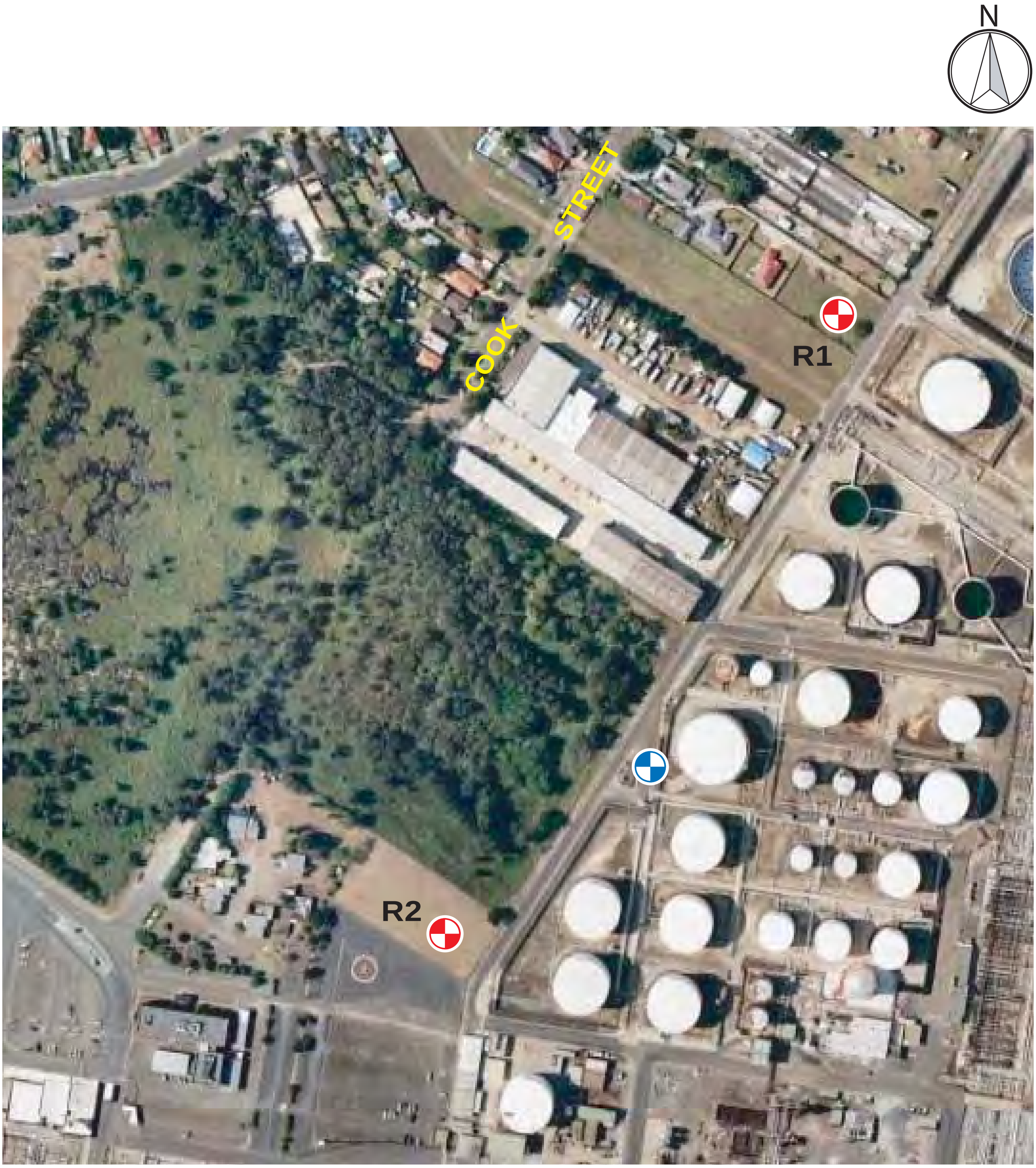
- All existing plant and the proposed jet fuel pumps and control valve are operating simultaneously in order to represent a worst-case scenario.

The following locations were chosen to represent the nearest receivers most affected by the proposed jet fuel pumps and control valve.

- **Receiver R1 – 30D Cook Street, Kurnell**
  Residential property located approx. 270m north of the proposed jet fuel pumps and control valve.

- **Receiver R2 – Proposed New Caltex Office Buildings**
  Proposed new office buildings located within the Caltex refinery site, where existing heli-pad is located and approx. 170m south west of the proposed jet fuel pumps and control valve.

Figure 1 following details the pump and control valve location, surrounding area and receiver location.



Notes

Receiver Locations

Jet Fuel Pump & Control Valve Location

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Title : Figure 1 - Aerial Photo Showing Jet Fuel Pumps, Control Valve and Receiver Locations

Project: Caltex Refinery, Kurnell

Date : 15/10/10	**Scale:** NTS	**Ref** : TE992-01P01 (rev 1)

4 NOISE ASSESSMENT

Noise emission from the proposed jet fuel pumps and control valve was calculated to the nearest and potentially most affected receivers. Noise emissions were determined by modelling the noise sources (existing and proposed), receiver locations and topographical features of the intervening area using the ENM (Environmental Noise Model) computer program. The program calculates the contribution of each noise source at the specified receptor point and allows for the prediction of the total noise from the site. The computer program is endorsed by the DECCW and its environmental noise predictions have been verified on many past occasions in the field.

The individual sound power levels of the proposed jet fuel pumps and control valve are summarised in Table 1 below. It is noted that the sound power levels presented for the jet fuel pumps include noise attenuation provided by the pump's acoustic enclosure.

Table 1 – Sound Power Level of Jet Fuel Pump (dB re 1pW)

Plant	Overall dB(A)	Octave Band Frequency (Hz) – dB(lin)							
		63	125	250	500	1000	2000	4000	8000
Jet Fuel Pump (1 pump)[1]	86	53	81	82	81	81	80	75	71
Control Valve	92	59	87	88	87	87	86	81	77

Notes: 1. Sound power levels presented include noise attenuation provided by acoustic enclosure

Noise levels were calculated to the nearest affected residential location considering the worst case scenario of all plant (existing refinery plant, one proposed jet fuel pump and control valve) operating simultaneously. In addition to the worst case scenario, the noise emission from only one jet fuel pump and the control valve operating was also calculated. Table 2 below presents calculated noise levels at the receiver locations.

Table 2 – Results of Noise Modelling, dB(A)

Receiver	Noise Level due to Existing Refinery	Noise Level due to Refinery with Additional Pump & Control Valve	Noise level due to One Jet Fuel Pump & Control Valve Only	Comply with DECCW Licence?[1]
Receiver R1 – 30D Cook St	57	58	36	Yes
Receiver R2 – New office buildings	65	65	40	Yes

Notes: 1. Based on DECCW Licence Condition L6 noise limit of 65dB(A)

From the above table, it can be seen that the noise levels from the proposed jet fuel pump (with an acoustic enclosure around the motor) and control valve are insignificant and there will be no significant change to the existing noise levels generated by the refinery at the receiver locations due to the proposed jet fuel pumps and control valve.

Therefore, the addition of the jet fuel pumps and control valve will not cause any significant increase in existing noise levels at the receiver locations and will comply with the noise limits of the DECCW licence. No additional noise mitigation measures are required.

5 CONCLUSION

An assessment of noise impact from the proposed jet fuel pumps and control valve to be located at the Caltex Refinery, Kurnell has been completed. The noise impact from the proposed jet fuel pumps and control valve at the nearest residential receiver and at the proposed new Caltex office building was assessed against relevant noise limits stipulated in the DECCW licence issued for the Caltex Refinery site at Kurnell. In addition to the noise limits, the perceptible change in total noise emission from the refinery due to the installation of the proposed jet fuel pumps and control valve was also assessed at the two receiver locations.

Modelling results presented in Table 2 for the two receiver locations indicate compliance with the DECCW licence and no significant change to existing noise levels once the proposed jet fuel pumps and control valve are installed and operating.

DOCUMENT CONTROL

Date	Revision History	Non-Issued Revision	Issued Revision	Prepared By (initials)	Instructed By (initials)	Reviewed & Authorised by (initials)
30/09/2010	Generation of report	-	0	MCH	-	MCH
15/10/2010	Revision of report	-	1	MCH	-	MCH
10/01/2011	Finalise report	-	2	MCH	-	MCH

The work presented in this document was carried out in accordance with the Renzo Tonin & Associates Quality Assurance System, which is based on Australian Standard / NZS ISO 9001.

This document is issued subject to review and authorisation by the Team Leader noted by the initials printed in the last column above. If no initials appear, this document shall be considered as preliminary or draft only and no reliance shall be placed upon it other than for information to be verified later.

This document is prepared for our Client's particular requirements which are based on a specific brief with limitations as agreed to with the Client. It is not intended for and should not be relied upon by a third party and no responsibility is undertaken to any third party without prior consent provided by Renzo Tonin & Associates. The information herein should not be reproduced, presented or reviewed except in full. Prior to passing on to a third party, the Client is to fully inform the third party of the specific brief and limitations associated with the commission.

The information contained herein is for the purpose of acoustics only. No claims are made and no liability is accepted in respect of design and construction issues falling outside of the specialist field of acoustics engineering including and not limited to structural integrity, fire rating, architectural buildability and fit-for-purpose, waterproofing and the like. Supplementary professional advice should be sought in respect of these issues.

Appendix E

Hazards and Risks

Planager
Risk Management Consulting

PRELIMINARY HAZARD ANALYSIS OF THE PROPOSED CALTEX JET FUEL UPGRADE PROJECT

Prepared for: URS Australia Limited

Document Number: URS\19-B273

Revision C2

Prepared by: Karin Nilsson

7 March 2011

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Preliminary Hazard Analysis of the Proposed Caltex Jet Fuel Upgrade Project

Acknowledgment

The author would like to thank Helen Bachas and Alan Parnell (ICD Asia Pacific) and Will Miles (URS Australia) for their assistance in preparing this report.

Disclaimer

Rev	Date	Description	Prepared By	Reviewed By	Authorised By
A	28/02/2011	Draft for Comment	Karin Nilsson	Maarten Tentij	Karin Nilsson
B	01/03/2011	2nd Draft for Comment	Karin Nilsson	Maarten Tentij	Karin Nilsson
C	04/03/2011	Final Report	Karin Nilsson	Maarten Tentij	Will Miles
C2	07/03/2011	Final Report with minor typos corrected	Karin Nilsson	Maarten Tentij	Will Miles

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EXECUTIVE SUMMARY

E1 Introduction

In order to increase the available capacity of the pipeline providing jet fuel from Kurnell Refinery to the Joint User Hydrant Installation Facility at Sydney Airport, it is proposed to install new pumps at the refinery and at Banksmeadow Terminal.

A Preliminary Hazard Analysis (PHA), in accordance with the NSW Department of Planning Director-General's Requirements (DGRs) for the proposed upgrade project, has been prepared by Planager Pty Ltd for inclusion in the Environment Assessment. The results are summarised in this report.

The following risks are assessed as part of the PHA:

- Risk from flammable material.
- Environmental risk from spills.

The main features of the proposed upgrade project include:

- Caltex Kurnell Refinery:
  - Installation of new transfer pumps and coalescers.
  - Installation of a new pigging station (to replace the one at the wharf);
- Banksmeadow terminal: Installation of new booster pumps and valves, upgrade and modification of the existing pigging stations and the installation of power supply equipment;
- KBL Pipeline: Installation of new pipeline from Kurnell Refinery to halfway along the Kurnell wharf, located within the existing easement. The old pipeline would be decommissioned but not removed. Installation of a new pigging station installed within the refinery to more effectively monitor the KBL and reduce environmental risks.

The aim of the PHA is to:

- Provide an assessment of the hazards and risks associated with the proposed upgrade project;
- Determine the incremental change (increase or decrease) in the risk levels associated with the transfer of petroleum products in the pipeline;
- Compare the resulting risk levels with the NSW Department of Planning's risk criteria for maximum tolerable risk of fatality, injury and propagation.

E2 Results

The main hazard associated with the proposed project is associated with the handling of jet fuel which is a flammable liquid at atmospheric conditions.

The predominant mode in which a hazardous incident may be generated is associated with a leak. This would generally only have the potential to cause injury or damage if there was ignition, which resulted in a fire or explosion incident. If the leak was not adequately contained and the jet fuel was allowed to enter the natural environment, an unignited release would be a threat to the biophysical environment

The risk assessment showed that the net result of the proposed upgrade project is an overall reduction in the risk associated with the KBL. This is due to:

- An increased ability to check the pipeline for any small reduction in it's integrity before it becomes an issue; and
- The relocation of the pigging station from the wharf to the refinery, a location which can be contained in case of any spills or leaks.

The slight increase in risk associated with the more complex operational procedures required to transfer jet fuel at different rates to different customers is managed through the installation of hardware and software features.

The increase in maximum operational pressure in the KBL is not believed to substantially increasing the risk associated with this pipeline. This is because the design pressure and Maximum Allowable Operational Pressure (MAOP) for the KBL exceeds the proposed operating pressure. Further, the pressure trips and alarms would also contribute to the management of this risk.

The risk associated with the Kurnell Refinery and the Banksmeadow Terminal is not expected to substantially change as a result of the installation of the new pumping stations. The quantitative risk assessment showed that all landuse criteria, as defined by the NSW Department of Planning are met for the two new pumping stations. The risk of fatality at any nearby residential areas, open spaces and sensitive development is well below the maximum tolerable risk criteria. The risk of propagation from the pumping stations to neighbouring facilities or to infrastructure on the same site (such as the neighbouring storage tanks), is also below the NSW Department of Planning risk criteria. The most stringent risk criteria, as set by the NSW Department of Planning for acceptable risks in industrial installations, are adhered to for the two pumping stations.

E3 Recommendations

Recommendation 1: As far as practicable, ensure pipes outside of contained areas are fully welded (not flanged).

Recommendation 2: Review existing Emergency Response Plans at both the Kurnell Refinery and at Banksmeadow Terminal as well as for the KBL for any changes required following implementation of the proposed upgrade.

Recommendation 3: Depending on the results of the Fire Safety Study, further risk reduction may need to be considered for the risk associated with a knock-on at the neighbouring foam pump house at Banksmeadow Terminal in case of a major fire at the booster pump station.

GLOSSARY

ADG	Australian Dangerous Goods
ALARP	As Low As Reasonably Practicable
AS	Australian Standard
CBD	Central Business District
CCTV	Closed Circuit Television
CP	Cathodic Protection
DCVG	Direct Current Voltage Gradient
DoP	Department of Planning
ESD	Emergency Shutdown
HAZID	Hazard Identification
HIPAP	Hazardous Industry Planning Advisory Paper
ILI	Inline Inspection
JUHI	Joint User Hydrant Installation Facility
JSA	Job Safety Analysis
KBL	Kurnell B Line
MAOP	Maximum Allowable Operational Pressure
NDT	Non Destructive Testing
OH&S	Occupational Health and Safety
PHA	Preliminary Hazard Analysis
PLC	Programmable Logic Control
QRA	Quantitative Risk Assessment
SCADA	Supervisory Control and Data Acquisition
TNO	The Netherlands Organisation for Applied Scientific Research

REPORT

1 INTRODUCTION

1.1 BACKGROUND

Jet fuel is currently being transferred from the Caltex Kurnell Refinery (*the refinery*) via the jet fuel pipeline known as the *Kurnell B Line* (the *KBL*) to the Joint User Hydrant Installation Facility (JUHI) facility at Sydney Kingsford Smith airport (*the JUHI*) and to Caltex terminal at Banksmeadow.

In order to increase the available capacity of the jet fuel pipeline it is proposed to increase jet fuel transfer rate from the refinery to the JUHI by installing new pumps at the refinery and at Banksmeadow Terminal.

A Preliminary Hazard Analysis (PHA), in accordance with the NSW Department of Planning (NSW DoP) Director-General's Requirements (DGRs) for the Development, has been prepared by Planager Pty Ltd for inclusion in the Environment Assessment. The results are summarised in this report.

The Director-General's requirements for the PHA are as follows:

> **Hazards and Risk** – *The PHA should consider changes proposed within the Kurnell Refinery boundary, the upgraded pipeline arrangements between the refinery and wharf, increase in pipeline operating pressures and the modifications within the Caltex Banksmeadow terminal. The analysis should include:*

- *identification of potential hazards associated with the project, to determine the potential for offsite impacts;*
- *an estimate of the consequences and likelihood of significant events;*
- *comparison of the estimated overall risks against the Department's risk criteria; and*
- *proposed safeguards to ensure risks are minimised.*

This PHA has been prepared with reference to the State Environment Planning Policy No 33 (Hazardous and Offensive Development), and in accordance with the NSW DoP's Hazardous Industry Planning Advisory Papers (HIPAPs) Numbers 4 (*Risk Criteria*) and 6 (*Hazard Analysis*), References 1, 2 and 3.

Further, references to the Australian Standard AS2885 (*Pipelines - Gas and Petroleum Liquids*, Ref 4) are also made with respect to the pipeline component of the upgrade project.

1.2 SCOPE AND AIM OF STUDY

1.2.1 Scope

The following risks are assessed as part of the PHA:

- Risk from flammable material.
- Environmental risk from spills.

The main features of the proposed upgrade project include:

- Caltex Kurnell Refinery:
  - Installation of new transfer pumps and coalescers.
  - Installation of a new pigging station (to replace the one at the wharf);
- Banksmeadow Terminal: Installation of new booster pumps and valves and upgrade and modification of the existing pigging stations and the installation of power supply equipment;
- Kurnell B Pipeline: Installation of new pipeline from Kurnell Refinery to halfway along the Kurnell wharf, within the existing easement. The old pipeline would be decommissioned. Installation of a new pigging station installed within the refinery to enable pigging of more of the pipeline than what was previously possible.

The existing pigging station at Bumborah Point (North of Botany Bay) will remain unaltered.

1.2.2 Aim

The aim of the PHA is to:

- Provide an assessment of the hazards and risks associated with the proposed upgrade project;
- Determine the incremental change (increase or decrease) in the risk levels associated with the transfer of petroleum products from Caltex Kurnell Refinery to the JUHI (Sydney Airport) via Bumborah Point and the Banksmeadow Terminal;
- Compare the resulting risk levels with the NSW DoP's risk criteria for maximum tolerable risk of fatality, injury and propagation.

The aim is in line with the requirements by the NSW DoP for the proposed upgrade project.

The risk associated with the modifications to the Caltex Kurnell Refinery and to Banksmeadow Terminal is assessed both qualitatively and quantitatively and the results are reported in Sections 6 and 7 below.

The risk associated with the Kurnell B Pipeline is assessed more appropriately using the methodology described in the AS2885.1 *Pipelines - Gas and Petroleum Liquids* (Ref 4) using a multidisciplinary team (as reported in Ref 5) and summarised in this PHA in the Hazard Identification Word Diagram in Table 6 and under Section 6 (below).

2 SITE AND PROJECT DESCRIPTION

2.1 PROJECT LOCATION

The Kurnell Refinery and Banksmeadow Terminal are located on opposite sides of Botany Bay in the southern part of metropolitan Sydney, as shown in Figure 1 below.

The Kurnell Refinery is located on the Kurnell Peninsula within Sutherland Shire, approximately 30km south of Sydney's CBD. The site is bordered by Botany Bay National Park to the east, Captain Cook's Landing Place Park to the south, Bonna Point Reserve in the west and the community of Kurnell to the north. The refinery mainly produces petrol (49%), diesel (22%) and jet fuel (15%).

A Kurnell B Pipeline (KBL) *right of way* runs north west from the refinery to a wharf located at the southern side of Botany Bay. The existing jet pipeline (the KBL) runs through this right of way, underground from the refinery, resurfacing after Prince Charles Parade and continuing along the wharf, before diving below Botany Bay. From here the KBL travels north until it reaches land at Bumborah Point. It is still underground at this point and remains so continuing north, before turning west and eventually surfacing at Banksmeadow Terminal.

Banksmeadow Terminal is located on the north side of Botany Bay, approximately 12km south of Sydney's CBD. The Terminal is bounded by industrial storage facilities to the north, the Patrick Stevedores Container Terminal to the south, the P&O Trans Australia Terminal to the east, and Penrhyn Road and the Penrhyn Estuary to the west. Access to the Terminal is off Penrhyn Road.

Banksmeadow is Caltex's main storage terminal in NSW and has a maximum storage capacity of 50 million litres. The facility stores products from the Kurnell Refinery which reach the terminal via pipelines under Botany Bay. The main products stored are petrol, diesel, heating oil, aviation fuel and fuel oils.

KBL heads west underground from Banksmeadow Terminal and eventually reaches the JUHI at Sydney Airport.

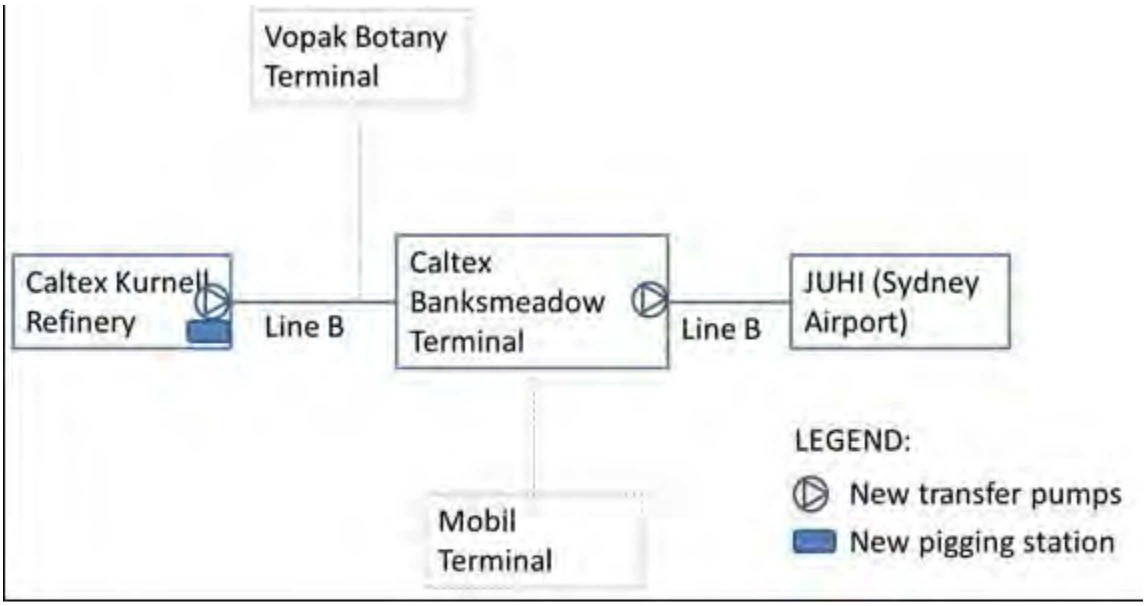
The KBL is approximately 12km long.

A block diagram of the KBL is provided in Figure 2 below.

The Vopak and Mobile terminals and their associated transfer facilities, also connecting into the KBL, do not form part of the present upgrade project and are hence not included in this PHA.

Figure 1 – Project Location

Figure 2 – KBL Block Diagram



2.2 MODIFICATIONS TO CALTEX KURNELL REFINERY

An overview of the modifications at the refinery is presented in Figure 3 below.

The proposed upgrade works at Kurnell Refinery would be limited to the north eastern part of the refinery where two new pumps (one duty and one standby), and a new pigging facility would be located close to tank 166 and 157, just off Road 7. Two new filter/coalescer and associated instrumentation would also be installed in this area.

The discharge pipes at the new pumps will allow for an increase in maximum operating pressure from the current 1,650kPa to 2,200kPa (refer Table 2 below). The design pressure will be increased from the current 1,950kPa (*Class 150 pound rating*) to 5,100kPa (*Class 300 pound rating*).

New suction pipes (300mm diameter), from the existing tanks (127, 166[1], 168, & 169) into the new pumps, will also fitted.

Modifications to existing instrumentation and control would be required, in the form of a new flow control loop and a new flow meter, as well as modifications to the existing SCADA and PLC.

[1] Tank 166 to be converted from fuel oil to Jet service as part of another proposed project.

This new equipment would be installed on a new concrete pad, in the area between an existing earth bund and the primary containment bund for tank 166 (refer to Figure 3 below).

Figure 3 – Overview of Modifications at Kurnell Refinery

The existing pigging station, which is currently located at the wharf, will be decommissioned, removed, and replaced with the new pigging station installed in proximity to the new pumps.

2.3 MODIFICATIONS FOR THE JET FUEL PIPELINE (KBL)

An overview of the modifications to the KBL is presented in Figure 3 above.

The KBL operates in different *modes* depending on the destination of the jet fuel, as follows:

- Deliver to JUHI with stripping to Banksmeadow Terminal
- Direct to JUHI
- Pigging

There will be no change in the flow rates for the mode where jet fuel is transferred from the refinery to the Banksmeadow terminal.

Flow rates will increase from a maximum of 205 kL/hour to a maximum of 400 kL/hour in the modes where jet fuel is transferred from the refinery into the JUHI.

To allow for the pressure increase achieved by the required increase in flow rates, a new 250 mm diameter (10 inch) pipeline would be installed from the new Kurnell Refinery pumping station to half way along the wharf. This pipeline would be rated for 5,100kPa design pressure (compared with the existing 1,950kPa design pressure).

This new, upgraded part of the KBL, would run approximately 1,200m north east alongside Road 7, (refer to Figure 5) from the new pumping station through Gate 5 and out to the wharf buried underground before running along part of the wharf itself (as shown on Figure 5 below). The new pipeline would tie into the existing 250 mm diameter submarine KBL at the wharf. The new pipeline would be buried as per AS2885 requirements (up to 1.5m in depth). This is a common easement with other product transfer lines.

There will be no change to the design pressure of the underwater pipeline, which will remain at 5,100 kPa (Class 300 pound rating), limited by the flanges at either end of the underwater section.

Figure 4 – Replacement KBL Pipeline Section at Kurnell

2.4 MODIFICATIONS TO CALTEX BANKSMEADOW TERMINAL

An overview of the modifications at Banksmeadow Terminal is presented in Figure 5 below.

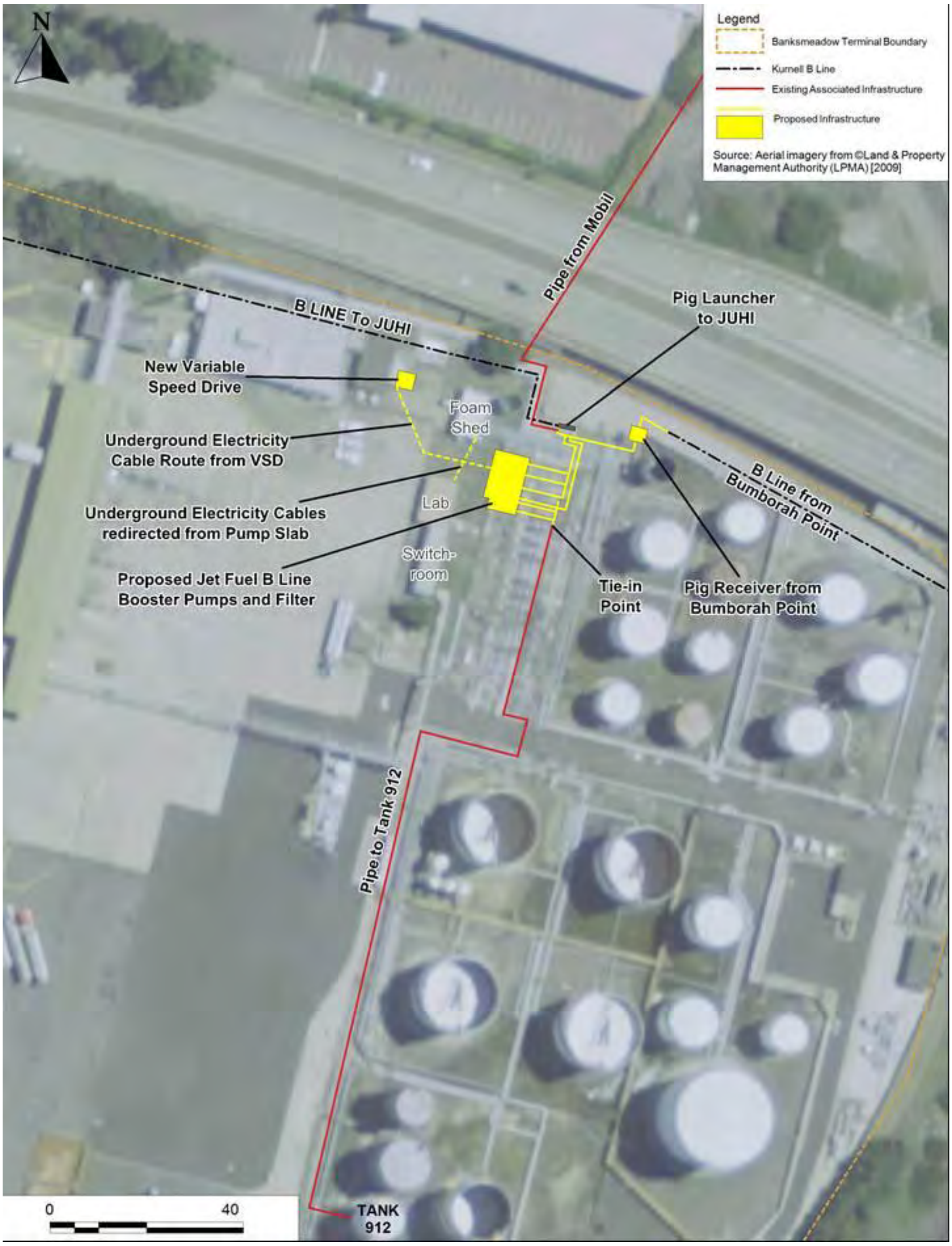
Two new booster pumps (variable speed, one duty and one stand-by) will be installed. Each pump will also be fitted with associated instrumentation. The inlet and outlet piping and valving associated with the new pumps will be modified.

. A new filter/coalescer will be installed to filter the fuel into Banksmeadow terminal.

Modifications to existing instrumentation and control valves would be required, as well as modifications to the existing SCADA and PLC control systems.

The existing pigging station will also be upgraded.

Figure 5 – Modifications at Banksmeadow Terminal



2.5 OPERATING CONDITIONS

The following table details the transfer rates before and after the upgrade.

Table 1 – Flow Rates Before and After Upgrade

	Current Flowrate	Flowrate After Upgrade	Change
Refinery to Banksmeadow Terminal	145-150 kL/hr (direct)	0-150 kL/hr (stripping)	Direct transfer is not proposed. New mode.
Refinery to JUHI	200-205 kL/hr (direct) 150 kL/hr (pigging) Stripping not currently applicable	400 kL/hr (direct) 150 kL/hr (pigging) 250-400 kL/hr (stripping)	Increase No change New mode.

The following table details the maximum operating pressures before and after the upgrade.

Table 2 – Max Operating Pressures Before and After Upgrade

Location	Current Max Operating Pressure	After Upgrade Max Operating Pressure	Change
Discharge at the refinery	1,650 kPag	2,200 kPag	Increase
At Banksmeadow Terminal	1,100 kPag (currently no booster pumps)	- 300 kPag (suction) - 3,845 kPag (discharge)	Decrease Increase
At JUHI	300 kPag (at JUHI)	390 kPag (at JUHI)	Slight increase

2.6 SECURITY

Both pump stations, as installed within the Kurnell Refinery and the within Banksmeadow Terminal, are surrounded by security fencing and are provided with security gates and close circuit television (CCTV) cameras. The sites are also patrolled and access to both facilities is strictly controlled.

The KBL runs underground for most of the way except for where it resurfaces after Prince Charles Parade to continue along the wharf, before diving below Botany Bay, and where it enters and leaves the Banksmeadow Terminal and the JUHI. There are no above ground valve stations or other facilities associated with the pipeline along this route except for one small section where the pipeline crosses a storm water channel beside Bumborah Point Road. No changes are being undertaken here.

3 STUDY METHODOLOGY

3.1 INTRODUCTION

The methodology for the PHA is well established in Australia. The assessment has been carried as per the Department of Planning's HIPAP No 4 (*Risk Criteria for Land Use Planning*, Ref 2) and HIPAP No 6 (*Guidelines for Hazard Analysis*, Ref 3). These documents describe the methodology and the criteria to be used in PHAs, as required by the NSW Department of Planning for major "potentially hazardous" development.

There are five stages in risk assessment (as per Ref 3):

3.1.1 Hazard Identification

The hazard identification includes a review of potential hazards associated with all dangerous and hazardous goods to be processed, used and handled as part of the upgrade project. The hazard identification includes a comprehensive identification of possible causes of potential incidents and their consequences to public safety and the environment, as well as an outline of the proposed operational and organisational safety controls required to mitigate the likelihood of the hazardous events from occurring.

The tasks involved in the hazard identification of the proposed upgrade project included a review of all relevant data and information to highlight specific areas of potential concern and points of discussion, including drafting up of preliminary hazard identification (HAZID) word diagram. For this particular study, a Hazard and Operability (HAZOP) study had already been completed by a multidisciplinary team comprised of people with operational / engineering / risk assessment expertise. The HAZID word diagram was prepared party based on the output from this study and partly based on Planager's knowledge of similar installations and facilities.

The review takes into account both random and systematic errors, and gives emphasis not only to technical requirements, but also to the management of the safety activities and the competence of people involved in them.

The final HAZID word diagram is presented in Table 6 in Section 4 below.

3.1.2 Consequence and Effect Analysis

The consequences of identified hazards are assessed using current techniques for risk assessment. Well established and recognised correlations between exposure and effect on people are used to calculate impacts. Estimations on the effects on the biophysical environment are also made.

A set of representative fire and explosion scenarios were identified in the Fire Safety Study in Ref 6. These scenarios include a range of the hazardous events that have some potential to occur.

For the present PHA, these scenarios have been further expanded on, based on the current design of the equipment which forms part of the Project and knowledge of similar facilities, applicable codes and standards, and good engineering practice. The scenarios can be divided into the following categories:

- Moderate releases, characterised by a hole equivalent to that of a flange failure (representing a potential flange or a pump seal). If ignited, such a leak may result in:
    - A jet fire (from an aerosol formed),
    - A sump fire and/or,
    - A flash fire.
- Large releases (ruptures), characterised by a hole with a diameter equal to the pipe diameter. If ignited, this leak may result in:
    - A pool fire,
    - A flash fire, or
    - A vapour cloud explosion.

For further details, please refer to Appendices 1 and 2.

Quantitative consequence analysis was undertaken using the TNO Quantitative Risk Assessment program *Riskcurves* (version 7.6) and consequence modelling software program *Effects* (version 8.0). The TNO tools are internationally recognised by industry and government authorities. The consequence models used within Effects Riskcurves are well known and are fully documented in the TNO Yellow Book (Ref 7).

3.1.3 Frequency Analysis

For incidents with significant effects, whether on people, property or the biophysical environment, the incident frequencies are estimated based on historical data. A probabilistic approach to the failure of vessels and pipes is used to develop frequency data on potentially hazardous incidents.

Details as to the likelihood analysis are provided in Appendix 1 and in Appendix 2.

3.1.4 Risk Analysis

The combination of the probability of an outcome, such as injury, propagation or death, combined with the frequency of an event, gives the risk from the event. In order to assess the merit of the proposal, it is necessary to estimate the risk at a number of locations so that the overall impact can be assessed. The risk for each incident is defined according to:

Risk = Consequence x Frequency

The risk associated with the proposed upgrade project is determined both *qualitatively*, using a risk matrix approach, and *quantitatively* using risk assessment software.

Qualitative risk: The result of the qualitative risk analysis is presented in table form in the Hazard Identification Word Diagram in Table 6 and in Section 6. Details on the qualitative risk assessment are presented in Appendix 1.

Quantitative risk: In quantitative risk analysis, risk levels from each scenario are calculated by considering each modelled scenario, and combining its frequency with the extent of its *harm footprints*. Total risk is obtained by adding together the results from the risk calculations for each incident, i.e. the total risk is the sum of the risk calculated for each scenario. The results of the quantitative risk analysis are presented in Section 7 in three forms:

- Fatality Risk:
    - *Individual Risk of Fatality*: The likelihood (or frequency) of fatality to notional individuals at locations around the site, as a result of any of the postulated fire and explosion events. The units for individual risk are probability (of fatality) per million per year. Typically, the result of individual risk calculations is shown in the form of risk contours overlaid on a map of the development area.
    - *Societal Risk of Fatality*: Societal risk takes into account the number of people exposed to risk. Whereas individual risk is concerned with the risk of fatality to a (notional) person at a particular location (person 'most at risk', i.e. outdoors), societal risk considers the likelihood of actual fatalities among any of the people exposed to the hazard. Societal risk is presented as so called *f-N curves*, showing 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 risk results with the population data, a societal risk curve can be produced
- Injury risk, i.e. the likelihood of injury to individuals at locations around the site as a result of the same scenarios used to calculate individual fatality risk.
- Propagation risk, i.e. the risk of propagation from one incident at the proposed upgrade to neighbouring installation and infrastructure.

The event frequency and hazard consequence data has been combined to produce estimates of risk using TNO's risk calculation and contour plotting program entitled *Riskcurves*.

Having determined the risk from a development, it must then be compared with accepted criteria in order to assess whether or not the risk level is tolerable. If not, specific measures must be taken to reduce the risk to a tolerable level. Where this is not possible, it must then be concluded that the proposed development is not compatible with the existing surrounding land uses.

The risk criteria, applicable for the proposed development, are detailed in Appendix 2 together with further details of the input and the results of the quantitative risk assessment (incident scenarios, likelihoods, consequence etc.).

3.1.5 Risk reduction

Where possible, risk reduction measures are identified throughout the course of the study in the form of recommendations.

3.2 SAFETY MANAGEMENT SYSTEMS

3.2.1 Safety Management in General

In quantitative risk assessments, incidents are assessed in terms of consequences and frequencies, leading to a measure of risk. Where possible, frequency data used in the analysis comes from actual experience, e.g. near misses or actual incidents. 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.

As with any sample of a population, the quality of the management systems (referred to here as "safety software") in place in these historical plants will vary. Some will have little or no software, such as work permits, planned maintenance 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 which has significantly below average safety software in place is assessed using the generic frequencies, it is likely that the risk will be underestimated. Conversely, if a plant is significantly above average, the risk will probably be overestimated. However, it is extremely difficult to quantify the effect of software on plant safety. Incorporating safety software as a means of mitigation has the potential to significantly reduce the frequency of incidents and also their consequences if rigorously developed and applied. The risk could also be underestimated if safety software is factored into the risk assessment but is not properly implemented in practice. Practical issues also arise when attempting to factor safety software into the risk assessment – applying a factor to the overall risk results could easily be misleading as in practice it may be the failure of one aspect of the safety software that causes the accident, while all other aspects are managed exemplarily.

In this study it is assumed that the generic failure frequencies used apply to installations which have safety software corresponding to accepted industry practice and that this site has similar management practices and systems. This assumption, it is believed, will be conservative in that it will overstate the risk from well-managed installations.

3.2.2 Safety Management System Implemented

Caltex have a commitment to Occupational Health and Safety (OH&S) and have numerous policies and procedures to achieve a safe workplace. Procedures specific to the upgraded plant and its environment will be developed and incorporated into the safety management system.

The upgraded plant equipment will comply with all current, relevant codes and statutory requirements with respect to work conditions. There will be no changes to existing precautions observed on site, in particular, standards and requirements for the handling of flammable liquids. All personnel required to work with these substances are trained in their safe use and handling, and are provided with all the relevant safety equipment.

Emergency procedures have been developed and will be reviewed in the light of the proposed changes. The emergency procedures include responses to emergency evacuation, injury, major asset damage or failure, critical failures, spillages, major fire, and threats.

The refinery and the Banksmeadow Terminal sites each have a manager with overall responsibility for safety, who is supported by experienced personnel trained in the operation and support of the plant.

A Permit to Work system (including Hot Work Permit) and a Management of Change system are in use on site to control work on existing plant and to protect existing plant and structure from substandard and potentially hazardous modifications.

Injury and incident management is proceduralised and people are trained in how to report incidents. An established incident reporting and response mechanism has been established, providing 24 hour coverage.

Protective Systems will be tested to ensure they are in a good state of repair and function reliably when required to do so. This will include scheduled testing of trips, alarms, detectors, relief devices and other protection systems.

All persons on the premises are provided with appropriate personal protective equipment suitable for use with the specific hazardous substances.

At least one person on the premises is trained in first aid; and a list of persons trained in, and designated as being responsible for the administering of, first aid is shown on the noticeboards on the premises.

3.3 MAIN CODES AND STANDARDS

The following table shows some of the main codes and standards which are applicable for the proposed upgrade project.

Table 3 – Codes and Standards for the Design of Proposed Upgrade Project

Area of Concern	Standard / Code
Plant layout and design philosophy	Chevron Global Aviation Specs • GPS A5 – Refinery layout and spacing • GPS A6 – Design philosophy
Bunding arrangement and design	• AS1940 *The storage and handling of flammable and combustible liquids* (Ref 8)
Pump and piping design	• STD 40.06.CES.PIM-LA-5112-B Piping Materials • STD 40.06.CES.PIM-LA-5138-A Piping Design • STD 40.06.CES.PVM-LA-4750-E Carbon Steel Pressure Vessels for General Refinery Service • STD 40.06.CES.PMP-983 Centrifugal Pumps for General Refinery Services • API 1581 – Aviation Jet Fuel Filter/Separators 5th Edition • API 610 – Refinery Pumps • ASME B31.3 - Process Piping • AS 1200:2000 - Pressure equipment • AS1200:2000 – Pressure equipment
Pipeline (design, operation and maintenance)	• AS2885 Pipelines - gas and liquid petroleum (Ref 4).
Electrical design	• GPS P1 – Electric Power and Lighting • STD 40.06.SPEC-P12 High Voltage Electric Motors • AS/NZS 2381 Electrical Equipment for Explosive Atmospheres – Selection, Installation and Maintenance • AS/NZS 3000 Australian / New Zealand Wiring Rules • AS/NZS 60079 Explosive Atmospheres - Explosion Protection Techniques • AS/NZS 60079.10.1:2009 Explosive Atmospheres Part 10.1: Classification of areas – Explosive gas atmospheres.
Emergency response and fire safety	• Control Of Major Hazard Facilities - National Standard (Ref 9) • National Code of Practice (Ref 10); • Hazardous Industry Planning Advisory Papers No 1 and No 2: *Emergency Planning Guidelines* and *Fire Safety Study* (Refs 11 and 12); • Building Code of Australia for any buildings and protected works (Ref 13).
Dangerous goods storage and transport	*Australian Code for Transport of Dangerous Goods by Road and Rail* (ADG Code), 7th Ed (Ref 14).
Occupational health and safety	(NSW) Occupational Health and Safety Act 2000. (NSW) Occupational Health and Safety Regulations 2001.

4 HAZARD IDENTIFICATION

The main risk associated with the proposed upgrade involves the transfer and storage of jet fuel, which is a flammable material at atmospheric conditions.

Other, less prominent hazards associated with the proposed upgrade, involve the use of high voltage electricity and the rotating machinery. Such hazards are predominantly limited to the local area and experienced by operators or maintenance personnel. They are unlikely to give rise to off-site hazards. As such, these potential hazards are generally dealt with using training, procedures, Job Safety Analysis (JSA), permit to work etc., and are not discussed further in this PHA.

4.1 HAZARDOUS MATERIALS

4.1.1 Storage Inventory

There will be no change to storage inventories of dangerous goods (i.e. flammable liquids) on either of the sites affected by the upgrade project.

4.1.2 Properties of Potentially Hazardous Material

Fire and explosion hazards were identified by considering the physical and chemical properties of the jet fuel being considered, and the potential for releases and loss of containment. The table below summarises the main properties of jet fuel.

Table 4 – Main Properties of Jet Fuel

Material	Property / Characteristics
Dangerous Goods Classification	Class 3 PG III, flammable liquid
Physical state at atmospheric conditions	Liquid
Appearance	Clear
Molecular weight	175
Boiling point	216^{o}C
Flash point	38^{o}C
Heat of combustion	36644 kJ/kg
Heat of vaporisation	341.2 kJ/kg
Heat capacity	1.9 kJ/kg K
Density	@ 10 ^{o}C - 797 kg/m^3 @ 15^{o}C – 794 kg/m^3 @ 25 ^{o}C - 787 kg/m^3
Vapour pressure	@ 10 ^{o}C – 0.14 kPa(a) @ 25 ^{o}C – 0.34 kPa(a)
Flammable range (vapour in air)	Between 0.7 and 6 vol%

4.2 HAZARDOUS INCIDENT SCENARIOS

In case of a loss of containment outside of bunded / contained areas, jet fuel may pose a threat to the biophysical environment or it may ignite and pose a threat to people and property.

Jet fuel can be ignited and burn provided the flammable vapour concentrations are within the flammable range and a source of ignition is present. For an explosion with any significant overpressure to occur however, sufficient quantities of vapour will need to be present in a dispersing or stagnant vapour cloud.

If jet fuel is released under high pressure, for example at the discharge of the pump, an aerosol or mist may form that is significantly more flammable than when stored under normal conditions, and lower ignition energy may cause a fire or explosion.

An important part of fire prevention is to avoid situations where fuels may be released as aerosols (Ref 6), which may form an explosive vapour.

Several variables must be addressed in developing an assessment of a release and its general dispersion, including potential for ignition sources. The factors, as presented in Appendix 3, determine the possible outcomes of an uncontrolled release, i.e. whether it:

- Disperses without a fire, leading to an environmental pollution issue,
- Burns as a pool fire,
- Burns as a flash fire, or
- Explodes in a vapour cloud.

A hazard identification exercise was undertaken by a multidisciplinary team (composed of personnel from design operations and engineering), addressing the nature of hazards that might occur during operation of the facility after implementation of the proposed upgrade (Ref 15). Further, a safety management assessment in accordance with AS2885 requirements was conducted for the project (Ref 5), using a multidisciplinary team from design, process, inspection, operation and project management.

A Hazard Identification Word Diagram has been prepared for this project and presented in Table 6. This table draws from the potential incident scenarios identified during the hazard identification exercises above and elsewhere, including initiating causes, consequences and proposed / existing safeguards to minimise consequences of likelihood of an incident.

A total of 10 hazards were identified in terms of their potential consequences and likelihoods, as listed in Table 5 below.

Table 5 - Summary of Identified Hazards

Hazardous Event Potential
Loss of Containment Events (Jet Fuel or Energy)
Leak of jet fuel from pipes or pumps on-site or off-site due to generic faults or impact leads to fire event
Leak of jet fuel from pipes or pumps on-site or off-site due to generic faults or impact leads to threat to the biophysical environment
Natural Hazards
Earthquake / Seismic hazard
Land subsidence hazard
Bush /brush fire
Flooding
Lightning strike
Other types of hazards
Aircraft crash
Intentional acts
Knock-on Effects / Cumulative Effects

The risk associated with each incident scenario has been evaluated in turn for the situation before and after the upgrade project. The risk matrix from AS2885 (Ref 4) was used in this exercise. The following terminology is used in the table:

- C: Consequence
- L: Likelihood
- R: Risk

Refer to Appendix 1 for details on the methods used for the qualitative assessment.

Refer to Appendix 2 for the calculations carried out for those scenarios with serious effects which were transferred to the quantitative risk assessment.

Table 6 – Hazard Identification Word Diagram

No	Hazard	Possible Causes and Threats	Possible Consequences	Preventative and Protective Safeguards	Risk Prior to Upgrade	Risk After Upgrade	Carried forward to QRA
Kurnell KBL							
1	Loss of containment event: Uncontrolled release from the pipeline due to generic faults.	- Construction damage, - Weld fault, - Coating flaw, - Faulty materials. - Design defects.	Damage to the pipeline and release of jet fuel. Environmental pollution if the spill is not contained. If ignition then possibility of flash or jet fire. If confinement then possibility of a vapour cloud explosion. Injury and property damage.	**Prevention:** Coating on external surfaces of underground pipelines; Cathodic Protection (CP); internal corrosion virtually absent with clean hydrocarbon; Pressure testing Radiography &/or ultrasonic testing of welds; design to limit crack propagation; Pipeline Integrity Management Plan. Welding procedures and welds radiographed; material certificates; hydrostatic testing and QA/QC. **Detection:** Routine inspection (incl. patrol, pigging, CP monitoring. **Protection:** Pipe thickness and design factor to AS2885 requirements. Below ground pipeline is buried and signposted as per AS2885 requirements. **Emergency response:** Emergency response plan, including emergency isolation of pipeline and links to external authorities.	**C: Severe** **L: Remote** **R: Low**	**C: Severe** **L: Remote** **R: Low** **Negligible change compare with situation prior to upgrade**	**No - AS2885-methodology used for the KBL**

No	Hazard	Possible Causes and Threats	Possible Consequences	Preventative and Protective Safeguards	Risk Prior to Upgrade	Risk After Upgrade	Carried forward to QRA
2	Loss of containment event: Loss of containment due to aging pipeline	Long term effects on old pipeline: - Damage to pipeline with no immediate effect but possible long term effect. - Wear and tear. - Maintenance failure with no immediate effect. - Stress corrosion cracking.	Damage to pipeline over a long period of time, usually starting with a small issue but could develop to an incident of more serious nature. Eventually leading to a release of jet fuel. The rest as above.	Entire existing pipeline (with the exception of the length of pipe between Gate 5 at the refinery to the pigging station at the wharf) can be pigged (Non Destructive Testing). Pigging is carried out at periodic and regular intervals. Both stress and temperature are below that required for external stress corrosion cracking After upgrade project: New pipeline in section of Gate 5 to the wharf which can be pigged. Detection, protection and emergency response as per No 1 above.	**C: Severe** **L: Unlikely** **R: Inter-mediate**	**C: Severe** **L: Remote** **R: Low**	**No - AS2885-methodology used for the KBL**
3	Loss of containment event: Uncontrolled release of jet fuel due to impact or damage to the pipeline.	3rd party involvement e.g. digging or trenching, or other earth work. Anchor damage. 1st party involvement (excavation inspection damages coating and corrosion). Destructive vibration near the pipeline.	As above	**Prevention:** Underground pipeline within a right-of-way. Pipeline along wharf is well away from the roadway and is protected by the road kerb. There are no changes to this compared with the existing pipeline. No 3rd party assets in right-of-way minimises activities near the pipeline. Signage. **Detection:** Pressure sensors and alarms transmitted to the control room (24hr/7d monitoring). Routine inspection and patrol. **Protection:** Resistance of pipelines to penetration through use of pipe thickness and adequate design factor and burial depth. Repair of any coating damage as required. **Emergency response:** Manual shut down at detection of pressure drop. Emergency response plan.	**C: Major** **L: Remote** **R: Inter-mediate**	**C: Major** **L: Remote** **R: Inter-mediate** **Negligible change compare with situation prior to upgrade.**	**No - AS2885-methodology used for the KBL**

No	Hazard	Possible Causes and Threats	Possible Consequences	Preventative and Protective Safeguards	Risk Prior to Upgrade	Risk After Upgrade	Carried forward to QRA
4	Loss of containment event: Maloperation	Operational error upstream or downstream facility.	As above	Use of mechanical over pressure and temperature protection at Kurnell Refinery new pumping station. Procedure to be written detailing risks and controls during manual operation (Ref 5). Detection, protection and emergency response – as above.	**C: Major** **L: Remote** **R: Inter-mediate**	**C: Major** **L: Remote** **R: Inter-mediate** **Some increase in risk due to increased pressures on the system and some increase in control comple-xity**	**No - AS2885-methodology used for the KBL**
5	Loss of containment event: During maintenance	Failure during pigging causes loss of containment	As above	Procedures for maintenance and pigging. After upgrade project: Pigging station at the wharf no longer used. New pigging station at the refinery, which is contained.	**C: Severe** **L: Unlikely** **R: Inter-mediate**	**C: Severe** **L: Remote** **R: Low**	**No - AS2885-methodology used for the KBL**

No	Hazard	Possible Causes and Threats	Possible Consequences	Preventative and Protective Safeguards	Risk Prior to Upgrade	Risk After Upgrade	Carried forward to QRA
6	Natural Event	- Flooding, - Earthquake, land subsidence, - Bush/brush fire, - Lightning strike.	As above	No change from existing situation. Regular inspections and patrol for any erosion. Structures and plant are designed to withstand earthquake effects using well-established procedures in accordance with relevant Australian or International standards. The pipeline route does not cross any known areas of mine subsidence. Bush fire risk minimised through maintenance of a buffer zone between buried pipeline and natural vegetation. Buried pipeline unlikely to be affected by above ground bush / brush fire. Lightning strike unlikely to damage buried pipeline and pipeline under water (but not impossible). Detection, protection and emergency response – as above.	**C: Minor** **L: Remote** **R: Negli-gible**	**C: Minor** **L: Remote** **R: Negli-gible** **Negligible change compare with situation prior to upgrade**	**No - AS2885-methodology used for the KBL**
7	Other types of hazards	- Aircraft crash - Intentional acts - Knock-on effects / Cumulative hazards	As above	An incident at a nearby facility or an aircraft crash is highly unlikely to expose a pipeline and, provided that the pipeline is not exposed, damage to the pipeline is highly unlikely. Negligible impact of proposed project on the risk of intentional acts on the pipeline such as terrorism, vandalism. Above ground sections not changed from existing layout. Detection, protection and emergency response – as above.	**C: Severe** **L: Hypo-thetical** **R: Negli-gible**	**C: Severe** **L: Hypo-thetical** **R: Negli-gible** **Negligible change compare with situation prior to upgrade**	**No - AS2885-methodology used for the KBL**

No	Hazard	Possible Causes and Threats	Possible Consequences	Preventative and Protective Safeguards	Risk Prior to Upgrade	Risk After Upgrade	Carried forward to QRA
Pump Stations at the Refinery and at the Banksmeadow Terminal							
8	Loss of containment event: Uncontrolled release of jet fuel due to generic faults.	Construction damage, weld fault, coating flaw or faulty materials. Corrosion (internal or external) Gasket leak. Seal failure Weld failure Vibration. Valve leak	Damage to the pump, pipes and equipment and subsequent release of jet fuel. If liquid release then formation of pool which would drain away into the sump and bund. If the spill is not contained then possible environmental pollution. If ignition of a liquid release then formation of a pool fire. Possibility of flash or jet fire and vapour cloud explosion. Injury and property damage. Propagation to neighbouring bushland at Kurnell Refinery.	**Prevention:** Painting of aboveground pipework in pump station to prevent external corrosion; internal corrosion virtually absent with clean hydrocarbon. Hydrotesting; radiography and / or ultrasonic testing of welds; welding procedure. On stream monitoring of pump vibration Draining of pump station away from potential sensitive infrastructure. **Detection:** Hydrocarbon detector alarms to be fitted at Kurnell and Banksmeadow. Seal leak detection system to be installed. Routine maintenance and inspection (including regular inspections and patrols). **Protection:** Resistance of pipes to metal loss through use of pipe thickness and adequate design factor. Location of pumps and associated infrastructure within bunded areas. **Emergency response:** Emergency response plan, including emergency isolation of pipeline and links to external authorities.	**C: Minor** **L: Remote** **R: Negli-gible**	**C: Minor** **L: Remote** **R: Negli-gible** **Negligible change compare with situation prior to upgrade**	**YES** **(generic likelihood data used)**

No	Hazard	Possible Causes and Threats	Possible Consequences	Preventative and Protective Safeguards	Risk Prior to Upgrade	Risk After Upgrade	Carried forward to QRA
9	Loss of containment event: Uncontrolled release of jet fuel due to mechanical impact or damage at one of the pump stations.	Mechanical impact e.g. motor vehicle impact. Failure of maintenance.	Damage to the pump, pipes and equipment and subsequent release of jet fuel. If liquid release then formation of pool which would drain away into the sump and bund. If the spill is not contained then possible environmental pollution. If ignition of a liquid release then formation of a pool fire. If ignition of an aerosol then possibility of flash or jet fire. If confinement then possibility of a vapour cloud explosion. Injury and property damage.	**Prevention:** Thickness and grade of equipment and pipes. Any major work within the facilities requires permit to work, including job safety analysis. Remote operated isolation valves available for Emergency Shut Down. Robust nature of valve body – tight shut-off feature. Regular inspection of facilities and routine maintenance. Electrical design for equipment in hazardous areas. Draining of pump station away from potential sensitive infrastructure. **Detection:** Pressure sensors and alarm transmitted to the control room (24hr/7d monitoring). Continuous detection system. Periodic leak surveys. Hydrocarbon alarms at pumps at Kurnell & Banksmeadow. **Protection:** Resistance of pipes and equipment to damage from mechanical impact through use of pipe thickness and adequate design factor. Pump stations are graded away from pumps. Spills will drain to oil sump system. Spills outside of bunded and contained areas would drain to the site drainage systems which is segregated so that any potentially contaminated surface water runoff are kept separate from clean rainwater runoff. **Emergency response:** Remote operated emergency shut-down valves.	**C: Minor** **L: Remote** **R: Negli-gible**	**C: Minor** **L: Remote** **R: Negli-gible** **Negligible change compare with situation prior to upgrade**	**YES** **(generic likelihood data used)**

No	Hazard	Possible Causes and Threats	Possible Consequences	Preventative and Protective Safeguards	Risk Prior to Upgrade	Risk After Upgrade	Carried forward to QRA
10	Natural Hazards	- Flooding, - Earthquake, land subsidence, - Bush/brush fire, - Lightning strike.	As above	Negligible incremental change in flood risk associated with the proposed upgrade project. Possible decrease due to newer installation and equipment located above grade. Protecting against lightning strike in accordance with Australian Standard AS 1768 Lightning Protection. Control of vegetation around facilities. The Council owned bushland to the west of the refinery pumping station (Marton Park Wetland) which is located relatively close to the proposed site of the new pumps may be an issue, refer Recommendations 1 and 2 below.	**C: Minor** **L: Hyo-thetical** **R: Negli-gible**	**C: Minor** **L: Hyo-thetical** **R: Negli-gible** **Negligible change in risk from flood, earthquak e and lightning. Some increase in risk to wetland near refinery pumps.**	**YES** **(generic likelihood data used)**

No	Hazard	Possible Causes and Threats	Possible Consequences	Preventative and Protective Safeguards	Risk Prior to Upgrade	Risk After Upgrade	Carried forward to QRA
11	Other Hazards	- Aircraft or heavy vehicle crash resulting in damage to the pump station and potentially in hazardous releases. - Damages station through terrorism or vandalism. - Knock-on effects / Cumulative hazards (incident at the neighbouring storage tank)	As above	Negligible change in risk profile from aircraft crash due to proposed upgrade project. Vehicle crash into pumping stations extremely unlikely in current situation. Security measures at pumping stations include fencing, patrols, etc. Receipt station at Banksmeadow Terminal is located inside a fenced area. Knock-on effects prevented through effective emergency response, refer recommendation 2 below.	**C: Severe** **L: hypo-thetical** **R: Negli-gible**	**C: Severe** **L: hypo-thetical** **R: Negli-gible** **Negligible change compare with situation prior to upgrade**	**YES** **(generic likelihood data used)**

5 DETAILED CONSIDERATION OF ALL HAZARDS AND ASSOCIATED CONTROLS

The Hazard Identification Word Diagram in Table 6 details the control mechanisms for each identified hazard associated with the proposed upgrade project. Further details on these controls are provided below.

5.1 CONTROL OF A LOSS OF CONTAINMENT EVENT

Safety associated with a loss of containment is ensured by the following four elements that provide multiple layers of protection both for the safety of workers and the safety of communities that surround the facilities:

- Primary containment;
- Secondary containment;
- Safeguard systems; and
- Separation distances.

Generally, these multiple layers of protection create four critical safety conditions, all of which are integrated with a combination of industry standards and regulatory compliance.

The following section summarises how the design and construction of the proposed upgrade will comply with these essential elements of safety.

5.1.1 Primary Containment

The first and most important requirement for containing the jet fuel is based on the integrity of containment, including the use of appropriate materials for the facilities, proper engineering design and construction practices and minimising the risk of damage and fatigue of pipelines, pumps and other plant and equipment. The measures to be used at the proposed upgrade include:

- The use of recognised and experienced plant designers.
- The design of pipeline and other piping in accordance with the most widely recognised and used codes for its type (refer Table 3 for a short summary of those standards and codes in particular applicable to hazards and risk management for this development);
- Material selection, robust and secured pipework to code requirements, welds radiographed, hydrostatic testing, design pressure and relief valves, and thermal reliefs.
- Minimising the risk of mechanical damage caused by malicious damage through burial of the KBL pipeline as far as practicable, through on-site security measures (to prevent sabotage), and through vehicular assess to the area, protection of plant and equipment and speed restrictions;
- Quality control during the construction of the piping, including radiography of welds, testing of weld and heat affected zones, pressure test and/or vacuum

tests as appropriate, production weld testing and other recognised Non Destructive Testing (NDT) requirements;
- Minimising lengths of piping and number of flanges (use welded connections wherever possible);
- Proper securing of piping;
- No use of flexible connection and hoses required as part of this project; and
- Regular and periodic inspection and maintenance.

5.1.2 Secondary Containment

The second layer of protection ensures that, if a leak or spill did occur, the jet fuel can be contained and isolated from the public. The Kurnell Refinery and the Banksmeadow Terminal includes a system of containment areas (or *bunds*), capable of containing the quantity of jet fuel that could be released by a credible incident involving the component served by each particular containment system.

Table 7 summarises the design of the sumps and bunds relevant to the present project. Note that both bunds are draining freely through an underground drainage system to the oily sewer where the spill would be captured. The bund has flammable gas detectors that alarm in the control room in case of a spill. The oily sewer is designed with gas seal catch basis to prevent the spread of fire through the oily sewer system.

Table 7 – Bund Design

Bund configurations	Surface Area (m^2) Maximum	Design Basis
Kurnell Refinery pump bund	264	Capable of restraining a massive release and directing it to the underground drain system and oily sewer. Maximum surface area of pool in case of completely blocked drainage system (refer Appendix 2 for discussion on the probability of this occurring).
	104	Total area covered by the catch basin closest to the pumps. Maximum surface area of pool in case of free drain to oily sump.
Banksmeadow Terminal pump bund	114	Capable of restraining a massive release and directing it to the underground drain system and oily sewer
	40	Total area covered by the catch basin closest to the pumps. Maximum surface area of pool in case of free drain to oily sump.

Should a spill occur, the chances of ignition will be minimised through the use of a combination of hardware plant design features (such as control of static electricity through earthing and electrical continuity and the installation of suitable electrical equipment to comply with hazardous area classification requirements) and through procedural requirements (through use of maintenance systems such as permit to work systems and preventative maintenance programs for electrical equipment in hazardous area).

A loss of containment may ignite at the source, for example due to the static electricity created at the point of release or by a mechanical impact causing the release in the first place. In the case of an ignition at the source, the jet fuel would burn as a jet fire (in the case of an aerosol release) or as a pool fire.

Some potential ignition sources are located within the refinery and Banksmeadow Terminal sites and are integral to the operation of these facilities. These sources are located well outside of the Hazardous Zones. However, in case of a large release of jet fuel it is conceivable that concentrations within the flammable range may reach such an ignition source, resulting in a flash back and a pool fire or possibly a flash fire or vapour cloud explosion (if the vapours were allowed to accumulate).

5.1.3 Safeguard Systems

The goal of the third layer of protection is to minimize the frequency and size of a release and prevent harm from potential associated hazards, such as fire.

For this level of safety protection, the refinery pumps and the Banksmeadow Terminal as well as the KBL are fitted with a number of sensors, detectors and alarms and back-up safety systems, which include an emergency shutdown (ESD) system.

Flammable vapour (hydrocarbon) sensors with alarms as well as detection of upset operating conditions (e.g. pressure, flow) with subsequent plant shut down will be provided.

The ESD system can identify problems and initiate shut off operations in the event certain specified fault conditions or equipment failures occur. The ESD is designed to prevent or limit significantly the amount of jet fuel that could be released in the event of a hazardous incident.

The ESD system is *fail safe*, i.e. the equipment associated with the ESD system are capable of compensating automatically and safely for a failure (e.g. failure of a mechanism or power source). The ESD system includes emergency shutdown buttons which are located in strategic locations within the refinery and the Banksmeadow Terminal, including at the control room. Automatic initiation of the ESD system has been designed into the system for critical trip events.

Hydrocarbon vapour detection (at the pumping stations) and fire fighting systems combine to limit effects if there is a release.

Necessary operating procedures, training, emergency response systems and regular maintenance to protect people, property and the environment from any release will also be established.

The details of this layer of protection will be defined during the detailed design process.

5.1.4 Separation Distances

The fourth layer of protection employed for facility design is required by regulation to maintain separation distances from communities and other public areas.

The separation distances are based on requirements code and on the maximum tolerable risk principles (as per the present hazard and risk assessment).

With respect to the code-based requirements, the Australian Standards (Ref 8) specify separation distances between storages and boundaries, ignition sources, protected places and accumulations of combustible materials. These separation distances must be large enough to safeguard people and property in case of a loss of containment incident.

In case of a spill at the pump platform, the jet fuel drains to sump further through an underground drainage system to an oily sump, minimising the surface area for evaporation and possible heat radiation (if ignition occurs) from neighbouring structures, tanks etc.

5.2 CONTROL RISKS TO THE BIOPHYSICAL ENVIRONMENT

A failure to contain a loss of containment of jet fuel could cause environmental pollution to surface and groundwater. Prevention includes:

- Adequately designed piping, vessels, and storage tanks used for liquids;
- Most of the new, above-ground pipework is located inside bunded areas;
- Pipeline manifolds and pumps (both at the refinery and the Banksmeadow Terminal) are located on concrete slabs which drain away to the oily water sewer system;
- Oily sumps are fitted with hydrocarbon detectors which initiate alarm, informing pipeline operator of loss of containment.

Recommendation 1: As far as practicable, ensure pipes outside of contained area are fully welded (not flanged).

5.3 CONTROL OF NATURAL HAZARDS

While the safety systems listed in Section 5.1 are in general also partly for the control of the risk associated with natural hazards (such as design to codes and standards, robust design, bunds etc.), specific controls associated with these hazards have been listed below.

5.3.1 Earthquake / Seismic Hazard and Hazards from Land Subsidence

Structures and plant are designed to withstand earthquake effects using well-established procedures in accordance with relevant Australian or International standards. The pipeline route does not cross any known areas of mine subsidence.

Note that the main part of the KBL will remain unaltered with regards to risk from seismic hazards and from hazards relating to mine subsidence.

5.3.2 Brush and Bushfires

The risk associated with an incident associated with the new pumping stations initiating a brush or bushfire is minimised through passive protection in the form of plant layout, equipment spacing and drainage of possible liquid spillages away from critical equipment to containment sumps. Further, active measures such as fire and/or hydrocarbon (flammable vapour) detection, a firewater system and overpressure protection will also be included in the detailed design, minimising the effect of an incident.

Further, emergency response plans and procedures have been developed for the facility in conjunction with NSW Fire Brigades. These plans and procedures will detail the steps to be taken in case of a bushfire in the vicinity of the facilities.

The Council owned bushland to the west of the refinery pumping station (Marton Park Wetland) is located relatively close to the proposed site of the new pumps and may be at threat from a fire in the vicinity of the station. This was also highlighted in the Fire Safety Study conducted for the upgrade project (Ref 6). It is noted that the existence of fire hydrants in close proximity to the pump area provides fire protection cover to the wetland area.

Recommendation 2: Review existing Emergency Response Plans at both the Kurnell Refinery and at Banksmeadow Terminal as well as for the KBL for any changes required following implementation of the proposed upgrade.

5.3.3 Flooding / Erosion Hazard

Floods are unlikely to cause erosion of the ground cover of the KBL pipeline or floatation of the pipeline. The current regime of regular inspections and patrols of the pipeline would be maintained in order to identify any erosion problems and initiate repair of the ground cover. The proposed upgrade project does not introduce any increase in the risk associated with flooding / erosion.

The level of the pumping stations at the Kurnell Refinery and Banksmeadow Terminal are typically above grade.

5.3.4 Lightning Strike

Lightning strike is unlikely (but not impossible) to affect a buried pipeline or a pipeline below the Bay.

The refinery and the Banksmeadow Terminal are protected against lightning strike in accordance with Australian Standard AS 1768 Lightning Protection (Ref 16) requirements.

5.4 Control of Other Types of Hazards

5.4.1 Aircraft Crash

The risk of an aircraft crashing into any given facility is based upon the following:

- The location of the airways relative to the facility;
- The location of the airport relative to the facility;
- The relative consequences should an aircraft crash into the facility.

The proposed location of the pumps at the refinery and at Banksmeadow Terminal site and the location of the KBL is within a few kilometers from Sydney Kingston Smith airport runways and hence in proximity of the arrival and departure flight paths. While airplane crashes are highly unlikely in Australia due to the stringent Civil Aviation Safety Authority requirements, they are possible and should the crash occur at one of the pump stations it is likely to result in massive releases of flammable liquids with subsequent fire and even possibly explosion.

While the consequences of airplane crash are serious, the likelihood of such an incident is extremely low. The incremental increase in risk resulting from the upgrade project, compared with the current risk of an airplane crash at the refinery or the Banksmeadow Terminal, is negligible.

The majority of the pipeline, being buried underground or well under the harbour, is unlikely to be seriously damaged even in the event of an aircraft crash.

5.4.2 Intentional Acts

Intentional acts include terrorism and vandalism. The incremental increase in risk resulting from the upgrade project, compared with the current risk of an intentional act at the refinery, the KBL or the Banksmeadow Terminal, is negligible.

Security at the refinery and at Banksmeadow Terminal is discussed in Section 2.6 above.

5.4.3 Knock-on Effects / Cumulative Effects

Consequence calculations carried out as part of the Fire Safety Study (Ref 6) shows that separation distances from the pumping stations at both the refinery and Banksmeadow Terminal to neighbouring facilities outside of the site boundaries ensures that the heat radiation or overpressure from credible scenarios are highly unlikely to cause major structural damage at neighbouring facilities.

The possibility of on-site knock-on effects from incidents at the new pumping stations was assessed in the Fire Safety Study for the proposed upgrade (Ref 6). This study showed that:

Kurnell Refinery

- In case of a major pool fire at the refinery, neighbouring tanks (T166 and T157) could be exposed to short time (1-2 minutes) intense heat radiation which was unlikely to pose any major threat to either of these tanks due to the short duration of the fire near the tanks with the pool draining away from the pumps (and hence the tanks) into the oily water sewer.

- Further, a major jet fire at the refinery was unlikely to pose a threat to nearby infrastructure (tanks) due to the bund wall which separates the pumps from the tanks.

- Hence, knock-on effects (or propagation) from a major incident at the Kurnell Refinery pumping station is unlikely to occur.

Banksmeadow Terminal

- In case of a major pool or jet fire at the new booster pump station at the Terminal, neighbouring foam pump house, laboratory and switchroom building could be exposed to intense heat radiation.

- A major jet fire at the new booster pump station at the Banksmeadow Terminal could pose a threat to nearby (existing) products pump.

- Hence, knock-on effects (or propagation) from a major incident at the Banksmeadow Terminal new booster pump station may occur without effective emergency response. This knock-on may cause damage to the Banksmeadow Terminal fire response equipment (foam house) which may lead to diminished emergency response and further damage to the Terminal.

Recommendation 3: Depending on the results of the Fire Safety Study, further risk reduction may need to be considered for the risk associated with a knock-on at the neighbouring foam pump house at

Banksmeadow Terminal in case of a major fire at the booster pump station.

Jet Fuel Pipeline (KBL)

The pipeline is buried from Bumborah Point to Banksmeadow Terminal and from Banksmeadow Terminal to JUHI.

An incident at a nearby facility is highly unlikely to expose the buried KBL (at a depth of a minimum of 750 mm) and, provided that the pipeline is not exposed, research has shown that a pipeline cannot be damaged by the radiated heat or explosion overpressure from a nearby incident (as discussed in the recent risk assessment of the Young to Bomen pipeline which will be installed alongside an existing high pressure pipeline (Ref 17)).

The pipeline is located underground from the Kurnell Refinery down to the wharf. Leak prevention is achieved through design, operation and maintenance to the requirements of applicable codes and standards (notably AS2885).

6 QUALITATIVE RISK ANALYSIS

As discussed above, the qualitative risk assessment has been prepared on the basis of the risk matrix and associated consequence and likelihood scoring tables in AS2885.1 (Ref 5), as presented in Appendix 1, and based on the hazardous incident identification exercise summarised in Table 6 above.

The risk profile of the current pumping stations (at Kurnell Refinery and at Banksmeadow Terminal) and the KBL line itself is presented in Table 8 below.

This risk profile can be compared with the risk profile for the pumping stations and the KBL line after completion of the proposed upgrade project, as presented in Table 9 below.

The scenarios refer to those identified in Table 6, as follows:

Scenario 1. KBL loss of containment event: Uncontrolled release from the pipeline due to generic faults.

Scenario 2. KBL loss of containment event: Loss of containment due to aging pipeline

Scenario 3. KBL loss of containment event: Uncontrolled release of jet fuel due to impact or damage to the pipeline.

Scenario 4. KBL loss of containment event: Maloperation

Scenario 5. KBL loss of containment event: During maintenance

Scenario 6. KBL loss of containment due to natural event

Scenario 7. KBL loss of containment due to other types of hazards (terrorism, aircraft crash, knock-on event)

Scenario 8. Pumping station loss of containment event: Uncontrolled release of jet fuel due to generic faults.

Scenario 9. Pumping station loss of containment event: Uncontrolled release of jet fuel due to mechanical impact or damage at one of the pump stations.

Scenario 10. Pumping station loss of containment due to natural hazards

Scenario 11. Pumping station due to other types of hazards (terrorism, aircraft crash, knock-on event)

Table 8 – Current Risk Profile, Pumping Stations and KBL Line

	Catastrophic	Major	Severe	Minor	Trivial
Frequent	EXTREME	EXTREME	HIGH	INTERMEDIATE	LOW
Occasional	EXTREME	HIGH	INTERMEDIATE	LOW	LOW
Unlikely	HIGH	HIGH	INTERMEDIATE SCENARIO 2 SCENARIO 3 SCENARIO 4 SCENARIO 5	LOW	NEGLIGIBLE
Remote	HIGH	INTERMEDIATE	LOW SCENARIO 1	NEGLIGIBLE SCENARIO 6 SCENARIO 8 SCENARIO 9	NEGLIGIBLE
Hypothetical	INTERMEDIATE	LOW	NEGLIGIBLE SCENARIO 7 SCENARIO 11	NEGLIGIBLE SCENARIO 10	NEGLIGIBLE

Table 9 – Risk Profile After Upgrade Project, Pumping Stations and KBL Line

	Catastrophic	Major	Severe	Minor	Trivial
Frequent	EXTREME	EXTREME	HIGH	INTERMEDIATE	LOW
Occasional	EXTREME	HIGH	INTERMEDIATE	LOW	LOW
Unlikely	HIGH	HIGH	INTERMEDIATE SCENARIO 3 SCENARIO 4	LOW	NEGLIGIBLE
Remote	HIGH	INTERMEDIATE	LOW SCENARIO 1 SCENARIO 2 SCENARIO 5	NEGLIGIBLE SCENARIO 6 SCENARIO 8 SCENARIO 9	NEGLIGIBLE
Hypothetical	INTERMEDIATE	LOW	NEGLIGIBLE SCENARIO 7 SCENARIO 11	NEGLIGIBLE SCENARIO 10	NEGLIGIBLE

It is evident from the above that a net risk reduction would be expected following the proposed upgrade project, as follows:

Risk Reduction: The risk associated with the following incident scenarios will be reduced (by approximately one order of magnitude):

- Loss of containment event: Scenario 1 - Loss of containment due to aging pipeline. Risk reduced from *Intermediate* to *Low.*

- Loss of containment event: Scenario 5 - During maintenance (failure during pigging causes loss of containment from the pigging station). Risk reduced from *Intermediate* to *Low.*

There will be some increased complexity in the operation of the pipeline which may somewhat increase the risk of operational error, as follows:

Increase in Risk: The risk associated with the following incident scenario will be somewhat increased:

- Loss of containment event: Scenario 4 - Operational error upstream or downstream facility.

The increase in risk is not expected to be a whole order of magnitude and cannot therefore be represented as such on the AS2885.1 Risk Matrix above. Further, safety features (including leak detection, pressure trips and alarm functions and procedures will come together to manage this risk.

The increase in pressure and flowrate may increase the rate of release if a pipeline leak was to occur and it may increase the stress on the pipeline. However, this increase is only relevant for certain operational modes (refer Table 1 and Table 2) and the pipeline and pumps have been designed to withstand higher operational pressure. Therefore the increase in pressure and flowrate is not expected to substantially affect the risk levels of the KBL.

7 QUANTITATIVE RISK ANALYSIS

The results of the quantitative risk assessment are presented below, as follows:

- Risk associated with the new pumping station at Kurnell Refinery
  - Individual fatality risk
  - Societal fatality risk
  - Propagation risk
  - Injury risk
- Risk associated with the new booster pump station at Banksmeadow Terminal
  - Individual fatality risk
  - Societal fatality risk
  - Propagation risk
  - Injury risk

7.1 NEW PUMPING STATION AT KURNELL REFINERY

7.1.1 Individual fatality risk

Individual risk contours are shown in Figure 6 for the Kurnell pumping station. The results show the following:

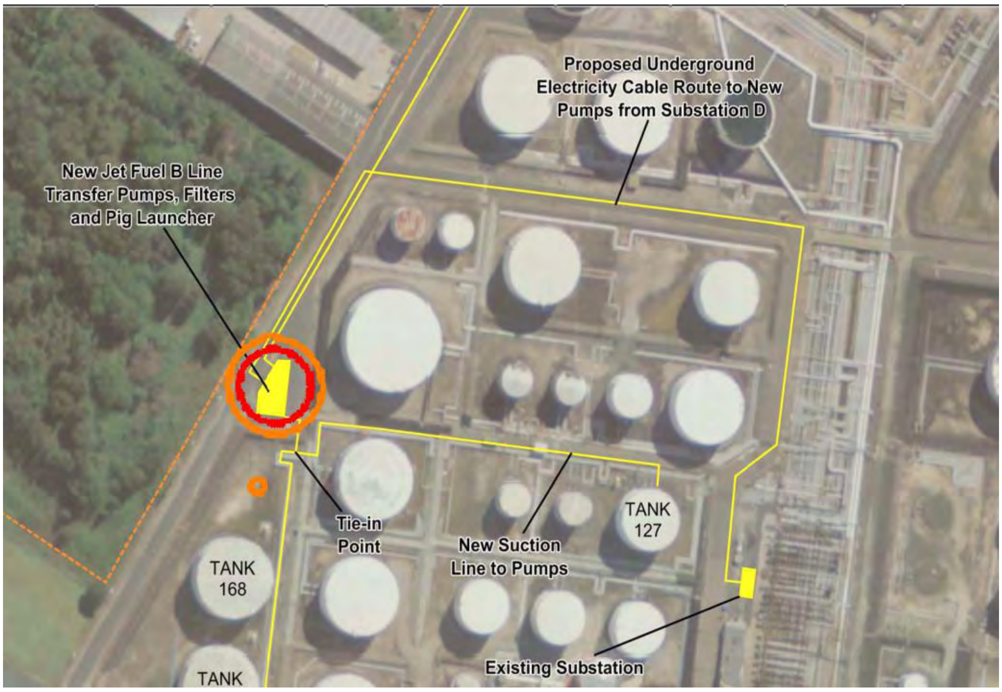
Maximum risk at site boundary: The maximum risk level at the site boundary is 0.08 x 10^{-6} per year.

Risk criterion for residential areas: The 1x10^{-6} per year risk contour, which is applicable for residential areas, is fully contained within the site boundary. The risk contours centre at the new pumping station and the lowest part of the bund where the pump and the catch basin leading to the underground drain system are located.

The risk of fatality at the nearest residential area from the new pumping station is less than 1 x 10^{-11} per year. This is less than the risk of dying from a meteorite (Refer 2) as well as being well below the maximum tolerable limit of one chance in a million per year (1 x 10^{-6} per year).

Risk criterion for active open space: The 10 x 10^{-6} per year risk contour for active open space is fully contained within the site boundary. The risk of fatality at the nearest active open space (i.e. at the wetland to the west of the new pump station) is 0.08 x 10^{-6} per year which is well below the criterion of ten chances per million years (10 x 10^{-6} per year) for open space.

Figure 6 - Individual Fatality Risk Contours, Kurnell After Upgrade



Legend:
------------ 10×10^{-6} per year (active open space buffer)
------------ 1×10^{-6} per year (residential buffer)

Risk criterion for industrial areas: The 50×10^{-6} per year risk contour for industrial buffer is never reached.

Risk criterion for sensitive development: The risk criterion for any sensitive development (0.1×10^{-6} per year) is contained in most directions except for a small excursion (of one to two meters) into the wetlands at the west of the new pump station. This risk contour does not however extend anywhere near any neighbouring sensitive developments such as nursing homes or schools etc.

Major Risk Contributors: The major risk contributors to the 1×10^{-6} per year and the $10x^{-6}$ per year risk contours are listed in Table 10 below.

Table 10 – Major Risk Contributors, Kurnell Pumping Station After Upgrade

Scenario	Contribution to the 10×10^{-6} per year contour	Contribution to the 1×10^{-6} per year contour
Pump leak at subsequent pool fire	99%	99%
Hole in one of the coalescers	1%	1%

7.1.2 Societal fatality risk

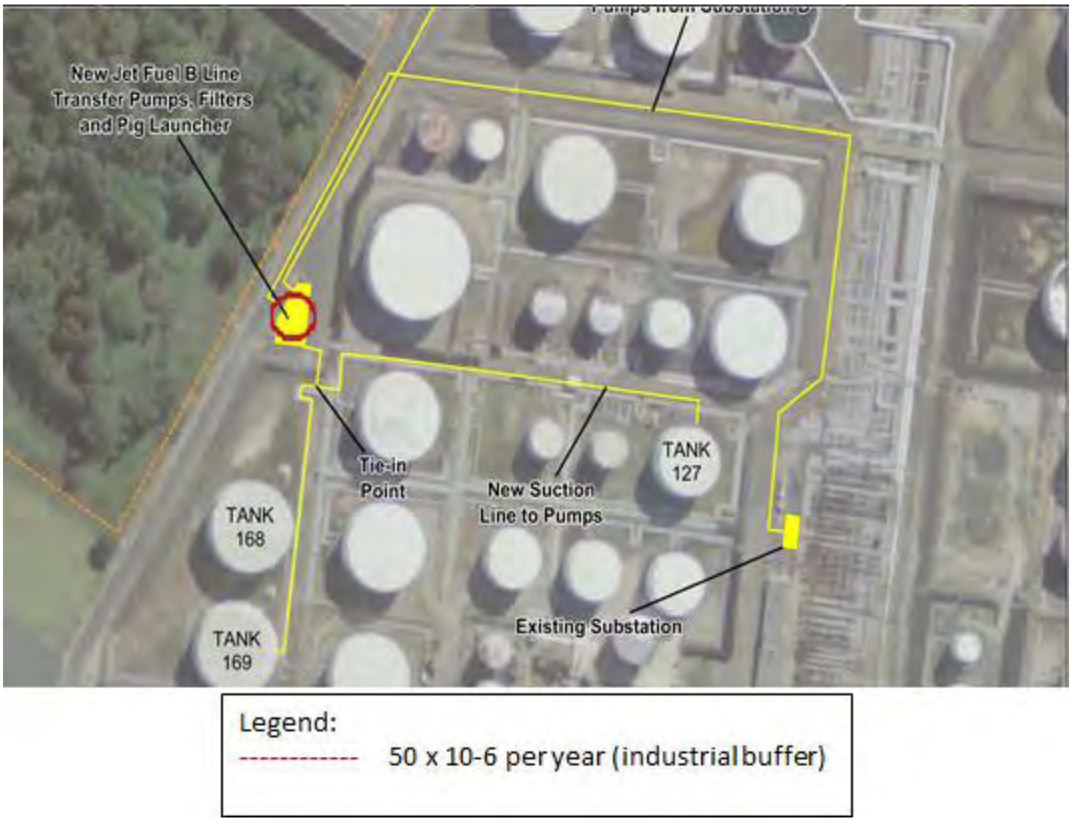
The risk of fatality at the nearest residential area from the new pumping station is less than 1 x 10^{-11} per year. With such low fatality risks at locations where residents and the public may reside, societal risk of fatality does not apply.

7.1.3 Propagation risk

The risk contour for levels of heat radiation and overpressures which may be damaging to process equipment (23 kW/m^2 and 14 kPa as per the NSW DoP risk criteria - Ref 2) is presented in Figure 7 below. The 50 x 10^{-6} per year risk contour, representing the maximum risk of propagation to neighbouring industrial facilities as per the DoP risk criteria, is contained within the site boundary. Further, it does not extend into any major infrastructure on the refinery site (such as neighbouring storage tanks).

The risk of propagation associated with the proposed pumping station is well below tolerable risk levels as per the DoP risk criteria.

Figure 7 – Propagation Risk, Kurnell After Upgrade

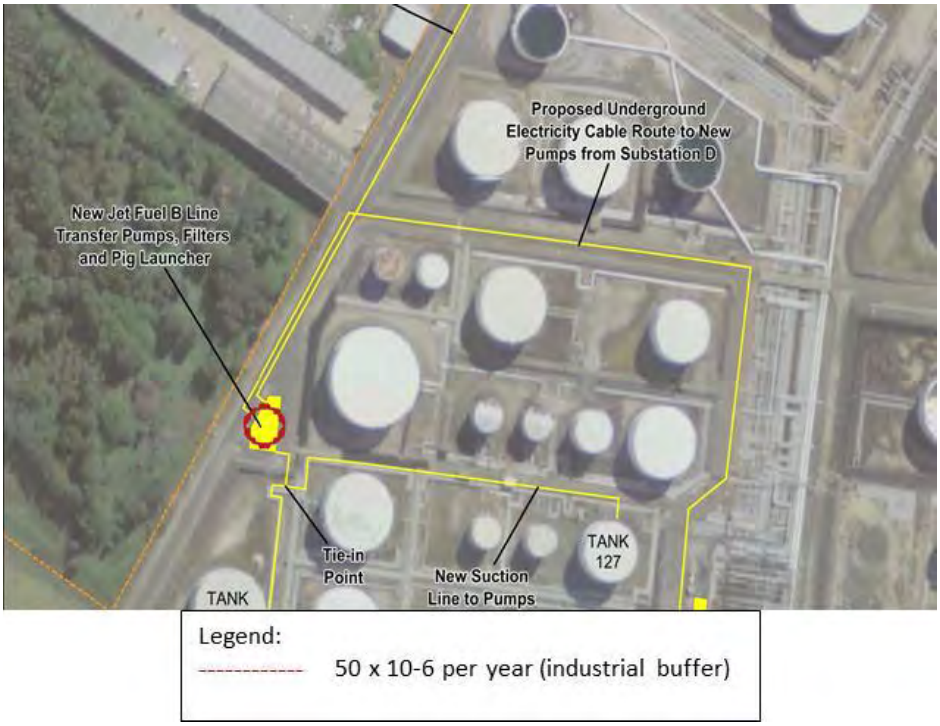


7.1.4 Injury risk

The risk contour for levels of heat radiation and overpressures which may be injurious (4.7 kW/m^2 and 7 kPa as per the NSW DoP risk criteria - Ref 2) is presented in Figure 8 below. The 50 x 10^{-6} per year risk contour, representing the maximum risk of injury outside of the site boundary, as per the DoP risk criteria, is contained within the site boundary.

The risk of injury associated with the proposed pumping station is below tolerable risk levels as per the DoP risk criteria.

Figure 8 – Injury Risk, Kurnell After Upgrade



7.2 NEW BOOSTER PUMP STATION AT BANKSMEADOW TERMINAL

7.2.1 Individual fatality risk

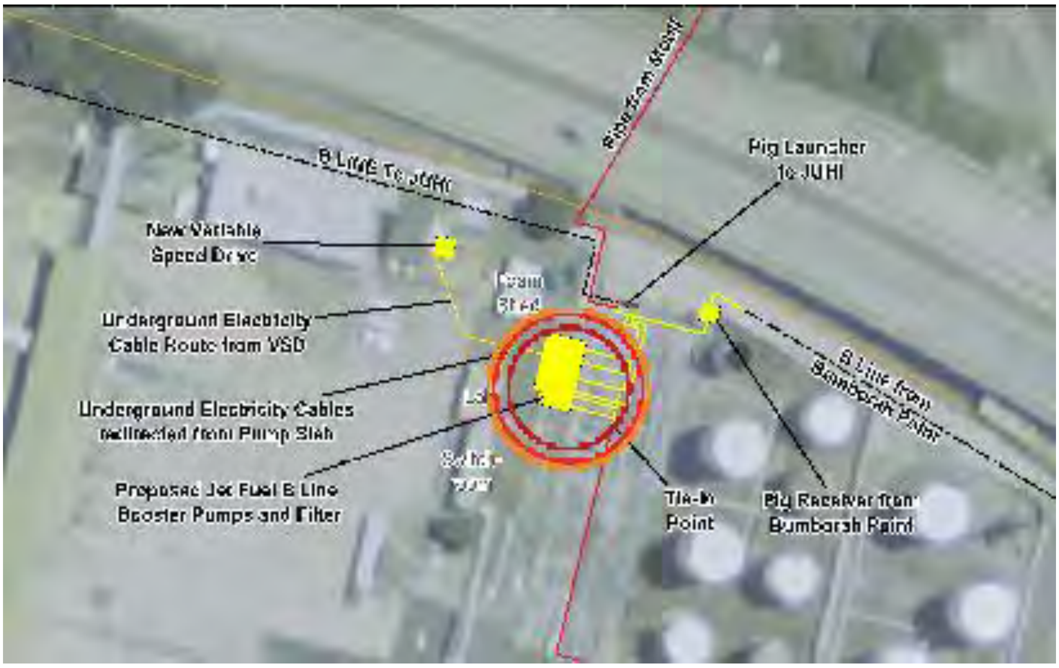
Individual risk contours are shown in Figure 9 for the Banksmeadow Terminal booster pumping station. The results show the following:

Maximum risk at the site boundary: The maximum risk level at the site boundary is less than 1 x 10^{-11} per year.

Risk criterion for residential areas: The 1x10^{-6} per year risk contour, which is applicable for residential areas, is fully contained within the site boundary. The risk contours centre around the new booster pumping station and the lowest part of the bund where the pump is located.

The risk of fatality at the nearest residential area from the new booster pumping station is less than 1 x 10^{-11} per year. This is less than the risk of dying from a meteorite (Refer 2). It is well below the maximum tolerable limit of one chance in a million per year (1 x 10^{-6} per year) set by the NSW DoP.

Figure 9 – Individual Fatality Risk Contours, Banksmeadow Terminal, After Upgrade



Legend:

------------ 10 x 10^{-6} per year (active open space buffer)

------------ 1 x 10^{-6} per year (residential buffer)

Risk criterion for active open space: The 10 x 10^{-6} per year risk contour for active open space is fully contained within the site boundary. The risk of fatality at the nearest active open space or the nearby public road, is well below the criterion of ten chances per million years (10 x 10^{-6} per year).

Risk criterion for industrial areas: The 50 x 10^{-6} per year risk contour for industrial buffer is fully contained within the site boundary in all other directions.

Risk criterion for sensitive development: The risk criterion for any sensitive development (0.1 x 10^{-6} per year) is fully contained within the site boundary.

Major Risk Contributors: The major risk contributors to the 1x10^{-6} per year and the 0.1x10^{-6} per year risk contours are listed in the table below.

Table 11 – Major Risk Contributors, Banksmeadow Terminal Booster Pumps After Upgrade

Scenario	Contribution to the 10x10^{-6} per year contour	Contribution to the 1x10^{-6} per year contour
Pump leak leading to a pool fire	99%	99%
Hole in one of the coalescers leading to a pool fire	1%	1%

7.2.2 Societal fatality risk

The risk of fatality at the nearest residential area from the new booster pumping station is less than 1 x 10^{-11} per year. With such low fatality risks at locations where residents and the public may reside, societal risk of fatality does not apply.

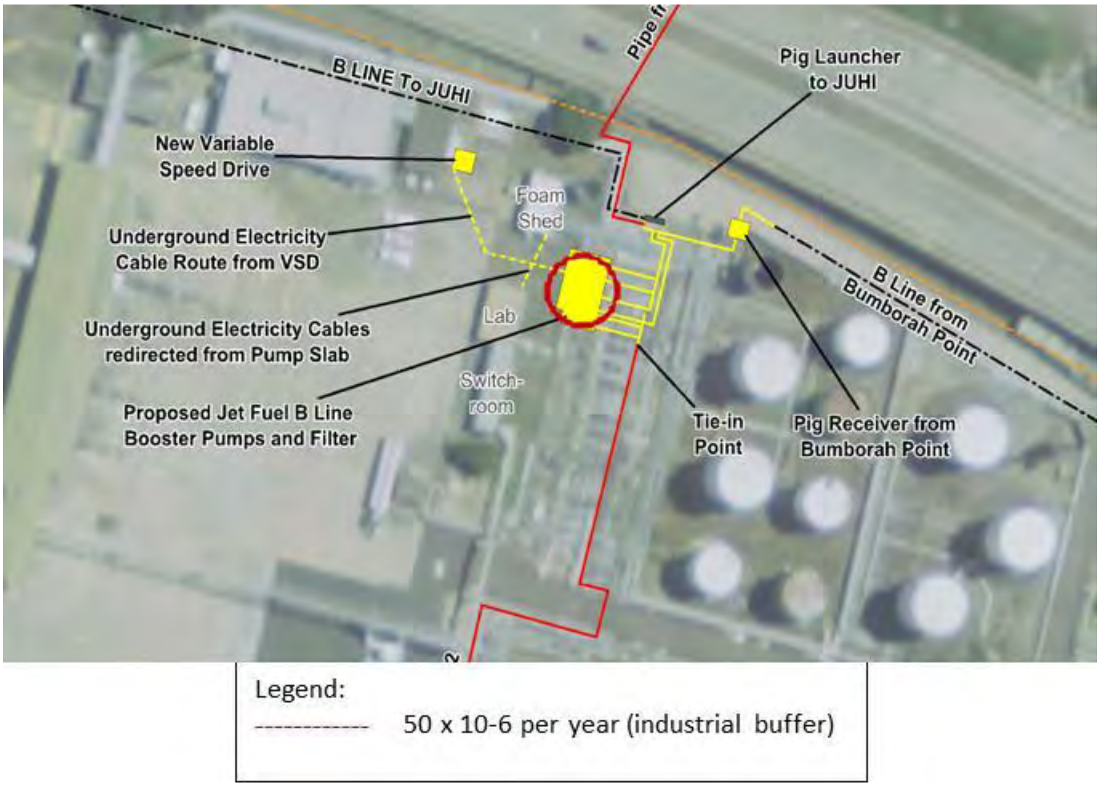
7.2.3 Propagation risk

The risk contour for levels of heat radiation and overpressures which may be damaging to process equipment (23 kW/m^2 and 14 kPa as per the NSW DoP risk criteria - Ref 2) is presented in Figure 10 below. The 50 x 10^{-6} per year risk contour, representing the maximum risk of propagation to neighbouring industrial facilities as per the DoP risk criteria, is contained within the site boundary.

Further, it does not extend into any major infrastructure on the site such as neighbouring storage tanks. However, the foam shed is located close to the new booster pump station and may be affected in a major fire at the station (also refer to the Fire Safety Study, Ref 6).

The risk of propagation associated with the proposed booster pumping station is below tolerable risk levels, as per the NSW DoP criteria.

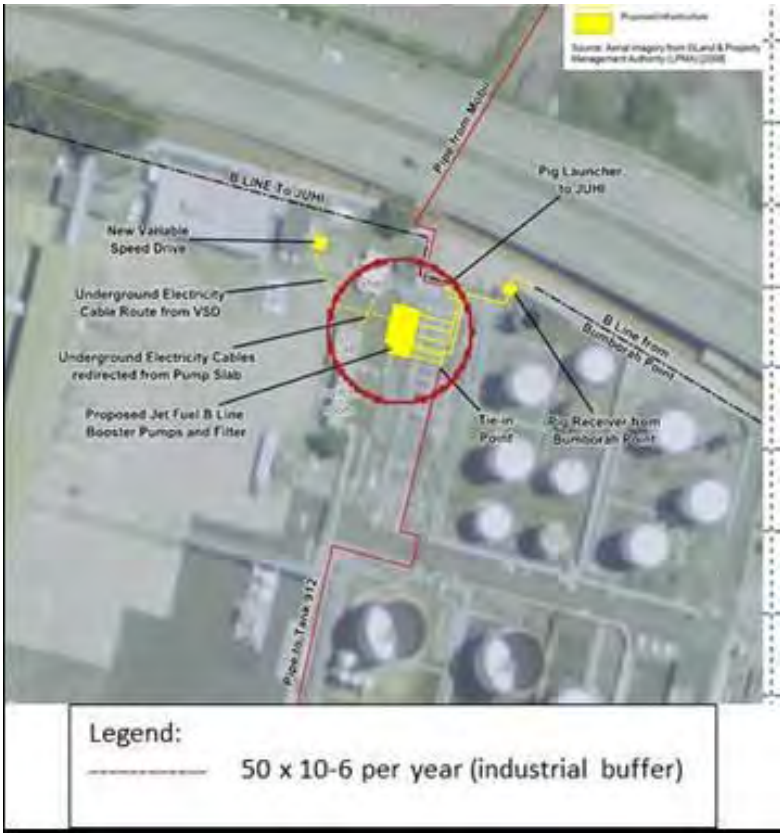
Figure 10 – Propagation Risk, Banksmeadow Terminal After Upgrade



7.2.4 Injury risk

The risk contour for levels of heat radiation and overpressures which may be injurious (4.7 kW/m^2 and 74 kPa as per the NSW DoP risk criteria - Ref 2) is presented in Figure 11 below. The 50 x 10^{-6} per year risk contour, representing the maximum risk of injury outside of the site boundary, as per the DoP risk criteria, is contained within the site boundary. The risk of injury associated with the proposed booster pumping station is below tolerable risk levels.

Figure 11 – Injury Risk, Banksmeadow Terminal After Upgrade



8 DISCUSSIONS AND CONCLUSION

8.1 OVERVIEW OF RISK

The main hazard associated with the proposed project is associated with the handling of jet fuel which is a flammable liquid at atmospheric conditions.

The predominant mode in which a hazardous incident may be generated is associated with a leak. This would generally only have the potential to cause injury or damage if there was ignition, which resulted in a fire or explosion incident. If the leak was not adequately contained and the jet fuel was allowed to enter the natural environment, an unignited release would be a threat to the biophysical environment

The factors involved are:

- Failure must occur causing a release. There are several possible causes of failure, with the main ones being corrosion and damage to the equipment by external agencies;

- For a pollution incident to occur, the release must either occur outside of contained areas (such as bunds) or containment must fail. The level of pollution will depend on the quantities of material released, the ease in which it can be removed and the area cleaned up, and the sensitivity of the environment in which the material was released;

- For a fire to occur, the released material must come into contact with a source of ignition. In some cases this may be heat or sparks generated by mechanical damage while in others, the possible ignition source could include non-flame proof equipment, vehicles, or a heat-source some distance from the release;

- Depending on the release conditions, including the mass of material involved and how rapidly it is ignited, the results of an ignition may be a localised fire (for example a so called jet fire or a pool fire) or a flash fire. If there is confinement a vapour cloud explosion is possible;

- Finally, for there to be a risk, people must be present within the harmful range (consequence distance) of the fire or explosion or the released jet fuel must enter the biophysical environment.

8.2 ADHERENCE TO QUANTITATIVE RISK CRITERIA – PUMPING STATIONS

The detailed design has not been completed as yet for this upgrade project. Despite the fact that many of the assumptions in this hazard and risk assessment are conservative, the results show that the risk associated with this the Kurnell Refinery and the Banksmeadow Terminal pumping stations falls within acceptable limits.

The quantitative risk assessment (QRA) showed that all landuse criteria, as defined by the NSW DoP (Ref 2) are met for the two pumping stations. The risk at any nearby residential areas, open spaces and sensitive development is well below the maximum tolerable risk criteria. The risk associated with the new pumping stations does not preclude further industrial development in the vicinity of the sites.

The risk of propagation from the pumping stations to neighbouring facilities on the same site, such as the neighbouring storage tanks at the refinery and the Terminal, is also below the NSW Department of Planning risk criteria.

The most stringent risk criteria, as set by the NSW DoP for acceptable risks in industrial installations, are adhered to for the two pumping stations.

8.3 ACCEPTABILITY OF OTHER RISKS AND HAZARDS

8.3.1 Qualitative Evaluation of Risk

The net result of the proposed upgrade project is an overall reduction in the risk associated with the KBL. This is due to:

- The upgrade project ensures that the entire pipeline can be subjected to a Non Destructive Testing method (called *intelligent pigging*) where possible reduction in the integrity of the pipeline can be identified through measurement of loss of wall thickness or coating damage on the pipeline, before it becomes an issue. This process, while performed at typically every 7 years for the rest of the pipeline, cannot currently be completed for a length of pipeline between the Kurnell refinery and the wharf. After the upgrade project the entire pipeline will be able to be intelligently pigged.

- The removal of the pigging station from the wharf and installing it instead at the refinery, in a location which can be contained in case of a loss of containment of jet fuel during pigging activities, is also seen as a clear risk reduction measure.

The slight increase in risk associated with the more complex operational procedures required to transfer jet fuel at different rates to different customers (which may lead to operational error at the upstream or downstream facilities) is managed through the installation of hardware features such as valve position pumping permissives, pressure trips and alarm functions as well as procedures and training.

The increase in maximum operational pressure in the KBL is not believed to substantially increase the risk associated with this pipeline, seeing that the design pressure and Maximum Allowable Operational Pressure (MAOP) exceeds this value. Further, the pressure trips and alarms would also contribute in the management of this risk.

The risk associated with the Kurnell Refinery and the Banksmeadow Terminal is not substantially changed as a result of the installation of the new pumping stations.

8.3.2 Risk to the Biophysical Environment

Risk to the biophysical environment from accidental releases of hazardous material at the new pumping stations will be minimised throughout the design, operation and maintenance process of plant and equipment. Further, spills outside of bunded areas will drain to the site drainage systems.

Risk to the biophysical environment from the KBL will be reduced as a result of the upgrade project, as discussed in Section 8.3.1 above.

8.3.3 Natural Hazards

A. Earthquake / Seismic Hazard and Hazards from Land Subsidence

The risk of earthquake, seismic hazards or land subsidence is minimal and is not altered as a result of the upgrade project.

B. Bushfire / Brush Fire

The risk associated with an incident associated with the new pumping stations initiating a brush or bushfire is minimised through a combination of active and passive protection (in the form of plant layout, equipment spacing, drainage, fire and/or hydrocarbon (flammable vapour) detection, a firewater system and overpressure protection).

The risk of a bush fire initiating an event at the KBL is not altered as a result of the upgrade project.

C. Flooding / Erosion

The risk associated with flooding or erosion is considered negligible in accordance with the risk ranking methodology in AS2885.1 (refer Appendix 1). It is not altered as a result of the upgrade project.

D. Lightning

The risk from lightning strike will be minimised through the use of relevant Australian or International standards.

8.3.4 External Hazards

A. Aircraft Crash

The risk associated with an aircraft crash is considered negligible in accordance with the risk ranking methodology in AS2885.1 (refer Appendix 1). It is not altered as a result of the upgrade project.

B. Incident Causes Knock-on Effect at Neighbouring Facility

The propagation risk calculations show that the current criteria for maximum acceptable risk at neighbouring industrial facilities is met at the boundary of the Kurnell Refinery pumping station and at Banksmeadow Terminal booster pump station.

Further, the said risk contour does not enter into major infrastructure at the two sites (such as storage tank areas).

The risk of knock-on effects at neighbouring installations is considered negligible in accordance with the risk ranking methodology in AS2885.1 (refer Appendix 1) for the KBL. It is not altered as a result of the upgrade project.

C. Intentional Acts

The risk of intentional acts (such as vandalism, terrorism) is considered negligible in accordance with the risk ranking methodology in AS2885.1 (refer Appendix 1). It is not significantly altered as a result of the upgrade project.

8.3.5 Cumulative Risk

Examination of the risk contours presented in Section 8.2 above shows that the risk associated with the new pumping stations at Kurnell Refinery and at Banksmeadow Terminal is low. It is expected to have low impact on the overall risk from the sites.

8.4 OVERALL CONCLUSION

The construction, commissioning and operation of the proposed upgrade project will be subject to rigorous scrutiny by Caltex and by the designing company, safeguarding delivery and operation of the project in a manner that minimises the risk to workers, contractors and the community.

The potential for incidents is well understood and the design of the plant and equipment will minimise the probability of an incident happening and mitigating an incident if it did occur.

The preliminary hazard and risk assessment of the proposed upgrade has found that the levels of risks to public safety from the two pumping stations are within generally accepted safety and risk guidelines.

Further, the upgrade project is expected to result in a net reduction in the overall risk from the KBL.

The present risk assessment has shown that the overall risk associated with the proposed upgrade project is low and does not introduce an excessive additional risk to the surrounding area.

9 RECOMMENDATIONS

Where possible, risk reduction measures have been identified throughout the course of the study in the form of recommendations. These are as follows:

- Recommendation 1: As far as practicable, ensure pipes outside of contained areas are fully welded (not flanged).
- Recommendation 2: Review existing Emergency Response Plans at both the Kurnell Refinery and at Banksmeadow Terminal as well as for the KBL for any changes required following implementation of the proposed upgrade.
- Recommendation 3: Depending on the results of the Fire Safety Study, further risk reduction may need to be considered for the risk associated with a knock-on at the neighbouring foam pump house at Banksmeadow Terminal in case of a major fire at the booster pump station.

10 REFERENCES

1 State Environment Planning Policy No 33 - *Hazardous and Offensive Development*, NSW Department of Planning

2 Hazardous Industry Planning Advisory Paper No. 4 (HIPAP No. 4): *Risk Criteria for Landuse Planning*, NSW Department of Planning

3 Hazardous Industry Planning Advisory Paper No. 6 (HIPAP No. 6): *Guidelines for Hazard Analysis*, NSW Department of Planning

4 Australian Standard AS2885 for Pipelines - Gas and Petroleum Liquids, 2007

5 *AS2885 Risk Assessment Workshop for the Caltex Jet Fuel B Line Stage 2 Upgrade*, ICD Asia Pacific, February 2011

6 *Caltex Jet Fuel Pipeline Upgrade Project, Fire Risk And Safety Assessment*, MATRIX RISK Pty Ltd, DRAFT November 2010

7 Yellow Book, *Methods for the Calculation of the Physical Effects of the Escape of Dangerous Material*, *CPR 14E, Parts 1& 2*, Committee for the Prevention of Disasters, TNO, 3rd edition 1997

8 AS1940 *The storage and handling of flammable and combustible liquids*

9 *Control Of Major Hazard Facilities* - National Standard, National Occupational Health and Safety Commission (NOHSC:1014), 2002

10 National Code of Practice National Occupational Health and Safety Commission (NOHSC:2016), 1996

11 Hazardous Industry Planning Advisory Paper No 1: *Industrial Emergency Planning Guidelines*, NSW Department of Planning 1993

12 Hazardous Industry Planning Advisory Paper No 2: *Fire Safety Study*, NSW Department of Planning 1993.

13 Building Code of Australia

14 *Australian Code for Transport of Dangerous Goods by Road and Rail* (ADG Code), 7th Ed, 2007

15 *Jet Fuel Upgrade Project A10027 - HAZOP Worksheets*, Caltex Refineries NSW, Kurnell, Printed 20 September 2010

16 AS 1768 Lightning Protection

17 Nilsson K, *Preliminary Hazard Analysis of the Natural Gas Delivery Pipeline between Young and Bomen in NSW*, Planager Pty Ltd, 13 October 2009

18 Dangerous Substances (PGS 3), Guidelines for quantitative risk assessment, Ministerie van VROM Ministerie van Verkeer en Waterstaat, December 2005

19 Cox A. W. Lees F. P, Ang M. L. Classification of Hazardous Locations, IChemE, 1990

20 Orica HAZAN Course, SHE Pacific, 1998

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Appendix 1

Qualitative Risk Assessment

Preliminary Hazard Analysis of the Proposed

Caltex Jet Fuel Upgrade Project

Appendix 1 – Qualitative Risk Assessment

A1.1 – Risk Matrix

The risk matrix from AS2885.1 (2007) was used to qualitatively assess the risks associated with the proposed upgrade.

A1.1 – Risk Matrix

	Catastrophic	Major	Severe	Minor	Trivial
Frequent	EXTREME	EXTREME	HIGH	INTERMEDIATE	LOW
Occasional	EXTREME	HIGH	INTERMEDIATE	LOW	LOW
Unlikely	HIGH	HIGH	INTERMEDIATE	LOW	NEGLIGIBLE
Remote	HIGH	INTERMEDIATE	LOW	NEGLIGIBLE	NEGLIGIBLE
Hypothetical	INTERMEDIATE	LOW	NEGLIGIBLE	NEGLIGIBLE	NEGLIGIBLE

A1.2 – Consequence Scoring Table

Dimension	Catastrophic	Major	Severe	Minor	Trivial
People	Multiple fatalities result	Few fatalities; several people with lifethreatening injuries	Injury or illness requiring hospital treatment	Injuries requiring first aid treatment	Minimal impact on health and safety
Environment	Effects widespread; viability of ecosystems or species affected; permanent major changes	Major off-site impact; longterm severe effects; rectification difficult	Localized (<1 ha) and short-term (<2 y) effects, easily rectified	Effect very localized (<0.1 ha) and very short-term (weeks), minimal rectification	No effect; minor on-site effects rectified rapidly with negligible residual effect

A1.3 – Likelihood Scoring Table

Frequency class	Frequency description
Frequent	Expected to occur once per year or more
Occasional	May occur occasionally in the life of the pipeline
Unlikely	Unlikely to occur within the life of the pipeline, but possible
Remote	Not anticipated for this pipeline at this location
Hypothetical	Theoretically possible but has never occurred on a similar pipeline

Appendix 2

Quantitative Risk Assessment

Preliminary Hazard Analysis of the Proposed
Caltex Jet Fuel Upgrade Project

Appendix 2 – Quantitative Risk Assessment

A2.1 – Risk Criteria

A2.1.1 - Individual Risk Criteria

The individual fatality risk is the probability of fatality to a person or a facility at a particular point. It is usually expressed as chances per million per year. It is assumed that the person will be at the point of interest 24 hours per day for the whole year. By convention in NSW, no mitigation is allowed, i.e. any possible evasive action that could be taken by a person exposed to a hazardous event, e.g. by walking out of a toxic cloud or a heat radiation. The assessment of fatality, incident propagation and injury risk should include all components contributing to the total risk, i.e. fire and explosion.

The NSW DoP uses a set of guidelines on acceptable levels or individual risk which are in line with the criteria used elsewhere in the world. These guidelines are published in the HIPAP No. 4: *Risk Criteria for Land Use Safety Planning* (Ref 2). The criteria for maximum tolerable individual risk from a new development are shown in Table A2.1 below. The criteria have been chosen so as not to impose a risk which is significant when compared to the background risk we are already exposed to. This table shows the criteria for individual risk of fatality, injury and propagation of an incident.

Table A2.1 - Criteria for Tolerable Individual Risk From New Development

Land Use		Max Tolerable Risk (per million per year)
Fatality risk criteria:		
Hospitals, Schools, etc		0.5
Residential areas, hotels, etc		1
Offices, retail centres, etc		5
Open space, recreation areas etc		10
Neighbouring industrial areas		50
Overpressure for Safety Distances:		
Property damage and accident propagation	14 kPa	50 Adjacent potentially hazardous installation, land zoned to accommodate such installations, or nearest public building
Injury risk levels	7 kPa	50 At residential areas
Maximum Heat Radiation:		
Injury risk levels	4.7 kW/m^2	50 At residential areas
Property damage and accident propagation	23 kW/m^2	50 Adjacent potentially hazardous installation or land zoned to accommodate such installations

In order to put these risks into perspective, published information on the level of risk to which each of us may be exposed from day to day due to a variety of activities has been shown in Table A2.2 below. Some of these are voluntary, for which we may accept a higher level of risk due to a perceived benefit, while some are involuntary. Generally, we tend to expect a lower level of imposed or involuntary risk especially if we do not perceive a direct benefit.

Table A2.2 - Risk to Individuals

Activity / Type of Risk	Published levels of risk (per million per year)
VOLUNTARY RISKS (AVERAGED OVER ACTIVE PARTICIPANTS)	
Smoking	5,000
Drinking alcohol	380
Swimming	50
Playing rugby	30
Travelling by car	145
Travelling by train	30
Travelling by aeroplane	10
INVOLUNTARY RISKS (AVERAGED OVER WHOLE POPULATION)	
Cancer	1,800
Accidents at home	110
Struck by motor vehicle	35
Fires	10
Electrocution (non industrial)	3
Falling objects	3
Storms and floods	0.2
Lightning strikes	0.1

A2.1.2 - Societal Risk Criteria

Societal risk is concerned with the potential for an incident to coincide in time and space with a human population. Societal risk takes into account the potential for an incident to cause multiple fatalities. Therefore, two components are relevant, namely:

- The number of people exposed in an incident, and
- The frequency of exposing a particular number of people.

In the absence of published criteria in HIPAP 4 (Ref 2), the criteria in the 1996 regional study of Port Botany by the NSW DoP[2] have been used for indicative purposes, as presented in Table A2.3 below.

Table A2.3 - Criteria for Tolerable Societal Risk

Number of fatalities (N) [-]	Acceptable limit of N or more fatalities per year	Unacceptable limit of N or more fatalities per year
1	3×10^{-5}	3×10^{-3}
10	1×10^{-6}	1×10^{-4}
100	3×10^{-8}	3×10^{-6}
1000	1×10^{-9}	1×10^{-7}

[2] then the Department of Urban Affairs and Planning

The societal risk criteria specify levels of societal risk which must not be exceeded by a particular activity. The same criteria are currently used for existing and new developments. Two societal risk criteria are used, defining acceptable and unacceptable levels of risk due to a particular activity. The criteria in Table A2.3 above are represented on the societal risk (f-N) curve as two parallel lines. Three zones are thus defined:

- Above the unacceptable/intolerable limit the societal risk is not acceptable whatever the perceived benefits of the development.
- The area between the unacceptable and the acceptable limits is known as the ALARP (as low as reasonably possible) region. Risk reduction may be required for potential incidents in this area.

Below the acceptable limit, the societal risk level is negligible regardless of the perceived value of the activity.

A2.2 - Consequence Analysis

A2.2.1 - Modelling Software

Consequence analysis was undertaken using the TNO Quantitative Risk Assessment program *Riskcurves* (version 7.6) and consequence modelling software program *Effects* (version 8.0). The TNO tools are internationally recognised by industry and government authorities.

The consequence models used within Effects Riskcurves are well known and are fully documented in the TNO Yellow Book (Ref 7).

Essentially, an appropriate release rate equation is selected based on the release situation and initial state of the material. The atmospheric dispersion model for denser-than-air releases - SLAB - is used to model dispersion behaviour for heavier than air vapours such as those formed from a jet fuel released into the atmosphere. The software tool is able to predict when the dispersed gas becomes neutral through incorporation of air and switches model automatically.

A2.2.2 - Evaluation Techniques

Leak Rates

Riskcurves and Effects model release behaviour for compressed gas, liquid or 2-phase releases from vessels, pipelines or total vessel rupture. Input data includes the type of release, location of release with respect to vessel geometry, pipe lengths etc. and initial conditions of the fluid (i.e. before release).

The release rate is assumed to remain constant until isolation can be achieved - this is a conservative approach as in reality there will be pressure reduction and hence reduction in leak rate.

Duration

The duration of a leak will depend on the hardware systems available to isolate the source of the leak, the nature of the leak itself and the training, procedures and management of the facility. While in some cases it may be argued that a leak will be isolated within one minute, the same leak under different circumstances may take 10 minutes to isolate. Under worst case conditions, such as where there are large quantities of materials between two isolating valves, the release may last even longer. In such cases, the release pressure and hence the release rate will decrease.

The approach used in this study for the failure scenarios identified is to assume the release continues until the inventory has been released, up to a maximum duration of one hour. This is a conservative assumption as the operators have the ability to isolate the leak using remote operated valves.

Where automatic response has been designed into the plant (e.g. in the form of process trips), such response has been taken into account, with the relevant probability of failure of the trip.

Pool Dimensions

The Riskcurves model calculates the rate of evaporation and spreading of a pool of liquid. There are three release options which have the following implications on the spreading of a pool of liquid:

1. Instantaneous release: the inventory is released instantaneously, with the associated speed of the pool being very rapid;

2. Continuous release: the inventory is released at a constant rate for a given time period; and,

3. Transient release: the inventory is released at a variable rate for a given time period.

The rate of evaporation will depend on many factors, including climatic and weather, as well as the surface area over which evaporation takes place. A large surface area means a higher degree of evaporation if all other variables remain constant. Table A2.4 below summarizes the main assumptions made in the calculation of pool spreading and evaporation rates.

Table A2.4 - Input factors used to model Jet Fuel Spreading and Evaporation Rate

Substrate:	Land, average soil
Roughness Parameter:	Low crops, occasional large object
Release Duration	Duration derived from release rate calculation.

Dispersion Distances

A gas released will disperse in the atmosphere. At concentrations between the upper flammable limit and the lower flammable limit, jet fuel can ignite and burn.

The Riskcurves model is used to estimate the distance to which a release of flammable vapours will disperse to half the LFL for momentum driven (high pressure, high velocity releases) and dense gas scenarios respectively. Feed rates for gas dispersion models are taken from vapour release rates calculated by the Effects model.

Weather Data

Weather conditions are described as a combination stability category and wind speed. This is usually denoted as a combination of a letter with a number, such as *D4* or *F2*. The letter denotes the Pasquil stability class and the number gives the wind speed in metres per second.

Wind speeds range from light (1-2 m/s) through moderate (around 5 m/s) to strong (10 m/s or more). The probability of the wind blowing from a particular direction is displayed graphically as a *wind rose*.

The Pasquil stability classes describe the amount of turbulence present in the atmosphere ranging from *unstable* weather (class *A*), with a high degree of atmospheric turbulence to *stable* conditions (class *F*). Class A would normally be found on a bright sunny day; class D (*neutral* conditions), corresponding to an overcast sky with moderate wind; and class F corresponds to a clear night with little wind.

The approach used in this study is to define one wind weather category to represent day time (D4) and one to represent nighttime (F2).

A2.2.3- Heat Radiation and Explosion Overpressures

Modelling Techniques - Theory

<u>Heat Radiation</u>

The effect or impact of heat radiation on people is shown in the table below.

Table A2.5 - Effects of Heat Radiation

Radiant Heat Level (kW/m^2)	Physical Effect (effect depends on exposure duration)
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 15-20 seconds and injury after 30 seconds' exposure
12.6	Significant chance of fatality for extended exposure High chance of injury

Radiant Heat Level (kW/m^2)	Physical Effect (effect depends on exposure duration)
23	Likely fatality for extended exposure and chance of fatality for instantaneous (short) exposure
35	Significant chance of fatality for people exposed instantaneously

In Riskcurves, heat radiation effects are calculated based on flame surface emissive power (which is dependent on the quantity of material, its heat of combustion, flame dimensions and the fraction of heat radiated), as per the Yellow Book by TNO (in Ref 7). The heat flux at a particular distance from a fire is calculated using the view factor method. The view factor takes into account the distance from the flame to the target, the flame dimensions and the orientation angle between the flame and the target.

The effect of heat radiation on a person is calculated from the probit equation which relates to the probability of fatality to the thermal *dose* received (i.e. the combined heat and exposure time) though the following equations.

$$\text{Probit Pr} = -36.38 + 2.56 \ln(tQ^{1.33})$$

With t = exposure time (sec) and Q = heat flux (W/m^2).

And with the relationship between the probit value and the probability of fatality is calculated as follows:

$$\text{Probability of fatality} = \frac{1}{2}\left(1 + \text{erf}\left(\frac{Pr - 5}{2^{0.5}}\right)\right)$$

Overpressure

The effect or impact of overpressure is shown in the table below.

Table A2.6 - – Effect 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

In Riskcurves, the Multi Energy method is used to predict the overpressures from flammable gas explosions, as per the Yellow Book in Ref 7. The key feature of the Multi-Energy method is that the explosion is not primarily defined by the fuel air mixture but by the environment in which the vapour disperses.

Partial confinement is regarded as a major cause of blast in vapour cloud deflagrations. Blast of substantial strength is not expected to occur in open areas. Strong blast is generated only in places characterized by partial confinement while other large parts of the cloud burn out without contributing to the blast effects. The vapour cloud explosion is not regarded as an entity but is defined as a number of sub-explosions corresponding to various sources of blast in the vapour cloud, i.e. each confined part of the cloud is calculated as a separate vapour cloud explosion.

The initial strength of the blast is variable, depending on the degree of confinement and on the reactivity of the gas. The initial strength is represented as a scale of 1 to 10 where 1 means slow deflagration and 10 means detonation. For explosions in process plant environments the initial strength is thought to lie between 4 to 7 on the scale.

Calculated Fire Dimensions

Flame dimensions will vary depending on the wind weather conditions. Riskcurves calculates the flame dimensions for each wind weather category and incorporates these into the risk assessment together with their respective probability of occurrence.

Pool fire evaporation and burning rates will also vary depending on the wind weather conditions. Riskcurves calculates the heat radiation from a fire for each wind weather category and incorporates these into the risk assessment together with their respective probability of occurrence.

Calculated Blast Overpressure Dimensions

For a release of flammable gas into an unconfined environment the chances of an explosion is small.

A vapour cloud explosion is possible however if some degree of confinement is present, for example in a cramped plant area.

For concentrations within the flammable range from a release of jet fuel to be able to reach a confined area the release must be relatively large. Hence, vapour cloud explosions were only considered for the pipe rupture cases.

A2.3 - Likelihood Analysis

A2.3.1 - Failure Rates

The frequency of each postulated equipment failure incident scenario listed above was determined using the data in the table below.

These frequencies for pipelines and vessel leaks are those that have been in use by Orica Engineering for over 15 years of risk assessments in Australia. These frequencies are based on Orica Engineering's interpretation of published and unpublished (internal ICI and Orica) data.

The frequencies for pump leaks are those from Dutch TNO *Purple Book* (Ref 18).

Table A2.7 - Equipment Failures and Associated Frequencies

Type of Failure	Failure Rate (pmpy)
PIPELINES WITHIN FIXED PLANT	
3 mm hole	9 / m
13 mm hole	3 / m
50 mm hole	0.3 / m
3 mm gasket (13 mm hole equivalent)	5 / joint
Guillotine fracture (full bore):	
< 50 mm	0.6 / m
> 50 mm but < 100 mm	0.3 / m
> 100 mm	0.1 / m
PRESSURE VESSEL	
6 mm hole	24 pmpy
13 mm hole	6 pmpy
25 mm hole	3 pmpy
50 mm hole	3 pmpy
Catastrophic rupture	1 pmpy
PUMP LEAK (FOR PUMPS WITHOUT ADDITIONAL PROVISIONS)	
Catastrophic failure (full bore rupture of the largest connecting pipeline)	100
Leak (leak with an effective diameter of 10% of the nominal diameter of the largest connecting pipeline)	500

A2.3.2- Ignition Probability

Cox, Lees and Ang (Ref 19) gives the probabilities for ignition, as presented in the table below. The probability increases as a function of the size of the release. For the smallest releases the ignition probability may be as low as 1%. Vapours, such as those evaporating from a jet fuel release, are considered to be of *medium* reactivity, with correspondingly medium ignition probability.

Table A2.8 – Probability of Ignition

Size Release	Ignition probability
Small	1%
Medium	3%
Large	8%

The probability of delayed ignition for pipeline incidents are takes as per the Orica Hazard Analysis (HAZAN) Course (Ref 20).

Table A2.9 - Probability of Delayed Ignition

Size Release (kg/s)	Probability of Delayed Ignition
Small to medium vapour cloud	0.1
Medium vapour cloud	0.22
Major vapour cloud	0.43

The probability of an explosion for the fixed plant (where there may be some confinement) is taken as 40% of the total delayed ignition case, with flash fires accounting for the other 60% of cases. This is as per the methodology in the TNO Purple Book (Ref 18) and more conservative than observations of actual incidents in process industry.

The frequency of outcome of each individual incident scenario is listed in the spread sheet below. The Event Tree in Figure A2.1 below shows the flammable even logic used in this assessment.

Blockage in the Bund Drainage System

In the case of a loss of containment at the pumps at Kurnell Refinery or at the booster pumps at Banksmeadow Terminal, the jet fuel would gravity drain through the underground drainage system to the oily water sewer located at either site.

There are three catch basins within the Kurnell pump bund where the spill could enter the underground oily water sewer system.

If there was a blockage in one of these catch basins it is assumed that the spill would be transferred through the slope in the bund floor to the next catch basins and so forth.

If there was a blockage in the common underground drain system then a spill would pool on the pump bund floor.

The absence of blockages is checked every time there is rain and procedures exist to ensure that the pump bunds are free of water. There are no common mode incidents identified where the blockage in the drain system is initiated through a leak at the pumps. Hence the blockage in the drain system is assumed to be fairly unlikely to coincide with a loss of containment at the pumps.

The following probability of failing to correct a blocked drain in either pump station bund is used in the present PHA, following the methodology suggested in the AIChE publication in Ref 21:

- General errors of omission for items imbedded in a procedure: 1×10^{-3} per demand

In the case of a totally blocked drainage system the maximum surface area of a loss of containment is that covering the total bund area.

If the drain is not blocked, the loss of containment scenario is evaluated buy fixing the maximum surface of the pool at that which is covered by the closest catch basin.

Figure A2.1 - Event Tree for Ignition of Jet Fuel Releases

ON PLANT INCIDENTS

Immediate ignition — Cox, Lees & Ang

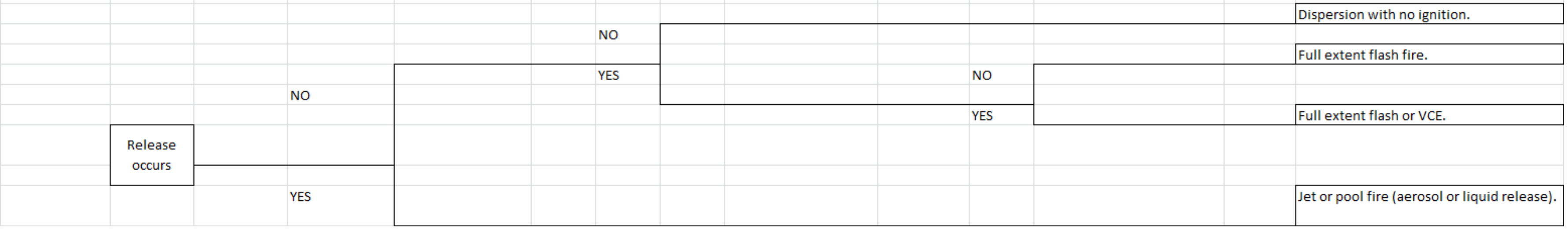
Cont. Release	**Prob**
Small	0.01
Medium	0.03
Large	0.08

Delayed ignition — Ref Orica HAZAN Course, P=M0.33

Cont. Release	**Prob**
Small	0.1
Medium	0.22
Large	0.43

Confinement allows accumulation of gas — TNO Purple book

Flash fire	0.6
Vapour Cloud Explosion	0.4



Input data for RiskCurves

Abbreviation	**Leak scenario**	**Material**	**State**
REFSMALL	3mm hole in pipe or flange (pinhole)	JET FUEL	AEROSOL
REFFLANGE	13mm hole in seal or flange	JET FUEL	AEROSOL
REFMAJOR	10% hole in pipeline	JET FUEL	LIQUID
REFRUPTURE	Rupture of pipeline	JET FUEL	LIQUID
BMTSMALL	3mm hole in pipe or flange (pinhole)	JET FUEL	AEROSOL
BMTFLANGE	13mm hole in seal or flange	JET FUEL	AEROSOL
BMTMAJOR	10% hole in pipeline	JET FUEL	LIQUID
BMTRUPTURE	Rupture of pipeline	JET FUEL	LIQUID
PV6	6mm leak in coalescer	JET FUEL	LIQUID
PV13	13mm leak in coalescer	JET FUEL	LIQUID
PV25	25mm leak in coalescer	JET FUEL	LIQUID
PV50	50mm leak in coalescer	JET FUEL	LIQUID
PVCAT	Catastrophic rupture of coalescer	JET FUEL	LIQUID
PUMPLEAK	10% leak in pump	JET FUEL	LIQUID
PUMPCAT	Rupture of connection to pump	JET FUEL	LIQUID

Planager
Risk Management Consulting

KURNELL REFINERY										
EQUIPMENT	LENGTH metres	#JOINTS	TRIP	LEAK FREQ. /yr	IGNITION FREQ/ /yr	IMMEDIATE IGNITION JET FIRE FROM AEROSOL FREQ. /yr	IMMEDIATE IGNITION POOL FIRE FREQ. /yr	IMMEDIATE IGNITION WITH BLOCKED DRAIN /yr	IMMEDIATE IGNITION POOL FIRE FREQ. /km yr	DELAYED IGNITION FLASH FREQ. /yr
REFSMALL	20	20	NO	1.80E-04	1.80E-06	9.00E-07	9.00E-07	9.00E-10	4.50E-05	1.08E-07
REFFLANGE	20	20	NO	6.00E-05	6.00E-07	3.00E-07	3.00E-07	3.00E-10	1.50E-05	3.60E-08
REFMAJOR	20	20	NO	6.00E-06	1.80E-07		1.62E-07	1.62E-10	8.10E-06	1.08E-08
REFRUPTURE	20	20	NO	2.00E-06	1.60E-07		1.60E-07	1.60E-10	8.00E-06	2.11E-08
REFSMALL DOWNSTREAM	20	20	NO	1.80E-04	1.80E-06	9.00E-07	9.00E-07	9.00E-10	4.50E-05	1.08E-07
REFFLANGE DOWNSTREAM	20	20	NO	6.00E-05	6.00E-07	3.00E-07	3.00E-07	3.00E-10	1.50E-05	3.60E-08
REFMAJOR DOWNSTREAM	20	20	NO	6.00E-06	1.80E-07		1.80E-07	1.80E-10	9.00E-06	1.08E-08
REFRUPTURE DOWNSTREAM	20	20	NO	2.00E-06	1.60E-07		1.60E-07	1.60E-10	8.00E-06	2.11E-08
PV6	N/A	N/A	NO	4.80E-05	4.80E-07	2.40E-07	2.40E-07	2.40E-10	N/A	2.88E-08
PV13	N/A	N/A	NO	1.20E-05	1.20E-07	6.00E-08	6.00E-08	6.00E-11	N/A	7.20E-09
PV25	N/A	N/A	NO	6.00E-06	1.80E-07		1.62E-07	1.62E-10	N/A	1.08E-08
PV50	N/A	N/A	NO	6.00E-06	1.80E-07		1.40E-07	1.40E-10	N/A	2.38E-08
PVCAT	N/A	N/A	NO	2.00E-06	1.60E-07		1.25E-07	1.25E-10	N/A	2.11E-08
PUMPLEAK	N/A	N/A	NO	1.00E-03	3.00E-05	1.30E-05	1.30E-05	1.30E-08	N/A	3.96E-06
PUMPCAT	N/A	N/A	NO	2.00E-04	1.60E-05	8.00E-06	8.00E-06	8.00E-09	N/A	4.13E-06

BANKSMEADOW TERMINAL										
EQUIPMENT	LENGTH metres	#JOINTS	TRIP	LEAK FREQ. /yr	IGNITION FREQ/ /yr	IMMEDIATE IGNITION JET FIRE FRO AEROSOL FREQ. /yr	IMMEDIATE IGNITION POOL FIRE FREQ. /yr	IMMEDIATE IGNITION WITH BLOCKED DRAIN /yr	IMMEDIATE IGNITION POOL FIRE FREQ. /km yr	DELAYED IGNITION FLASH FREQ. /yr
BMTSMALL	20	20	NO	1.80E-04	1.80E-06	9.00E-07	9.00E-07	9.00E-10	4.50E-05	1.08E-07
BMTFLANGE	20	20	NO	6.00E-05	6.00E-07	3.00E-07	3.00E-07	3.00E-10	1.50E-05	3.60E-08
BMTMAJOR	20	20	NO	6.00E-06	1.80E-07		1.80E-07	1.80E-10	9.00E-06	1.08E-08
BMTRUPTURE	20	20	NO	2.00E-06	1.60E-07		1.60E-07	1.60E-10	8.00E-06	2.11E-08
PV6	N/A	N/A	NO	4.80E-05	4.80E-07	2.40E-07	2.40E-07	2.40E-10	N/A	2.88E-08
PV13	N/A	N/A	NO	1.20E-05	1.20E-07	6.00E-08	6.00E-08	6.00E-11	N/A	7.20E-09
PV25	N/A	N/A	NO	6.00E-06	1.80E-07		1.80E-07	1.80E-10	N/A	1.08E-08
PV50	N/A	N/A	NO	6.00E-06	1.80E-07		1.80E-07	1.80E-10	N/A	2.38E-08
PVCAT	N/A	N/A	NO	2.00E-06	1.60E-07		1.25E-07	1.25E-10	N/A	2.11E-08
PUMPLEAK	N/A	N/A	NO	1.00E-03	3.00E-05	1.50E-05	1.50E-05	1.50E-08	N/A	3.96E-06
PUMPCAT	N/A	N/A	NO	2.00E-04	1.60E-05	8.00E-06	8.00E-06	8.00E-09	N/A	2.11E-06

KURNELL REFINERY						BEFORE UPGRADE					AFTER UPGRADE				
EQUIPMENT	DIAM ORIF. Metres	CROSS AREA m2	REL. HEIGHT m	MAX POOL SURFACE (M2)	MAX POOL SURFACE IF DRAIN SYSTEM NOT BLOCKED (M2)	LEAK RATE BEFORE UPGRADE kg/s (Effects)	EVAPORATION RATE (kg/s) (Effects)	DISTANCE TO LEL (m) (Effects)	CLOUD (KG) F2 (Effects)	CLOUD (KG) D4 (Effects)	LEAK RATE AFTER UPGRADE kg/s (Effects)	EVAPORATION RATE (kg/s) (Effects)	DISTANCE TO LEL (m) (Effects)	CLOUD (KG) F2 (Effects)	CLOUD (KG) D4 (Effects)
REFSMALL	3.00E-03	7.07E-06	0.00E+00	8.00E-01	8.00E-01	2.38E-01	0.021959	<1	0.00E+00	0.00E+00	2.58E-01	0.022612	<1	0.00E+00	0.00E+00
REFFLANGE	1.30E-02	1.33E-04	0.00E+00	2.64E+02	1.04E+02	4.48E+00	2.1986	<1	0.00E+00	0.00E+00	4.85E+00	2.1978	<1	0.00E+00	0.00E+00
REFMAJOR	5.00E-02	1.96E-03	0.00E+00	2.64E+02	1.04E+02	6.61E+01	5.5899	22.6	3.16E+01	0.00E+00	7.16E+01	5.7422	23	3.21E+01	0.00E+00
REFRUPTURE	2.00E-01	3.14E-02	0.00E+00	2.64E+02	1.04E+02	7.30E+02	8.6368	22	1.03E+02	0.00E+00	7.91E+02	8.68	24	1.05E+02	0.00E+00
REFSMALL DOWNSTREAM	3.00E-03	7.07E-06	0.00E+00	8.00E-01	8.00E-01	2.04E-01	0.020711	<1	0.00E+00	0.00E+00	3.44E-01	0.022612	<1	0.00E+00	0.00E+00
REFFLANGE DOWNSTREAM	1.30E-02	1.33E-04	0.00E+00	1.14E+02	1.04E+02	3.82E+00	1.0735	<1	0.00E+00	0.00E+00	6.46E+00	1.3353	<1	0.00E+00	0.00E+00
REFMAJOR DOWNSTREAM	5.00E-02	1.96E-03	0.00E+00	1.14E+02	1.04E+02	5.64E+01	3.0456	18.6	1.00E+00	0.00E+00	9.54E+01	3.4001	18.6	1.10E+00	0.00E+00
REFRUPTURE DOWNSTREAM	2.00E-01	3.14E-02	0.00E+00	1.14E+02	1.04E+02	6.24E+02	4.0278	23.8	3.00E+00	0.00E+00	1.05E+03	4.15	23.8	3.20E+00	0.00E+00
PV6	6.00E-03	2.83E-05	0.00E+00	8.00E-01	8.00E-01	3.80E+00	0.6	<1	0.00E+00	0.00E+00	600	0	<	0.00E+00	0.00E+00
PV13	1.30E-02	1.33E-04	0.00E+00	2.64E+02	1.04E+02	4.48E+00	2.1986	<1	0.00E+00	0.00E+00	4.85E+00	2.1978	<1	0.00E+00	0.00E+00
PV25	2.50E-02	4.91E-04	0.00E+00	2.64E+02	1.04E+02	3.20E+01	3.4	<1	0.00E+00	0.00E+00	3.20E+01	3.4	<1	0.00E+00	0.00E+00
PV50	5.00E-02	1.96E-03	0.00E+00	2.64E+02	1.04E+02	6.61E+01	5.5899	22.6	3.16E+01	0.00E+00	7.16E+01	5.7422	23	3.21E+01	0.00E+00
PVCAT	RUPTURE	RUPTURE	0.00E+00	2.64E+02	1.04E+02	INSTANT.	6.1	26	1.20E+02	0.00E+00	INSTANT.	6.1	26	1.20E+02	0.00E+00
PUMPLEAK	2.50E-03	4.91E-06	0.00E+00	2.64E+02	1.04E+02	6.61E+01	5.5899	22.6	3.16E+01	0.00E+00	7.16E+01	5.7422	23	3.21E+01	0.00E+00
PUMPCAT	2.00E-01	3.14E-02	0.00E+00	2.64E+02	1.04E+02	7.30E+02	8.6368	22	1.03E+02	0.00E+00	7.91E+02	8.68	24	1.05E+02	0.00E+00

BANKSMEADOW TERMINAL						BEFORE UPGRADE					AFTER UPGRADE				
EQUIPMENT	DIAM ORIF. Metres	CROSS AREA m2	REL. HEIGHT m	POOL SURFACE (M2)	MAX POOL SURFACE IF DRAIN SYSTEM NOT BLOCKED (M2)	LEAK RATE BEFORE UPGRADE kg/s (Effects)	EVAPORATION RATE (kg/s) (Effects)	DISTANCE TO LEL (m) (Effects)	CLOUD (KG) F2 (Effects)	CLOUD (KG) D4 (Effects)	LEAK RATE AFTER UPGRADE kg/s (Effects)	EVAPORATION RATE (kg/s) (Effects)	DISTANCE TO LEL (m) (Effects)	CLOUD (KG) F2 (Effects)	CLOUD (KG) D4 (Effects)
BMTSMALL	3.00E-03	7.07E-06	0.00E+00	8.00E-01	8.00E-01	2.04E-01	0.020711	<1	0.00E+00	0.00E+00	3.44E-01	0.022612	<1	0.00E+00	0.00E+00
BMTFLANGE	1.30E-02	1.33E-04	0.00E+00	4.00E+01	1.04E+02	3.82E+00	1.0735	<1	0.00E+00	0.00E+00	6.46E+00	1.3353	<1	0.00E+00	0.00E+00
BMTMAJOR	5.00E-02	1.96E-03	0.00E+00	4.00E+01	1.04E+02	5.64E+01	3.0456	18.6	1.00E+00	0.00E+00	9.54E+01	3.4001	18.6	1.10E+00	0.00E+00
BMTRUPTURE	2.00E-01	3.14E-02	0.00E+00	4.00E+01	1.04E+02	6.24E+02	4.0278	23.8	3.00E+00	0.00E+00	1.05E+03	4.15	23.8	3.20E+00	0.00E+00
PV6	3.00E-03	7.07E-06	0.00E+00	8.00E-01	8.00E-01	2.04E-01	0.020711	<1	0.00E+00	0.00E+00	3.44E-01	0.022612	<1	0.00E+00	0.00E+00
PV13	1.30E-02	1.33E-04	0.00E+00	4.00E+01	1.04E+02	3.82E+00	1.0735	<1	0.00E+00	0.00E+00	6.46E+00	1.3353	<1	0.00E+00	0.00E+00
PV25	5.00E-02	1.96E-03	0.00E+00	4.00E+01	1.04E+02	5.64E+01	3.0456	18.6	1.00E+00	0.00E+00	9.54E+01	3.4001	18.6	1.10E+00	0.00E+00
PV50	2.00E-01	3.14E-02	0.00E+00	4.00E+01	1.04E+02	6.24E+02	4.0278	23.8	3.00E+00	0.00E+00	1.05E+03	4.15	23.8	3.20E+00	0.00E+00
PVCAT	RUPTURE	RUPTURE	0.00E+00	4.00E+01	1.04E+02	INSTANT.	3.22	22	1.00E+02	0.00E+00	INSTANT.	3.22	22	1.00E+02	0.00E+00
PUMPLEAK	2.50E-03	4.91E-06	0.00E+00	4.00E+01	1.04E+02	6.61E+01	5.5899	22.6	3.16E+01	0.00E+00	7.16E+01	5.7422	23	3.21E+01	0.00E+00
PUMPCAT	2.00E-01	3.14E-02	0.00E+00	4.00E+01	1.04E+02	7.30E+02	8.6368	22	1.03E+02	0.00E+00	7.91E+02	8.68	24	1.05E+02	0.00E+00

KURNELL REFINERY	DISTANCE TO HEAT RADIATION (m) (Effects)		
EQUIPMENT	4.7kW/m2	12.5kW/m2	23kW/m2
REFSMALL	25	11	9
REFFLANGE	25	11	9
REFMAJOR	25	11	9
REFRUPTURE	25	11	9
REFSMALL DOWNSTREAM	18	8	6
REFFLANGE DOWNSTREAM	18	8	6
REFMAJOR DOWNSTREAM	18	8	6
REFRUPTURE DOWNSTREAM	18	8	6
PV6	25	11	9
PV13	25	11	9
PV25	25	11	9
PV50	25	11	9
PVCAT	25	11	9
PUMPLEAK	25	11	9
PUMPCAT	25	11	9

BANKSMEADOW TERMINAL	DISTANCE TO HEAT RADIATION (m) (Effects)		
EQUIPMENT	4.7kW/m2	12.5kW/m2	23kW/m2
BMTSMALL	18	8	6
BMTFLANGE	18	8	6
BMTMAJOR	18	8	6
BMTRUPTURE	18	8	6
PV6	18	8	6
PV13	18	8	6
PV25	18	8	6
PV50	18	8	6
PVCAT	18	8	6
PUMPLEAK	25	11	9
PUMPCAT	25	11	9

URS

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