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Orica Mining Services

Report for Kooragang Island
Uprate

PHA MOD1 Report

March 2012



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1. Introduction

Orica Mining Services commissioned GHD in 2008 to undertake the preliminary risk assessment (PHA) of the upgrade of the Kooragang Island (KI) facility for the purpose of planning approval from the NSW government. Since the Project Approval for the KI ammonium nitrate expansion was issued, Orica has advanced its engineering and design for the project, including the completion of its feasibility study. This process has included changes to the layout of project elements which has led Orica to submit an application to the Department of Planning and Infrastructure to modify the original project approval. The feasibility process has also led to the finalisation of technology vendors and capacities for individual plants. The modification is seen as likely to reduce or result in negligible change to the project risk impacts.

The purpose of this study (MOD 1) is to assess the impact of the changes on the project risk, check that the HIPAP4 criteria are met, and to suggest appropriate additional risk reduction measures if this is not the case.

The areas of variation to the original preliminary hazard assessment include the following:

- ▶ Orica has undertaken a number of layout optimisation studies to improve safety, hazards & risk, constructability as well as optimisation of project costs. This has led to some relocation of new plants and storages, and re-arrangement of new plant equipment within the Orica KI boundary. These include:
 - o Changes to the location of the new ammonium nitrate plant 3 (AN3) with the AN3 plant located closer to the new nitric acid plant (NAP4) to minimise ammonia piping and improve integration;
 - o Relocation of the ammonium nitrate (AN) bag store to the southern end of the site; and
 - o Relocation of the AN container stacks to the south-western end of the site.
- ▶ Orica has finalised its selection of technology vendor and capacity for the nitric acid plant & associated ammonium nitrate solution plant. This has included a selection of Nitric Acid plant capacity 20% larger than assessed in the original PHA as part of the environmental assessment. The solid ammonium nitrate (Nitropril ®) plant capacity remains unchanged. Orica intends to operate the new plants in association with the existing plants in such a way that production of nitric acid and ammonium nitrate will be retained within the original regulatory limits of the project approval. The key changes to the design include:
 - o Separating the AN wet (manufacturing) section from the AN dry (prilling) section and locating the wet section to the east of the nitric acid plant, where it is partially integrated into the nitric acid plant, resulting in a reduction in the length of liquid ammonia piping and in the number ammonia vaporisers;
 - o Reduced inventory in the ammonia vaporisers; and
 - o Replacement of the ammonia cooling system in the solid ammonium nitrate (Nitropril ®) plant with a non-ammonia refrigeration system.

In addition, Orica has progressed the design of the ammonia storage and supply system for the purposes of simplification and risk reduction. The key changes are as follows:

- ▶ No.1 ammonia storage bullet, located closest to the site boundary, will be decommissioned;



- ▶ No.2 bullet will be replaced with a new bullet and will become an off-line spare bullet that will only be used when maintenance is required on No.6 bullet;
- ▶ A new bullet (No.6) will be installed adjacent to No.2 bullet and will be the primary intermediate ammonia storage for the nitrates plants.
- ▶ No.5 bullet (Ammonia bottling bullet V115) will be retained but will be operated at a lower normal working inventory.
- ▶ The major pipeline from the ammonia plant and the ammonia refrigerated storage tank to the new bullet no.6 will be replaced with a high integrity stainless steel line.
- ▶ The new pipeline from bullet no.6 to the new nitric acid plant no.4 will also be a high integrity stainless steel line.
- ▶ All pressurised storages and liquid ammonia transfer lines will be fitted with modern protective and isolation systems.

The design concept for storage and transport of ammonia is to reduce the resultant risk profile associated with the potential release of toxic gases particularly associated with injury and irritation risk for the full KI site. Orica is also progressing other measures to reduce the risks associated with ammonia venting and emergency relief.

This report presents the main changes to the design since the completion of the original PHA and the updated risk profiles and references the original PHA report (Rev 8)¹.

The following appendices have been updated for the MOD 1 case and are presented in the relevant sections. All other appendices are included for completeness.

- ▶ Appendix II – Hazard Identification
- ▶ Appendix V – Consequences
- ▶ Appendix VI – Frequency Analysis

1.1 Scope of MOD 1

Orica have engaged GHD to update the original PHA risk model and the associated documentation to accurately reflect the changes to the design. The main purposes of this exercise are to determine the effects on the risk profile of the changes encompassed by MOD 1, to check if the risk profile has been significantly altered, to check this against the HIPAP4 criteria, and if required to recommend appropriate risk reduction measures.

The scope of the MOD 1 PHA includes the following:

- ▶ Update of the PHA model to reflect the current state of the existing operating plant and current event and failure frequency estimates.
- ▶ Conversion of the PHA model to DNV's most recent supported Phast Risk² software version v6.7³. The original risk modelling was undertaken using DNV's risk modelling software package SAFETI v6.42, but since then DNV has withdrawn licences and ceased support for this version.

¹ Orica Mining Services, Report for Kooragang Island Facility Upate, Preliminary Hazard Analysis, May 2009, GHD Document Number 158758.

² Phast Risk has replaced SAFETI as the name for DNV's software for onshore QRA.



- ▶ Comparison of results between the PHA models created in SAFETI v6.42 and the updated PHA model using Phast Risk v6.7.
- ▶ Revision of the updated PHA model to the MOD 1 model with the changes listed in Section 2 (mainly updates to inventories and location of new plant and equipment bag stores and container stacks) and generation of MOD 1 risk contours;
- ▶ Comparison of MOD 1 risk contours with the original risk contours in the PHA submitted to the DoP; and
- ▶ MOD 1 Report showing the key changes.

³ Full details of the changes between v6.42 and v6.7 are proprietary to DNV, but in general, the main changes which affect this PHA reflect improved understanding and modelling of gas dispersion. This mainly affects the results for toxic gas releases.



2. Description of MOD 1 Changes

This section presents the changes to the design and the location of the new plant & equipment.

2.1 Location Changes

The new layout of the facility is presented in Figure 2-1. The key changes are:

- ▶ Changes to the location of the new ammonium nitrate plant 3 (AN3) with the AN3 plant located closer to the new nitric acid plant (NAP4) to minimise ammonia piping and improve integration;
- ▶ Relocation of the ammonium nitrate (AN) bag store to the southern end of the site; and
- ▶ Relocation of the AN container stacks to the south-western end of the site.



2.2 Design Changes

A summary of the changes to the design is provided below. This has resulted in an update to the hazards identified as outlined in Appendix II.

Nitric Acid Plant & Ammonium Nitrate Plant

Orica has finalised its selection of technology vendor and capacity for the nitric acid plant & associated ammonium nitrate solution plant. This has included a selection of Nitric Acid plant capacity 20% larger than assessed in the original PHA as part of the environmental assessment. The solid ammonium nitrate (Nitropril ®) plant capacity remains unchanged. Orica intends to operate the new plants in association with the existing plants in such a way that the production of nitric acid and ammonium nitrate will be retained within the original Regulatory limits.

The key changes to the design include:

- ▶ Separating the AN wet (manufacturing) section from the AN dry (prilling) section and locating the wet section to the east of the nitric acid plant where it is partially integrated into the nitric acid plant resulting in a reduction in liquid ammonia piping and a reduction in the number of ammonia vaporisers. The integration also has energy efficiency benefits;
- ▶ A reduction in the inventory of the ammonia vaporisers on the nitric acid plant through design optimisation; and
- ▶ Replacement of the ammonia cooling system in the solid ammonium nitrate (Nitropril ®) plant with a non-ammonia refrigeration system.

Ammonia Storage & Supply

Orica has also progressed the design of the ammonia storage and supply system for the purposes of simplification and risk reduction. The key changes are as follows:

- ▶ A new 30T bullet (No.6) will be installed adjacent to No.2 bullet and will be the primary intermediate storage for the nitrates plants. Typical working capacity will be 15T, allowing the remaining 15T capacity for operational surge requirements;
- ▶ No.1 bullet, located closest to the site boundary, will be decommissioned;
- ▶ No.2 bullet will be replaced with a new bullet, with a capacity of 30T, and will become an off-line spare bullet that will be used for when maintenance is required on No.6 bullet;
- ▶ No.5 bullet (ammonia bottling bullet V115) will be retained but will be operated at a lower normal working inventory, nominally 10T with 15T allowed for surge requirements for the occasional road tanker filling operation. Orica is also currently investigating whether operation of ammonia bottling can be safely and reliably achieved without the need for the no.5 bullet.;
- ▶ Each of the operating bullets will be upgraded with modern safety systems, including local toxic gas detectors and shut-off valves on the discharge lines to mitigate toxic gas release;



- ▶ All major ammonia transfer pipelines will be fitted with ammonia detection and remote isolation systems to reduce to the time taken to respond to a potential ammonia leak from 30 minutes to no more than 5 minutes;
- ▶ The major pipeline from the ammonia plant and the ammonia refrigerated storage tank to the new bullet no.6 will be replaced with a high integrity stainless steel line which will be fitted with the above protective systems;
- ▶ The new pipeline from bullet no.6 to the new nitric acid plant no.4 will also be a high integrity stainless steel line fitted with the above protective systems.

The design concept for storage will result in a 50% reduction in normal working inventory of pressurised liquid ammonia in the bullets from a current 50 tonnes to a future 25 tonnes as shown in the table below.

Table 2-1: Summary of Ammonia storage inventories

Bullet	Current Total Capacity - max (tonnes)	Current Normal Working Inventory (tonnes)	Future Total Capacity – max (tonnes)	Future Normal Working Inventory (tonnes)
No. 1	45	25	decommissioned	decommissioned
No. 2	15	10	Spare*	Spare*
Triella (No. 5)	60(30)**	20	60(30)**	10***
New No.6			30	15****
Total	120 (90)	50	90 (60)	25

* Replacement bullet to be used as an off-line spare for maintenance. The bullet will be of the same capacity as bullet no.6

**high level trip at 30T

***surge capacity of 15T for occasional road tanker filling

**** surge capacity of 15T to allow for Nitrates plant trips

The design concept for storage and transport of ammonia is to effect significant risk reduction associated with the potential release of toxic gases particularly associated with injury and irritation risk. Orica is also currently undertaking additional work to investigate directing of all ammonia vents and relief systems to a scrubber and flare system in addition to existing and proposed ammonia scrubbing systems

Other

Orica has also advanced risk reduction recommendations in the PHA and the risk reduction program condition in Development Consent (condition 18) which includes:

- ▶ Progression of a ChlorGuard system on the chlorine disinfection system for the ammonia cooling towers into its budgeted sustenance program, and hence inclusion in the base case; and
- ▶ Layout changes which result in the explosion property damage propagation contour not impinging into neighbouring land-uses.

2.3 Frequency Analysis

The failure and event frequencies used in the original PHA were reviewed and amended for the updated PHA to reflect updated event and failure estimates. Incorporation of MOD 1 changes required further revisions to failure frequencies for additional or different equipment e.g. pipeline lengths and for other equipment changes such as inventory changes. Relocation of new plant and storages has led to



changes in the mitigation factors (risk reduction measures) used for AN storages and consequently revised AN storage explosion frequencies. The failure scenarios and frequencies for all ammonia vaporisers have been amended to be consistent with the Dutch Purple Book method.

The frequencies used for the MOD 1 model are summarised in Appendix VI.

2.4 Model Update from SAFETI v6.42 to Phast Risk v6.7

Since its release in August 2004, SAFETI v6.42 has undergone numerous updates and changes to reflect latest research, data and modelling approaches. The most current DNV supported software version is Phast Risk v6.7, which was released in July 2011. Full details of the changes between v6.42 and v6.7 are proprietary to DNV, but in general, the main changes which have affected this PHA (taken from the DNV release notes accompanying each new software version release) are summarised below.

Improvements to Modelling of Liquid Droplets

The mathematical model for the Unified Dispersion Model (UDM) has been improved to involve two sets of differential equations for the droplets and the plume.

Change in material probit coefficients

During development and modelling work on v6.51 a new material property system was introduced. DNV took the opportunity to quality assure values in the materials database. The values are obtained from published data in the following preferential order:

- ▶ Dutch Purple Book
- ▶ UK HSE data
- ▶ DNV and historical PHAST and SAFETI data

As a result of this work the toxic materials covered in this QRA have changed fatality probit constants. This may have an impact on toxic fatality results.

A combination of the changes mentioned above has contributed to a change in risk contours. In particular, changes relating to the dispersion modelling and toxic averaging / exposure calculations have led to significant changes in results, especially those involving low concentrations and low wind speed / stable conditions (e.g. 1.5F). As the proportion of the F stability occurrence for the KI site is large (approximately 42%), this has a significant effect on the irritation contours (refer to Section 3).

3. Risk Results

The results presented in the following sections include:

- 3.1** The New Plant & Equipment (not including existing site equipment) against all of the risk criteria of NSW DoP presented in Hazardous Industry Planning Advisory Paper (HIPAP) No 4; and
- 3.2** The individual fatality risk (IFR) and societal risk in the form of FN Curve for the whole site (aggregate results).

Three separate risk results are presented for each criterion showing the results for:

- The PHA model created using SAFETI v6.42 i.e. the results presented in the original 2008 PHA;
- The Updated PHA model created using Phast Risk v6.7 (conversion from SAFETI v6.42); and
- The MOD 1 model using Phast Risk v6.7.

The updated consequence results for thermal radiation, toxic lethality and ammonium nitrate explosion overpressure distances are presented in Appendix V.

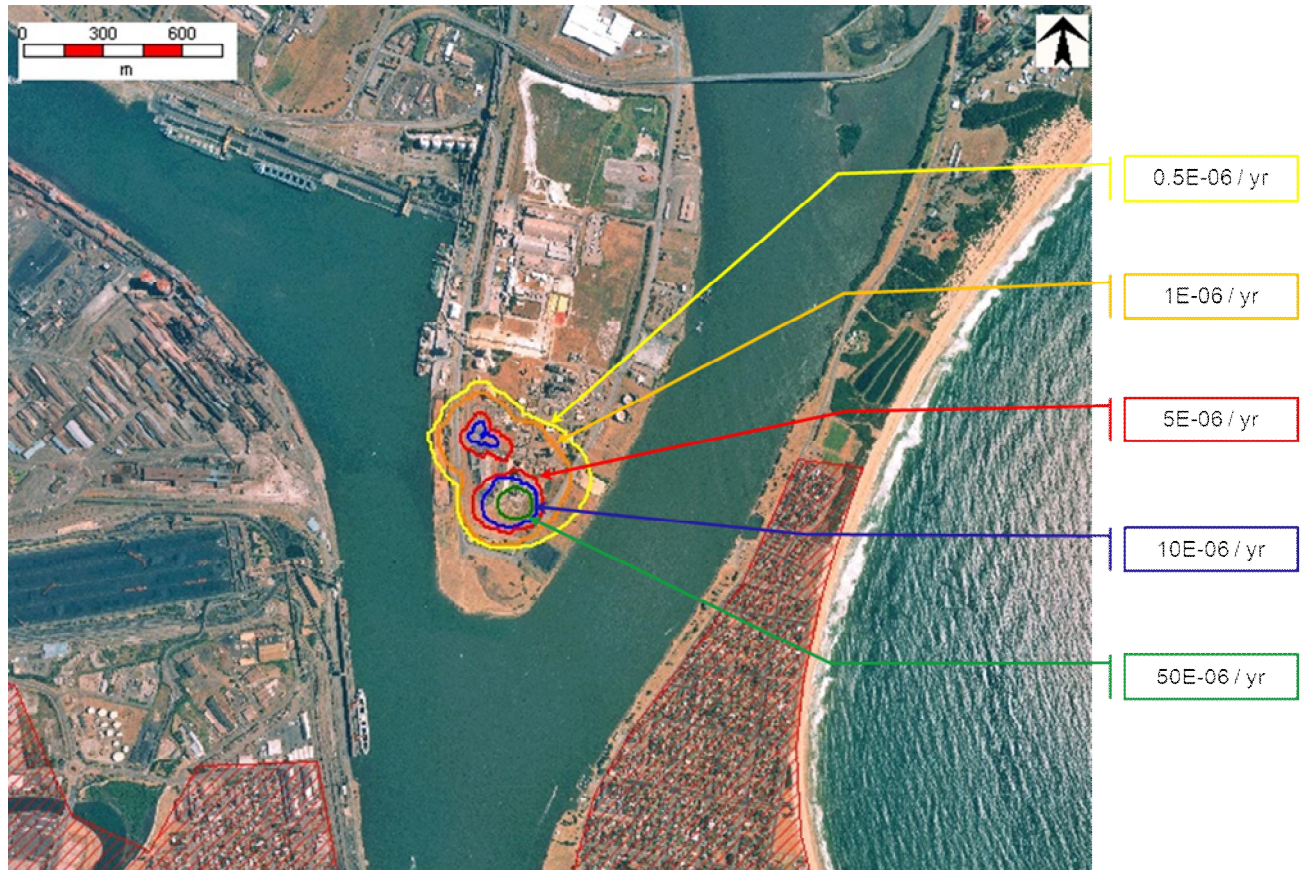
3.1 New Plant & Equipment

3.1.1 IFR contours – New Plant & Equipment

Figure 3-1: New Plant & Equipment IFR – PHA (v6.42)

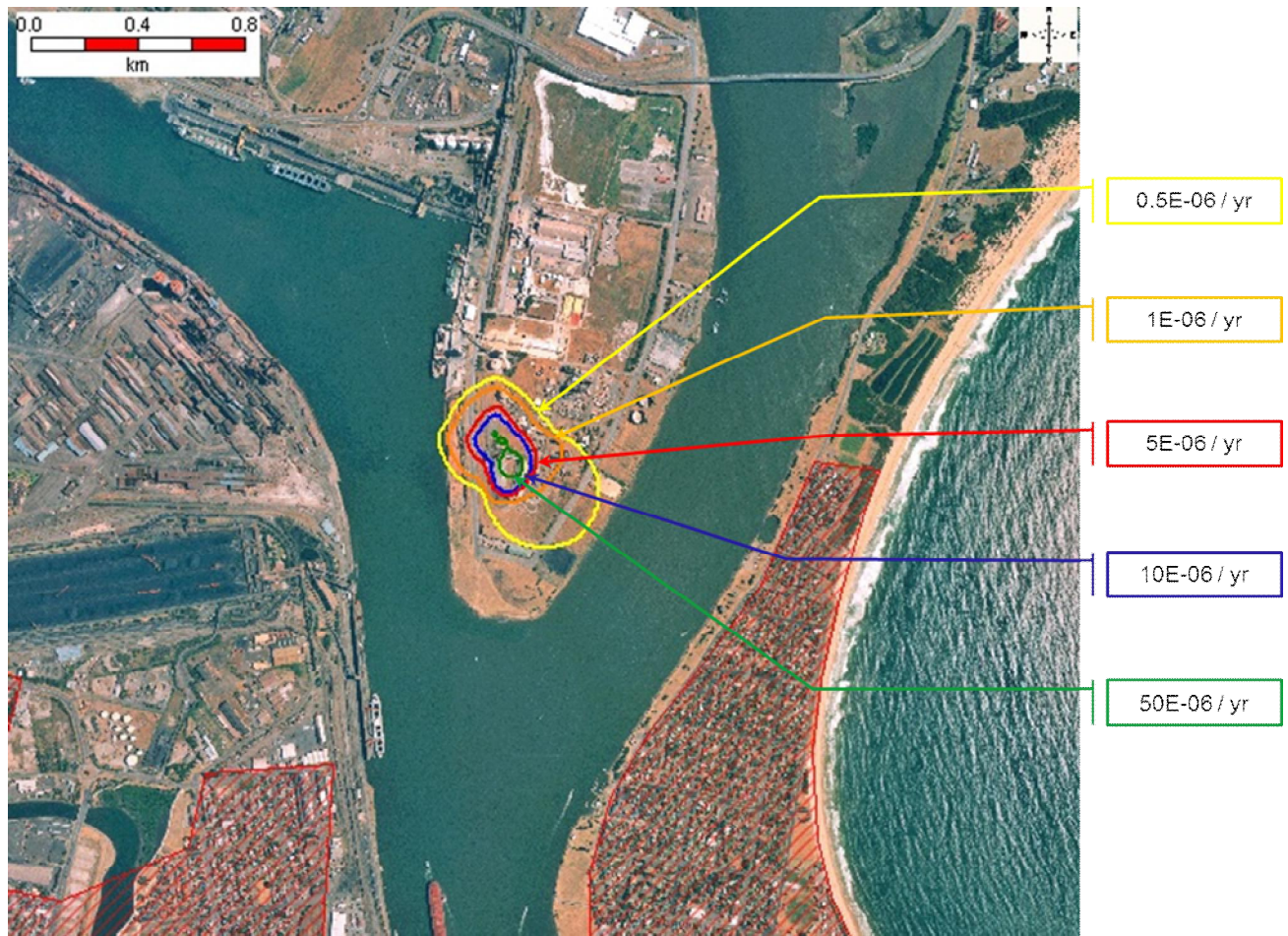


Figure 3-2: New Plant & Equipment IFR – Updated PHA (v6.7)



For the new plant and equipment, there is a noticeable increase in the extent of the outer individual fatality risk contours using Phast Risk v6.7 compared to the contours using SAFETI v6.42, especially towards the eastern side. This is mainly due to revisions in the software modelling of toxic gas release and dispersion. Despite this each contour remains well within its criterion.

Figure 3-3: New Plant & Equipment IFR - MOD 1 (v6.7)



Comparing the risk contours for the MOD 1 case to the Updated PHA v6.7 (Figure 3-2), the outer contours have generally contracted with some expansion of the 0.5×10^{-6} pa to the south east. The inner contours have combined and moved slightly north due to the relocation of the new plant and equipment.

These minor changes in IFR contours with MOD 1 have not affected the 2008 PHA outcomes of full compliance with all the HIPAP 4 individual fatality risk criteria.

In particular the 50×10^{-6} pa contour for MOD 1 remains within the site boundary and the 1×10^{-6} pa contour does not extend to areas zoned for residential development.

In conclusion, the New Plant & Equipment IFR for MOD 1 is in compliance with all the HIPAP 4 risk criteria for individual fatality risk.

3.1.2 Societal Risk

Due to the limited possible incident outcomes involved with the New Plant & Equipment and associated low frequencies, no results were obtained for the FN curve, i.e. the societal risk for the New Plant & Equipment falls below the criteria.

3.1.3 Toxic Injury Risk – New Plant and Equipment

Figure 3-4: Toxic Injury Risk New Plant & Equipment – PHA (v6.42)

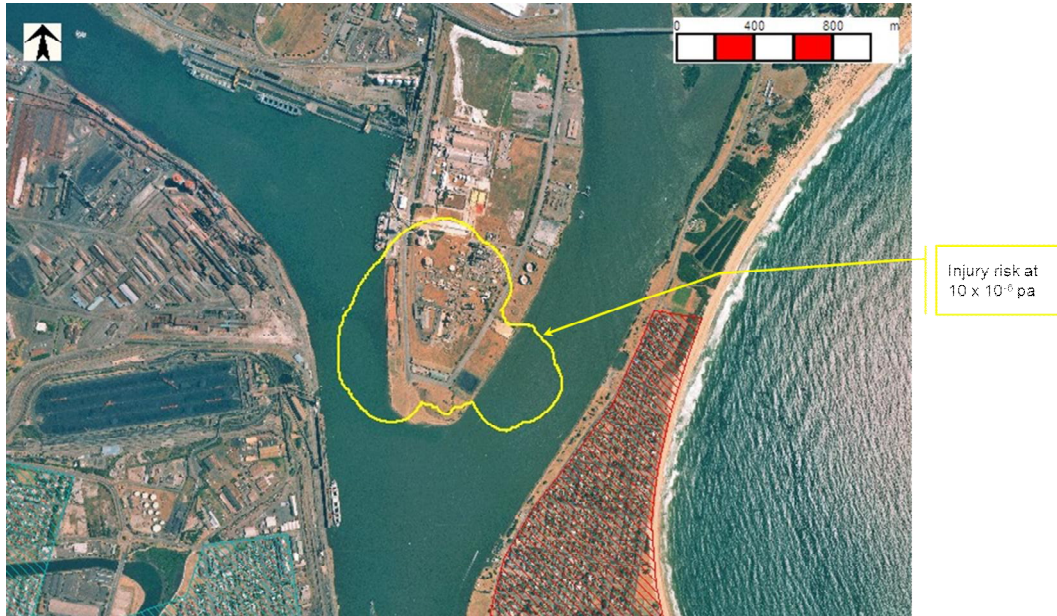


Figure 3-5: Toxic Injury Risk New Plant & Equipment – Updated PHA (v6.7)



The toxic injury risk contour has changed from SAFETI v6.42 to Phast Risk v6.7. This is mainly due to changes in the software modelling parameters and revision of the frequencies used in the original PHA study.

Figure 3-6: Toxic Injury Risk New Plant & Equipment – MOD 1 (v6.7)



The toxic injury risk contour for the MOD 1 case is smaller than that for the Updated PHA mainly due to the following changes.

- ▮ Risk reduction measures adopted for the new ammonia transfer pipeline from Bullet # 6 to the new Nitric Acid Plant 4 and Ammonium Nitrate Plant 3;
- ▮ AN3 solid vaporiser replaced with a refrigeration system; and
- ▮ Inventories reduced for NAP4 vaporisers.

The toxic injury contour does not extend to areas zoned for residential development and so the modified proposal continues to comply with this HIPAP 4 requirement.

3.1.4 Toxic Irritation Risk – New Plant and Equipment

Figure 3-7: Toxic Irritation Risk New Plant & Equipment PHA (v6.42)

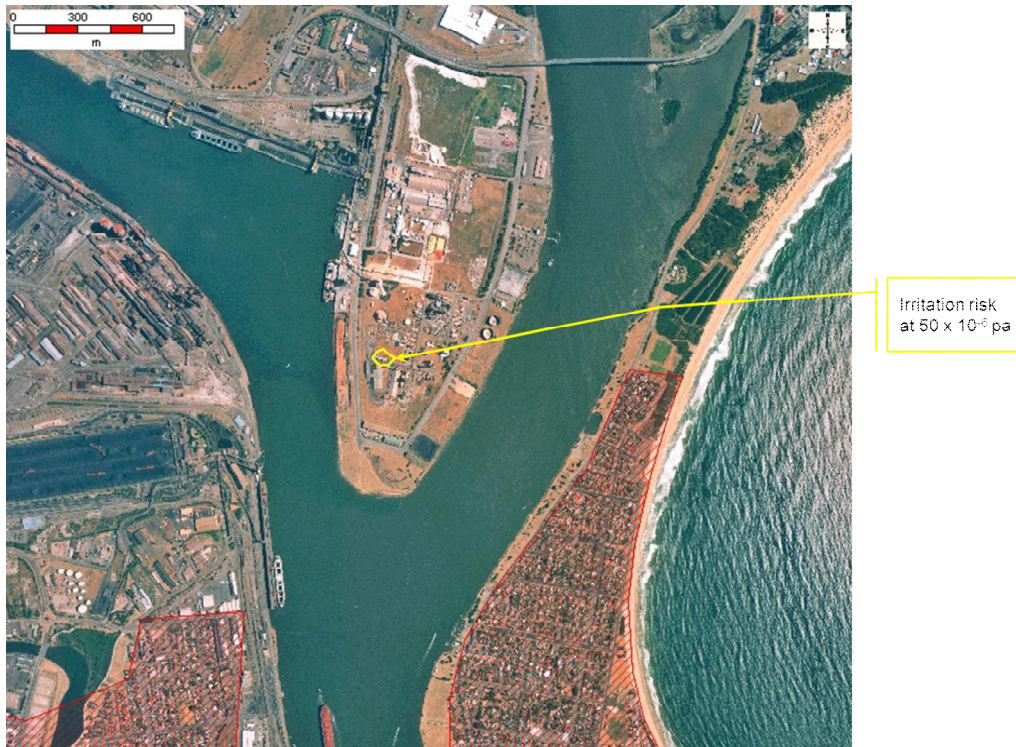


Figure 3-8: Toxic Irritation Risk New Plant & Equipment – Updated PHA (v6.7)



The toxic irritation risk contour produced by Phast Risk v6.7 is larger than that created in SAFETI v6.42 due to the numerous software modelling changes as discussed in section 2.4 above.

Figure 3-9: Toxic Irritation Risk New Plant & Equipment – MOD 1 (v6.7)



Similarly to the toxic injury contour but to a greater extent, the 50×10^{-6} pa toxic irritation contour is significantly reduced for the MOD 1 case due to the following:

- Risk reduction measures adopted for the new ammonia transfer pipeline from Bullet # 6 to the new Nitric Acid Plant 4 and Ammonium Nitrate Plant 3;
- AN3 solid vaporiser replaced with a refrigeration system; and
- Inventories reduced for NAP4 vaporisers.

The toxic irritation contour does not extend to areas zoned for residential development and so the modified proposal continues to comply with this HIPAP 4 requirement.

3.1.5 7 kPa Overpressure Explosion Injury – New Plant & Equipment

Figure 3-10: 7 kPa Overpressure Explosion Injury New Plant & Equipment – PHA



Figure 3-11: 7 kPa Overpressure Explosion Injury New Plant & Equipment - MOD 1



The size of the 7 kPa explosion overpressure for injury contour is slightly smaller for the MOD 1 case compared to the PHA case. The location has moved towards the west due to the relocation of AN3 plant. The MOD 1 explosion injury risk for New Plant & Equipment complies with the HIPAP4 criterion as it does not extend to any residential areas.

3.1.6 14 kPa Overpressure Explosion Property Damage and Propagation Risk

Figure 3-12: 14 kPa Overpressure Explosion Property Damage and Propagation Risk – PHA



Figure 3-13: 14 kPa Overpressure Explosion Property Damage and Propagation Risk - MOD 1



The 14 kPa overpressure risk contour for explosion property damage and propagation risk has moved towards the north-west end of the site due to the relocation of the AN3 plant. The risk contour has contracted to within the site boundary and the New Plant & Equipment now fully complies with the 14 kPa explosion overpressure property damage and propagation risk criterion. The contour now satisfies the requirements of condition 18 in the project approval.

3.2 Site Risk Results

3.2.1 IFR - Site

Figure 3-14: IFR Site – PHA (v6.42)

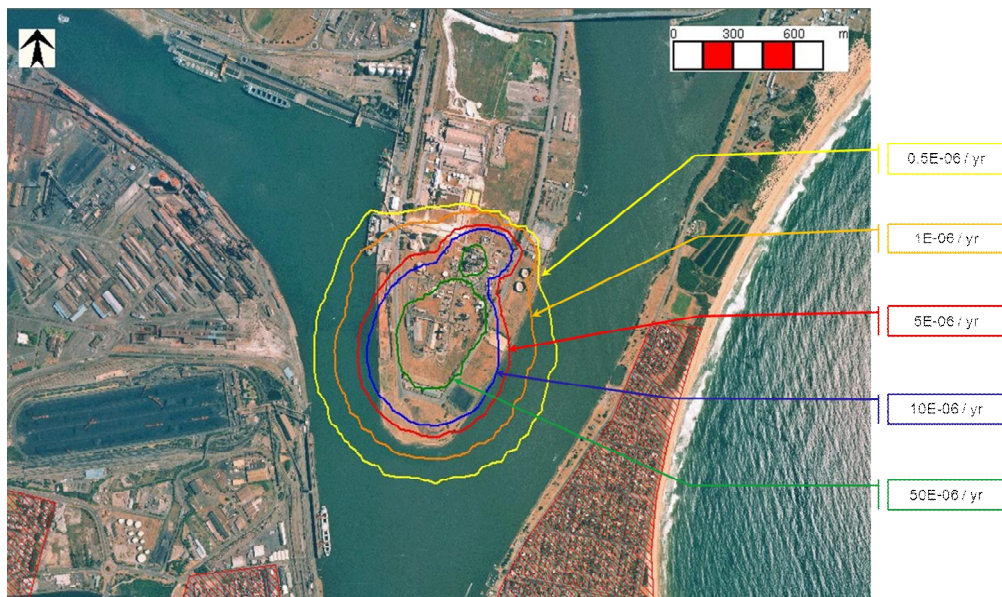
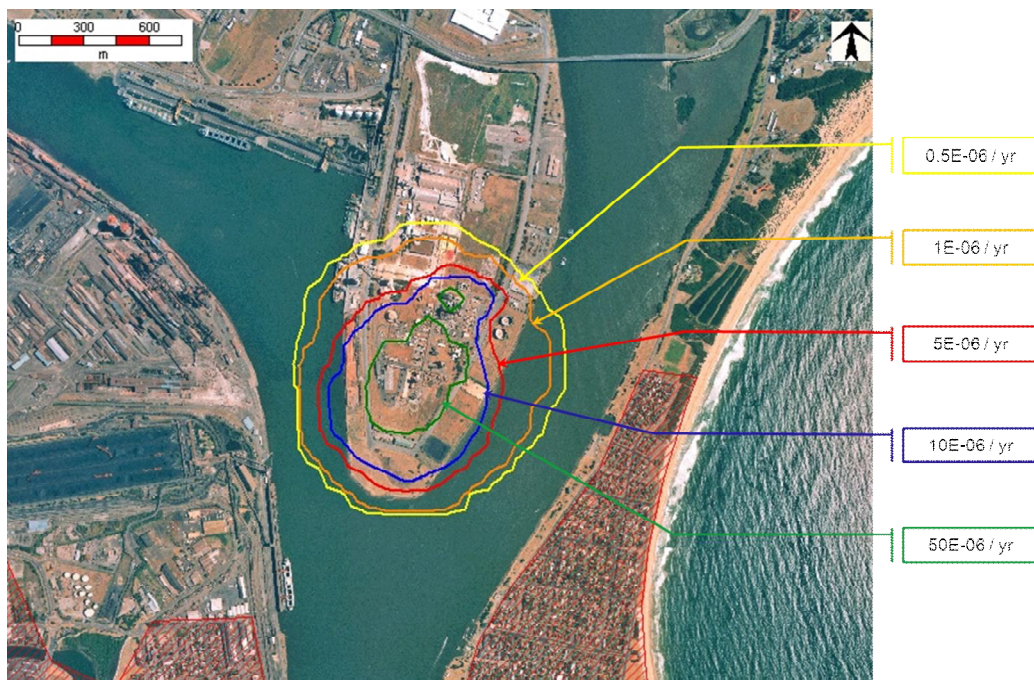
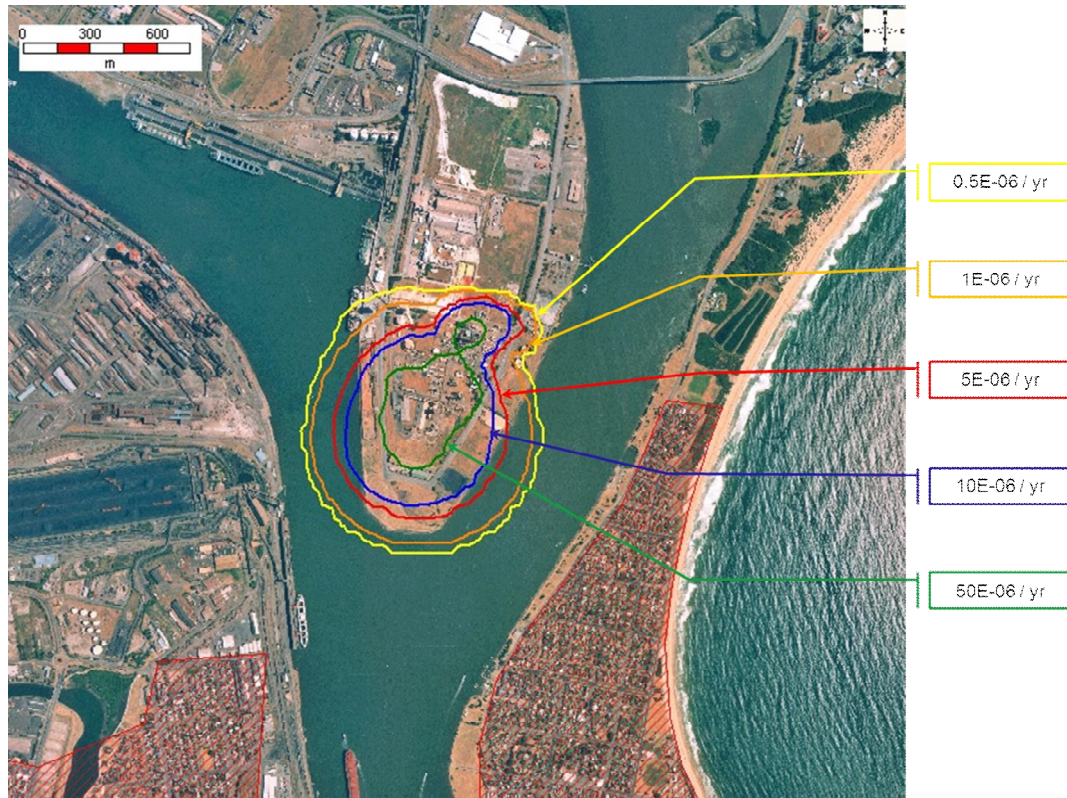


Figure 3-15: Site IFR – Updated PHA (v6.7)



In comparison to the v6.42 PHA model, the v6.7 Updated PHA Site IFR contours are similar in shape except for the outer contours which have expanded on the northern and north eastern side. These changes are attributed mainly to the software modelling changes.

Figure 3-16: Site IFR - MOD 1 (v6.7)



Comparing the MOD 1 IFR contours to the v6.7 Updated PHA contours, there is a noticeable change to the outer contours which have contracted on the north eastern side and on the northern side. This is mainly due to the relocation of the AN3 plant and equipment and the relocation of the container stacks to the western boundary.

Boundary risks have reduced significantly on the eastern side and somewhat on the western side when comparing MOD 1 to the update PHA (v6.7) and have marginally changed to the north and south when comparing to the original PHA. The maximum actual risk at each boundary is given in Table 3-1.



Table 3-1: Maximum Actual Risk at boundary

Boundary	PHA EA Original (x 10-6/yr) v6.42	PHA EA Original (x 10-6/yr) v6.7	MOD 1 (x 10-6/yr) v6.7	Major Contributors
North	45	53	56	Events in the Ammonia Plant involving ammonia and gas releases
East	78	85	43	Explosion events involving Ammonium Nitrate
South	92	78	81	Explosion events involving Ammonium Nitrate
West	61	66	58	Explosion events involving Ammonium Nitrate

3.2.2 Site Societal Risk

Figure 3-17: Site FN Curve – PHA (v6.42)

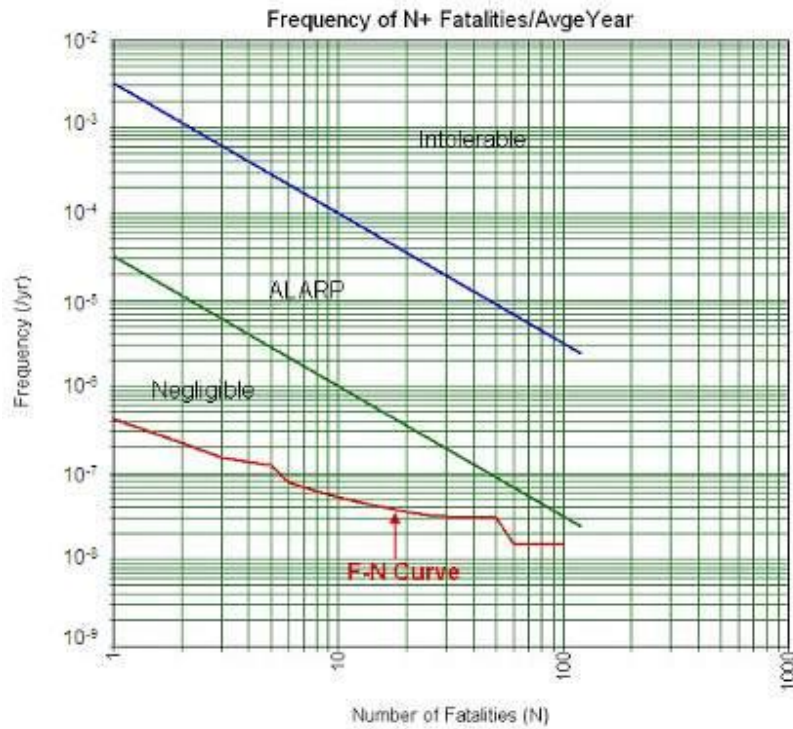


Figure 3-18: Site FN Curve – Updated PHA (v6.7)

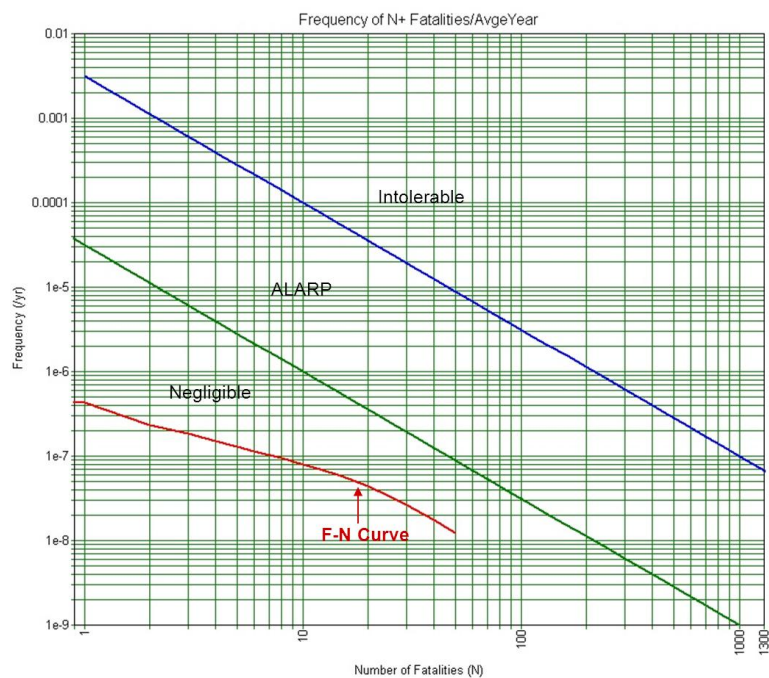
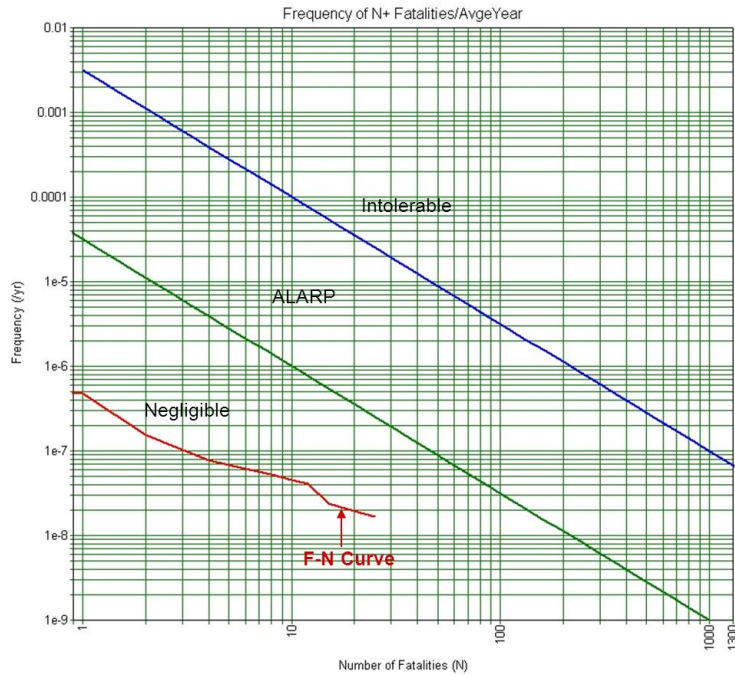


Figure 3-19: Site FN Curve – MOD 1



Compared to the PHA v6.42 and the updated PHA v6.7, the societal risk for the MOD 1 case is lower. Therefore, the MOD 1 Site complies with the indicative HIPAP 4 criteria for societal risk.

The risks associated with the Project for the site case remain consistent with the PHA and continue to comply with HIPAP 4 risk criteria for “intensification of hazardous activities in an existing complex”, i.e. the 1×10^{-6} contour does not encroach into residential areas and the cumulative risks as shown in the Site FN Curve remain acceptable.



4. Conclusions

Since the preliminary hazard assessment (PHA) of the upgrade of the Kooragang Island facility, Orica has advanced its engineering and design for the project, which has included changes in plant layout and also finalisation of technology vendors and capacities for individual plants. These activities have led to a number of variations to the project in relation to the inputs into the preliminary hazard assessment. Orica has also progressed the design of ammonia storage and supply system to effect additional risk reduction.

The QRA model developed in the original PHA (2009) was updated to incorporate the changes to the design and layout of the New Plant & Equipment for the Kooragang Island expansion. The purpose of this was to check the impact of the design changes on the risk profiles established during the PHA of the New Plant & Equipment and the site, and produce a MOD 1 Report documenting the changes.

As part of the scope, the original PHA model (developed using DNV's SAFETI v6.42) was converted into the latest version of DNV's Phast Risk i.e. v6.7. This is due to the fact that DNV no longer supports SAFETI v6.42. Updates to the SAFETI / Phast Risk software have resulted in noticeably larger toxic irritation risk contours for the model created using Phast Risk v6.7. This is due to numerous changes made to the software relating to the toxic modelling and property data in order to reflect latest research.

The new plant and equipment risk contours for the MOD 1 case only differed slightly from the contours created for the Updated PHA case using Phast Risk v6.7. They reflect the changes incorporating the new design and layout, in particular, the revised inventories in the new plant and equipment and the relocation of the proposed Ammonium Nitrate Plant 3, AN bag storage and AN container storage. The risk contour for explosion property damage and propagation risk no longer impinges on neighbouring properties and now fully satisfies the HIPAP4 criteria and the requirements of condition 18 in the project approval.

In conclusion, the risk contours of the New Plant & Equipment incorporating the design and layout changes comply with all of the risk criteria given in HIPAP No 4. The overall site individual fatality risk and societal risk contours including the MOD1 changes also comply with the relevant criteria in HIPAP 4.



Appendix I

Background Data

(Same as 2009 PHA report Rev 8)



APPENDIX I

A I	Background Data	i
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A I.3	Hazardous Material Identification	ii
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A I Background Data

A I.1 Existing Site Layout

The Kooragang Island existing site layout is shown in Figure AI-1 below.

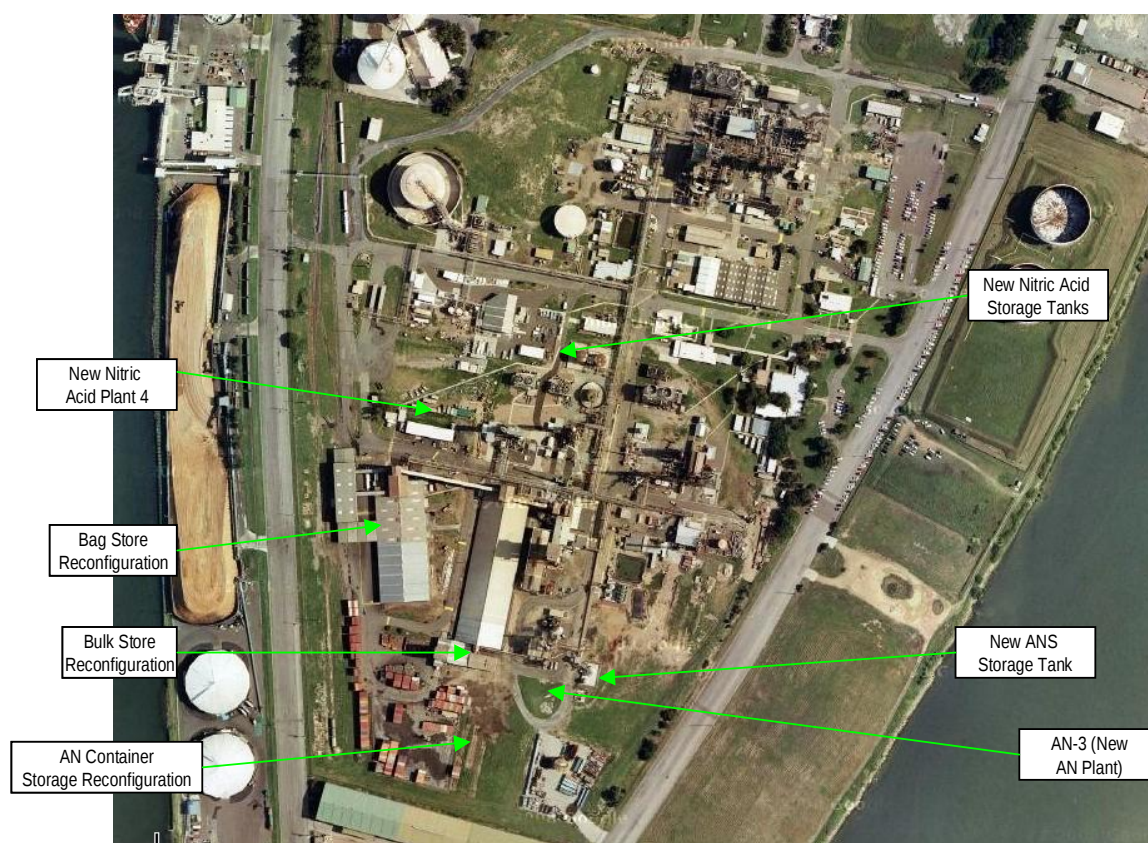
Figure AI-1: Existing Site Layout



A I.2 Expanded Facility Site Layout

Figure AI-2 shows the proposed plants and modifications as part of the expansion project.

Figure AI-2: Expanded Facility Site Layout



A I.3 Hazardous Material Identification

Hazardous materials identified as being either produced or consumed in the Nitric Acid and Ammonium Nitrate Plants are presented in Table AI-1: Hazardous Materials on Site

Table AI-1: Hazardous Materials on Site

Hazardous Material	Phase	Class of DG	Produced/Use
--------------------	-------	-------------	--------------



Hazardous Material	Phase	Class of DG	Produced/Use
Anhydrous ammonia	Pressurised Liquid and Gas	Toxic	Manufactured on site and used in both plants for the production of acid and ammonium nitrate.
Natural Gas	Gas	Flammable	Feed stock for ammonia.
Ammonium nitrate	Solution and Prill	Oxidising Agent	Produced in Ammonium Nitrate Plant as end product
Nitrogen oxides (monoxide, dioxide, tetroxide, nitrous)	Intermediate Gas	Toxic	Produced in Nitric Acid Plant as part of the production process
Hydrogen	Gas	Flammable	Used as a feedstock for ammonia production.
Nitric acid	Liquid	Highly Corrosive	Produced in Nitric Acid Plant and consumed in Ammonium Nitrate Plant to produce ammonium nitrate.
Alkyl amine (coating agent)	Liquid		Consumed in Ammonium Nitrate Plant for prill coating.
Steam	Liquid and Gas		Produced and consumed by all plants.
Nitrogen	Pressurised Liquid and Gas	Compressed Gas	Consumed by all plants as purge.
Chlorine	Pressurised Liquid and Gas	Toxic	Used in cooling water treatment in the Ammonia Plant

Of the materials mentioned above, only anhydrous ammonia, ammonium nitrate, the nitrogen oxides, chlorine, natural gas and hydrogen were considered capable of having an offsite safety risk impact. These materials are discussed further in the following sections.

A I I.3.1 Ammonia

Ammonia is a toxic gas, which, while flammable, is acknowledged to be extremely difficult to ignite. Considering this, the flammable effects of ammonia were screened from the study with its toxicity being the principal issue considered in this assessment.

Although ammonia is lighter than air, a pressurised or cold release of ammonia may form a dense cloud (due to temperature) after expansion to atmospheric pressure or form a fog resulting from the interaction of ammonia molecules with ambient water vapour.

Ammonia can be readily detected in the atmosphere by smell at concentrations below 20 ppm. It is a powerful irritant to eyes and mucous membranes of the respiratory tract. At low concentrations in air, ammonia vapour irritates the eyes, nose and throat. Inhalation of high concentrations produces a sensation of suffocation, quickly causes burning of respiratory tracts and may result in death.



Table AI-2: Toxicity of Ammonia

Concentration (ppm)	Exposure Effects	Exposure Duration
10-20	Odour detectable by most people.	Prolonged repeated exposure produces no injury.
25	No adverse effects for average workers.	Maximum allowable concentration for 8-hour working day (NIOSH TWA)
35	No adverse effects for average workers.	Exposure should not exceed 15min and there should be no more than 4 periods above 15min, with at least 1 hour between episodes.
300	Nose and throat irritation. Eye irritation with tearing.	NIOSH IDLH, based on statement by AIHA (1971) that 300 – 500ppm for 30 to 60min have been reported as the maximum short exposure tolerance (Henderson and Haggard, 1943).
2000-3000	Convulsive coughing, severe eye irritation.	No permissible exposure.
5000-7000	Respiratory spasm, rapid asphyxia.	No permissible exposure. Rapidly fatal.

“The odour of ammonia can be detected by humans at concentrations >5 ppm; the odour is highly penetrating at 50 ppm (10 min). Human volunteers exposed to ammonia showed slight irritation at 30 ppm (10 min); moderate irritation to the eyes, nose, throat, and chest at 50 ppm (10 min to 2 h); moderate to highly intense irritation at 80 ppm (30 min to 2 hr); highly intense irritation at 110 ppm (30 min to 2 h); unbearable irritation at 140 ppm (30 min to 2 hr), and excessive lachrymation and irritation at 500 ppm. Reflex glottis closure, a protective response to inhaling irritant vapours, occurred at 570 ppm for 21- to 30-year-old subjects, 1,000 ppm for 60-year-old subjects, and 1,790 ppm for 86- to 90-year-old subjects.” (Taken from Ref 16.)

A I I.3.2 Natural Gas

Natural gas is a non-toxic, colourless gas at ambient conditions. While it is odourless of itself, an odorant is normally added before it is transported to end-users. Natural gas is lighter than air. It is a highly flammable gas, with flammability ranging from 5 to 15% volume in air. If it does not immediately ignite upon release, it can form an explosive mixture with air. If it is burned in limited supply of air, carbon monoxide may be produced. While it is regarded as being stable, it is not compatible with strong oxidising agents.

A I I.3.3 Hydrogen

Hydrogen is a highly flammable gas. Its density is much below that of ambient air, so that in a release it rises rapidly. Its flammability range in air extends from 4% to 75% and because of this it will rapidly form an explosive mixture with air. It burns with a pale blue, almost invisible flame, making hydrogen fires more dangerous.



A I I.3.4 Ammonium Nitrate

Ammonium Nitrate (AN) is a strong oxidising agent that will support combustion of organics and metal powders as it produces oxygen as one of its decomposition products. It is not flammable or combustible in itself. When subjected to heat, ammonium nitrate undergoes a series of complex decomposition reactions that produce low levels of nitrogen oxides (namely nitrous oxide) at atmospheric pressure. If the reaction is confined and the gases are maintained at the temperature at which they were formed, further gas phase reactions can occur giving off nitric oxide and nitrogen dioxide gases. Nitrogen dioxide is the most toxic product that may form under these conditions and is discussed in Section A I I.3.5.

The plume of combustion products resulting from an ammonium nitrate fire have been shown to be buoyant due to the high temperatures involved, and disperse to non-hazardous concentrations before returning to grade.

The sensitivity of ammonium nitrate to detonation is largely dependent on three variables; temperature, confinement and contamination. Without any of these three being present, ammonium nitrate would require a strong initiation charge (ie high explosive) to detonate at all.

Variables in the calculation of overpressure consequences from an ammonium nitrate explosion include the proportion of the sensitised material that actually detonates in the explosion (efficiency), and an equivalency of the sensitised material to that of TNT (equivalency). This technique is used because of the significant quantity of information on the consequences of explosions involving TNT.

A I I.3.5 Nitrogen Oxides

Nitrogen oxides (nitrogen monoxide, dioxide, tetroxide, di-nitrogen oxide (nitrous oxide), etc) are produced in the Nitric Acid Plant in the production of acid and by the high-temperature decomposition reaction of ammonium nitrate.

Nitrogen Dioxide

Nitrogen dioxide (NO₂) is a respiratory irritant, however its main danger lies in the delay before its full effects upon the lungs occur. Symptoms include feelings of weakness and coldness, headache, nausea, dizziness, abdominal pain and cyanosis. In severe cases, convulsions and death by asphyxia may follow. Table AI-3 overviews the toxicity of nitrogen dioxide.

Table AI-3: Toxicity of Nitrogen Dioxide

Concentration (ppm)	Exposure Effects
1	NIOSH REL Short Term Exposure Limit (STEL)
3	Recommended Time Weighted Average (TWA) for continued workplace exposure with no adverse effect for an 8hr day, 5 days per week.
5	OSHA PEL (Permissible Exposure Limit)
20	NIOSH IDLH



The exposure limits for nitrogen dioxide as per Acute Exposure guidelines Limit (AEGL) are given below.

Table AI-4: Exposure Limits for Nitrogen Dioxide

	Exposure Duration				
	10 min	30 min	1 hr	4 hr	8 hr
AEGL-1 (Non disabling)	0.5 ppm	0.5 ppm	0.5 ppm	0.5 ppm	0.5 ppm
AEGL-2 (Disabling)	20 ppm	15 ppm	12 ppm	8.2 ppm	6.7 ppm
AEGL-3 (Lethal)	34 ppm	25 ppm	20 ppm	14 ppm	11 ppm

Nitrous Oxide

Nitrous oxide (N_2O) is a non-toxic anaesthetic. However, it may result in a fatality due to an asphyxiation effect by displacing oxygen. Populations exposed to nitrous oxide are likely to feel light-headed and anaesthetised before asphyxiation occurs. Concentrations of approximately 150,000 ppm of gas are required to reduce the oxygen concentration in air to a level, which is considered as the starting point for asphyxiation (18%). Nitrous oxide was therefore screened from the analysis, as concentrations leading to asphyxia will not be reached beyond the site boundary.

Nitric Oxide (NO)

Nitric Oxide is a colourless gas but in high concentrations it changes to brown in colour. It has a sharp sweet odour. Nitric oxide changes to nitrogen dioxide in air. Nitrogen dioxide, NO_2 , is 5 times more toxic than nitric oxide (NO).

NIOSH Recommended Exposure Limit (REL) for NO is 25 ppm (30 mg/m³) averaged over a work shift of 10 hours per day, 40 hours per week.

A I I.3.6 Chlorine

Chlorine (Cl_2) is a greenish-yellow gas or clear amber liquid (under pressure) with a pungent suffocating odour. It is shipped in 920 kg drums as a compressed liquefied gas under a pressure of approximately 650 kPa at 21.1 deg C. The exposure limits to chlorine based on AEGL and NIOSH recommendations are given in Table AI-5. The Immediately Dangerous to Life and Health (IDLH) value is 30 ppm and is 'based on the statement by ILO (1971) that exposure to 30 ppm will cause intense coughing, fits, and exposure to 40 to 60 ppm for 30 to 60 minutes or more may cause serious damage'.



Table AI-5: Toxicity Effects of Chlorine

Classification	Exposure Duration				
	10 min	30 min	1 hr	4 hr	8 hr
AEGL-1 (Non disabling)	0.5 ppm	0.5 ppm	0.5 ppm	0.5 ppm	0.5 ppm
AEGL-2 (Disabling)	2.8 ppm	2.8 ppm	2.0 ppm	1.0 ppm	0.71 ppm
AEGL-3 (Lethal)	50 ppm	28 ppm	20 ppm	10 ppm	7.1 ppm
NIOSH Recommended Exposure Limit (REL)	0.5 ppm (max 15 minute ceiling)				
OSHA Permissible Exposure Limit (PEL)	1.0 ppm				
IDLH – Immediately Dangerous to Life or Health	10 ppm				

A I I.3.7 Miscellaneous Chemicals

The remainder of materials mentioned above are considered to only have localised effects.

- Nitric acid and Steam will cause severe burns with bodily contact however will not travel sufficient distances upon release to affect an offsite populations.
- The coating agent (alkyl amine) may cause localised pool fires that likewise were considered unable to affect an offsite population. Toxic smoke plumes will not affect offsite populations due to the separation distance of the storage / production facilities from the site boundary.
- Nitrogen poses both an asphyxiation and frostbite hazard however will rapidly disperse to safe concentrations, before reaching the site boundary.

A I I.3.8 Storage and Quantity

Table AI-6 lists the full range of dangerous goods stored on Orica's KI site, along with their storage method, quantity and throughput.



Table AI-6: List of Dangerous Goods Stored Onsite

DG Storage Description	Proper Shipping Name	UN Number	Class	PG	Product / Common Name	Current			New		
						Max storage capacity	Typical Quantity	Annual Throughput (per annum)	Max storage capacity	Typical Quantity	Annual Throughput
AN Bag Store	Ammonium Nitrate	1942	5.1	III	Ammonium Nitrate	2500 t	2 000 t	100 000 t	No change	No change	150 000 t
AN Bulk Store	Ammonium Nitrate	1942	5.1	III	Ammonium Nitrate	15 500 t	9 200 t	220 000 t	No change	9 200 t	400 000 t
Ammonium Nitrate Container Storage	Ammonium Nitrate	1942	5.1	III	Ammonium Nitrate	4 800 t	3 250 t	95 000 t	No Change	No Change	150 000 t
CPAN Store	Ammonium Nitrate	1942	5.1	III	Ammonium Nitrate	300 t	200 t	8 000 t	600 t	200 t	No Change
AN Solution Tanks	Ammonium Nitrate Liquid	2426	5.1	II	88.5% Ammonium Nitrate Solution	375 t	350 t	110 000 t	1 375 t	1200 t	200 000 t
60% AN Solution Tanks	Dilute Ammonium Nitrate Liquid	3098	5.1	II	60% Ammonium Nitrate Solution	-	-	-	250 t	200 t	50 000 t



DG Storage Description	Proper Shipping Name	UN Number	Class	PG	Product / Common Name	Current			New		
						Max storage capacity	Typical Quantity	Annual Throughput (per annum)	Max storage capacity	Typical Quantity	Annual Throughput
Chlorine Cylinder – NH3 Cooling Tower	Chlorine	1017	2.3	-	Chlorine	4 t	3 t	16 t	No change	No change	No change
Refrigerated Ammonia Storage Tank (V101)	Anhydrous Ammonia	1005	2.3	-	Anhydrous Ammonia	12 000 t	8 000 t	100 000 t	No change	No change	50 000 kt
Pressurised Ammonia Bullets	Anhydrous Ammonia	1005	2.3	-	Anhydrous Ammonia	183 t	100 t	200 kt	100 t	50 t	350 kt
Cylinder Store	Acetylene Dissolved	1001	2.1	-	Acetylene Dissolved	270 kL	150 kL	288 m ³	No change	No change	No change
Nitric Acid Tanks	Nitric Acid	2031	8	I	Nitric Acid	2930 t	1663 t	345 000 t	5022 t	2682 t	605 000 t
Nitrogen Tank	Nitrogen Refrigerated Liquid	1977	2.2	-	Nitrogen Refrigerated Liquid	40 kL	30 kL	690 000 m ³	No change	No change	No Change



DG Storage Description	Proper Shipping Name	UN Number	Class	PG	Product / Common Name	Current			New		
						Max storage capacity	Typical Quantity	Annual Throughput (per annum)	Max storage capacity	Typical Quantity	Annual Throughput
MDEA Solution Tank	Amine Liquid Corrosive N.O.S – 40%.	2735	8	II	M.D.E.A.	400 kL	0 kL	40 kL	No Change	No Change	No Change
MDEA Solution Tank	Amine Liquid Corrosive N.O.S – 100%	2735	8	II	M.D.E.A.	40 kL	30 kL	40 kL	No Change	No Change	No Change
Aqua Ammonia Tanks	Ammonia Solution	2672	8	III	Ammonia Solution	220 kL	125 kL	904 t	No Change	No Change	No Change
Caustic Soda Tank	Sodium Hydroxide Solution	1824	8	II	Sodium Hydroxide Solution	30 t	25 t	460 t	No Change	No Change	No Change
Sulfuric Acid Tank	Sulfuric Acid <51%	1830	8	II	Sulfuric Acid <51%	30 t	25 t	300 t	No Change	No Change	No Change
R407C ISOTainer	Pentafluoroethane,1,1,1,1-Trifluoroethane & 1,1,1,2-Tetrafluoroethane azeotropic mixture	3340	2.2	-	Refrigerant Gas R407C	16 t	15 t	36 t	No Change	No Change	No Change



DG Storage Description	Proper Shipping Name	UN Number	Class	PG	Product / Common Name	Current			New		
						Max storage capacity	Typical Quantity	Annual Throughput (per annum)	Max storage capacity	Typical Quantity	Annual Throughput
R134A ISOTainer	1,1,2-Tetrafluoroethane	3159	2.2	-	Refrigerant Gas R134A	16 t	15 t	194 t	No Change	No Change	No Change



A I.4 Weather Data

Weather is classed according to wind speed and weather stability class. Table AI-7 below shows the different weather stability classes.

Table AI-7: Weather Stability Classes

Class	Type	Description
A	Very Unstable	Daytime – sunny, light winds (strong insolation)
B	Unstable	Daytime – moderately sunny, light to moderate winds
C	Unstable / Neutral	Daytime – moderate winds, overcast or windy and sunny
D	Neutral	Daytime – windy, overcast or Night-time - windy
E	Stable	Night-time - moderate winds with little cloud or light winds with more clouds
F	Very Stable	Night-time - light wind, little cloud (strong temperature inversion)

To ensure consistency, GHD have used meteorological data provided by Orica, which was used by ENSR for stack plume modelling. The wind/weather data set obtained covers the period of 2006 and was divided into four classes based on wind speed and weather class as follows:

- ▶ Wind 1 m/s, weather stability class C;
- ▶ Wind 3 m/s, weather stability class D;
- ▶ Wind 7 m/s, weather stability class D; and
- ▶ Wind 1.5 m/s, weather stability class F.

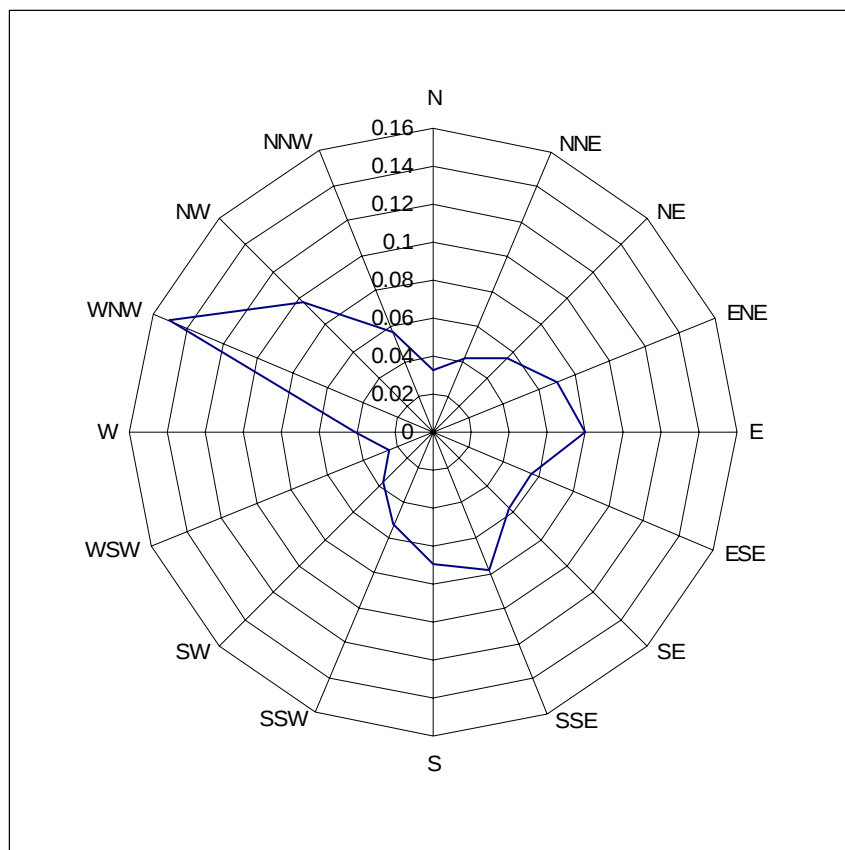
The combined wind rose for all wind speeds and weather classes is shown in Figure AI-3 below.

The annual average ambient weather conditions identified for the site are as follows;

- ▶ 18°C
- ▶ 70% humidity.



Figure AI-3: Annual Average Wind Rose



A I.5 Population Data

The population data for the residential areas used in the model was obtained from the ABS 2006 census. The population of the surrounding industrial sites is not included in the model.

The cut off for the population count was based on the distance to 1% fatality (4 km from KI).

Table AI-8: Population Data Used in QRA

Area	Population
Stockton	4200
Suburban (Tighes Hill, Islington, Carrington, Mayfield, Wickham, Maryville, Newcastle)	12418



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Appendix II

Hazard Identification

This Appendix has been withheld from the publicly exhibited Environment Assessment as it is an "exempt document" for the purposes of the Government Information (Public Access) Act 2009 (NSW).



Appendix III

Consequence Models

(Same as 2009 PHA report Rev 8)



APPENDIX III

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A III Consequence Modelling

One part of the risk assessment process involves generating consequences for the release events identified. The steps involved in determining consequences are:

- ▶ Determine release conditions based upon materials involved, process conditions and available inventory etc;
- ▶ Based on release conditions, determine the types of events which will occur (eg jet fire, toxic cloud, evaporating pool or explosion etc);
- ▶ Calculate the extent of the consequences; and
- ▶ Establish the impact of the consequence (e.g. proportion of people killed when exposed to a toxic dose)

The consequences are calculated using empirically derived models, which can then be used to determine which release cases generate offsite effects and should be included in the risk model. The level at which fatal consequences are considered to occur will directly influence the risks.

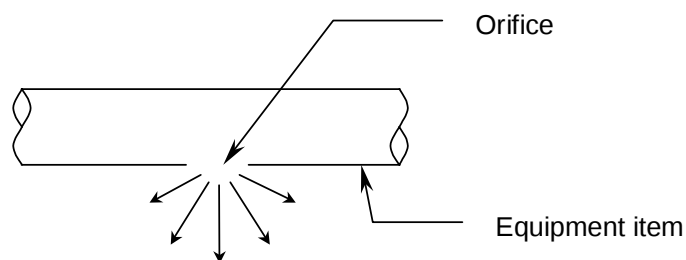
This Appendix discusses basic concepts and theory behind the various consequence models used in the analysis. The models discussed are:

- ▶ Discharge Modelling
- ▶ Dispersion
- ▶ Flammable Effects - Jet Fire
- ▶ Toxic Effects
- ▶ Ammonium Nitrate Explosions

A III.1 Discharge Modelling

If there is a hole in a pipeline, vessel, flange or other piece of process equipment, the fluid inside will be released through the opening, provided the process pressure or static head is higher than ambient pressure. The properties of the fluid upon exiting the hole play a large role in determining consequences, eg, vapour or liquid, velocity of release etc. Figure AIII-1 illustrates an example scenario.

Figure AIII-1: Typical Discharge



The discharge can be considered to occur in two stages, the first is expansion from initial storage conditions to orifice conditions, the second from orifice conditions to ambient conditions.



The conditions at the orifice are calculated by assuming isentropic expansion, i.e., entropy before release equals entropy at orifice. This allows enthalpy and specific volume at the orifice to be calculated.

The equations for mass flow rate ($\dot{m}$) and discharge velocity (u_0) are then given by:

$$\dot{m} = C_d A_o \rho_o \sqrt{-2(H_0 - H_i)}$$

AND

$$u_0 = C_d \sqrt{-2(H_0 - H_i)}$$

Where

- C_d = Discharge coefficients
- A_o = Area of the orifice
- ρ_o = density of the material in the orifice
- H_o = Enthalpy at the orifice
- H_i = Enthalpy at initial storage conditions

The discharge parameters passed forward to the dispersion model are as follows:

- ▶ Release height (m) and orientation;
- ▶ Thermodynamic data: release temperature (single phase) or liquid mass fraction (two-phase), initial drop size;
- ▶ Other data:
 - for instantaneous release: mass of released pollutant (kg), expansion energy (J)
 - for continuous release: release angle (degrees), rate of release (kg/s), release velocity (m/s), release duration (s).

A III.2 Dispersion

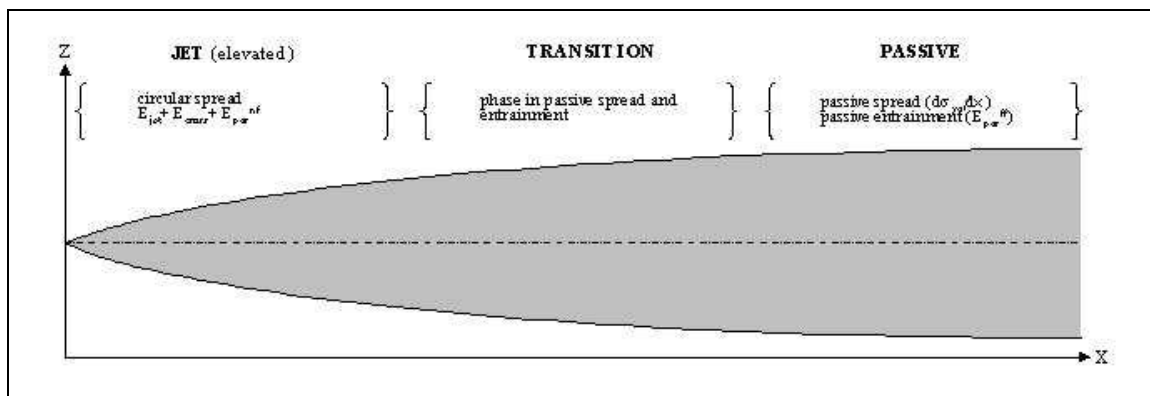
When a leak occurs, the material will be released into the atmosphere. Upon being released, it will start to disperse and dilute into the surrounding atmosphere. The limiting (lowest) concentration of interest is related to flammable and toxic limits for flammable and toxic substances respectively. The model used to determine extent of release is described below, along with some of the key input parameters.

PHAST is a consequence-modelling package that utilises the Unified Dispersion Model (Witlox *et al*, 1999). This models the dispersion following a ground level or elevated two-phase unpressurised or pressurised release. It allows for continuous, instantaneous, constant finite duration and general time varying releases. It includes a unified model for jet, heavy and passive two phase dispersion including possible droplet rain out, pool spreading and re-evaporation.

A III.2.1 Jet Dispersion

For a continuous, pressurised release, the material is released as a jet, i.e., high momentum release. The jet eventually loses momentum and disperses as a passive cloud. Figure AIII-2 below shows a typical release and the various phases involved.

Figure AIII-2: Jet Dispersion



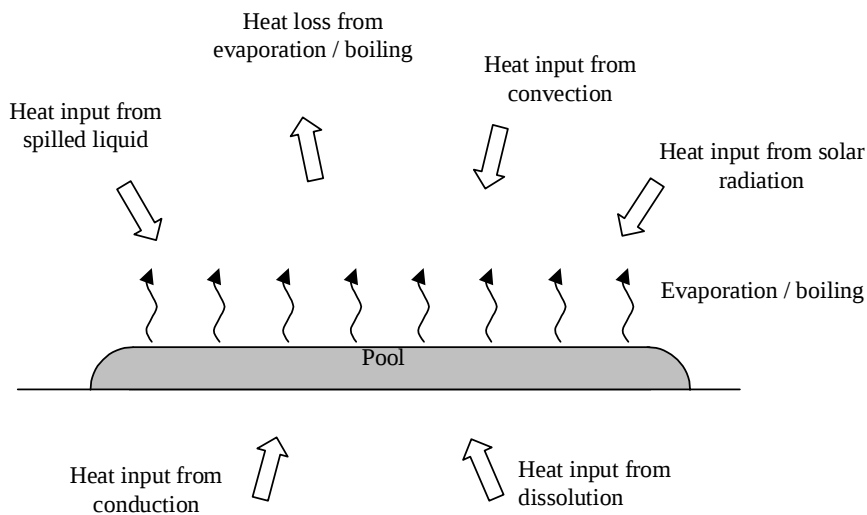
The cloud is diluted by air entrainment until it eventually reaches the lower limit of concern. During the jet phase, the mixing is turbulent and much air is entrained. In the passive phase, less air is potentially entrained, and it occurs via a different mechanism to the turbulent jet phase. The calculation of the plume therefore depends on many factors, the key parameters being:

- Material released, specifically molecular weight;
- Discharge conditions including phase(s) of release, velocity, etc.;
- Atmospheric conditions (a cloud will generally travel further in more stable conditions with lower wind speeds).

A III.2.2 Dispersion from Pool Evaporation

If a rupture occurs from a refrigerated tank or vessel such as the refrigerated ammonia tank V101, the refrigerated liquid product will leak out and form a pool on the ground. (This may also occur to some extent with pressurised liquids stored at ambient conditions such as liquid chlorine, due to 'self-refrigeration' ie evaporative cooling, where much of the liquid will vaporise immediately on vessel rupture but some will not vaporise, or will condense and rain out, and form a pool.) This pool will evaporate and the resulting vapour cloud disperses as a low momentum cloud. Due to the low momentum, the cloud is not turbulent, which is a significant factor in air entrainment and dilution of the cloud. Figure AIII-3 below shows a typical release and some of the inputs into the calculation.

Figure AIII-3: Pool Evaporation Heat Balance



The rate of the evaporation depends on numerous factors, the most important ones being:

- ▶ Surface it is released onto (eg. its thermal properties and temperature);
- ▶ Atmospheric conditions (a cloud will generally travel further in more stable conditions with lower wind speeds).
- ▶ Boiling point of the liquid;
- ▶ Pool size.

The concentration of interest is normally related to the flammable or toxic limits set for the hazardous material.

A III.3 Flammable Effects

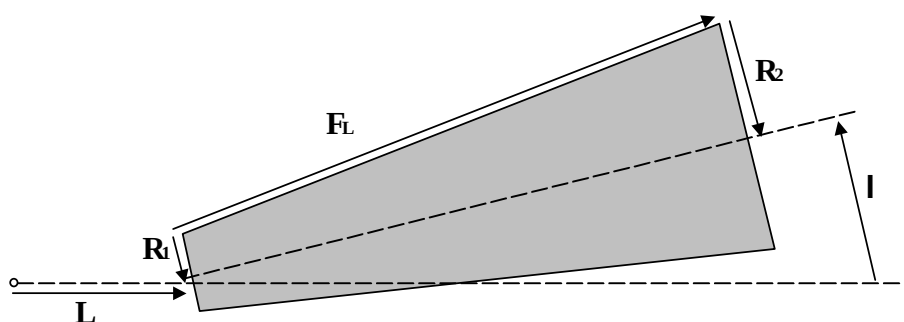
If the release is of a flammable material, it is possible for the release to be ignited. The resulting type of fire (eg. jet, pool, explosion etc) depends on the physical properties of the release and whether the ignition is immediate or delayed. For Orica's Kooragang Island facility, only jet fire is of interest for flammable effects due to the nature of the materials that can be released.

A III.3.1 Jet Fire

Jet fires are a result of high momentum releases. If a flammable release is ignited instantaneously, a jet fire will result. The flame will have a degree of 'lift off' as the flammable mixture has to dilute to be within the flammable limits. This section briefly discusses the model used for jet fires as well as key parameters in the calculation.

The jet fire calculation utilises the Chamberlain model (Chamberlain 1987). In this model, jet fires are modelled as a conical flame, with the ignited portion lift off, inclination and shape being determined by the material being released, the pressure at which it is being released and the hole size that it is being released through. These release parameters are the main inputs to the jet fire radiation calculations. Figure AIII-4 below shows a graphical representation of the jet fire model.

Figure AIII-4: Truncated Cone Jet Fire Model



Where;

L = Lift off

I = Flame Inclination

R_1 = Flame Base Radius

R_2 = Flame End Radius

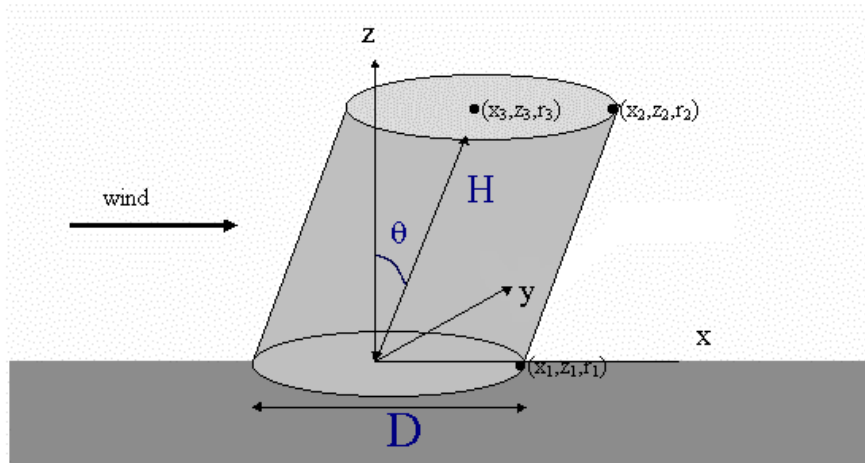
F_L = Flame Length

The jet fire calculations model radiation from the entire surface of the ignited portion of the jet. This includes radiation from the cone forming the body of the flame, as well as from the ends of the cone. The amount of radiation that a nearby receiver is exposed to is determined by its distance from the flame surface, as well as by the orientation of the flame relative to the receiver. The key parameters in the calculation of the radiation exposure of a receiver are therefore the flame lift off, the flame inclination, and the dimensions of the ignited portion of the jet (i.e. flame length and end radii).

A III.4 Pool Fire

Pool fire flames are modelled as cylinders sheared in the direction of the wind, with diameter D , height H and tilt angle q (measured from the vertical). The flame is described by three circles (c1, c2, c3) arranged along the centreline of the flame, each defined by the downwind co-ordinate x and elevation z of the centre of the circle, and by the radius r . These flame-circle co-ordinates are the main input to the radiation calculations.

Figure AIII-5: “Sheared Cylinder” Pool Fire Model



With these three circles, the radiation calculations will model radiation from two surfaces: from the side of the flame between c1 and c2, and from the top of the flame between c2 and c3. This approach ensures that the bottom of the pool fire is not treated as a radiating surface.

The flame length H , flame diameter D and tilt angle θ are used to calculate three co-ordinates of the flame, as follows:

$$\begin{array}{lll} x_1 = 0.0 & x_2 = H \sin \theta & x_3 = H \sin \theta \\ z_1 = d_{elev} & z_2 = H \cos \theta + d_{elev} & z_3 = H \cos \theta + d_{elev} \\ r_1 = D/2 & r_2 = D/2 & r_3 = 0.0 \\ \phi_1 = 0.0 & \phi_2 = 0.0 & \phi_3 = 0.0 \end{array}$$

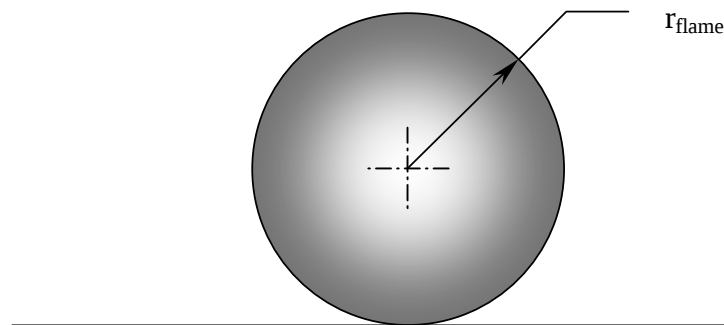
ϕ is the inclination of the circle with respect to the horizontal. For pool fires, this is set to zero for all three circles, but for jet flames each circle may have a different, non-zero inclination.

A III.5 BLEVE

A BLEVE is a 'Boiling Liquid Expanding Vapour Explosion' and refers to the release of energy when a vessel of liquefied gas erupts due to flame impingement. If there is direct flame impingement beneath the liquid line on the vessel, the evaporating liquid will provide cooling to the vessel walls. If designed correctly, the vessel pressure relief ensures that the pressure inside the vessel does not rise above design limits. If the flame impingement is on the vapour space, the pressure will also increase but there is inadequate cooling of the vessel wall. The metal temperature will rise to an extent where the mechanical strength is reduced. A point will be reached where the mechanical integrity of the vessel is insufficient for the pressure inside the vessel and the vessel erupts in a BLEVE. The BLEVE itself is the explosion resulting from rapid evaporation of the liquefied gas as it is released to atmospheric pressure. This section describes the equations used to determine BLEVE properties and key input parameters.

BLEVEs are modelled as spheres as shown below, with the shape described by ten circles. The method of using circles is also used for pool and jet fires. These circles are equally spaced along the flame diameter. Each circle is defined by the elevation z of the centre of the circle and the radius r . The centre of the fireball is located immediately above the point of release, at a height equal to the radius of the fireball.

Figure AIII-6: BLEVE Model



The radius of the BLEVE is calculated from:

$$r_{\text{flame}} = 2.9M_{\text{BLEVE}}^{\frac{1}{3}}$$

Where M_{BLEVE} is the flammable mass involved in the BLEVE. This is a function of the total mass released and the vapour fraction.

The duration of the BLEVE is important as it gives the time for which personnel are exposed to the effects of the fireball. It is a function of the BLEVE mass, and is given by the equations below:

$$t_{\text{flame}} = \begin{cases} 0.45M_{\text{BLEVE}}^{\frac{1}{3}}, & M_{\text{BLEVE}} < 37000\text{kg} \\ 2.59M_{\text{BLEVE}}^{\frac{1}{6}}, & M_{\text{BLEVE}} \geq 37000\text{kg} \end{cases}$$

The amount of radiation that a person receives is dependent not only on the duration of exposure but also on their distance from the fireball and the heat emitted by the fireball. The emissive power of the flame surface is a function of M_{BLEVE} , heat of combustion of the material and fire ball size and duration.

A III.6 Overpressure

The overpressure from an explosion can lead to much damage due to the pressure wave which results from the explosion. Generally with an explosion, the pressure wave causes more damage than the fireball. This is because the size of the pressure wave is larger than the fireball.

The TNT equivalence model is used to calculate explosion overpressure. This compares the heat of combustion of the material to the value for TNT, and thus calculates an equivalent mass of TNT. This mass is reduced by a factor for the explosion efficiency.



The explosion overpressure is then calculated according to the relationship developed by Kingery & Bulmash:

$$\log_{10} P = a(\log_{10} z)^2 + b \log_{10} z + c$$

Using the efficiency and equivalence factors, a mass of ammonium nitrate is equated to a mass of TNT. The distances to defined overpressures of interest are calculated using the 'TNT overpressure vs. scaled distance' relationship.

$$Z \text{ is a scaled distance and is calculated according to } z = \frac{R'}{m_{TNT}^{1/3}}$$

Where m_{TNT} is the mass equivalence of TNT and R' is the explosion radius.

In calculating the overpressure distance for ammonium nitrate the equation is represented as:

$$R' = m_{TNT}^{1/3} \times 10^{(2.061 - 1.092 \log_{10}(P) + 0.158(\log_{10}(P))^2)}$$

A III.7 Toxic Impact

The toxic effects of an on-site toxic release are evaluated using a probit equation in SAFETI. The probit uses dispersion data from the consequence modelling to determine the probability of fatality for a person at a given distance from the release, over the entire duration of the release.

The probit function, generally used for calculating fatality consequences from toxic releases is a measure of time dependent probability of fatality from exposure to toxic chemicals. For toxicity it is a function of concentration of exposure and time exposed to this concentration. The general form of the function is:

$$Pr = k_1 + k_2 \ln[C^n t]$$

Where Pr = Probit value

C = Concentration of interest

t = time exposed to concentration, C

k_1 , k_2 , n = constants specific to each material

It is converted to a probability of fatality via the function:

$$P(\text{death}) = \frac{1}{2} \left[1 + \operatorname{erf} \left(\frac{Pr - 5}{\sqrt{2}} \right) \right]$$

The Probit functions used are shown in Table AIII-1 below.

Table AIII-1: Toxic Probits

Material	Probit Function Used	Source
Ammonia	$-9.82 + 0.71 \ln[C^2 \times t]$	DCMR 19853, C3399
Nitrogen Dioxide	$-13.79 + 1.4 \ln[C^2 \times t]$	Harris DSM78
Chlorine	$-10.1 + 1.11 \ln[C1.65 \times t]$	Van Heemst



A III.8 Ammonium Nitrate Explosion

The following sections detail the scenarios that can result in the detonation of ammonium nitrate, the modelling of the resultant overpressure and fatalities and finally the risk that this poses on the facility and offsite.

Since completion of the 1992 study, there has been increased understanding of the risks of ammonium nitrate (AN) explosions. In particular, it is now recognised that it is possible for solid AN explosions to occur in storage as a result of intense and prolonged fires, or following substantial contamination with certain sensitising materials. It has also been found that solid AN may detonate if exposed to sufficiently high energy initiation, such as from a high energy missile or projectile which could be produced in an adjacent plant detonation.

Highly concentrated AN solutions may explode if sufficiently contaminated and acidic, when heated for prolonged periods to abnormally high temperatures.

As a result additional hazardous scenarios have been included in the PHA covering such events.

A III.8.1 Detonability of Ammonium Nitrate

Ammonium nitrate, as prepared by Orica, is classed as an oxidiser and has the following characteristics:

- ▶ It cannot burn without a combustible material present;
- ▶ It melts at 169°C;
- ▶ It starts to decompose after melting, releasing fumes of NO_x, HNO₃, NH₃ and H₂O;
- ▶ At roughly 290°C decomposition reactions of both exothermic and endothermic types generate an equilibrium keeping the temperature constant at this temperature, noting that this is dependant upon the decomposition gases being able to vent.

The sensitivity of ammonium nitrate to detonation is largely dependant on three variables; temperature, confinement and contamination. Without any of these three being present, ammonium nitrate requires a strong initiation charge (an example being high explosives) to detonate.

Higher temperature makes ammonium nitrate more sensitive to detonation as detailed below:

- ▶ Higher temperature causes decomposition. The ammonia, which is evolved, causes the pH of the remaining ammonium nitrate to drop, leading to greater detonation sensitivity.
- ▶ High temperature decomposition can lead to bubbles in the molten ammonium nitrate, which reduces the density of the liquid and hence increases sensitivity to detonation.

Confinement makes ammonium nitrate more sensitive to detonation as detailed below:

- ▶ Confinement of molten ammonium nitrate increases the sensitivity to detonation by restraining the decomposition gases.
- ▶ For ammonium nitrate, typically 80 atmospheres are required for detonation.

Contamination makes ammonium nitrate more sensitive to detonation as detailed below:



- ▶ As a pure compound, ammonium nitrate is less sensitive to detonation than if it is contaminated. At 1% contamination with hydrocarbons (eg. oils / diesel, etc.), it is at its most sensitive.
- ▶ Other impurities, such as some metals, acids (or low pH from decomposition) and salts, have a strong catalytic effect on the decomposition of ammonium nitrate and hence increase its sensitivity to detonation.

Interactions between heat, confinement and contamination combine together to increase the detonation sensitivity of ammonium nitrate, often resulting in an impact greater than their individual effects.

A III.8.2 Factors Influencing Ammonium Nitrate Explosions

Without any of the three variables previously discussed being present, ammonium nitrate requires a strong initiation charge to detonate. This scenario represents a malicious activity (such as terrorism) which is not assessed numerically as part of a Quantitative Risk Assessment (QRA). The threat of malicious activity is best assessed and mitigated through security assessments and control measures.

There is little value in attempting to quantify the risk of malicious activities due to the uncertainty involved in estimating the frequency of persons being sufficiently disgruntled with an organisation (or the connections to an organisation a disgruntled person may perceive to exist) to actively damage facilities or harm personnel. It should be noted that there may be a portion of the historical accident events included in the data sets used in this study which were malicious activities where the cause was not accurately identified.

Once intentional detonation of ammonium nitrate is excluded from the QRA, only accidental scenarios remain to be assessed for credibility. Assessing the credibility of accidental scenarios is carried out to ensure that alarmist or excessively conservative scenarios are not modelled and that those scenarios that are modelled are considered to be as realistic as possible and reflect the historical record. Accordingly, the characteristic of such accidental detonations is usually the presence of all three contributors; heat, confinement and contamination.

Detonation from Heat

Heat alone has never been recorded to cause detonation of ammonium nitrate, which is not confined or contaminated. However, heat can lead to ammonium nitrate melting and flowing to areas where confinement or contaminants may also be contributors. There, toxic gases can also be emitted due to heating of ammonium nitrate.

A vehicle fire on its own in the ammonium nitrate Bulk Store is unable to cause an ammonium nitrate explosion. However, if burning fuel from the vehicle were to mix with molten ammonium nitrate and an explosion from the vehicle caused high-velocity shrapnel to impact the molten contaminated ammonium nitrate, an explosion is possible, an event borne out by the historical record [Shah, 1996 - Table 4, No. 24].

Detonation from Confinement

Confinement alone has never been recorded to cause detonation of ammonium nitrate, which is not heated or contaminated. However, heated ammonium nitrate will decompose and release vapours which if confined leads to increased pressure and greater sensitivity to detonation. While the pressure required is 80 atmospheres, this can be reduced by the presence of contaminants. This can reduce the pressure required for detonation to 20 atmospheres.



The historical record shows several fatalities caused by maintenance work on screw conveyor shafts, which have become filled with ammonium nitrate over time. The heat from welding causes decomposition of the trapped ammonium nitrate, the pressure increases leading to detonation and injuries or fatalities [Shah, 1996 - Table 4, No. 6, 10, 25, 29, 31, 61].

Detonation from Contamination

Contamination can lead to catalytic decomposition of ammonium nitrate and can also (if a combustible material) lead to fire, which adds heat to the scenario. Accordingly, Australian Standard "AS 4326-2008: The storage and handling of oxidizing agents" directs that the storage of ammonium nitrate be free of contaminants and details the housekeeping requirements to ensure this. In the instance that ammonium nitrate solution is stored in acidic conditions, the decomposition can lead to bubbles forming in the solution. With heating, these bubbles may lead to detonation [Shah, 1996 - Table 4, No. 48, 60, 69].

A III.8.3 Credible Detonation Scenarios

Appendix II details the significant ammonium nitrate inventories on site. Each one is assessed for credible scenarios leading to detonation. Note that potential fire or fumes as an outcome is not detailed here, only detonation. Consequences of an ammonium nitrate explosion were determined according to the following steps.

The plume of combustion products resulting from an ammonium nitrate fire in previous studies (eg. Bunbeg Harbour, etc.) have been shown to be buoyant due to the high temperatures involved, and disperse to non-hazardous concentrations before returning to grade. On this basis, toxic effects from ammonium nitrate fires are excluded from the analysis.

Proportion Sensitised to Detonation

The proportion of material sensitised to detonation helps define the consequences of an explosion. As detailed in Section A III.8.2, the action of higher temperature, confinement and contaminants sensitise ammonium nitrate to explosion. However, the effects of heat, confinement or contamination may not extend to the entire inventory.

Explosion of ammonium nitrate in storage could lead to offsite effects. Bulk ammonium nitrate prill is stored in freestanding piles, hence it is difficult for the influence of heat, confinement and contaminants to carry over the entire inventory. A review of all the known significant ammonium nitrate accidents between 1961 to the present [Shah 1996 and GHD Review] has only resulted in two cases where bulk prill has exploded. These are the Toulouse incident [Dechy, 2004, event occurred in 2001] and the Cherokee incident [Shah 1996, Table 4, Entry 24, event occurred in 1973]. The Toulouse incident involved contamination of prill and the Cherokee incident involved a fire with a front-end loader. In both cases only a small proportion of the ammonium nitrate present was detonated. The proportion of material involved in the explosion is taken in the model as a realistic proportion of the total present.

A III.8.4 Overall TNT Equivalence

The Overall TNT Equivalence of ammonium nitrate provides an estimate of the blast energy of ammonium nitrate relative to TNT, best represented by the following equation:

$$\text{Overall TNT Equivalence} = \text{Chemical TNT Equivalence} \times \text{Explosive Yield}$$



The Chemical TNT Equivalence is a ratio based on the relative thermodynamic properties of the two chemicals. Published values ranges from 55% to 32%, depending on the thermodynamic method used. Orica has adopted an "industry" value of 32% chemical equivalence (as referenced e.g. in the Queensland Explosives Inspectorate Information Bulletin 53).

The estimate of Explosive Yield is based on expert judgement within Orica Mining Services (via the Orica AN Expert Panel).

While there are several categories of ammonium nitrate products, the predominant type produced at Orica's Kooragang Island facility is low-density (i.e. < 0.92 g/cc), porous prills/granules, often referred to as technical grade ammonium nitrate (TGAN). For this material, Orica proposed three distinct explosion scenarios, with the corresponding estimates of Overall TNT Equivalence:

- ▶ High energy decomposition due to chemical contamination, 16% Overall TNT Equivalence;
- ▶ Molten AN decomposition from radiation and confinement, 5% Overall TNT Equivalence;
- ▶ Detonation from high energetic impact, 32% Overall TNT Equivalence.

The equivalency and efficiency used in this QRA mutually agreed between Orica and NSW Department of Planning are listed below. These figures are considered more conservative than those figures originally proposed by Orica.

Table AIII-2: Overall TNT Equivalency Values used in QRA

	Bags	Bulk in Bays	Bulk in free Stockpiles
Fire	20%	15%	10%
Contamination	20%	15%	10%
Projectile	32%	32%	32%

A III.8.5 Thermal Decomposition of AN

Fire involving ammonium nitrate and thermal decomposition results in the release of toxic fume, which contains NO_x, typically nitric oxide (NO) and nitrogen dioxide (NO₂). NO₂ gas is considered more toxic than NO.

There is limited published data on NO_x generation from AN fires. The investigation completed by W. D. Adams for UK HSE estimated NO₂ releases for:

1. Externally applied heat to AN in a pile produced NO₂: 3g/s/m² floor space. This is applied to the Bulk Store fire and thermal decomposition.
2. Fire involving AN in bags stacked on timber pallets produced NO₂: 10 g/s/ per 250kg bag AN. This is applied to Bag Store fire and thermal decomposition.



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Appendix IV Assumptions

(Same as 2009 PHA report Rev 8)



APPENDIX IV

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A IV Key Modelling Assumptions

In the process of undertaking the quantitative risk assessment of Orica's Kooragang Island facility, a number of key modelling assumptions have been identified that are critical to the risk results. This appendix lists the key modelling assumptions along with their assumed operating parameters.

The majority of modelling assumptions are associated with risk mitigation measures and are presented here as essential requirements to the design and operation of the facilities. These measures were developed through discussions with Orica engineers, safety and operations specialists. GHD has recorded these key mitigation measures here to ensure that the operation and performance of key mitigation measures is clearly defined as a key input into the risk results.

A IV.1 General Assumptions

The following assumptions are applicable to the risk modelling of all facilities.

- ▶ For vessels not connected to a dump system, leaks continue until the whole inventory is lost, but subject to a maximum time limit of 60 minutes. Within a 60 minute period all releases will have reached a steady state in term of hazard distance and potential fatal impacts. Therefore the modelling of consequences beyond the 60-minute period is not required. This assumption is not critical to the risk analysis.
- ▶ The study focus is on release events capable of producing an offsite fatality risk and injury / irritation risk; events that pose only an on-site risk are not modelled.
- ▶ The time to detect, investigate and isolate a process leak (other than for the ammonia transfer pipeline) using remotely operated valves (ROVs) has been (conservatively) assumed and modelled as ten minutes. The ten-minute response time is estimated from Orica response systems based on the following information from Kooragang Island Operations Specialists: Within two minutes of a major release in the processing plant a leak will be detected. The operators wearing appropriate PPE will investigate the indicated area and identify the point of leakage and initiate the necessary isolation measure(s). The time required for this operation is estimated to be eight minutes.
- ▶ Under Orica's operating philosophy, in the event of gas detection, the appropriate response will be decided by the operators on a case-by-case basis. Training in the selection of the appropriate response to different release scenarios is provided to all operators on a regular basis.
- ▶ Natural gas is imported to the site via a buried cross-country pipeline. The natural gas feeds the Ammonia Plant.
- ▶ The major plant equipment items and vessels containing significant inventories of hazardous materials are modelled. Minor lines and fittings are not modelled, as the consequences of failures of such items will be included in the failure scenarios for the major plant equipment items.
- ▶ The compositions of streams in the plant are simplified. For example, this enables natural gas streams typically comprising 90% methane, 8% ethane, 1.5% propane and 0.5% heavier components to be modelled as pure methane, which simplifies the analysis but does not affect the results of the modelling.



A IV.2 Ammonia Plant

- ▶ Liquid ammonia (99.88% concentration) is transported via pipeline to the Ammonia Storage Tank. The ammonia transfer pipelines can be isolated remotely by actuated valves. For the base case (existing operation) in the event of loss of containment from the pipeline ammonia will be released for up to 30 minutes at the normal production feed rate.
- ▶ A major leak in the Ammonia Plant will be detected and isolated in 10 minutes.
- ▶ The failure of the flash drums and receiver containing ammonia in the Ammonia Plant will result in loss of total inventory of the vessel involved.

A IV.3 Ammonia Transfer and Storage

- ▶ The atmospheric Ammonia Storage Tank, V101, is surrounded by a bund (4m in height) designed to contain the full content of the tank. The bund will not fail during rupture of the tank.
- ▶ In the event of a release of refrigerated ammonia within the storage tank bund, the spill surface temperature will drop rapidly as the cold ammonia moves across the surface.
- ▶ All potential liquid spills from the tank and associated plant equipment are located within the bund.
- ▶ In the event of a release of ammonia from the tank all liquid droplets are assumed to be contained within the bund.
- ▶ The ammonia pipeline from the ship is mostly underground. Pipe failure and ammonia release is considered only for the exposed section of the pipeline. The underground section 100m approx is located within a secondary containment pipe – a failure from NH₃ pipe in this section could result in NH₃ emitting from either end of the containment pipe.
- ▶ An ammonia release at the wharf involving the pump or pipe is assumed to result in 50% of the ammonia falling into the water and 50% onto dry land. Ammonia ending up in the water is assumed to result in 60% of ammonia being absorbed by the water and 40% evolved into the air.
- ▶ Ammonia supplies the Nitric Acid and Ammonium Nitrate Plants.
- ▶ In the event of a major leak involving the ammonia transfer pipeline from Ammonia Plant to other users, the time to detect and isolate the pipeline is estimated to take 30 minutes for the Existing case. There will be some delay in isolating the pipeline including the time it takes to detect the leak depending upon the location of the leak. Currently there are no gas detectors to warn the control room in the event of a leak.
- ▶ For the ammonia transfer pipelines for the Expanded Facility the time to detect and isolate a leak has been assumed to be 5 minutes based on appropriate means of leak detection (combination of gas detection and flow detection). Trevor Kletz in Lees Vol 2, page 17/154, suggests that 'if a remotely controlled emergency isolation valve is fitted, it may be assumed that it will be operated within 5 minutes'.

A IV.4 Ammonium Nitrate Production and Storage

- ▶ Explosions of ammonia nitrate (AN) have been identified as a hazard associated with the production and storage of ammonium nitrate.



- ▶ Explosions involving AN solution is considered for solutions greater than 85% strength. Explosions involving AN solution lower than 85% strength is considered extremely unlikely and has not been modelled.
- ▶ Explosion involving dry ammonium nitrate in production is considered for the unit operations with greater than 1 tonne inventory.
- ▶ The separation distance, to be determined by Orica, between the bulk stock piles in the Bulk Store and bag stacks in the Bag Store are assumed to be sufficient to prevent sympathetic explosion.

Reference:

1. Lees F.P, Loss Prevention in the Process Industries, Hazard Identification, Assessment and Control, Vol 2, 2nd Edition, 1996.



Appendix V

Consequences

This Appendix has been withheld from the publicly exhibited Environment Assessment as it is an "exempt document" for the purposes of the Government Information (Public Access) Act 2009 (NSW).



Appendix VI

Frequency Analysis

This Appendix has been withheld from the publicly exhibited Environment Assessment as it is an "exempt document" for the purposes of the Government Information (Public Access) Act 2009 (NSW).



Appendix VII

Methodology

(Same as 2009 PHA report Rev 8)



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A VII Individual Fatality Risk

Location Specific Individual Risk (LSIR) is a measure of the level of risk an individual would be exposed to, if continuously present in a particular location for a whole year (or for the full duration of the activity). It does not take into account any actions that people might take in the area to escape from an event, or the actual time that people are present. It is also independent of land use and exposed population type. The risk exposure is calculated for all relevant hazards and summed to give the overall level of risk in each location.

The LSIR for any given location, failure case and associated consequence outcomes (e.g. pool fire, jet fire, flash fire, vapour cloud explosion (VCE), toxic exposure) can be represented as:

$$\text{LSIR} = R \times I \times \sum (M \times C \times F)$$

where:

Σ = Sum of probability of fatalities for each alternate type of consequence (jet fire, toxic release etc) for the location for which the LSIR is calculated.

R = Release frequency.

I = Ignition probability (not relevant for toxic releases).

M = Fractional probability of each alternate type of consequence occurring (governed by the SAFETI MPACT parameter file(s)).

C = Consequence result for each type of consequence in terms of level of toxic gas, radiant heat or explosion overpressure, experienced at the location.

F = Fractional probability of fatalities for each alternate type of consequence result, based on exposure level / event duration, experienced at the location.

The total LSIR at any location may be calculated by summing the frequency of fatalities for all release events and consequence outcomes for that location.

NSW Individual Risk Criteria

The New South Wales Government requires that new potentially hazardous developments comply with the risk criteria defined and published by NSW DoP *Hazardous Industry Planning Advisory Paper No. 4 – Risk Criteria for Land Use Safety Planning* (HIPAP 4). The criteria covers public fatality, injury, and irritation risk criteria to which all new potentially hazardous industrial developments must adhere. The fatality criteria are summarised in Table AVII-1.



Table AVII-1: Risk Criteria published in HIPAP 4

Exposure Type	Risk Levels
Hospitals, schools, child-care facilities and old age housing developments	Half in a million per year (0.5×10^{-6} per year)
Residential developments and places of continuous occupancy (hotels/resorts)	One in a million per year (1×10^{-6} per year)
Commercial developments, including offices, retail centres, warehouses with showrooms, restaurants and entertainment centres	Five in a million per year (5×10^{-6} per year)
Sporting complexes and active open space areas	Ten in a million per year (10×10^{-6} per year)
Industrial sites	Fifty in a million per year (50×10^{-6} per year)

The risk contours generated by SAFETI provide a means to determine whether the risk presented by the facility exceeds any of the defined criteria.

For an industrial site, the risk of fatality should, as a target, be contained within its boundary at a level of fifty-in-a-million (50×10^{-6}) per year. HIPAP 4 does however allow for some flexibility in the interpretation of this criterion. In particular, it indicates that “where an [adjacent] industrial site ... involves only the occasional presence of people, such as in the case of a tank farm, a higher level of risk may be acceptable”. The neighbours around the KI facility that would meet this definition are:

- ▶ Grain storage with occasional presence of people;
- ▶ Vacant space that could be occupied in the future;



A VII Societal Risk

Societal risk sets out how risks to the public vary with changing levels of hazard severity. It is generally represented graphically as a curve on log-log axes, called an FN-curve, with the frequency (F) on the vertical axis plotted against the cumulative fatalities (N) on the horizontal axis.

The FN-curve is often plotted against two regulatory risk limits; the unacceptable and tolerable risk limits, therefore defining three zones on the FN-curve. By convention, the tolerable risk limit is taken as two orders of magnitude below the unacceptable risk limit.

The three risk zones defined on a typical FN-curve are:

- a) Above the upper risk limit, where the risk level is unacceptable;
- b) Between the upper and lower risk limits, where the risk level is deemed tolerable. In this zone, the risk level should be "as low as reasonably practicable" (ALARP), i.e. any further risk reduction is not commensurate with the cost of achieving that risk reduction. The ALARP principle arises from the fact that it would be possible to spend an inordinate amount of time, effort and/or money attempting to reduce a negligible risk to near to zero.
- c) Below the lower risk limit, where the risk level can be considered to be acceptable and therefore there is no need to consider any risk reduction measures.

By applying tests (a), (b) and (c), a series of tolerability limits can be proposed for incidents involving a defined number of casualties.

FN-curves allow a visual interpretation of the effectiveness of proposed risk reduction measures as significant changes in the frequency of large-fatality events may not easily be detected in risk assessments due to high frequency / low impact events dominating an analysis.

International Experience

Major hazardous incidents involving multiple fatalities (e.g. Seveso 1976, Flixborough 1978 and Bhopal 1984) were key drivers for the development of societal risk criteria. Leaders in the development of criteria for societal risk have been the UK, Netherlands and Hong Kong.

The UK HSE (UK Health and Safety Executive) has undertaken fundamental development work over many years in establishing appropriate values of societal risk. The UK HSE work has been used as the basis for developing societal risk criteria in some other European countries and in other parts of the world.

Guidance on societal risk was first developed in the province of Groningen in the Netherlands, primarily in response to several major hazardous incidents in Europe. In the Asian region, societal risk criteria have been published in Hong Kong and it is understood that these are based on modification of the UK criteria. The development of societal risk criteria in Hong Kong was proposed as a result of pressure for residential developments close to petrochemical facilities.

Australian Experience

The values for the societal risk limits were established by DNV (Det Norske Veritas) in 1984 (believed to be based on work from the Netherlands).



The NSW Department of Planning has published FN criteria for societal risk assessment in its Land Use Planning Safety Studies for Port Botany (1996) and for the Botany Randwick Industrial Area (2001), and the values are given in Table AVII-2 below. These were a 'composite of some typical criteria adopted elsewhere.'

Table AVII-2: Published DoP FN-Curve Limits

Number of Fatalities	Frequency of N or more fatalities	Frequency of N or more fatalities
10	1×10^{-4}	1×10^{-6}
1000	1×10^{-7}	1×10^{-9}



A VII Fatality Impact Levels

A VII.1 Heat Radiation Criteria

The heat radiation fatality probability is based on the effects of heat radiation in the *Hazardous Industry Planning Advisory Paper (HIPAP) No's 4 and 6* by the NSW Department of Planning. Table AVII-3 is an extract from the HIPAP 4 and 6 guidelines.

Table AVII-3: Effects of Thermal Radiation

Heat Radiation kW/m ²	Effect
1.2	Received from the sun at noon in summer
2.1	Minimum required to cause pain in 1 minute
4.7	Will cause pain in 15 – 20 seconds and injury after 30 second exposure (2 nd degree burns)
12.6	Significant chance of fatality for extended exposure. High chance of injury. After long exposure causes the temperature of wood to rise to a point where it can be readily ignited by a naked flame. Thin steel insulation on the side of the fire may reach a thermal stress level high enough to cause structural failure.
23	Likely fatality for extended exposure and chance of fatality for instantaneous exposure. Spontaneous ignition of wood after long exposure. Unprotected steel will reach thermal stress temperatures which can cause failures. Pressure vessel needs to be relieved or failure will occur.
35	Cellulosic material will pilot ignite within one minutes exposure. Significant chance of fatality for people exposed instantaneously.

SAFETI uses a probit function to calculate the fatality rate from thermal radiation. The probit function uses exposure time and thermal radiation level to estimate a fatality rate. The probit function used for the KI model is:

$$Y = -36.38 + 1.56 \ln(I^{1.33} \times t)$$

Where I = thermal dose in W/m² and t is time in seconds.

This probit is used for pool fires, jet fires and fireballs from explosions or BLEVES.



A VII.2 Flash Fire Criteria

In terms of consequence criteria the hazard distance relating to the dispersion distance is taken at less than the Lower Flammable Limit (90% of LFL). This distance defines the size of the flash fire engulfed region from which escape is not possible, ie 100% fatality inside this envelope. Modelling flammable clouds to 90% LFL is conventionally assumed to account for longer than anticipated dispersion anomalies (incomplete mixing, ground effects, building wake effects etc). Outside the cloud the fatality probability is assumed to be zero.

A VII.3 Boiling Liquid Evaporating Vapour Explosion (BLEVE) / Fireball Fatality Criteria

Exposure to a thermal dose of 250 kJ/m² is taken to be fatal. For a radiant heat level of 23 kW/m² this would correspond to a duration of 11 seconds.

A VII.4 Explosion Overpressure Fatality Criteria

The explosion overpressure fatality rate criteria used is also based on the only consequence effects publicly documented in Australia, the Hazardous Industry Planning Advisory Paper (HIPAP) No. 6, by the NSW Department of Planning. is an extract from the HIPAP guideline.

Table AVII-4: General Overpressure Consequence Levels

Overpressure level (kPa)	Consequence of Overpressure
3.5	90% glass breakage. No fatality and very low probability of injury from overpressure.
7	Steel frame of a clad building slightly distorted. Associated with an injury probability of 10%, but a 0% chance of fatality.
14	Partial collapse of timber framed buildings. Buildings may become uninhabitable (again no fatalities are expected).
21	Storage tanks may buckle and fail. Can result in a 20% chance of fatality among people in a building but still no fatalities among those outside.
35	Timber framed buildings become uninhabitable, plant items may be overturned. There is a 50% chance of a fatality for a person in a building and 15% chance of a fatality for a person in the open.
70	100% chance of fatality for a person in a building or in the open. Complete demolition of buildings.

From the above table of overpressure effects, consequence impacts were assumed based on the level of overpressure received. Therefore the assumed fatality levels were conservatively assumed and used in the risk assessment as follows:

- ▮ At 70 kPa overpressure, 100% chance of fatalities for outdoor population.
- ▮ At 35 kPa overpressure, 15% chance of fatalities for outdoor population
- ▮ At 21 kPa overpressure, 1% chance of fatalities for outdoor population.



A VII.5 Toxic Criteria

If the release is a toxic material, it is necessary to attempt to relate the specific atmospheric concentrations and durations of exposure following a release to the level of toxicity produced within the surrounding population. The impact is determined from reports of accidental single exposure of humans to the airborne substance, or generated in single exposure inhalation studies in animals. All the data available in this area relates to toxic effects, which become apparent soon after exposure (acute impact).

Other effects, including mutagenicity, carcinogenicity and teratogenicity, may also arise as a result of a single exposure. These chronic impacts are not considered in this study.

For most substances, existing reliable data on acute effects arising from a single exposure in humans are sparse. For a few substances some information is available from their use in warfare (e.g., chlorine). Nevertheless, for most substances the data is limited to a few reports of accidental exposures, often involving only a few people and rarely containing accurate measurements or even estimates of exposure concentrations and times.

Consequently, heavy reliance needs to be placed on the results of experiments on animals, in attempting to predict the responsiveness of a human population. In general, extrapolation from laboratory animals to humans with any degree of accuracy and reliability is difficult, principally because of the inadequate information. Even so, for most substances it is necessary to make the assumption that results from animal experiments will be representative of effects on the human population, in terms of both the nature of the effects produced and the dose-effect relationships observed.

For some substances the scarcity of toxicity data will make any analysis extremely tenuous, and in these situations further experimental work by manufacturers or their trade associations would be advisable if important decisions depend on the results. For Orica, the public domain information available for the toxic materials assessed is suitable to base this study on.

Toxicity of a material can be measured against criteria for either fatality or survivability. Fatality criteria can be presented in terms of probits or dangerous dose. A probit is a mathematical system for estimating the probability of fatality based on the concentration and time exposed to a particular material. A dangerous dose is a single criterion that defines a certain level of dosage received over any time period that will result in fatality. Survivability criteria are those that, if a person is exposed to levels below the criteria, there is strong confidence that he or she will survive. There can be considerable separation between survivability and fatality criteria, which makes them difficult to compare.

A VII.6 Ignition Probabilities

Ignition can be either immediate or delayed. This section discusses the ignition probabilities for both immediate and delayed ignition.

A VII.6.1 Immediate Ignition Probability

Immediate ignition and explosion probabilities are used in this study. These are derived from Cox, Lees and Ang data (1990). Cox Lees & Ang ignition probabilities are based on historical offshore data, in particular the North Sea and Gulf of Mexico data (i.e. process leaks, blow-outs etc). The likelihood of immediate ignition takes into account all causes including the initiating mechanism for a release. Table AVII-5: shows, the immediate ignition probability as a function of the phase of the material released (liquid or gas / aerosol) and the release rate.



Table AVII-5: Immediate Ignition Probabilities

Release	Immediate Ignition Probability	
	Gas / Aerosol	Liquid Spill (pool evaporation)
Small	0.5%	3%
Medium	4%	4%
Large	10%	6%
Full-bore	30%	8%



A VII Injury and Irritation Risk Assessment Methodology

Different people have different levels of tolerance to toxic chemicals depending upon the physiological condition, weather condition, exposure level and duration. The exposure levels that can cause injury or irritation are reported in various sources, some of the common exposure levels reported are given in Appendix I.

The toxic risk criteria of NSW DoP as given in the 'Hazardous Industry Planning Advisory Paper HIPAP No 4' for injury risk requires assessment for:

1. Injury Risk:

Toxic concentrations in residential area should not exceed a level, which would be seriously injurious to sensitive members of the community following a relatively short period of exposure at a maximum frequency of 10 in a million per year.

2. Irritation Risk:

Toxic concentrations in residential area should not cause irritation to eyes or throat, coughing or other acute physiological responses in sensitive members of the community over a maximum frequency of 50 in a million per year.

This section describes the criteria adopted for the assessment of injury and irritation risk associated with toxic chemicals.

A VII.1 Acute Exposure Guidelines Limits (AEGL)

The US EPA have developed the AEGL primarily to provide guidance in the event of accidental exposure to a particular chemical from the release or spill of a particular chemical that can involve the general public. They are designed to protect the general population including the elderly and children.

The AEGL have been developed for short term exposure to the hazardous chemicals. The AEGLs are defined as:

AEGL-1: is the airborne concentration (expressed as parts per million or milligrams per cubic meter (ppm or mg/m^3)) of a substance above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic nonsensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure.

AEGL-2: is the airborne concentration (expressed as ppm or mg/m^3) of a substance above which it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape.

AEGL-3: is the airborne concentration (expressed as ppm or mg/m^3) of a substance above which it is predicted that the general population, including susceptible individuals, could experience life-threatening health effects or death.

AEGLs are defined for 10 minute, 30 minute, 60 minute, 4 hour and 8 hour exposures.



A VII.2 Emergency Response Planning Guideline (ERPG)

The Emergency Response Planning Guideline (ERPG), developed by AIHA Emergency Response Planning Committee, are based on concentrations at which some adverse effect on people can be expected. ERPG are based on exposure for 1 hour duration. The definitions of ERPG are:

ERPG-1: is the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hr without experiencing other than mild transient adverse health effects or perceiving a clearly defined, objectionable odour.

ERPG-2: is the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hr without experiencing or developing irreversible or other serious health effects or symptoms which could impair an individual's ability to take protective action.

ERPG-3: is the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects.

The ERPG approach is based on 1 hour exposure duration whereas the NSW DoP HIPAP No 4 injury risk criteria requests assessment based on short term exposure.

A VII.3 UK HSE

The UK HSE has developed a method, Specified Level of Toxicity (SLOT), for assessing the exposure to toxic material for land use planning (LUP). UK HSE has defined SLOT as:

- ▶ Severe distress to almost every one in the area;
- ▶ Substantial fraction of exposed population requiring medical treatment;
- ▶ Some people seriously injured, requiring prolonged medical treatment;
- ▶ Highly susceptible people possibly being killed.

SLOT is based on concentration and exposure time given by the formulae:

$$\text{SLOT} = C^n T$$

Where:

- ▶ C = concentration in ppm;
- ▶ T = time in minutes.
- ▶ n = constant specific to each material (can be obtained from the UK HSE website)

SLOT values for:

- ▶ Ammonia: $3.78 \times 10^8 \text{ ppm}^n \cdot \text{min}$ (n=2);
- ▶ Chlorine: $1.08 \times 10^5 \text{ ppm}^n \cdot \text{min}$ (n=2); and
- ▶ Nitrogen Dioxide: $9.6 \times 10^4 \text{ ppm}^n \cdot \text{min}$ (n=2).

The SLOT approach is on the borderline of fatality and does not meet the NSW DoP injury and irritation risk criteria.



A VII.4 Method Selected

The AEGL approach developed by the US EPA has been selected to assess the injury risk and irritation risk for Kooragang Island plant expansion.

- ▶ The 10 minute AEGL-1 will be used to assess the off site irritation risk from exposure to ammonia (30 ppm), chlorine (0.5 ppm) and nitrogen dioxide (0.5 ppm).
- ▶ The 10 minute AEGL-2 will be used to assess the off site injury risk from exposure to ammonia (220 ppm), chlorine (2.8 ppm) and nitrogen dioxide (20 ppm).

The main reasons for selection are:

- ▶ The definition of AEGL-1 is reasonably similar to the definition of the HIPAP 4 irritation criterion, in particular odour is not included, but is conservative compared to HIPAP4 in that it does not refer to 'coughing' or 'acute physiological responses'. The HIPAP 4 definition also does not mention the AEGL-1 phrase 'transient and reversible';
- ▶ The definition of AEGL-2 is reasonably similar to the definition of the HIPAP 4 injury criterion, taking 10 minutes as 'a relatively short period of exposure'. It may be conservative for some chemicals in that it also includes the phrase 'or the impaired ability to escape' which is not specifically mentioned in the HIPAP4 injury definition;
- ▶ It is specifically developed for assessing the risk to the general population including sensitive (susceptible) individuals, the elderly and children;

It should be noted for the three toxic materials considered here, the AEGL-1 values are constant with time ie AEGL-1 (10 minutes) is the same AEGL-1 (8 hours).



Appendix VIII

Project Case risk assessment results



APPENDIX VIII

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A VIII PHA MOD 1 Project Case Risk Assessment Results

A VIII.1 Scope

This Appendix presents the detailed results of the quantitative risk assessment for the Project Case.

The Project Case is defined as the new plant and equipment, modifications to existing plants, and the existing site operations, i.e. the total future site risk profile after completion of all proposed work.

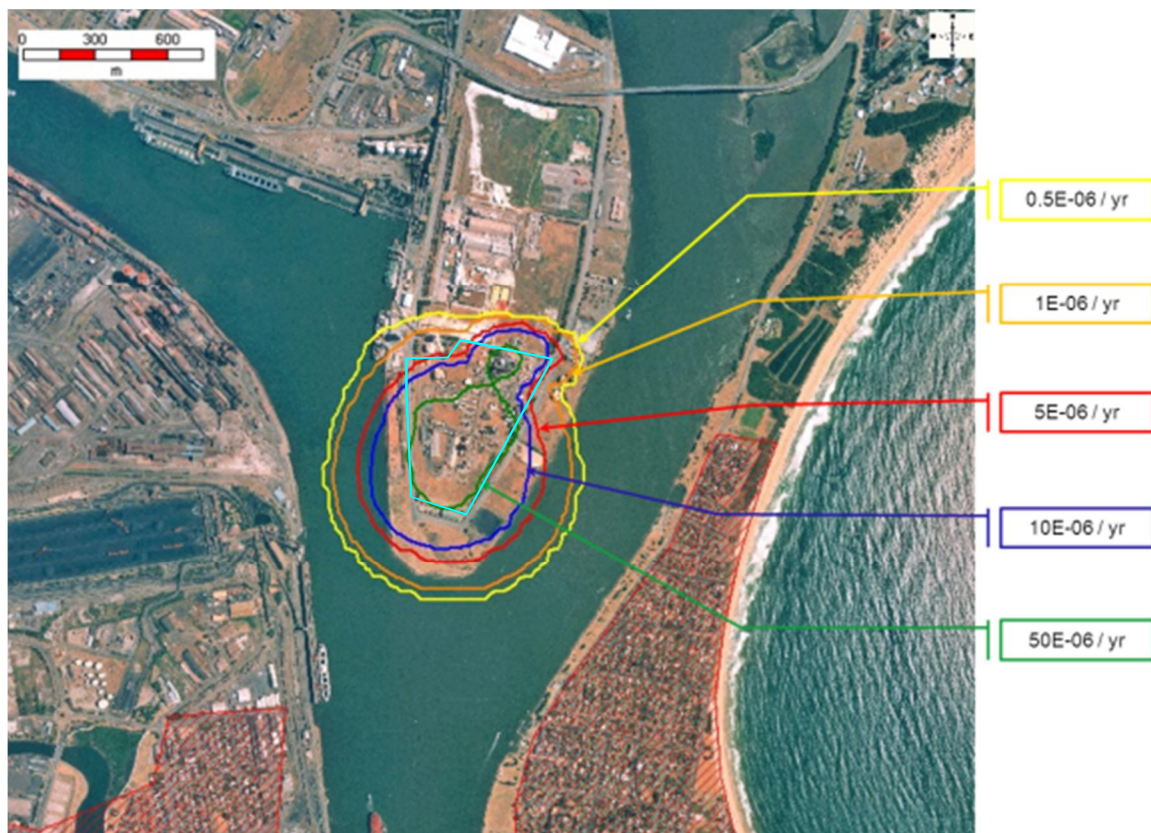
The HIPAP 4 risk criteria apply specifically for a new development. HIPAP 4 suggests the appropriate criteria to be applied for installation of additional plant and equipment at a facility, which already comprises several large existing plants carrying out activities of a hazardous nature.

However to enable a more complete understanding of all aspects of the risk profile of the Project Case, risk contours have been calculated for the Project Case for all the HIPAP 4 criteria applicable to a new development. These results will also provide a benchmark for any future developments on the facility.

A VIII.2 Project Case Individual Fatality Results

Figure VIII-1 plots risk contours for the Project Case for each of the HIPAP 4 individual fatality risk criteria.

Figure VIII-1: Individual Fatality Risk Contours (Project Case)





These results are summarised in Table VIII-1 below.

Table VIII-1: Individual Fatality Risk Criteria and PHA Findings for the MOD 1 Case

Land-Use	Hazard	NSW DoP Risk Criterion (p.a.)	Project Case Complies?	Comments
Individual Fatality Risk				
Hospitals, schools, child-care facilities and old age housing developments.	Individual Fatality	0.5×10^{-6}	Yes	No such developments within the extent of this contour.
Residential developments and places of continuous occupancy such as hotels and tourist resorts.	Individual Fatality	1×10^{-6}	Yes	No such developments within the extent of this contour.
Commercial developments, including offices, retail centres, warehouses with showrooms, restaurants and entertainment centres.	Individual Fatality	5×10^{-6}	Yes	No such developments within the extent of this contour.
Sporting complexes and active open space areas.	Individual Fatality	10×10^{-6}	Yes	No such developments within the extent of this contour.
Industrial Sites	Individual Fatality	50×10^{-6}	No	Marginal exceedance into industrial land to north, west and south of the site. The actual fatality risk at the relevant boundaries is provided in Table VIII-2 below.

As shown, the Project Case meets the HIPAP 4 IFR criteria for new developments for all land use applications other than for industrial. This is despite the fact that much of the Kooragang Island industrial



area and most of the Orica Site were developed prior to the application of the HIPAP 4 land use planning criteria. This high level of compliance is due to:

1. Implementation of risk reduction measures based on the recommendations from the DoP 1992 Study, as noted in Section 3.3 of the Executive Summary in this PHA.
2. Substantial efforts made to reduce risk as part of the Project, not only in the new plant and equipment but also by modifying existing plant and equipment. These are described in Section 2.2 of the main MOD 1 report.

In the case of industrial fatality risk, the 50×10^{-6} pa individual fatality risk contour extends beyond the site boundary on the northern, southern and western sides.

The maximum actual IFRs at the Orica site boundary on all sides for the Project Case and Base Case are given in Table VIII-2 below. The HIPAP 4 criterion is 50×10^{-6} /yr.

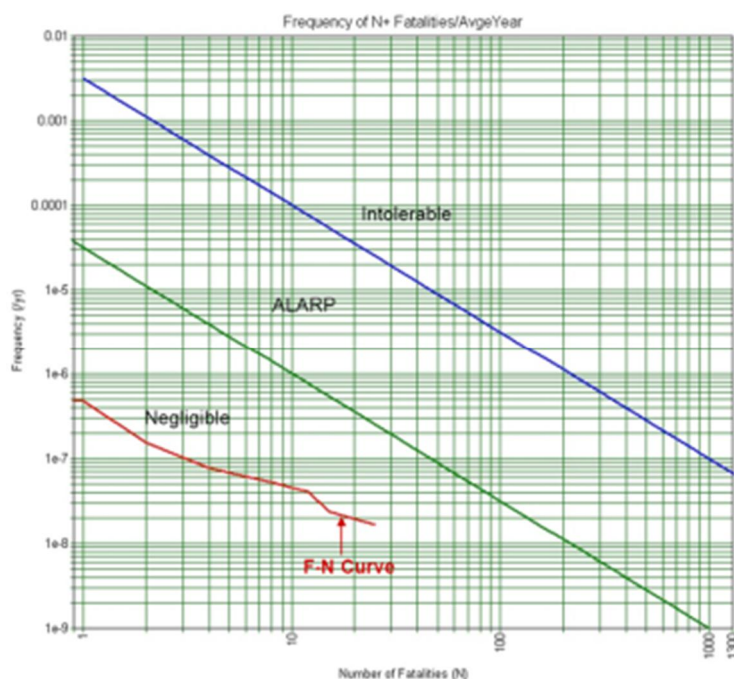
Table VIII-2: Maximum Actual IFR At Site Boundary

	IFR Project Case (x 10⁻⁶/yr)	IFR Base Case (x 10⁻⁶/yr)	Major Contributors
North	56	30	Events in the ammonia plant involving ammonia and gas releases.
East	43	154	Explosion events involving ammonium nitrate
South	81	96	Explosion events involving ammonium nitrate
West	58	146	Explosion events involving ammonium nitrate

A VIII.3 Project Case Societal Risk Results

The societal risk plot for the Project Case is shown as the red curve in Figure VIII-2.

Figure VIII-2: Societal Risk- Project Case



This shows that the Project case societal risk remains entirely within the “negligible” zone. Therefore, the Project case complies with the suggested societal risk guidelines in the HIPAP 4 (2010). The reduction in risk shows the significant risk reduction benefit provided by this Project. This is consistent with the risk contours for the Project case being smaller than for the Base case. The main contributor to the improvement in the FN-curve is the change in ammonium nitrate storage layout, which results in reduced consequences and, therefore, a reduction in the size of the population, which is potentially impacted.

A VIII.4 Project Case Injury and Irritation Results

These estimate the extent to which incidents from the Project case could cause injury or irritation to residential areas. The risk contour plots for injury due to heat radiation, overpressure and toxic exposure, and irritation from toxic exposure, are presented below.

A I VIII.4.1 Thermal Radiation Injury

The potential for a significant fire is mainly in the Ammonia Plant where flammable gases (natural gas, ammonia, hydrogen and synthesis gas) are present. The HIPAP 4 criterion is not to exceed a frequency of $50 \times 10^{-6}/\text{yr}$ at the nearest residential area for a radiation level of 4.7 kW/m^2 . The risk of injury from thermal radiation (4.7 kW/m^2) as a result of a flammable gas fire on the Orica site is shown below in Figure VIII-3.

Figure VIII-3: Thermal Radiation Injury Risk – Project Case



The Project case complies with the thermal radiation injury criterion, as the contour does not extend into residential areas.

A I VIII.4.2 Overpressure Injury

The injury risk from explosion overpressure is primarily associated with the production, storage and handling of ammonium nitrate onsite.

The HIPAP 4 criterion is not to exceed 50×10^{-6} /yr at the nearest residential area at an overpressure level of 7 kPa. The risk of injury from overpressure (7kPa) as a result of explosions on the Orica site is shown below in Figure VIII-4.

Figure VIII-4: 7 kPa Overpressure Injury Risk



The Project case complies with the overpressure injury risk criterion as the contour does not extend to residential areas.

A I VIII.4.3 Toxic Injury

The injury risk from toxic gas is primarily associated with the production, storage and handling of ammonia onsite. The toxic injury exposure is assessed with respect to AEGL-2 concentrations based on 10 minutes exposure time. The risk criterion is not to exceed a frequency of $10 \times 10^{-6}/\text{yr}$ at the nearest residential area at the AEGL-2 (10 minutes) level. The details of AEGLs can be found in Appendix VII.

The injury risk contour from exposure to toxic gases for residential areas of $10 \times 10^{-6}/\text{yr}$ is shown below in Figure VIII-5.

Figure VIII-5: Toxic Injury Risk



The Project case complies with the toxic injury risk criterion as the contour does not extend to residential areas.

A I VIII.4.4 Toxic Irritation

The irritation risk from exposure to toxic gases has been assessed using AEGL-1 concentrations. The details of AEGLs can be found in Appendix VII. The risk criterion is not to exceed a frequency of $50 \times 10^{-6}/\text{yr}$ at the nearest residential area at the AEGL-1 (10 minutes) level. The risk of irritation from exposure to toxic chemicals is shown below in Figure VIII-6.

Figure VIII-6: Toxic Irritation Risk



The Project case complies with the toxic irritation risk criterion as the contour does not extend to residential areas.

A VIII.5 Property Damage and Accident Propagation

These criteria estimate the extent to which incidents from the Project could cause a hazardous event at a nearby potentially hazardous industrial installation, or damage to a nearby potentially hazardous industrial installation or public building. The risk contour plots for assessment of the potential for property damage and accident propagation are provided below.

A I VIII.5.1 Thermal Radiation (23 kW/m^2)

The HIPAP 4 criterion is not to exceed a frequency of $50 \times 10^{-6}/\text{yr}$ at the nearest industrial area zoned for potentially hazardous installations at a radiation level of 23 kW/m^2 . The thermal radiation risk contour for 23 kW/m^2 at $50 \times 10^{-6}/\text{yr}$ is shown in Figure VIII-7.

Figure VIII-7: Thermal Radiation - Property Damage Risk

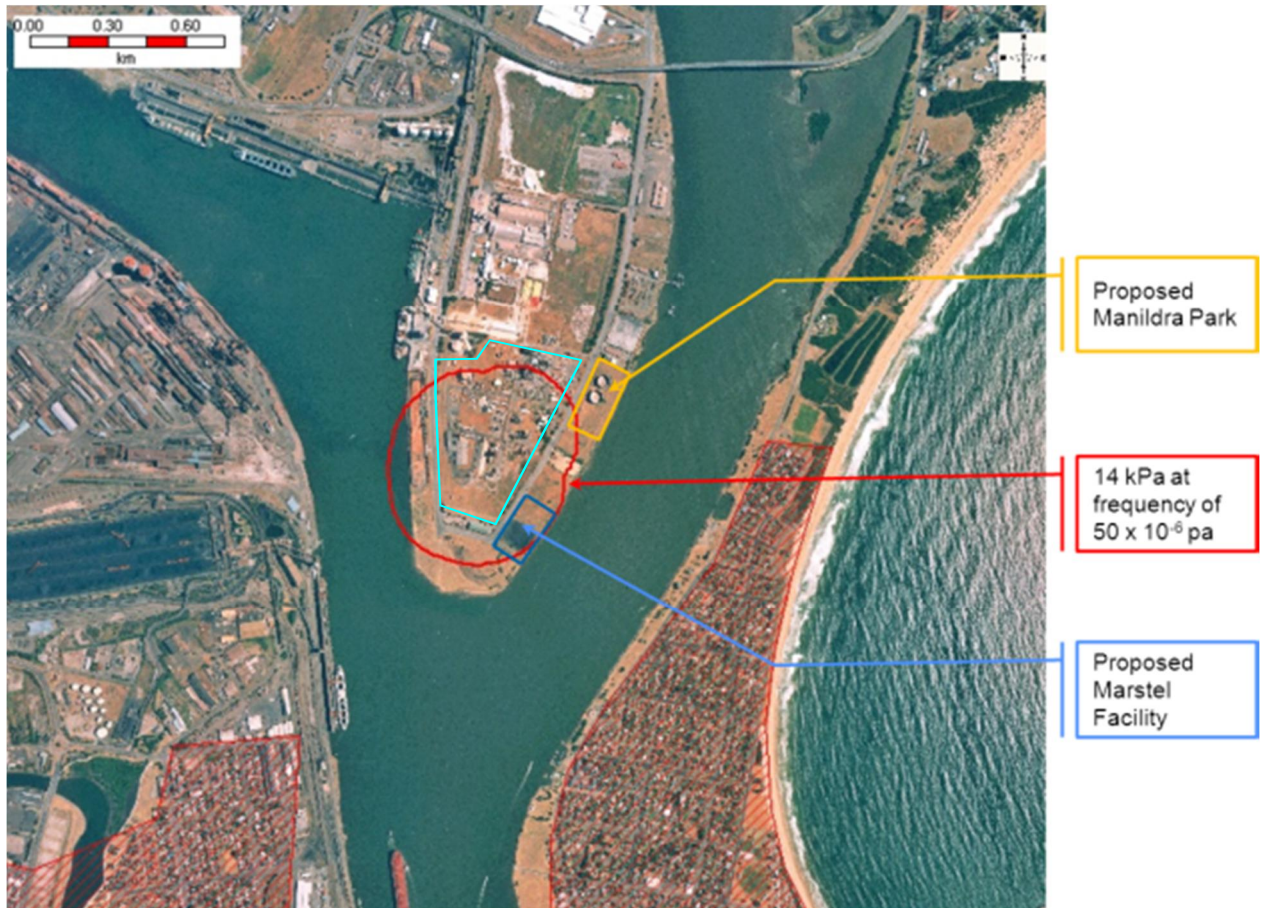


This thermal radiation risk contour does not affect any potentially hazardous installations, land zoned for such installations or public buildings surrounding Orica's KI facility. Therefore, the Project meets the requirements of HIPAP 4 for property damage from thermal radiation.

A I VIII.5.2 Explosion Overpressure (14 kPa)

The HIPAP 4 criterion is not to exceed a frequency of $50 \times 10^{-6}/\text{yr}$ at the nearest industrial area zoned for potentially hazardous installations or nearest public buildings at an overpressure level of 14kPa. The explosion overpressure risk profile for the Project at 14 kPa at 50×10^{-6} per annum is shown in Figure VIII-8.

Figure VIII-8: 14 kPa Overpressure Damage - Property Damage Risk



The Project does not meet the criterion for explosion overpressure damage as this risk contour extends into the neighbouring industrial facilities zoned for potentially hazardous developments (including the Manildra Park facility lots 10-12 and Marstel lots 1-4 to the east of the Orica KI site).

The actual risk of 14 kPa overpressure for the Project Case and the Base Case at the site boundaries of the proposed developments including Manildra Park facility (lots 10-12) and Marstel (lots 1-4) on the eastern side of Kooragang Island are given in Table VIII-3 below.

Table VIII-3: Actual Project and Base Case Explosion Overpressure Risk at Site Boundaries of Adjacent Proposed Potentially Hazardous Sites

Potentially Hazardous Development	Project Case - Actual overpressure risk per annum (x 10 ⁻⁶ /yr)	Base Case - Actual overpressure risk per annum (x 10 ⁻⁶ /yr)	Description
Manildra Park (lots 10-12)	65	85	The main contributors to overpressure risk are ammonium nitrate explosion



			events in the storage area.
Marstel (lots 1-4)	120	85	The main contributors to overpressure risk are ammonium nitrate explosion events in the storage area.

The proposed Manildra Park location is away from the ammonium nitrate storage and the production facilities, hence is only marginally impacted by the 14 kPa overpressure. The proposed Marstel facility is located closer to the ammonium nitrate storage and production facility, therefore, the impact from an explosion overpressure is relatively higher compared to the Manildra site as can be seen from Table VIII-3. The existing developments on the western and southern sides of the Orica site are not potentially hazardous.

The above non-compliance largely reflects an increased understanding of the likelihood and consequences of incidents involving storages of ammonium nitrate. While justifiable risk reduction measures have been included in the Project, which are reflected in the generally lower fatality risks at the Orica site boundary for the Project compared to the existing site (Base Case) as shown in Table VIII-2, these cannot entirely compensate for the existing site location and inventories which have not been increased by this proposed development.

A VIII.6 Conclusions

The above risk assessment of the Project, comprising the entire site after completion of the proposed uprate, shows that it complies with all except two of the risk criteria, which would be applied to a new project. The two non-compliances are offsite industrial fatality and accident propagation/property damage explosion overpressure. The non-compliances do not extend beyond the Kooragang Island industrial and port areas.

These non-compliances reflect the historical location of the Orica site close to adjacent industries, with small separation distances between the sites, and recent increased understanding of the risks associated with the storage and handling of solid ammonium nitrate.

As shown above and in the main report (section 3.1), overall the Project is estimated to provide lower risks than the existing site.



Appendix IX

Changes in Design



The list of changes provided by Orica and incorporated into the QRA is presented below.

Table A1: Design Changes

DESCRIPTOR	CHANGE	ORIGINAL DESIGN (PHA)	CURRENT DESIGN (MOD 1)	Comment
All.2 Natural Gas	Location	Boiler near ammonia plant 35 t/hr, 40 bar	Boiler located at NAP4 plant 58 t/hr, 60 bar	
All.3 Ammonia Plant	No Change			
All.4 Ammonia Pipelines	Configuration	Supply to Bullet No.1 (actually bullet 5)	Lines to Bullet 1 decommissioned New line to Bullet 6 adjacent to Bullet 2	



DESCRIPTOR	CHANGE	ORIGINAL DESIGN (PHA)	CURRENT DESIGN (MOD 1)	Comment
All.5 Ammonia Storage & Associated Pipeline	Configuration & Location	Bullet 1, 2 & 5 being reduced to one bullet (termed Bullet 1* (V115) in the PHA)	<u>Bullet #1</u> Decommissioned <u>Bullet #2</u> Not normally used for supply Can supply all nitrates plants Used to blow back ammonia for maintenance. Full spare for Bullet # 6 Operating pressure 1750 kPag Operating capacity: empty Max Capacity of 30T <u>Bullet #5 (V115)</u> Remains in service Operating capacity of 10T (353 days per year) 25T during road tanker filling (12 days per year) <u>Bullet # 6</u> New bullet Operating pressure 1750 kPag Operating capacity of 15T. Max Capacity of 30T Supplies all nitrates plants	



DESCRIPTOR	CHANGE	ORIGINAL DESIGN (PHA)	CURRENT DESIGN (MOD 1)	Comment
			Existing NA plants supplied via bullet no.6 New NA plants supplied via bullet no.6 <u>Pipe run from Bullet 2 & 6 to AN3:</u> Line length: 220m Pipe Size: 80 NB (no change) <u>Pipe run from Bullet 2 & 6 to NAP4:</u> Line length: 245m Pipe Size: 80NB (no change)	
All.8 – Nitric Acid Plants	Capacity	750tpd Uhde plant	900tpd GPN plant	
All.9 0 Ammonium Nitrate Plants	Location	AN3 plant at southern end of site	AN3 plant to south of NAP4. Pipe reactor (AN Solution) plant located within NAP4 plant area	



DESCRIPTOR	CHANGE	ORIGINAL DESIGN (PHA)	CURRENT DESIGN (MOD 1)	Comment
Ammonium Nitrate Plants	AN Inventories Table AII-12	<u>AN Solution Plant</u> - AN3 Product Separator 4.86t - AN3 Product Tank 9.91t <u>AN Prill Plant</u> - AN3 Evap Feed Tank 21.91t - AN3 Drier 35 tonne - AN3 Bulk Flow Cooler 7t	<u>AN Solution Plant (located NAP4)</u> - AN3 Product Separator 5.83t - AN3 Product Tank 11.89t <u>AN Prill Plant</u> - AN3 Evap Feed Tank 27.67t - AN3 Pre-drier 15t - AN3 Drier 22.5t - AN3 Bulk Flow Cooler 12t	
AN Conveying		Small AN conveyer from AN plant 1 x conveyor to Bagging line (75t/h) (not considered) 1 x conveyor to RBLO (300 t/h) (Packaged up as a 5 tonne inventory)	Small AN conveyer from AN plant 2 conveyors from Bulk Store to Bag store (Bag line area) 1 x 300 t/hr 1 x 75 t/hr (normally operated 325 h/y) 300 t/h conveyor from Bag Store (bag line area) to RBLO	Minor risk
AII.9 ANS Storage	ANS Storage	New 880/1000t (100%/88.5%) ANS tank)	New 2 x 500t/565t (100%/88.5%) tanks	



DESCRIPTOR	CHANGE	ORIGINAL DESIGN (PHA)	CURRENT DESIGN (MOD 1)	Comment
All.10 STORAGE Bag Store	Location	<u>Existing bag store extended</u> 12 x 151 t stacks 1 x 184.8 t stacks 1 x 48 t CPAN stack	<u>New bag store at southern end of site</u> No change in inventories	Existing Bag store is demolished
Small Bag Line	Location	In existing store	Moved to new store	
Existing Bulk Store - AN	No change	4 x 1250 T Conical piles	No change	
Existing Bulk Store – Opal/ CPAN	Configuration	1 x 200 T CPAN pile 1 x 200 T OPAL pile	1 x 300 T CPAN pile <u>OR</u> 1 x 300 T OPAL pile	CPAN and OPAL are in a common bay. Only one product to be stored in there at a time. Approx max capacity 340 T. Manufactured in campaigns
New Bulk Store	Configuration	2 x 2000 T Slumped Piles Treated as 1 x 4000 T pile	2 x 2000 T Slumped Piles with sufficient separation. Treated as 1 x 4000 T pile	Modelled as single 1 x 4000 T pile



DESCRIPTOR	CHANGE	ORIGINAL DESIGN (PHA)	CURRENT DESIGN (MOD 1)	Comment
Container park	Location & Configuration	Stack 1: 200 t (10 x 20 t container) Stack 2: 400 t (20 x 20 t container) Stack 3: 480 t (24 x 20 t container) Stack 4: 400 t (20 x 20 t container) Stack 5: 320 t (16 x 20 t container) Stack 6: 320 t (16 x 20 t container) Stack 7: 480 t (24 x 20 t container) Stack 8: 480 t (24 x 20 t container) Stack 9: 480 t (24 x 20 t container) Stack 10: 480 t (24 x 20 t container) Stack 11: 680 t (34 x 20 t container) Total: 4720 t	9 stacks of: 500 t (27 x 20 t container ⁴) Total: 4500 t	
All-11.4 : AN Transportation - Loadout silos	Configuration	60 t inventory (modelled as 1 x 60t silo)	120 tonne inventor (2x 60t silos)	Modelled as 2 x 60t silos

⁴ Containers hold 20 te nominal but some containers will be empty and each container stack will not exceed 500 te of stored AN



GHD

180 Lonsdale Street
Melbourne, Victoria 3000
T: (03) 8687 8000 F: (03) 8687 8111 E: melmail@ghd.com.au

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Document Status

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0	R Chatiar					
1	L. Dinh	R. Mills	*R. Mills	R. Mills	*R. Mills	25/03/11
2	L. Dinh	R. Mills	*R. Mills	R. Mills	*R. Mills	04/04/11
3	L. Dinh	R. Mills	*R. Mills	R. Mills	*R. Mills	03/06/11
4	L. Dinh	R. Mills	*R. Mills	R. Mills	*R. Mills	18/07/11
5	L. Dinh	M. Erskine	<i>M. Erskine</i>	M. Erskine	<i>M. Erskine</i>	20/03/12

* Signature on file