AECOM

SURROUNDING LAND USES

Preliminary Hazard Analysis

Mayfield Site Port-Related Activities Concept Plan

Figure 3-2

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3.3 Brief Description of the Concept Plan Operation

The concept description provided below is considered representative of the current planning for the site. It should be noted that a detailed project description would be submitted prior to development of each part of the site at subsequent Project approval stages. This would also be supported by the relevant hazard and risk studies required under the planning provisions.

Figure 3-1 provides a site layout identifying the arrangement of port-related land uses on the site which includes the five key operational precincts:

- NPC Operations Precinct – likely consisting of various personnel buildings, maintenance workshops and small scale facilities. The precinct would also likely be the location of the NPC Dredging Fleet and pilot cutters. Port craft, owned by, NPC would be refuelled at the wharf adjacent to the NPC Operations Precinct, using an on-site underground diesel fuel storage tank (10,000 litres). NPC vehicles would also be refuelled at the NPC Operations Precinct from an underground unleaded petrol tank (5,000 litres), using a bowser type filling operation. Whilst minor storages of Dangerous Goods would also be held in the maintenance areas, these would not constitute a hazard to surrounding land uses.
- Bulk and General Precinct – likely consisting of bulk and general purpose use including grain storage, briquettes, coke cargoes. This precinct would not be used for the storage and handling of Dangerous Goods, however, fumigation operations may be performed in this Precinct using Methyl Bromide.

  Ships would tie up at the dry bulk/multi-purpose terminal area and goods would be unloaded using ship mounted equipment. For bulk goods this could be a variety of equipment including crane mounted grabs, lifting the bulk materials from the ship hold and depositing it into a hopper where it is transferred by conveyor to stockpiles or silos. Unloading may also be via pneumatic conveyance, where dry products are carried in an air stream in ducts to stockpiles or silos. Loading ships may occur using ship loader gantries that convey the materials by belt conveyor and deliver them to the cargo holds via spouts. Details of bulk loading/ unloading are not finalised at this stage, however, the bulk goods area would not handle bulk Dangerous Goods transferred by conveyor/pneumatic operation.

- General Purpose Precinct – likely consisting of cargo containers, heavy machinery, Ro / Ro and break bulk. A temporary General Cargo Handling Facility has been already approved within this precinct (DA-293-08-00 (MOD-56-7-2008)) and commenced operation in 2010. This area has approval for the storage and handling of AN in a dedicated storage area located adjacent to the wharf. The handling of shipping containers in this area may also require fumigation operations using Methyl Bromide.

  AN would not be transported in large bulk lots (i.e. uncontained bulk storage in sheds at the wharf or transferred directly to or from the holds of ships). The AN would be held in 1 tonne bulk-bags in shipping containers or in plastic lined shipping containers. Where AN is being shipped out of the site, the containers would be transported to the area fronting Berths 3 and 4 by truck and loaded to the ship directly from the trucks, there would be no AN storage at the wharf. For cargoes entering the site, the containers would be unloaded using ship or wharf equipment (cranes) and loaded directly to trucks where it would be transported off-site, there would be no storage of AN at the site. The maximum cargo capacity for AN that would be loaded to, or unloaded from, the ship would be 6,500 tonnes.

- Container Terminal Precinct – likely consisting of container storage and transfer which would include an area to accommodate 3000-5000 TEU container vessels or 1 Million TEU per annum.

  Once tied up, the ships would unload the cargo using ship mounted lifting equipment which lowers the containers to the dock where they are transported to the container storage area. A percentage of these containers are fumigated, which consists of the dosing of the containers with a charge of methyl bromide (up to 100 kilograms per container). Once fumigation has been completed, the fumigated containers are transferred to temporary storage, with the non-fumigated containers, where they remain until cleared by customs. Once cleared, the containers are then transferred off-site.

  As part of the container terminal operations, there is a potential for Dangerous Goods to be transported using shipping containers. These goods would be delivered to the site by the owners for transport to other ports within Australia or overseas. In some cases, Dangerous Goods may be shipped into the site for distribution to owners within the Newcastle region or further afield. The goods would only be stored for a relatively short time during the clearance period (customs) and the loading to, or unloading from, the ships.

- Bulk Liquid Precinct – a bulk liquid storage facility is proposed for the receival, storage, blending and distribution of fuels and biofuels for customers in the local region.

  The Bulk Liquids Precinct would likely contain 2 fuel terminals consisting of fuel tanks, transfer pumps, pipelines and truck loading bays. Fuels would be delivered to the site in tankers (ships) and transferred at a dedicated tanker unloading berth. Once berthed, flexible hoses would be connected to the ship and shore pipelines and the fuel transferred using ship mounted pumps. Once the fuel transfer is complete, the flexible hoses would be disconnected and the ship would leave the berth.

  Fuel bunkering operations may also occur at the site whereby fuel bunkering barges would be loaded from the terminals via the transfer pipeline (to and from the terminals to the wharf) and flexible hoses. Once the barge transfer is complete, the hoses are disconnected and the barges transferred by tug to the ship requiring fuelling. The barges are tied up to the ship and flexible hoses connected to the ship fuel filling manifold. Fuel is then transferred using Barge Mounted Pumps. On completion of the fuel transfer, the hoses are disconnected and the barge leaves the fuelling area.

  Fuel will be distributed to the Newcastle region and areas further afield by road tankers. Road tankers would be loaded using dedicated fuel transfer gantries constructed within the terminal areas. Trucks would load using loading arms, operated by a trained driver and computer based loading system. Once loaded, trucks would leave the Bulk Liquids Precinct and deliver the fuel off-site.

In addition the proposed concept includes:

- An Access Corridor – likely accommodating various infrastructure (e.g. road and rail infrastructure).
- Berth Precinct –containing seven berths (including a bulk liquids transfer berth) to support the functioning of the five land based operational precincts described above.

The descriptions presented above have been provided to explain the operations at the site in general. More detail on the potential operations in each precinct is provided in the Hazard Analysis section of the study (**Section 4**). The proposed concept has been prepared to show the potential best locations for the port-related activities nominated for the site. The location of each precinct has been selected with regard to strategic objectives (State and Regional), market analysis, known and predicted infrastructure provision, interactions with surrounding land uses and other barriers to development.

‘Environmental Envelopes’ are intended to identify an acceptable level of impact which the development of the various precincts would have cumulatively on the local environment. Prior to seeking approval, individual activities proposing to locate within each precinct would need to demonstrate that its impacts would not cause the environmental envelope criteria to be exceeded. This would be assessed as part of the more detailed Project applications for each proposed development on the site.

3.4 Description of Ship Movements and Operations

3.4.1 General Ship Operations

The existing Port of Newcastle currently operates as a Port under the Marine Safety Act 1998 (MSA) with ships moving to and from the berths under the direction and control of the Harbour Master who is an employee of NPC. Vessels entering, leaving or moving within the Port must take on board a Marine Pilot to conduct the vessel during such movement unless the vessel or its master is specifically exempted under the MSA from this requirement. Pilotage is provided in Newcastle by Marine Pilots who are appropriately trained and licensed in accordance with the Marine Pilotage Licensing Regulations. NPC is responsible for exercising Port safety functions in accordance with the terms of the Port Safety Operating Licence (PSOL) issued by the Minister for Ports. These functions include:

- Installation and maintenance of navigation aids;
- Vessel traffic control;
- Pilotage services;
- Dredging and maintenance of navigation channels;
- Hydrographic services; and
- Emergency environment protection services for dealing with pollution incidents in relevant waters.

Port safety functions are exercised in accordance with clear performance standards set out in the PSOL. Procedures and records relevant to port safety functions are documented and maintained within a quality management system that is independently audited and subject to continual improvement. The existing regulatory functions and operating practices of NPC will continue to apply to operations associated with the proposed concept.

Ships arriving off-shore would contact NPC's Vessel Traffic Information Centre (by radio) and either be directed immediately to a berth or anchor and await further directions. Once directed to enter the harbour, a Marine Pilot would travel to the ship in a small craft and board the ship, while off-shore. The Marine Pilot will provide local knowledge and shiphandling advice to guide the vessel on its course into the harbour and to the berth. The pilot operations would be conducted under constant radio contact with the Port facilities.

Tugs would be used within the NPC Port area to assist the berthing operations. Tugs would meet ships as they enter the harbour and, where required, assist the vessels into the berth to which they were directed. In some cases, ships would be fitted with shiphandling aids, such as bow and stern thrusters, which may, at the discretion of the Marine Pilot, allow un-assisted berthing (i.e. without the use of tugs). Notwithstanding this, tugs would be available to assist all berthing operations as required. The Marine Pilot would remain with the ship until it is securely berthed alongside the wharf to which it was directed. The masters of the vessel and the Marine Pilot would ensure that it is operated in accordance with the International Regulations for Preventing Collisions at Sea including the provision for safe speed, maintaining a look-out and avoiding collisions. Marine Pilots would have full control of the ships when entering the harbour, hence, the potential for excessive speed in the Port is negligible.

Once the cargo has been loaded/unloaded, the reverse operation would occur. A Marine Pilot would board the ship at the berth and guide the vessels departure. Where required, tugs would assist vessels to move into the main channel prior to leaving the Port. Once in the main channel, the Marine Pilot would direct sailing operations until the vessel is clear of the Port and at sea. The Marine Pilot would then disembark the ship and return to the Port via a small craft.

3.4.2 Vessels Carrying Bulk Liquids Cargos (Fuels)

Bulk liquid tankers would travel from other ports in Australia and overseas and enter the South Arm of the Hunter River directly on arrival at the Newcastle Port. Oil delivery planning would obviate the need for tankers to anchor off the Port, resulting in the potential for a ship grounding hazard in heavy seas. Once the tanker approaches the Port it would be met by a Marine Pilot (as detailed in **Section 3.4.1**), who will assist with the navigation duties whilst entering and traversing the Newcastle Port entry and Hunter River environs. As the tanker approaches the wharf it would be met by tugs that will be used to assist the berthing of the vessel. Key hazard reduction and safety features of this method of harbour entry and berthing are:

- Tanker does not anchor off-shore, eliminating the potential for the ship to be driven on to the coast by heavy seas;
- Pilot assisted navigation entering and in the harbour, which eliminates the hazard of unfamiliarity with the harbour entry and port navigation requirements; and
- Tug assistance in berthing, which reduces the risk of striking the wharf and damaging the tanker hull leading to release.

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4.0 Hazard Analysis

The operation of a port involves many hazards, most of which occur within the port confines and have little if any impact on the areas surrounding the Port precincts. However, the transport and handling of Dangerous Goods has the potential to result in incidents that may have impact consequences well beyond the boundaries of the Port operational areas.

The hazard analysis in this report has therefore been conducted on potential Dangerous Goods storages at the site. As noted earlier in this document, in some areas, the quantities of Dangerous Goods are reasonably well defined, however in other areas the exact quantities of Dangerous Goods stored and handled are not fully known. In these areas, the uncertainty makes the hazard analysis, and subsequent risk analysis, difficult. Notwithstanding this, in areas where the quantities of Dangerous Goods stored are uncertain, estimates have been made based on the typical goods stored and handled in similar port facilities.

It is noted that this report refers to “storage” and handling throughout the document. In general terms, storage would refer to the location of materials at a site on a constant basis (i.e. in tanks and storage sheds), however, as the proposed facility is a port operation, Dangerous Goods would not be stored for extended periods in the general cargo areas, storage for extended periods would only occur in the terminal areas at the Bulk Liquids Precinct. Typically, goods transported in containers would be delivered to the Port, either by road, rail or ship and would remain for only a relatively short period (nominally less than 3 days), before being moved to the next form of transport (i.e. loaded to ships, rail cars or trucks) and removed off-site.

4.1 Dangerous Goods Transit at the Proposed NPC Concept Plan

Dangerous Goods would not be transported in bulk via the Bulk and General Precinct or the Container Terminal Precinct. However, containers that transport Dangerous Goods may enter the Port and require temporary storage at the Container Terminal Precinct until clearance from customs and prior to transfer to the owner’s premises. Whilst containers may pass through the Bulk and General Precinct, it is not proposed to handled Dangerous Goods containers in this area.

As noted earlier in this assessment, at this stage of the development, the type and quantity of Dangerous Goods that may enter the Port via containers has not been defined and therefore it is difficult to provide a list of the exact quantities of Dangerous Goods that may be stored at the site. However, it is not anticipated that explosives would be transported through the site at this stage. To ensure appropriate hazard management is provided for the areas where Dangerous Goods may be stored, the protection systems proposed for inclusion at the site, for each Dangerous Goods Class, are listed in **Table 4-1**.

The quantities of each of the DGs listed in **Table 4-1** are estimated within each section of the detailed hazard analysis in the following sections.

Table 4-1: List of Dangerous Goods Protection Systems Proposed for Inclusion at the Site

Dangerous Goods Class	Precinct Location	Dangerous Goods Properties	Proposed Protection
Class 1	N/A	Explosives	Not intended to be stored at this stage
Class 2.1	General Purpose Precinct (Container Terminal)	Flammable Gas (Cylinders)	Separation, ventilation, placed clear of other areas on and off-site.
Class 2.3	General Purpose Precinct (Container Terminal)	Toxic Gas (cylinders/drums)	Separation, ventilation, placed clear of other areas on and off-site.
Class 3	General Purpose Precinct (Container Terminal)	Flammable Liquids (Drums)	Bunding surrounding the storage area and separation from other areas on and off-site.
Class 4	General Purpose Precinct (Container Terminal)	Flammable Solids (Drums)	Separation, ventilation, placed clear of other areas on and off-site
Class 5	General Purpose Precinct (Container Terminal)	Oxidising Agents (Drums, 1000 kg and 25 kg bags)	Placed clear of other areas on site, AN in container stacks no larger than 100 tonnes
Class 6	General Purpose Precinct (Container Terminal)	Toxic Substances (Drums, 1000 kg and 25 kg bags)	Bunding surrounding the storage area. Separated from other temporary Dangerous Goods stores
Class 7	N/A	Radioactive	Not stored
Class 8	General Purpose Precinct (Container Terminal)	Corrosive Substances (Drums, Isotainers, 1000 kg and 25 kg bags)	Bunding surrounding the storage area and separation from other Dangerous Goods areas.
Class 9	General Purpose Precinct (Container Terminal)	Environmentally Active Substance (Drums, Isotainers, 1000 kg and 25 kg bags)	Bunding surrounding the storage area and separation from other Dangerous Goods areas

4.2 Dangerous Goods at the Bulk Liquids Terminals

The bulk liquids terminals would store a range of fuels for distribution in the Newcastle region and further outlying areas. As noted above, the most likely layout would consist of two bulk liquids terminals located within the proposed Bulk Liquids Precinct. It is understood that the total annual quantity of fuels handled in the Bulk Liquids Precinct would be around a maximum of approximately 1,010 ML, however, the total storage quantity within the area is much less than this. An estimate of the total fuel quantity stored by fuel type, in the bulk liquids terminal area, is presented in **Table 4-2**.

Table 4-2: Typical Terminal Storage Tank Details

Tank No.	Product Stored	Tank Capacity (m^3)
ND1	Unleaded Petrol	24,000
ND2	Unleaded Petrol	24,000
ND3	Premium Unleaded	6,000
ND4	Ethanol	6,000
NN5	Bio-Diesel	6,000
NN6	Diesel	50,000
NN7	Fuel Oil	50,000
TOTAL		166,000

4.3 Dangerous Good at the General Purpose Precinct

The only Dangerous Goods proposed for storage/handling in the General Purpose Precinct is AN. As detailed in previous sections, AN will not be stored on-site. AN transported from the Port will be loaded directly to the ship from trucks and AN delivered to the Port would be unloaded directly to trucks and transported off-site.

Detailed AN storage risk assessments (Final Hazard Analysis or FHA, Ref. 6 and Preliminary Hazard Analysis or PHA, Ref. 7) have been conducted for the General Purpose Precinct. These risk assessments have identified that AN will be loaded to, or unloaded from, ships to and from the Port in the following quantities:

- Import – 6,500 tonnes
- Export – 3,000 tonnes

There will be no storage of AN at the wharf, the AN quantities listed above will be held on the ship only. The quantitative risk analysis in the PHA has been based on these quantities.

4.4 Safeguards at the Proposed NPC Port Facility

In addition to the safety management of the Port temporary Dangerous Goods storages (i.e. transit storages), and the safeguards listed above, a number of additional safeguards would be provided, these include:

- Fire hydrants located throughout the facility;
- Fire pumps that draw water from the harbour (unlimited water supply);
- Fire hose reels located throughout the buildings in the facility (i.e. administration areas, NPC Operations Precinct, etc.);
- Fire extinguishers located throughout the buildings in the facility and on each vehicle used within the Port (e.g. forklifts, trucks, etc.);
- Port Emergency Response Plan, with a dedicated Port Emergency Response Team; and
- Spill retention equipment (spill kits, booms, etc.) for quick response and deployment (including training of personnel at the Port).

4.5 General Hazard Identification

A hazard identification table has been developed and is presented at **Appendix A**. Those hazards, identified to have a potential impact off-site, are assessed in detail in the following section of this document.

Table 4-3 lists the type and quantity of Dangerous Goods that may be stored and handled at the proposed Site. It is noted that not all goods listed in **Table 4-3** are flammable or combustible liquids and therefore the hazard characteristics will be different for each type of Dangerous Goods "stored" and handled. It is also noted that the quantity of combustible liquids that are likely to be "stored" at the Site would trigger the requirements for compliance with the *NSW Occupational Health and Safety (Dangerous Goods Amendment) Regulation 2005* (the Regulation). The facility, under this regulation, would be classified as a 'Manifest' site. It is understood that NPC would develop the appropriate safety management systems to comply with the requirements of the Regulation. **Table 4-3** lists the characteristics of the Dangerous Goods that are likely to be stored at the site.

Table 4-3: Properties of the Dangerous Goods Proposed for Storage at the Site

Material Name	Class/ PG	Hazardous Properties
Flammable Gas (e.g. LPG, Acetylene)	2.1	Flammable gases may be heavier than air or lighter than air, depending on the gas stored. LPG/acetylene are heavier than air gases and can tend to accumulate in low lying areas, Ignition of a larger cloud of gas may result in flash fire or explosion.
Toxic Gas (e.g. Chlorine, Ammonia, Methyl Bromide)	2.3	Toxic gases are generally heavier than air and if release tend to accumulate on low lying areas being dispersed as they are carried downwind. The gases are toxic to people and usually affect the mucus membranes and breathing functions, causing involuntary coughing and eventual restriction of airways. Continued exposure to high concentrations of the gas may lead to fatality.
Flammable (alcohols based liquid-ethanol), Petrol and Combustible Liquid (diesel, fuel oil, etc.)	3 - II and III (e.g. Petrol)	Flammable liquids have a flash point below 60.5^{o}C. In the event of spill, the liquid may vaporise creating a vapour cloud that if ignited results in a flash fire and pool fire at the spill source. Pool fires may impact adjacent areas causing fire growth.
	C1	Combustible liquid with a flash point greater than 60.5^{o}C but less than 150^{o}C are classified as C1. Diesel fuel has a flash point of around 90-100^{o}C, hence, is classified as a combustible liquid. Under these circumstances, the liquid does not flash (vaporise) readily at ambient temperature, hence, vapour clouds do not form and flash fires, at ambient temperature do not occur. Localised heating and minor vapour generation may result in ignition and pool fire which may escalate to larger incidents
Flammable Solid (matches, metal powders, firelighters, naphthalene)	4.1 - II and III	Flammable solids may be ignited and catch fire causing intense local burning in the containers. The spread of fire is limited as the flammable materials would generally burn in-situ and would not spread much beyond the immediate storage.
Flammable Solid (generates flammable gas when wet) e.g. Dross or Aluminium Smelting by Products or Aluminium Remelting by Products	4.3 – III	Dross is a waste product from the aluminium smelting industry. It contains a number of compounds such as aluminium carbide, aluminium nitride and compounds of fluoride. In the event these products mix with water, there is a potential for a reaction that could release ammonia (NH_3), acetylene (C_2H_2) and methane (CH_4). With significant water contact with a large volume of dross, sufficient quantity of gas could be generated such that ammonia could reach harmful levels and acetylene and methane could reach the lower explosive limit.

Material Name	Class/ PG	Hazardous Properties
Oxidising Agents Ammonium Nitrate (with not more than 0.2% combustible substances, including any organic substance calculated as carbon, to the exclusion of any other added substance)	5.1 – III	Ammonium Nitrate (AN) is a stable solid, molten or in solution. It can become less resistant to detonation/ initiation due to the presence of contaminants or on exposure to high temperatures (e.g. fire or radiant heat). Other factors may also cause AN to become less stable and a greater risk of detonation, these are: • Exposure to chlorides or metals such as chromium, copper and nickel • A decrease in pH (i.e. more acidic) • Formation of bubbles in the molten AN or solutions of AN Explosion may occur due to string shocks (shockwaves from nearby explosions, high temperatures from adjacent fires, a smaller detonation can trigger a larger explosion.
Toxic Substances (herbicides, pesticides)	6 - II and III	Toxic substances may be stored in solid or liquid form. In the event of release there is a potential for the substance to reach escape off-site causing damage to the biophysical environment. The damage severity is dependent on the release quantity and location.
Corrosive Substances (acids and alkalis)	8 - II and III	Corrosive substances, such as sulphuric acid, may be stored in solid or liquid form. Like the toxic materials, In the event of release there is a potential for the substance to reach escape off-site causing damage to the biophysical environment. The damage severity is dependent on the release quantity and location. In some cases, release of corrosive chemicals (e.g. sulphuric acid) may lead to dangerous reactions with other substances (e.g. water, caustic) causing heating and violent reactions.
Environmentally Active Substances (battery powered vehicles, ammonium nitrate fertiliser not classified as 5.1)	9 – III	Environmentally active substances may be stored in solid or liquid form. In the event of release, there is a potential for the substance to reach the harbour with potential detrimental effects to the marine species in the harbour.

4.6 Detailed Hazard Identification – Bulk Liquids Storage

4.6.1 Bulk Fuel Delivery – Berth 7

Bulk fuel would be delivered to the bulk liquids storage area by ship. Ships would berth at Berth 7, closest to the Bulk Liquids Precinct. The ships would be berthed by a Newcastle Harbourmaster with the assistance of tugs. Once berthed, the ships would be tied to the wharf using double ropes (i.e. two ropes at every tie point). On completion of securing the ship the fuel transfer operations can commence. However, to minimise the potential for impact of spills to the Hunter River, an emergency boom containment system would be available at the wharf and ready for installation should a spill occur. A spill response procedure would be developed for boom deployment and training and boom deployment exercises would be conducted annually.

Prior to the commencement of fuel transfer it would be necessary to complete all of the requirements of the International Safety Guide for Oil Tankers and Terminals (ISGOTT). This guide requires a detailed checklist completion under the direction of the NPC Harbour Master before any transfers can be commenced. The standard also requires complete monitoring of the transfer by ships staff and land based (terminal) personnel. Ships staff must monitor pump flows and have a crew member located at the transfer point at all times. Terminal staff must be present at the wharf and monitor tank loading at all times.

Once the approval for transfer has been given by the Harbour Master, the flexible hoses can be connected to the ship and wharf and the system configured for fuel transfer. On completion of equipment configuration, inspection and nitrogen pressure test, the transfer operation can commence. The ship's officer in charge of the transfer would start the ship's pumps and continually monitor the transfer operation. On completion, the ship's officer would shut-down the pumps and the fuel would be drained from the lines into the transfer pipeline. The flexible lines would then be disconnected and the ISGOTT procedures completed prior to the ship leaving the wharf.

A number of hazardous incidents may occur during this operation, mainly as a result of leaks from the flexible lines. Whilst the fuel is contained in the pipework and flexible lines, there is a minimal risk of incident, as air is not present in the line during the transfer operation. As the line would be purged with nitrogen prior to discharge, there are no ignition sources in the line and as the lines are earthed to prevent static build up, the potential for this incident has been effectively controlled.

Once the pipelines are full and fuel is being transferred, the flexible lines may leak or rupture due to overpressure or wear (from continual handling). Overpressure protection is provided in flexible line design. The flexible lines will be designed to withhold the full "dead-head" pressure from pumps on all ships that deliver fuel to the terminal. Hence, the overpressure potential would be designed out of the system. However, continual handling of the lines may cause abrasive wear on the line exterior resulting in weak points and the potential for release of fuel to the wharf area. Minor nitrogen leaks would be immediately detected by the wharf/terminal staff and transfer not commenced until line repairs were effected. In the event of ignition of a minor leak, the fire would be contained in the immediate area of the release and local fire fighting equipment (extinguishers) would be available to commence fire fighting in the area. As the transfer of fuel at the wharf is conducted near the South Arm of the Hunter River, it would be advisable to avoid using any water for minor fires. Hence, first attack fire fighting by ship's staff and terminal operators would be conducted using fire extinguishers, this would form part of the fire fighting training at the Port. As the fire is fuelled by a flammable liquid, the capacity of a normal hand held fire extinguisher (dry powder – 9 kilograms) may not be sufficient to control the fire. Hence, larger wheeled extinguishers would be installed at the wharf that would provide sufficient fire fighting capacity for any small fires that may occur in the area. As minor fires would be controlled by ship's and terminal staff, and within the confines of the wharf (i.e. no off-site impact), this incident has not been carried forward for further analysis.

In the unlikely event of a flexible hose split (i.e. catastrophic failure), the hose contents would be released to the wharf. Staff on the ship and at the terminal would immediate identify the split/release and initiate shut down of the delivery by activating the emergency shut down valves at the ships manifold and wharf connection. However, this would not prevent the contents of the hose spilling to the wharf resulting in a pool of flammable liquid. As the wharf is located adjacent to the South Arm of the Hunter River, it is possible for the fuel to spill to the river itself, resulting in potential environmental damage. However, the wharf would be "bunded" with a raised concrete edge around the whole wharf. This, in effect, provides a containment bund for any spills. The wharf would be fitted with a drainage system that would direct any spills to a storage tank and oil separator. Any spills would be collected and treated to ensure no oil release occurs to the environment. However, it is noted that in the event of a spill of oil and ignition, a fire may occur, requiring the application of fire fighting foam. This could result in emulsification of the oil with the fire water, defeating the effectiveness of the oil separator. The spill retention tank would therefore be designed with the capability of retaining sufficient contaminated fire water (i.e. oil/water mix) without release to the environment. The exact details of the tank design would form part of the detailed terminal designs and would be incorporated within the specialist hazard and risk studies for the terminal sites.

Further, as part of the ISGOTT requirements, a containment boom is available for installation around the ship and wharf. Hence, in the unlikely event any fuel reaches the river, it would be contained in the immediate area of the wharf. As the wharf is bunded and spill booms are available, this incident has not been carried forward for further analysis under the assumption that dedicated emergency plans would be developed for the site.

In the event of a flexible line rupture, and fuel spill, a pool of flammable liquid would form in the area around the leak point. Ignition of diesel fuel in this incident is highly unlikely, as the fuel does not readily "flash" into vapour. However, petrol and ethanol vaporise more readily, resulting in a localised flammable vapour close to the release. As ship and terminal staff are present, there would be insufficient time for the flammable vapours to generate into a sizeable cloud before emergency response is initiated. Hence, vapour cloud explosion has not been considered in this scenario. However, immediate ignition of the release would result in a pool fire, within the bunded area on the wharf. Pool fires have the potential to radiate heat to the surrounding area resulting in impact to off-site structures and personnel. At present, there are no buildings on or within the vicinity of the wharf. However, as the area surrounding the facility becomes more developed, structures may be constructed close to the wharf area. Hence, it is important to identify the appropriate separation of buildings from the wharf operational area. Therefore, this incident has been carried forward for further analysis and determination of the impact zone around a pool fire at the wharf.

4.6.2 Bulk Fuel Transfer – Berth 7 to Terminal

The fuel would be delivered from the wharf to the terminal by an above ground pipeline located in a piperack. The pipeline would follow a direct route from the wharf to the bulk liquids area, entering the area from the northern side.

The single pipeline would be installed for the transfer of fuel products (ULP/Diesel/ Bunker Fuel Oil). Transfers would be performed as detailed via a Diesel/ULP Pipeline or a Marine Bunker Oil Pipeline.

The Diesel/ULP Pipeline would be constructed from steel and would be fully welded along its length. NDT of welds would be conducted on completion of construction to confirm weld integrity. The pipeline would also be "pigged" on completion of every transfer of flammable liquid and diesel to extract all fuel from the line so that any pipeline breaches (e.g. external interference) would not result in environmental release or fire incident involving higher risk materials (i.e. flammable liquid or diesel fuel). During transfer, fuel flow rates (from the ship and into the terminal) and fuel delivery reconciliation would be performed to identify potential leaks. Any discrepancies during transfer would initiate an immediate shut down and investigation.

The Marine Bunker Oil Pipeline would also be used for the transfer of marine bunker oil. Due to the higher viscosity of marine bunker oil, the pipeline would be heat traced and insulated to maintain product temperature during transfer. During transfers, fuel flow rates (from the ship to the terminal or vice versa) and fuel delivery reconciliation would be performed to identify potential leaks. Any discrepancies during transfer would initiate an immediate shut down and investigation. It is noted that the pipeline would rest full, hence, to minimise the potential for leaks, the pipeline would be inspected regularly to detect signs of loss of integrity. The testing and inspection would include visual inspection every hour during transfer operations and annual hydro test. It is also noted that the pipeline would be heated, hence, the potential for the formation of water in the pipeline from condensed water vapour in the fuel oil would be eliminated and the risk of internal corrosion would be low.

The potential for pipeline leaks are significantly reduced by the location of the pipelines in a dedicated piperack and pipeline corridor, allowing inspection for damage or other impacts that may cause loss of pipeline integrity. The location of the pipeline in a piperack corridor would also reduce the potential for impact from vehicles, as the rack would be readily identified by any vehicles in the area.

As noted above, the risk of internal corrosion of the pipeline is low as the pipeline would not rest with flammable liquids and the marine bunker oil would be heated to prevent high viscosity and the potential for the formation of condensation in the pipeline. Whilst internal pipeline corrosion potential is low, it would be difficult to identify corrosion on the outer pipe surface, as the pipeline would be externally insulated (lagged). To address this issue, the line would be "Pigged" at regular intervals (i.e. after every diesel or flammable liquid delivery) and an annual hydrostatic pressure test of the pipeline would be conducted. Hence, the risk of leaks from external corrosion in the pipeline is low.

The proposed design, construction, installation and management systems for the control of the pipeline have reduced the risks to a very low level, considering the pipeline would not carry diesel/ULP fuel for the vast majority of its life (i.e. pigged and purged after every use), and the regular testing of the pipeline (including annual hydrostatic pressure test). Incidents involving the pipeline are considered to be low risk and therefore have not been carried forward for further analysis.

4.6.3 Barge Operations (Transfer – Terminal to Berth 7 and Barge Loading)

The transfer of marine bunker fuel to the barge is performed using the pipeline analysed in **Section 4.6.2**. The risks associated with this transfer (i.e. pipeline risks) are the same as those analysed previously, hence, they are considered low and not carried forward for further analysis.

The marine bunker fuel will be transferred to the barge using flexible hoses. Following the same procedure for connection, transfer, isolation and disconnection as described and analysed in **Section 4.6.1**. Hazards and risks during this operation relate mainly to the potential for flexible hose failure and release of combustible liquid to the wharf. As noted earlier, the NPC Operations Precinct wharf would be bunded to contain any spills and spill containment booms would be available for deployment in the event of release between the ship and wharf. The potential for spill and environmental impact would be contained by the proposed spill containment measures, however ignition and fire could result in impact to surrounding wharf infrastructure. This incident, like the previous analysis (refer to **Section 4.6.1**), has therefore been carried forward for further analysis.

4.6.4 Bunkering Operations (Ship Refuelling)

Once the fuel transfer to the barge is complete, the barge would be towed by tugs to the ship that is to be refuelled. The transfer operation would be controlled by an experienced tug master who has the appropriate masters “ticket” for operating the tug. Whilst collisions between the barge and other vessels, and groundings are possible during the barge movements, the risk is very low due to the experience of the barge/tug operators, Newcastle harbour regulations (e.g. speeds and operations) and the controlled movement of the barge (i.e. direct between wharf and ship, barge does not generally travel around the harbour).

In addition to the experience of operators and the relevant controls, the barge would be constructed with a “double-bottom”, meaning that there is a space between the barge storage tanks and the external hull. Hence, in the event of a collision or grounding, breach of the tanks and release of fuel to the harbour is unlikely. It is noted that the speed of barge operations is a critical factor in minimising potential incident impact. Barges are limited to 5-6 knots (about 15 kph) therefore in the event of collision with another vessel or if grounded, the impact would be low and contained to the outer hull. Hence, this incident has not been carried forward for further analysis.

Once the barge has reached the ship that is to be refuelled, a similar procedure to that described in **Section 4.6.3** would be used. Flexible hoses would be connected between the barge and ship and once connection security and integrity has been established, the fuel oil would be pumped to the ship. During transfer of the fuel oil, the tank levels would be continually monitored by the ships staff and continually relayed to the barge operations. Hence, the potential for tank overfill is low. Once the ships tanks are filled, the remaining liquid in the flexible transfer lines would be drained back to the barge and the isolation valves on the barge and ship closed. The flexible hose would then be disconnected and stowed on the barge ready for the next operation.

As described in the previous transfer operations, there is a potential for flexible hose failure resulting in release of fuel oil and spill to the environment. To minimise the potential for this incident, the barge would carry containment booms that may be deployed to contain any spills that may occur between the barge and ship. Releases and spills on the barge or ship’s deck would be contained by the deck bunding. All “scuppers” on the barge and ship’s deck would be blocked during the transfer to ensure no minor spillage reaches the harbour.

In the event of a spill and fuel oil ignition, there is a potential for fire on the deck of the barge/ship. However, it is noted that the fuelling operation would be conducted on the harbour side of ships, not on the wharf side, hence, there would be considerable distance between the fuelling point and wharf infrastructure (well over 40 metres in most cases). Further, the fuelling operations will be staffed by barge and ship’s crews during the full transfer providing immediate response in the event of an incident (noting that barge and ship’s crews would be trained in spill and fire response). Impacts at the wharf from fire incidents at the barge/ships would therefore be minimal. Noting that there would be well over 100 metres between the barge and any off-site areas (i.e. outside the Port confines), the potential for impact from incidents in this area are low and therefore no incidents have been carried forward for further analysis.

4.6.5 Terminal Storage Tanks and Associated Equipment

The terminals in the proposed bulk liquids storage area would consist mainly of tanks contained within bunded areas (tank volumes in the order of 20,000 m^3) with bunds walls around 600 millimetres high. Whilst contained within the tanks, the fuel poses low risk, however, the space above the fuel surface in the tank ("air" gap or ullage space) would contain vapours that evaporate from the surface of the stored liquid. Normally, the concentration of vapours is well above the upper flammable limit of the vapours, hence, there is no potential for explosion and fire. However, when tanks are emptied there is a potential to draw air into the ullage space creating a flammable mixture (i.e. within the flammable range of the vapours when mixed with air). To prevent this occurrence, the flammable liquids tanks at the terminal would all be fitted with floating pans. The floating pans would remain in direct contact with the liquid surface, preventing the release of vapours into the ullage space of the tank. This eliminates the potential for a flammable vapour mix in the tank, as long as the floating pan remains intact.

Notwithstanding the fact that floating pans have been installed in the flammable liquid tanks, there is a potential for floating pans to sink, albeit unlikely, exposing the fuel surface to potential ignition sources. To prevent ignition, all tanks would be fitted with electrical equipment (level instruments, etc.) that comply with the requirements of the applicable hazardous area into which they are installed. Hence, ignition sources in the tanks have been eliminated.

The safety features installed in the tanks indicate that the risk of tank fire is low, however, this cannot be fully eliminated as tank fires continue to occur in the industry. Hence, a tank fire incident has been carried forward for further analysis to identify the potential for impact to adjacent sites.

In the unlikely event of a tank fire, there is a potential for the fire in the tank to spill into the bund. Tank failure could lead to loss of containment of the tank and the full tank contents spilling into the bund. The bund would contain the spill, however, the subsequent bund fire could impact adjacent sites. In addition, fuel transfer pipework failures in the bund could lead to a spill of flammable/combustible liquid into the bund that if ignited would lead to a bund fire. Further damage of the pipelines and tanks from the fire could release more fuel resulting in a full bund fire. A full bund fire incident has been carried forward for further analysis.

4.6.6 Tanker Loading Transfer Pumps and Associated Pipework

It is noted that road tanker filling operations are not yet fully designed, hence, operations at similar terminals have been investigated and a typical tanker fuelling operation assessed.

Fuel would be transferred from the tanks to the tanker loading bays/gantries using fuel transfer pumps.

Fuel transfer to the road tankers would be controlled by computer. The filling commencement would be initiated by the road tanker driver using a swipe card. Once initiated, the tanker transfer would commence and the specific pump would transfer the fuel to the selected bay/loading arm.

The pumps installed at the terminal would all be fitted with mechanical seals to minimise the potential for leaks at the pump seal housing. In addition, combustible gas detectors would be installed at the low point in the pump bund, to automatically shutdown loading and close control valves (isolating the transfer pipeline) in the event of a product leak. In the unlikely event of a pump leak, the fuel would spill to the ground under the pump and be contained in the pump gallery bund. Hence, there would be no release off-site. Pipework leaks from the pipelines between the tanks and the pumps would all be contained within the main tank bunding at the terminal. Hence, there would be no environmental impact from leaks in these areas.

In the event of an ignition of a fuel leak, a fire in the tank bunded area could result in a pump bund fire. However, the pump bund is relatively small and the impacts beyond the immediate area of the bund would be minimal and would not project beyond the boundaries of the Bulk Liquids Precinct, considering the separation distances provided between the Bulk Liquids Precinct and the adjacent precincts. In addition, the pump bunds would be protected by a foam deluge system, which is extended from the fuel loading gantry foam protection system. Hence, the risk of off-site impact is very low and this incident has not been carried forward for further analysis. It is noted that the tank/bund fire incidents carried forward for further analysis (refer to **Section 4.6.5**) are considerably larger than the pump bund fires and separation distances provided for these fires (from consequence analysis) would provide adequate separation for the pump bund fires.

4.6.7 Loading Bays & Gantries – Fuel Tankers Loading

Tanker Trucks would enter the designated loading bay and stop adjacent to the specified loading arm. Trucks would be loaded by bottom filling only (i.e. loading arms would be connected to filling points at the bottom of the tanker). The tanker driver would then connect the earthing strap to prevent static electricity generation during the transfer. In order to connect the loading arm, the tanker driver would activate the "driveaway" protection bar that is fitted across the fill points. Pushing down the bar, in order to connect the loading arm, activates the tanker brakes, preventing driveaway by error. Once the loading arm is connected to the tanker, the driver would swipe a card at the computer interface and the computer automatically configures the valves accordingly. In the event the driver incorrectly selects a loading arm (i.e. connects the wrong arm to the tanker), the computer would identify this error and alarm the driver and terminal operator that an incorrect connection has been made. Once the correct arm is selected and the appropriate connections made, the transfer can commence. Filling is continually monitored by the computer control and by the operator, who remains with the vehicle during the full filling cycle. Once complete (i.e. tanker full), the computer ceases the filling cycle, stops the pump and shuts all isolation valves. The driver can then disconnect the tanker and leaves the site, noting that the driver cannot leave until the loading arm is disconnected and the "driveaway" protection bar raised.

Minor spill may occur as a result of connection/disconnection of the loading arm. However, to prevent this dry break couplings would be used on all tankers, eliminating the potential for spills from this source. Loading arm leaks may occur at joints and flanges, resulting in minor spills to the ground around the tanker. Premature disconnection of the loading arm could occur due to driver/operator error, resulting in spills around the fill point area. These leaks & spills could have the potential to reach the environment (i.e. the adjacent sites of access road). However, to prevent this, the loading bays would be fitted with a "speed-hump" style bunded area, where spills would be contained. In the unlikely event a spill escapes beyond the loading bay bunded area, the drains adjacent to the bay would all report to a stormwater retention pit. Hence, leaks and spills would not escape off-site and would be contained, preventing environmental impact.

In the event of a coupling release (by fault or error) or a leak at joints/flanges/valves, the flammable/combustible liquid would form a pool under the leak/spill point. In the event of ignition, a pool fire may result. To minimise the potential for ignition, the terminal would control all ignition sources in the loading bay/gantry area. Smoking would not be permitted on site and no work would be permitted in the loading bay/gantry area unless a work permit has been issued. All equipment in the loading bay/gantry area would be installed in accordance with the appropriate hazardous area classification, hence, ignition would be unlikely in this area. However, notwithstanding the ignition control, there is still a potential for leak and fire, with impact off site. Notwithstanding this, the gantry areas would be fitted with fire detectors and foam deluge systems that would mitigate the potential impacts. In addition, the gantry area is relatively small, in comparison to the tanks and bunds and impacts at adjacent areas would not be significant as the pool fires would be relatively well contained within the site confines. As there are fire detection and automatic response systems and as the area is relatively small (i.e. contained fire), this incident has not been carried forward for further analysis.

4.7 Detailed Hazard Identification – Container Storage (Container Terminal Precinct)

4.7.1 Flammable Gas (Cylinders)

Flammable gases in cylinders may be delivered to the site in containers. In the unlikely event of a gas release, there is a potential for the gas to accumulate within the container itself, resulting in a flammable gas mixture that could be ignited causing flash fire or explosion. The release of gas from more than a single cylinder would be highly unlikely, due to the cylinder caps installed to protect the valves from damage. However, a single cylinder release from a valve or thread failure is more likely.

In the event of a release, the quantity of gas in a single cylinder (maximum cylinder water capacity of 500 litres) would escape and if immediately ignited would result in a jet fire at the leak point. This may impact adjacent cylinders causing cylinder explosion. In the event of delayed ignition, the released gas would mix with the air in the container. This would, at some point, reach flammable levels (i.e. lower flammable limit) and if ignited would result in an explosion. In the event of immediate ignition, the explosive force may cause overpressure impact off-site, hence, this incident has been carried forward for consequence analysis.

4.7.2 Toxic Gas Drums/Cylinders

Toxic gas in drums and cylinders may be delivered to the site in containers. In the unlikely event of a gas release, there is a potential for the gas to accumulate in the container itself and escape via minor holes and seal leaks at the doors. As the gas escapes, it would disperse with the wind and be carried down wind potentially impacting on and off-site areas in the wind direction. People off-site, in the direction of the wind, may be impacted by the toxic gas, resulting in injury and, in the worst case, fatality. This incident has therefore been carried forward for consequence analysis.

In addition to the storage of toxic gases that may enter the site in containers, it is necessary to provide fumigation services for a percentage of the containers that arrive from overseas, in order to kill potential harmful insects and wildlife that could be in the containers. To fumigate containers, methyl bromide is dosed to the container over a 24 hour period and then released to the atmosphere. Methyl Bromide is a HCFC gas and has the potential to add to the depletion of the ozone layer if released. Continued releases of this gas could have significant impacts on the environment and safety of personnel within the fumigation area. Whilst it is recognised that Methyl Bromide dosing is currently performed in all Ports within Australia where overseas containers are received, and that in many cases the gas is released directly to atmosphere, this practice is not recommended. There are a number of fumigation recycling systems available whereby Methyl Bromide is dosed to the containers and recycled through a “clip-on” front to the container door. Once the recycling process is complete the gas can be captured and scrubbed out of the exhaust stream prior to release to atmosphere. This system minimises the risk to people and the environment.

It is therefore recommended that the Container Terminal Precinct be designed and operated with Methyl Bromide dosing and capture systems to minimise the risk of harmful gas release to the atmosphere.

4.7.3 Flammable/Combustible Liquid

Flammable and combustible liquids may be delivered to the site in drums, within containers, or isotainers (20,000 litres tanks in a container sized frame). A leak of liquid from a drum would initially be contained within the container itself, gradually leaking from the container into the area surrounding the storage. The Container Terminal Precinct would be constructed with a Dangerous Goods holding area (i.e. transit storage) for the location of specific Dangerous Goods. The area would be constructed with spill containment to retain any releases that may occur. A minor spill from a drum would not result in a significant spread of the liquid, however, a leak from an isotainer could result in 20,000 litres being released to the bund. The simultaneous leak of isotainers is unlikely, hence, the containment of a single isotainer would be required within the spill containment area.

It is therefore recommended that the spill retention area, constructed for the storage of flammable liquids, be designed to contain a minimum of 20,000 litres.

In the event of a release of flammable liquid, the bund would contain the liquid, preventing spill to the environment. However, in the event of ignition of the flammable liquid, a pool fire would form radiating heat to the surrounding area. There is a potential for the heat radiation to impact off-site, hence, this incident has been carried forward for consequence analysis.

4.7.4 Flammable Solids

Flammable solids would be stored within the containers and ignition/fire would be highly unlikely as there are no ignition sources within the containers themselves. However, this does not mean to say that a fire within these materials cannot occur. Excessive heat from external sources (i.e. localised fires, high ambient temperature, etc.) may result in ignition of the materials within the containers resulting in fire.

In the event of a fire, there is a potential for the container roof to be damaged, releasing the fire externally to the container. In the event the container is located close to the site boundary, there is a potential for the heat to radiate to adjacent areas. This incident has therefore been carried forward for further analysis.

4.7.5 Solids that Emit Flammable Gas when Wet

As an example of this type of event, dross has been used to demonstrate the potential gas development from Class 4.3 Dangerous Goods becoming wet whilst stored at the site. This is a reasonable example for the Newcastle Port area as there are two major aluminium smelters in the Hunter Region and a large dross recycling facility at Kurri Kurri, hence, it would be anticipated that dross would be shipped through the site on a regular basis.

The dross or Class 4.3 solids would be stored at the Container Terminal Precinct in bulk bags in containers, or in plastic lined containers, and located in a dedicated container storage area at the site. Whilst the dross (Class 4.3) remains dry, there is little or no risk, hence, the prevention of contact between water and dross is important in managing the potential hazards of storage of this material.

There is a potential for rainwater to leak into a container resulting in contact between dross and water. Dross, however, would be stored in bulk bags (plastic) inside shipping containers, or in plastic lined containers, to ensure there is no contact between water and dross in the event of water ingress to the container. Whilst it is recognised that small amounts of dross dust may accumulate inside the container (between the container and bulk-bags or container and plastic lining) the quantity of dust would be insufficient to generate harmful quantities of ammonia (i.e. at levels that would exceed Lc50 concentrations, about 5,000ppm, Ref.9) or methane/acetylene (i.e. at levels that would reach LEL). As a check, the following analysis has been performed to identify the quantity of gas that may be generated.

Chemical Reactions

The mixing of water and dross results in a reaction that takes place according to the equation:

$$AlN + 3(H_2O) \rightarrow NH_3 + Al(OH)_3.$$

This calculation assumes that all water mixing with dross is available for reaction. However, this is not usually the case in water dross mixes. In reality, other reactions take place in conjunction with the aluminium nitride/water reaction above. One important reaction is:

$$2\ AlN + 3\ (H_2O) \rightarrow 2NH_3 + Al_2O_3$$

This reaction creates significant heat, liberating water in the form of vapour and steam, limiting the water that is available for reaction.

Ammonia Release Calculation

To estimate the quantity of ammonia released as a result of water ingress to the container, it is assumed that the dust within the container would accumulate to about 1 kilogram in total quantity. It is conservatively assumed that as the water gradually leaks into the container, it would contact all the dross, mix stoichiometrically and release the maximum quantity of ammonia available.

A stoichiometric mixture of 1 mole of AlN (41 kilograms) and 3 moles of H_2O (54 kilograms) gives 1 mole of NH_3 (17 kilograms). Proportionally, for 1 kilogram of AIN, H_2O = 1.32 kilograms and NH_3 = 0.42 kilograms. In previous studies conducted for the storage and handling of aluminium dross, it was identified that dross materials from smelters in Australia contain around 10% aluminium nitride and 1% aluminium carbides. Hence, the quantity of ammonia released is 10 percent of that estimated above for 1 kilogram of AIN, NH_3 release = 0.1 x 0.42 = 0.042 kilograms.

Assuming the leak occurs over an hour (i.e. a gradual leak into the container through a small hole and contact is made with the dross over this period (liberating the full extent of the ammonia over 1 hour), then the ammonia release rate would be 0.042/3600 = 0.014 g/s or 14 mg/s. This would not cause a significant impact in and around the container, even if the ammonia accumulated within the container. Once the container doors were opened, the gas would disperse rapidly and would not reach harmful levels at the site boundary (noting that there would be no continued gas generation once the dross dust in the container had reacted with the water).

Other Chemical Reactions

Two other important chemical reactions that may occur as a result of water and dross mixing are:

Al2C6 = 1 kilogram of water mixed with 2.33 kilograms of carbide leads to 1.44 kilograms of acetylene

Al4C3 = 1 kilogram of water mixed with 1.33 kilograms carbide leads to 0.44 kilograms of methane.

Hence, by proportion, 1 kilogram of carbide stochiometrically mixed with water may generate 0.62 kilogram of acetylene and 1 kilogram of carbide stochiometrically mixed with water may generate 0.33 kilograms of methane. Based on the premise that dross from Australian smelters contains around 1percent carbide, and assuming the carbide evenly distributes to form acetylene and methane, the quantity of acetylene and methane generated from 1 kilogram of dross is:

Acetylene = 0.05 x 0.62 = 0.031 kilograms or 31 grams

Methane = 0.05 x 0.33 = 0.017 kilograms or 17 grams

Similar to the ammonia scenario above, assuming the water leaks into the container over an hour period, the release rate would be:

Acetylene = 0.031/3600 = 0.0086 grams or 8.6 milligrams

Methane = 0.017/3600 = 0.0047 grams or 4.7 milligrams

These quantities of gas are very small and would not result in the development of a flammable mixture within the container (noting that there would be no continued gas generation once the dross dust in the container had reacted with the water).

Summary of Dross Storage Analysis

Based on the analysis conducted above, the storage of dross (Class 4.3) is considered to be adequately managed with respect to the prevention of dross (Class 4.3) and water mixing. In the event of container damage or leak (i.e. water ingress from rain), there would be insufficient gas generated to result in the accumulation of toxic or flammable gas that would impact off-site areas. Hence, this incident has not been carried forward for further analysis.

4.7.6 Oxidising Agents

The most likely oxidising agent that would be pass through the site would be AN. This has been assessed in detail in **Section 4.8**.

4.7.7 Toxic Substances

Toxic substances may be delivered to the site in liquid and solid form in drums or packages within containers. In solid form, spills and releases would be localised and retained within the container itself, resulting in no impact outside the container itself. However, liquids may be delivered to site in drums, within containers, or isotainers (20,000 litre tanks in a container sized frame). A leak of liquid from a drum would initially be contained within the container itself, gradually leaking from the container into the area surrounding the storage. The Container Terminal Precinct will be constructed with a Dangerous Goods (including toxic substances) holding area (i.e. transit storage) for the location of containers and isotainers containing toxic materials. The area would be constructed with a bund to contain any spills that may occur. A minor spill from a drum would not result in a significant spread of the liquid, however, a leak from an isotainer could result in 20,000 Litres being released to the bund. The simultaneous leak of isotainers is unlikely, hence, the containment of a single isotainer would be required within the bunded area.

It is therefore recommended that the Toxic Substances bund be constructed to retain a minimum of 20,000 litres.

In the event of a release of toxic substance, there is also a potential for impact to people, however, the site would be operated with an Emergency Response Plan that would contain a response procedure to spills of chemicals. The procedure will include the wearing of the appropriate personal protective equipment (PPE) to minimise the risk of impact to people involved with spill clean up. As spill kits and other spill response equipment will be available at the Port, along with a trained Emergency Response Team, the risk of impact to people is low.

Construction of the bund would minimise the potential for impact to the environment and the risk of environmental damage would be low. The trained emergency response team, along with a dedicated emergency response plan would minimise the potential for impact to people. Assuming the bund for toxic substances is constructed, and the emergency response plan for the site is effective, the risk of impact is considered to be low. Hence, this incident has not been carried forward for further assessment as there will be no off-site impact.

4.7.8 Corrosive Substances

Like toxic substances, corrosive substances may be delivered to the Site in liquid and solid form. Hence, releases of solids would be retained within the container itself and there would be little if any impact beyond the container itself. Potential leaks of corrosive liquids delivered to site in drums or isotainers, would be essentially contained within the container itself and there would be no impact beyond the immediate container area. However, a leak from an isotainer could result in 20,000 litres of liquid being released to the environment. Like the toxic liquids, the corrosive liquids storage area will be bunded and larger spills would be retained within the confines of the bund and there would be no release off-site.

It is therefore recommended that the Corrosive Substances bund be constructed to retain a minimum of 20,000 L.

4.7.9 Environmentally Active Substances

Similar to the toxic and corrosive substances, the environmentally active substances may be delivered in solid or liquids form in bags, drums or isotainers. Releases of solids (i.e. broken bags) would be retained within the confines of the container and there would be no release to the environment. However, liquid releases, particularly isotainer leaks, may escape beyond the immediate area of the storage causing damage to the biophysical environment. To minimise the potential for this incident to occur, the Environmentally Active Substances holding area (i.e. transit storage) would be bunded to contain spills and prevent damage to the environment.

As environmentally active materials may be delivered in isotainers, it is recommended that the environmentally active substances bund be constructed to retain a minimum of 20,000 litres.

Assuming that the materials would be located at the site in transit only and that emergency response plan would be effective in managing the spill clean up, the risk of release to the environment or impact to people is considered to be low and therefore this incident has not been carried forward for further assessment.

4.8 Detailed Hazard Identification – Ammonium Nitrate (General Purpose Precinct)

AN is a Class 5.1 (oxidising) solid with a packaging group III classification. It is a hygroscopic colourless crystalline solid, which is very soluble in water. In the dry state it is non-corrosive, but, when moist, it reacts with various metals forming a variety of compounds, some of which are highly unstable (e.g. copper nitrate tetramine). The main decomposition product when AN is heated above 200^{o}C is N_2O, but above 250^{o}C other oxides of nitrogen can be formed.

The most common form of AN is fertiliser, which exists in a variety of forms but these are classified into two groups according to the nitrogen content. All fertilisers with a nitrogen content of more than 28percent are assumed to have the same hazard potential, although it is known that low density material and compounds containing potassium are more likely to detonate. It has been assumed that the AN would be in a relatively pure form with little if any potassium as this is the more common product used for fertiliser. Hence, the likelihood of detonation is diminished.

Pure AN is not shock or friction sensitive and cannot be induced to detonate under normal storage conditions; however, the following characteristics increase its sensitivity:

- High temperature.
- Confinement.
- Contamination with organic substances.

There is some confusion and uncertainty in the literature and in safety reports about the explosive power of AN and whether it detonates or only deflagrates (detonation results in shock compression or explosion, deflagration is rapid burning and gas expansion). Experiments have shown (Ref. 10) that, to all intents and purposes, AN is incapable of deflagration or detonation unless at least some of the stack is heated above its melting point. Detonation, which is characterised by a supersonic pressure wave moving through the material, can occur only if the dimensions of the explosive are greater than some particular value, known as the critical charge diameter. For solid AN this diameter is about 3 metres which implies that a stack of less than 300 tonnes is unlikely to detonate. The corresponding diameter for molten AN (i.e. heated by fire) is only about 100 millimetres.

Deflagration is not constrained by dimensions and occurs when a subsonic combustion generated pressure wave moves through the material. Under certain conditions the energy released and the damage caused by the two processes (detonation and deflagration) in a sample of AN can be different, but, in hazard analysis, it is not usual to distinguish between them and therefore to refer to these only as an explosion.

In the event of a large fire during an AN transit, a pool of liquid AN would form at the side of the stack that is nearest to the fire. If this pool is struck by a high speed projectile (e.g. something falling from the roof or part of a drum that has exploded) then a local explosion will occur sending a shock wave into the main AN stack that has not melted. If this stack contains just less than 300 tonnes it will not support a detonation but will deflagrate and, in doing so, will release an amount of energy equivalent to 41 tonnes of TNT (Ref. 10). As the proposed operations at the site include the transit of AN only, whilst containers are transported off-site, it is unlikely stacks exceeding 300 tonnes would accumulate before the containers are removed off-site.

Whilst the discussion above indicates that hazards related to the storage of AN may result in explosion, this is related to the impact on an AN stack by fire. It is clear that a stack of AN will not explode without both heat (fire) and shock (impact). Hence, as the AN would be contained in containers, the likelihood of heat impact is low and the potential for impact from external sources greatly diminished.

In August 2009, a quantitative risk analysis was completed (Ref. 7) detailing the hazards and risks associated with the AN “storage” and handling operations. This analysis identified that fire and explosion risks had the potential to impact off-site, hence, detailed consequence, frequency and risk analysis was conducted. The results of this study are carried forward for further review in the following sections of this assessment.

4.9 Ship Movement Hazards

During the movements of ships in the Port of Newcastle there is a potential for collision between ships moving in and out of the Port or between ships moving to or from berths and stationary vessels alongside wharves.

Ship collision is highly unlikely due to a number of factors including the following:

- Vessel scheduling, tracking and communication systems as managed by NPC’s Vessel Traffic Information Centre.
- Maritime rules and regulations for ship movements (i.e. direction of passing, rules for right of way, etc.).
- NPC Port Parameters and Berthing Priority (i.e. entry and exit of ships from the harbour occur one at a time, no multiple entry exits).
- Tugs available to assist movement and berthing operations.
- Use of Marine Pilots for all ship movements in and out of the harbour.

The key component in the Port operation is the use of a Marine Pilot for all ship movements in the Port. The use of Marine Pilots prevents ship’s Masters, who may be unfamiliar with the, making errors of judgement resulting in serious consequences such as collisions or grounding. Marine Pilots undergo a comprehensive program of training and examination before obtaining a license to operate in the Port. Pilotage activities are supported by sophisticated systems including:

- Vessel booking and scheduling system, including information about the vessel such as its dimensions, draft, weight and the forms of propulsion available.
- Continuous automated monitoring of weather and sea state conditions with data available in real time.
- Dynamic Under-Keel Clearance system to predict the distance between the keel of the vessel and the bed of the harbour based on vessel parameters, hydrographic data and current tide, weather and sea state information.

- Portable Pilot Units – portable computer system with global positioning system that is carried on-board by pilots and used to track vessel movements during the pilotage against planned pathways.
- Navigation Aids such as lead lights and channel markers.

The use of these systems is supported by the guidance contained within the Port priority system, quality management system and standard operating procedures.

As noted in **Section 3.4.2**, bulk liquid vessels will be directed immediately to the Bulk Liquids Precinct unloading wharf, without the requirement to anchor offshore. Hence, there would be a low risk of grounding as a result of anchoring and awaiting a berth allocation.

NPC maintains a Marine Oil and Chemical Spill Contingency Plan to deal with any spills of oil or chemicals which may enter the Hunter River. The plan is integrated with the Newcastle Local Disaster Plan and covers all aspects of spill response including planning, notification, containment and clean-up techniques.

A review of the potential impacts as a result of collisions indicates that the consequences of a release of Dangerous Goods would be negligible, due to the safeguards used at the Port. This is supported by the existing incident record at the Port showing no collisions between ships in the past 10 years. Based on this assessment, no further analysis has been conducted.

4.10 Detailed Hazard Identification – NPC Operations Precinct

The NPC Operations Precinct would contain a number of minor Dangerous Goods storages such as paint, aerosols, corrosive liquids, etc., all stored in workshop areas in flammable/corrosive liquids cabinets. Hence, the risks associated with these goods is low and incidents, such as spill and fire would be contained within the site confines, resulting in no impact off-site.

In addition to the minor storage facilities, diesel and ULP is stored in tanks for fuelling of vessels (boats) and vehicles owned by NPC. Diesel would be stored in a 10,000 litres underground tank and ULP would also be stored in a separate 5,000 litres underground tank. Both tanks would be double walled to minimise the risk of release to the environment (i.e. leaking tank). The vapour space between the walls of the tank would contain leak detection and therefore any releases from the inner tank would be detected and alarmed. The risk of environmental impact from tank leaks is therefore low and no further assessment is conducted.

Fuel would be delivered to site using road tankers. The tankers would park adjacent to the fuel tank filling point in a bunded area. The tanker driver would then dip the tanks to ensure there is adequate space to receive the delivered fuel. The driver would then connect a flexible hose between the tanker and tank filling point and commence the fuel delivery, dipping the tanks regularly to ensure there is adequate ullage in the tank to receive the fuel. Once full, the driver would shut-off the fuel delivery, drain the hoses to the tank, remove and stow the hoses on the tanker and leave the site.

During the tank filling operation there is a potential for fuel spill to occur from hose leak or rupture, or from connection failure. As the driver is located close to the tanker at all times, activation of the emergency stop button can be effected to stop the fuel release. In the worst case, the fuel from the hose would spill to the containment area under the tanker, resulting in a pool within the bund. The containment of the fuel would prevent any environmental impact, however, in the event of ignition of the fuel, a pool fire would occur, with the potential to impact areas surrounding the fuel delivery point. This incident has been carried forward for further analysis to determine the fire impact distance.

Vehicles are refuelled using a bowser type operation (i.e. similar to a service station). In the event of a fuel spill at the bowser (i.e. failed bowser hose, leaking pump, etc.), the fuel would be contained within the immediate area of the bowser, which would be fitted with a containment bund (speed hump). Hence, there would be no impact to the environment. However, if the fuel release was ignited, a pool fire would result with the potential to radiate heat to the surrounding areas. This could impact the adjacent land uses to the NPC Operations Precinct, hence, this incident was carried forward for further analysis.

NPC vessels (boats) are also refuelled at the wharf. This is performed from a bowser on the wharf, adjacent to the boat mooring area. Vessels (boats) are refuelled in a similar manner to vehicle refuelling, using the bowser hose. A filling nozzle is inserted into the vessel fuel tank and the tank filled under the direct supervision of the operator. In the event of a leak (e.g. hose failure), there is a potential for release to the environment (particularly the South Arm of the Hunter River). In this event, spill retention booms and spill response kits would be located on the wharf adjacent to the refuelling area. NPC personnel, involved with refuelling, would be trained in spill response and involved in emergency response drills conducted annually. Based on these safeguards, the risk of permanent impact from spills is considered low and no further assessment is performed.

Like the vehicle refuelling incidents, spills during vessel (boat) refuelling may result in ignition and fire, causing heat radiation impacts to the surrounding areas. Fire dimensions would be similar to those detailed above, as the fuel would be contained either on the wharf, or within the confines of the vessel (boat). Hence, this incident has been carried forward for further analysis to determine the potential impacts to the surrounding land uses.

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5.0 Consequence Analysis

5.1 Incidents Carried Forward for Consequence Analysis

As a result of the Hazard Analysis, the following incidents have been carried forward for consequence analysis.

Bulk Liquids Precinct

- Fuel release at the bulk liquids wharf, ignition and pool fire.
- Ignition of fuel in a bulk liquids terminal storage tank, tank roof fire.
- Release of fuel into a bulk liquids terminal tank bund, ignition and pool fire in the bund.

Container Terminal Precinct

- Flammable gas leak into a container, from a gas cylinder, delayed ignition and explosion.
- Flammable liquids release, ignition and pool fire.
- Flammable solids ignition and fire within the container.
- Toxic gas release and dispersion downwind towards sensitive land uses (off-site).

General Purpose Precinct

- Fire in the AN transit area leading to explosion with the potential to impact adjacent sites.

NPC Operations Precinct

- Fuel release, ignition and fires at the NPC Operations Precinct.

Each incident has been assessed in detail in **Appendix B**. All incidents assessed were for impacts at specific heat radiation levels (fire), overpressure (explosion) and toxic gas impact (toxic gas release). The distances to the specific levels of consequence impact were calculated to determine whether the impact at the site boundary exceeded the acceptable impact criteria.

HIPAP No.4, Risk Criteria for Land Use Safety Planning (Ref. 4), indicates that the following heat radiation and explosion overpressure should not be exceeded without further assessment (i.e. risk analysis).

- Heat radiation Impact – 4.7 kW/m^2.
- Explosion Overpressure – 7 kPa.

Hence, any incident that has a heat radiation or explosion overpressure impact above this level would require further review (risk analysis).

5.2 Bulk Liquids Incident Consequence Analysis

5.2.1 Fuel Spill and Fire – Berth 7

Figure 3-1 shows the current bulk liquids berth location and surrounding areas. At present there are no structures within the vicinity of the wharf as the wharf and adjacent areas are currently under development. During transfer of fuels, the ship would be located directly to the north of the bulk liquids terminals (i.e. adjacent to the wharf). In the event of a fuel release on the wharf, ignition and fire, the heat would be radiated towards the ship and surrounding areas. The ship is steel and has a fire protection system installed. Personnel on the ship would activate the fire protection systems providing cooling water for the ship and mitigating any impact on the ship. The ship itself would provide a “shield” form the heat radiation impact into the South Arm of the Hunter River, hence, there would be no impact in this direction. The main impact would be towards the bulk liquids terminals.

A detailed consequence analysis has been conducted in **Appendix B. Table 5-1** summarises the heat radiation impacts from a fire at the wharf as a result of a fuel release, ignition and fire. A review of **Table 5-1** indicates that the impact distance to 4.7kW/m2 for incidents at the wharf is 25.4 metres. A review of the wharf layout indicates that there is adequate space in the berth area to provide the required separation without impacting adjacent facilities. The adjacent wharf (Koppers wharf – west) is over 50 metres from the bulk liquids transfer area, hence, there would be no impact at this location from incidents at the bulk liquids wharf.

A detailed review of the impacts and risks should be conducted in the specific terminal and wharf hazard studies, however, based on the proposed concept, the bulk liquids wharf could be configured such that acceptable hazards and risks are not exceeded.

Table 5-1: Distance to Selected Heat Radiation Impact - Flexible Hose Rupture and Fire

Heat Radiation Level (kW/m^2)	Distance (m)
35	9.8
23	11.8
15	14.4
12.5	15.8
8	19.5
6	22.5
4.7	25.4
2	38

5.2.2 Terminal Tank Roof and Bund Fires

A detailed analysis of fires in tanks and bunds at the proposed Bulk Liquids Precinct has been conducted in **Appendix B**. In summary, typical tank sizes for mid-sized terminals (the types proposed for the site) were estimated, and the corresponding bunds determined from AS1940 (Ref.12). Based on the proposed storage quantities at each terminal, a typical terminal layout was developed and the heat radiation from fires in bunds was assessed. Fires in bunds were assessed to be the worst case incident at the terminals due to the bund size in relation to the smaller tank diameters. The results of the heat radiation impact analysis is summarised in **Table 5-2**.

Table 5-2: Distance to Selected Heat Radiation Impact Fuel Terminal Full Bund Fire

Heat Radiation Level (kW/m^2)	Distance (m)
35	30.5
23	35.8
15	43.3
12.5	47.4
8	59.0
6	68.5
4.7	77.5
2	120

It can be seen from **Table 5-2** that the distance to a heat radiation level of 4.7 kW/m^2, the selected maximum permissible heat radiation impact level (Ref. 4), is 77.5 metres. A review of the Bulk Liquids Precinct indicates that the bulk liquids terminal(s) could be located such that there would be no consequential impacts to the adjacent properties to the south (IIP) and west (OneSteel) and that any impacts on the adjacent precinct to the east (Container Terminal Precinct) could be managed by locating and potentially hazardous storage areas clear of the potential impact zone.

It is noted that the assessment conducted in this study has not considered detailed safeguards that may be incorporated within the specific terminals by terminal owners. As the study conducted in this document is based on concept layouts only, it is not possible to provide detailed safeguards and management systems for the terminals. However, the implementation of such safeguards would be expected to provide effective risk reduction with the potential to reduce the impact contours (risk) such that the risk criteria published in HIPAP No.4 would not be exceeded at the Bulk Liquids Precinct boundary. It is noted that terminal operators would be expected to submit individual preliminary hazard analysis studies as part of the Project applications for the proposed bulk liquids terminals. These studies would detail the assessed risks, meeting the recommended risk performance criteria in this document.

Based on the analysis of the bulk liquids concept, it is considered that the Bulk Liquids Precinct can be configured such that impacts to off-site adjacent areas does not exceed the acceptable impact criteria and that impacts to adjacent precincts can be managed by the establishment of Non-Hazardous/ Dangerous Goods storages clear of potential impact zones.

Notwithstanding this, it is recommended that the detailed hazard analysis studies conducted for the specific bulk liquids terminals include the assessment of risks to identify whether the buffer zones assessed in this concept analysis can be reduced by the introduction of terminal safety features (e.g. fire detection and protection systems, emergency response plans, etc.).

5.3 Container Terminal Precinct Incident Consequence Analysis

5.3.1 Flammable Gas Explosion

In the event of a flammable gas release (e.g. LPG) from a cylinder into a container, the gas would mix with air resulting in a flammable mixture that if ignited may result in explosion. A detailed gas release and explosion analysis was conducted in **Appendix B**. This analysis identified that the distance to an explosion overpressure of 7kPa was estimated to be 78 metres.

It is therefore recommended that in the detailed design phase that containers holding flammable gas be stored no closer to the container terminal boundary than 78 metres.

5.3.2 Flammable Liquids Pool Fire

In the unlikely event of a release of flammable liquid from an isotainer into the flammable liquids bunded area, there is a potential for the liquid to ignite resulting in a pool fire. The fire would radiate heat to the surrounding area with the potential to impact off-site. The maximum permissible heat radiation level at the site boundary, before risk assessment is required, is 4.7kW/m^2 (Ref.8). A detailed heat radiation impact analysis was conducted and is shown in **Appendix B**. The results of the analysis, showing the distance to various heat radiation levels is presented in **Table 5-3**.

It can be seen from **Table 5-3** that the distance to a heat radiation level of 4.7kW/m^2 is 26.5 metres.

Hence, it is recommended that the isotainer and flammable liquids storage areas be located a minimum of 30 metres from the Container Terminal Precinct boundary and the same distance from the adjacent precincts (Bulk Liquids Precinct and the General Purpose Precinct). It is also recommended that the assessment conducted in this study for the heat radiation impact from flammable liquids fires be reviewed during the detailed design of each facility.

Table 5-3: Distance to Selected Heat Radiation Impacts - Isotainer Storage Area Bund Fire

Heat Radiation Level (kW/m^2)	Isotainer Storage Distance (m)
35	10.3
23	12.4
15	15.1
12.5	16.4
8	20.5
6	23.5
4.7	26.5
2	40

5.3.3 Flammable Solids Fire

Flammable solids would be transported in containers and may be ignited whilst in transit storage at the Site. As the materials are solids, they do not spread like flammable liquids and therefore the fire is contained in the immediate vicinity of the container itself. In the worst case, the container roof would collapse and the fire would be exposed across the top of the whole container.

A detailed fire consequence analysis has been conducted in **Appendix C**. The summary results of this analysis are shown in **Table 5-4**.

It can be seen from **Table 5-4** that the distance to a heat radiation level of 4.7 kW/m^2 is 14.4 metres.

Hence, it is recommended that the isotainer and flammable solids storage areas be located a minimum of 14.4 metres from the Container Terminal Precinct boundary and the same distance from the adjacent precincts (Bulk Liquids Precinct and the General Purpose Precinct). It is also recommended that the assessment conducted in this study for the heat radiation impact from flammable solids fires be reviewed during the detailed design of each facility.

Table 5-4: Distance to Selected Heat Radiation Impacts – Flammable Solids Container Fire

Heat Radiation Level (kW/m^2)	Isotainer Storage Distance (m)
35	5.6
23	6.8
15	8.3
12.5	9.1
8	11.2
6	12.9
4.7	14.4
2	21.5

5.3.4 Toxic Gas Release

Ammonia

Ammonia would be transported in cylinders (1,000 kilograms) and possibly horizontal tanks (2,000 kilograms). Cylinders would be transported in the container in the upright position, with the valves at the top. Horizontal tanks would also be stored with the valves at the top. Valve caps and covers are installed on the cylinders and tanks, and damage to valves is highly unlikely, however, as a worst case incident a broken valve has been assumed.

In the event of a broken valve, the gas would be released via the hole remaining where the valve is fitted to the cylinder. Whilst it is recognised that excess flow valves are fitted to cylinders and tanks, this has not been included in the assessment for the sake of conservatism. A leak and dispersion analysis was conducted and is detailed in **Appendix B**. The results of the analysis identified that there is a potential for fatality from ammonia gas at distances of up to 320 metres the ammonia transit area in the Container Terminal Precinct.

The location of the storage of toxic gases would depend on the results of the assessment of the gas of highest toxicity. For example, chlorine incidents may result in a longer downwind distance for potential fatality/injury incidents. Hence, the recommended placement of the toxic gas storage area would depend on the results of the chlorine assessment. The recommendation relating to the location of the storage of toxic gases is made in the chlorine consequence analysis (refer **Section 5.4.2**).

Chlorine

Chlorine would be transported in 70 kilogram cylinders and 900 kilogram drums. Chlorine cylinders and drums have an extremely robust cap fitting and drums have concave dished ends with the valves set back inside the concave section of the end. The potential for damage to valves in chlorine cylinders and drums is negligible, and anecdotal evidence indicates that such incidents have not occurred in the industry. However, leaks at valve connection and through valve seats is possible, albeit very low probability. A detailed chlorine leak and dispersion analysis has been conducted in **Appendix B**. The results of this analysis indicates that there is a potential for fatality from chlorine gas release at distances up to 558 metres from the chlorine storage area at the container terminal. The study also identified that there is a potential for injury as a result of chlorine release up to a distance of 1,558 metres from the chlorine storage area at the Container Terminal Precinct.

The potential fatality and injury distances are higher than those for ammonia, hence, the location of the toxic gas storage area would be governed by the chlorine analysis. A review of the proposed Container Terminal Precinct layout indicates that the storage for toxic gases could be located clear of adjacent properties, however, by locating the toxic gas storage close to the berths in the container terminal area, the maximum distance to the site boundary (adjacent industrial site to the south) is only 500 metres. Therefore, the toxic chlorine plume may extend into the adjacent site at potentially lethal concentration. In addition, there is also a potential for a harmful (injurious) toxic plume to reach the residential areas to the south, as these area are closer than 1,550 metres. This incident has therefore been carried forward for risk review.

5.4 Ammonium Nitrate Storage Explosion – General Purpose Precinct

A detailed AN quantitative risk analysis (Ref. 7) was conducted as part of the approval for preliminary operation to occur in the General Purpose Precinct. This study also conducted a detailed consequence analysis for fire, explosion and toxic plume risks.

The study analysis showed that at the nearest sensitive land uses (School - 1.7 kilometres), only an explosion of 6500 tonne of AN could cause injury to any occupants. The explosion analysis did not identify any explosion case that would cause a fatality due to overpressure in the residential areas. At the nearest residence (1.4 kilometres) an explosion of 3000 tonne or 6500 tonne could cause injury to occupants. The analysis identified that an explosion of 6500 tonne AN would potentially injure a much larger number of people than an explosion of 3000 tonne AN, due to the larger area exposed to an overpressure of greater than 7 kPa. This incident has been carried forward for risk review.

Fires involving ammonium nitrate can generate toxic gases (e.g. nitrous oxides). Hence, the analysis conducted for AN transit (Ref.7) identified that in the event of fire, a toxic smoke plume could result in fatalities up to 350 metres from the fire location. This distance is contained within the site, therefore no further analysis is conducted.

5.5 NPC Operations Precinct Incident Consequence Analysis

The hazard analysis (refer to **Section 4**) identified that incidents associated with the underground tanks would not result in impact off-site. However, incidents resulting in release of fuels (diesel/petrol) during filling of tanks, fuelling of vehicles and/or boats could result in fuel ignition and fire, leading to heat radiation impact to the surrounding areas.

A detailed consequence analysis for fuel releases during filling of tanks, fuelling of vehicles and/or boats has been conducted in **Appendix B**. It was identified that the worst case incident related to releases and subsequent fires during the filling of the underground tanks. **Table 5-5** summarises the results of this analysis.

It can be seen from **Table 5-5** that fires as a result of spills during underground fuel tank filling could impact the off-site areas within 16.1 metres of the filling point with a heat radiation level of 4.7 kW/m^2. A review of the NPC Operations Precinct indicates that a there would be sufficient area within this precinct to locate the underground tanks greater than 16.1 metres from the site boundary and adjacent precincts. Hence, there would be no impact off-site (adjacent industrial areas) or cumulative hazards/risks to adjacent precincts.

Table 5-5: Distance to Selected Heat Radiation Impact - Underground Fuel Tank Filling Incident Fire

Heat Radiation Level (kW/m^2)	Distance (m)
35	6.2
23	7,6
15	9.2
12.5	10.1
8	12.5
6	14.3
4.7	16.1
2	24

5.6 Emergency Response

The analysis conducted in this study has identified a number of incidents that may occur with the potential to impact off-site. In many cases, the development of these incidents can be mitigated by early response (i.e. local fire fighting, evacuation, etc.). Whilst it is recognised that the proposed concept would be subject to the DoP seven stage process (Ref.4), it is reiterated that an effective emergency plan would provide for a significant impact reduction in the event of an incident occurring.

Whilst it is recognised that NPC currently operates an emergency response plan, it will be necessary to ensure that this plan is regularly updated to include additional facilities as they are developed within the various precincts at the site. Hence, it is recommended that a methodology be developed for the regular update of the existing NPC emergency plan, for the Port of Newcastle, to incorporate additional operational facilities as they are developed.

6.0 Risk Analysis

6.1 Incidents Carried Forward for Risk Analysis

The consequence analysis identified that the impact distances for the majority of incidents could be contained within the proposed boundaries of the site, however, two incidents were identified to have a potential to impact off-site (i.e. at adjacent industrial sites and local residential areas). Therefore, two incidents were carried forward for risk review, these were:

- Leak from a chlorine drum valve leading to the development of a toxic plume which is directed towards the adjacent sites and residential areas by wind.
- AN incidents (fire, explosion, toxic plume).

The risks associated with each area are assessed in detail below.

6.2 Chlorine Release Incident Risks

The hazard and consequence analyses identified that a release of chlorine from a valve on a chlorine drum could impact industrial off-site areas causing fatalities after an extended period of exposure to the toxic plume. The concentration of gas at residential areas may result in injury after an extended period of exposure to the toxic plume, but fatality would not result in this area.

The risk of fatality at the adjacent industrial site is a function of the exposure period, the wind direction, the weather conditions and the release frequency. The exposure to chlorine at concentrations of ppm, the concentration at the closest site boundary, would not immediately cause fatality. The time of exposure to result in fatality for a concentration of 20 ppm can be estimated using probit analysis, which is a method for estimating the probability of fatality from exposure to a consequence impact (i.e. toxic gas, heat radiation, explosion overpressure, etc.).

The probit equation for exposure to toxic gas takes the form:

$$Y = k1 + k2 \ln (C^n t)$$

Where: k1 = -14.9 (Ref.16);

k2 = 2.56 (Ref.16);

C = gas concentration (ppm);

n = 2 (Ref.16); and

t = exposure time (minutes)

The resultant calculation of probit is then applied to the probit curve (refer to **Figure 6-1**) to determine the fatality probability.

It can be seen from the form of the probit equation that a time can be determined for a specific toxic gas concentration whereby the most sensitive member of the community can be affected (i.e. fatality). This would occur where Y>0. Hence, by estimating the of exposure to set Y=0 would result in a very conservative analysis. For a chlorine concentration of 20ppm, the time of exposure for Y=0 is 20 minutes.

Hence, in the event of a chlorine release, the container terminal site would have more than 20 minutes to raise the alarm and commence evacuations. As chlorine has such a pungent odour, early detection at extremely low levels is most likely, providing more than adequate time to initiate evacuation. The probability that evacuation is not effected successfully has been conservatively estimated to be 0.1.

As noted above, chlorine drums are extremely robust and, historically, there are many reported incidents of drums falling from truck or involved in fires without drum damage or chlorine release. Minor leaks from pigtail lines often occur, however, it is highly unlikely that larger releases (6 millimetre diameter equivalent hole) occurs through a drum valve. Discussion with the chlorine manufacturer (Orica Australia, Ref. 19) indicates that there is no record of releases of this magnitude, only minor fugitive emissions occur from valve leaks.

Based on this analysis, an estimate of a valve leak (Ref. 20) has been made, this value is 0.07 failures per 106 hours (Ref. 20, Taxonomy 4.3.5). The value selected for the analysis is the lower percentile value selected from the failure rate data base. The lower percentile value has been selected as the chlorine drum valves are historically robust and not prone to leakage (Ref. 19). Annual failure rate (leak) for the drum valves is therefore 0.07 x 8760/106 = 0.0006.

It would also be necessary for the wind to blow in the direction of the industrial sites and residential areas at a velocity of 1 m/s and weather conditions “F”. A review of the wind rose shown in the AN report (Ref. 7) indicates that the probability of the wind blowing in the direction of the adjacent industrial and residential areas (south) is 0.1. It is noted that the probability of weather conditions “F” occurring has not been considered for the sake of conservatism. Weather conditions B, C & D would not result in impacts at the residential areas, hence assuming probability of wind direction only, and impacts under all weather conditions occur, the results would be very conservative.

It is noted that the chlorine storage would be transit storage only and the containers (holding chlorine drums) would only be on site for a maximum of 3 days. At this stage of the site development it is difficult to identify how often chlorine would be transported through the Port. However, a conservative estimate would be once per month. Assuming the containers/drums are on site 3 days per month (total of 36 days, over 365 days per year, the probability of release when the drums are on-site is 36/365 = 0.1.

A review of typical chlorine shipments involve the loading of about 10 drums into a 12-metre shipping container. Assuming 5 containers are shipped at one time, the total drums in transit at any one time would be 50.

The potential fatality frequency (risk) is therefore:

Fatality Risk (chlorine release) = No. drums x valve leak x probability of wind direction (at F1 conditions) x probability drums on site during release x period failure to implement the emergency evacuation

Fatality Risk (chlorine release) = 50 x 0.00006 x 0.1 x 0.1 x 0.1
= 30 x10^{-6} or 30 pmpy.

Injury risks would also occur with this frequency.

A review of the acceptable fatality and injury risk criteria indicates that the permissible fatality risk at adjacent industrial land uses is 50 pmpy. The acceptable injury risk criteria at residential areas is also 50 pmpy. The assessed risk is 30 pmpy, hence, the risks are within the acceptable range and no further analysis is conducted.

It is noted that the main contributor to risk is the potential release of chlorine and impacts at the closest residential area. This risk may be reduced by implementation of a gas detection system around the storage area, including alarms and implementation of an emergency response plan for evacuation of the downwind occupied areas.

It is noted that the above analysis has been conducted using very conservative data and that even under these circumstances, the risks associated with the toxic gas storage at the site are extremely low and well below the acceptable risk criteria.

6.3 Ammonium Nitrate Incident Risks

As noted in the hazard and consequence analysis sections, a quantitative AN risk analysis has been conducted (Ref. 7), detailing the risks associated with the transit of ammonia at the site. **Figure 6-1** shows the results of the risk cumulative analysis for explosions, fires and toxic plumes from fires.

Figure 6-1: Ammonium Nitrate Explosion and Smoke Fatality Risks NPC Concept Plan Operations

It can be seen from **Figure 6-1** that the risks are localised around the AN operations. The risks do not extend beyond the site boundary at levels that exceed the acceptable risk criteria. Hence, no further assessment has been conducted for AN transit operations.

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7.0 Cumulative Impacts

The implementation of the proposed concept would result in the location of a number of potentially hazardous facilities within the various precincts at the site. Whilst the individual sites may not result in a potential risk to the surrounding land use, the location of potentially hazardous facilities at adjacent precincts may lead to the accumulation of hazard and risks such that cumulative impact could exceed the acceptable risk criteria (Ref. 8).

A review of the consequence impacts, detailed in **Sections 4, 5** and **6**, at each of the potentially hazardous facilities within each precinct, indicates that there is adequate space within the precincts such that the potentially hazardous facilities (e.g. terminals, Dangerous Goods transit storages, fuel tanks, AN transit storages, etc,) do not result in an accumulation of risk. The analysis conducted in this study identified that the potentially hazardous facilities can be located within the specific precincts such that the impacts do not overlap causing accumulation of risks.

Based on this assessment, the proposed concept can be implemented such that the total plan does not exceed the acceptable risk criteria both individually (i.e. each potentially hazardous facility) and as a total site, taking account of all potentially hazardous facilities installed at the Port.

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Appendix A

Hazard Identification Table

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A.1 Hazard Identification Table

CONTAINER STORAGE (DRUMS, CYLINDERS, etc.)			
Area/Section	**Hazard Cause**	**Hazard Consequence**	**Proposed Safeguards**
Class 2.1 Gas (e.g. LPG, acetylene)	Release from gas cylinder	Ignition and explosion followed by localised jet fire at the cylinder head	Single cylinder release only, limited release quantity Cylinders will be sealed and capped (damage prevention) No ignition sources in the storage area Separation between the storage and surrounding land uses
Class 2.3 Gas (e.g. chlorine, ammonia)	Release from gas cylinder	Accumulation of gas inside containers and around the container, impact to people near the container and downwind of the release.	Single cylinder/drum release only, limit release quantity Cylinders will be sealed and caped (damage prevention) Container limits direct release to atmosphere Separation between the storage and surrounding land uses
Class 3 Flammable Liquids (e.g. alcohols, paints) C1/C2 Combustible Liquids (e.g. diesel, oil, etc.)	Release from drum or isotainer	Ignition and pool fire	Drums protected by container storage (i.e. unlikely impact damage to drums) Bunding provided around the flammable liquid storage area Fire fighting equipment provided (fire hydrants, extinguishers and hose reels) Site Emergency Response Plan and dedicated emergency response team Site is attended 24 hours, 7 days per week (i.e. personnel on hand to raise alarms)
Class 4.1 Flammable Solids (e.g. matches, metal powders)	Solids heated by external source	Ignition of solids and fire in container	Fire contained within the container, localised due to nature of product Fire fighting equipment provided (fire hydrants, extinguishers and hose reels) Site Emergency Response Plan and dedicated emergency response team Site is attended 24 hours, 7 days per week (i.e. personnel on hand to raise alarms)
Class 4.3 Solids that emit flammable gas when wet (e.g. Dross)	Leak of water into the dross storage container	Potential generation of ammonia and methane/acetylene	Fire safety systems, fire main, sprinklers, on-site pumping system Solids would be stored in bulk bags within containers (minimal potential for contact with water from leaking container) Small quantities of water and solid mix (low gas generation potential) Containers provide protection from rainwater

CONTAINER STORAGE (DRUMS, CYLINDERS, etc.)			
Area/Section	**Hazard Cause**	**Hazard Consequence**	**Proposed Safeguards**
Class 5.1 (e.g. Ammonium Nitrate)	Note: A detailed quantitative risk analysis (PHA & FHA) has been conducted for the AN handling operations at Berth 4. Hence, additional analysis has not been conducted in this study as the proposed operations at Berth 4 will not change within the NPC Port Concept Plan. Hazard Analysis results can be viewed in the Advitech & Lloyd's Register Reports (Refs.6 & 7 in the main report)		
Class 6 Toxic Substances (e.g. pesticides, herbicides)	Leaking drum/Isontainer	Potential for release off-site, impact to the biophysical environment Acute Impact to people	Limited release quantity from drum, minor release inside container Drums protected from impact damage by containers Bunded area around containers (spill retention on site) Regular inspection of storage area and containers to identify leaks Product Quarantine area set aside for damage materials
Class 8 Corrosive Substance (e.g. acid, alkali)	Leaking drum/Isontainer/sulphuric acid pipeline	Potential for release off-site, impact to the biophysical environment Acute Impact to people	Limited release quantity from drum, minor release inside container Drums protected from impact damage by containers Bunded area around containers (spill retention on site) Regular inspection of storage area, containers and pipelines to identify leaks Product Quarantine area set aside for damage materials
Class 9 Environmentally Hazardous Substance (e.g. ammonium nitrate fertiliser not classified as Class 5.1, battery powered equipment, air-bag inflator)	Leaking containers	Potential for release off-site, impact to the biophysical environment	Limited release quantity from drum, minor release inside container Drums protected from impact damage by containers Bunded area around containers (spill retention on site) Regular inspection of storage area and containers to identify leaks Product Quarantine area set aside for damage materials

CONTAINER STORAGE (DRUMS, CYLINDERS, etc.)			
Area/Section	**Hazard Cause**	**Hazard Consequence**	**Proposed Safeguards**
Truck and Rail Loading/Unloading Areas	Dropped bags, containers	Potential for spill of dangerous goods, contamination of ground and rainwater and release off-site	Operator present when incident occurs Operator can implement emergency spill response Spill kits available around the site All materials are transported in shipping containers (dropped container will retain minor spills) Damaged container quarantine area
Transport of Dangerous Goods	Truck accident	Potential for spill of dangerous goods and impact to the environment Potential for release of flammable liquid/gas ignition and fire Potential for release of toxic liquid/gas impact to environment or people close to the container	All Dangerous Goods are transported in shipping containers Incidents involving shipping containers would result in minimal impact (spills retained within the container) Drivers transporting dangerous goods will all be licensed under the DECCW requirements All dangerous goods transport vehicles will carry emergency response plans Materials proposed for transport are currently transported on roads within the Port area

BULK LIQUIDS PRECINCT (BERTH TRANSFERS, TANKS, VEHICLE LOADING, BUNKERING, etc.)			
Site Area	**Hazard Cause**	**Hazard Consequence**	**Proposed Safeguards**
Liquids Transfer Berth (Wharf)	Ships enters berth at too high speed	Potential for ship to strike the wharf resulting in damage to ship's hull, hull breach and release of flammable liquid to the South Arm of the Hunter River	Ship is berthed with assistance from Newcastle Ports Pilot (trained in Newcastle berth procedures) Ships speed is limited during approach to berth (monitored by Pilot) Berthing assistance is provided by Newcastle Harbour Tugs (prevent direct approach to wharf by ship) Berthing facilities and operations follow strict ISGOTT procedures Ship's captain is certified master mariner, with extensive ship handling experience Wharf is fitted with "Fenders" to prevent direct strike of solid wharf components on the ship This incident has not been carried forward to the Hazard Analysis section as the risk of ship impact to the wharf, resulting in liquid release, is extremely low.
Liquid (Fuel) Delivery & transfer using flexible hose (including bulk fuel deliveries and barge transfers at wharf and ship)	Hose failure Connection failure Human error (incorrect connection) Ship/barge moves away from berth (wind, failed lines)	Potential spill on the ship's deck Spill onto the Mayfield No. 4 Berth or Koppers wharf Potential spill off ship's deck or wharf into the South Arm of the Hunter River – environmental impact Ignition of spill and fire on the wharf and in the contained boom area around the ship/barge	Personnel (Ship/Barge and Shore) in attendance during full fuel delivery/transfer Wharf area where fuel lines are located is bunded to prevent direct spill to the Hunter River A spill containment boom will be established around the ship/barge and wharf for all delivery/transfer operations Site emergency plan will be developed to respond to spills Spill kit will be available for minor spills Monitor, with foam generation facilities, will be installed adjacent to the fuel transfer point at a safe distance from the flexible lines (to be established by Fire Safety Study) Additional fire hydrants located close (within 60 metres) of the fuel transfer location Emergency shut off valves installed on pipework, operated automatically or by remote actuation "button" on the ship and shore Ship/barge is tied up with two lines at every tie point

BULK LIQUIDS PRECINCT (BERTH TRANSFERS, TANKS, VEHICLE LOADING, BUNKERING, etc.)			
Site Area	**Hazard Cause**	**Hazard Consequence**	**Proposed Safeguards**
Liquid transfer via pipeline (including diesel/ULP line and marine bunker fuel oil line)	Pipeline leak due to corrosion, overpressure, poor construction (welding), external interference	Leak of liquid to environment Ignition of leak and fire at leak point	Pipeline will be fully welded steel along the full length (no flanges creating leak sources) Pipeline welding will be fully non-destructive tested (e.g. x-ray and magnetic particle) Pipeline will be designed to withstand full pump “dead-head” with a conservative factor of safety (i.e. no rupture) Pipeline will be “pigged” after each delivery to extract all fuel from the line so that no fuel will be present when the line is not in use (diesel/ULP only) Pipeline will be installed on a gantry along its full length to minimise the potential for impact from external sources Pipeline will be hydraulically tested to a pressure in excess of operating pressure on completion of construction Pipeline transfer will be fully monitored by instruments both on ship and shore facilities (i.e. pressure, flow, etc.) The pipeline will be inspected and tested with an “intelligent” pig on a regular basis (time frame to be determined) to identify potential faults Pipeline will be painted to protected against external corrosion Nitrogen will be used to purge the line after each transfer
Barge operations	Barge/tug collision with other vessels Barge runs aground	Barge is damaged leading to spill of fuel oil to the South Arm of the Hunter River – environmental impact Ignition of spill and fire resulting in heat radiation impact to the surrounding area.	Barges move at slow speed, minimal collision impact, low likelihood of breach of barge Barges are constructed with a “double-bottom” (barge tanks do not contact outer hull of barge) Tug/Barge masters are certified and “ticketed” operators Tug/barge is fitted with spill response and fire fighting equipment Emergency response plan will be developed for the barge operations (including drills and exercises) Harbour emergency spill response team available for Newcastle Harbour (tug/barge is in radio contact with NPC at all times

BULK LIQUIDS PRECINCT (BERTH TRANSFERS, TANKS, VEHICLE LOADING, BUNKERING, etc.)			
Site Area	**Hazard Cause**	**Hazard Consequence**	**Proposed Safeguards**
Fuel storage	Overfill of tank during tank filling Spill of fuel into the bund	Potential off-site release, environmental impact	Fuel storage is bunded, no off-site release Tanks are monitored during filling using level instrumentation (level in tanks repeated in the site office) All tank are fitted with high level instruments and alarms (audible & visual in the site office) Visual inspection and checking of tank/bund area is performed during the transfer/filling operation Tank fill volume is passed to ship for monitoring, ship constantly monitors the transferred volume and notifies shore when volume limit is approaching
Fuel storage	Overfill of tank during tank filling Spill of fuel into the bund Ignition and bund fire	Potential off-site heat radiation impact to surrounding areas	Fire main (complying with AS2419-Ref.15), fire pumps (complying with NFPA20 – Ref.13) and fire water tank Fire hydrants and hose reels close to the storage Fire monitors with foam generation installed adjacent to the bund (but at safe distance) Fire contained to bund – bund capacity exceeds largest tank in bund (plus sprinkler allowance) For the diesel & fuel oil storages, diesel and fuel oil is difficult to ignite (low ignition probability) Control of ignition sources in the bund area (bund will be classified as a hazardous area in accordance with Australian Standards – e.g. AS60079 (Ref.14) All tanks will be regularly inspected for potential leaks and corrosion impact, water build up in the tanks will be drained regularly to prevent internal corrosion potential. Tank level monitoring will be conducted at all times to identify potential rapid tank level loss indicating potential leaks
Fuel Storage	Ignition of fuel in the tank	Tank explosion and tank roof fire Explosion overpressure and/or Heat radiation impact to surrounding area	Flammable liquid tanks are all fitted with internal floating pans to eliminate the potential for vapour build up in the ullage space of the tank All tanks will be fully vented with anti-flash gauze on vents to prevent ignition from entering the tank via the vent All electrical equipment in the tank will be suitably specified for the specific hazardous area in which it will be installed (i.e. flameproof equipment installed on tanks and in the bund) Tank temperature monitoring will be installed in all tanks to ensure liquids do not vaporise and generate flammable mixtures in tanks

BULK LIQUIDS PRECINCT (BERTH TRANSFERS, TANKS, VEHICLE LOADING, BUNKERING, etc.)			
Site Area	**Hazard Cause**	**Hazard Consequence**	**Proposed Safeguards**
Flammable Liquid Transfer Pumps (Tank Farm)	Pipework, valve or flange leak Pump seal leak Ignition and fire in bunded area, at pumps	Release of fuel to bunded area Potential for ignition of fuel leak and fire	Pump seals are double mechanical type to minimise the potential for leak Pump area is bunded to contain spills Fire main (complying with AS2419-Ref.15), fire pumps (complying with NFPA20 – Ref.13) and fire water tank Fire hydrants and hose reels close to the pumps and pipework Control of ignition sources in the pump bund area (bund will be classified as a hazardous area in accordance with Australian Standards – e.g. AS60079 (Ref.14) Ignition sources controlled on site (no smoking, hot work controlled by Permit, vehicle access monitored and controlled)
Tanker loading pipework & Pumps	Pipework, valve or flange leak Pump seal leak	Release of fuel to bunded area or in area between pumps and gantry Potential to impact environment if release escapes off-site	Pipework between tanks and pumps is bunded and leaks will be contained within the tanks bunded area Pump seals are double mechanical type to minimise the potential for leak Pump area is bunded to contain spills Pipework between pumps and gantry is located in a spill containment to prevent spills off-site Pump operation is only conducted when site is staffed and pump/filling operations can be continually monitored
Tanker loading pipework & Pumps	Pipework, valve or flange leak Pump seal leak Ignition and fire in bunded area, at pumps or in area between pumps & gantry	Release of fuel to bunded area or in area between pumps and gantry Potential for ignition of fuel leak and fire	Fire main (complying with AS2419-Ref.15), fire pumps (complying with NFPA20 – Ref.13) and fire water tank Fire hydrants and hose reels close to the pumps and pipework Fire monitors with foam generation installed adjacent to the pump bund (but at safe distance) Control of ignition sources in the pump bund area (bund will be classified as a hazardous area in accordance with Australian Standards – e.g. AS60079 (Ref.14) Ignition sources controlled on site (no smoking, hot work controlled by Permit, vehicle access monitored and controlled)

BULK LIQUIDS PRECINCT (BERTH TRANSFERS, TANKS, VEHICLE LOADING, BUNKERING, etc.)			
Site Area	**Hazard Cause**	**Hazard Consequence**	**Proposed Safeguards**
Fuel Tanker loading bays & gantry	Tanker impacts gantry Tanker driveaway whilst connected Gantry loading arm failure (leak/rupture) Operator error – incorrect connection of loading arm	Release of fuel into the loading bay Potential spill and impact to the environment	Gantry/loading bay area is bunded to contain spills Tanker loading operation is monitored by tanker drivers and terminal operators during the full transfer operations Gantry area is under closed circuit television (CCTV) surveillance at all times, with screens in the main site office Trucks are fitted with driveaway protection to prevent drivers leaving the site whilst the truck is connected to the gantry (via the loading arm) Loading arms are fully tested at installation and maintained continually throughout the plant's life Bollard and "Armco" protection at the entry to the gantry/bay area Dry break coupling installed on loading arm for connection to the tanker loading point
Fuel Tanker loading bays & gantry	Fuel leak, ignition and fire	Heat radiation impact Potential spill and impact to the environment	UV/IR fire detection installed in the gantry area Foam sprinkler/deluge system installed over the gantry area Fire main, hydrants and hose reels installed in the gantry area Monitors with foam generation equipment installed adjacent to the gantry area Control of ignition sources in the gantry area (gantry area will be classified as a hazardous area in accordance with Australian Standards – e.g. AS60079 (Ref.14) Computer controlled filling system operated by the tanker driver using a "swipe-card" Operator & driver in full attendance during all transfer operations – alarm can be immediately raised in the event of spill & fire Emergency button shut down (stops pump & isolates delivery valves) located in the gantry bays

NPC OPERATIONS PRECINCT (FUEL TANK, VESSEL REFUELLING)			
Site Area	**Hazard Cause**	**Hazard Consequence**	**Proposed Safeguards**
Bulk Fuel Storage Diesel Fuel	Fuel leak from tank(s) [Underground Tanks]	Potential spill to the ground surrounding the tank – environmental impact (eventual release to the South Arm of the Hunter River via seepage)	Tanks will be double walled with a vapour gap between the inner and outer walls of the tank Leak detection and alarm in the vapour space between the inner/outer tank walls Regular inspections and audits of Dangerous Goods storages (including alarm tests) Storage & transfer operations will be designed to comply with the requirements of AS1940-2004 (Ref.12) Tank leak monitoring systems in accordance with the DECCW requirements
Bulk Fuel Storage Diesel Fuel	Tank filling and vessel/vehicle refuelling leak and spill requiring spill clean-up	Potential for personnel contact with the fuel whilst clean-up occurs – chemical burns and dermatological effects	Spill kits contain PPE (providing protection during clean up) Spill clean-up procedures, including proper use of PPE Spill response training and drills Minor spills only (relatively small quantity of goods released)
Bulk Fuel Storage Diesel Fuel	Failure of flexible connection between tank/road tanker and tank/vessel (i.e. during bulk fuel storage refuelling or vessel refuelling) – rupture, connection fails, hole in hose, etc.	Potential spill to the area surrounding the transfer point – release to the environment and environmental impact	Transfer point will be bunded as per AS1940 (Ref.12) – spill retained on-site Personnel (driver/operator) in attendance at the fuel transfer point during the whole fuel transfer operation Driver/operator is experienced and trained in flexible connection failure and spill response Emergency shut down button provided on the truck and transfer pump (button activation closes the fuel delivery valve and shuts down the transfer pump) Drive-away protection on trucks (prevents vehicle being moved whilst connected to the fill point)

NPC OPERATIONS PRECINCT (FUEL TANK, VESSEL REFUELLING)			
Site Area	**Hazard Cause**	**Hazard Consequence**	**Proposed Safeguards**
Bulk Fuel Storage Diesel Fuel	Failure of flexible connection between tank/road tanker and tank/vessel (i.e. during bulk fuel storage refuelling or vessel refuelling) – rupture, connection fails, hole in hose, etc.	Potential spill to the area surrounding the transfer point – release, ignition and fire	Transfer point will be bunded as per AS1940 (Ref.12) – spill retained on-site Personnel (driver/operator) in attendance at the fuel transfer point during the whole fuel transfer operation Driver/operator is experienced and trained in flexible connection failure and spill response Emergency shut down button provided on the truck and transfer pump (button activation closes the fuel delivery valve and shuts down the transfer pump) Drive-away protection on trucks (prevents vehicle being moved whilst connected to the fill point) Diesel fuel has a low probability of ignition at ambient temperature (i.e. diesel fuel flash point exceeds 60.5^{o}C)

Appendix B

Consequence Analysis

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Consequence Analysis

B.1 Flammable Gas Explosion

The analysis conducted in **Section 4.7.1** identified that in the event of a gas release within a container there is a potential for the gas to mix with air and form a flammable mixture that of ignited would explode causing explosion overpressure that could impact at the beyond the site boundary.

To estimate the quantity of gas within the container that could explode, the mixture of LPG in air at the Upper Flammable Limit (UFL) has been used. This will provide a conservative estimate as the quantity of gas at the lower flammable limit will be considerably less and the explosion less powerful. The volume of the container is estimated to be 2.4 metres x 2.2 metres x 6 metres = 31.7 m^3. The container will hold a number of gas cylinders that will take up volume within the container reducing the free space such that there is less gas air mixture available. An estimate of 40 percent reduction in space has been made. Hence, the space available for gas/air is 31.7x0.6 = 19 m^3.

The mass of LPG (propane), at UEL, within 19 m^3 of is calculated as follows:

1 mole of gas is contained within each 22.4 litres of volume. Hence, for 19,000 litres of gas the number of moles = 19,000/22.4 = 850 mole

At UEL there is a 10 percent mixture of propane gas in air. Hence, the total number of mole of propane = 850 x 0.1 = 85 mole. The molecular weight of propane is 44.1. Hence, the total mass of propane in the enclosure is 3,748 kilograms. Whilst the UFL would require 3,748 kilograms, it is noted that only one cylinder would leak, hence, based on a single 500 litres water capacity cylinder (the largest cylinder that would be transported), the maximum mass of gas released at a density of 580 kg/m^3 = 580 x 0.5 = 265 kilograms. Hence, the equivalent mass of TNT is calculated by:

$$W_{TNT} = \alpha\left(\frac{W.H_c}{H_{TNT}}\right) \qquad \text{------------- B1}$$

Where: W = mass of fuel in the cloud (265 kilograms in the container)
H_c = heat of combustion of the fuel (50,000 kj/kg for propane)
H_{TNT} = TNT blast energy (5420 kj/kg)
α = explosion efficiency (0.04 for propane, Ref. 15)

Hence,

W_{TNT} = 0.04 (265x50,000/5420) = 97 kilograms TNT

Overpressure is now calculated using a scaled distance curve, based on actual distance from the blast and the TNT equivalent, this is given by:

$$z = \frac{R}{(W_{TNT})^{1/3}} \qquad \text{--------------------------B2}$$

Where: R = distance from the blast (metres)
W_{TNT} = kilogram equivalent of TNT

The maximum permissible overpressure at the boundary of a site is 7 kPa. Overpressure values exceeding this must be subjected to risk assessment. From **Figure B1**, for 7 kPa, the scaled distance is 17. From **Formula B2**:

$17 = \xi/(97)^{0.333}$
$\xi = 17 \times (97)0.333 = 78$ metres

The distance to an overpressure of 7 kPa from an explosion in a container is 78 metres.

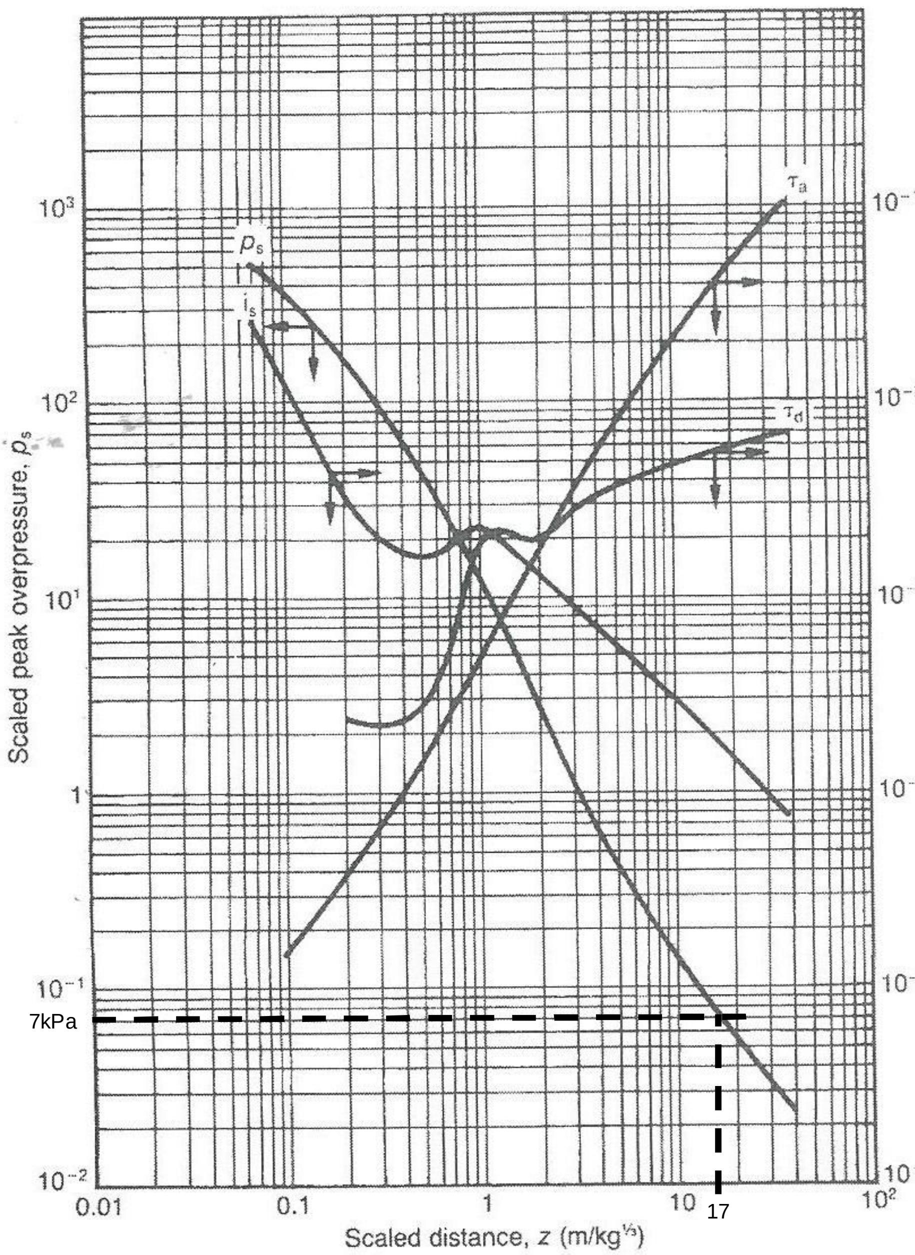


Figure B1: Scaled Parameter Plots for TNT Explosions(Ref.11)

B.2 Flammable Liquids Pool Fire – Container Terminal Precinct

Flammable liquids may be transported in drums or isotainers to and from the Container Terminal Precinct. The storage area in which these containers would be located would be bunded. For this analysis, an area containing around 8 isotainers has been used. The isotainer is 2.2 metres wide x 6 metres long. Hence the area in which the isotainers would be located (i.e. transit storage) would be around 16 metres long x 10 metres wide. In the event of a continuing leak from an isotainer, the bund would fill with flammable liquid and if ignited would result in a full bind fire.

Whilst unlikely, a spill scenario at the isotainer storage bund would result in a pool fire which would radiate heat to the areas surrounding the storage. The isotainer storage bund is 16 metres x 10 metres.

Pool Equivalent Diameter: $\pi/4 \times D^2$ = 16 metres x 10 metres
$D = (160 \times 4/\pi)^{0.5}$
D = 14.3 metres

B.2.1 Fire Modelling

Figure B2 shows an illustration of a typical pool fire in a fuel transfer location. It can be seen from this illustration that the flame tilts with the wind directions.

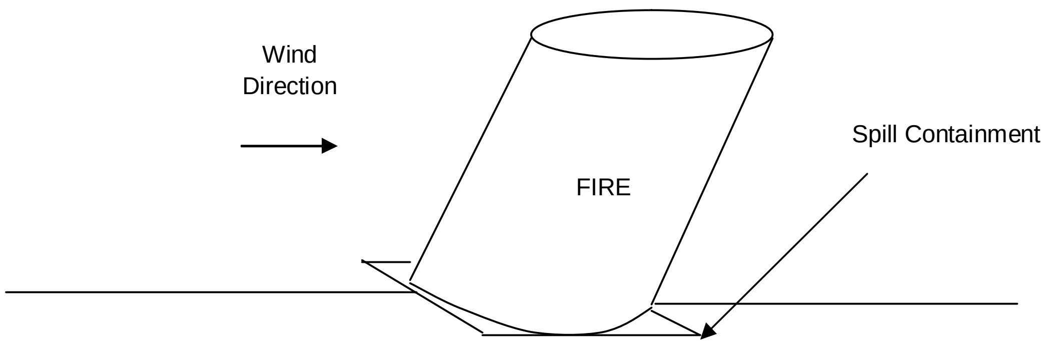


Figure B2: Example of Typical Fire in a Bund

Whilst the spill containment is a rectangle shape, the fire will act as a cylinder within the rectangular spill containment, the flames being drawn into a cylindrical shape as a result of the updraft within the fire. Heat from the cylindrical flame radiates to the surrounding area. A number of mathematical models may be used for estimating the heat radiation impacts at various distances from the fire. The point source method is adequate for assessing impacts in the far field, however, a more effective approach is the view factor method, which uses the flame shape to determine the fraction of heat radiated from the flame to a target. The radiated heat is also reduced by the presence of water vapour and carbon dioxide in the air. The formula for estimating the heat radiation impact at a set distance is:

$Q = E F \tau$

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

Figure B3 shows the heat radiation path for the fire. It can be seen from this figure that flame tilt and height above ground level will have impacts on the amount of heat flux received by the target.

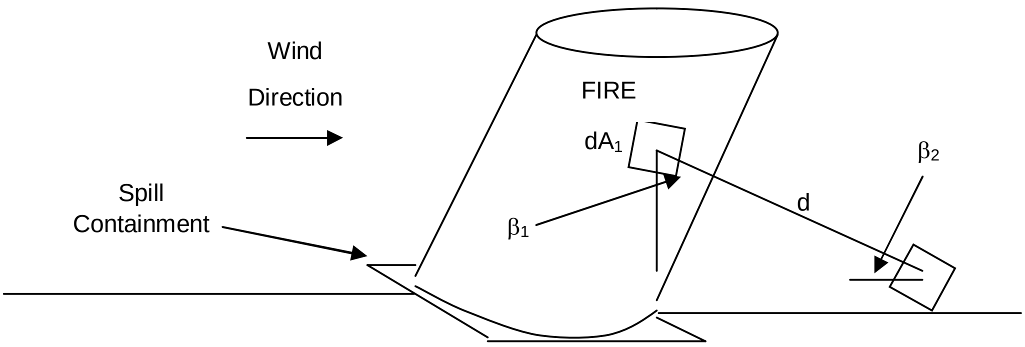


Figure B3: Heat Radiation Impact on a Target from a Cylindrical Flame

The calculation of the view factor (F) in **Figure B3** depends upon the shape of the flame and the location of the flame to the receiver. F is calculated using an integral over the surface of the flame, S. The formula can be shown as:

$$F = \iint_S \frac{\cos\beta_1 \cos\beta_2}{\pi d^2}$$

The above formula may be solved using the double integral or using a numerical integration method in spread sheet form. This is explained in **Section B3**.

B.2.2 Development of the Numerical Integration Model

Introduction

The spreadsheet calculator (SSC) determines the radiation flux experienced at a “target” originating from a cylindrical fire. It is intended typically for fires of flammable liquids (Class 3) though it can be used with any material so long as the “emissivity” of the flame is known. This is the heat flux at the surface of the flame and is given in kilo Watts per square metre (kW/m^2). The other parameters needed are: diameter of the fire, height of the fire walls, distance to target, height of flame, tilt of flame caused by wind. It is assumed that the walls have some height although there is no reason not to use the calculator for pool fires at ground level by entering a zero height.

Design Basis

The SSC is designed on the basis of finite elements. The fire is assumed to be in the shape of a cylinder of the same diameter as the equivalent pool diameter. The height of the fire can be calculated using the following formula:

$$L = 42D\left(\frac{m}{\rho_o (gD)^{0.5}}\right)^{0.61}$$

Formula B1 (Ref.8)

where: L= mean flame height (m)
D= pool diameter (m)
ρ = ambient air density (typically 1.2 kg/m^3)
m = mass burning rate (kg/m^{2}s) = 0.0667, based on 5mm/min burn down rate (Ref.16)
g = acceleration due to gravity (9.81 m/s^2)

Once the flame height is known, the surface of the cylinder can be divided into many separate plane surfaces. To do this, a plan view of the fire was drawn and the relevant distances and angles allocated. The plan view is for the target and the base of the fire in the same horizontal plane.

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

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

For the simple case, where the fire is of unit height, the view factor of an element is simply given by the expression:

$VF = \Delta A. \sin(gamma)/(\pi. x4. x4)$ .... Eq 1

where ΔA is the area of an individual element at ground level.

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

Applying the above approach, we see the value of x4 increase as theta increase, and the value of sin(gamma) decreases as theta increase. This means that the contribution of the radiation from the edge of the circular fire drops off quite suddenly compared to a view normal to the fire. Note that the SSC adds up the separate contributions of Eq 1 for values of theta between zero until x4 makes a tangent to the circle.

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

$VF = \Delta A. \sin(gamma).\cos(alpha)/(\pi. x4'. x4')$ .... Eq 2

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

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

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

B.3 Analysis Results

Prior to the development of the model, parameters were developed (e.g. pool equivalent diameter, flame height, SEP, wind tilt, etc.). Pool equivalent diameter has been estimated as 14.3 metres (refer to **Section B2.1**).

B.3.1 Flame Height:

$$L = 42D\left(\frac{m}{\rho_0 (gD)^{0.5}}\right)^{0.61}$$

where: L= mean flame height (metres)
D= pool diameter (metres)
ρo= ambient air density (typically 1.2 kg/m^3)
m= mass burning rate (kg/m^{2}s) = 0.0667, based on 5mm/min burn down rate (Ref.16)
g= acceleration due to gravity (9.81 m/s^2)

Using a diameter of 14.3 metres, the flame height is 22.8 metres.

Wind Tilt has been estimated to be 15^{o}C.

B.3.2 Surface Emissive Power (SEP)

SEP is a function of the fire magnitude (i.e. diameter and height), which governs the amount of heat at the surface of the fire. Larger fires tend to generate larger quantities of soot or smoke, which shields the more luminous components of the flame. Large diameter pool fires average an SEP of about 20 kW/m^2. The average SEP of an 80 metres kerosene fire is about 10 kW/m^2, suggesting the correlation is conservative (Ref. 11).

From the correlation of Mudan (Ref.11) the following formula may be developed for calculating the SEP of a flame:

SEP = SEPm exp(-sD) + Es (1-exp(-sD))

Where: SEP = the total surface emissive power of the flame
SEPm = the maximum surface emissive power of luminous spots on a large hydrocarbon fuel flame (140kW/m^2)
SEPs = the surface emissive power of a smokey flame (20 kW/m^2)
S = 0.12 m-1 (an experimentally determined parameter)
D = diameter of the pool

Based on the above formula, the calculated SEP for the flammable liquids fire in the container transit storage area is 41.6 kW/m^2.

B.3.3 Transmissivity

Transmissivity is the reduction in heat radiation due to the presence of water vapour and carbon dioxide in the atmosphere between the radiation source and the target. This can be calculated using the following formula:

Transmissivity = 1.006 - 0.01171(log10X(H_2O) - 0.02368($\log_{10}$X(H_2O)))^2 - 0.03188($\log_{10}$X(CO_2) + 0.001164($\log_{10}$X(CO_2)))^2

Where: X(H_2O) = (RH x L x Smm x 2.88651 x 102)/T
X(CO_2) = L x 273/T
RH = relative humidity
L = path length in metres
Smm = saturated water vapour pressure in mm mercury (= 17.535 @ 293 K)
T = temperature in degrees Kelvin (293 K)

The distance to a heat radiation level of 4.7 kW/m^2 from the flame (isotainer bund) is about 26.5 metres, relative humidity is selected as 70 percent (0.7). Using these values and the values listed above, the transmissivity parameter is calculated to be 0.79.

B.3.4 Summary of Inputs to the SCC Model

Using the methodology presented in **Section B2** the following inputs have been developed for the heat radiation model.

Fire Diameter	14.3 metres
Fire height	22.81 metres
Flame tilt	15 degrees
SEP	41.6 kW/m^2
Transmissivity	0.77 (at 26.5 metres)

B.4 Consequence Analysis (SCC Model Results)

The SCC model was entered into a Microsoft Excel spread sheet and the data above input to the model. A heat radiation level of 4.7 kW/m^2 was selected and the distance to this level of heat radiation was estimated to be 26.5 metres. **Table B1** shows the distances to selected values of heat radiation.

Table B1: Distance to Selected Heat Radiation Impacts - Isotainer Storage Area Bund Fire

Heat Radiation Level (kW/m^2)	Isotainer Storage Distance (m)
35	10.3
23	12.4
15	15.1
12.5	16.4
8	20.5
6	23.5
4.7	26.5
2	40

B.5 Flammable Solids Fire

Flammable solids would be transported in containers and may be ignited whilst in transit storage at the site. As the materials are solids, they do not spread like flammable liquids and therefore the fire is contained in the immediate vicinity of the container itself. In the worst case, the container roof would collapse and the fire would be exposed across the top of the whole container. The container is 6 metres x 2 metres, hence the equivalent diameter is 4 metres. Using this value as the basis for the fire diameter, the following is developed for the container fire:

Fire Diameter	4 metres
Fire height	9.41 metres
Flame tilt	15 degrees
SEP	94.25 kW/m^2
Transmissivity	0.83 (at 14.4 metres)

The application of the SSC results in the heat radiation impacts, shown at **Table B2**, at selected distances from the fire.

Table B2: Distance to Selected Heat Radiation Impacts - Flammable Solids Fire

Heat Radiation Level (kW/m^2)	Isotainer Storage Distance (m)
35	5.6
23	6.8
15	8.3
12.5	9.1
8	11.2
6	12.9
4.7	14.4
2	21.5

B.6 Toxic Gas Release

B.6.1 Ammonia

Ammonia would be transported in cylinders (1,000 kilograms) and possibly horizontal tanks (2,000 kilograms). Cylinders would be stored in the container in the upright position, with the valves at the top. Horizontal tanks would also be stored with the valves at the top. Valve caps and covers are installed on the cylinders and tanks, and damage to valves is highly unlikely, however, as a worst case incident a broken valve has been assumed. The valve fitted to the cylinder has been assumed to be 20 millimetres NPT, with a 3 millimetres wall thickness on the valve threaded section where the valve screws into the top of the cylinder. In the event of a broken valve, the diameter of the discharge hole would be 20-(2x3) = 14 millimetres.

Release rate from a 14 millimetres hole is estimated as follows.

Liquid Release rate $G_L = C_dA(2.\rho.\delta P)^{0.5}$

Where: C_d = Co-efficient of discharge (0.6)
A = cross sectional area of the release hole (m^2)
ρ = density of the liquid (kg/m^3)
δP= pressure difference across the hole (Pa)

Hence, for a 14 millimetre hole, the cross sectional area = $1.54x10^{-4}m^2$

Density of anhydrous ammonia = 682 kg/m^3

Pressure differential = 8.8 bar (or $8.8x10^5$ Pa)

$G_L = 0.6 \times 1.45x10^{-4} \times (2 \times 682 \times 8.8x10^5)^{0.5}$ = 3 kg/s

To calculate the adiabatic flash rate (i.e. the quantity of vapour formed from a liquid release), the following formula is used:

$V = (W.C_{p(mean)}.(T_1-T_2))/H_v$

Where: V = weight of the flash vapour produced (kg/s)
W = weight of liquid spilled (3 kg/s)
$C_{p(mean)}$ = geometric mean of the specific heats over a range between T_1 and T_2 (1.37)
T_1 = Temperature of the liquid in the process (21°C)
T_2= Atmospheric pressure boiling temperature of the liquid (-33°C)
H_v = Latent Heat of Vaporisation (287.84 kJ/kg)

V = 3 x 1.37 x (21 – (-33))/287.84

Vapour Release Rate = 0.77 kg/s

A dispersion analysis was conducted using the gas release rate estimated above. When a gas is released, the downwind dispersion is a function of wind speed and weather conditions. In bright sunny conditions, with high wind, the gas disperses readily, but in light wind and overcast conditions the cloud tends to disperse slowly. To model such releases dispersion analysis analyse weather conditions in 6 classes:

A – Bright sunny conditions, highly unstable air streams;

B – Bright sunny conditions, moderately stable air streams;

C – Partial cloud, moderately stable air streams;

D – Mostly cloudy, some patches of sun, moderately stable air;

E – Full cloud cover, very light to stable air streams;

F – Full cloud, virtually no wind, very stable air streams.

To the values above, a wind speed is added to estimate the dispersion at the selected wind weather condition. For example, D5 represents partial cloud with moderate air stream and a wind speed of 5 m/s. The selected values are input to a computer model that assesses the dispersion of the release and estimates the downwind concentration of the gas over a range of distances from the release source. The results are read in ppm of gas content in air.

The model used for the analysis was SLAB. This model was developed by the University of California (Lawrence Livermore Laboratories) for the US Department of Energy. This model is also used as the basis for the EFFECTS© consequence analysis program used by the TNO organisation in the Netherlands. The model was applied for each of the release scenario detailed above.

For ammonia, the concentration levels of interest are:

- Lowest reported lethal concentrations for any species for 30 minutes exposure (Ref. 17) – 5000 ppm
- Injuriuos (50 percent of lowest reported lethal concentrations) – 2500 ppm

For conservatism, the SLAB model was run using a concentration level of interest of 1000 ppm to determine the impact distance at the lower level of concentration. Further conservatism was applied by assuming the cylinder released in the open, whereas the release occurs inside the container providing some “hold-up” of dispersion and reducing the downwind impacts. Model simulations were undertaken for time averaging periods of 1 second and 900 seconds to represent peak and typical short term (STEL) exposures. The source and meteorological parameters used in the model are presented in **Table B3** and **B4**. It

Table B3: Source Parameters

Parameter	Ammonia
Spill source type	Stack
Source duration (seconds)	3600
Source height (metres)	0.3
Storage temperature (K)	288
Source Area (m^2)	0.000028
Averaging Time (seconds)	1 and 900
Emission Rate (kg/s)	0.77
Analysis level of interest (ppm)	1000

Table B4: Meteorological Parameters

Parameter	Value
Surface Roughness (metres)	0.05
Temperature (K)	288
Relative Humidity (%)	40
Wind Speed and Stability Scenarios (PG stab, m/s)	B3, B5, D3, D5, D9, E1.5, F1

The result of the analysis is shown in **Tables B5** and **B6**.

Table B5: Ammonia 1000 PPM Maximum Distance from Source (Metres) – 1 Second Averaging Period

Met Condition	Height (m) Above Ground Level			
	0.01	**1.5**	**1.8**	**2.5**
B3	88	87	87	86
B5	75	74	74	73
D3	167	163	161	155
D5	148	145	144	139
D9	121	119	118	113
E1.5	223	213	210	199
F1	320	300	291	260

Table B6: Ammonia 1000 PPM Maximum Distance from Source (Metres) 900 Second Averaging Period

Met Condition	Height (m) Above Ground Level			
	0.01	**1.5**	**1.8**	**2.5**
B3	73	72	72	71
B5	57	56	55	54
D3	146	143	141	135
D5	120	117	115	110
D9	89	86	85	80
E1.5	212	206	202	191
F1	314	294	286	256

It can be seen from **Tables B5** and **B6** that the maximum downwind distance for a concentration level of ammonia of 1000 ppm is 320 metres. This occurs using a 1 second averaging period, at 0.01 metres above ground level, and under F class stability 1 m/s conditions (i.e. postulated worst case conditions).

B.6.2 Chlorine

The chlorine would be transported in cylinders and 900 kilogram drums. Chlorine cylinders and drums have an extremely robust cap fitting and drums have concave dished ends with the valves set back inside the concave section of the end. The potential for damage to valves in chlorine cylinders and drums is negligible, and anecdotal evidence indicates that such incidents have not occurred in the industry. However, leaks at valve connection and through valve seats is possible. A leak at a valve has been assumed to be 6 millimetres, as this is a common leak scenario where chlorine cylinders and drums are used (i.e. broken “pigtail” pipe connection). This would be conservative, as a leak across a valve or through damaged threads on the valve to cylinder/drum connection would be expected to be much smaller. The release rate is estimated as follows:

Liquid Release rate $G_L = C_d A(2.\rho.\delta P)^{0.5}$

Where: C_d = Co-efficient of discharge (0.6)
A = cross sectional area of the release hole (m^2)
ρ = density of the liquid (kg/m^3)
δP= pressure difference across the hole (Pa)

Hence, for a 6 millimetre hole, the cross sectional area = $2.83x10^{-5}m^2$

Density of chlorine = 1.56 kg/m^3

Pressure differential = 6.95 bar (or $6.95x10^5$ Pa)

$G_L = 0.6 \times 2.83x10^{-5} \times (2 \times 1560 \times 6.95x10^5)^{0.5} = 0.79kg/s$

To calculate the adiabatic flash rate (i.e. the quantity of vapour formed from a liquid release, the following formula is used:

$V = (W.C_{p(mean)}.(T_1\text{-}T_2))/H_v$

Where:
V = weight of the flash vapour produced (kg/s)
W = weight of liquid spilled (0.79 kg/s)
$C_{p(mean)}$ = geometric mean of the specific heats over a range between T_1 and T_2 (1.3)
T_1 = Temperature of the liquid in the process (21°C)
T_2= Atmospheric pressure boiling temperature of the liquid (-34.6°C)
H_v = Latent Heat of Vaporisation (1,370.84 kJ/kg)

V = (0.79 x 1.3 x (21 – (-34.6))/1370.84

Vapour Release Rate = 0.041 kg/s

The model used for the analysis was SLAB (see details listed in **Section B3.1**). This model was developed by the University of California (Lawrence Livermore Laboratories) for the US Department of Energy. The model was applied for the release scenarios detailed above.

For chlorine, the concentration levels of interest are:

- Fatality potential (Ref.10) – 20 ppm
- Injuriuos (50 percent of lowest reported lethal concentrations) – 5 ppm

The SLAB model was run using the two concentration levels above (20 and 5 ppm) to determine the impact distance at these levels of concentration. Model simulations were undertaken for time averaging periods of 1 second and 900 seconds to represent peak and typical short term (STEL) exposures. The source and meteorological parameters used in the model are presented in **Table B7** and **B8**.

Table B7: Source Parameters

Parameter	Chlorine
Spill source type	Stack
Source duration (seconds)	3600
Source height (metres)	0.3
Storage temperature (K)	288
Source Area (m^2)	0.000028
Averaging Time (seconds)	1s and 900s
Emission Rate (kg/s)	0.041
Analysis level of interest (ppm)	5 and 20

Table B8: Meteorological Parameters

Parameter	Value
Surface Roughness (metres)	0.05
Temperature (K)	288
Relative Humidity (%)	40
Wind Speed and Stability Scenarios (PG stab, m/s)	B3, B5, D3, D5, D9, E1.5, F1

The result of the analysis is shown in **Tables B9** and **B10**, for 5ppm and **B11** and **B12** for 20ppm.

Table B9: Chlorine 5 ppm Maximum Distance from Source (Metres) 1 Second Averaging Period

Met Condition	Height (m)			
	0.01	1.5	1.8	2.5
B3	175	175	175	174
B5	136	136	136	135
D3	402	401	400	389
D5	308	307	307	305
D9	225	225	224	223
E1.5	786	783	782	778
F1	1570	1561	1558	1546

Table B10: Chlorine 5 ppm Maximum Distance from Source (Metres) 900 Second Averaging Period

Met Condition	Height (m)			
	0.01	1.5	1.8	2.5
B3	115	114	114	113
B5	90	90	89	89
D3	261	260	259	258
D5	197	196	195	192
D9	143	141	140	137
E1.5	536	533	531	526
F1	1135	1127	1124	1111

It can be seen from **Table B9** and **Table B10** that the maximum downwind distance for a concentration level of chlorine of 5 ppm is 1,558 metres. This occurs using a 1 second averaging period, at 1.8 metres above ground level, and under F class stability 1 m/s conditions.

Table B11 Chlorine 20 ppm Maximum Distance from Source (Metres) 1 Second Averaging Period

Met Condition	Height (m)			
	0.01	1.5	1.8	2.5
B3	84	83	83	83
B5	68	67	67	66
D3	182	180	179	176
D5	142	140	138	136
D9	106	104	103	100
E1.5	326	321	319	313
F1	576	563	558	540

Table B12: Chlorine 20 ppm Maximum Distance From Source (Metres) – 900 Second Averaging Period

Met Condition	Height (m)			
	0.01	1.5	1.8	2.5
B3	58	57	57	56
B5	46	45	45	43
D3	124	121	120	117
D5	94	92	91	87
D9	69	66	65	61
E1.5	243	239	237	230
F1	464	453	446	432

It can be seen from **Tables B11** and **B12** that the maximum downwind distance for a concentration level of chlorine of 20 ppm is 558 metres. This occurs using a 1 second averaging period, at 1.8 metres above ground level, and under F class stability 1 m/s conditions.

B.7 Bulk Liquids Incidents

B.7.1 Fuel Transfer at Wharf – Fuel Release, Ignition and Fire

As noted in the hazard analysis (main report), the worst case incident at the wharf would be a flexible hose failure, discharging the hose contents to the wharf, resulting in a pool of flammable liquids. Ignition of the release would then result in a pool fire on the wharf.

The transfer of bulk flammable/combustible liquids would be conducted using two 200 millimetre hoses connected to the ship/shore. In the event of a hose rupture, it is feasible that only one hose would fail at any given time, hence, only single hose failure has been considered in this study.

The hose will be connected from the ship to the shore and will be about 20 metre long. The volume of fuel in the hose is therefore:

$$V = \pi/4 \times D^2 \times L = \pi/4 \times 0.2^2 \times 20 = 0.628 \text{ m}^3 \text{ or } 628 \text{ litres}$$

In the event of a rupture, the release will be immediately shut down, by ship and shore operators, using the isolation valves at the ship/shore connections. Hence, the remaining hose volume will spill to the wharf and spread across the wharf deck. The liquid will spread to a thickness of 0.005 millimetres (Ref.21 – main report) which will result in a pool diameter of:

$$D = (0.628/0.005 \times 4/\pi)^{0.5} = 12.65 \text{ metres}$$

In the event of an ignition, the pool diameter of the fire would be 12.65 metres. This diameter has been used to estimate the impact to surrounding areas.

Using the methodology presented in **Section B2** the following inputs have been developed for the heat radiation model.

Fire Diameter	12.65 metres
Fire height	20.95 metres
Flame tilt	15 degrees
SEP	46.3 kW/m^2
Transmissivity	0.81 (at 25.4 metres distance, equivalent distance to 4.7 kW/m^2)

The SCC model was entered into a Microsoft Excel spread sheet and the data above input to the model. The distance to a heat radiation level of 4.7 kW/m^2 was estimated and identified to be 25.4 metres. A value of 4.7 kW/m^2 was selected as the impact level of heat radiation above which people should not be exposed (Ref. 4).

The SCC was applied to determine the distance to selected heat radiations. The summary of results is presented in **Table B13**.

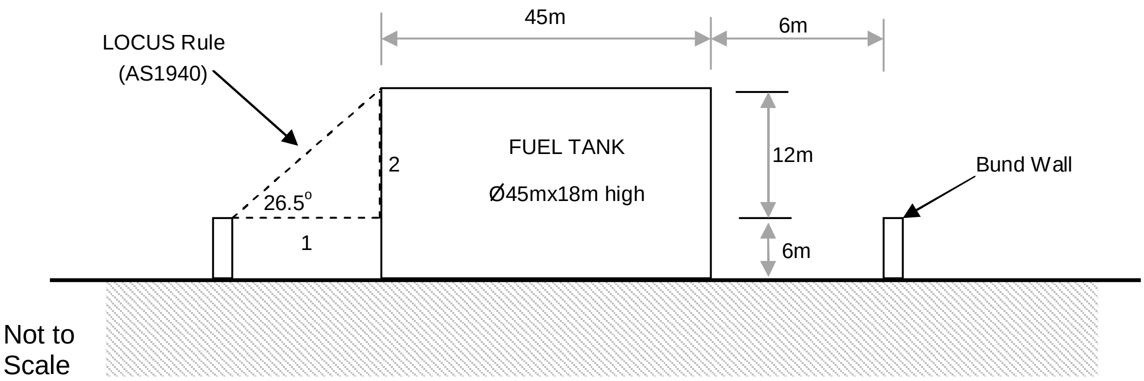
Table B13: Distance to Selected Heat Radiation Impact - Flexible Hose Rupture and Fire

Heat Radiation Level (kW/m^2)	Distance (m)
35	9.8
23	11.8
15	14.4
12.5	15.8
8	19.5
6	22.5
4.7	25.4
2	38

B.7.2 Tank Roof and Bund Fires

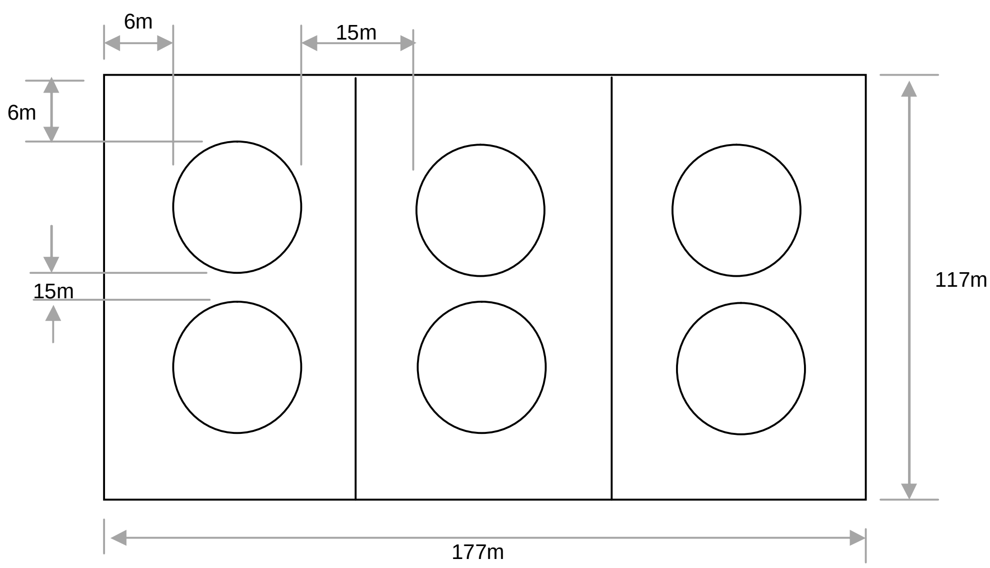
At this stage of the bulk liquids development, detailed terminal designs and layouts are not available. However, total storage of fuels at each of the proposed terminals (2) has been estimated to be 166,000 m^3. A typical storage tank size for a medium sized terminal (the type proposed at the NPC site) would be 45 metres diameter x 18 metres high, holding about 28,000 m^3 of fuel. Based on a total storage of 166,000 m^3, there would be a total of 6 tanks at each terminal. AS1940 has been used, to determine the minimum bund size for each tank (i.e. LOCUS rule and capacity) for a bund wall height of 6 metres. **Figure B4** shows the bund dimensions.

Figure B4: Bund Dimensions Determined Using As1940



A typical terminal layout incorporating 6 tanks with three bunds is shown in **Figure B5**. The bund dimensions determined in **Figure B4** have been used to develop the typical terminal layout, along with the minimum tanks separation requirements detailed in AS1940 (Clause 5.7.3(c)).

Figure B5: Typical Terminal Layout – NPC Concept Plan



A review of the tank/bund fire dimensions indicates that the bund fire is considerably larger than the tank fire, hence, this has been used as the worst case incident to identify whether the heat radiation impact at adjacent areas can be maintained within the terminals can be located to ensure the maximum permissible level of 4.7kW/m^2. Hence, for the worst case incident (bund fire), the equivalent fire diameter is:

$$D = (4/\pi\ (117x58.5))^{0.5} = 93.4 \text{ metres}$$

Using the methodology presented in **Section B2** the following inputs have been developed for the heat radiation model.

Fire Diameter 93.4 metres

Fire height 84.1 metres

Flame tilt 15 degrees

SEP 20kW/m^2

Transmissivity 0.72 (at 77.5 metre distance, equivalent distance to 4.7 kW/m^2)

The SCC model was entered into a Microsoft Excel spread sheet and the data above input to the model. The distance to a heat radiation level of 4.7 kW/m^2 was estimated and identified to be 77.5 metres. A value of 4.7 kW/m^2 was selected as the impact level of heat radiation above which people should not be exposed (Ref. 4).

The SCC was applied to determine the distance to selected heat radiation. The summary of results is presented in **Table B14**.

Table B14: Distance to Selected Heat Radiation Impacts - Fuel Terminal Full Bund Fire

Heat Radiation Level (kW/m^2)	Distance (m)
35	30.5
23	35.8
15	43.3
12.5	47.4
8	59.0
6	68.5
4.7	77.5
2	120

B.8 Fuel Handling Incidents – NPC Operations Precinct

The hazard analysis conducted in **Section 4** of the main report identified that releases may occur from tank filling and fuel transfer operations in the NPC Operations Precinct. There are three operations that involve fuel handling:

- Filling of underground tanks using a road tanker;
- Fuelling of vehicles using a bowser type "pump"; and
- Fuelling of boats using a bowser type "pump".

The incident scenarios associated with each operation are reviewed below.

B.8.1 Filling Underground Tanks

Road tankers would be used to fill the underground tanks. Tankers would park adjacent to the underground tanks in a bunded area ("speed hump" type bund) that would contain any spills that may occur during tank filling. In the event of a major release, the "bund" would contain the spill forming a pool of flammable/combustible liquid. In the event of an ignition, a pool fire would result, radiating heat to the surrounding area.

The "bund" would need to be of sufficient area so that any spills from the tanker would be contained in the spill retention area. The "bund" would therefore need to be 6 metres long x 3 metres wide. In the worst case event, this "bund" would fill with flammable/combustible liquid, resulting in a full "bund" fire.

B.8.2 Fuelling Vehicles

Vehicle fuelling would be conducted using a bowser and within the "speed-hump" type bund detailed in **Section B5.1**. Hence, incidents involving fuel spills into this bunded area would, in the worst case, be the same as that discussed above.

B.8.3 Fuelling Boats

Boat refuelling would also be conducted using bowser operations. A spill retention area would be provided around the bowser, feeding to a spill retention tank under the wharf. Any spills in the boat refuelling area (i.e. on the wharf) would be collected in the spill retention area and directed to the spill retention tank under the wharf. As the boat refuelling operation occurs in a relatively small area, the spill retention facilities would also be relatively small (2 metres x 2 metres). This is much smaller than the tanker unloading area and therefore the worst case incident would be tanker unloading. It is also noted that the wharf area is considerably further from the site boundary than the tanker unloading bay, hence, based on potential incident magnitude and incident location, the underground tank filling operation has been selected as the worst case incident.

B.8.4 Heat Radiation Impact – Underground Tank Filling Incident

In the event of a leak into the "bunded" area under the road tanker,. Flammable or combustible liquid would, in the worst case, fill the "bund". Ignition of this pool of liquid would result in a pool fire with an equivalent diameter of:

$$D = (4/\pi\ (6x3))^{0.5} = 4.8 \text{ metres}$$

Using the methodology presented in **Section B2** the following inputs have been developed for the heat radiation model.

Fire Diameter	4.8 metres
Fire height	10.7 metres
Flame tilt	15 degrees
SEP	87.5 kW/m^2
Transmissivity	0.83 (at 16.1 metres distance, equivalent distance to 4.7 kW/m^2)

The SCC model was entered into a Microsoft Excel spread sheet and the data above input to the model. The distance to a heat radiation level of 4.7 kW/m^2 was estimated and identified to be 16.1 metres. A value of 4.7 kW/m^2 was selected as the impact level of heat radiation above which people should not be exposed (Ref. 4).

The SCC was applied to determine the distance to selected heat radiation. The summary of results is presented in **Table B15**.

Table B15: Distance to Selected Heat Radiation Impacts – Underground Fuel Tank Filling Incident Fire

Heat Radiation Level (kW/m^2)	Distance (m)
35	6.2
23	7,6
15	9.2
12.5	10.1
8	12.5
6	14.3
4.7	16.1
2	24

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