Economic Impact Study of Sydney's Ports 2001/02

A report prepared for

Sydney Ports Corporation

Prepared by

EconSearch Pty Ltd

June 2003

EconSearch Pty Ltd
PO Box 746, Unley BC SA 5061
Tel: (08) 8357 9560
Fax: (08) 8357 2299
www.econsearch.com.au

Acknowledgments

EconSearch relied heavily on the voluntary cooperation of port-related businesses and organisations in providing data for the port impact survey. Without this assistance the compilation and estimation of the port economic impacts would not have been possible. The advice provided by the Sydney Ports Corporation is also greatly appreciated. Officers provided assistance, were supportive of the data collection and offered valuable advice. We are particularly grateful to Mr Denis Dillon and Mr George Gomez for their assistance and support.

As required by the terms of reference, this study follows the analytical framework detailed in the Bureau of Transport Economics' 2000 report, *Regional Impacts of Ports*. The Association of Australian Ports and Marine Authorities facilitated the initiation and early stages of the study.

Contents

Executive Summary vi

1. Introduction 1

2. Sydney's Ports 4
   - 2.1 Infrastructure, facilities and port-related activity 4
   - 2.2 Cargo and trade patterns 10

3. Method, Input-output Table and Port-related Multipliers 13
   - 3.1 Method and data collection 13
   - 3.2 New South Wales input-output table 13
   - 3.3 Estimation of the flow-on effects 13

4. Economic Impact of Sydney's Ports 16
   - 4.1 Overall economic impact 16
   - 4.2 Components of the port's economic impact 19
     - 4.2.1 Port functions 19
     - 4.2.2 Cargo type 20
     - 4.2.3 Port area 21
   - 4.3 Projected Impacts: 2009/10, 2014/15, 2019/20 and 2024/25 23

5. Economic Impact of the Port Botany Expansion 25
   - 5.1 Construction Impact 25
   - 5.2 Operation Impact 27

Appendix I Survey Questionnaires 29

Appendix II Economic Impact Analysis 33

Appendix III Input-Output Sector Definitions 38

Appendix IV Disaggregated Multipliers 41

Appendix V Methods and Data Collection 45

Appendix VI Trade Through Sydney's Ports by Port Area 51

Appendix VII Projected Economic Impact of Sydney's Ports by Cargo Type 52

Appendix VIII Projected Economic Impact of Sydney's Ports by Port Area 56

Glossary 60

References 62

Figures

Figure 2.1 Current facilities at Sydney Harbour ... 5
Figure 2.2 Current facilities at Port Botany ... 6
Figure 2.3 Total cargo shipped through Sydney's ports, 1997/98 to 2001/02 ... 11
Figure 2.4 Total containers shipped through Sydney's ports, 1997/98 to 2001/02 ... 11

Tables

Table 1 Economic impact of Sydney's ports, 2001/02 ... vi
Table 2 Detailed measures of the economic impact of Sydney's ports, 2001/02 ... viii
Table 3 Economic impact of Sydney's ports by port area, 2001/02 ... ix
Table 4 Projected economic impact of Sydney's ports (all cargo), selected years ... x
Table 5 Projected economic impact of Port Botany expansion, selected years ... xi
Table 2.1 Main use of SPC managed berths ... 7
Table 2.2 Definition of port functions ... 9
Table 2.3 Cargo exported through Sydney's ports [a], 1997/98 to 2001/02 (mass tonnes) ... 12
Table 2.4 Cargo imported through Sydney's ports [a], 1997/98 to 2001/02 (mass tonnes) ... 12
Table 3.1 Input-output multiplier components ... 14
Table 3.2 Multipliers for Sydney's ports, 2001/02 ... 15
Table 3.3 Multipliers for components of Sydney's ports, 2001/02 ... 15
Table 4.1 Economic impact of Sydney's ports, 2001/02 ... 16
Table 4.2 Flow-on effects from the economic impact of Sydney's ports by industry sector, 2001/02 ... 17
Table 4.3 Economic impact of Sydney's ports by port function, 2001/02 ... 19
Table 4.4 Economic impact of Sydney's ports by cargo type, 2001/02 ... 21
Table 4.5 Economic impact of Sydney's ports by port area, 2001/02 ... 22
Table 4.6 Projected economic impact [a] of Sydney's ports (all cargo), selected years [b] ... 24
Table 5.1 Projected economic impact of Port Botany construction expenditures [a] ... 26
Table 5.2 Projected economic impact of Port Botany expansion, 2001/02 – 2024/25 [a] ... 28

Table IV.1 Disaggregated output multipliers ... 41
Table IV.2 Disaggregated value added multipliers ... 42
Table IV.3 Disaggregated income multipliers ... 43
Table IV.4 Disaggregated employment multipliers ... 44
Table V.1 Responses to port industry survey ... 49
Table VI.1 Trade through Sydney's ports by port area, 2001/02 (revenue tonnes) ... 51
Table VII.1 Economic impact of Sydney's ports by cargo type, 2009/10 ... 52

Table VII.2 Economic impact of Sydney's ports by cargo type, 2014/15 53
Table VII.3 Economic impact of Sydney's ports by cargo type, 2019/20 54
Table VII.4 Economic impact of Sydney's ports by cargo type, 2024/25 55
Table VIII.1 Economic impact of Sydney's ports by port area, 2009/10 56
Table VIII.2 Economic impact of Sydney's ports by port area, 2014/15 57
Table VIII.3 Economic impact of Sydney's ports by port area, 2019/20 58
Table VIII.4 Economic impact of Sydney's ports by port area, 2024/25 59

Executive Summary

Role and Impact of Ports

The operation of a port generates employment and income for the local community, as well as flow-on effects to other local industries. In addition, all levels of government receive revenue from taxes and other charges on these activities.

In recent years, there has been increased pressure across Australia to restrict the scope of port activities. Such restrictions can reduce the efficiency of a port and the competitiveness of shippers that use the port. There may also be adverse effects on local income and employment.

Port economic impact studies can contribute to a balanced assessment of the role of ports and to informed consideration of issues such as port planning (Bureau of Transport Economics 2000).

Sydney's Ports

Sydney's ports comprise one of New South Wales major assets and handle around $42 billion worth of trade each year. The port facilities include the second largest container and one of the largest general cargo ports in Australia. The specialised facilities at Sydney Harbour handle a wide range of vessels and cargoes, including dry bulk and general cargo, containers and motor vehicles. At Port Botany the two container terminals are complemented by a bulk liquids facility, an adjacent bulk liquids storage and distribution complex and by container support businesses.

Sydney is the natural transport hub for south-eastern Australia. The State's major road and rail network provide access from Sydney to Victoria, South Australia, Western Australia, regional New South Wales and the east coast of the Australian mainland.

Conduct of the Study

The study aimed to measure the economic impact of port-related activity. For the purposes of this study, port-related activity was defined as the activity undertaken by firms and organisations in moving cargo through Sydney's ports and in providing goods and services to directly facilitate the movement of cargo through the ports. Port impact was measured in terms of output, value added, household income and employment (refer to the Glossary for definition of these measures).

The study was undertaken using the general framework for port impact studies developed by the Bureau of Transport Economics (2000). The framework was initially applied in a study of the Port of Fremantle. This framework provides what can be termed the **economic impact** of the Port.

The estimates of the **economic impact** cover the direct effects of the port and the subsequent flow-on effects to other sectors of the regional economy. A survey with responses from 71 organisations involved in Sydney's port-related activity provided the majority of the data for estimating the direct effects. An input-output table for New South Wales was used to calculate the flow-on effects to other industry sectors.

Estimates of Economic Impact

Table 1 presents estimates of the economic impact of Sydney's ports, in terms of the direct and flow-on effects.

Direct effects

The direct impact of port-related activity on output, value added, household income and employment is shown in the first column of Table 1. The value of output, estimated to be $1,163 million for the 2001/02 financial year, is the sum of gross business revenue of firms defined as port-related and gross expenditure by port-related government, semi-government and non-profit organisations. These are revenues generated and expenditure incurred in New South Wales.

The value added from port-related activity was estimated to be $641 million for 2001/02. This represents approximately 0.3 per cent of New South Wales' estimated gross state product for 2001/02.

Direct employment (full-time equivalents) was estimated to be 6,945 and corresponding household income was $385 million. This indicates an average gross annual income of around $55,000 for those employed in firms and organisations engaged in port-related activity.

Table 1 Economic impact of Sydney's ports, 2001/02

Measure	*Direct effects*	*Flow-on effects*	*Total Impact*
Output ($m)	1,162.7	1,345.7	2,508.5
Value added ($m)	640.8	738.2	1,379.0
Household income ($m)	384.7	353.8	738.5
Employment[a]	6,945	10,075	17,020

[a] Number of jobs (full-time equivalent).

Source EconSearch analysis.

Flow-on effects

The flow-on effects of port-related activity to other sectors in the New South Wales economy for the 2001/02 financial year were estimated to total $1,346 million in output, $738 million in value added, over 10,000 jobs and $354 million in corresponding household income.

Finance and business services, wholesale and retail trade and manufacturing are the three sectors where port-related activity has the largest impact. For all four measures of economic impact (output, value added, employment and income), over 50 per cent of the total flow-on effect occurred in these three sectors. For employment, the combined impact in these sectors was more than 56 per cent (5,694 jobs) of the total employment flow-on from port-related activity (10,075 jobs).

Total economic impact

Sydney's ports generated a total economic impact on the New South Wales economy of $2,509 million in output in 2001/02.

Value added attributable to the operation of the ports was almost $1,380 million. This was equivalent to approximately 0.5 per cent of gross state product in 2001/02, which provides a measure of the overall level of economic activity in New South Wales.

Household income generated by the operation of the ports totalled over $738 million. Employment was estimated at around 17,020 jobs (full-time equivalent), which represented 0.6 per cent of total employment in New South Wales.

There were 2,189 ship visits to Sydney's ports by commercial cargo vessels in 2001/02. The results of the analysis indicate that, on average, each ship call at Sydney's ports involved the following impact on the economy of New South Wales:

- $1,146,000 of output;
- $630,000 of value added;
- $337,000 of household income; and
- 7.8 full-time equivalent jobs for one year.

Detailed Economic Impact Measures

Estimated economic impacts have been disaggregated to identify the relative contribution of the individual port functions and cargo types (Table 2).

Port functions

The largest impacts, in terms of output and value added, occurred in the *land transport and storage* sector. The value of services provided by this sector was $393 million in 2001/02, with flow-ons to other sectors in the economy of $434 million, giving a total output impact of $827 million. Direct employment in the sector was measured at 2,266 with associated household income of around $93 million. Flow-on employment in other sectors was estimated to be 3,278, earning around $115 million in household income during 2001/02.

The *ship loading and unloading*, *ship operations* and *cargo services* sectors had similar levels of impact, although somewhat less than the land transport and storage sector. Direct and flow-on employment in the ship loading and unloading sector accounted for an estimated 3,699 full-time equivalent jobs, while the ship operations sector generated 4,225 jobs and the cargo services sector 2,408 jobs.

The *port administration* sector provided services valued at over $85 million, with flow-ons to other sectors in the economy of around $76 million. Employment in the sector was measured at 210 with associated household income of over $18 million. Flow-on employment in other sectors was estimated to be over 582, earning around $21 million in household income during 2001/02.

The port-related activity of *government agencies* comprises a minor component of the total port impact.

Table 2 Detailed measures of the economic impact of Sydney's ports, 2001/02

Component	*Output ($m)*	*Value added ($m)*	*Household income ($m)*	*Employment no.*
Function				
Port administration	161.3	106.2	39.5	792
Ship operations	614.8	345.7	193.0	4,225
Ship loading/unloading	527.7	308.7	183.3	3,699
Cargo services	329.1	186.0	100.8	2,408
Land transport & storage	826.6	408.6	207.3	5,544
Government agencies	48.9	23.7	14.7	352
Total	*2,508.5*	*1,379.0*	*738.5*	*17,020*
Cargo Type				
Containers	1,547.9	853.5	458.3	10,518
General cargo	93.6	53.3	28.0	616
Bulk liquids and gas	567.1	305.1	162.5	3,869
Dry bulk	115.4	61.9	33.0	778
Motor vehicles	152.2	86.6	46.9	1,024
Passengers	32.4	18.6	9.9	214
Total	*2,508.5*	*1,379.0*	*738.5*	*17,020*

Note Components may not sum to totals due to rounding.

Source EconSearch analysis.

Cargo type

Although just 50 per cent of the port's total ship visits were *container* ships in 2001/02, over 60 per cent of the port's economic impact was related to container cargo: the equivalent of 4,316 people directly employed in container-related Port activity and around 10,518 jobs when indirect effects are included.

Bulk liquids and gas, which is predominantly comprised of imported petroleum products, accounted for 19 per cent of all ship visits. Although this is a relatively low input intensive loading and unloading operation, the high land transport activity meant that this cargo group provided over 22 per cent of the total economic impact.

Motor vehicles accounted for around 12 per cent of ship visits. In terms of output, value added, employment and household income this cargo group provided only 6 per cent of the total economic impact.

General breakbulk cargo accounted for 6.6 per cent of total ship visits in 2001/02. In terms of output, value added, employment and household income, this cargo group provided around 4 per cent of the total economic impact.

Dry bulk cargo accounted for around 9 per cent of ship visits. In terms of output, value added, employment and household income this cargo group provided just 4.5 per cent of the total economic impact.

Passenger vessels accounted for just 2.7 per cent of total ship visits in 2001/02. In terms of output, value added, employment and household income, this was the smallest impacting category, providing just 1.3 per cent of the total economic impact.

Port area

Port Botany has the largest impact of all the areas managed by Sydney Ports Corporation (SPC). Movement of cargo through Port Botany accounted for almost 60 per cent of the total economic impact of Sydney's ports in 2001/02. The total of 10,063 full-time equivalent jobs (direct plus flow-on) earned an estimated $438 million in household income in 2001/02. Direct and flow-on value added was estimated at over $815 million (Table 3).

The bulk liquids facility at *Kurnell*, the site of the Caltex refineries, contributed almost 12 per cent of the total economic impact of all the areas managed by SPC. The other major bulk liquids facility, Shell's *Gore Bay* terminal, contributed just under 8 per cent of the total economic impact of Sydney's ports in 2001/02.

Movement of cargo through the *Glebe Island* berths, *Darling Harbour* and *White Bay* each contributed in the range 5 to 7 per cent of the total economic impact of Sydney's port. For example, the movement of cargo and vessels through the Glebe Island berths generated a total of 1,176 full-time equivalent jobs and an associated $52 million in household income in 2001/02. Direct and flow-on value added was more than $97 million.

Passenger terminals and *other* port areas comprise a minor component of the total port impact

Table 3 Economic impact of Sydney's ports by port area, 2001/02

Port Area	*Output ($m)*	*Value added ($m)*	*Household income ($m)*	*Employment no.*
Darling Harbour	162.2	90.9	48.5	1,088
White Bay	139.0	77.3	41.3	937
Glebe Island	174.7	97.3	52.3	1,176
Kurnell	295.1	158.7	84.6	2,013
Gore Bay	198.4	106.7	56.9	1,354
Port Botany	1,480.8	815.6	437.7	10,063
Passenger Terminals	32.4	18.6	9.9	214
Others	25.9	13.9	7.4	175
Total	*2,508.5*	*1,379.0*	*738.5*	*17,020*

Note Components may not sum to totals due to rounding.
Source EconSearch analysis.

Projected Impacts

As part of its planning activities, SPC makes regular projections of future trade flows. Forecasts of trade to the year 2024/25 (unconstrained forecasts) have been used to project the possible impact of these cargo flows on the New South Wales economy.

Table 4 shows projected impacts for all cargo types (including passengers) for the years 2009/10, 2014/15, 2019/20 and 2024/25. By 2024/25, for example, containers are forecast to more than treble, motor vehicles almost double and bulk liquids and gas increase by over two-thirds when compared with the 2001/02 levels. These increased cargo movements will raise the economic impact in 2024/25 by around 80 per cent above the 2001/02 estimates across each of the economic impact indicators - output, value added, household income and employment.

Table 4 Projected economic impact[a] of Sydney's ports (all cargo), selected years[b]

	Output ($m)	*Value added ($m)*	*Household income ($m)*	*Employment no.*
2009/10				
Direct impact	1,405	774	465	8,397
Indirect impact	1,623	891	427	12,156
Total	*3,028*	*1,665*	*892*	*20,553*
2014/15				
Direct impact	1,610	888	534	9,631
Indirect impact	1,861	1,021	489	13,933
Total	*3,471*	*1,909*	*1,023*	*23,564*
2019/20				
Direct impact	1,854	1,023	615	11,089
Indirect impact	2,141	1,175	563	16,034
Total	*3,995*	*2,198*	*1,178*	*27,123*
2024/25				
Direct impact	2,076	1,146	689	12,419
Indirect impact	2,397	1,315	630	17,950
Total	*4,473*	*2,461*	*1,319*	*30,368*

[a] Based on unconstrained forecasts to 2024/25 including the effect of Port Botany expansion. Does not include the construction-related impacts of the Port Botany expansion.

[b] 2002 prices.

Note Components may not sum to totals due to rounding.

Source Appendix VII.

Port Botany Expansion

The proposed Port Botany expansion, which is a component of the unconstrained forecasts detailed above, will give rise to substantial infrastructure requirements as well as enable a significant increase in trade through the port. This activity will generate substantial economic impacts, from both the construction activity and the operation of the expanded facility.

Construction expenditures will occur in the terminal area, the container area and the commercial area. The economic impact from the construction phase of the proposed Port Botany expansion is expected to peak over the years 2004/05 to 2006/07. In 2004/05 business turnover directly related to the development will be around $91 million with flow-ons to other firms adding another $39 million. Associated value added, a measure of the net contribution to the state's economy, is projected to total over $35 million. Household income generated directly from construction activities during the peak impact year (2006/07) is anticipated to be around $6.5 million, with 155 full-time equivalent (fte) jobs. Indirect household income is projected to be $9.6 million with an associated 258 jobs, giving total employment (direct + flow-on) of 413.

Table 5 shows the projected direct and indirect impacts of construction and operational activity associated with the Port Botany expansion for the years 2009/10, 2014/15, 2019/20 and 2024/25.

Table 5 Projected economic impact of Port Botany expansion, selected years [a]

	Projected Trade (million teus)	*Output ($m)*	*Value added ($m)*	*Household income ($m)*	*Employment no.*
2009/10	**0.320**				
Direct Impact					
Construction		13	2	1	20
Operations		193	107	65	1,159
Total		*206*	*109*	*65*	*1,179*
Total Impact					
Construction		18	5	2	54
Operations		416	229	123	2,823
Total		*433*	*234*	*125*	*2,877*
2014/15	**0.800**				
Direct Impact					
Construction		13	2	1	15
Operations		460	255	154	2,754
Total		*472*	*256*	*154*	*2,769*
Total Impact					
Construction		17	4	2	45
Operations		988	545	292	6,712
Total		*1,005*	*549*	*294*	*6,758*
2019/20	**1.000**				
Direct Impact					
Construction		13	2	1	15
Operations		546	303	182	3,274
Total		*559*	*304*	*183*	*3,289*
Total Impact					
Construction		17	4	2	42
Operations		1,174	648	348	7,979
Total		*1,191*	*652*	*350*	*8,022*
2024/25	**1.200**				
Direct Impact					
Construction		13	2	1	15
Operations		623	346	208	3,737
Total		*636*	*347*	*209*	*3,752*
Total Impact					
Construction		17	4	2	40
Operations		1,340	739	397	9,106
Total		*1,357*	*743*	*399*	*9,146*

[a] 2002 prices.

Note Components may not sum to totals due to rounding.

Source SPC, EconSearch analysis.

SPC provided estimates for container throughput of the proposed Port Botany expansion. These estimates show an additional 320,000 TEUs in the 2009/10 financial year and increasing thereafter to an additional 1,200,000 TEUs by 2024/25. Total port-related output (direct + flow-on) associated with the expansion in 2024/25 was estimated at over $1.3 billion.

Value added attributable to the construction and operation of the expansion site in 2024/25 was estimated at $743 million. Household income generated by the proposed expansion was projected to be around $399 million in 2024/25. Associated employment was estimated to be 9,146 jobs (full-time equivalent).

Interpreting the Results

The estimates of economic impact from this type of analysis indicate the general magnitude of effects associated with the port's activities. They do not provide precise estimates, as only approximate data were available for some parts of the analysis.

The results of the study provide estimates of the impact attributable to activities required for the movement of ships and cargo through the port. They do not indicate net economic benefits, technical efficiency, competitiveness, trade facilitation effects or the contribution of port infrastructure to regional development.

1. Introduction

Background

The operation of a port generates employment and income for the local community, as well as flow-on effects to other local industries. In addition, all levels of government receive revenue from taxes and other charges on these activities.

In recent years, there has been increased pressure across Australia to restrict the scope of port activities. Such restrictions can reduce the efficiency of a port and the competitiveness of shippers that use the port. There may also be adverse effects on local income and employment.

Port economic impact studies can contribute to a balanced assessment of the role of ports and to informed consideration of issues such as port planning (Bureau of Transport Economics 2000).

Study brief

With this in mind, the Sydney Ports Corporation, in consultation with the Association of Australian Ports and Maritime Authorities (AAPMA), contracted EconSearch Pty Ltd to undertake an Economic Impact Study of Sydney ports. Julian Morison of EconSearch undertook the study. Hassall and Associates undertook the main survey for the study. The requirements of the study were as follows:

Impact of Sydney's ports on the Sydney and New South Wales economy - BTE Framework

1. The study must utilise the general framework and methodology set out in Bureau of Transport Economics (2000) *Regional Impacts of Ports*, Report No. 101, BTE, Canberra.
2. The impact measures should be calculated in terms of:
   - Output;
   - Value-added;
   - Household income; and
   - Employment.
3. The impact measures should be able to be disaggregated in terms of:
   - Port function (i.e. the major activities undertaken within the port – port administration, ship movement & operation, cargo loading & unloading, etc.); and
   - Cargo type (containers, general cargo, dry bulk, etc.).
4. The impact measures should also be disaggregated in terms of the geographical location of berths within the port (Port Botany, Kurnell, Darling Harbour, Glebe Island, etc.).
5. Estimate the impacts of expanding an existing activity - SPC's proposed expansion of container facilities. This is to be estimated in two parts: the impacts of the construction phase and the impacts of the operating phase of the developments.

6. Based on estimates of future trade flows, make projections of the economic impact of Sydney's ports. These projections are to be disaggregated in terms of port area and cargo type.

Study aims

One of the key objectives of the project was to assess the direct and indirect economic impact of the movement of cargo through Sydney's ports (the economic impact). The income and expenditures of the Sydney Ports Corporation, of firms engaged in port-related activity and of firms transporting freight to and from the port comprise the direct economic impact.

These direct impacts were used as a basis for assessing the indirect economic impacts of port-related activity. All economic impacts were measured in terms of household income, output, value added and employment.

The economic impacts were disaggregated by major port function which are listed below.

- Administration
- Ship operations
- Ship loading and unloading
- Cargo services
- Land transport and storage
- Government agencies

The economic impacts were also disaggregated by cargo type, as detailed in the terms of reference. These are:

- Containers
- General cargo
- Bulk liquids and gas
- Dry bulk
- Motor vehicles
- Passengers

To assess the spatial distribution of the impacts, estimates were also made with reference to the location of berths within the port. These are:

- Darling Harbour
- White Bay
- Glebe Island
- Kurnell
- Gore Bay
- Port Botany
- Passenger Terminals
- Others

The disaggregation of impacts by port function and cargo type, as described above, is consistent with that used in the Bureau of Transport Economics (2000) port impact framework.

Port-related activity

For the purpose of measuring the impact of *port-related activity* on the economy, i.e. the economic impact of the port, it is necessary to have a clear definition of what comprises such activity.

Port-related activity is the activity undertaken by firms and organisations in moving cargo through Sydney's ports and in providing goods and services to directly facilitate the movement of cargo through the ports.

Included under this definition are firms that provide various maritime services such as transport firms, stevedoring companies and shipping agents. However, users of the port are not included. For example, manufacturing firms, distributors and retailers that import and export goods through the port in the course of their business, although dependent on the port to move their cargo, are not considered to be firms directly involved in *port-related activity*[1,2].

1 Some port users are involved in cargo loading and unloading, for example, and the expenditures associated with this part of their operations are included in the analysis.

2 Activities related to commercial fishing and recreational boating are excluded from the definition.

2. Sydney's Ports

Sydney's ports are one of New South Wales' major assets and handles around $42 billion worth of trade each year. The facilities include the second largest container and one of the largest general cargo ports in Australia.

Sydney Ports Corporation is a statutory State-owned corporation charged with the ownership and operation of the commercial ports of Sydney Harbour and Botany Bay.

Sydney Harbour's commercial wharves are located less than 10 km from bluewater shipping lanes. The port's specialised facilities handle a wide range of vessels and cargoes, including dry bulk and general cargo, containers and motor vehicles. The port is linked to road and rail networks serving Sydney, New South Wales and Australia. Sydney Harbour is also the leading destination for cruise shipping in the South Pacific region.

Port Botany is located 12 kilometres from Sydney's CBD and is well serviced by road and rail networks as well as Sydney's international and domestic airports. Port Botany's two container terminals are complemented by a bulk liquids facility, an adjacent bulk liquids storage and distribution complex and by container support businesses.

2.1 Infrastructure, facilities and port-related activity

The port provides five types of commercial shipping facilities:

- Container terminals;
- Multi-purpose terminals (including break bulk, motor vehicles and coastal trade);
- Dry bulk berths and storage;
- Bulk liquid berths and storage; and
- Passengers

The facilities include common user berths which are required for transient vessels not contracted to a particular stevedore. There are specialised berths for dry cargoes including cement, grain, sugar, soda ash and gypsum, and facilities for a variety of liquids from petrochemicals and crude oil to molasses.

The location of these facilities is illustrated in Figure 2.1 (Sydney Harbour) and Figure 2.2 (Port Botany). The berths shown in Figure 1 are those managed by SPC and have a wide variety of uses, as described in Table 2.1.

Figure 2.1 Current facilities at Sydney Harbour

- A Overseas Passenger Terminal
- B Darling Harbour (Patrick - The Australian Stevedore)
- C Darling Harbour Passenger Terminal
- D Glebe Island (Australian Automotive Terminals)
- E Australian Cement Holdings
- F Sugar Australia
- G Penrice Soda Products
- H White Bay 3/6 (P&O Ports)
- ① Berth Numbers
- Sydney Ports Property
- Railway Lines

Sydney Ports Corporation's Facilities in Sydney Harbour

Source Sydney Ports Corporation

Figure 2.2 Current facilities at Port Botany

Source Sydney Ports Corporation

Table 2.1 Main use of SPC managed berths

Sydney Harbour	
Darling Harbour Berths 3–7	Darling Harbour 3-7 is a container, general, Ro/Ro and bulk cargo facility. It comprises paved storage and hardstand areas, enclosed storage sheds, offices and amenities. The terminal operates 24 hours a day, seven days a week.
Glebe Island Berths 1-2	Glebe Island Berths 1-2 comprise a dedicated motor vehicle discharge facility with capacity to accommodate 4,500 vehicles. The facility operates 24 hours a day, seven days a week.
Glebe Island Berth 7-8 (Common user berths)	Glebe Island Berths 7-8 provide common user bulk dry cargo discharge facilities, equipped for self discharging vessels using wharf manifold to pipelines, conveyors and adjacent storage silos. Cargo discharged at this facility include bulk cement, bulk refined sugar and soda ash.
White Bay Berths 3-6	This facility handles containers as well as general, break-bulk and Ro/Ro cargoes. It comprises paved storage and hardstand areas, enclosed storage sheds, offices and amenities. The terminal operates 24 hours a day, seven days a week.
Blackwattle Bay	This privately owned facility is used for the discharge of bulk concrete aggregate.
Gore Bay Terminal – Shell	Shell's Gore Bay Terminal is used for the import, export and storage of oil products. Crude oil, feedstocks and products are transferred to the Clyde Refinery by underground pipeline. The Terminal is staffed 24 hours a day, seven days per week.
Botany Bay	
Brotherson Dock 1-3	Brotherson Dock is the major container facility for Sydney's ports. This terminal, operated by Patrick Stevedores is located on the northern side of Brotherson Dock and operates 24 hours per day, 7 days a week.
Brotherson Dock 4-6	Brotherson Dock is the major container facility for Sydney's ports. This terminal, operated by P&O Ports is located on the southern side of Brotherson Dock and operates 24 hours a day, seven days a week.
Bulk Liquid Berth	The Bulk Liquids Berth at Port Botany services the discharge and load requirements of the petro-chemical industry in New South Wales. Bulk liquid petro-chemical cargoes are transferred by pipeline to nearby industry storage facilities which are operated by private companies including VOPAK, Terminals Pty Ltd, Origin Energy Ltd and Elgas Ltd.
Kurnell - Caltex Refineries	Located on the southern side of Port Botany, Caltex Australia Limited operates a jetty with two berths and a multi-buoy mooring, primarily for crude oil imports as well as other petro-chemical products.

Source Sydney Ports Corporation

As noted earlier, the firms and organisations involved in port-related activity can be grouped according to their function. These are detailed in Table 2.2. A brief explanation of each group is provided below.

(1) Administration

This function is comprised of general port management and operations.

(2) Ship operations

Three sub-groups make up the shipping group. The first of these relates to the activities of shipping lines and agents. The local expenditures incurred by these companies in the operation of their business comprise part of the shipping component of port-related activity.

The second sub-group relates to moving the ships into and out of the port. This includes pilotage, towage, linesmen services and mooring and unmooring.

The third sub-group includes services provided to ships while they are in the port. Firms providing these services include ship chandlers and provedores, ship repairers and oil bunkering companies.

(3) Ship loading and unloading

This group relates to the movement of cargo on and off the ship. For containers and other general cargo, this generally involves moving the cargo across the wharf and onto (or off) some form of land-based transport (road or rail). This type of cargo movement is undertaken by stevedoring companies. Bulk cargoes (oil, chemicals, gas, etc) are generally moved through specialised facilities, sometimes owned and operated by the importing/exporting firm.

(4) Cargo services

This group includes customs agents, freight forwarders, container packing/unpacking, container parks and fumigation services.

(5) Land transport and storage

This group comprises the activities of the railways and road transport firms in moving cargo to and from the port. Only expenditures directly related to cargo moving through the port are included in this component of port-related activity. Port related storage is also included in this category.

(6) Government agencies

This group includes cargo inspection and regulation (customs, quarantine, and environmental inspections) as well as ship safety.

Table 2.2 Definition of port functions

Port industry group	*Components*
Port administration	Planning, co-ordination & promotion Land and property management Safety and emergency response Port maintenance Dredging
Ship operation	Shipping lines Ship managers Ship repairs and maintenance [a] Bunkering Ship chandlers/provedores [b] Marine and cargo surveyors Waste disposal
Ship movement	Shipping channels Navigation aids Ship agents Towage operators Pilots Mooring/unmooring services [c]
Ship loading/unloading	Wharves, berths, jetties, etc. [d] Stevedoring (non-bulk) Bulk cargo loading/unloading Passenger terminals
Cargo services	Customs agents Freight forwarders Container packing/unpacking Container parks Fumigation
Land transport and storage [e]	Road transport Rail transport Storage facilities
Government agencies	Customs Quarantine Ship safety [f]

a. Only for vessels in the port for the purpose of bringing in or taking out cargo or passengers.

b. Supply of stores and provisions to ships. Excludes supplies to commercial fishing or recreational boating sectors.

c. Includes linesmen and launch service.

d. Construction and maintenance.

e. Port-related activities only. Involves movement of cargo within the port and between the port and closest inland points (e.g. warehouses, bonded storage).

f. Australian Maritime Safety Authority.

2.2 Cargo and trade patterns

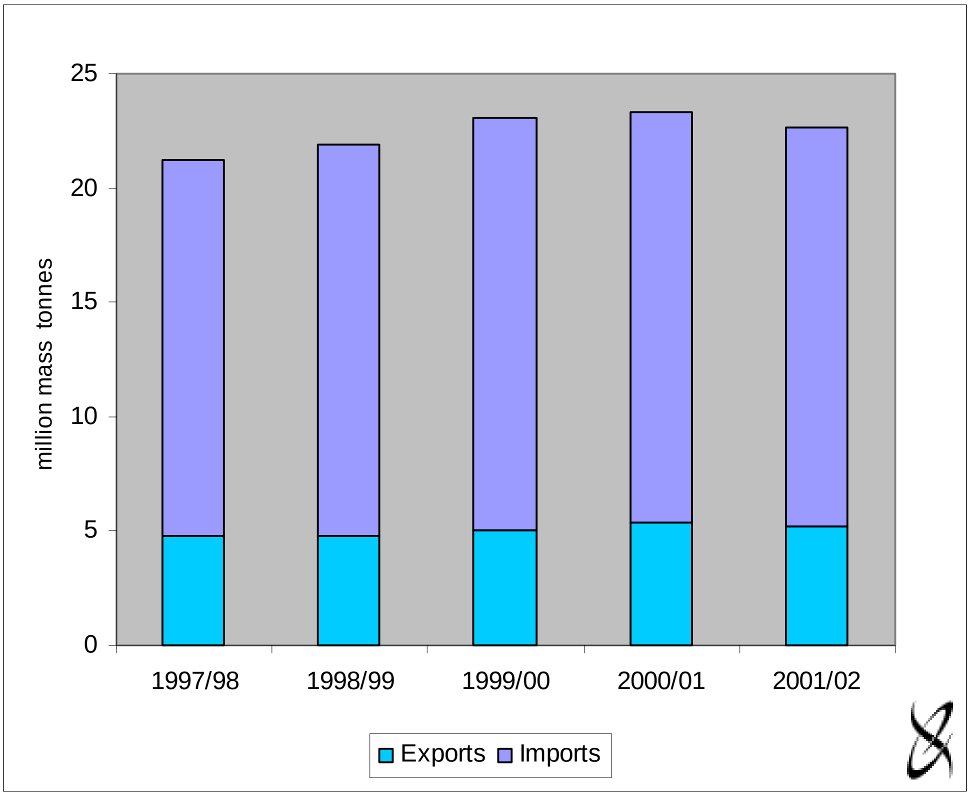
Total cargo moved through Sydney's ports, over the five years 1997/98 to 2001/02, grew by 6.5 per cent on a tonnage basis (Figure 2.3) and 26 per cent on a TEU basis (Figure 2.4). In 2001/02 the value of cargo handled through the ports was estimated at approximately $42 billion, comprising imports valued at $30.9 billion and exports of $10.8 billion.

In total, the volume of exports increased by 8.1 per cent over the five-year period, with significant growth in food preparations, beverages, animal foods, paper and paper products (Table 2.3). The volume of imports increased by 6.0 per cent over the same period with significant growth in electrical machinery and equipment, propane, food preparations and refined oil (Table 2.4).

For the purpose of the impact analysis, cargo and passengers have been classified according to one of six groups:

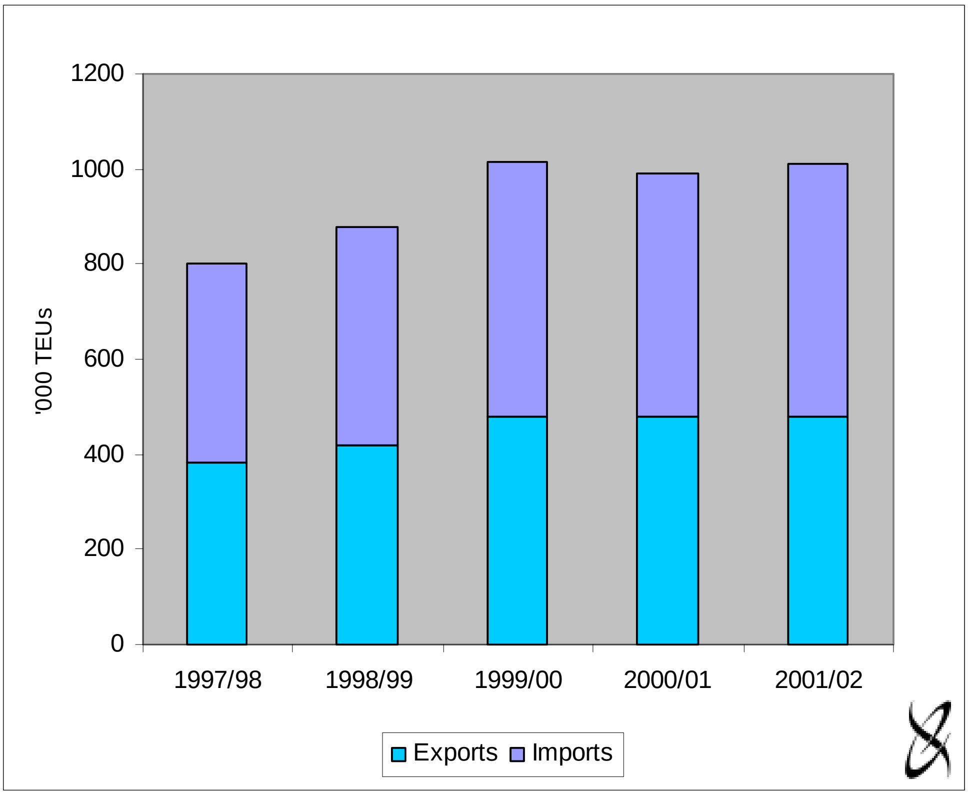
- Containers
- General cargo
- Bulk liquids and gas
- Dry bulk
- Motor vehicles
- Passengers

Figure 2.3 Total cargo shipped through Sydney's ports, 1997/98 to 2001/02



Source Sydney Ports Corporation

Figure 2.4 Total containers shipped through Sydney's ports, 1997/98 to 2001/02



Source Sydney Ports Corporation

Table 2.3 Cargo exported through Sydney's ports [a], 1997/98 to 2001/02 (mass tonnes)

Cargo Type	1997/98	1998/99	1999/00	2000/01	2001/02
Oil - refined	1,045,946	969,748	754,460	788,131	693,541
Cereals and cereal preparations	296,361	380,583	406,944	462,695	350,065
Paper and paper products	197,359	172,336	185,023	164,891	329,419
Aluminium and articles thereof	218,078	278,355	296,535	283,003	321,632
Cotton	289,940	292,634	278,045	356,711	285,978
Meat	263,206	284,962	257,797	295,071	277,340
Iron and steel and articles thereof	268,676	225,519	255,443	262,611	275,125
Food preparations	112,436	109,985	151,553	204,533	246,343
Animal foods	145,429	146,148	185,582	206,167	219,989
Beverages	68,659	75,890	92,906	118,316	147,623
Other	1,883,578	1,855,954	2,142,457	2,251,489	2,031,004
Total	4,789,668	4,792,114	5,006,745	5,393,618	5,178,059

a Includes coastal and overseas trade

Source Sydney Ports Corporation

Table 2.4 Cargo imported through Sydney's ports [a], 1997/98 to 2001/02 (mass tonnes)

Cargo Type	1997/98	1998/99	1999/00	2000/01	2001/02
Oil - crude	9,688,317	9,194,513	8,656,579	9,219,245	9,016,337
Oil - refined	902,052	1,429,008	1,903,689	1,874,334	1,362,758
Paper and paper products	606,529	551,842	670,805	599,649	608,418
Cement	343,953	480,209	454,602	442,791	468,614
Electrical machinery and equipment	61,074	336,437	343,918	306,421	369,318
Gypsum	303,094	324,625	399,265	344,736	317,865
Propane	178,259	235,872	207,527	268,227	287,997
Food preparations	173,245	185,854	238,849	277,616	269,843
Assembled passenger vehicles	228,676	217,910	238,471	243,242	253,863
Wood and articles	248,157	269,859	398,516	268,514	244,813
Other	3,729,112	3,856,045	4,543,986	4,085,108	4,257,025
Total	16,462,468	17,082,174	18,056,207	17,929,883	17,456,851

a Includes coastal and overseas trade

Source Sydney Ports Corporation

3. Method, Input-output Table and Port-related Multipliers

3.1 Method and data collection

The method used to estimate the economic impact of Sydney's ports is described in Appendix V. As required in the project brief, the approach adopted for this analysis follows that described in Bureau of Transport Economics (2000). The data collection procedures are also detailed in Appendix V, describing the survey of port-related firms and organisations, the aggregate port data compiled by the Sydney Ports Corporation and the preparation of the New South Wales input-output table for 2001/02. The concept, nature and methodology of impact measurement at the regional level are described in general terms in Appendix II.

3.2 New South Wales input-output table

The New South Wales input-output tables for 1996/97[3] were based on the 1996/97 Australian Bureau of Statistics' National Input-Output Table. The New South Wales tables were estimated using the GRIT (Generation of Regional Input-output Tables) and RAS[4] techniques. These techniques involve using the national input-output table structure as the initial estimate of the New South Wales structure. The national structure is then adjusted using an interactive row and column adjustment process where the column sums and row sums are the relevant New South Wales industry total for 1996/97.

The 107 industries of the New South Wales table are defined in Appendix III. The row and column totals were estimated by CARE[5] using:

(i) Australian Bureau of Statistics' Agriculture, Mining and Manufacturing production, value added and wages estimates per annum for 1996/97 as published in the relevant Industry Censuses;

(ii) Australian Bureau of Statistics four digit ANZSIC Labour Force Survey New South Wales Employment estimates for 1996/97; and

(iii) Value added, and salary and wage estimates totals per one digit ANZSIC service industries published in the ABS "State Accounts".

The estimated table was for the direct allocation of imports. That is, the flows in the table represent the flows between industries in New South Wales.

3.3 Estimation of the flow-on effects

The input-output table, modified so as to include Sydney port-related activities[6], was used to prepare the port-specific multipliers. The essence of impact measurement is

3 The data in the models were inflated to 2001/02 to ensure consistency with survey and other port-related data used in the analysis.
4 See ABS (2001) for a description of the RAS technique.
5 The Centre for Agricultural and Regional Economics (CARE) Pty Ltd provided the Sydney region model used in the analysis.
6 Section 3 of this report and BTE (2000, pp. 96-97) describe the process of modifying input-output tables and preparing port-specific multipliers.

the empirical measurement of the relationship between cause and effect, or between the impacting agent and the expected impact. This relationship can be expressed in terms of a multiplier.

In this study, output, income, employment and value added multipliers are used to express impacts in terms of a 'per unit of output of port-related activity'.

Each multiplier can be disaggregated into a number of components, differentiating the direct and flow-on effects of port-related activity. *Direct effects*, sometimes referred to as *initial effects*, are the stimulus for the impact analysis and correspond, in this analysis, to port-related activity. *Flow-on effects* measure the economic activity in other sectors of the economy in response to the initial stimulus. The various multiplier components are shown in Table 3.1.

Flow-on effects are divided into two components, *production-induced effects,* which are a measure of business-to-business transactions, and *consumption-induced effects*, which represents the expenditure of household income received as payments for labour used in producing the additional output. Production-induced effects can be further divided into *first-round effects* and *industrial-support effects*.

Table 3.1 Input-output multiplier components

Multiplier component	**Description**
Direct (initial) effect	The stimulus for the impact analysis – normally assumed to be a dollar change in sales to final demand
Flow-on effects:	
Production-induced effects:	
First-round effects	Refers to the purchases of inputs required from other sectors in the economy in order to produce the additional output
Industrial-support effects	Refers to second, third and subsequent-round industrial flow-on effects triggered by the purchases in the first round
Consumption-induced effects	Stem from the spending of household income received as payments for labour used in producing the additional output
Total effect	Direct effect+ flow-on effects
Type I multiplier	(Direct + production induced)/direct
Type II multiplier	(Direct + production induced + consumption induced)/direct

Utilising the modified New South Wales input-output table, which incorporated the Sydney ports sector, a range of multipliers were calculated for the various dimensions of impact analysis required in the study brief. Aggregate multipliers are shown in Tables 3.2 and 3.3. Disaggregated multipliers are provided in Appendix IV.

Multipliers are usually presented in 'per unit of output terms', as they are here. The output multiplier (Table 3.2) can be interpreted as follows: an initial $1 of output in the port sector leads to a flow-on effect in other sectors of the New South Wales economy of $1.16, giving a total effect of $2.16. Each dollar of output also generates 33 cents in direct household income (i.e., wages and salaries paid to employees of port-related firms and organisations) and a further 30 cents to workers in associated industries. Similarly, each dollar of output results in 55 cents in value added in the port sector and a further 64 cents in value added in other sectors of the economy.

Employment multipliers are expressed in terms of jobs per *million* dollars of output and relate to full-time equivalent jobs. In Table 3.2, the direct effect of 6 jobs per million dollars of output results in 9 jobs in other sectors of the economy, realising a total effect of approximately 15 jobs per million dollars of port sector output.

Table 3.2 Multipliers for Sydney's ports, 2001/02

Measure	*Direct effects*	*Flow-on effects*	*Total Impact*
Output[a]	1.00	1.16	2.16
Value added[a]	0.55	0.64	1.19
Household income[a]	0.33	0.30	0.64
Employment[b]	6	9	15

a. Dollar impact of $1.00 of output in port industry.

b. Number of jobs (full-time equivalent) per $million of output in port industry.

Source EconSearch analysis.

As noted earlier, multipliers were estimated not only for the port as a whole but also for the port activity disaggregated on the basis of port function (port administration, ship operations, etc.) and cargo type (containers, general cargo, etc.). These multipliers are presented in Table 3.3. Note that they are *total* multipliers, as defined in Table 3.1, and correspond to the "Total Impact" multipliers presented in Table 3.2.

Table 3.3 Multipliers for components of Sydney's ports, 2001/02

Port component	*Output* [a]	*Value added* [a]	*Household income* [a]	*Employment* [b]
Function				
Port administration	1.89	1.24	0.46	9
Ship operations	2.35	1.32	0.74	16
Ship loading/unloading	2.20	1.28	0.76	15
Cargo services	2.01	1.14	0.62	15
Land transport & storage	2.10	1.04	0.53	14
Government agencies	2.66	1.29	0.80	19
Total	*2.16*	*1.19*	*0.64*	*15*
Cargo Type				
Containers	2.15	1.19	0.64	15
General cargo	2.18	1.24	0.65	15
Bulk liquids and gas	2.14	1.15	0.61	14
Dry bulk	2.21	1.19	0.63	14
Motor vehicles	2.22	1.26	0.68	15
Passengers	2.28	1.31	0.70	16
Total	*2.16*	*1.19*	*0.64*	*15*

a. Dollar impact of $1.00 of output in port industry.

b. Number of jobs (full-time equivalent) per $million of output in port industry.

Source EconSearch analysis.

4. Economic Impact of Sydney's Ports

This section presents estimates of the economic impact of Sydney's ports in terms of output (gross revenue/expenditure), value added (payments to primary inputs of production), household income and employment. Detailed impact measures cover the impact attributable to individual port functions, commodities, and cargo types.

Although output provides a readily understandable indicator of economic activity, problems of double counting can arise when the output of a number of firms are aggregated to give an industry view. For example, if the output of the Ports Corporation is added to the output of the firms that provide services to the Corporation (e.g. dredging services, pest control, etc), then the value of those services will be counted twice in the aggregate figure. A more appropriate indicator of the port's relative contribution to the State's economy is value added (payments to primary inputs of production, i.e. gross operating surplus plus wages and salaries). Value added can be directly compared to gross state product and it avoids the problem of double counting.

4.1 Overall economic impact

Table 4.1 presents estimates of the overall economic impact of Sydney's ports, incorporating the direct effects and the flow-on effects.

Direct effects

The ***direct impact*** of port-related activity on output, value added, household income and employment is shown in the first column of Table 4.1. The value of output, estimated to be $1,163 million in the 2001/02 financial year, is the sum of gross business revenue of firms defined as port-related (or that proportion of firms' revenues attributable to port-related activity), and gross expenditure by port-related government, semi-government and non-profit organisations. These are revenues generated and expenditure incurred in New South Wales.

The value added from port-related activity was estimated to be $641 million for 2001/02. Value added refers to the difference between the total revenue of a firm and the cost of bought-in materials, services and components. In other words, it represents payments to the primary inputs of production (labour, capital and land), and can be used to describe the contribution of an industry to gross domestic (state) product. The value added of port-related activity ($641 million) represents approximately 0.3 per cent of the New South Wales' estimated gross state product for 2001/02.

Table 4.1 Economic impact of Sydney's ports, 2001/02

Measure	*Direct effects*	*Flow-on effects*	*Total Impact*
Output ($m)	1,162.7	1,345.7	2,508.5
Value added ($m)	640.8	738.2	1,379.0
Household income ($m)	384.7	353.8	738.5
Employment[a]	6,945	10,075	17,020

[a] Number of jobs (full-time equivalent).

Source EconSearch analysis.

Direct employment (full-time equivalents) was estimated to be 6,945, and corresponding household income was $385 million. This indicates an average gross annual income of around $55,000 for those employed in firms and organisations engaged in port-related activity. Household income includes overtime payments and income tax, although is net of payroll tax and other related charges.

Flow-on effects

As described earlier, input-output multipliers can be used to estimate the ***indirect (flow-on) impact*** of Sydney port-related activity on the New South Wales economy. Multipliers were used to calculate flow-on effects for each of the four economic indicators, output, value added, employment and household income, and are shown in Appendix IV.

The flow-on effects of port-related activity total $1,346 million in output, $738 million in value added, 10,075 jobs and $354 million in corresponding household income (Table 4.1).

Flow-on impacts from port-related activity occur in many sectors of the New South Wales economy. A unique characteristic of the input-output model is the facility to calculate the size of the flow-on multiplier and the extent of the impact in each of the other sectors in the local economy. The sectoral distribution and ranking of the indirect impacts, in terms of output, value added, employment and household income, are shown in Table 4.2.

Table 4.2 Flow-on effects from the economic impact of Sydney's ports by industry sector, 2001/02

Sector [a,b]	*Output ($m)*	*Value added ($m)*	*Household income ($m)*	*Employment no.*
Finance, business services	268.9	172.6	92.3	2,181
Wholesale and retail trade, etc.	215.7	120.5	69.9	2,391
Manufacturing	280.2	96.8	42.4	1,122
Ownership of dwellings	137.9	81.3	0.0	0
Transport, storage (excl port)	101.7	57.5	23.2	533
Community services	70.3	53.5	40.4	1,219
Communication	63.1	42.4	18.0	418
Utilities	38.9	28.2	7.2	149
Recreation, personal services	48.4	25.9	18.7	613
Accommodation, restaurants, etc.	51.6	25.0	18.7	833
Construction	40.0	19.0	14.7	375
Primary	19.0	9.5	5.3	192
Mining	7.7	5.1	2.1	29
Public administration	2.3	1.0	0.9	20
Total	*1,345.7*	*738.2*	*353.8*	*10,075*

a. Individual sectors are ranked by value added.

b. Refer to Appendix III for detailed sector definitions.

Note Components may not sum to totals due to rounding.

Source EconSearch analysis.

The ranking of sectors is determined, to a certain extent, by the labour intensity of the impacting industry (in this study, the Sydney port sector). Generally, if the industry is labour intensive and direct purchases of goods and services by firms in the industry are relatively small, then the flow-on effects will occur predominantly in those sectors providing goods and services to households, i.e. those sectors where households spend the wages and salaries earned working in the impacting sector. It will be these sectors which are ranked highly in terms of economic impact.

To identify the nature of the linkage between the impacting sector and other sectors in the economy, a distinction is made between *consumption-induced* and *production-induced* flow-on effects in calculating sector multipliers. Consumption-induced effects are those brought about by household expenditures, while production-induced effects are generated by the direct purchases of local goods and services by firms in the impacting sector. Generally, in a relatively labour intensive sector (such as the Port sector), the consumption induced effects will be large and the production-induced effects relatively small. The port sector has traditionally been labour intensive, but with the productivity improvements of recent years and where the majority of cargo is handled in bulk, such as at Sydney's ports, the labour intensity is much less than was previously the case. For the Sydney port sector, about 70 per cent of the output flow-ons were estimated to be consumption-induced and about 30 per cent production-induced. These proportions were similar for the value added, employment and household income flow-on effects (see Appendix IV for details).

As revealed in Table 4.2, finance and business services, wholesale and retail trade and manufacturing are the three sectors where port-related activity has the largest impact. For all four measures of economic impact (output, value added, employment and income), over 50 per cent of the total flow-on effect occurred in these three sectors. For employment, the combined impact in these sectors was more than 56 per cent (5,694 jobs) of the total employment flow-on from port-related activity (10,075 jobs).

Total economic impact

The operation of Sydney's ports generated a total impact on the New South Wales economy of $2,508 million in output in 2001/02.

Value added attributable to the operation of the port was almost $1,380 million. This was equivalent to approximately 0.5 per cent of gross state product in 2001/02, which provides a measure of the overall level of economic activity in New South Wales.

Household income generated by the operation of the port totalled over $738 million. Employment was estimated at around 17,020 jobs (full-time equivalent), which represented 0.6 per cent of total employment in New South Wales.

There were 2,189 ship visits to Sydney's ports by commercial cargo vessels in 2001/02. The results of the analysis indicate that, on average, each ship call at Sydney's ports involved the following impact on the economy of New South Wales:

- $1,146,000 of output;
- $630,000 of value added;
- $337,000 of household income; and
- 7.8 full-time equivalent jobs for one year.

4.2 Components of the port's economic impact

Estimated economic impacts have been disaggregated to identify the relative contribution of the individual port functions and cargo types. The proportion for a particular component often varies according to the impact measure being used. This variation reflects differences in factors such as profitability, capital intensity, average income and labour intensity.

4.2.1 Port functions

As described in Section 2, total port-related activity was partitioned into six specific functions: port administration; ship movement; ship loading and unloading; cargo services; land transport and storage; and government services. The dimensions of these sectors, in terms of output, value added, employment and household income, are detailed in Table 4.3.

Total multipliers were calculated for each of these port-related sectors and are shown in Table 3.3. Table 4.3 provides estimates of the total economic impacts calculated using these multipliers.

The largest impacts, in terms of output and value added, occurred in the *land transport and storage* sector. The value of services provided by this sector was $393 million, with flow-ons to other sectors in the economy of $434 million, giving a total output impact of $827 million for the 2001/02 financial year. Direct employment in the sector was measured at 2,266 with associated household income of around $93 million. Flow-on employment in other sectors was estimated to be 3,278, earning around $115 million in household income during 2001/02.

Table 4.3 Economic impact of Sydney's ports by port function, 2001/02

Function	*Output ($m)*	*Value added ($m)*	*Household income ($m)*	*Employment no.*
Direct Effects				
Port administration	85.5	65.1	18.6	210
Ship operations	261.2	152.3	101.1	1,626
Ship loading/unloading	240.4	149.5	108.2	1,545
Cargo services	163.6	94.1	57.3	1,169
Land transport & storage	393.7	172.7	92.9	2,266
Government agencies	18.4	7.1	6.7	129
Total	*1,162.7*	*640.8*	*384.7*	*6,945*
Total Impact				
Port administration	161.3	106.2	39.5	792
Ship operations	614.8	345.7	193.0	4,225
Ship loading/unloading	527.7	308.7	183.3	3,699
Cargo services	329.1	186.0	100.8	2,408
Land transport & storage	826.6	408.6	207.3	5,544
Government agencies	48.9	23.7	14.7	352
Total	*2,508.5*	*1,379.0*	*738.5*	*17,020*

Note Components may not sum to totals due to rounding.

Source EconSearch analysis.

As noted in BTE (2001, p. 22) it is, in practice, difficult to accurately identify the components of land transport that are port-related. The general approach in port impact studies therefore focuses on land transport activities in the vicinity of the port. Port-related land transport is broadly defined as the movement of cargo between port-related facilities and the nearest warehouse, terminal, customer premises or processing plant in the local region.

Cargoes are moved by rail and road to Sydney's ports from locations many hundreds of kilometres away. It could be argued that the impact of road and rail activities should incorporate the full journey from the point of origin (e.g. stockpiles at mine sites). However, the resulting impact estimates would not be consistent with the primary purpose of a port impact study, which is to indicate the effects on the community immediately affected by the physical operation of the port. In addition, the inclusion of the full road and rail journeys would result in impact estimates for port-related rail transport that would exceed the impact of all other components of Sydney port-related activities.

The *ship loading and unloading*, *ship operations* and *cargo services* sectors had similar levels of impact, although somewhat less than the land transport and storage sector. Direct and flow-on employment in the ship loading and unloading sector accounted for an estimated 3,699 full-time equivalent jobs, while the ship operations sector generated 4,225 jobs and the cargo services sector 2,408 jobs.

The *port administration* sector provided services valued at over $85 million, with flow-ons to other sectors in the economy of around $76 million. Employment in the sector was measured at 210 with associated household income of over $18 million. Flow-on employment in other sectors was estimated to be 582, earning around $21 million in household income during 2001/02.

The port-related activity of *government agencies* comprises a minor component of the total port impact.

4.2.2 Cargo type

Table 4.4 shows the breakdown of direct and total impacts by the major cargo types traded in 2001/02. Details on tonnages for 2001/02 are provided in Tables 2.3 and 2.4.

Although just 50 per cent of the port's total ship visits were *container* ships in 2001/02, over 60 per cent of the port's economic impact was related to container cargo, an equivalent of 4,316 people directly employed in container-related port activity and around 10,518 jobs when indirect effects are included.

Bulk liquids and gas, which is predominantly comprised of imported petroleum products, accounted for 19 per cent of all ship visits. Although this is a relatively low input intensive loading and unloading operation, the high land transport activity meant that this cargo group provided over 22 per cent of the total economic impact.

Motor vehicles accounted for around 12 per cent of ship visits. In terms of output, added, employment and household income this cargo group accounted for only 6 per cent of the total economic impact.

Table 4.4 Economic impact of Sydney's ports by cargo type, 2001/02

Cargo type	*Output ($m)*	*Value added ($m)*	*Household income ($m)*	*Employment no.*
Direct Effects				
Containers	720.1	399.1	240.6	4,316
General cargo	43.0	25.6	14.7	238
Bulk liquids and gas	264.7	139.3	83.0	1,602
Dry bulk	52.2	27.4	16.4	307
Motor vehicles	68.5	40.7	24.9	402
Passengers	14.2	8.6	5.1	80
Total	*1,162.7*	*640.8*	*384.7*	*6,945*
Total Impact				
Containers	1,547.9	853.5	458.3	10,518
General cargo	93.6	53.3	28.0	616
Bulk liquids and gas	567.1	305.1	162.5	3,869
Dry bulk	115.4	61.9	33.0	778
Motor vehicles	152.2	86.6	46.9	1,024
Passengers	32.4	18.6	9.9	214
Total	*2,508.5*	*1,379.0*	*738.5*	*17,020*

Note Components may not sum to totals due to rounding.

Source EconSearch analysis.

General breakbulk cargo accounted for 6.6 per cent of total ship visits to Sydney's ports in 2001/02. In terms of output, value added, employment and household income, this cargo group provided around 4 per cent of the total economic impact.

Dry bulk cargo accounted for around 9 per cent of ship visits. In terms of output, value added, employment and household income this cargo group provided just 4.5 per cent of the total economic impact.

Passenger vessels accounted for just 2.7 per cent of total ship visits to Sydney's ports in 2001/02. In terms of output, value added, employment and household income, this was the smallest impacting category, providing just 1.3 per cent of the total economic impact.

4.2.3 Port area

Table 4.4 shows the breakdown of direct and total impacts by the major areas in Sydney's ports in 2001/02. Details on tonnages for each port area by cargo type for 2001/02 are provided in Appendix VI.

Port Botany has the largest impact of all the areas managed by SPC. This area includes the Brotherson Dock container facilities, two terminals operated by Patrick Stevedores and P&O Ports and a Bulk Liquids Berth primarily used for liquid cargoes and gases. Movement of cargo through Port Botany accounted for almost 60 per cent of the total economic impact of Sydney's ports in 2001/02. As detailed in Table 4.5, direct employment in port-related activities accounted for an estimated 4,131 full-time equivalent jobs and a further 5,932 flow-on jobs were generated by the port-related activity. The total of 10,063 full-time equivalent jobs earned an estimated $438 million in household income in 2001/02. Direct and flow-on value added was estimated at over $815 million.

Table 4.5 Economic impact of Sydney's ports by port area, 2001/02

Port Area	*Output ($m)*	*Value added ($m)*	*Household income ($m)*	*Employment no.*
Direct Effects				
Darling Harbour	74.1	42.6	25.4	430
White Bay	64.5	36.4	21.7	379
Glebe Island	78.9	44.8	27.2	462
Kurnell	137.7	72.5	43.2	834
Gore Bay	92.6	48.7	29.0	560
Port Botany	689.0	381.0	229.5	4,131
Passenger Terminals	14.2	8.6	5.1	80
Others	11.7	6.1	3.7	69
Total	*1,162.7*	*640.8*	*384.7*	*6,945*
Total Impact				
Darling Harbour	162.2	90.9	48.5	1,088
White Bay	139.0	77.3	41.3	937
Glebe Island	174.7	97.3	52.3	1,176
Kurnell	295.1	158.7	84.6	2,013
Gore Bay	198.4	106.7	56.9	1,354
Port Botany	1,480.8	815.6	437.7	10,063
Passenger Terminals	32.4	18.6	9.9	214
Others	25.9	13.9	7.4	175
Total	*2,508.5*	*1,379.0*	*738.5*	*17,020*

Note Components may not sum to totals due to rounding.

Source EconSearch analysis.

The bulk liquids facility at *Kurnell*, the site of the Caltex refineries, contributed almost 12 per cent of the total economic impact of all the areas managed by SPC. At the site, Caltex Australia Limited operates a jetty with two berths and a multi-buoy mooring, primarily for crude oil imports as well as other petro-chemical products. Direct employment in port-related activities accounted for an estimated 834 full-time equivalent jobs and a further 1,179 flow-on jobs were generated by the port-related activity (Table 4.5). The total of 2,013 full-time equivalent jobs earned an estimated $85 million in household income in 2001/02. Direct and flow-on value added was estimated at almost $159 million.

Shell's *Gore Bay* terminal contributed just under 8 per cent of the total economic impact of Sydney's ports in 2001/02. The terminal is used for the import, export and storage of oil products. Crude oil, feedstocks and products are transferred to the Clyde Refinery by underground pipeline. As detailed in Table 4.5, direct employment in port-related activities accounted for an estimated 560 full-time equivalent jobs and a further 793 flow-on jobs were generated by the port-related activity. The total of 1,354 full-time equivalent jobs earned an estimated $57 million in household income in 2001/02. Direct and flow-on value added was estimated at almost $107 million.

Movement of cargo through the *Glebe Island* berths contributed approximately 7 per cent of the total economic impact of Sydney's ports in 2001/02. Glebe Island berths 1-2 comprise a dedicated motor vehicle discharge facility. Berths 7-8 provide common user bulk dry cargo discharge facilities, equipped for self discharging vessels using wharf manifold to pipelines, conveyors and adjacent storage silos. Cargo discharged at this facility include bulk cement, bulk refined sugar and soda ash. Direct employment in port-related activities accounted for an estimated 462 full-time equivalent jobs and a further 713 flow-on jobs were generated by the port-related activity (Table 4.5). The total of 1,176 full-time equivalent jobs earned an estimated $52 million in household income in 2001/02. Direct and flow-on value added was estimated at over $97 million.

Movement of cargo through *Darling Harbour* contributed 6.5 per cent of the total economic impact of Sydney's ports in 2001/02. Darling Harbour is a container, general, roll on/roll off and bulk cargo facility. As detailed in Table 4.5, direct employment in port-related activities accounted for an estimated 430 full-time equivalent jobs and a further 657 flow-on jobs were generated by the port-related activity. The total of 1,088 full-time equivalent jobs earned an estimated $48 million in household income in 2001/02. Direct and flow-on value added was estimated at approximately $91 million.

Cargo movement at the facility at *White Bay* contributed around 5.5 per cent of the total economic impact of Sydney's ports in 2001/02. The White Bay facility handles containers as well as general, break-bulk and roll on/roll off cargoes. Direct employment in port-related activities accounted for an estimated 379 full-time equivalent jobs and a further 558 flow-on jobs were generated by the port-related activity (Table 4.5). The total of 937 full-time equivalent jobs earned an estimated $41 million in household income in 2001/02. Direct and flow-on value added was estimated at over $77 million.

Passenger terminals and *other* port areas comprise a minor component of the total port impact

4.3 Projected Impacts: 2009/10, 2014/15, 2019/20 and 2024/25

As part of its planning activities, Sydney Ports Corporation makes regular projections of future trade flows. Forecasts of trade to the year 2024/25 (unconstrained forecasts) have been used to project the possible impact of these cargo flows on the New South Wales economy.

Appendix VII shows projected trade figures for each cargo type for the years 2009/10, 2014/15, 2019/20 and 2024/25. For each cargo type, projections of direct and flow-on impacts were made in terms of output, value added, household income and employment. The projected impacts for each of the four years are summarised in Table 4.6. Impacts on an area basis (Darling Harbour, White Bay, etc.) for the four projection years are provided in Appendix VIII.

Care should be taken in interpreting and using these projections. They are based on assumptions about future trade flows, productivity improvements at the port, productivity improvements in other sectors of the economy and changes in structure of the New South Wales economy.

Cargo trade flows are based on projections made by SPC to 2019/20. Projections to 2024/25 were made using the average growth over the previous five-year period (2014/15 – 2019/20). Productivity (labour and capital) was assumed to improve over the projection period at an average rate (compound) of 1.0 per cent per annum. These productivity improvements were imposed on all sectors of the economy over the projection period.

As with other estimates in this report, these projections of economic impact indicate the general magnitude of effects. They do not provide precise estimates, as only approximate data were available for some parts of the analysis.

Table 4.6 Projected economic impact [a] of Sydney's ports (all cargo), selected years [b]

	Output ($m)	*Value added ($m)*	*Household income ($m)*	*Employment no.*
2009/10				
Direct impact	1,405	774	465	8,397
Indirect impact	1,623	891	427	12,156
Total	*3,028*	*1,665*	*892*	*20,553*
2014/15				
Direct impact	1,610	888	534	9,631
Indirect impact	1,861	1,021	489	13,933
Total	*3,471*	*1,909*	*1,023*	*23,564*
2019/20				
Direct impact	1,854	1,023	615	11,089
Indirect impact	2,141	1,175	563	16,034
Total	*3,995*	*2,198*	*1,178*	*27,123*
2024/25				
Direct impact	2,076	1,146	689	12,419
Indirect impact	2,397	1,315	630	17,950
Total	*4,473*	*2,461*	*1,319*	*30,368*

[a] Based on unconstrained forecasts to 2024/25 including the effect of Port Botany expansion. Does not include the construction-related impacts of the Port Botany expansion.
[b] 2002 prices.

Note Components may not sum to totals due to rounding.

Source Appendix VII.

5. Economic Impact of the Port Botany Expansion

5.1 Construction Impact

The proposed Port Botany expansion will give rise to substantial infrastructure requirements. These will occur in the terminal area, the container area and the commercial area. The development works to meet these infrastructure needs will include:

- approvals, design and preliminary works;
- dredging and reclamation;
- finishing works;
- basic infrastructure and services;
- construction of berths 1-5; and
- many other engineering and construction components.

Expenditure on the Port Botany project will be incurred by SPC and private operators. The $576 million development, scheduled over the 24 year period 2001/02 to 2024/25, is anticipated to have a significant impact on the economy of New South Wales. Data from SPC gave an indication of the magnitude and nature of local expenditures and formed the basis for estimating the direct and indirect impact of the infrastructure works. These estimates are provided in Table 5.1.

Note that the budget of $576 million excludes acquisition of land but does include purchases of equipment from outside the region. Both land acquisition and purchases from outside the region have been excluded from the construction phase impact assessment.

The economic impact from the construction phase is expected to peak over the years 2004/05 to 2006/07. In 2004/05 business turnover directly related to the development will be around $91 million with flow-ons to other firms adding another $39 million. Associated value added, a measure of the net contribution to the state's economy, is projected to total approximately $35 million.

Household income generated directly from construction activities during the peak impact year (2006/07) is anticipated to be around $6.5 million, with 155 full-time equivalent (fte) jobs. Indirect household income is projected to be $9.6 million with an associated 258 jobs, giving total employment (direct + flow-on) of 413.

Table 5.1 Projected economic impact of Port Botany construction expenditures [a]

	2001/02	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24	2024/25	Total [b]
Output ($m)																									
Direct	3.0	3.0	3.0	91.2	90.2	90.2	72.4	45.0	12.5	0.0	0.0	12.5	30.0	12.5	0.0	0.0	12.5	30.0	12.5	0.0	0.0	12.5	30.0	12.5	576
Indirect	4.1	4.1	4.0	39.1	38.2	37.9	30.1	18.5	5.1	0.0	0.0	4.9	11.7	4.8	0.0	0.0	4.7	11.2	4.6	0.0	0.0	4.5	10.6	4.4	242
Total	**7.1**	**7.1**	**7.0**	**130.3**	**128.4**	**128.1**	**102.5**	**63.5**	**17.6**	**0.0**	**0.0**	**17.4**	**41.7**	**17.3**	**0.0**	**0.0**	**17.2**	**41.2**	**17.1**	**0.0**	**0.0**	**17.0**	**40.6**	**16.9**	818
Value added ($m)																									
Direct	1.9	1.9	1.9	14.4	14.1	13.9	11.1	6.8	1.9	0.0	0.0	1.8	4.3	1.8	0.0	0.0	1.7	4.1	1.7	0.0	0.0	1.6	3.9	1.6	90
Indirect	2.3	2.3	2.3	20.7	20.3	20.1	16.0	9.8	2.7	0.0	0.0	2.6	6.2	2.6	0.0	0.0	2.5	5.9	2.4	0.0	0.0	2.4	5.6	2.3	129
Total	**4.2**	**4.2**	**4.1**	**35.1**	**34.4**	**34.0**	**27.0**	**16.6**	**4.6**	**0.0**	**0.0**	**4.4**	**10.5**	**4.4**	**0.0**	**0.0**	**4.2**	**10.0**	**4.1**	**0.0**	**0.0**	**4.0**	**9.5**	**3.9**	220
Household income ($m)																									
Direct	0.0	0.0	0.0	1.4	5.0	6.5	3.1	0.9	0.9	0.0	0.0	0.7	0.7	0.7	0.0	0.0	0.7	0.7	0.7	0.0	0.0	0.7	0.7	0.8	24
Indirect	1.1	1.1	1.1	9.9	9.7	9.6	7.6	4.7	1.3	0.0	0.0	1.2	3.0	1.2	0.0	0.0	1.2	2.8	1.2	0.0	0.0	1.1	2.7	1.1	62
Total	**1.1**	**1.1**	**1.1**	**11.3**	**14.7**	**16.1**	**10.7**	**5.5**	**2.2**	**0.0**	**0.0**	**1.9**	**3.6**	**1.9**	**0.0**	**0.0**	**1.9**	**3.5**	**1.9**	**0.0**	**0.0**	**1.9**	**3.4**	**1.9**	86
Employment (no.)																									
Direct	0	0	0	35	121	155	73	20	20	0	0	15	15	15	0	0	15	15	15	0	0	15	15	15	559
Indirect	31	30	30	271	263	258	203	123	34	0	0	32	74	30	0	0	29	67	27	0	0	26	61	25	1613
Total	**31**	**30**	**30**	**306**	**384**	**413**	**276**	**143**	**54**	**0**	**0**	**47**	**89**	**45**	**0**	**0**	**44**	**82**	**42**	**0**	**0**	**41**	**76**	**40**	2172

[a] 2002 prices.

[b] These are simple, undiscounted totals over the 24 year period.

Note Components may not sum to totals due to rounding.

Source EconSearch analysis.

5.2 Operation Impact

Value of economic activity at Port Botany expansion site

SPC provided estimates for container throughput of the proposed Port Botany expansion. These estimates are a component of the unconstrained forecasts detailed in Section 4.3. These estimates show total port-related activity (construction and operation) at the Port Botany expansion site of $433 million in 2009/10 and increasing thereafter.

Direct and Indirect effects

The ***direct impact*** of the Port Botany expansion on output, value added, household income and employment is shown in Table 5.2. The impacts relate to the years 2001/02 to 2024/25. The proposed expansion will facilitate an estimated throughput of 320,000 TEUs in 2009/10 increasing thereafter to an additional 1,200,000 TEUs by 2024/25.

The value of output generated directly by port-related activity (operation impact), estimated to be $623 million in 2024/25, is the sum of gross business revenue of firms engaged in moving containers through the new container terminal at Port Botany. These are revenues generated and expenditure incurred in New South Wales.

The anticipated direct value added from Port Botany expansion activity in 2024/25 was estimated to be $346 million. As noted earlier, value added refers to the difference between the total revenue of a firm and the cost of bought-in materials, services and components. In other words, it represents payments to the primary inputs of production (labour, capital and land), and can be used to describe the contribution of an industry to gross domestic (state) product.

In 2024/25, direct employment (full-time equivalents) was estimated to be 3,737, and corresponding household income was $208 million. This indicates an average gross annual income of around $55,000 (2002 prices) for those employed in firms and organisations engaged in the movement of containers through the Port of Botany. Household income includes income tax, although is net of payroll tax and other related charges.

As described earlier, input-output multipliers can be used to estimate the ***indirect (flow-on) impact*** of Port Botany expansion activity on the economy of New South Wales. Multipliers from the New South Wales input-output table were used to calculate flow-on effects for each of the four economic indicators, output, value added, employment and household income.

In 2024/25, the flow-on effects derived from the Port Botany expansion activity (operation impact) are estimated to total $717 million in output, $393 million in value added, 5,369 jobs and $189 million in corresponding household income (Table 5.2).

The operation of the proposed Port Botany expansion is anticipated to generate a ***total impact*** (direct + flow-on) on the New South Wales economy of over $1.3 billion in output in 2024/25. Value added attributable to the operation of the expansion site was estimated at almost $740 million.

Household income generated by the operation of the proposed Port Botany expansion was projected to be around $397 million in 2024/25. Associated employment was estimated to be 9,106 jobs (full-time equivalent). As can be seen in Table 5.2, the impact of Port Botany will increase substantially as container throughput increases with the construction and development of additional berths.

Table 5.2 Projected economic impact of Port Botany expansion, 2001/02 – 2024/25 [a]

	2001/02	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24	2024/25	Total [b]
TEUs (million)	-	-	-	-	-	-	-	-	0.32	0.42	0.51	0.61	0.70	0.80	0.84	0.88	0.92	0.96	1.00	1.04	1.08	1.12	1.16	1.20	
Output ($m)																									
Direct Impact																									
Construction	3	3	3	91	90	90	72	45	13	0	0	13	30	13	0	0	13	30	13	0	0	13	30	13	576
Operations	0	0	0	0	0	0	0	0	193	247	300	353	406	460	477	494	512	529	546	562	577	593	608	623	7,480
Total	*3*	*3*	*3*	*91*	*90*	*90*	*72*	*45*	*206*	*247*	*300*	*366*	*436*	*472*	*477*	*494*	*524*	*559*	*559*	*562*	*577*	*605*	*638*	*636*	*8,055*
Total Impact																									
Construction	7	7	7	130	128	128	102	64	18	0	0	17	42	17	0	0	17	41	17	0	0	17	41	17	818
Operations	0	0	0	0	0	0	0	0	416	530	644	759	873	988	1,025	1,062	1,100	1,137	1,174	1,207	1,241	1,274	1,307	1,340	16,078
Total	*3*	*3*	*7*	*130*	*128*	*128*	*102*	*64*	*433*	*530*	*644*	*776*	*915*	*1,005*	*1,025*	*1,062*	*1,117*	*1,178*	*1,191*	*1,207*	*1,241*	*1,291*	*1,348*	*1,357*	*16,887*
Value added ($m)																									
Direct Impact																									
Construction	2	2	2	14	14	14	11	7	2	0	0	2	4	2	0	0	2	4	2	0	0	2	4	2	90
Operations	0	0	0	0	0	0	0	0	107	137	166	196	225	255	264	274	284	293	303	311	320	328	337	346	4,145
Total	*2*	*2*	*2*	*14*	*14*	*14*	*11*	*7*	*109*	*137*	*166*	*197*	*230*	*256*	*264*	*274*	*285*	*297*	*304*	*311*	*320*	*330*	*341*	*347*	*4,236*
Total Impact																									
Construction	4	4	4	35	34	34	27	17	5	0	0	4	11	4	0	0	4	10	4	0	0	4	10	4	220
Operations	0	0	0	0	0	0	0	0	229	292	355	418	482	545	565	586	606	627	648	666	684	702	721	739	8,865
Total	*4*	*4*	*4*	*35*	*34*	*34*	*27*	*17*	*234*	*292*	*355*	*423*	*492*	*549*	*565*	*586*	*611*	*637*	*652*	*666*	*684*	*706*	*730*	*743*	*9085*
Household income ($m)																									
Direct Impact																									
Construction	0	0	0	1	5	6	3	1	1	0	0	1	1	1	0	0	1	1	1	0	0	1	1	1	24
Operations	0	0	0	0	0	0	0	0	65	82	100	118	136	154	159	165	171	177	182	188	193	198	203	208	2,499
Total	*0*	*0*	*0*	*1*	*5*	*6*	*3*	*1*	*65*	*82*	*100*	*119*	*136*	*154*	*159*	*165*	*172*	*177*	*183*	*188*	*193*	*199*	*204*	*209*	*2,523*
Total Impact																									
Construction	1	1	1	11	15	16	11	6	2	0	0	2	4	2	0	0	2	4	2	0	0	2	3	2	86
Operations	0	0	0	0	0	0	0	0	123	157	191	225	259	292	304	315	326	337	348	357	367	377	387	397	4,760
Total	*1*	*1*	*1*	*11*	*15*	*16*	*11*	*6*	*125*	*157*	*191*	*227*	*262*	*294*	*304*	*315*	*327*	*340*	*350*	*357*	*367*	*379*	*390*	*399*	*4846*
Employment (no.)																									
Direct Impact																									
Construction	0	0	0	35	121	155	73	20	20	0	0	15	15	15	0	0	15	15	15	0	0	15	15	15	559
Operations	-	-	-	-	-	-	-	-	1,159	1,478	1,797	2,116	2,435	2,754	2,858	2,962	3,066	3,170	3,274	3,367	3,459	3,552	3,644	3,737	44,830
Total	*0*	*0*	*0*	*35*	*121*	*155*	*73*	*20*	*1,179*	*1,478*	*1,797*	*2,131*	*2,450*	*2,769*	*2,858*	*2,962*	*3,081*	*3,185*	*3,289*	*3,367*	*3,459*	*3,567*	*3,659*	*3,752*	*45,389*
Total Impact																									
Construction	31	30	30	306	384	413	276	143	54	0	0	47	89	45	0	0	44	82	42	0	0	41	76	40	2,172
Operations	-	-	-	-	-	-	-	-	2,823	3,601	4,379	5,157	5,935	6,712	6,966	7,219	7,473	7,726	7,979	8,205	8,430	8,655	8,881	9,106	109,246
Total	*31*	*30*	*30*	*306*	*384*	*413*	*276*	*143*	*2,877*	*3,601*	*4,379*	*5,203*	*6,024*	*6,758*	*6,966*	*7,219*	*7,516*	*7,808*	*8,022*	*8,205*	*8,430*	*8,696*	*8,956*	*9,146*	*111,419*

[a] 2002 prices.

[b] These are simple, undiscounted totals over the 24 year period.

Note Components may not sum to totals due to rounding.

Source EconSearch analysis.

Appendix I Survey Questionnaires

This appendix contains the version of the questionnaire that was sent to firms whose activities were primarily Sydney port-related. The covering letter is also included.

HASSALL & ASSOCIATES
PTY LTD
4/52 Phillip St
GPO Box 4625
SYDNEY NSW 1044
Telephone: 02 9241 5655

CONFIDENTIAL

SYDNEY PORTS ECONOMIC IMPACT STUDY 2001/02 –
PORT SERVICE PROVIDERS QUESTIONNAIRE

Please read this first:

- If exact figures are not available, please provide careful estimates.
- Please report all monetary values in ***thousands of dollars*** ($'000).
- An electronic version of this questionnaire can be sent to you by email, if requested.

1. Company Information

Company Name: ____________________

Port – Related Activities: ____________________

Contact Name: ____________________

Contact Phone Number: ____________________

2. **Staff numbers and associated costs incurred in New South Wales related to activities through Sydney's port:** (average for financial year 2001/02, including working proprietors, managers, directors):

Full Time _____________

Part Time _____________ (total)

_____________ (full – time equivalents)

Contractors _____________ (full – time equivalents)

Gross wages & salaries and all associated costs (super, etc.) in 2001/02 ($'000) ________

3. **What other major costs, in addition to gross wages and salaries, were incurred in New South Wales in 2001/02 related to activities through Sydney's ports ($'000): (e.g. fuel, repairs and maintenance or contractors)**

Expenditure item	($'000)

4. **Please break down your Sydney port-related revenue:**
   a. **by cargo type; OR**
   b. **estimate the quantity of cargo handled by cargo type; OR**
   c. **estimate market share (in your field of business) by cargo type.**

Cargo Type	a., OR Revenue in 2001/02 ($'000)	b., OR Estimated quantity of cargo handled (teus/tonnes/no.)	c. Estimated market share by cargo type (%)
Containers			
General cargo			
Dry bulk			
Liquid bulk			
Motor vehicles			
Passengers			
TOTAL			**100%**

If you have any queries don't hesitate to contact Cheryl by phone on 02 9241 5655 or email ckalisch@hassall.com.au.

Please return the questionnaire by 23 September 2002:

BY POST:

Hassall & Associates
Reply Paid 4625
Sydney, NSW 2001

or

FAX: 02 9241 5684

Thank you for your time and cooperation.

HASSALL & ASSOCIATES
PTY LTD
4/52 Phillip St
GPO Box 4625
SYDNEY NSW 1044
Telephone: 02 9241 5655

XX September 2002

Dear

The Economic Impact of Sydney's port

The Sydney Ports Corporation wrote to you on 5 September 2002 advising that EconSearch and Hassall and Associates have been engaged to undertake an economic impact study of Sydney's Port.

As part of the study, we are conducting a survey of firms involved in port-related activities. The survey will provide information that is not available from published sources. It will enable us to estimate the direct impacts of the port, to calculate multipliers for the estimation of flow-on effects and to prepare specific impact measures (eg by major cargo type).

To maintain the confidentiality of data from individual organisations, the final report will present results in *aggregated* forms only. All completed forms will be held by Hassall and Associates, treated in-confidence and subsequently destroyed.

I would be grateful if you would support the port impact study by completing the attached questionnaire and returning it to Hassall and Associates by **25 September 2002**. During the week beginning 23 September, a member of the Hassall team will contact you to assist you in the completion of the questionnaire by 25 September 2002, if we have not already heard back from you.

In the meantime, if you have any queries with regard to the project or the questionnaire, please contact me by phone on 02 92415655 or email ckalisch@hassall.com.au.

Yours sincerely,

Cheryl Kalisch

Cheryl Kalisch,
Survey Coordinator

Appendix II Economic Impact Analysis

This study provides estimates of the economic impact of *port-related activity* on the economy of New South Wales. The methodological basis for the study is input-output analysis. In this appendix the concept of economic impact, the process of impact measurement and the use of input-output models in impact measurement are briefly reviewed. The research methodology applied in this study is outlined in more specific terms in Section 3.

The input-output model is suitable for the detailed description of regional economies and for measuring the impacts of existing industries, new industries or changes in the size of industries on the regional economy. It is therefore appropriate to apply the model in estimating the impact of port-related activity on the economy of New South Wales.

In the following sections the method of economic impact analysis is outlined and the structure of the input-output model and multipliers, the tools used in the estimation of economic impacts, are detailed.

Economic impact analysis

The term *impact* has no unambiguous meaning; it is used in a wide variety of contexts, and synonymously with several terms such as *results*, *incidence*, *effect*, *significance*, *contribution*, *consequence* and *importance*. It is therefore important to define clearly the concept of economic impact, and the particular use of the term applied in this study.

One of the main ends of economic research is the study of impacts, where the term refers generally to the consequences of some expected or hypothetical phenomenon, either physical or social. For example, the recent emergence of environmental impact statements reflects a desire on the part of authorities to be informed on the likely consequences of a new development, both in terms of effects on the physical environment and the socio-economic environment. An impact study is intended to isolate and identify the more significant consequences of an event or phenomenon for planning purposes.

It is necessary to distinguish between the *impacting agent*, which is the phenomenon or event under study, and the *impacts*, which are the results of the existence of, or change in, the impacting agent. Socio-economic impact studies tend to be restricted to the consequences of significant existing or new phenomena. These phenomena cause a wide variety of impacts to occur in economic, sociological, political, physical and welfare terms. For example, the activity associated with Sydney's ports has resulted in a wide variety of impacts on the regional, social and economic structure of New South Wales as a whole. Apart from the economic consequences of the port, some of which are the subject of this study, virtually every facet of the state's social structure will be affected by the existence of the port.

Since this study is concerned solely with economic impact, it omits the wide variety of non-economic impacts of the industry on the region, many of which are clearly significant. The *economic* consequence of the presence of the port will be felt in many aspects of activity in New South Wales, ranging from levels of regional output, income and employment, to land prices (including residential, commercial and industrial land), house and building prices, local government rates, supply and demand of labour, demand and supply of urban infrastructure and so on. Unfortunately, fully comprehensive models, including all aspects of regional economic activity, are not available and more complex econometric models with an ability to include a wide variety of economic phenomena have not been satisfactorily developed for impact analysis at a regional level in Australia.

Consistent with the BTE (2000) approach, the input-output model was considered the most appropriate for this economic impact assessment. This model is, however, limited to those aspects of impact which can be represented in the input-output model, i.e. output, income, employment and value added. The procedures used in input-output analysis are detailed in the following section.

While it is quite clear that significant economic and social impacts are associated with port-related activity, measurement of these impacts does not, *per se*, constitute an economic evaluation of the industry. Such an evaluation is possible only through a comprehensive cost-benefit analysis of the industry, which would take into account both the direct and indirect impacts of the industry as recorded in this study.

In summary, an economic impact may be defined in general terms as the measured economic effect of, or change which is attributable to, the impacting agent[7] on the economy in question.

Multipliers and impact measurement

The essence of impact measurement is the empirical measurement of the relationship between cause and effect, or between the impacting agent and the expected impact. This relationship can be expressed in two ways:

(i) on a 'per unit of impact' basis. This is normally expressed in terms of a multiplier which expresses the cause-effect relationship in empirical terms. In this study, output, income, employment and value added multipliers are used to express impacts in terms of a 'per unit of output of port-related activity'.

(ii) on an aggregate value basis. This expresses the total absolute effect, measured in terms of output, income, employment, and value added of the existence of port-related activity.

The selection of methodology for impact measurement is therefore selection of the most appropriate method of estimation of multipliers. Four general methods are available for this purpose, namely economic base multipliers, regional Keynesian multipliers, econometric models and input-output models. The consultants had access to an established methodological and research structure for the calculation of an input-output table for New South Wales, and to methods of calculating multipliers from these tables. There was, therefore, a distinct advantage in the use of the input-output technique, apart from the fact that it is generally considered to be methodologically superior to the simpler techniques such as the economic base approach or the use of regional Keynesian employment multipliers. This superiority is generally considered to be attributable to the following factors (Jensen and West 1986):

[7] The impacting agent may be an actual or potential source of economic change, or an industry which is established and operating in the economy.

(i) In terms of the incidence of impact, the economic base and the Keynesian approaches normally provide impact measurement only in aggregate terms, i.e. the total impact felt by all sectors collectively. Input-output multipliers allow the analyst to examine the manner in which the total impact is distributed among the sectors of the economy. This is a reflection of the internal linkages and interdependencies in the economy which are specified in the input-output table.

(ii) Input-output multipliers also allow the identification of the components of the multiplier; the economic base and Keynesian models do not, in their standard form, provide all of these details. The components are as follows:

(a) the **initial** effect, which is the stimulus for the impact analysis – normally assumed to be a dollar change in sales to final demand;

(b) the **first-round** effect, which refers to the purchases of inputs required from other sectors in the economy in order to produce the additional output;

(c) the **industrial-support** effect, which refers to second, third and subsequent-round industrial flow-on effects triggered by the purchases in the first round; and

(d) the **consumption-induced** effects, which stem from the spending of household income received as payments for labour used in producing the additional output.

Regional econometric models, including models of the general equilibrium family, were not available for the region or project in question, and were not considered necessary for the view of impact taken in this study.

Input-output analysis

An outline of the input-output technique can be found in any one of a number of standard texts dealing with the subject (see, for example, Hewings (1985), Midmore and Harrison-Mayfield (1996), Miller and Blair (1985), Jensen and West (1986) and West (1993, 1995, 1999). An input-output table is a simple mathematical representation of the production aspects of an economy viewed at a particular point in time. In the purely hypothetical case of no significant change in the economy from one time period to another, the table would remain relatively unchanged over that period. In reality, any economy continually experiences many types of shocks or stimuli (positive and negative) and these may be ephemeral in nature or lead to long-term structural changes in the nature of the economy. Many of these stimuli can be represented in the input-output model by appropriate adjustments to the input-output table. Some of these methods are outlined in the following section.

Methods of impact measurement using input-output analysis

The task of measuring economic impacts through the input-output model is largely one of representing the impact in the most appropriate manner in the transactions table. Once this has been completed, the analytical derivation of the impact is possible through multiplier calculation in the conventional manner.

The responsibility of the input-output analyst is to determine the nature of the impact under study, the relationship of the impacting agent with the economy in question, and to simulate this relationship as closely as possible in the transactions table of the regional economy. Some common types of impact, requiring different treatment of the input-output table, are listed below.

(a) A change in the level of output of a sector or sectors, due to changes in the level of final demand, may be traced by use of multipliers or by matrix multiplication using the table in its original form.

(b) A change in the technology or trading patterns of an existing industry would be reflected in changed column or row entries in the existing transactions table. The effects of this type of change would be measured by comparing multipliers, output levels and employment levels before and after the impact occurred.

(c) A new or existing firm or industry can be incorporated into the study in either of two ways. If the impact is regarded as of little significance, or if the firm is thought to show a cost structure (ie a column in the A matrix) similar to the average existing firm in the table, the new firm can be adequately represented by the existing sector of the table without any significant strain on the assumptions of the model. If, however, the firm or industry to be examined is considered to be of some significance, or if the requirements of the study called for a detailed study of the firm or industry *per se*, a new row and column representing that firm or industry should be prepared and incorporated into the input-output table and normal multiplier calculation carried out. Only in this manner is a detailed study of the impact of the firm or industry possible. The latter procedure was used in this study and new rows and columns were prepared for each aspect of port-related activity, as described in Appendix V.

Limitations of input-output analysis

The input-output model, like all economic models, is not capable of a perfect or near-perfect simulation of economic reality. It is therefore important to clarify the limitations of the model. Two points are made in the context of the present study.

The first point refers to the accuracy of multiplier estimates. The results of any social or economic analysis must, by the nature of the data and the techniques of analysis used, be interpreted in a broad accuracy framework. While the mathematical operations of the technique produce results which appear to be precise, a professional assessment of accuracy in general terms is necessary. The accuracy of the estimates in this study as in other studies of this nature, should be interpreted in an 'order of magnitude' holistic framework (Jensen 1980).

The second point refers to the question of the linearity assumption of the input-output model. The notion of linearity is common to most methods of impact analysis, including most of the alternative methods discussed above. This or some other equally convenient assumption is usually necessary to achieve workable economic models. The main question is not the existence of the assumption but the extent to which it results in unacceptable inaccuracies in empirical work. In this study it was felt that since port-related activity is long-established, and clearly a 'permanent' and integrated part of the regional economy, the linearity assumption posed no problem in the estimation and interpretation of the significance of the industry in the economy of New South Wales.

Appendix III Input-Output Sector Definitions

New South Wales input-output table sectors	Corresponding national input-output table sectors [8]
1. Primary	0101 Sheep 0102 Grains 0103 Beef cattle 0104 Dairy cattle 0105 Pigs 0106 Poultry 0107 Other agriculture 0200 Services to agric., hunting & trapping 0300 Forestry and logging 0400 Commercial fishing
2. Mining	1100 Coal; oil and gas 1301 Iron ores 1302 Non-ferrous metal ores 1400 Other mining 1500 Services to mining
3. Manufacturing	2101 Meat & meat products 2102 Dairy products 2103 Fruit and vegetable products 2104 Oils and fats 2105 Flour & cereal foods 2106 Bakery products 2107 Confectionery 2108 Other food products 2109 Soft drinks, cordials and syrups 2110 Beer and malt 2111 Wine & spirits 2112 Tobacco products 2201 Textile fibres, yarns etc. 2202 Textile products 2203 Knitting mill products 2204 Clothing 2205 Footwear 2206 Leather & leather products 2301 Sawmill products 2302 Other wood products 2303 Pulp, paper & paperboard 2305 Paper bags and products 2401 Printing & services to printing 2402 Publishing; recorded media etc.

8 Concordance between the national input-output sectors and ANZSIC sectors can be found in Australian Bureau of Statistics (2001).

New South Wales input-output table sectors	Corresponding national input-output table sectors
3. Manufacturing (cont.)	2501 Petroleum & coal products 2502 Basic chemicals 2503 Paints 2504 Pharmaceuticals etc. 2505 Soap & other detergents 2506 Cosmetic & toiletry preparations 2507 Other chemical products 2508 Rubber products 2509 Plastic products 2601 Glass & glass products 2602 Ceramic products 2603 Cement, lime and concrete slurry 2604 Plaster & other concrete products 2605 Other non-metallic mineral products 2701 Iron & steel 2702 Basic non-ferrous metals etc. 2703 Structural metal products 2704 Sheet metal products 2705 Fabricated metal products 2801 Motor vehicles & parts; other t/port equip 2802 Ships and boats 2803 Railway equipment 2804 Aircraft 2805 Photographic & scientific equipment 2806 Electronic equipment 2807 Household appliances 2808 Other electrical equipment 2809 Agricultural, mining etc. machinery 2810 Other machinery & equipment 2901 Prefabricated buildings 2902 Furniture 2903 Other manufacturing
4. Utilities	3601 Electricity 3602 Gas 3701 Water, sewerage and drainage
5. Building and construction	4101 Residential building 4102 Other construction
6. Wholesale and retail trade, etc., trade	4501 Wholesale trade 5101 Retail trade 5401 Mechanical repairs 5402 Other repairs
7. Accommodation, cafes & restaurants	5701 Accommodation, cafes & restaurants

New South Wales input-output table sectors		Corresponding national input-output table sectors
8.	Transport (excl Port)	6101 Road transport 6201 Rail, pipeline & other transport 6301 Water transport 6401 Air & space transport 6601 Services to transport; storage
9.	Sydney's port	This sector is a composite of parts of a number of other sectors including 6601,6101 and 6201.
10.	Communication	7101 Communication services
11.	Finance, business services	7301 Banking 7302 Non-bank finance 7303 Financial asset investors 7401 Insurance 7501 Services to finance etc. 7702 Other property services 7801 Scientific research, technical and computer services 7802 Legal, accounting etc. 7803 Other business services
12.	Ownership of dwellings	7701 Ownership of dwellings
13.	Public administration	8101 Government administration (part) 8201 Defence
14.	Community services	8601 Health services 8401 Education 8701 Community services
15.	Recreation, personal services	9101 Motion picture, radio etc. 9201 Libraries, museums & the arts 9301 Sport, gambling etc. 9501 Personal Services 9601 Other services

Appendix IV Disaggregated Multipliers

Table IV.1 Disaggregated output multipliers for Sydney's ports, 2001/02

Sector [a]	*Initial*	*First* [b]	*Indust.* [b]	*Total*	*(%)*	*Consumption* [c]	*Total*	*%*
Primary	0.00	0.00	0.00	0.00	0.25	0.01	0.02	0.76
Mining	0.00	0.00	0.00	0.00	0.18	0.00	0.01	0.31
Manufacturing	0.00	0.04	0.04	0.07	5.31	0.17	0.24	11.17
Utilities	0.00	0.01	0.00	0.01	1.04	0.02	0.03	1.55
Construction	0.00	0.01	0.00	0.01	0.99	0.02	0.03	1.60
Wholesale and retail trade, etc.	0.00	0.03	0.01	0.05	3.39	0.14	0.19	8.60
Accommodation, restaurants, etc.	0.00	0.01	0.00	0.01	0.54	0.04	0.04	2.06
Transport, storage (excl port)	0.00	0.03	0.01	0.04	3.10	0.05	0.09	4.05
Port	1.00	0.00	0.00	1.00	73.45	0.00	1.00	46.35
Communication	0.00	0.02	0.01	0.03	2.12	0.03	0.05	2.52
Finance, business services	0.00	0.08	0.04	0.12	8.80	0.11	0.23	10.72
Ownership of dwellings	0.00	0.00	0.00	0.00	0.00	0.12	0.12	5.50
Public administration	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.09
Community services	0.00	0.00	0.00	0.00	0.09	0.06	0.06	2.80
Recreation, personal services	0.00	0.01	0.00	0.01	0.65	0.03	0.04	1.93
Total	1.00	0.24	0.13	1.36	100.00	0.80	2.16	100.00

a. Sector definitions are given in Appendix III.

b. First-round + industrial-support effects = production-induced effects.

c. Consumption refers to consumption-induced effects.

Note Components may not sum to totals due to rounding.

Type I Multiplier 1.36

Type II Multiplier 2.16

Source EconSearch analysis.

Table IV.2 Disaggregated value added multipliers for Sydney's ports, 2001/02

Sector [a]	*Initial*	*First* [b]	*Indust.* [b]	*Total*	*(%)*	*Consumption* [c]	*Total*	*%*
Primary	0.00	0.00	0.00	0.00	0.23	0.01	0.01	0.69
Mining	0.00	0.00	0.00	0.00	0.22	0.00	0.00	0.37
Manufacturing	0.00	0.01	0.01	0.03	3.32	0.06	0.08	7.02
Utilities	0.00	0.01	0.00	0.01	1.36	0.01	0.02	2.05
Construction	0.00	0.01	0.00	0.01	0.85	0.01	0.02	1.37
Wholesale and retail trade, etc.	0.00	0.02	0.01	0.03	3.43	0.08	0.10	8.74
Accommodation, restaurants, etc.	0.00	0.00	0.00	0.00	0.47	0.02	0.02	1.81
Transport, storage (excl port)	0.00	0.02	0.01	0.02	3.17	0.03	0.05	4.17
Port	0.55	0.00	0.00	0.55	73.31	0.00	0.55	46.47
Communication	0.00	0.01	0.01	0.02	2.58	0.02	0.04	3.07
Finance, business services	0.00	0.05	0.03	0.08	10.23	0.07	0.15	12.52
Ownership of dwellings	0.00	0.00	0.00	0.00	0.00	0.07	0.07	5.90
Public administration	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.07
Community services	0.00	0.00	0.00	0.00	0.12	0.05	0.05	3.88
Recreation, personal services	0.00	0.00	0.00	0.01	0.63	0.02	0.02	1.87
Total	0.55	0.13	0.07	0.75	100.00	0.43	1.19	100.00

a. Sector definitions are given in Appendix III.

b. First-round + industrial-support effects = production-induced effects.

c. Consumption refers to consumption-induced effects.

Note Components may not sum to totals due to rounding.

Type I Multiplier 1.36

Type II Multiplier 2.15

Source EconSearch analysis.

Table IV.3 Disaggregated income multipliers for Sydney's ports, 2001/02

Sector [a]	*Initial*	*First* [b]	*Indust.* [b]	*Total*	*(%)*	*Consumption* [c]	*Total*	*%*
Primary	0.00	0.00	0.00	0.00	0.22	0.00	0.01	0.72
Mining	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.28
Manufacturing	0.00	0.01	0.01	0.01	2.53	0.03	0.04	5.74
Utilities	0.00	0.00	0.00	0.00	0.61	0.00	0.01	0.98
Construction	0.00	0.01	0.00	0.01	1.15	0.01	0.01	1.99
Wholesale and retail trade, etc.	0.00	0.01	0.00	0.02	3.46	0.05	0.06	9.46
Accommodation, restaurants, etc.	0.00	0.00	0.00	0.00	0.61	0.01	0.02	2.53
Transport, storage (excl port)	0.00	0.01	0.00	0.01	2.23	0.01	0.02	3.14
Port	0.33	0.00	0.00	0.33	76.55	0.00	0.33	52.10
Communication	0.00	0.01	0.00	0.01	1.91	0.01	0.02	2.44
Finance, business services	0.00	0.03	0.01	0.04	9.51	0.04	0.08	12.50
Ownership of dwellings	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Public administration	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.12
Community services	0.00	0.00	0.00	0.00	0.16	0.03	0.04	5.47
Recreation, personal services	0.00	0.00	0.00	0.00	0.79	0.01	0.02	2.53
Total	0.33	0.07	0.03	0.43	100.00	0.20	0.64	100.00

a. Sector definitions are given in Appendix III.

b. First-round + industrial-support effects = production-induced effects.

c. Consumption refers to consumption-induced effects.

Note Components may not sum to totals due to rounding.

Type I Multiplier 1.31

Type II Multiplier 1.92

Source EconSearch analysis.

Table IV.4 Disaggregated employment multipliers[a] for Sydney's ports, 2001/02

Sector [b]	*Initial*	*First* [c]	*Indust.* [c]	*Total*	*(%)*	*Consumption* [d]	*Total*	*%*
Primary	0.00	0.00	0.03	0.04	0.40	0.13	0.17	1.13
Mining	0.00	0.00	0.01	0.01	0.11	0.02	0.03	0.17
Manufacturing	0.00	0.15	0.14	0.29	3.35	0.68	0.97	6.59
Utilities	0.00	0.04	0.02	0.05	0.62	0.07	0.13	0.87
Construction	0.00	0.12	0.00	0.13	1.47	0.20	0.32	2.20
Wholesale and retail trade, etc.	0.00	0.38	0.13	0.51	5.92	1.55	2.06	14.05
Accommodation, restaurants, etc.	0.00	0.09	0.03	0.12	1.37	0.60	0.72	4.89
Transport, storage (excl port)	0.00	0.16	0.06	0.22	2.56	0.24	0.46	3.13
Port	5.97	0.00	0.00	5.97	69.09	0.00	5.97	40.81
Communication	0.00	0.13	0.06	0.19	2.22	0.17	0.36	2.46
Finance, business services	0.00	0.63	0.34	0.97	11.24	0.90	1.88	12.81
Ownership of dwellings	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Public administration	0.00	0.01	0.00	0.01	0.12	0.01	0.02	0.12
Community services	0.00	0.01	0.01	0.02	0.25	1.03	1.05	7.16
Recreation, personal services	0.00	0.06	0.05	0.11	1.30	0.41	0.53	3.60
Total	5.97	1.79	0.88	8.65	100.00	5.99	14.64	100.00

a. Jobs per million dollars.

b. Sector definitions are given in Appendix III.

c. First-round + industrial-support effects = production-induced effects.

d. Consumption refers to consumption-induced effects.

Note Components may not sum to totals due to rounding.

Type I Multiplier 1.45

Type II Multiplier 2.45

Source EconSearch analysis.

Appendix V Methods and Data Collection

General approach

The general approach is presented in a number of steps, although they did not always occur as discrete stages and were often carried out concurrently. They are listed in summary form and discussed in more detail below.

Summary of Methodology

Step 1	Preparation of an input-output table.
Step 2	Definition and estimation of the economic structure of each port-related sub-sector.
Step 3	Definition of cargo sectors and port areas.
Step 4	Estimation of total port-related activity.
Step 5	Final table adjustment.
Step 6	Estimation of the economic impact of the port.

These steps are now described in more detail.

Step 1 Preparation of an input-output table for New South Wales

An input-output table can be constructed largely from secondary sources, although these are almost always supplemented with some primary data. Prior to the commencement of the project an input-output table for New South Wales did exist. The model was prepared by CARE and provided to EconSearch for use in this study. Notes on the construction of the New South Wales input-output table are provided in Section 3.2.

Step 2 Definition and estimation of the economic structure of each port-related sub-sector

Total port-related activity was disaggregated into six categories of port-related activity (sub-sectors), detailed in Table 2.2. In order to represent port-related activity in the input-output table for impact estimation, it was necessary to estimate the economic transactions directly attributable to each of these industry sub-sectors. In effect, this required the estimation of the cost structures of the sub-sectors and identification of that expenditure which occurred inside and outside New South Wales. This expenditure corresponds to the first round of the total economic impact of each sector in the economy.

The cost structures of the industry sub-sectors were derived from a survey of port-related firms. Details of the survey are provided in Section 3.2 below.

Step 3 Definition of six cargo sectors and eight port areas

The six port-related sub-sectors described in Step 2 above represent the various port-related activities on a functional basis, i.e. the contribution of each of these functions to the total economic activity of Sydney's port. These functions can be applied to the whole range of cargo types handled through the port. It was therefore important to identify the extent to which each cargo type contributed to the activity of the port.

For these reasons, six cargo sectors, as detailed in Section 2.2, were identified for separate representation in the impact estimation procedure. These cargo types were distinguished largely by method of handling; for example the different handling requirements of containers and dry bulk cargoes impose different mixes of support service requirements in the port.

The six cargo sectors described above represent the various port-related activities on a cargo-type basis. These cargo data can be applied to each of the port areas that SPC has responsibility for.

Eight port areas were identified for separate representation in the impact estimation procedure, based on the information in Table 2.1. The port areas were distinguished largely by cargo type and the location of the berths; these factors imposing different mixes of support service requirements.

Step 4 Estimation of total port-related activity

Total port-related activity was calculated by aggregating the estimates derived for the six sub-sectors defined in Step 2. This provided an indication of the total direct contribution of port activity to the economy of New South Wales.

Step 5 Final table adjustment

The preceding steps provided the necessary basic data for the impact estimation process. Step 5 involved the insertion into the input-output table of the rows and columns developed for representation of the six port-related sectors and the five cargo groups. Adjustments were carried out to comply with certain technical requirements of the input-output technique, including the avoidance of double counting and the subtraction of these 'new' sectors from the existing sectors of the table.

Step 6 Estimation of the economic impact of Sydney's Port

The completion of Step 5 provided an input-output table with rows and columns showing the five port-related sectors and another table showing the two cargo sectors. These rows and columns represented the direct impact of the port sectors on the economy of New South Wales. The final stage of the study involved the manipulation of the input-output table (calculation of multipliers) to produce estimates of the direct and indirect impacts of these sectors on the New South Wales economy.

The results of this step are discussed in detail in Sections 4 and 5.

Some Technical Notes

It is important to note two points relating to the impact methodology. These relate to:

1. The use of 'representative years'. To preserve uniformity, data collection was directed at establishing the level of economic activity of each component of port-related sector in the same year, i.e. 2001/02. Problems associated with studies of this nature inevitably arise, namely with respect to overlapping financial years and abnormal conditions. These problems were managed by

attempting to ensure that the rows and columns representing each component in the appropriate input-output tables were as faithfully representative of a normal trading year as the data allowed.

2. Double counting. Port-related activity shows a high degree of integration within the New South Wales economy, with consequent high intersectoral linkages between components of the industry. Since the input-output table by its nature measures the strength of backward linkages, double counting of backward linkages can occur if the multiplier effects of linked industries are simply summed. This study has been undertaken in 'net' terms, i.e. by ensuring that double counting of impacts attributable to different components of the industry does not occur. This has been achieved by expressing the value of output of each component net of backward linkages between components of the industry.

Survey of port-related firms

Questionnaire

A series of succinct questionnaires were prepared for completion by firms and government agencies that undertake economic activity in, or related to, Sydney's port. The questions were designed to elicit the scale of the respondent's port-related activity, the amounts paid by the respondent to other parties for the labour and other inputs used in such port-related work and the amounts of revenue received from customers in payment for such work. For both payments and receipts, information was sought on how the amounts were divided between parties located within, and parties located outside, New South Wales. The full questionnaires are reproduced in Appendix I.

A covering letter for the questionnaires was prepared, encouraging individual organisations to participate in the survey. It outlined the background and objectives of the study, explained why the survey was required and indicated that all survey data would be treated in confidence. The covering letter is also contained in Appendix I.

Organisations who received the questionnaire

The Sydney Ports Corporation's list of clients was used as a basis for preparing a comprehensive list of port-related firms and organisations. The final list comprised some 149 organisations (including a few government departments who provide services, such as customs inspection), and approaches were made to all of these.

The port industry (loosely defined to also include trucking companies that serve the port) is marked by a considerable degree of interlocking ownership and control. There is also a fair degree of such interconnection among large, well-known companies who are principally port users, but who also undertake some port-related activity. As a consequence, separate questionnaires sent to organisations with distinct trading names sometimes met each other inside the same head office.

This interlocking made it difficult to gauge the extent of coverage of some sub-sectors, and even makes it difficult to say how many separate companies etc. were surveyed. Nevertheless, the total figure of 149 gives a good picture.

The Sydney Ports Corporation provided Hassall & Associates with a list of 149 port related entities including 128 service providers, 17 port users and 4 government agencies. To pre-empt the survey, Greg Martin, CEO of the Sydney Ports Corporation, sent each contact on this list a letter introducing the study and asking for industry participation through the completion of a survey questionnaire.

Hassall & Associates consultants followed up on this letter through telephone contact with the addressees during the week commencing September 9, 2002. Where contact was made the consultants offered further information on the survey and forwarded the appropriate questionnaire (as designed by EconSearch) to the appropriate contact by either fax, email or post. At this stage the port-related activity for the organisation was also clarified. A letter outlining Hassall & Associates involvement in the study by collecting information through a survey questionnaire was also provided to potential survey participants.

Distribution of the survey was followed by calls to provide further information, assistance in completion of surveys, provide assurance of confidentiality and reminders to ensure that surveys were returned within the collection period. During this time a series of email reminders were sent to those contacts who had provided email addresses. From an initial return date of 23 September, the survey deadline was extended until 11 November 2002 to allow for an increase to the response rate. Consultants continued to follow up on surveys during this extended period by both telephone and email. During this process a Microsoft Excel spreadsheet was kept to store information on contact details for each organisation, and to record all points of contact made with the organisation.

Upon receipt of completed surveys, the information was entered into a Microsoft Access database. Incomplete or unclear survey responses were followed up with the appropriate contact by telephone or email. Notes have been included within the database where there is any ambiguity relating to a question response.

Responses

Around half of the eventual respondents completed the questionnaire upon receipt or soon after. However many did not. The principal reported reasons for not providing ready cooperation were that:

(i) pressure of work made it difficult to find the time to extract data from company records; and

(ii) much of the data requested was commercially sensitive, and some firms made it clear that they considered the data to be confidential.

In regard to the first difficulty, every effort was made to ease the burden by offering help in response to questions of interpretation. The response deadline was extended until from 23 September to 11 November 2002, timely reminder contact was made regularly, businesses were given the option of providing an alternative company representative to complete the survey and assurance was offered with respect to confidentiality from Hassall & Associates in the form of an email/letter from company management. Eventually, most firms who had emphasised the difficulty of finding time did complete the questionnaire although many of those with confidentiality concerns did not respond.

Towards the end of this data-collection work, the numbers of responses in the various sectors were examined. Selected non-respondents were asked to give some very limited information about number of employees and estimated market share. Those firms thus approached did provide information (which has been used in calculations made to estimate sub-sector totals by extrapolation from the details provided in the completed questionnaires).

Although there is no simple statistic for "the response rate", Table V.1 summarises the nature and extent of the various kinds of responses that were obtained in this part of the data-collection task. Of the 149 contacts provided by SPC, Hassall & Associates were able to make contact with 133 of these organisations (a number of companies no longer exist or were not able to be contacted even after address and phone number checks). The effective sample size was further reduced to 131 as some companies indicated that two or more company contacts provided by Sydney Ports Corporation were for the same business unit. In the context of the "core sample" (i.e. the net total of firms from whom data were sought), the number of responses (70) represented 53 per cent of the total.

Table V.1 Responses to port industry survey

Total number of firms approached	149
- of these, number of firms found not to undertake any (significant) port-related activity in Sydney in 2001/02 or be part of a larger group that was already responding or could not be contacted	18
Net total of firms from whom data were sought	131
Total number of responses	70
Number of firms who did not provide data	61

The distribution of the responses across port functions provided a reasonably representative sample. The responses by port category were as follows:

Port administration	1
Ship operation and movement	29
Ship loading and unloading	7
Cargo services	14
Land transport and storage	16
Government agencies	3
Total	**70**

Safeguarding and processing of the questionnaires

Upon receipt of a completed questionnaire, the responses were scrutinised for comprehensiveness and internal consistency. In a few cases, relationships between reported amounts seemed to be incorrect or unusual; telephone discussion invariably resolved the problems, allowing corrected data to be recorded.

Also upon receipt, identification of the company was separated from the statistical return. The latter was coded, and the company identification stored in a separate place, to enhance the security of the storage arrangements. The returned questionnaires and the electronic data recorded from individual returns have been destroyed.

Aggregate data collected from Sydney Ports Corporation

The survey data were complemented with information provided by the Sydney Ports Corporation. A set of statistics was compiled from the Corporation's database for the purpose of this study. These statistics provided information on cargo tonnages and estimates of various ship and cargo costs broken down by commodity type. These costs included wharfage, pilotage, navigation services, ships utilities and site occupation. Data were also provided on ship numbers, on a cargo type basis.

The data related to the study period of 2001/02. Much of the information provided a useful cross-reference against data obtained from the survey.

Appendix VI Trade Through Sydney's Ports by Port Area

Table VI.1 Trade through Sydney's port by port area, 2001/02 (revenue tonnes)

Port Area	Containers	General Cargo	Bulk Liquids & Gas	Dry Bulk	Motor Vehicles	Total
Darling Harbour	944,097	288,199	10,341	317,696	762,059	2,322,393
White Bay	2,580,655	212,489	8,285	0	1,057	2,802,486
Glebe Island	231	42,067	41,519	799,420	1,548,574	2,431,812
Kurnell	0	0	7,587,102	0	0	7,587,102
Gore Bay	0	0	5,101,557	0	0	5,101,557
Port Botany	35,340,767	11,996	1,832,300	22	909	37,185,993
Others	1,848	0	0	322,092	0	323,940
GRAND TOTAL	*38,867,598*	*554,752*	*14,581,104*	*1,439,230*	*2,312,599*	*57,755,283*

Note Components may not sum to totals due to rounding.

Source Sydney Ports Corporation.

Appendix VII Projected Economic Impact of Sydney's Ports by Cargo Type

Table VII.1 Economic impact of Sydney's ports by cargo type, 2009/10 [a]

Cargo type	*Forecast Trade* [b]	*Increase over 2001/02*	*Output ($m)*	*Value added ($m)*	*Household income ($m)*	*Employment no.*
Containers (million teus)	1.600	59%				
Direct impact			961	532	321	5,757
Indirect impact			1,104	606	290	8,273
Total impact			*2,065*	*1,138*	*611*	*14,030*
General cargo (mt) [c]	0.560	1%				
Direct impact			36	22	12	201
Indirect impact			43	23	11	319
Total impact			*79*	*45*	*24*	*520*
Bulk liquids and gas (mt)	17.850	22%				
Direct impact			271	143	85	1,642
Indirect impact			310	170	81	2,323
Total impact			*581*	*313*	*167*	*3,965*
Dry bulk (mt)	1.705	18%				
Direct impact			52	27	16	303
Indirect impact			62	34	16	465
Total impact			*114*	*61*	*33*	*768*
Motor vehicles (mt)	2.860	24%				
Direct impact			71	42	26	419
Indirect impact			87	48	23	649
Total impact			*159*	*90*	*49*	*1,068*
Passengers (no. vessels)	68	13%				
Direct impact			13	8	5	76
Indirect impact			17	9	4	127
Total impact			*31*	*18*	*9*	*202*
All Cargo						
Direct impact			1,405	774	465	8,397
Indirect impact			1,623	891	427	12,156
Total impact			*3,028*	*1,665*	*892*	*20,553*

[a] 2002 prices.
[b] Forecast by SPC for the year 2009/10.
[c] Million tonnes.
Note Components may not sum to totals due to rounding.
Source EconSearch analysis, SPC forecasts.

Table VII.2 Economic impact of Sydney's ports by cargo type, 2014/15 [a]

Cargo type	*Forecast Trade* [b]	*Increase over 2001/02*	*Output ($m)*	*Value added ($m)*	*Household income ($m)*	*Employment no.*
Containers (million teus)	2.000	99%				
Direct impact			1,142	633	381	6,844
Indirect impact			1,313	720	345	9,834
Total impact			*2,454*	*1,353*	*727*	*16,678*
General cargo (mt) [c]	0.585	5%				
Direct impact			36	21	12	199
Indirect impact			42	23	11	316
Total impact			*78*	*45*	*23*	*516*
Bulk liquids and gas (mt)	19.779	35%				
Direct impact			286	150	90	1,730
Indirect impact			326	179	86	2,448
Total impact			*612*	*329*	*175*	*4,178*
Dry bulk (mt)	1.884	30%				
Direct impact			54	28	17	318
Indirect impact			65	36	17	489
Total impact			*120*	*64*	*34*	*807*
Motor vehicles (mt)	3.316	44%				
Direct impact			79	47	29	462
Indirect impact			96	53	25	716
Total impact			*175*	*100*	*54*	*1,178*
Passengers (no. vessels)	73	21%				
Direct impact			14	8	5	77
Indirect impact			18	10	5	130
Total impact			*31*	*18*	*10*	*207*
All Cargo						
Direct impact			1,610	888	534	9,631
Indirect impact			1,861	1,021	489	13,933
Total impact			*3,471*	*1,909*	*1,023*	*23,564*

[a] 2002 prices.
[b] Forecast by SPC for the year 2014/15.
[c] Million tonnes.
Note Components may not sum to totals due to rounding.
Source EconSearch analysis, SPC forecasts.

Table VII.3 Economic impact of Sydney's ports by cargo type, 2019/20 [a]

Cargo type	*Forecast Trade* [b]	*Increase over 2001/02*	*Output ($m)*	*Value added ($m)*	*Household income ($m)*	*Employment no.*
Containers (million teus)	2.500	148%				
Direct impact			1,357	752	453	8,135
Indirect impact			1,560	856	410	11,690
Total impact			*2,918*	*1,609*	*864*	*19,825*
General cargo (mt) [c]	0.618	11%				
Direct impact			36	22	12	200
Indirect impact			43	23	11	318
Total impact			*79*	*45*	*24*	*518*
Bulk liquids and gas (mt)	22.005	51%				
Direct impact			302	159	95	1,830
Indirect impact			345	189	91	2,590
Total impact			*648*	*349*	*186*	*4,421*
Dry bulk (mt)	2.082	44%				
Direct impact			57	30	18	335
Indirect impact			69	38	18	514
Total impact			*126*	*67*	*36*	*848*
Motor vehicles (mt)	3.844	67%				
Direct impact			87	52	32	510
Indirect impact			106	58	28	789
Total impact			*193*	*110*	*59*	*1,299*
Passengers (no. vessels)	78	31%				
Direct impact			14	9	5	79
Indirect impact			18	10	5	133
Total impact			*32*	*18*	*10*	*212*
All Cargo						
Direct impact			1,854	1,023	615	11,089
Indirect impact			2,141	1,175	563	16,034
Total impact			*3,995*	*2,198*	*1,178*	*27,123*

[a] 2002 prices.
[b] Forecast by SPC for the year 2019/20.
[c] Million tonnes.
Note Components may not sum to totals due to rounding.
Source EconSearch analysis, SPC forecasts.

Table VII.4 Economic impact of Sydney's ports by cargo type, 2024/25 [a]

Cargo type	*Forecast Trade* [b]	*Increase over 2001/02*	*Output ($m)*	*Value added ($m)*	*Household income ($m)*	*Employment no.*
Containers (million teus)	3.000	198%				
Direct impact			1,549	858	517	9,284
Indirect impact			1,781	977	468	13,340
Total impact			*3,330*	*1,836*	*986*	*22,624*
General cargo (mt) [c]	0.659	18%				
Direct impact			37	22	13	203
Indirect impact			43	24	11	322
Total impact			*80*	*46*	*24*	*526*
Bulk liquids and gas (mt)	24.484	68%				
Direct impact			320	168	100	1,937
Indirect impact			366	200	96	2,741
Total impact			*686*	*369*	*196*	*4,678*
Dry bulk (mt)	2.301	59%				
Direct impact			60	31	19	352
Indirect impact			72	40	19	540
Total impact			*132*	*71*	*38*	*891*
Motor vehicles (mt)	4.456	94%				
Direct impact			96	57	35	562
Indirect impact			117	64	31	870
Total impact			*213*	*121*	*66*	*1,432*
Passengers (no. vessels)	85	41%				
Direct impact			14	9	5	81
Indirect impact			18	10	5	136
Total impact			*33*	*19*	*10*	*218*
All Cargo						
Direct impact			2,076	1,146	689	12,419
Indirect impact			2,397	1,315	630	17,950
Total impact			*4,473*	*2,461*	*1,319*	*30,368*

[a] 2002 prices.
[b] Forecast by SPC for the year 2024/25.
[c] Million tonnes.
Note Components may not sum to totals due to rounding.
Source EconSearch analysis, SPC forecasts.

Appendix VIII Projected Economic Impact of Sydney's Ports by Port Area

Table VIII.1 Economic impact of Sydney's ports by port area, 2009/10 [a]

Port Area	*Output ($m)*	*Value added ($m)*	*Household income ($m)*	*Employment no.*
Direct Effects				
Darling Harbour	77	44	26	450
White Bay	78	44	26	460
Glebe Island	80	45	28	469
Kurnell	141	74	44	854
Gore Bay	95	50	30	574
Port Botany	908	502	303	5,445
Passenger Terminals	13	8	5	76
Others	12	6	4	68
Total	*1,405*	*774*	*465*	*8,397*
Total Impact				
Darling Harbour	169	94	51	1,135
White Bay	168	93	50	1,133
Glebe Island	177	99	53	1,193
Kurnell	302	163	87	2,063
Gore Bay	203	109	58	1,387
Port Botany	1,952	1,075	577	13,266
Passenger Terminals	31	18	9	202
Others	26	14	7	173
Total	*3,028*	*1,665*	*892*	*20,553*

[a] 2002 prices.

Note Components may not sum to totals due to rounding.

Source EconSearch analysis.

Table VIII.2 Economic impact of Sydney's ports by port area, 2014/15 [a]

Port Area	*Output ($m)*	*Value added ($m)*	*Household income ($m)*	*Employment no.*
Direct Effects				
Darling Harbour	85	48	29	494
White Bay	90	50	30	532
Glebe Island	86	49	30	506
Kurnell	149	78	47	900
Gore Bay	100	53	31	605
Port Botany	1,075	595	358	6,445
Passenger Terminals	14	8	5	77
Others	12	6	4	72
Total	*1,610*	*888*	*534*	*9,631*
Total Impact				
Darling Harbour	185	103	55	1,242
White Bay	193	107	57	1,308
Glebe Island	191	107	57	1,288
Kurnell	319	171	91	2,174
Gore Bay	214	115	61	1,462
Port Botany	2,310	1,273	683	15,701
Passenger Terminals	31	18	10	207
Others	27	14	8	181
Total	*3,471*	*1,909*	*1,023*	*23,564*

[a] 2002 prices.

Note Components may not sum to totals due to rounding.

Source EconSearch analysis.

Table VIII.3 Economic impact of Sydney's ports by port area, 2019/20 [a]

Port Area	*Output ($m)*	*Value added ($m)*	*Household income ($m)*	*Employment no.*
Direct Effects				
Darling Harbour	93	53	32	545
White Bay	104	58	35	618
Glebe Island	93	53	32	548
Kurnell	157	83	49	952
Gore Bay	106	56	33	640
Port Botany	1,273	705	424	7,632
Passenger Terminals	14	9	5	79
Others	13	7	4	75
Total	*1,854*	*1,023*	*615*	*11,089*
Total Impact				
Darling Harbour	204	114	61	1,369
White Bay	224	124	67	1,518
Glebe Island	207	115	62	1,393
Kurnell	337	181	97	2,300
Gore Bay	227	122	65	1,547
Port Botany	2,736	1,508	809	18,593
Passenger Terminals	32	18	10	212
Others	28	15	8	191
Total	*3,995*	*2,198*	*1,178*	*27,123*

[a] 2002 prices.

Note Components may not sum to totals due to rounding.

Source EconSearch analysis.

Table VIII.4 Economic impact of Sydney's ports by port area, 2024/25 [a]

Port Area	*Output ($m)*	*Value added ($m)*	*Household income ($m)*	*Employment no.*
Direct Effects				
Darling Harbour	102	58	35	595
White Bay	117	65	39	696
Glebe Island	101	58	35	592
Kurnell	167	88	52	1,008
Gore Bay	112	59	35	678
Port Botany	1,450	802	483	8,689
Passenger Terminals	14	9	5	81
Others	13	7	4	79
Total	*2,076*	*1,146*	*689*	*12,419*
Total Impact				
Darling Harbour	222	124	66	1,494
White Bay	252	140	75	1,707
Glebe Island	224	125	67	1,507
Kurnell	357	192	102	2,434
Gore Bay	240	129	69	1,637
Port Botany	3,115	1,717	922	21,171
Passenger Terminals	33	19	10	218
Others	30	16	9	201
Total	*4,473*	*2,461*	*1,319*	*30,368*

[a] 2002 prices.

Note Components may not sum to totals due to rounding.

Source EconSearch analysis.

Glossary

Consumption-induced effects are additional output, employment and income resulting from re-spending by households that receive income from employment in direct and indirect activities. Consumption-induced effects are sometimes referred to as "induced effects".

Direct effects are the initial round of output, employment and income generated by an economic activity.

Employment is the number of working proprietors, managers, directors and other employees, in terms of the number of full-time equivalent jobs.

Flow-on effects are the sum of the production-induced effects and the consumption-induced effects.

Gross regional product (at factor cost) is a measure of value added on a regional basis. It can be calculated using two methods. The income method calculates GRP as household income plus other value added. The expenditure method calculates GRP as household expenditure plus other final demand, that is, in total, gross regional expenditure, plus exports less imports.

Household income is wages and salaries and other payments to labour including overtime payments and income tax, but excluding payroll tax.

Input-output analysis is an accounting system of inter-industry transactions based on the notion that no industry exists in isolation.

Input-output table is a transactions table that illustrates and quantifies the purchases and sales of goods and services taking place in an economy at a given point in time. It provides a numerical picture of the size and shape of the economy and its essential features. Each item is shown as a purchase by one sector and a sale by another, thus constructing two sides of a double accounting schedule.

Multiplier is an index (ratio) indicating the overall change in the level of activity that results from an initial change in economic activity. They are an indication of the strength of the linkages between a particular sector and the rest of the regional economy. They can be used to estimate the impact of a change in that particular sector on the rest of the economy. See Table 4.1 for a description of multiplier components.

Output is gross revenue of goods and services produced by commercial organisations plus gross expenditure by government agencies.

Production-induced effects are additional output, employment and income resulting from re-spending by firms that receive income from the sale of goods and services to firms undertaking, for example, agricultural activities. Production-induced effects are sometimes referred to as "indirect effects".

Total impact is the sum of the direct effects and the flow-on effects.

Type I multiplier is calculated as (direct effects + production induced effects)/direct effects.

Type II multiplier is calculated as (direct effects + production induced effects + consumption induced effects)/direct effects.

Value added is calculated as the value of output less the cost of goods and services (including imports) used in producing the output. It represents payments to the primary inputs of production (labour, capital and land). Value added is consistent with standard measures of economic activity, such as gross domestic, state or regional product, and it provides an assessment of the net contribution to regional economic growth of a particular enterprise or activity.

References

Australian Bureau of Statistics (ABS) 2001, *Australian National Accounts: Input-Output Tables, 1996-97*, ABS Cat. No. 5209.0, AGPS, Canberra.

Bureau of Transport Economics 2000, *Regional Impacts of Ports*, Report No. 101, BTE, Canberra.

Bureau of Transport Economics 2001, *Regional Impact of the Port of Gladstone*, Working Paper No. 47, BTE, Canberra.

Hewings, G.J.D. 1985*, Regional Input-Output Analysis*, Sage Publications, Beverly Hills.

Jensen, R.C. and West, G.R. 1986, *Input-Output for Practitioners: Theory and Applications*, Australian Regional Developments No. 1, AGPS, Canberra.

Midmore, P. and Harrison-Mayfield, L. 1996, *Rural Economic Modelling: an Input-Output Approach*, CAB International, Wallington, UK.

Miller, R.E. and Blair, P.D. 1985, *Input-Output Analysis: Foundations and Extensions*, Prentice-Hall, Englewood Cliffs, NJ.

Sydney Ports Corporation 2001, *Annual Report 2001,* June.

___2001, *First Port, Future Port: meeting the needs of container trade growth in Sydney to 2025*, SPC, Sydney.

West, G.R. 1993, *Input-Output Analysis for Practitioners, Version 7.1: User's Guide*, University of Queensland, St Lucia.

___1995, 'Comparison of input-output, input-output + econometric and computable general equilibrium impact models at the regional level', *Economic Systems Research*, 7:2, 209-227.

___1999, 'Notes on some common misconceptions in input-output impact methodology', *Discussion Paper* No. 262, Department of Economics, University of Queensland, St Lucia.

Port Botany Expansion Preliminary Hazard Analysis

for

Sydney Ports

QEST CONSULTING ENGINEERS PTY. LTD.
LEVEL 19, 100 MILLER STREET
NORTH SYDNEY
NSW, 2060
AUSTRALIA

DATE:	June 6, 2003
JOB NO.:	SPC1S
REVISION NO.:	3
PREPARED BY:	D. HITCHCOCK
CHECKED BY:	R. HUTCHISON
APPROVED BY:	D.HITCHCOCK

DOCUMENT REVISION RECORD					
Title:	**Port Botany Expansion Preliminary Hazard Analysis**				
Job No:	SPC1S				
Rev	**Description**	**Prepared by:**	**Checked by:**	**Approved by:**	**Date:**
1	Draft for client comment (DNV Report)	DH	RH		October 02
2	Final (DNV Report)	DH	RH		December 02
3	Incorporation of client comments	DH	RH		May 03

Effective from the 1st May 2003 Det Norske Veritas (DNV) has sold its Risk and HSE consulting operations in the Australia region (Australia and New Zealand) to the Qest Consulting Group. The sale includes a cooperation agreement that will see the combined resources of both organisations available to clients across Australia and worldwide for consistency and will also allow for the pooling of specialist resources for major risk projects around the world. In line with the sale, all of the consultants previously employed by DNV in Australia have been transferred to the Qest Consulting Group. Under the instructions of Sydney Port Corporation all project related documentation issued to DNV has been transferred to the Qest Consulting Group, Sydney Office.

CONTENTS

1. EXECUTIVE SUMMARY 1

2. INTRODUCTION 2
   - 2.1. Background 2
   - 2.2. Aims and Objectives 2

3. SCOPE AND METHODOLOGY 4
   - 3.1. Study Scope 4
   - 3.2. Study Methodology 5

4. FORMS OF RISK PRESENTATION 7
   - 4.1. Introduction 7
   - 4.2. Individual Risk 7
   - 4.3. Societal Risk 7

5. HAZARD IDENTIFICATION 8
   - 5.1. Hazards due to Dangerous Goods Handling 8
   - 5.2. Hazards due to Dangerous Goods Transport 9
   - 5.3. Escalation Hazards – External Impact 11
   - 5.4. Transportation of Radioactive Materials (Class 7) 12

6. KEY MODELLING ASSUMPTIONS 14
   - 6.1. General Assumptions 14

7. DANGEROUS GOODS TRADE ANALYSIS 16
   - 7.1. Sydney Ports Trade 16
   - 7.2. Dangerous Goods Trade Assumed in PHA 19
   - 7.3. Transportation Analysis 23

8. RISK CRITERIA 25
   - 8.1. Individual Fatality Risk 25
   - 8.2. Consequence Criterion 26
   - 8.3. Risk of Property Damage and Accident Propagation 26

9. RISK ANALYSIS 27
   - 9.1. External Impacts 27
   - 9.2. Diesel Fuel Storage 28

10. RISK RESULTS 29
   - 10.1. Individual Risk Contours 29
   - 10.2. Bio Physical Risk Analysis 32
   - 10.3. Societal Risk 37

11. RISK ASSESSMENT 39

11.1. Individual Fatality Risk 39
11.2. Injury Risk 39
11.3. Irritation Risk 39
11.4. Bio Physical Risk Assessment 39
11.5. Response to Recommendations – Port Botany Land Use Safety Study 40
12. CONCLUSIONS 43
12.1. Conclusions 43
13. APPENDICES 44

1. EXECUTIVE SUMMARY

Det Norske Veritas (DNV) was commissioned by Sydney Ports Corporation (SPC) to undertake a Preliminary Hazard Assessment (PHA) of the proposed expansion of facilities at Port Botany, Sydney. Effective from the 1st May 2003 Det Norske Veritas (DNV) has sold its Risk and HSE consulting operations in the Australia region (Australia and New Zealand) to the Qest Consulting Group. Under the instructions of Sydney Port Corporation all project related documentation issued to DNV has been transferred to the Qest Consulting Group, Sydney Office. Qest has subsequent to the sale completed the PHA under the instructions of SPC.

This report includes an assessment of the proposed operations following the development of the expansion site.

This assessment has been undertaken with reference to the NSW Department of Planning's Hazardous Industry Planning Advisory Paper (HIPAP) No. 6, "Guidelines for Hazard Analysis". An assessment of the risk has been undertaken with reference to the NSW Department of Planning's HIPAP No. 4, "Risk Criteria for Land Use Planning".

The analysis developed the following key conclusions:

1. The risks from the expansion area of the Port Botany terminal have been assessed by DNV against the PlanningNSW Risk Criteria based on a throughput of 1.5M TEUs per year. The basis of assessment is conservative and beyond the current Sydney Port's trade forecast for the expanded terminal for the year 2024/2025.
2. The proposed port expansion is considered acceptable with respect to the Planning NSW fatality risk criteria.
3. The injury and irritation risk criteria based on the design capacity of the terminal are considered acceptable with respect to the Planning NSW criteria.
4. The assessment of the risk to the bio-physical environment concluded that the risk contribution due to the port expansion is very low compared to the background risk. The consequences of the more likely spill events do not threaten the long-term viability of the ecosystem or any individual species, since the effects of the more likely spills will generally be very localised and reversible. Hence the HIPAP4 risk criteria should be considered to be satisfied.
5. The risk to the surrounding communities along the transportation routes leading into and out of the port due to the transportation of dangerous goods has been assessed to be acceptable for the combined Port operations.
6. The individual fatality contour for residential criteria (1×10^{-6} per year) for the proposed expansion is within the relevant bounds determined for cumulative risk by the Port Botany Land Use Safety Study (DUAP 1996).

2. INTRODUCTION

2.1. Background

Det Norske Veritas (DNV) was commissioned by Sydney Ports to undertake a Preliminary Hazard Assessment (PHA) of the proposed expansion at Port Botany, Sydney.

This study was commissioned as input into the planning assessment of the proposed development of the site.

This report includes an assessment of the proposed operations following the proposed reclamation of the site. This assessment has been undertaken with reference to the NSW Department of Planning's Hazardous Industry Planning Advisory Paper (HIPAP) No. 6, "Guidelines for Hazard Analysis" [i]. An assessment of the risk has been undertaken with reference to the NSW Department of Planning's HIPAP No. 4, "Risk Criteria for Land Use Planning"[ii].

2.2. Aims and Objectives

The general aim of the PHA study is to assess the level of risk associated with the proposed facilities as shown in Figure 1.1. The specific objectives of the study are to:

- Identify the hazardous incidents that relate to the operation of the facilities.
- Assess the significance of each incident in terms of its potential off-site impact.
- Assess and quantify the off-site levels of risk to people, property and the environment due to the proposed plant and its operation, using iso-risk levels (individual risk contours).
- Provide a clear, concise report of the analysis in line with the requirements of HIPAP No. 6 [i].

Figure 1.1 Proposed Port Expansion

3. SCOPE AND METHODOLOGY

3.1. Study Scope

The PHA was conducted using the NSW Department of Planning's guidelines for hazard analysis studies [i].

The study assessed the risks to the public arising from both normal operations and typical occurrences associated with the storage and handling of hazardous materials at the container terminal.

The scope of the study included the following tasks:

1. Preliminary Hazard Analysis of the proposed expansion at Port Botany.
2. Semi quantitative assessment of the risks to the biophysical environment including an assessment of both the acute and chronic effects using the guidance in HIPAP No. 6. The biophysical assessment has been undertaken with reference to the current status of the surrounding environment.
3. Detailed analysis of the current dangerous goods trade.
4. Consideration of the cumulative impacts of the Patrick facilities upgrade with reference to the Patrick's Terminal PHA risk model developed by DNV in 2001/2.
5. Consideration of the impacts of the proposal with reference to the Port Botany Land Use Safety Study (DUAP, 1996)
6. An assessment of the risk of aircraft impacts on the expansion given the close proximity of the port to the airport. The analysis has considered the impact of an aircraft crash on the port area for events significantly larger than the aircraft impact itself.
7. An assessment of the risk due to escalation following an incident on the neighbouring Sydney to Newcastle fuels pipeline (SMP) and the Sydney Airports jet fuel line (JUHI). Consequence analysis of potential fires and explosions following a loss of containment from the pipelines has been carried out to determine the potential for escalation to the proposed Container Terminal.
8. Assessment of the risk due to the presence of a storage tank containing 150 tonnes of diesel.
9. An assessment of the risk due to marine operations involving hazardous materials on Botany Bay with the potential for impact or escalation onto the proposed site. The scope of the assessment includes vessel movements in the Bay and the berth movements at the proposed facility.
10. The analysis of the risks due to road and rail transportation to and from the container terminals has been undertaken for a representative section of the road and rail routes. A detailed breakdown of the risks between each of the various road routes and the rail route has been undertaken based on a detailed traffic breakdown provided by Sydney Ports.

11. The analysis of the development impact in terms of societal risk has been undertaken based on estimated populations in the surrounding area. No analysis of societal risk along the transportation routes has been undertaken.
12. A qualitative analysis of the risks from Class 7 dangerous goods (radioactive materials) has been undertaken as suggested in discussions with PlanningNSW. This methodology is consistent with similar studies recently undertaken by DNV in NSW.

3.2. Study Methodology

The PHA methodology used in this study is that of classical risk assessment. This is a systematic approach to the analysis of what can go wrong in complex industrial systems. The normal conditions of operation of the system are defined and then the following questions asked:

- What accidental events can occur in the system?
- How frequently would each event occur?
- What are the consequences of each event?
- What are the total risks (frequencies x consequences) of the system?
- What is the significance of the calculated risk levels?

These questions correspond to the five basic components of a PHA. Once a system has been analysed, if the risks are assessed to be too high according to some criteria, the system can be modified in various ways to attempt to reduce the risks to a tolerable level, and the risk levels recalculated. The process may therefore be viewed as iterative, where the design of the system may be changed until it complies with the needs of society. By objectively quantifying the risks from each part of the system, a quantitative risk analysis enables identification of the most effective measures to reduce risks.

In its overall scheme, the methodology used follows the "classical" form of risk analysis and involves the following steps:

- System definition, in which information on the facility is collected and assimilated.
- Hazard identification, in which site events and external events are identified which may lead to the release of hazardous material.
- Frequency estimation, in which the frequency (i.e. likelihood per year of occurrence) of each of the accidental events is estimated, based on historical failure data.

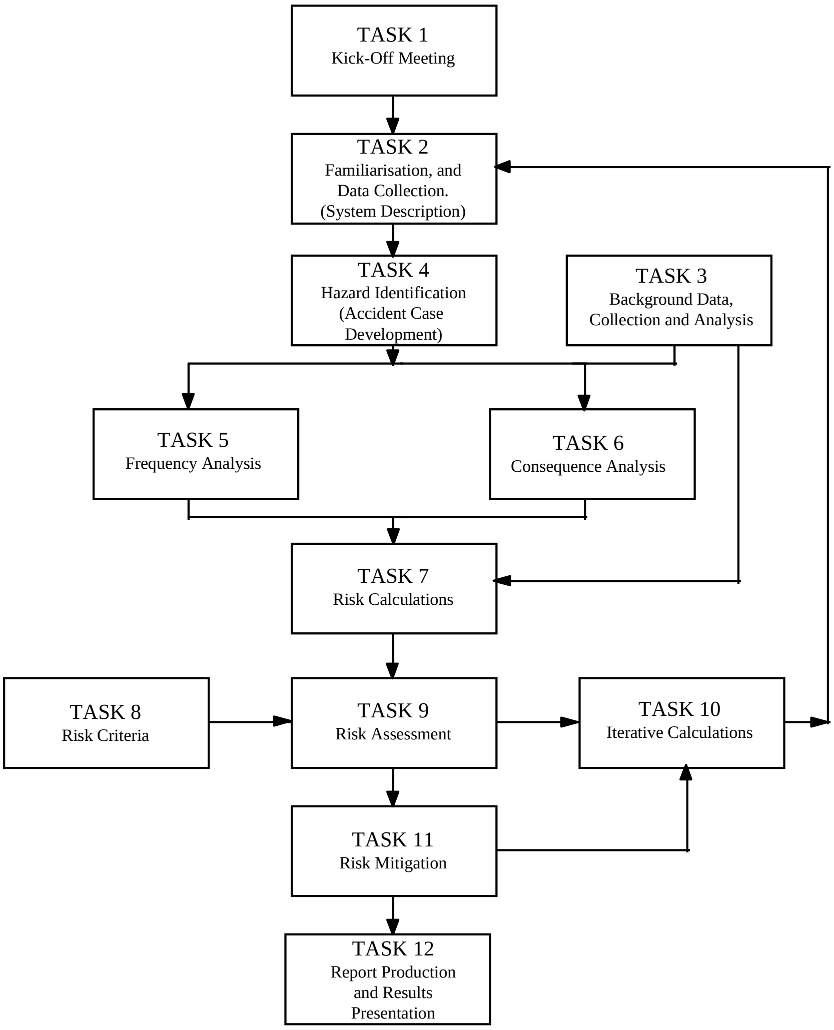
- Consequence modelling, in which all the possible consequences of each event are estimated.

- Risk calculation, in which the frequencies and consequences of each event are combined to determine levels of fatality risk.

- Risk assessment, in which the risks calculated are compared with risk criteria.

Table 3.1 shows the project flow by task.

Table 3.1 Typical Risk Analysis Methodology



The SAFETI package (Software for the Assessment of Fire, Explosion, and Toxic Impact) was used to undertake the project. This package was developed by DNV and is used by many chemical and petrochemical companies and government agencies in different countries around the world. In the past, SAFETI has been used by DNV in many QRAs involving dispersion of flammable and/or toxic gases, such as ammonia, LPG and chlorine.

4. FORMS OF RISK PRESENTATION

4.1. Introduction

There are a number of ways of presenting risk. In this section, some of the various forms of risk presentation are described in order to make the discussions that take place in subsequent sections easier to understand.

4.2. Individual Risk

Individual risk is the risk experienced by a single individual in a given time period. It reflects the severity of the hazards and the amount of time the individual is exposed to them. The number of people present does not significantly affect individual risk although there could be second order effects such as the number of surrounding persons affecting the chances of successful evacuation from a fire.

Individual risk is defined formally by the IChemE [iii] as the frequency at which an individual may be expected to sustain a given level of harm from the realisation of specified hazards. It is usually taken to be the risk of death, and usually expressed as a risk per year.

Individual risk is presented in this report in the form of individual risk of fatality contours over a map of the expanded Port site and surrounds.

4.3. Societal Risk

Societal (or group) risk is the risk experienced in a given time period by the whole group of personnel exposed. It reflects the severity of the hazard and the number of people exposed to it. It is usually taken to refer to the risk of death, and usually expressed as a risk per year.

Societal risks are defined by the IChemE [iii] as the relationship between the frequency and the number of people suffering a given level of harm due to the realisation of specified hazards. Societal risks may be expressed in the form of:

- **Annual fatality rates**, in which the frequency and fatality data are combined into a convenient single measure of group risk.
- **FN curves**, showing the relationship between the cumulative frequency (F) and number of fatalities (N).

4.3.1. FN Curves

FN curves are frequency-fatality plots, showing the cumulative frequencies (F) of events involving N or more fatalities. They are derived by sorting the frequency-fatality (F-N) pairs from each outcome of each accidental event, and summing them to form cumulative frequency-fatality (F-N) co-ordinates for the plot. The cumulative form is used to ensure that steadily declining curves are obtained even when some sizes of accident do not occur in the analysis.

FN curves are graphical measures of group risk that show the relationship between frequency and size of the accident. Unlike the annual fatality rate, an FN curve allows a judgement to be made on the relative importance of different sizes of event. Drawbacks of FN curves are that they are awkward to derive and potentially confusing to interpret.

5. HAZARD IDENTIFICATION

Hazard identification has been undertaken based on a review of the activities at and around the proposed expansion location.

Detailed consideration of the hazards associated with each of the dangerous goods classes traded via the port has then been carried out with respect to the inherent hazards of each of the dangerous goods classes.

In summary the following hazards have been identified:

1. Loss of containment from dangerous goods due to handling at the terminal.

2. Loss of containment from hazardous cargo during transport to and from the terminal.

3. Loss of containment from dangerous goods cargo due to impact from an external event.

4. Loss of containment from dangerous goods cargo whilst in transit at the port.

Each of these hazards is discussed separately below.

5.1. Hazards due to Dangerous Goods Handling

The handling of dangerous goods in the proposed container facility will be subject to the provisions of the Dangerous Goods (General) Regulation 1999 (NSW) and in particular AS 3846 (The handling and transport of dangerous cargoes in port areas) which is included in the Regulation. AS 3846 requires conformance with the Australian Dangerous Goods (ADG) Code for interface with road and rail activities to or from the facility and with the International Maritime Dangerous Goods (IMDG) Code on vessels. Quantities of some classes of dangerous goods (e.g. Class 1 Explosives and Class 5.1 Oxidising Substances) present on a berth are limited in accordance with the provisions of AS 3846. Materials denoted as “red line” dangerous goods (see Table 4.1) are generally limited to a presence of 12 hours, whereas other dangerous goods (green line) are allowed a presence of 5 days on a berth.

Table 4.1 Red Line Dangerous Goods

<u>“Red Line” dangerous goods are defined as:</u>

1. All Dangerous Goods in break-bulk.
2. All containers with Class 1 & Class 7 Dangerous Goods.
3. All containers packed with more than 500 kg of:
    - Class 2.1 (excluding UN 1950 – aerosols)
    - Class 2.3
    - Class 3 Packaging Group 1
    - Class 4 Packaging Group 1
    - Class 5.1 Packaging Group 1

- Ammonium nitrate UN No's 1942, 2067, 2068, 2069, 2070 and 2072
- Calcium hypochlorite UN No's 1748 and 2880
- Class 6.1 Packaging Group 1
- Class 8 Packaging Group 1

With reference to previous risk assessments into container terminal operations in Port Botany the following basic activities have been identified that may lead to the loss of containment of hazardous material.

- Vessel loading / unloading via portainers.
- Transportation of containers onsite via straddle carriers.
- Stacking of containers via straddle carriers.
- Loading / unloading of dangerous goods containers onto trucks using straddle carriers.
- Loading / unloading of trucks and rail cars via overhead rail mounted gantries.
- Transportation onsite via trucks and rail cars.

There are three major hazards associated with the activities on the site. These are:

1. Damage to containers and loss of containment caused by dropping of a container during a lift or impact of a container on a solid object during a lift;
2. Damage to containers and loss of containment occasioned by a vehicle accident on site, either the straddle carriers, the trucks or the rail cars;
3. A "spontaneous" leak occurring from a container during the storage of the container on site.

5.2. Hazards due to Dangerous Goods Transport

Dangerous goods, along with all other trade, will be transported to and from the new terminal via road, rail and sea. For each of these modes of transport two major hazards have been identified with the potential for a loss of containment of dangerous goods that may pose a risk to the community. Those hazards are:

1. Damage to containers and other vessels following a transportation accident.
2. A "spontaneous" leak occurring from a container during transport.

With respect to the three modes of transport listed above a review of the hazards with respect to their potential for impacting on to the community has been undertaken.

5.2.1. Road Transport

Road vehicles transporting containers of dangerous goods to and from the site will utilise an established network of transport routes for the movement of both heavy vehicles and dangerous goods. In line with any other driving activity on public roads the potential exists for accidents between vehicles transporting dangerous goods.

As members of the public are likely to be in relatively close contact with these vehicles, either as occupants of other vehicles sharing the road or as pedestrians, the potential risk due to a loss of containment of dangerous goods is significant.

Detailed analysis of the risk due to road transport of dangerous goods has been included in the transportation risk analysis covered under the scope of this study.

5.2.2. Rail Transport

Similar to the road transport, containers will be transported to and from the site via established rail infrastructure. Whilst the risk of interactions with other vehicles is recognised to be lower than that of road transport, trains hold the potential to transport multiple containers in a single movement. Hence the potential consequences from a single incident may be several times higher than that from a single road transport incident involving one container.

As with road transport, members of the public are likely to be in relatively close proximity to the rail line as it passes through industrial, commercial and residential areas. Detailed analysis of the risk to the community due to the transportation of dangerous goods via rail has been included in the transportation risk analysis covered under the scope of this study.

5.2.3. Sea Transport

Transport by sea will be the primary means of export and import of goods through the terminal. Hazards resulting in a loss of containment of dangerous goods from containers at sea will have negligible impact on the surrounding community due to the separation distances.

Incidents involving loss of containment in Port Botany may be as a result of ship to ship collisions, ship/berth strikes, grounding or sinking.

Ship to ship collisions is not considered as a realistic scenario given the restrictions placed on vessel movements in the bay. Current port controls limit the movement to not more than 1 vessel at any one time, thus all but eliminating the potential for ship to ship collisions.

Grounding of a vessel in the bay or vessel / berth strikes are likely to be limited to structural and hull damage to the vessel. Escalation of the incident to the loss of containment of dangerous goods held in containers or isotainers is considered unlikely. In the event of grounding the vessel would come to rest as the vessel hull is dragged against the sea bed. For vessel / berth striking the vessel would rebound off the berth back into the bay. The forces generated via the impact and deceleration of the vessel would be transferred in part to the stack of containers onboard the vessel. However, as vessels travel and manoeuvre at low speeds in the port and the containers have been stacked and lashed in an appropriate manner suitable to withstand the movement generated during sea conditions, it is considered that the containers would not be affected. The potential for loss of containment due to vessel grounding or vessel / berth striking is considered negligible and has been excluded from further analysis.

5.3. Escalation Hazards – External Impact

The following sources of external impact on to the site of the expansion has been identified:

- Aircraft impact; and
- Impact due to incident on neighbouring hazardous facility including pipelines.
- Loss of containment at the neighbouring Patrick facilities.

The proposed expansion of Port Botany lays approximately 700m from the 3rd runway of Sydney's Kingsford Smith Airport. Given the close proximity of the terminal to the 3rd runway, there exists potential for impact from aircraft due to a crash landing. Detailed analysis of the likelihood and possible consequence of an impact, excluding the impact generated via the aircraft alone have been included in the analysis.

There are a number of industrial sites in the local Botany area surrounding the Port. The potential for escalation onto the site of the expansion is unlikely due to the physical separation distances between the terminal site and the industrial area.

Exceptions to the above include major fuels pipelines running around the boundary of the site. Loss of containment from neighbouring fuels pipelines may results in a large pool or jet fire with the potential for escalation on to the expansion site. Quantification of this hazard has been undertaken in the PHA.

Loss of containment from specific types and classes of hazardous cargoes handled on the adjacent Patrick terminal presents a risk to people on the proposed expansion site. The potential however for escalation to others dangerous goods handled on the expansion site is limited. Potential initiating scenarios on the Patrick site that may lead to escalation and hence a release of dangerous goods on the expansion facilities is limited to fires and explosions. As the hazardous goods profile of both sites is similar, reference to the hazard identification and analysis presented in Appendix II has been used to assess the risk of escalation from the Patrick terminal.

Explosion Overpressure

Sources of overpressure include class 1, and class 5.1 dangerous goods. The overpressure level required to fail an isotainer containing pressurised flammable or toxic gases is estimated to be in the order of 7 psi (Ref 5). Inspection of Figure II.2.1 notes a 12 t explosion of TNT generates up to 7 psi at a distance of 200m. Overpressures of 7 psi are estimated to be capable of turning over rail cars, and therefore in the event of such overpressure in a container terminal such as Patrick Port Botany, would be expected to result in the collapse of neighbouring container stacks. Whilst unlikely, such an impact should generally be limited to the confines of the Patrick terminal, and hence present negligible risk of escalation on the expansion terminal site.

Fire

Jet fires from Class 2.1 flammable gas isotainers have been discussed in Section II.2.2. Inspection of the jet fire consequence analysis undertaken using PHAST notes a heat radiation of 37.5 kW/m^2 with a hazard range of up to 130m, based on a 50mm hole. Escalation on to the expansion facilities from such an incident is limited due to the range of the fire. However in addition, the duration of such a fire would be strictly limited by the storage capacity of the isotainer. With a maximum inventory of 20 tonnes it is unlikely that the fire duration would be long enough to ensure failure of an impacted container.

Based on the analysis of potential escalation scenarios on the Patrick facilities the risk of escalation is considered unlikely, due to the nature and dimension of potential initiating incidents and the distances involved.

5.4. Transportation of Radioactive Materials (Class 7)

When radioactive materials are to be transported, there are a number of requirements that manage the risk of accidents. The surface activity of the packaged goods are required to be below a certain amount for the different packaging groups for Class 7. In accordance with the requirements of AS3846 (The handling and transport of dangerous cargoes in port areas) extensions to the time limitation requirements on the port for any Class 7 goods may only be issued for Low Specific Activity (LSA) materials. These materials include rare earth sands that contain a small amount of naturally-occurring radioactive isotopes.

The requirements on manufacturers or consignors of Class 7 materials that are transported by ships are detailed in Volume 1 of the International Maritime Dangerous Goods (IMDG) Code [iv]. These requirements include:

- Before the first shipment of a package containing radioactive material, the package must be demonstrated to be able to withstand the internal pressure able to be generated. In addition, for fissile material, the effectiveness of the shielding and containment systems must be demonstrated.
- Before each shipment, all the provisions of the Code must be demonstrated to be satisfied. Also, where the package needs to be sealed, the closure and sealing of those seals must be demonstrated.
- Notification to the Competent Authorities is required for significant quantities or activities of shipments. The Competent Authority will supply an approval certificate, details of which must be included in the transport documentation.
- Low Specific Activity material excludes those materials that can dissolve or transfer activity to water when immersed for 7 days and is restricted to materials that by their nature have limited specific activity. These materials can be exempted from the red line time limit provision by Sydney Ports Corporation.
- Special form radioactive material is a sealed capsule containing radioactive material or an indispersible solid radioactive material. Such material must pass impact tests, percussion tests, bending and heat tests.
- Transport Indices (TI) and Criticality Safety Indices (CSI) are used to determine the packaging group applied to the loads and to determine whether the load is permitted to be transported.

- There are limits to the quantity of radioactive material able to be transported in a single package. These limits vary depending on the particular isotope or mixture of isotopes being transported.
- The design of each package approved for transportation of radioactive material must be tested and approved using UN tests prior to being used.
- The consignor of each shipment of radioactive materials must ensure that there is a description of the physical and chemical form of the radioactive contents. In addition, the maximum activity of the radioactive contents, the category of the package (I, II or III) and detailed statement of the contents of each package within the freight container must also be included.

In addition, transportation of Class 7 materials are scrutinised by the regulator on many occasions during the year to ensure that the requirements are being met. The public concerns that exist regarding transportation of radioactive material focuses the attention of all agencies associated with the transport. This reduces the likelihood of any sub-standard packaging or incorrect labelling being missed by the manufacturer or consignor.

Should an accident occur associated with the transportation of Class 7 materials, the container body and the internal packing will reduce the likelihood of any escape of radioactive material. In the event of any significant accident, the Hazmat team from the NSW Fire Brigade will immediately evacuate personnel around any package with a Class 7 label and call in experts in managing and recovering the material.

As radioactive effects are dose dependent, and effective medical aid can reduce the acute consequences of exposure to radioactive materials, prompt medical aid can reduce the risk. Provided the labelling and documentation is adequate, the risk of transport of Class 7 materials through the terminal is considered low.

6. KEY MODELLING ASSUMPTIONS

In the process of undertaking the quantitative risk assessment of the expansion of the Port Botany site, a number of key modelling assumptions have been identified, which are critical to the risk results.

The majorities of the modelling assumptions are associated with likelihoods of hazardous scenarios occurring.

6.1. General Assumptions

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

G-1. The study focus is on release events capable of producing an offsite fatality risk; events that pose only an on-site risk are not analysed.

G-2. The manifest for the period of 1 April 2001 to 31 March 2002 has been taken as representative of an average year for the operation of the terminal.

G-3. The package sizes for each of the dangerous goods classes were estimated based on the dangerous goods transported and package description.

G-4. Class 1 – Explosives have been modelled in two package sizes: 12 tonnes and 2 tonnes. All package sizes greater than 10 tonnes have been modelled as 12 tonnes. All package sizes less than 10 tonnes have been modelled as 2 tonnes.

G-5. Class 1 – Explosives. In the event of a dropped container, 1 in a thousand incidents has been assumed to result in a detonation.

G-6. Class 2.1 – Flammable Gases of less than 20 tonnes have been screened out of the analysis as they will not pose a risk beyond the terminal boundary. All movements of greater than 10 tonnes identified in the manifest have been modelled as a 20 tonne release as determined by package size.

G-7. All Class 2.1 materials have been modelled as propane.

G-8. Class 2.2 – Non-flammable Gases have been screened out of the analysis on the basis that they will have no significant offsite consequences.

G-9. Class 2.3 – Toxic Gases except chlorine have been modelled in two package sizes: 20 tonne isotainers and 1 tonne cylinders (drums). All movements of 10 tonnes or more identified in the manifest have been modelled as a 20 tonne release. All movements of less than 10 tonnes in other than tanks, have been modelled as a 1 tonne release based on the assumption that in the event of an incident only one cylinder will be affected.

G-10. All movements of 1 tonne or more of chlorine have been modelled as movements of 920 kg drums. No isotainers of chlorine were modelled in the analysis as none were present in the manifest.

G-11. Class 2.3 materials have been modelled in detail. All movements of sulphur dioxide and chlorine have been modelled as sulphur dioxide and chlorine respectively. All other class 2.3 materials have been modelled as ammonia.

G-12. Class 3 – Flammable Liquids have been screened out of the analysis on the basis that they will have no offsite consequences.

G-13. The current total volume of trade of the Patrick and the P & O Terminal was estimated in the study period of 2001-2002 at 892,275 TEU per year.

G-14. The analysis of the risk from the proposed expansion has been undertaken based on a throughput 1.5 million TEUs per year.

G-15. No modification to the incident frequencies has been undertaken with reference to the performance or benchmarking of the proposed sites management practices and standards.

G-16. Class 5.1 – Oxidising Materials. Explosions of ammonia nitrate (AN) have been identified as a hazard associated with the transportation of ammonium nitrate. An explosion of two tonnes of ammonium nitrate has been assumed to be the largest likely explosion scenario. This scenario is based on the incident in Taroom, Qld in 1972. Following a fire involving the prime mover, which spread to the wooden deck of the trailer, a sealed fuel tank contained under the trailer deck exploded causing detonation of some of the ammonium nitrate carried on the truck. Much of the ammonium nitrate was scattered rather than involved in the explosion.

G-17. Explosions are modelled with two fatal effect-zones:

R1: inner zone, with high fatalities. This is typically set at the overpressure to cause heavy building damage. For this study, heavy damage is assumed to occur at an over pressure of 5 psi.

R2: outer zone, with lower fatalities. This is typically set at the overpressure to cause repairable building damage. For this study, light damage is assumed to occur at an overpressure of 2 psi.

7. DANGEROUS GOODS TRADE ANALYSIS

This section presents the analysis of the dangerous goods trade currently passing through the Port Botany Terminals. The trade analysis has been undertaken based on a review of the electronic trade manifest collected by Sydney Ports. The information analysis includes the period between 1 April 2001 and 31 March 2002.

7.1. Sydney Ports Trade

Currently there are two major stevedore operations at Port Botany: Patrick and P & O.

Review of the trade manifest for the 12 month study period identified a total of 892,275 TEU movements.

The analysis of dangerous goods trade based on the electronic database has broken the current Port Botany trade down into the number of movements per dangerous goods class, per net movement weight (with the exception of Class 1 materials which have been broken down on the basis of Net Explosive Quantity (NEQ).

Table 7.1 presents the breakdown of the number of movements per year for each dangerous goods class per net weight. Due to the hazardous nature of Class 2.3 materials and the potential for significant differences in the hazardous properties of such material a detailed breakdown of Class 2.3 materials has been undertaken to determine the risk in greater detail.

In the analysis of future trade movements the number of container movements identified in the study period (1 April 2001 and 31 March 2002) was multiplied by a factor equivalent to the ratio of TEU movements during the study period over the number of TEU movements forecast in the future.

For example:

Number TEU movements 2001	892,275 per year
Number TEU movements in future	1,500,000 per year
Number container movements Class 2.3 Tanks - 2001	8 per year (example)
Forecast container movements Class 2.3 Tanks - Future	= 8 x (1,500,000 / 892,275)
	= 8 x 1.68
	= 13.45 containers per year – future
	= 14 containers (modelled)

Table 7.1 Summary of Port Botany Total DG Movement [1]

Class	Sub Class	No of Movements per Year					Totals
		<1 T	1 - 5T	5 - 10T	10 – 24T	24 - 30T	
1	1	5	0	0	0	0	5
	2	2	0	0	0	0	2
	3	18	4	6	22	0	50
	4	175	35	4	14	1	229
2	-	1441	565	333	226	0	2565*
	1	573	160	174	147	0	1054
	2	422	96	71	118	27	734
	3	105	37	22	42	0	206
3	-	1307	329	108	316	29	2089
	1	470	143	35	107	3	758
	2	2197	450	166	303	34	3150
	3	2039	637	289	621	115	3701
4	1	203	50	56	576	7	892
	2	35	7	17	49	1	109
	3	53	21	13	415	23	525
5	1	509	132	38	1758	60	2497
	2	48	25	4	6	0	83
6	1	707	233	72	1741	183	2936
7		1	0	0	23	0	24
8		1930	695	263	1234	72	4194
9		700	378	526	1142	51	2797
	Totals	12940	3997	2197	8860	606	28600

Note: 1. Not all DG trade is electronically reported, however all *red line* DGs are required to be included in the electronic manifest.

* Including aerosols.

Table 7.2 Summary of Port Botany Total Class 2.3 and Hydrogen Fluoride Movements

Class	Sub Class	DG	No of Movements					Totals
			<1 T	1 - 5T	5 - 10T	10 - 24T	24 – 100T	
2	3	Chlorine	8	2	1	19	0	30
		Sulphur Dioxide	18	1	2	1	0	22
		Other Class 2.3	79	34	19	22	0	154
		Total Class 2.3	105	37	22	42	0	206
8		Hydrogen Fluoride	2	6	0	8	4	22

With respect to the data in Table 7.2, the number of movements for example between 10 – 24 tonnes refers to the total net weight of the container. From the data supplied there are no imports or exports via Port Botany of chlorine in vessels or drums greater than 920 kg each. Inspection of the data in Table 7.2, notes 19 movement of chlorine between 10 and 24 tonnes during the study period (April 2001 – March 2002). Based on the above data regarding chlorine movements, it was assumed that the 19 movements consisted of 19 containers, holding more than 10, but less than 24, drums.

In order to determine the number of movements of dangerous goods per average year via the proposed expansion, the data in Table 7.1 and Table 7.2 has been multiplied by the estimated fraction of trade to be handled by the proposed site based on its throughput.

Based on an analysis prepared by Sydney Ports the container trade is forecast as follows:

Year (Million TEUs)	2004/5	2009/10	2014/15	2019/20	2024/25
TEU Trade Forecast Port Botany	1.1	1.6	2.0	2.5	3.0

The analysis of the risk from the proposed expansion has been undertaken with reference to a throughput of 1.5 million TEUs per year. With reference to the dangerous goods trade manifest of 2002, presented in Table 7.1, the total number of movements per dangerous goods class has been forecast based on a total trade volume of 1.5 million TEUs per year. The results of the proposed site trade analysis is presented in Table 7.3 and Table 6.4.

Table 7.3 Summary of Proposed Site DG Movement [1]

Class	Sub Class	No of Movements per Year					Totals
		<1 T	1 - 5T	5 – 10T	10 – 24T	24 – 30T	
1	1	8	0	0	0	0	8
	2	3	0	0	0	0	3
	3	30	7	10	37	0	84
	4	294	59	7	24	2	385
2	-	2422	950	560	380	0	4312*
	1	963	269	293	247	0	1772
	2	709	161	119	198	45	1234
	3	177	62	37	71	0	346
3	-	2197	553	182	531	49	3512
	1	790	240	59	180	5	1274
	2	3693	756	279	509	57	5295
	3	3428	1071	486	1044	193	6222
4	1	341	84	94	968	12	1500
	2	59	12	29	82	2	183
	3	89	35	22	698	39	883
5	1	856	222	64	2955	101	4198
	2	81	42	7	10	0	140
6	1	1189	392	121	2927	308	4936
7		2	0	0	39	0	40
8		3245	1168	442	2074	121	7051
9		1177	635	884	1920	86	4702
	Totals	21753	6719	3693	14895	1019	48079

Note: 1. Not all DG trade is electronically reported, however all *red line* DGs are required to be included in the electronic manifest.

* Including aerosols.

Table 7.4 Summary of Sydney Ports Proposed Site Class 2.3 Movements

Class	Sub Class	DG	No of Movements					Totals
			<1 T	1 - 5T	5 – 10T	10 - 24T	24 – 30T	
2	3	Chlorine	13	3	2	32	0	50
		Sulphur Dioxide	30	2	3	2	0	37
		Other Class 2.3	133	57	32	37	0	259
		Total Class 2.3	177	62	37	71	0	346
8		Hydrogen Fluoride	3	10	0	13	7	33

7.2. Dangerous Goods Trade Assumed in PHA

Based on the total dangerous goods trade for the proposed expansion presented in Table 7.3 and Table 6.4, further simplifications of the trade levels were undertaken in the course of the development of the risk model. In order to simplify the risk analysis, conservative assumptions were made in relation to the number of movements of different quantities of different dangerous goods classes. This section outlines the assumptions and presents a final dangerous goods trade included in the risk model.

Table 7.5 presents a summary of the key assumptions that have been applied in determining the number of movements of dangerous goods of differing classes and inventories. With reference to the data in Table 7.3 and Table 7.4, the assumptions in Table 7.5 have been applied to generate the data in Table 7.6. The data in this table has been used as a multiplier in the risk model to determine the risk per annum due to the total number of movements of a particular hazardous material through the proposed expansion at Port Botany.

Table 7.5 Dangerous Goods Trade Modelling Assumptions

Dangerous Goods Class	Description	Modelling Assumptions
Class 1	Explosives	All Class 1 movements between 10 – 24 tonnes modelled as potential 12 tonne equivalent TNT explosion.
		All Class 1 movements greater than 1 tonnes, but less than 10 tonnes modelled as a potential 2 tonne equivalent TNT explosion.
Class 2.1	Flammable Gases	All Class 2.1 movements between 10 and 24 tonnes, with a Package Type of either Tank, Tank, rectangular or Tank, cylindrical have been modelled as 20 tonne vessel of liquid propane.
		All other Class 2.1 movements have been eliminated from the analysis due to the consequence of any potential loss of containment being limited within the terminal site boundary.
Class 2.2	Non-flammable Gases	All screened out of the analysis on the basis that they will have no offsite consequences.
Class 2.3	Toxic Gases	Chlorine and sulphur dioxide trade separated from other Class 2.3
		All SO_2 movements between 5-10 and 10 – 24 tonnes have been modelled as 20 tonne isotainers of SO_2. Detailed inspection of the SO_2 trade by Sydney Ports have identified 1 x 20 t + 2 x 9 t per year through the combined Port Botany facilities. Therefore this analysis is conservative.
		All SO_2 movements less than 5 tonnes have been modelled as 1 t drums.
		Detailed inspection of the chlorine trade in Port Botany has noted the absence of any single package movements greater than 1 tonne. Therefore no isotainers have been modelled in the analysis. All chlorine movements greater than 1 tonne have been modelled as multiple 920 kg drums.
		All non Cl_2 or SO_2 Class 2.3 movements have been modelled as ammonia. All movements greater than 10 tonnes and less than 24 tonnes have been modelled as 20 tonne isotainers of NH_3.

Dangerous Goods Class	Description	Modelling Assumptions
		All other non Cl_2 or SO_2 Class 2.3 movements between 1 and 10 tonnes have been modelled as 1 tonnes drums of ammonia.
Class 3	Flammable Liquids	All screened out of the analysis on the basis that they will have no offsite consequences. Included in the transportation risk analysis presented in Appendix IV. All Class 3 movements greater than 10 tonnes were modelled as 20 tonne tankers.
Class 4	Flammable Solids	All screened out of the analysis on the bases that they will have no offsite consequences.
Class 5.1	Oxidising Materials	All movements of Class 5.1 materials between 10 and 30 tonnes have been modelled as a 12 tonne equivalent mass of TNT.
		All movements of Class 5.1 materials less than 10 tonnes and greater than 1 tonne have been modelled as 2 tonne equivalent mass of TNT.
Class 5.2	Organic Peroxides	All screened out of the analysis on the bases that they will have no offsite consequences.
Class 6.1	Toxic Materials	All screened out of the analysis on the bases that they will have no offsite consequences.
Class 7	Radioactive Materials	Please refer to qualitative analysis.
Class 8	Corrosive Materials	All Class 8 movements of hydrogen fluoride (HF) between 10 and 24 tonnes, with a Package Type of either Package, Tank, Tank, rectangular or Tank, cylindrical have been modelled as 20 tonne vessel of saturated HF. All HF movements between 1 - 10 tonnes have been modelled as 1 tonne drums of HF.
Class 9	Miscellaneous Material	All screened out of the analysis on the basis that they will have no offsite consequences.

Table 7.6 Summary of Dangerous Goods Movements Modelled in the PHA

Dangerous Goods Class	Description	Representative Material	Unit Size and Number of Movements		
			NEQ < 1 tonne	NEQ 2 Tonnes	NEQ 12 Tonnes
1	Explosives	TNT	Screened out	83	63
				1 Tonnes	20 Tonnes
2.1	Flammable Gases	Propane	Screened out		111[2]
2.2	Non-flammable Gases		Screened out		
2.3	Toxic Gases	Chlorine	Screened out	37	0
		Sulphur Dioxide	Screened out	32	5
		Ammonia [1]	Screened out	89	37
3	Flammable Liquids	Acrylonitrile	Screened out		
4.1	Flammable Solids	As per Class 3	Screened out		
4.2	Spontaneously Combustible		Screened out		
4.3	Dangerous When Wet	As per Class 3	Screened out		
5.1	Oxidising Materials	Ammonium Nitrate	Screened out	286	3056
5.2	Organic Peroxides		Screened out		
6.1	Toxic Materials		Screened out		
7	Radioactive Materials		Please refer to qualitative analysis		
8	Corrosive Materials	Hydrogen Fluoride	Screened out	13	20
9	Miscellaneous Materials		Screened out		

Notes:

1. Ammonia referenced as a representative material for all other Class 2.3 materials excluding chlorine and sulphur dioxide due to their high toxic properties.
2. Only isotainers have been modelled as 20 tonnes movements. Trade involving more than 10 tonnes of flammable gases carried in a Package Type other than a tank (rectangular or cylindrical) have been assumed to be multiple numbers of smaller vessels together in a single container. In the event of a incident involving such a container it has been assumed that only a single vessel will be involved initially and that any potential escalation scenario will again only involve one other vessel of a similar type and size.

7.3. Transportation Analysis

Two possible means of land transport are available for goods imported or exported from the Sydney Ports Terminal and they include road trucks and rail freight.

An analysis of transportation movements prepared by Sydney Ports has identified five main routes in and out of the Port Botany Terminal area:

- Rail Route;
- Foreshore Road;
- Botany Road;
- Military Road; and
- Beauchamp Road to the east of the Patrick gate.

A breakdown of the fraction of the total incoming and outgoing traffic volume for each of the above routes has been determined via the Sydney Ports traffic movements analysis for 2021. The results of the analysis are summarised in Table 7.7.

Table 7.7 Traffic Movements

Route	Fraction of Trade
Rail Route	40%
Foreshore Road	43%
Botany Road	12%
Military Road	4%
Beauchamp Road	1%
Total	100%

The draft DUAP guideline on route selection (DUAP 1995) requires a review to consider the physical and subjective factors associated with the choice of routes for transport.

The subjective factors include the land uses on either side of the roads. This shows that Foreshore Rd is the preferred route for a number of reasons:

- Foreshore Rd is straighter than the alternatives (Botany Rd, Stephen St or Denison St),
- Foreshore Rd is wider than the alternatives (2 lanes each way rather than 1 lane each way),
- Foreshore Rd has fewer traffic lights and a higher speed limit,
- Foreshore Rd is bounded by open space (foreshore and a golf course) along most of its length. Botany Rd, Stephen St and Denison St have residences and shops at various locations along their route.

For all of the above reasons, Foreshore Rd has been assessed as the preferred route for dangerous goods vehicle movements to and from Port Botany container terminal sites. This brief qualitative assessment is reflected in the Sydney Ports traffic movements analysis with 43% of the trade using Foreshore Road. This is equal to 72% of all road traffic movements in and out of the port.

For movements to the east, vehicles use Beauchamp Rd, Botany Rd or Military Rd. However, as the destinations or origins of the vehicles is predominately in the Botany area, the choice of road route is mainly determined by the shortest distance between the origin and the destination.

One significant exception to the above discussion is the movement of chlorine drums from the Orica site in Denison St to Port Botany. This route is the only practicable route from Orica to the Port and passes through industrial areas, except for the section along Denison St, which has residences along one side. For the purposes of the quantitative risk analysis all Chlorine trade into the Port is assumed to travel along Beauchamp Road.

8. RISK CRITERIA

8.1. Individual Fatality Risk

The individual fatality risk level in residential zones should not exceed one in a million (1 x 10^{-6}) per year. This means that, if a person was permanently located there, 24 hours a day for a whole year, then the probability of fatality caused by a major accident at the terminal must not exceed one chance in a million during that period.

The individual risk level for "sensitive developments", such as hospitals, schools, child care facilities and aged care housing developments should not exceed half in a million (0.5 x 10^{-6}) per year.

The individual risk level for commercial developments including offices, retail centres, warehouses with showrooms, restaurants and entertainment centres should not exceed five in a million (5 x 10^{-6}) per year.

The individual risk level for sporting complexes and active open space areas should not exceed ten in a million (10 x 10^{-6}) per year.

For neighbouring industrial sites, the risk of fatality should, as a target, be limited to fifty in a million (50 x 10^{-6}) per year. HIPAP 4 [ii] does, however, allow for some flexibility in the interpretation of this criterion. In particular it indicates that ‘where an industrial site involves only the occasional presence of people, such as in the case of a tank farm, a higher level of risk may be acceptable’.

8.1.1. Injury Risk

In HIPAP 4 [ii] criteria are presented for injury risk levels. These are in the form of heat radiation, explosion overpressure, and toxic gas exposure. In this case the most serious is the potential for toxic gas exposure. In the case of heat radiation and explosion overpressure the effects tend to be localised, however in the case of toxic gas exposure there is the potential for significant exposure offsite. Therefore, the injury risk level of interest is as follows:

- The risk of injury from toxic gas exposure to individuals in residential areas should not exceed a level which would be seriously injurious to sensitive members of the community following a relatively short period of exposure at a maximum frequency of ten in a million per year (10×10^{-6}).

8.1.2. Irritation Risk

For toxic gas exposure there is a second criteria level, which is concerned with lower concentration effects that may result in irritation rather than injury. The irritation risk level is as follows:

- The risk of irritation from toxic concentrations in residential areas should not cause irritation to eyes or throat, coughing or other acute physiological responses to sensitive members of the community over a maximum frequency of fifty in a million per year (50×10^{-6}).

8.2. Consequence Criterion

The risk of heat radiation exceeding 4.7 kW/m^2 or explosion overpressure exceeding 7 kPa should not exceed fifty chances in a million (50×10^{-6}) per year at residential areas.

The risk of property damage at neighbouring industrial sites should not exceed 50 in a million per year (23 kW/m^2 heat flux or 14 kPa overpressure).

8.3. Risk of Property Damage and Accident Propagation

The risk of heat radiation exceeding 23 kW/m^2 may cause unprotected steel to suffer thermal stress that may cause structural damage. In addition, explosion overpressure levels of 14 kPa can cause damage to piping and low pressure equipment. Thus the probability of these incidents should be less than 50 in a million (50×10^{-6}) per year at the boundary to neighbouring industrial facilities.

9. RISK ANALYSIS

9.1. External Impacts

The analysis of the risk due to external impacts has been undertaken with reference to the hazards identified in section 5.3.

9.1.1. Aircraft Impacts

The risk to the surrounding community due to aircraft impact onto the proposed expansion site was limited to consideration of the escalation risk following a release of hazardous materials in transit on the port at the time of the aircraft impact. Hence, the impact to the surrounding community as a result of an aircraft impact excludes the risk due to fire and explosion as a result of the loss of containment of fuel and other flammable products on board the aircraft.

A review of the estimated frequency of an aircraft crash per year prepared from the Proposed 3rd Runway Sydney Kingsford Smith Airport Environmental Impact Statement (EIS) noted an estimated frequency per year of crash in the area of the proposed Expansion of between $1x\ 10^{-4}$ and 0.1×10^{-4}.

In analysing the risk due to escalation following an aircraft impact, consideration of the probability of hazardous material being present on the expansion has been considered. Assuming an average of 12 hours in transit on the terminal for each container of red line dangerous goods, and that aircraft are restricted to use the airport between the hours of 6:00am and 11:30pm each day the probability of each of the classes of dangerous goods being present was estimated.

Table 9.1 Aircraft Impacts Escalation Frequencies

Dangerous Good	Number of Movements per Year at Design Capacity	Probability of being Present	Escalation Frequency Due to Aircraft Impact Per Year
Class 2.1 (20 T Tanks)	111	2.40×10^{-1}	2.4×10^{-5}
Class 2.3 (SO_2 9 T Tanks)	5	1.12×10^{-2}	1.12×10^{-6}
Class 8 (HF 20 T Tanks)	13	$2.90x\ 10^{-2}$	$2.90x\ 10^{-6}$

With reference to the data in Table 9.1, the frequency of an aircraft impact resulting in loss of containment has been included in the risk model, as a large leak of 20 tonnes of each of the dangerous goods listed in each case.

9.1.2. Flammable Liquids Fuel Pipelines – Sydney to Newcastle Pipeline

A flammable liquids fuel pipeline runs from the fuels terminal north of the Patrick terminal, along the southern side of Foreshore Rd toward the Airport. The SMP pipeline is used to transport a range of flammable liquids such as aviation fuel, diesel and petrol. The Sydney Airport jet fuel line (JUHI) runs from the Caltex Banksmeadow terminal, crosses Foreshore Road adjacent to the Penrhyn Road intersection and then generally on the northern side of Foreshore Road.

Buried underground, a loss of containment from the pipeline would leak into the surrounding soil with the fuel plume rising to the surface forming a flammable liquid pool. Alternatively the leaking fuel may run down through the ground to the water line, and into the bay.

Surface Pool

For the SMP pipeline, in the event that the flammable liquid pool did ignite, a pool fire on the road side would result. Escalation to the neighbouring scrub is most likely, generating large smoke plumes that may impact onto the Port or the neighbouring residential and industrial areas. Escalation onto the Port is unlikely due to the separation distances. Similarly for the JUHI pipeline, escalation onto the Port is even more unlikely because of the greater distances involved.

Spill into Bay

Dispersion through the soil would result in a volatile flammable pool in the bay. Movement with the tide and waves may position the pool around the expanded port area, bring the flammable vapour cloud with in the range of a number of potential ignition sources such as container unloading cranes and tug boats. Ignition of the flammable pool would result in a floating pool fire.

Impact from the fire onto the expanded terminal facilities or escalation on the containers located on the terminal is unlikely due to the separation of the containers from the water and hence the fire and the height difference between the water line and the deck of the terminal.

Releases from the Sydney to Newcastle fuels pipeline or the JUHI pipeline may result in fire on the road side and in the bay neighbouring the expanded terminal, however they are unlikely to result in impact to people or escalation to assets and / or cargo on the terminal.

9.2. Diesel Fuel Storage

A 150 tonne diesel fuel storage tank is planned for the expansion terminal. Hazards associated from the handling and storage of the diesel may results in the generation of pool fires following the ignition of diesel spills.

The consequence in terms of heat radiation capable of causing injury from a pool fire would be confined to the site boundary. Therefore the diesel storage facilities present negligible risk to the surrounding community.

10. RISK RESULTS

10.1. Individual Risk Contours

The risk results presented in Figure 10.1 are Location Specific Individual Fatality Risk per year contours for the proposed development based on a throughput equivalent to 1.5 million TEUs per year.

Figure 10.1 Proposed Port Expansion – Fatality Risk Contour

Figure 10.2 Proposed Port Expansion – Injury Risk Contour

Figure 10.3 Proposed Port Expansion – Irritation Risk Contour

The irritation contour appears to be centred over the Patrick facilities due to the dominance of the low velocity, highly stable weather conditions over the west to west-north-westerly direction. Due to the low concentrations applied in the assessment of irritation risk, higher velocity, less stable weather patterns rapidly dilute and disperse the releases below their impact concentrations, unlike the low velocity, highly stable weather conditions, and therefore present less of an influence in the far field.

10.2. Bio Physical Risk Analysis

Some of the materials handled at the existing and new port facilities have the potential to adversely impact on the natural environment. In particular numerous chemicals are handled which could harm both aquatic, bird and plant life if there is a spill which finds its way into the bay. The more obvious examples are acidic/alkaline materials (Class 8), toxic chemicals (especially Class 6) and hydrocarbon products (e.g. Class 3 oil spill type events).

The HIPAP 4 criteria for assessment of risk to the biophysical environment relate only to the possibility of a threat to the *long-term viability of a species or ecosystem*. It only relates to risks from *accidental* events – environmental impacts due to planned changes in the environment, or continuous / anticipated operational emissions are considered elsewhere in the EIS. The wording of HIPAP4 in respect of environmental risk can be paraphrased as:

- The consequences of the more likely accidental emissions must not threaten the long-term viability of the ecosystem or any individual species.

- The likelihood of impacts (which threaten the long-term viability of the ecosystem or species) must be substantially lower than the background risk.

Due to the unpredictable nature of container trade it is impossible to predict precisely which materials will be handled (since this is governed by international shipping rules and by the variations of trade). It is not practical to conduct a detailed quantitative assessment of the risks to the environment since the consequences cannot be predicted with any certainty and frequency estimates are limited to consideration of generic classes of Dangerous Goods.

The primary concern for this assessment is the possibility that an accidental event could cause such major damage as to destroy the entire ecosystem or species. For this to happen, the following would be required:

- A major loss of containment event resulting in contamination of a large area of the Bay (say effects out to a distance of several hundred metres)

- The damage to be irreversible (the HIPAP4 criteria relate only to long-term damage)

The primary potential incident types can be summarised as follows:

- Loss of containment from container cargoes, especially Classes 3, 6 and 8. Harmful effects are also possible from other DG classes but the likelihood of major damage is very low (see Section 6).

- Bunker fuel spills, from container ships (e.g. in the event of a grounding or striking of wharf etc). However, the effects of such a spill should be readily reversible with a low risk of long term damage. Bunker spills from refuelling activities are minor volume incidents with minor transient impacts. This issue is addressed elsewhere in the EIS.

- Loss of containment from truck transportation. The likelihood of this is very low compared to spills on the road system offsite (which would be expected to find their way into the bay, via the stormwater system), hence the risk of this type of event at the port is much lower than the background risk.

- Introduction of foreign organisms via ballast water pump-out. This is an issue of national and international concern and whilst an international protocol for ballast water is nearing completion, mandatory ballast water management was introduced in Australia in July 2001 supported by a risk assessment system. This is discussed in more detail elsewhere in the EIS.

- Diesel spill from diesel storage. Effects would be reversible and fairly localised. Modern facility design in accordance with AS1940 and associated bunding requirements and clean-up capability should ensure that the likelihood of a major spill is low. There are numerous fuel storage tanks of this type in many industrial facilities around the Bay. The risk from the proposed installation is therefore is considered low, and significantly lower than the background level of risk.

- Fire in container storage areas. Major fires in container stacks are very infrequent since there is little opportunity for initiating mechanisms and even if a fire starts in one container, it is very unlikely to spread to others (since the container shell provides a fire barrier). The primary environmental concern is contaminated firewater runoff, in particular if a major fire develops involving containers of dangerous goods (especially Class 6). It is recommended, that this issue be addressed comprehensively as part of the fire system design. This issue is normally dealt with by a standard condition of development consent requiring a Fire safety Study (HIPAP2).

Any of the above scenarios that occur on the proposed facility will be captured by the first-flush system installed for treatment of stormwater and spills incidents. A more detailed description of this system is provided elsewhere in the EIS.

Table 10.1 Overview of Environmental Risks of DG Cargoes

DG Class	Description	Comments
1	Explosives	Limited environmental consequence potential
2	Flammable, toxic and pressurised gases	Limited potential consequences. Gases will mostly vaporise and could have a limited effect on bird life. Some potential for liquid runoff and dissolving in water, but this is low risk (both consequences and likelihood)
3	Flammable liquids	Generally immiscible with water. Mostly any spills will float on the surface and may cause limited damage to bird life and shoreline plant life. Containers have relatively low volume (20 te) that the first flush system will contain. Bunker fuel spills from ship impacts could be a major incident, but the effects are reversible (unlikely to result in loss of ecosystem).
4	Flammable Solids, Spontaneously Combustible, Dangerous when Wet	Generally localised effects
5	Oxidising Materials, Organic Peroxides	Generally localised effects
6	Toxic Materials	Some of the materials could be environmentally hazardous in very low concentrations, for example active ingredients of pesticides or herbicides. This category is of greatest concern. However the majority of cargoes would only have limited environmental consequences if spilled.
7	Radioactive Materials	Generally low level radiation hazard. Very few cargoes handled (40 per year). Packaging standards are strict and so breach of packaging is very unlikely even if a container is breached.
8	Corrosives	Spills could result in temporary pH changes, with relatively localised effects due to the large volume of water in the bay. Effects would generally expected to be reversible.
9	Miscellaneous	Many of these cargoes are containers under fumigation. Possible that some cargoes (environmental pollutants) could cause damage, but not a major risk.

Of all the incidents identified, the one of greatest concern is the possibility of a spill from a cargo which is extremely toxic to the environment (in particular Class 6). In order to satisfy the HIPAP4 risk criteria, the following two conditions must be satisfied, as previously indicated:

1. The consequences of the more likely accidental emissions must not threaten the long-term viability of the ecosystem or any individual species.

As discussed above, only a tiny fraction of DG cargoes (if any) would have the potential for widespread damage to the extent that the long-term viability of the Bay ecosystem is threatened. Whilst a detailed assessment is not practical, it is suggested that the percentage of DG cargoes with this potential would be less than 1%, and in all likelihood less than 0.1%. It was concluded that this condition is satisfied since the more likely emissions would certainly not threaten the long-term viability of the ecosystem or any one species –spills would be contained by the first flush system and even if they found their way into the Bay, the vast majority would have localised or reversible effects.

2. The likelihood of impacts (which threaten the long-term viability of the ecosystem or species) must be substantially lower than the background risk.

   In order to assess this risk, a rudimentary frequency calculation has been performed. As stated above, it is considered that the most likely source of a environmentally catastrophic event is a Class 6.1 cargo, for instance a large volume of active ingredient of pesticide/herbicide. It is acknowledged, however, that some Class 8s could also cause significant damage and these have been included in the frequency calculation for the sake of conservatism.

The spill frequency calculations have been undertaken using conservative assumptions, to counteract the significant uncertainties involved. A basic assumption of the calculation is that the dominant spill scenario is that of a dropped or damaged container during transfer. This has been confirmed by previous studies (see Appendix III for more detail). The following data and assumptions have been utilised:

- No. of container movements per year, Class 6: 4,936
- No. of container movements per year, Class 8: 7,051
- Probability of dropped container: 6.70E-07 per movement (see Appendix III)
- Percentage of Class 6/8 spills that have potential for widespread irreversible damage: conservatively assumed 1% (in fact 0.01 – 0.1% is likely to be a more realistic estimate, but 1% has been assumed in the interests of conservatism)
- In the event of a spill from a container, probability that the spill is unnoticed and/or isolation fails: conservatively assumed 0.1 (it is unlikely that a major spill will be unnoticed).

Using this data, the frequency of an environmentally catastrophic event which threatens the long-term viability of the ecosystem is conservatively calculated to be once every 125,000 years.

Even recognising some of the uncertainties involved, this likelihood is considered very low compared to the background risk in this urban, industrialised environment. Some of the key background threats can be summarised as:

- Major oil or chemical spills from oil and chemical tanker trade (e.g. deliveries to the Caltex refinery or Bulk Liquids Berths)
- The plume of contaminants known to be moving through the water table towards Botany Bay from the Botany petrochemical complex and the contamination of sediments in and around Penrhyn Estuary by Mercury and hexachlorobenzene.
- Spills from dangerous goods road transportation throughout the area for many kilometres around the bay (many spills would find their way through the stormwater system into the bay). Note that the likelihood of such a spill is much greater than at the port due to the uncontrolled environment and relatively high frequency of traffic accidents.
- General degradation of the aquatic environment due to increased urban runoff resulting from the ever-increasing development density in the area (industrial, commercial, residential).
- Major fuel spills from the Sydney-Newcastle fuel pipeline and other fuel lines nearby or on the seabed in the bay.
- Major industrial accidents/spills or contaminated firewater runoff at one of the many neighbouring chemical/industrial facilities.

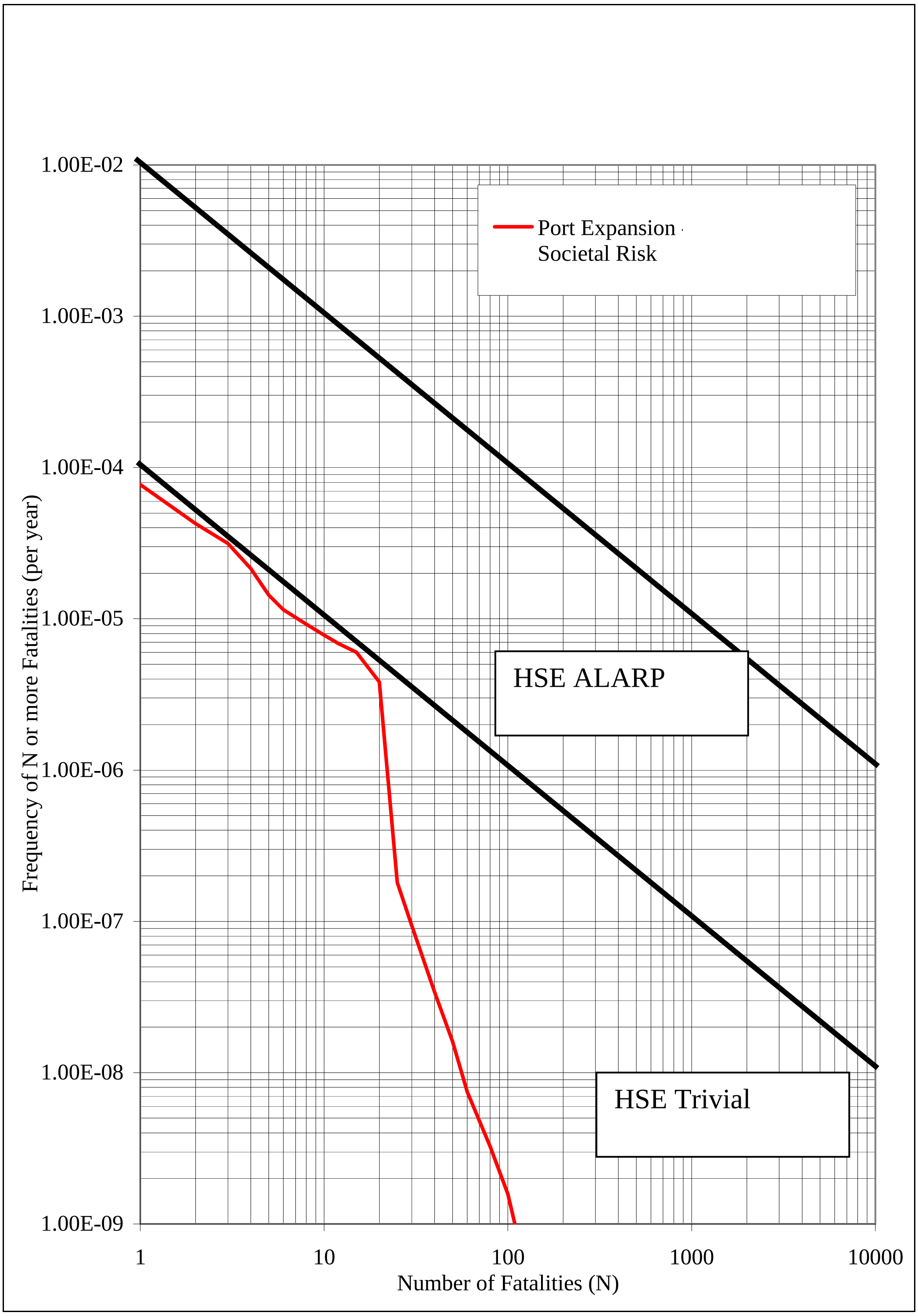
Whilst it is recognised that the addition of the port will undoubtedly involve a small increase in the risk of an environmentally damaging event, it is concluded, based on the arguments above that:

- The risk is very low compared to the background risk
- The consequences of the more likely spill events do not threaten the long-term viability of the ecosystem or any individual species (since the effects of the more likely spills will generally be very localised and reversible).
- Hence the HIPAP4 risk criteria should be considered to be satisfied.

10.3. Societal Risk

The societal risk results have been calculated based on the assumed offsite population in the form of an F-N Curve. The results of the expanded facilities based on the trade level are presented in Figure 10.4.

Figure 10.4 F-N Curve – Port Expansion



Using these HSE criteria lines, the societal risks associated with the proposed Port expansion are considered trivial based on the forecast trade level. Thus, as long as the risks of the operation are managed effectively to ensure that they are kept as low as reasonably practicable, the operation would meet the UK criteria.

Although there are no set criteria in NSW for assessment of societal risks, having the risks at the upper end of the trivial band suggests that the risks would not be unacceptable to communities in NSW.

It should be noted that whilst the UK criterion refer to fixed installation, the HSE has specified criteria for the assessments of Ports. Based on the throughput trade of DGs per year the UK Ports criteria allow for the adjustment of the intolerable criteria level. The result of such an adjustment in this case would not impact on the assessment of the Port Botany expansion given the risk is below the tolerable limit.

11. RISK ASSESSMENT

In this section the results of the analysis are compared to the risk acceptance criteria presented in the Hazardous Industries Planning Paper No 4.

11.1. Individual Fatality Risk

The risk results for the expansion at Port Botany based on the forecast throughput of the expanded facilities have been presented in Figure 10.1.

Based on the risk contours in Figure 10.1 , the 0.5 x 10^{-6} per year (0.5 chance in a million per year) contour for sensitive populations does not encroach on any sensitive facilities and is mostly confined to industrial zoned land.

The 1 x 10^{-6} per year (one chance in a million per year) contour does not encroach on any residential populations after the expansion.

The 5 in a million per year risk contours do not encroach onto commercial developments or open sporting complexes following the expansion.

Based on the above assessment of the risk, the existing and forecast future risk due to the trade in dangerous goods via the Port Botany expansion is considered acceptable in terms of the fatality risk criteria.

11.2. Injury Risk

The injury risk results for the expansion at Port Botany site is presented in Figure 10.2 for the throughput of 1.5 Million TEUs per year.

Based on the forecast trade of the expanded port terminal the criteria level of 10 x 10^{-6} p.a. risk of injury does encroach slightly into residential areas, and hence the risk criteria is not met. However, the extent of the exceedance is considered minor and given the conservatism built into the analysis and the margin of error inherent in the analysis the risk is considered acceptable.

11.3. Irritation Risk

The irritation risk results for the expanded Port Botany terminal are shown in Figure 10.3. The irritation criteria risk levels (50 x 10^{-6} p.a.) in residential areas are maintained based on the throughput of 1.5 Million TEUs per year.

11.4. Bio Physical Risk Assessment

Though the development of the Port Botany expansion will involve a small increase in the risk of an environmentally damaging event, it was concluded, that:

- The risk is very low compared to the background risk.
- The consequences of the more likely spill events do not threaten the long-term viability of the ecosystem or any individual species (since the effects of the more likely spills will generally be very localised and reversible).

Hence the HIPAP4 risk criteria should be considered to be satisfied.

11.5. Response to Recommendations – Port Botany Land Use Safety Study

Five primary recommendations were made following the conclusions of the Port Botany Land Use Safety Study (DUAP, 1996). As per the Director Generals requirements on the PHA the following conclusions have been drawn by DNV in response to those five recommendations:

1. *Future developments in the Port area should undergo early risk assessment and comprehensive environmental impact process to conclusively demonstrate that they will not contribute to any increase in cumulative risk as shown in Figure 2* [of the area study report]. *Developments should also conclusively demonstrate that, consistent with the Department of Urban Affairs and Planning risk criteria there will not be any propagation of risk to neighbouring facilities.*

Figure 2 of the Area Study presents the cumulative individual risk contours including postulated future developments at the Port Botany area. Comparing this figure with the risk results calculated for the expanded terminal is not straight forward because Figure 2 includes the cumulative risk from a number of operators, including a number of postulated facilities. Examination of the individual risk results show that the residential criteria contour (1×10^{-6} per year) is contained within the bounds of Figure 2.

In the Port Botany Area Study the 50 in a million (50×10^{-6}) contour features strongly. Based on this assessment of the future development of the proposed Port Botany site the highest risk level is more than an order of magnitude lower at 5 in a million per year. This presents a significant reduction in the risk levels estimated in the Area Study.

The far field, offsite risks due to the proposed expansion are dominated by the risk from flammable and toxic gases (Class 2.1 and 2.3). The Port Botany Area Study recommended that there should be no significant increase in toxic compressed or liquefied gases stored or handled at the Port. In this PHA a significant increase in the movement of all Red Line Dangerous Goods has been assessed. This includes the handling of packaged toxic compressed or liquefied gases. Clarification of the number of movements of Class 2.3 materials should be undertaken against the estimated number of movements included in the Port Botany Area Study to ensure that a reasonable comparison of the trade levels has been undertaken. Full details of the number of movements of Class 2.3 Dangerous Goods is presented in Section 6 of this report. Sydney Port have determined that movements of class 2.3 toxic gases in isotanks have not occurred since mid 2002. It is also known that Orica ceased on-site bulk storage of chlorine during 2002 and accordingly the export of Chlorine drums conducted in previous years is no longer carried out through Botany.

An analysis of the cumulative societal risk from the Port Botany Area Study is presented in Figure 9 of the DUAP report (DUAP 1996). Figure 10.4 presents the societal risk results for the throughput of the proposed expansion. Comparison of the cumulative curve with the curve for the proposed development in Figure 10.4 shows that the societal risk from the proposed expansion is lower than the total Port Botany cumulative societal risk.

2. *Development controls should be put in place to ensure there is no significant increase in the number of people exposed to risk inside the residential risk contour in Figure 2.*

The proposed port expansion does not involve the addition of further residential populations. Therefore the proposed development complies fully with recommendation 2.

3. *Risk reduction and safety management measures, identified in the individual site studies, should be implemented in accordance with an agreed program ……*

Where practical, means of reducing the risk from the operations have been identified and considered in the analysis of risk from the proposed facilities.

The risk analysis undertaken as part of the PHA does not include any modification to the likelihood or consequences based on an assumed performance of the Port's management system. The results of the expanded facilities are based on a trade level forecast beyond the year 2024/5. During the next twenty years it is reasonable to consider that improvements in management systems and performance will have an impact by reducing the likelihood and consequences of an incident on the port. Further more, improvements in dangerous goods handling, vessel design and construction, lifting and transfer equipment and road and rail safety will also have an impact in reducing the risk to the employees working on the port and the community on the neighbouring industrial and residential areas.

Based on the above arguments the risk analysis of the expanded port facilities based on a trade throughput of 1.5 M TEUs per year is considered conservative.

4. *Emergency plans and procedures and fire prevention and protection systems should be kept up to date. Security arrangements for the Port area should be strengthened.*

5. *Port users should adopt community-right-to know principal to ensure the community is adequate informed about port activities, associated risks and the safety management measures that are adopted. The Responsible Care Program adopted by the Plastics and Chemicals Industry Association (PACIA) is an appropriate model.*

With respect to recommendations 4 and 5 of the Port Botany Area Study they are considered outside of the scope of the PHA and would be addressed during the completion of other requirements of the planning approval process.

With respect to potential interactions with the Botany / Randwick Industrial Area, it is apparent from comparison with Figure 9.1 of this assessment with Figure 9 of the

Botany / Randwick Industrial Area Land Use Safety Study (DUAP, 2001) that there is no interaction of the residential criteria contours.

12. CONCLUSIONS

12.1. Conclusions

1. The risks from the expanded Port Botany terminal have been assessed by DNV against the New South Wales, Department of Planning Risk Criteria based on a throughput of 1.5M TEUs per year. The basis of assessment is conservative and beyond the current Sydney Port's trade forecast for the expanded terminal for the year 2024/25.
2. With respect to the fatality risk criteria of PlanningNSW to the surrounding community the proposed port expansion is considered acceptable.
3. The injury and irritation risk criteria based on the design capacity of the terminal are considered acceptable with respect to the PlanningNSW criteria.
4. The assessment of the risk to the bio-physical environment concluded that the risk contribution due to the port expansion is very low compared to the background risk and that the consequences of the more likely spill events do not threaten the long-term viability of the ecosystem or any individual species (since the effects of the more likely spills will generally be very localised and reversible). Hence the HIPAP4 risk criteria should be considered to be satisfied.
5. The risk to the surrounding communities along the transportation routes leading into and out of the port due to the transportation of dangerous goods has been assessed to be acceptable for the combined Port operations with respect to the criteria.
6. The individual fatality contour for residential criteria (1×10^{-6} per year) for the proposed expansion is within the relevant bounds determined for cumulative risk by the Port Botany Land Use Safety Study (DUAP 1996).

13. APPENDICES

i DUAP 1996, *Guidelines for Hazard Analysis*, NSW Department of Planning: Hazardous Industry Planning Advisory Paper No. 6

ii DUAP 1990 *Risk Criteria for Land Use Planning*, NSW Department of Planning: Hazardous Industry Planning Advisory Paper No. 4

iii IChemE 1992, Nomenclature for Hazard and Risk Assessment in the Process Industries, Institution of Chemical Engineers, Rugby, UK.

iv IMDG, *IMDG Code Amdt 30-00*, International Maritime Dangerous Goods Code.

v. Clancey V.J., Diagnostic Features of Explosion Damage, 6th Int. Meeting of Forensic Sciences, Edinburgh, 1972.

vi. DUAP 1996, *Port Botany Land Use Safety Study*.

APPENDIX I

BACKGROUND DATA

BACKGROUND DATA

CONTENTS

I.1. INTRODUCTION 1

I.2. BACKGROUND 2

- I.2.1. Geographical Data 2
- I.2.2. Meteorology 2
- I.2.3. Topographical Parameters 5
- I.2.4. Offsite Population 6
- I.2.5. Ignition 8

I.1. INTRODUCTION

This appendix presents the descriptions of the Port Botany expansion site and the background information required to undertake the quantitative risk assessment.

Figure I.1.1 presents the proposed expansion and surrounding area with respect to the existing terminal facilities.

FIGURE I.1.1 PORT BOTANY

I.2. BACKGROUND

I.2.1. Geographical Data

This section describes the parameters used for the on-site and off-site terrain.

I.2.1.1. On-site and Off-site Terrain

The proposed terminal is located at Port Botany on the north side of Botany Bay and east of the main north-south runway at Sydney's Kingsford Smith International Airport.

The land surrounding the port is mainly used for industrial and commercial applications. Apart from the industrial land usage the area is also used for recreational, residential and special uses purposes such as schools. The closest residential area is approximately 500 metres away, as shown on Figure I.1.1, and is the suburb of Botany to the north west of the proposed facility.

I.2.2. Meteorology

I.2.2.1. Data Requirements

Meteorological data is required at two stages of the risk assessment. First, various parts of the consequence modelling require specification of wind speed, atmospheric stability, ambient temperature, ambient humidity and ambient pressure. Second, the impact (risk) calculations require wind-rose frequencies for each combination of wind speed and stability class used.

For the dispersion modelling, suitable combinations of wind speed and stability class are chosen. These combinations must reflect the full range of observed variations in these quantities; at the same time it is neither necessary nor computationally efficient to consider every combination observed. The procedure used is therefore to group the observed combinations of wind speed and stability into representative weather classes which together cover all conditions observed. The classes chosen must be sufficiently different to produce significant variations in dispersion modelling results but must not smooth out important variations between the speed-stability combinations grouped into each. In particular, the conditions most likely to give rise to large effect distances (and hence the possibility of significant offsite risk) must not be grouped with those leading to shorter effect distances.

Once the weather classes have been chosen, frequencies for each wind direction associated with each of the selected weather classes are calculated by summing the frequencies in the appropriate wind speed-stability classes.

I.2.2.2. Wind and Weather Stability Category Data Sources

The data used for compiling the wind and weather stability data for the study are presented Table I.2.1. The data has been obtained via Sydney Ports and was applied in the Port Botany Land Use Safety Study, undertaken by Planning NSW and Sydney Ports in 1996/7.

TABLE I.2.1 METEOROLOGICAL DATA

WEATHER CATEGORY	WIND DIRECTION																TOTAL
	N	**NNE**	**NE**	**ENE**	**E**	**ESE**	**SE**	**SSE**	**S**	**SSW**	**SW**	**WSW**	**W**	**WNW**	**NW**	**NNW**	
B 2.25 m/s	0.14	0.246	0.316	0.432	0.269	0.222	0.174	0.42	0.419	0.28	0.211	0.374	0.954	0.489	0.222	0.163	**5.331**
D 3.75 m/s	1.223	1.874	2.886	2.036	2.365	1.804	2.794	3.2	3.992	1.513	1.045	2.398	4.225	4.783	1.817	1.152	**39.107**
D 5.25 m/s	0.221	1.524	3.91	1.617	0.792	0.687	1.059	2.351	6.156	2.677	0.745	2.398	4.55	0.885	0.163	0.117	**29.852**
E 2.25 m/s	0.803	1.153	0.873	0.641	0.396	0.536	0.874	0.769	0.861	0.362	0.35	0.872	1.535	2.712	1.082	0.512	**14.331**
F 1.5 m/s	0.664	0.815	0.407	0.327	0.407	0.361	0.535	0.501	0.338	0.222	0.326	0.687	0.955	2.153	1.222	1.489	**11.409**
TOTAL	3.051	5.612	8.392	5.053	4.229	3.61	5.436	7.241	11.766	5.054	2.677	6.729	12.219	11.022	4.506	3.433	**100.03**[1]

Note:

1. The total is 100.03% and not 100% due to rounding of numbers– note that SAFETI normalises the data

The wind roses show the percentage of time that the wind, in each of the stability class groups, is blowing from the direction indicated. This shows that although the prevailing winds are from the south and north-west, the stable winds predominantly blow only from the north-west. Thus any releases of toxic gases will be likely to extend further to the south-east before being dissipated by the wind.

I.2.2.3. Atmospheric Parameters

It is also necessary to define various parameters for the atmosphere. For this study the following values are used for these parameters:

- Atmospheric Pressure: 1.01325 x 10^5 N/m^2
- Atmospheric Temperature: 20 ºC
- Atmospheric Humidity: 60%

I.2.3. Topographical Parameters

I.2.3.1. Surface Roughness

The topographical parameter used in the analysis is the surface roughness. This parameter is used in the consequence modelling.

It determines the amount of turbulence generated by wind of a given velocity as it passes over the ground. The degree of roughness relates to a comparison of the average height of surface "protuberances" with the depth of the laminar sub-layer in the air stream. There are two alternative means of "measuring" the roughness, either a roughness length or a roughness parameter. The roughness length, Z_o, is approximately 1/30 of the effective average height of the protuberances. The roughness parameter is a measure of the root mean square fluctuating velocity as a fraction of the mean velocity at 10 m height above ground. It is given by:

$$\text{Roughness Parameter} = \frac{0.4}{\ln(10/z_o)}$$

The surface roughness parameter is a more practical value to use and SAFETI requires this value to be input.

TABLE I.2.2 TYPICAL SURFACE ROUGHNESS PARAMETERS

SURFACE	SURFACE ROUGHNESS PARAMETER
Sea	0.06
Flat land with few trees	0.07
Open farm land	0.09
Open countryside	0.11
Woods, rural area or industrial site	0.17
Urban area	0.33

The turbulence in the wind is generated over a terrain between 1000 and 2000 m upwind of the point of interest. The releases under consideration can have significant consequences for up to about 1 km downwind of the site. So the surface roughness to use is that of the site and its surroundings within about 2 kilometres.

The area of Port Botany is relatively flat. The area consists of industrial land with some industrial buildings, faces the bay to the south and the west.

A surface roughness factor of 0.14 (between open countryside and industrial site) has therefore been used in the modelling of the release cases at the site, to account for the range of land uses.

I.2.4. Offsite Population

The only population considered was the offsite population in the surrounding area.

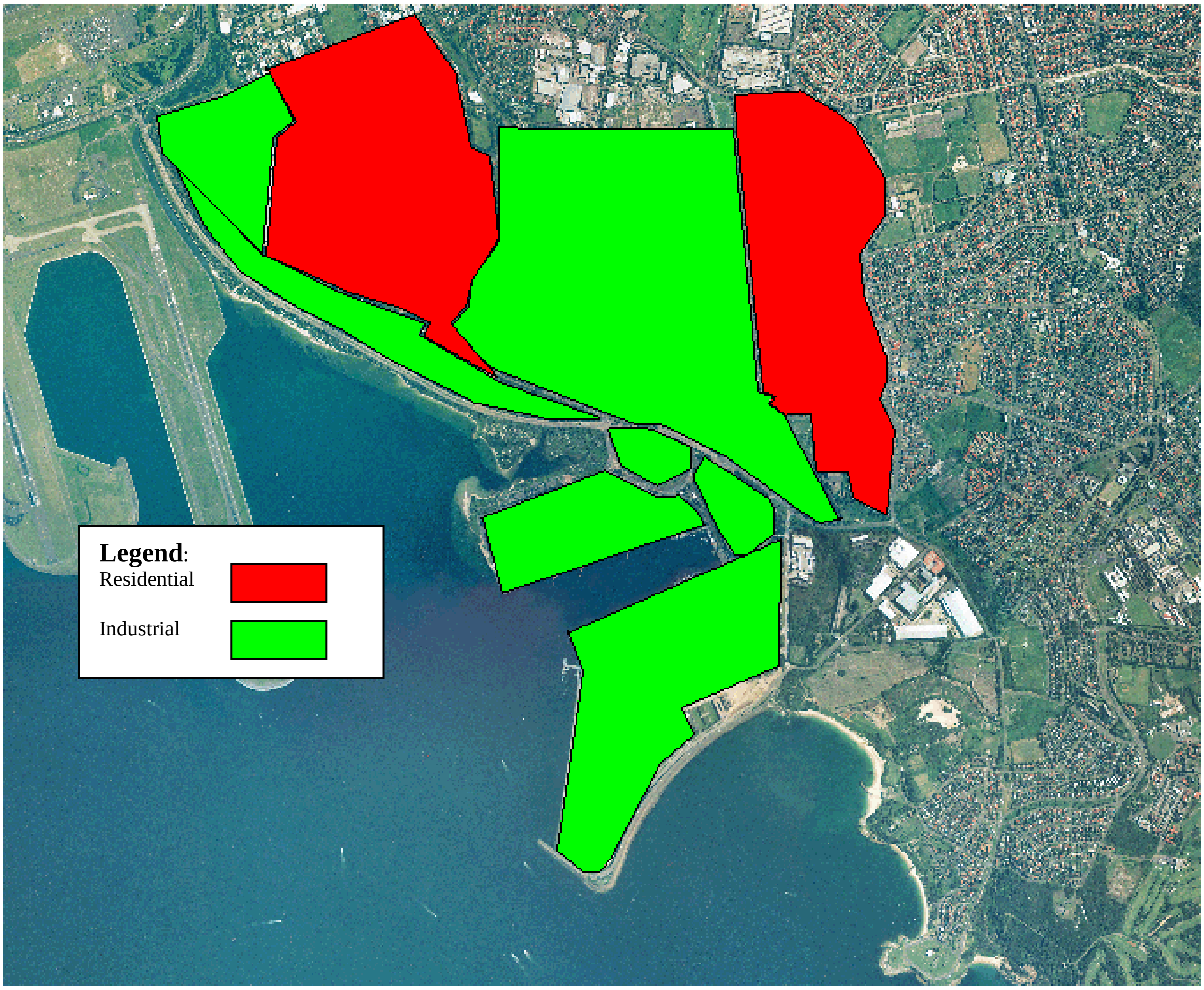
In defining the offsite population for the study area due regard was taken of the hazard range shown by individual risk contours in previous comparable risk studies. These showed risk contour hazard distances to the lowest defined criteria level (0.5×10^{-6} per year) of up to 1 km. To ensure that all events will be covered, the limit for population data was set at 2.0 km away from the centre of the terminal. Table I.2.3 shows the population densities used in this study.

TABLE I.2.3 POPULATION DENSITIES

ZONE	POPULATION DENSITY
Residential	50 / ha
Industrial	5 / ha

A summary of the population model applied in the SAFETI is presented in Figure I.2.1.

FIGURE I.2.1 POPULATION DATA



I.2.5. Ignition

In order to calculate the risk from flammable materials, a likelihood of ignition was applied. The likelihood of ignition of any release is correlated with the size of the release. Small releases are less likely to be ignited whereas large releases have a higher likelihood of ignition. However, analysis of historical accidents has shown that even large releases have been ignited only 30% of the time. For this study likelihood of ignition of 30% was used in recognition of the potential sizes of a release required to generate offsite impacts, and due to the level of activity on the Terminal such as trucks, straddle cars etc.

In addition to the likelihood of immediate ignition, an area ignition source was applied to the entire site to account for ignition sources such as straddle carriers, road and rail vehicles, cars, maintenance activities, buildings, etc.

APPENDIX II

HAZARD IDENTIFICATION

HAZARD IDENTIFICATION

CONTENTS

II.1. INTRODUCTION.. 1

II.2. SELECTION OF REPRESENTATIVE MATERIALS......... 2

II.2.1. Explosives Class 1.. 5

II.2.2. Class 2.1 Flammable Gases...................................... 6

II.2.3. Toxic Gases Class 2.3... 9

II.2.4. Class 3 Materials – Acrylonitrile............................ 10

II.2.5. Class 5.1 Materials – Ammonium Nitrate.............. 10

II.3. TOXIC VAPOUR RISK.. 12

II.3.1. ERPG and TEEL Values 12

II.3.2. Probit Functions.. 12

II.4. FLASH FIRE RISKS 14

II.5. BLEVE RISKS.. 14

II.6. SPILL FIRE RISKS 14

II.7. VCE (Vapour Cloud Explosion) RISKS............................. 14

II.8. AMMONIUM NITRATE EXPLOSIONS........................... 15

II.8.1. Review of Accident Histories................................. 15

II.8.2. Identification of Accident Scenarios 20

II.8.3. Consequence Assessment....................................... 24

II.8.4. Conclusions 24

II.9. REFERENCES... 26

II.1. INTRODUCTION

This appendix presents the hazard identification, and screening analysis of the products that would be imported and transported at the proposed expansion of the container terminal at Port Botany, Sydney. Due to the wide variety of products moved at the port, the hazard identification has been undertaken based on the Dangerous Goods classification system. Representative materials for each of the Dangerous Goods classes have been selected by DNV on a conservative basis.

This section describes and discusses the hazardous material properties of such chemicals under conditions relevant for transportation at the terminal.

II.2. SELECTION OF REPRESENTATIVE MATERIALS

Table II.2.1 and Table II.2.2 summarise the types of potential hazards posed by major hazard materials under transportation conditions.

Table II.2.1 Representative Materials per Dangerous Goods Class

Dangerous Goods Class	Description	Modelling Assumptions
Class 1	Explosives	All Class 1 movements between 10 – 24 tonnes modelled as potential 12 tonne equivalent TNT explosion.
		All Class 1 movements greater than 1 tonnes, but less than 10 tonnes modelled as a potential 2 tonne equivalent TNT explosion.
Class 2.1	Flammable Gases	All Class 2.1 movements between 10 and 24 tonnes, with a Package Type of either Tank, Tank, rectangular or Tank, cylindrical have been modelled as 20 tonne vessel of liquid propane .
		All other Class 2.1 movements have been eliminated from the analysis due to the consequence of any potential loss of containment being limited within the terminal site boundary.
Class 2.2	Non-flammable Gases	All screened out of the analysis on the basis that they will have no offsite consequences.
Class 2.3	Toxic Gases	Chlorine and sulphur dioxide trade separated from other Class 2.3
		All SO_2 movements between 5-10 and 10 – 24 tonnes have been modelled as 20 tonne isotainers of SO_2. Detailed inspection of the SO_2 trade by Sydney Ports have identified 1 x 20 t + 2 x 9 t per year through the combined Port Botany facilities. Therefore this analysis is conservative.
		All SO_2 movements less than 5 tonnes have been modelled as 1 t drums.
		Detailed inspection of the chlorine trade in Port Botany has noted the absence of any single package movements greater than 1 tonne. Therefore no isotainers have been modelled in the analysis.

Dangerous Goods Class	Description	Modelling Assumptions
		All chlorine movements greater than 1 tonne have been modelled as multiple 920 kg drums.
		All non Cl_2 or SO_2 Class 2.3 movements have been modelled as ammonia. All movements greater than 10 tonnes and less than 24 tonnes have been modelled as 20 tonne isotainers of NH_3.
		All other non Cl_2 or SO_2 Class 2.3 movements between 1 and 10 tonnes have been modelled as 1 tonnes drums of ammonia.
Class 3	Flammable Liquids	All screened out of the analysis on the basis that they will have no offsite consequences. Included in the transportation risk analysis presented in Appendix IV. All Class 3 movements greater than 10 tonnes were modelled as 20 tonne tankers.
Class 4	Flammable Solids	All screened out of the analysis on the bases that they will have no offsite consequences.
Class 5.1	Oxidising Materials	All movements of Class 5.1 materials between 10 and 30 tonnes have been modelled as a 12 tonne equivalent mass of TNT.
		All movements of Class 5.1 materials less than 10 tonnes and greater than 1 tonne have been modelled as 2 tonne equivalent mass of TNT.
Class 5.2	Organic Peroxides	All screened out of the analysis on the bases that they will have no offsite consequences.
Class 6.1	Toxic Materials	All screened out of the analysis on the bases that they will have no offsite consequences.
Class 7	Radioactive Materials	Please refer to qualitative analysis.
Class 8	Corrosive Materials	All Class 8 movements of hydrogen fluoride (HF) between 10 and 24 tonnes, with a Package Type of either Package, Tank, Tank, rectangular or Tank, cylindrical have been modelled as 20 tonne vessel of saturated HF. All HF movements between 1 - 10 tonnes have been modelled as 1 tonne drums of HF.

Dangerous Goods Class	Description	Modelling Assumptions
Class 9	Miscellaneous Material	All screened out of the analysis on the basis that they will have no offsite consequences.

Table II.2.2 Hazards under transportation conditions

	Flammable Data			Toxic Data		Hazards at Maximum Process Temperature					
Chemical	**Boiling Point (deg C)**	**O.C. Flash Point (deg C)**	**Max Transp. Temp (deg C)**	**TLV (ppm)**	**IDLH (ppm)**	**Pool Fire**	**Jet Fire**	**Flash Fire**	**VCE**	**Bleve**	**Tox Vap**
Ammonia	-33	< -33	40	25	300		+	+			++
Hydrogen Sulphide	-60	Flam gas	40	10	100		+	+			++
Chlorine	-35	-	40	0.5	10						++
Acrylonitrile	77	-1	40	2	500	++	+	+	+	++	+
Propane	-42	Flam gas	40	-	-	+	++	++	++	++	
Ammonium Nitrate	Decomp.	-	40	-	-					++ Expl.	+ fire

NOTES:

1. This table represents potential hazards posed by releases under maximum transport conditions.
2. Hazards indicated by a "+" denote hazards possible, not posing an offsite risk.
3. Hazards indicated by a "++" denote the type of hazard which would dominate the risk result for each material in terms of fatality hazard distance; which may pose an offsite risk. Note that pool fires do not pose an offsite risk, unless located at the site boundary.
4. Note that most materials pose a flammable and/or toxic vapour hazard, as they are in process above minimum flash point temperature. If held under pressure but below boiling point the flash fraction is low, typically 1 to 10 percent may be released as an aerosol. If above boiling point, the flash fraction may be much higher.

II.2.1. Explosives Class 1

A review of the Class 1 package sizes imported through Port Botany over a 2 month period in 2001 identified a maximum package sizes of 12 tonnes.

Figure II.2.1 Explosion Overpressure versus Distance

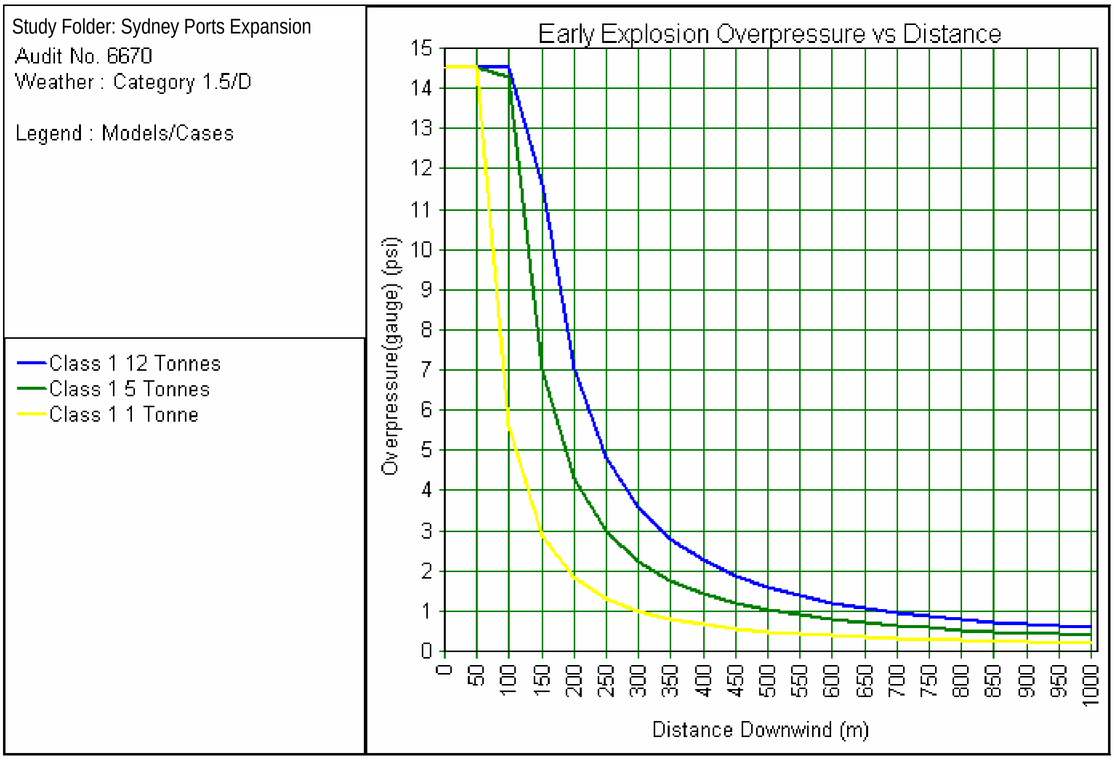


Figure II.2.1 presents a comparison of the overpressure levels generated following a 12, 5 and 1 tonne explosion of TNT versus distance from the explosion epicentre. Assuming a fatal threshold of 3 psi for people indoors, the fatal hazard range for a single tonne explosion of TNT is estimated to be 150 metres. For an explosion of 5 tonnes, the fatal hazard range is 250 m and for 12 tonnes, the fatal hazard range is nearly 350 m.

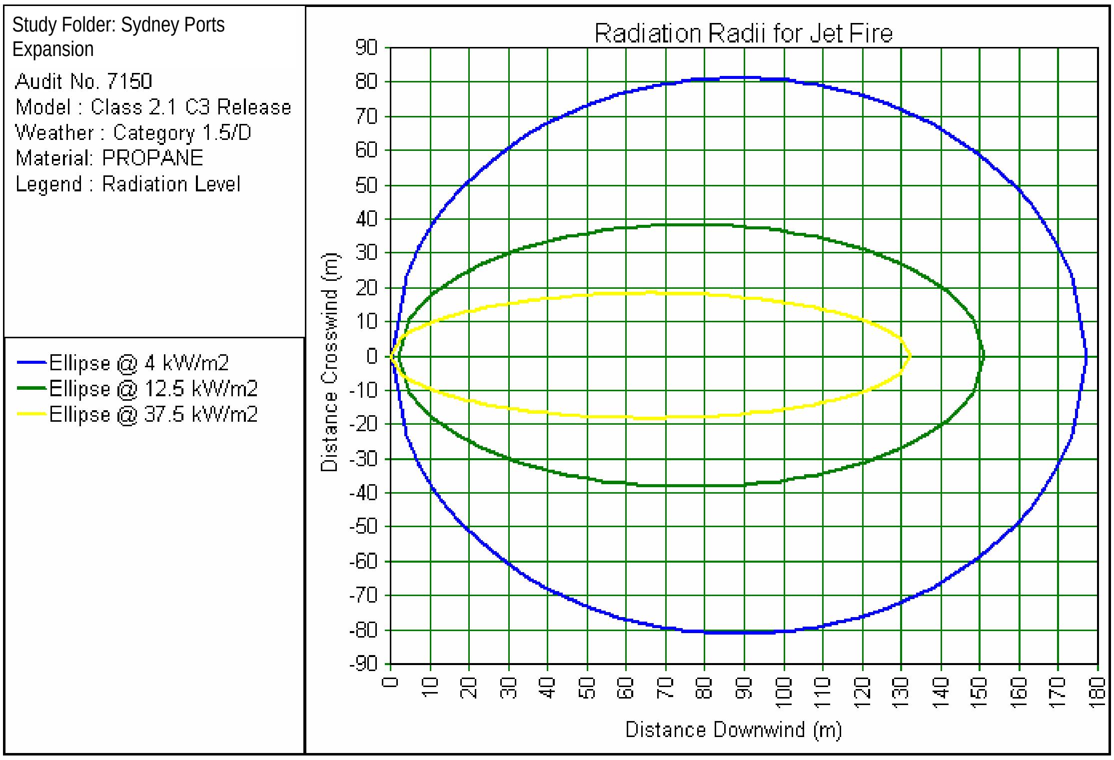
Thus explosions of all magnitudes are included in the study as they could have off-site fatal effects.

II.2.2. Class 2.1 Flammable Gases

Propane is used as the surrogate for all Class 2.1 materials as it is commonly transported, has a high pressure during storage (950 kPa at 25 ºC) and is highly flammable.

The following Figure shows the distance that jet fire from a 50 mm diameter hole in a vessel containing propane could kill or injure people.

Figure II.2.2 Jet Fire Radii – 50 mm Propane Release



This Figure shows that at a distance of 180 m, a jet fire of propane could potentially kill a person.

As well as jet fires, a container of propane could BLEVE. However, the usual circumstances for a BLEVE of a full isotainer involves the release without BLEVE of half the contents followed by a BLEVE of the remainder. The following Figures show the consequences of BLEVEs of 10 tonnes and 1 tonne of propane.

Figure II.2.3 Radiation Distances – 10 Tonne propane BLEVE

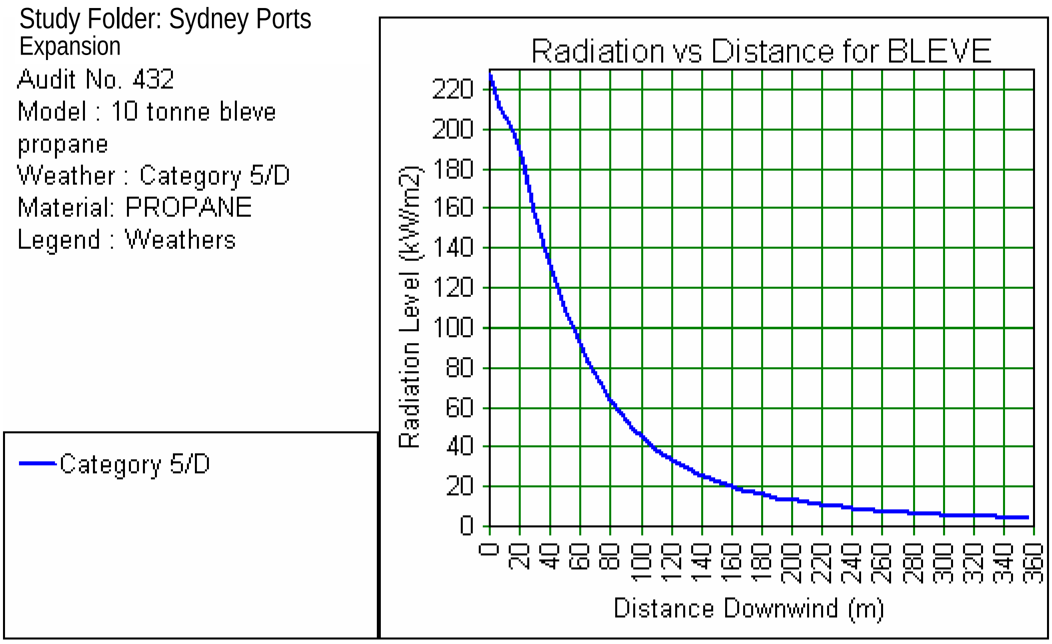
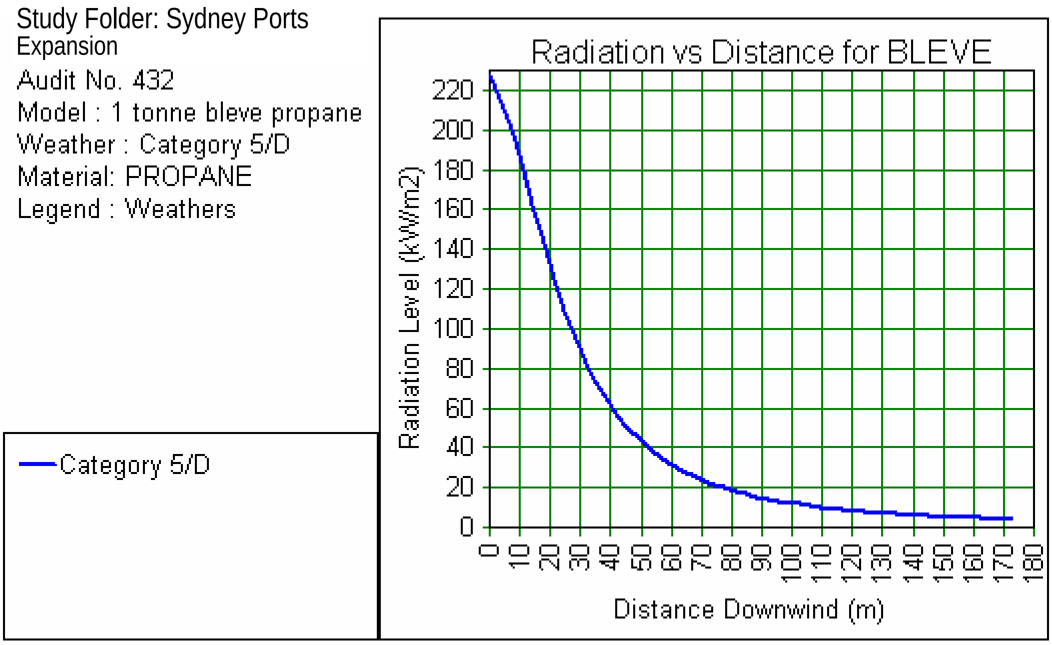


Figure II.2.4 Radiation Distances – 1 Tonne propane BLEVE



These Figures show that a BLEVE of a one-tonne propane tank can produce heat radiation levels of 4 kW/m^2 at a distance of 170 m. However, such radiation levels for the duration of a BLEVE are not likely to kill people. In any case these Figures show that BLEVEs have the potential to kill or injure people off site.

Figure II.2.5 Extent of Flash Fire Envelope – Propane Leak

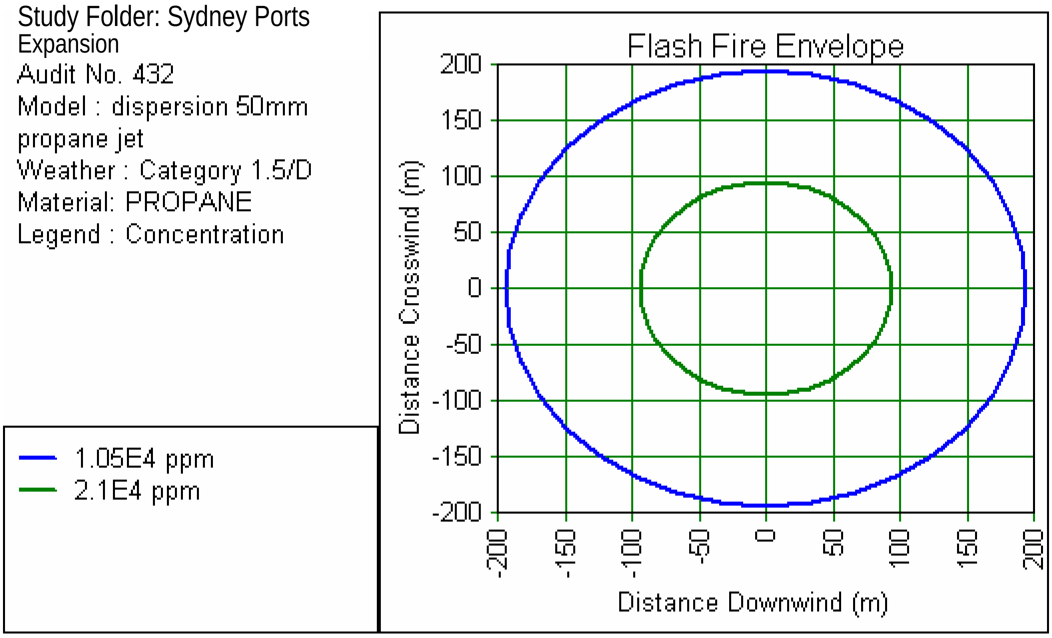


Figure II.2.5 shows that a relatively large hole (50 mm diameter) in a tank containing propane will produce a flammable gas cloud up to 100 m distant from the incident. If swirling in air movements are in cluded, the distance for a flash fire envelope is extended to nearly 200 m. These distances are significant but do not extend to the nearest residences off site.

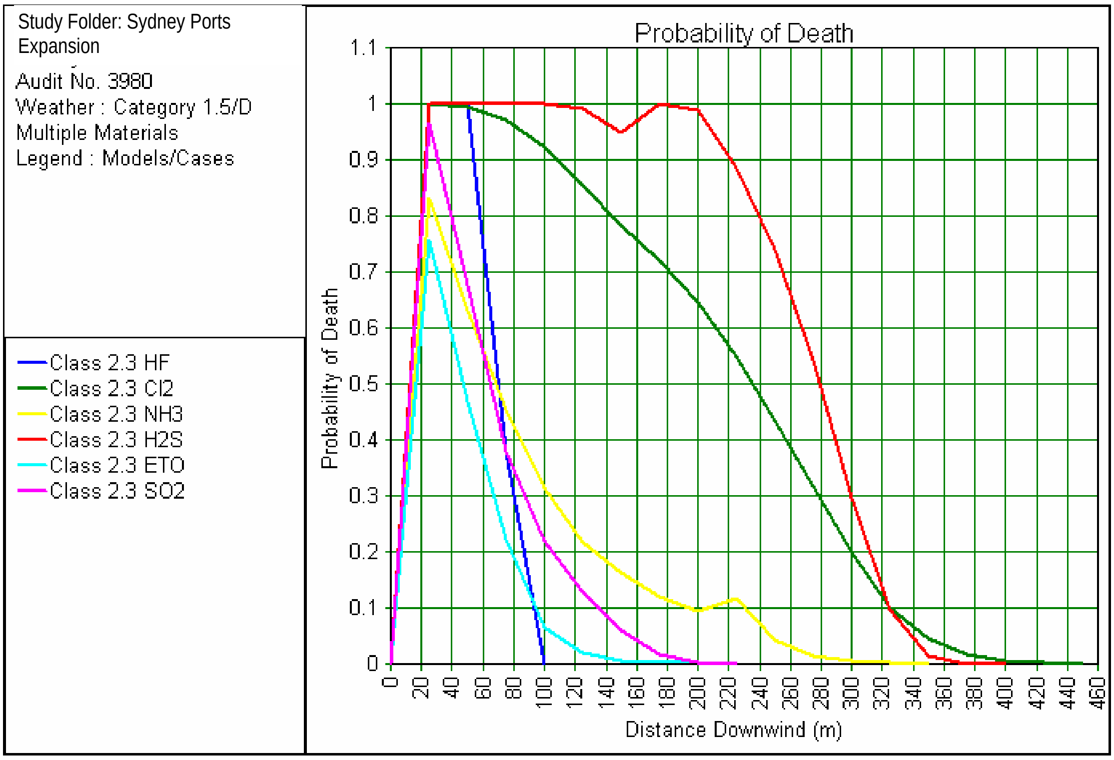
II.2.3. Toxic Gases Class 2.3

In selection of representative materials for the Class 2.3 Toxic Gases, a comparison was undertaken of the hazards of various Class 2.3 products known to be handled at the terminal from time to time. The toxicity of six chemicals was compared based on the analysis of the probability of death versus distance. The analysis involved the release of material from a 25 mm hole in a vessel containing 5 tonne saturated liquid at 20 ºC.

Hydrogen fluoride is formally defined as a Class 8 corrosive material, however for the purpose of the risk assessment hydrogen fluoride has been included in the analysis of Class 2.3 toxic gases. This has been done as its danger to people remote from the immediate location of the spill is due to the toxic gases evolved, rather than its corrosive nature.

The comparison was undertaken using DNV's PHAST consequence modelling software. The results of the analysis are presented in Figure II.2.6.

Figure II.2.6 Comparison of Class 2.3 Toxic Gases



Inspection of the Figure II.2.6 shows clearly that hydrogen sulphide (H_2S) poses the greater hazard, closely followed by chlorine. All of the other materials analysed presented a similar hazard profile in terms of their lethality versus distance. Inspection of recent dangerous goods manifest for Port Botany has noted that there are no movements of greater than 1500 kg of H_2S via the port in an average year, and only 3 movements greater than 1000 kg. Based on this data the risk due to loss of containment of H_2S has been screened from the PHA. Further inspection of the manifest has noted the movement of 3 bulk isotainers of Sulphur dioxide. These are the largest movements of Class 2.3 materials and hence have been modelled in detail in the PHA.

II.2.4. Class 3 Materials – Acrylonitrile

Figure II.2.7 Radiation Distances – Pool Fire of Acrylonitrile

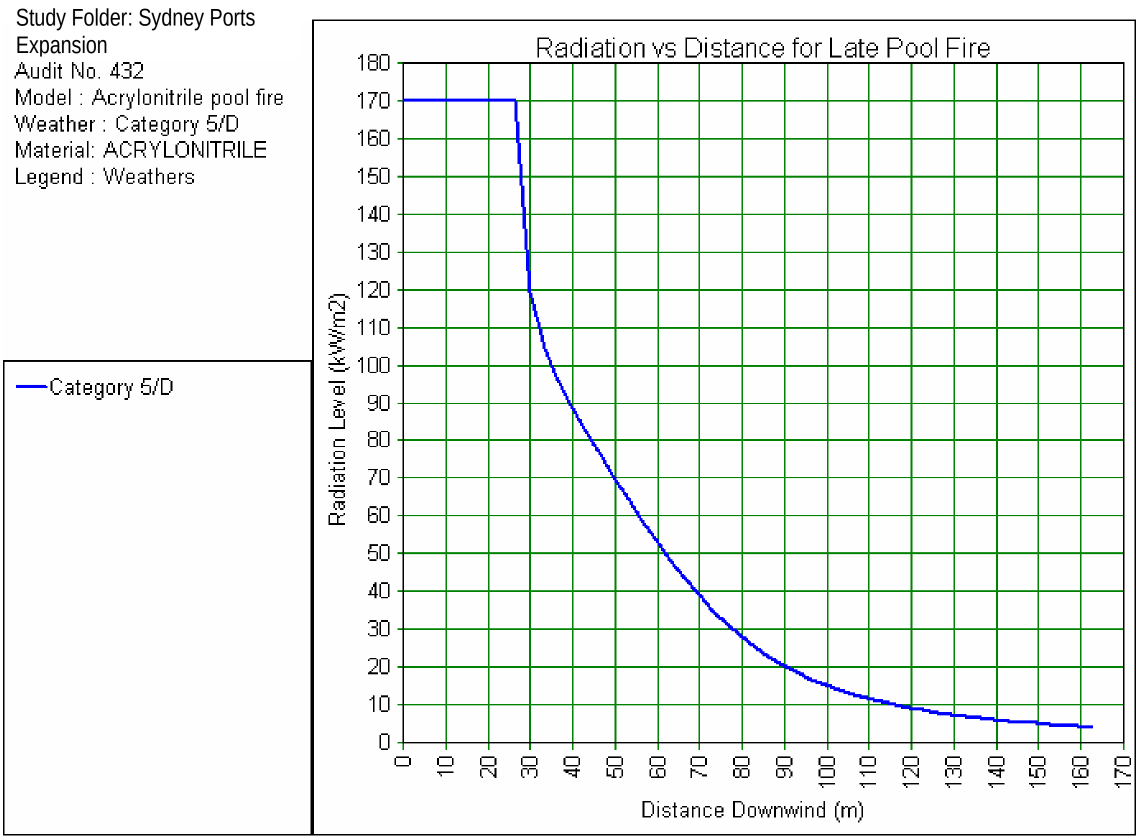


Figure II.2.7 shows that an unconfined pool fire of acrylonitrile will produce potentially lethal heat radiation levels (4 kW/m^2) up to 160 m from the centre of the pool.

II.2.5. Class 5.1 Materials – Ammonium Nitrate

For an explosion of ammonium nitrate, the blast wave will potentially kill or injure people off site. Figure II.2.8 shows that the distance to kill a person from an explosion of 2 tonnes of ammonium nitrate is 75 m. Figure II.2.9 shows that for 21 tonnes of ammonium nitrate, people could be killed at a distance of 175 m.

Although these distances can go off site, the likelihood of 21 tonnes of ammonium nitrate detonating is extremely remote and the fatality distance for 2 tonnes of ammonium nitrate is not very far (see Section II.8).

Figure II.2.8 Over Pressure – Explosion of 2 tonnes Ammonium Nitrate

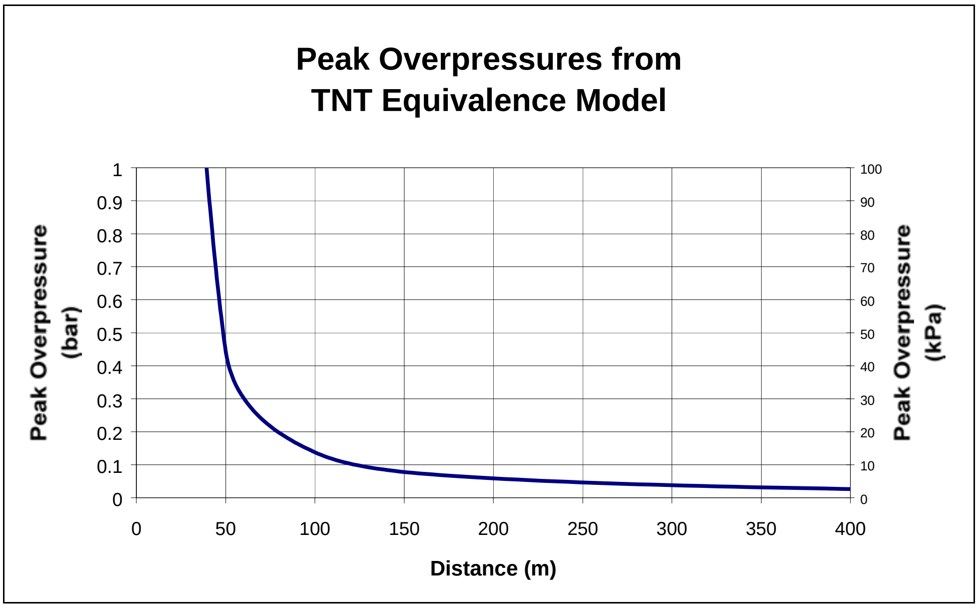
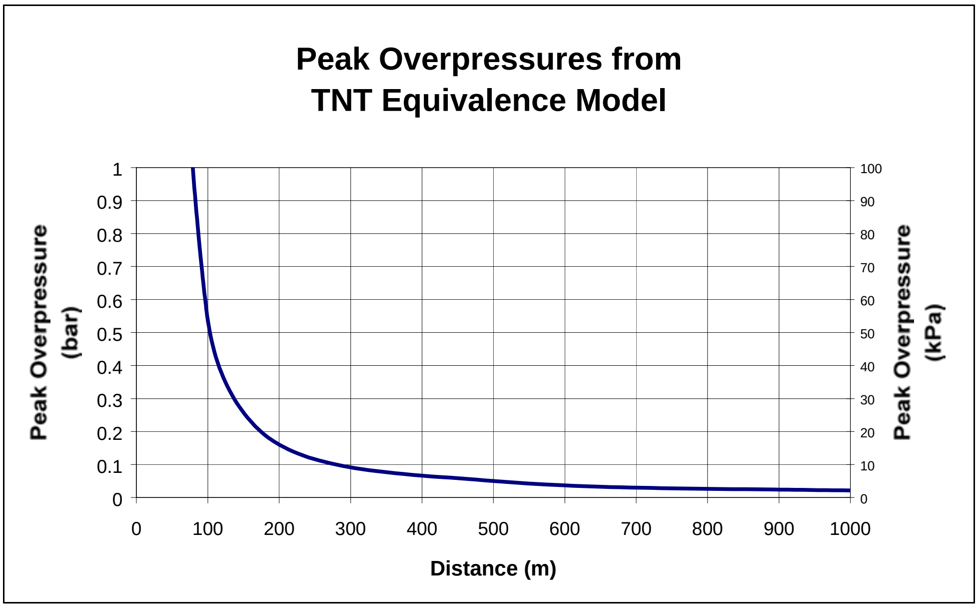


Figure II.2.9 Over Pressure – Explosion of 21 tonnes Ammonium Nitrate



II.3. TOXIC VAPOUR RISK

For materials presenting a toxic vapour risk, the following criteria are often used to describe their toxicity.

II.3.1. ERPG and TEEL Values

The ERPG values (Emergency Response Planning Guidelines) and TEEL (Temporary Emergency Exposure Limits) are used for determination of the injury and irritation effects of chemicals.

ERPG-1 and TEEL-1 are used to identify the concentration that could produce irritation. The definitions of these quantities is given below.

- ERPG-1 The maximum concentration in air below which it is believed nearly all individuals could be exposed for up to one hour without experiencing other than mild transient adverse health effects or perceiving a clearly defined objectionable odor;

- TEEL-1 The maximum concentration in air below which it is believed nearly all individuals could be exposed without experiencing other than mild transient adverse health effects or perceiving a clearly defined objectionable odor.

Similarly, ERPG-2 and TEEL-2 are used to identify the concentration that could produce injury.

- ERPG-2 The maximum concentration in air below which it is believed nearly all individuals could be exposed for up to one hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action;

- TEEL-2 The maximum concentration in air below which it is believed nearly all individuals could be exposed without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action;

II.3.2. Probit Functions

The range of susceptibility in a population to a harmful consequence can be expressed mathematically using a criterion in the form of an equation which expresses the percentage of a defined population which will suffer a defined level of harm (normally death) when it is exposed to a specified dangerous load. This is a ‘Probit Equation’ which has the form:

$$Pr = A + B\ln(C^n t)$$

where

Pr is the ‘probit’ or probability measure
A, B and n are constants for a given substance
C is the toxic vapour concentration (in ppm)

T is the exposure time in minutes

To determine the values of A and B ideally requires data on the percentage of the population affected for varying doses.

Table II.3.1 shows the probit constants for the toxic substances considered in this study.

Table II.3.1 TOXIC PROBIT – FATAL EXPOSURE

Toxic Substance	Probit Constants		
	A	B	N
Ammonia	-9.82	0.71	2
Chlorine	10.1	1.11	1.65
Sulphur Dioxide	-31.42	3.008	1.43

Table II.3.2 TOXIC PROBIT – INJURY EXPOSURE

Toxic Substance	Probit Constants		
	A	B	N
Ammonia	-5.02	0.71	2
Chlorine	-1.56	1.11	1.65
Sulphur Dioxide	-5.05	2.100	1

Table II.3.3 TOXIC PROBIT – IRRITATION EXPOSURE

Toxic Substance	Probit Constants		
	A	B	N
Ammonia	-2.48	0.71	2
Chlorine	0.46	1.11	1.65
Sulphur Dioxide	-1.07	2.100	1

II.4. FLASH FIRE RISKS

Flash fire risks can only be expected due to highly flammable materials. The Class 2.1 materials are those that are likely to be able to produce a flash fire, as when they leak, much of the material is immediately vaporised. This vapour is produced at a significant rate and the flammable cloud can potentially travel for some distance.

Whilst there maybe the potential for a flash fires from large spills of Class 3 materials onsite, they would not result in fatal consequences beyond the site boundary (see section II.2.4).

II.5. BLEVE RISKS

BLEVEs are only possible for those flammable liquids that under fire exposure conditions would instantaneously flash a significant amount of material when a vessel fails catastrophically.

Whilst there maybe the potential for a BLEVE of a Class 2.1 material vessel onsite, it would not result in fatal consequence beyond the site boundary (see section II.2.2).

II.6. SPILL FIRE RISKS

As this study is only concerned with off-site risk, all spill fires in the terminal area were eliminated from the scope of the study.

Whilst there maybe the potential for a large spill fire (pool fire) onsite, they would not result in fatal consequence beyond the site boundary (see section II.2.2).

II.7. VCE (Vapour Cloud Explosion) RISKS

In SAFETI there is a lower limit of one tonne of material that must be in a vapour cloud in order for explosion modelling to take place. This threshold limit was based on experience of vapour cloud explosions and physical trials. Preliminary SAFETI runs show that only some materials were capable of producing a vapour cloud in excess of one tonne. Such materials are all Class 2.1 flammable compressed gases such as propane

Modelling of the consequence of potential VCE from an isotainer of propane demonstrated that whilst there maybe the potential for a VCE onsite, they would not result in fatal consequences beyond the site boundary (see section II.2.2).

II.8. AMMONIUM NITRATE EXPLOSIONS

II.8.1. Review of Accident Histories

Based on a recent literature review on ammonium nitrate explosions DNV has developed the following understanding of the risks of ammonium nitrate. This review of historical accidents forms the basis for DNV's analysis of scenarios involving ammonium nitrate in this study.

A number of accidents have been described as "ammonium nitrate" related explosions in media reports. However, further examination of the details of the incidents have shown that many of the explosions involved mixtures of ammonium nitrate with other materials, such as diesel. Due to the partial knowledge of these incidents to many people in industry and government, all grades of ammonium nitrate may have been "tarred with the one brush".

This section summarises the details and considered causes of some accidents that have been reported associated with storage and transportation of ammonium nitrate. This will show the relevance or otherwise of these incidents to the potential of ammonium nitrate (UN 1942 – the grade most commonly transported through Sydney's ports) to explode under accidental conditions. In most of these accidents that have involved explosions, there was probably a rapid deflagration of the ammonium nitrate rather than a complete detonation [i].

A number of explosions that have involved mixtures of ammonium nitrate that would not be classed as UN 1942 are included, as readers of this report may have heard of some details of an explosion involving ammonium nitrate. By providing details on those explosions in this section, the relevance or otherwise of those explosions to this study can be determined.

The list of accidents is in chronological order within the following groups:

- Class 1 Explosives Involved in the Accident
- Explosions of Ammonium Nitrate Not Involving Explosives
- Fires and Explosions Involving Fertilisers Containing Ammonium Nitrate, Ammonium Phosphate and Potassium Chloride (NPK Fertilisers)
- Accidents Involving Ammonium Nitrate Without an Explosion.

8.1.1. Class 1 Explosives Involved in the Accident

Each of the following incidents involved ammonium nitrate mixed with organic material, such as diesel, wax, fuel oil and petrol. The dangerous goods class of pure ammonium nitrate is 5.1 (oxidising agent), whereas when mixed with greater than 0.2% organic materials, the mixture is classed as an explosive (Class 1). The following incidents were not accidents involving pure ammonium nitrate but were accidents involving an explosive material containing ammonium nitrate as a major component.

- Morgan, New Jersey, 4 October 1918 [ii]
- Oppau Germany 21 September 1921 [ii, iii, iv,]
- Stolberg 12 April 1920 and Kriewald 26 July 1921 [ii, iii, iv]
- Miramas, 5 August 1940 [ii]
- Tessenderloo, Belgium 29 April 1942 [iii]
- Texas City Ships 16 April 1947 [ii, iii, v]
- Brest 28 July 1947 [ii, iii,vi]
- Red Sea 23 January 1953 [ii, iii]
- Kansas City Fire and Explosion 29 November 1988 [vii, viii]
- Porgera Gold Mine, PNG, 2 August 1994 [ix]

8.1.2. Explosions of Class 5.1 Ammonium Nitrate Not Involving Explosives

The following explosions are of ammonium nitrate under accident conditions and are discussed below as they are relevant to the potential for ammonium nitrate to explode under accidental conditions.

- Traskwood, Arkansas, 17 December 1960 [iii]
- Taroom, Queensland Explosion 30 August 1972 [x, xi, xii]
- Cherokee Ammonia Plant Explosion 17 January 1973 [ii, iii, xiii, xii]
- Brazil Truck Accident 8 October 1997 [xiv]
- Toulouse Explosion 21 September 2001 [xv]

8.1.3. Fires and Explosions Involving Manufacture of Ammonium Nitrate

The following explosions are of ammonium nitrate during manufacture. They show that the fires and explosions are caused by a combination of contamination, overheating and confinement of concentrated solutions or molten ammonium nitrate.

- Finland, January 1963 [xii]. A violent explosion occurred in 8 tonnes of molten ammonium nitrate in a mixing tank. Likely causes included uneven feeding of organic anti-caking agent (sodium dodecyl benzene sulphonate) to mixing tank and failure of steam control system leading to overheating.

- UK, September 1967 [xii]. Combined ammonium nitrate ammonium phosphate melt underwent explosive decomposition within minutes of the plant being shut down. A small section of the line full of the melt continued to be heated by the jacket steam (190 ºC). Also, carbon contamination of the melt due to soot.

- Switzerland, January 1969 [xii]. Contamination of ammonium nitrate melt with calcium chloride. The melt increased in temperature from 140 ºC to 200 ºC over a three hour period, then exploded.

- France, October 1970 [xii]. A pump handling ammonium nitrate/ ammonium phosphate solution exploded when left running for 8 hours after the production had been stopped for maintenance.

- Norway, August/September 1972 [xii]. An explosion occurred in a pump seal made of carbon, asbestos and organic fibre threads. Tight seal caused friction and overheating of 73% ammonium nitrate solution as cooling water out of service.

- Canada, 1976 [xii]. A minor explosion in oil sump of an ammonium nitrate solution pump occurred as a result of migration of ammonium nitrate into the sump along the shaft.

- Norway, December 1976 [xii]. Rapid decomposition (not explosion) occurred in a mixing vessel for potash and ammonium nitrate/ ammonium phosphate melt (150 ºC) prior to prilling when pump failed. Excess potash caused solid crust. Delay in stopping mixing device resulted in further heat input.

- UK, January 1978 [xii]. Overheating of built up material in drier shell occurred when drier was stopped due to failure of a conveyor. Fumes released – no explosion.

- Finland, March 1978 [xii]. Decomposition (no explosion) of ammonium based fertiliser when material spilled back into the chamber between furnace and drier.

- Canada, April 1978 [xii]. Rapid decomposition occurred in a filter for hot concentrated ammonium nitrate when off line and being steam cleaned. Organic contamination from recycled ammonium nitrate suspected as cause.

- UK, August 1978 [xii]. Rapid decomposition in 92% ammonium nitrate solution (130 ºC) in pump gland – packed type due to friction following failure of water supply.

- Canada, July 1979 [xii]. Damage to filter element internals due to rapid thermal decomposition of ammonium nitrate probably contaminated by organic material and low in pH.

- Denmark, January 1980 [xii]. Failure of sealing water to an NPK slurry pump caused evaporation of slurry trapped in the sealing water impeller, followed by overheating and explosion of the trapped material.

- Norway, April 1981 [xii]. Blockage of suction and discharge lines caused by deposited solids, caused an explosion in a pump handling 50% NPK solution.

- South Africa, June 1982 [xii]. Ingress of contaminants and a pump running dry caused an explosion in a weak ammonium nitrate solution (10-50%).

- Canada, September 1984 [xii]. An ammonium nitrate melt line became blocked during a shutdown and was being freed using live steam when an explosion occurred in a 5m section of the steam jacketed line.

- USA, December 1984 [xii]. A major explosion occurred in an ammonium nitrate neutraliser and associated plant as the plant was being restarted after being off line for some days. The blast killed four employees.

- South Africa, 1988 [xii]. Following a steam failure, a blockage occurred in a 92% ammonium nitrate solution line. Live 8 bar steam was applied which resulted in an explosion damaging the line.

- Lithuania, May 1989 [xii]. A major incident involving catastrophic failure of a 7000 tonne ammonia tank, followed by a fire/ decomposition in a warehouse containing fertiliser.

- USA, March 1989 [xii]. An explosion occurred in the reactor of an ammonium nitrate plant due to acidic composition initiating an exothermic reaction.

8.1.4. Fires and Explosions Involving Fertilisers Containing Ammonium Nitrate, Ammonium Phosphate and Potassium Chloride (NPK Fertilisers)

The following explosions involve mixtures of ammonium nitrate with other materials to produce fertilisers. These materials can exhibit "cigar burning" in which a mass of material slowly burns through the entire mass emitting large quantities of smoke. These materials are not used in Australia but were used in Europe and the USA.

- Holland, November 1963 [xii]

- South Africa, February 1965 [xii]

- Central Atlantic Ocean, “Sophocles” February 1965 [xii]

- Norway, April 1965 [xii]

- Mount Vernon, Missouri 9 November 1966 [ii, iii, xii]

- Germany, December 1966 [xii]

- Norway, July 1968 [xii]

- Rhodesia, October 1968 [xii]

- France, January 1970 [xii]

- USA, January 1975 [xii]
- Germany, June 1975 [xii]
- UK, December 1978 [xii]
- UK, October 1982 [xii]
- Nantes, 29 October 1987 [xvi]
- UK, October 1993 [xii]

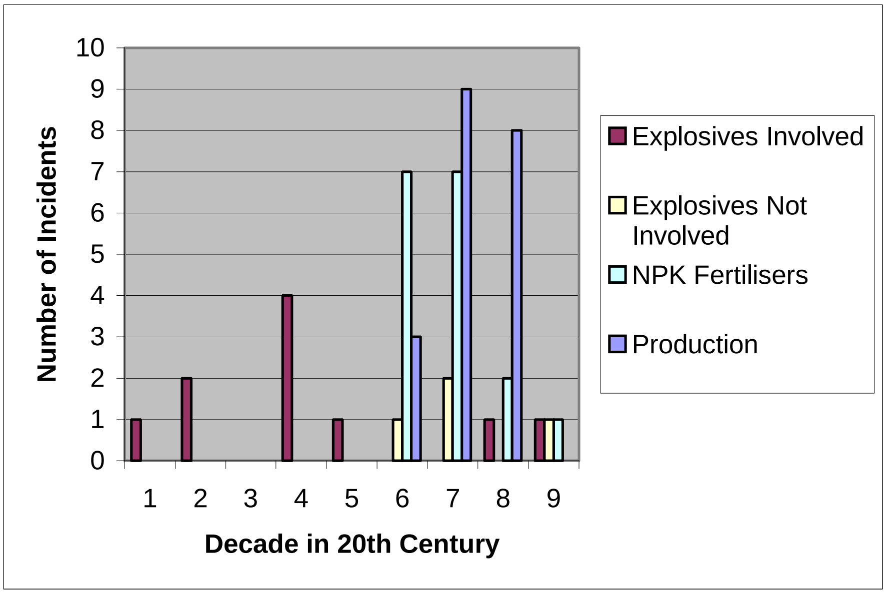
8.1.5. Discussion of Accident Summaries

The above list of accidents is not exhaustive although any major explosion involving loss of life due to transportation or storage of ammonium nitrate is likely to be included. Incidents, which did not result in a loss of life or major property, damage or occurred in more remote areas may not have been included.

The disastrous explosion in a fertiliser factory in Toulouse, France on Friday 21 September, 2001, which killed 30 people, is too recent to have full details of the causes known at this time. However, the news reports [xvii] stated that the explosion occurred in a warehouse used for storing 300 tonnes of substandard ammonium nitrate awaiting recycling. This suggests that the ammonium nitrate was not pure and could have been mixed with contaminants rendering it much more susceptible to detonation. The likely trigger for the explosion is the addition of 500 kg of sodium dichloro-isocyanate. Such contamination is very difficult to achieve in an accident scenario at the container terminal.

Figure II.8.1 shows that incidents involving Class 1 explosives (either detonators, gelignite or ANFO) have decreased in frequency since the 1950’s, with no incidents recorded. Similarly, following the introduction of NPK fertilisers, a number of fires occurred in the 1960’s and 1970’s but many fewer in the 1980’s and 1990’s. There have been four notable incidents involving ammonium nitrate that did not involve Class 1 explosives, in 1960, 1972, 1973 and 1997. The data for incidents during production is incomplete with data unavailable for the period before 1963 or after 1989. Overall, despite increasing tonnage of ammonium nitrate being produced and transported around the world, the number of accidents in the last 20 years has decreased, as has the severity of the consequences.

Figure II.8.1 Distribution of Ammonium Nitrate Related Incidents



Of the explosions of stored ammonium nitrate that did not involve Class 1 explosives or NPK fertilisers, all of them involved an externally fuelled fire that continued for some time. These fires melted ammonium nitrate in at least three of the incidents and caused a triggering explosion to occur (rupturing fuel tanks or BLEVE of a propane cylinder). In each of these accidents only part of the ammonium nitrate detonated. Two of the accidents involved trucks, one involved a train derailment and the fourth was in a warehouse. In both of the truck incidents, wooden decks were used on the trailers. Contamination of the ammonium nitrate occurred in at least three of the incidents prior to the detonation. Confinement did not contribute to any of the incidents.

These incidents are consistent with theoretical and experimental studies, which require an accident to occur that may cause contamination and initiates a fire. The fire continues for some time due to the presence of combustible materials, resulting in significant heating of the ammonium nitrate and melting a portion of it. Some of the ammonium nitrate is now in a sensitised state, being molten and possibly contaminated. The final factor was the strong impact from an adjacent explosion. This caused detonation of the sensitised ammonium nitrate and dispersed the rest of the ammonium nitrate.

II.8.2. Identification of Accident Scenarios

This section identifies some credible accident scenarios, and thus the credible range of compositions, that are covered in this literature review.

The process for identifying the credible accident scenarios and the credible range of compositions used historical accident data, previous risk assessments and discussions with experienced personnel. Where scenarios were identified and then eliminated from consideration as not being credible, notes on the reasons for determination as non-credible are given.

The scenarios are detailed in Figure II.8.2 and have been classified into those factors that are considered to contribute to the potential to explode.

Figure II.8.2 Accident Scenarios

Contamination
- At Source
  - Low pH
  - Small particle size
  - Low density
  - High level of chlorides
  - High level of organic material
  - High acidity
- Storage
  - Inclement weather
  - Previously stored material
  - Nearby other material
- Road Transport
  - Road accident
  - Diesel/ fuel from truck
  - Other goods on truck

Heating
- At Source
  - Overheated in evaporator
  - Pumping bearings overheating
  - Loaded hot into storage or transport containers
- Storage
  - Hot weather
  - Self-heating from contamination with other goods
  - Fire in warehouse
  - Hot work in warehouse
- Road Transport
  - Hot weather
  - Axle & tyre fires
  - Prime mover fire
  - Accident resulting in fire
  - Hot work on vehicle
  - Other goods catch fire

Confinement
- At Source
  - Pump dead-headed
  - Blockage caused by crystallisation
  - Line isolated
- Storage
  - Shipping containers
  - Buildings
- Road Transport
  - Shipping containers
  - Fully enclosed trucks

Strong Impact
- At Source
  - Physical impact onto evaporator
  - Explosion of nearby equipment
  - Steam explosion
- Storage
  - Nearby storage of explosives
  - BLEVEs of stored liquid vessels
  - Explosive ruptures of fuel tanks of vehicles such as front end loaders
- Road Transport
  - Explosive ruptures of fuel tanks of vehicles
  - BLEVEs of carried cylinders (LPG)
  - Transport of explosives
  - Tyre blowouts

Of these scenarios, a number could cause increased risk of explosion if they occur. They are discussed under the headings of contamination, heating, confinement and strong impact.

8.2.1. Contamination

At the source of the ammonium nitrate, a number of scenarios have been suggested that could lead to increased risk of explosion. These were low pH, low bulk density, high chlorides, high organic material levels, high levels of acidity, and high temperature when filling. The effect of the contamination events (low pH, high chlorides, high acidity and high organic levels) make the material more sensitive to the effects of overheating, fire or strong impact.

Weather incidents, such as lightning strike and storms, could be an initiator for a fire but their direct effect on ammonium nitrate does not cause a direct hazard or make the ammonium nitrate more sensitive.

It is reasonably foreseeable that ammonium nitrate could be contaminated in storage due to previously stored material or adjacent material. The range of possible contaminants is vast, ranging from inert materials that have no effect on the ammonium nitrate, through materials such as oils or fuels that make the ammonium nitrate more sensitive to fires or strong impacts, to materials such as reducing agents that will react immediately with the ammonium nitrate and produce a fire. For this study, materials that make the ammonium nitrate more sensitive, such as contamination with oils, wood and other combustible material is included. Mixing with materials that cause an immediate reaction are included in this study only so far as they could cause a fire.

During transportation, there is the potential for contamination of the ammonium nitrate. Most of the contamination scenarios involve a vehicle accident, such as rollover, collision with another vehicle or striking an object by the side of the road. Again the contamination scenario possibilities are vast but contamination with organic material such as diesel from the truck is the most credible scenario. One facet of this scenario is that the maximum quantity which could be involved is one truckload (~ 20 tonnes) and experience suggests that only a small portion of that truckload would actually detonate.

The potential for contamination of ammonium nitrate from other goods carried on the truck, that could cause increased risk, is very low due to the requirements of the ACTDG code. In addition, part loads are not common due to the large quantities usually transported.

8.2.2. Heating

Heating of ammonium nitrate is one of the factors associated with increased sensitivity.

During manufacturing of the ammonium nitrate, hot ammonium nitrate is produced. If the ammonium nitrate is overheated during the evaporation stage of the process, it can detonate. However, once the ammonium nitrate is crystallised, the highest credible temperature for loading of ammonium nitrate has been shown not to be subject to self-heating. Tests for self-heating potential have been carried out [v] and theoretical studies have also demonstrated that ammonium nitrate loaded at the maximum credible temperature (80 ºC) can not cause self-heating.

During storage or transport, hot weather can not induce self-heating of the ammonium nitrate. However, if some of the ammonium nitrate is contaminated with materials high in chlorides, for example, the contaminated material is potentially able to self heat. Another source of heat in storage and transport is from a fire involving other combustible materials. The ammonium nitrate is not combustible and by itself can not burn. If the ammonium nitrate is melted, it becomes more likely to become contaminated as it will flow and would become more sensitive to strong impact.

During road transport, there are a number of scenarios that can produce heating of the ammonium nitrate. As has been discussed previously, hot weather will not affect the ammonium nitrate. The other scenarios all involve fire. The initiators of fires include tyre and wheel bearing fires, maintenance activities, electrical fires on the prime movers and fires initiated within other goods carried on the vehicle. Such fires will burn the combustible materials on the vehicle including the diesel fuel, the tyres, the tarpaulins, any pallets, etc. The heat from the burning will damage the bulka bags resulting in spillage of the ammonium nitrate and can melt some of the ammonium nitrate. Such melted ammonium nitrate will flow onto the roadway where it could be contaminated with bitumen from the road, spilled diesel or other organic material. This material will not explode of itself and requires a strong impact or confinement to initiate detonation.

The potential for a road accident to result in a fire involving the ammonium nitrate also exists. This could involve contamination with the goods carried on a second vehicle. In this scenario, there is simultaneous contamination and fire involving the ammonium nitrate. The bulka bags will act to prevent complete contamination of the entire load but will burn during the fire. If the ammonium nitrate is contaminated with diesel or another combustible liquid and then is exposed to fire there is the potential for an explosion to occur from a strong impact or confinement.

8.2.3. Confinement

Confinement of ammonium nitrate coupled with heating is known to cause sensitisation of ammonium nitrate. This has contributed to incidents during manufacture.

When bulka bags are used in truck transport, they are loaded directly onto the bed of the truck, with strap securing, and then a tarpaulin is lashed over them to protect against weather. This does not provide any potential for sufficient confinement of the ammonium nitrate to increase its sensitivity.

During warehousing, ammonium nitrate can be stacked a number of bulka bags high, depending on the rating of the bags. Although this increases the pressure at the base of the stack, the confinement at the bottom of such a stack of bags is insufficient to increase the sensitivity of the ammonium nitrate. However, if the ammonium nitrate has been contaminated with an organic substance, the confinement at the base of such a stack of bags could increase the sensitivity of the ammonium nitrate.

During shipping, the ammonium nitrate bulka bags are often transported within shipping containers. The structure of the shipping container would provide some potential for confinement. However, shipping containers are not air tight and in the event of a fire, melting and decomposing ammonium nitrate could escape from the container.

8.2.4. Strong Impact

Strong impact is known to be able to detonate ammonium nitrate. However, many impacts that would be considered ‘strong’ in ordinary use have been found to be unable to cause an explosion with ammonium nitrate.

Based on the tests with falling impacts [xviii] and bullets fired into molten ammonium nitrate [ii], it is considered that during road or rail transport, the impact from an accident, however serious, is insufficient to detonate ammonium nitrate.

During manufacture, impact from a mechanical object can cause detonation of hot strong ammonium nitrate liquor, particularly if it is excessively acid or contaminated.

During road transport, there can be other strong impacts such as from an exploding fuel tank, a BLEVE of an LPG cylinder or from explosive devices such as detonators and booster charges. Even so, without some other sensitisation, such as contamination with organic material or melting, or strong confinement, these strong impacts are unlikely to cause detonation of the ammonium nitrate.

In summary, the credible accident scenarios that increase the sensitivity of ammonium nitrate to detonation are contamination by organic materials and other materials such as chlorides, heating of the ammonium chloride to melting or decomposition temperatures, strong confinement to limit the release of decomposition gases and a strong impact from an adjacent explosion.

II.8.3. Consequence Assessment

Ammonium nitrate explosions act as slow detonations or fast deflagrations. The assessment of the consequences of an explosion is modelled using the TNT equivalence model. In this model one tonne of ammonium nitrate is equilibrated to 350 kg of TNT. The shock wave from the equivalent quantity of TNT is calculated using the standard formulae (Lees 1996).

II.8.4. Conclusions

There are a number of conditions that are necessary before an explosion involving ammonium nitrate during transportation or storage could occur.

Contamination with organic material changes the sensitivity of ammonium nitrate and this is recognised in the change of dangerous goods class from ‘oxidising agent’ to 'explosive'. However, even contaminated with organic materials, ammonium nitrate is still difficult to explode and requires additional factors.

Melting of ammonium nitrate increases its sensitivity to strong impact and also facilitates contamination with any nearby materials.

Confinement of ammonium nitrate that is being heated is known to produce explosions but the degree of confinement required is very difficult to achieve in accident scenarios.

Strong impact can cause detonation or deflagration of ammonium nitrate in most of its states. However, for prills of ammonium nitrate (UN 1942) a significant quantity of primer explosive is required. This is not likely to occur in an accident scenario. For molten ammonium nitrate, a very high-energy projectile such as a high-velocity bullet can cause detonation. For contaminated ammonium nitrate in the solid form, a smaller quantity of primer explosive is required. For molten contaminated ammonium nitrate the impact provided by an exploding fuel tank or gas cylinder could initiate an explosion.

An accidental explosion of ammonium nitrate is usually a deflagration rather than a detonation and usually does not involve all the material.

The history of accidents involving ammonium nitrate show that, despite increasing manufacture, transport and usage of ammonium nitrate, the number of accidents has decreased during the last 20 years. This decrease in accidents is considered to be due to the major increases in understanding of the properties of ammonium nitrate and the subsequent changes to manufacture, storage and transportation practices. The consequences of more recent ammonium nitrate incidents have also been less severe than those that occurred in the first half of the 20^{th} Century. The improvements to emergency response during this time have also prevented accidents being exacerbated by incorrect responses.

Thus modelling of 2 tonnes ammonium nitrate explosions only has been undertaken in this study.

II.9. REFERENCES

i A. King & A. Bauer, *A review of accidents with ammonium nitrate,* The Department of Mining Engineering, Queen's University, Kingston, Ontario, June 1977.

ii L.A. Medard, *Accidental Explosions Volume 2: Types of Explosive Substances*, Translator P. Fawcett, Ellis Horwood Limited, 1990, chapter 23 (Ammonium nitrate and its thermal decomposition) and chapter 24 (The explosive properties of ammonium nitrate).

iii A.W. King, Shock Initiation Characteristics of Ammonium Nitrate, Ph. D. Thesis, Queens University, Kingston, Canada, March 1979.

iv F.P. Lees, *Loss Prevention in the Process Industries*, 2nd edn, Butterworth, 1996, ISBN 0 7506 1547 8.

v G.M. Kintz, G.W. Jones & Charles B. Carpenter, Report of Investigations Explosions of Ammonium Nitrate Fertilizer on Board the S.S. Grandcamp and S.S. High Flyer at Texas City, Tex., April 16, 17, 1947..

vi W.G. Sykes, R.H. Johnson & R.M. Hainer, Ammonium nitrate explosion hazards, Chemical Engineering Progress, vol. 59, No. 1, pp. 66, 1963.

vii J. W. Hoffmann, and W. Keith, *Six Kansas City firefighters die in ammonium nitrate blast*, Firehouse, January 1989.

viii Committee on Government Operations, *Fire and Explosion in Kansas City: Lack of Information About Hazardous Materials Jeopardizes Firefighters*, Second Report, 11 July, 1989, House of Representatives, Washington DC

ix Inspection and Engineering Branch, Department of Mining and Petroleum, *Inquiry Report Dyno Wesfarmer's Plant Explosions 2nd August 1994 Porgera Gold Mine,* Mining (Safety) Act Chapter 195A, 1995

x A.D. Murray, Memorandum to Chief Inspector of Explosives, Brisbane, Government Chemical Laboratory, William St Brisbane, 8 September 1972.

xi K.S. McPaul, letter to Austin Powder Company, 7 December 1977.

xii K.D. Shah, *Safety of Ammonium Nitrate Fertilisers*, The Fertiliser Society, proceedings No. 384, 10 October 1996, ISBN 0 85310 018 7.

xiii R. Freeman, *The Cherokee Ammonia Plant Explosion*, Chemical Engineering Progress 71(11), November 1975.

xiv SAFEX International, *Accident Report No. 606 Major Accident Ammonium Nitrate in Transit*, SAFEX International, Ayrshire, Scotland, 8 October 1997.

xv http://www.saunalahti.fi/ility/AZF.htm

xvi A. Bentata (trans.), Elements of the study of chemical disasters and note relative to the fire that happened on 29 October 1987 at Nantes, ICI Research Group, 5 August 1990

xvii Petrochemical news, 26 September, 2001, www.petrochemicalnews.com

xviii A.H. Heemskere, P. Schuurman, A.C. v.d. Steen, *Investigations into the initiation of a detonation of molten ammonium nitrate by falling objects*, TNO, PML 1987-C24, March 1987.

APPENDIX III

FREQUENCY ANALYSIS

FREQUENCY ANALYSIS

CONTENTS

III.1. INTRODUCTION....................1
III.2. CONTAINER MOVEMENTS 2
III.1.1. Dropped Containers 2
III.1.2. Explosions of Class 1 materials in Dropped Containers........3
III.3. ROAD TRANSPORTATION ACCIDENTS 4
III.1.3. Introduction....................4
III.1.4. Truck Accident Rates in NSW....................4
III.1.5. UK Heavy Vehicle Accident Rates....................4
III.3.1. LPG Tankers 4
III.4. ATMOSPHERIC STORAGE TANKS....................6
III.4.1. Summary 6
III.5. References....................7

III.1. INTRODUCTION

Frequency estimates are usually developed based on historical data at the site, similar experience in other locations or on developed fault trees. None of these are exact sciences and have margins of uncertainty around the estimates. Notwithstanding that, many estimates have been accepted as appropriate for PHAs as they have passed through the approval process. This process involves estimation by risk experts, review by operations personnel and review by the regulator. Through each of these steps, the estimates have the opportunity to be scrutinised and refined. Eventually, the likelihood estimates are accepted as appropriate.

In this study, there are two main initiators of incidents: dropped or impacted containers associated with crane lifts, and transportation accidents associated with vehicle movements. Such vehicle movements include straddle cars, road trucks and rail cars. The crane lifts include those undertaken by portainer cranes, straddle cars and rail mounted gantries.

Other causes of incidents, such as 'spontaneous' leaks or fires are considered to be a lower order cause of incidents, as they occur much less frequently. Thus, the likelihood estimates for lifts and transportation have been developed to include the likelihood of these lower order incidents.

III.2. CONTAINER MOVEMENTS

III.1.1. Dropped Containers

Containers can be dropped from portainer cranes, straddle cars or rail mounted gantries. The likelihood of such drops is low due to the positive engaging checks that are required to be energised before the lifts can be commenced. The more likely drop scenarios are where a container is raised slightly under another one, is lowered onto the edge of another container or hits an object during a traverse associated with the lift. The likelihood of such drops is difficult to estimate. Experience from the offshore industry suggests a dropped object frequency of 1×10^{-5} per lift (DNV, 2001).

Previous work for another Australian Port (DNV, 1993) established that they had experienced eight reports of dropped containers over the previous 10 years. This was used to estimate a likelihood of dropping containers: 6.7×10^{-6} per transfer between the ship and the truck or train car including any set-downs or raises associated with intermediate storage. This frequency is in reasonable agreement with the figure from the offshore industry and is considered appropriate for this study.

The severity of the damage to the container was also studied. Based on no loss of outer containment in the 8 drops, a probability of 0.1 was conservatively estimated for loss of outer containment. It is considered that isotainers would be more vulnerable to loss of containment than normal containers if they fell on a sharp object. However, given the uncertainties involved it is considered that a total release frequency for isotainers of 6.7×10^{-7} per transfer is a reasonable estimate.

The experience quoted above was applied to the situation at the proposed expansion at Port Botany

For containers of drummed material, a conditional probability of drums leaking of 0.5 was assumed given loss of outer containment. Thus a release frequency of 3.4×10^{-7} per transfer for drums is estimated. It will further be assumed that only 1 drum in a container will leak in a release case.

Based on the distribution of leak sizes for pressure vessels, the relative likelihood of different size leaks, for both isotainers and drums, was assumed to be: 25 mm leak 25%, 100 mm leak 65%, rupture 10%.

III.1.2. Explosions of Class 1 materials in Dropped Containers

If a shipping container with Class 1 material is dropped, there is a potential for it to be detonated.

Previous work (DNV 2216, October 1996) discussed test drops of cartridge explosives on to a hard flat surface from a height of 11 m. Of the 1150 drops, none resulted in detonation. Based on this result a conservative estimate of 1 in 1000 is applied. Thus if a shipping container with Class 1 material is dropped, it is assumed that there is a 0.001 chance of it detonating the explosives.

Combining the likelihood of dropping a container and the likelihood of it exploding, the likelihood of a container carrying explosives detonating during transfer is 6.7×10^{-9} per transfer between ship and truck.

III.3. ROAD TRANSPORTATION ACCIDENTS

III.1.3. Introduction

This section presents a small selection of available data, drawn from NSW, UK and Hong Kong sources on the likelihood of incidents initiated by road accidents.

III.1.4. Truck Accident Rates in NSW

The City South Freight Strategy published by DUAP in 1998, quotes truck accident rate targets of a maximum of 80 crashes per 100 million vehicle kilometres. This is equivalent to 8×10^{-7} crashes per vehicle km. This estimate is compared below with experience in the UK.

III.1.5. UK Heavy Vehicle Accident Rates

Table III.3.1 presents traffic accident data for the UK, for which an analysis is published annually (DETR 1998). The table gives the involvement rates for different classes of vehicles and severity of road traffic accident.

Table III.3.1 Road Traffic Accident Frequency, 1997 (per 100 million vehicle km)

VEHICLE TYPE	ALL CASUALTY ACCIDENTS	SERIOUS/FATAL ACCIDENTS	FATAL ACCIDENTS
Cars	92	13	1.1
Buses/coaches	230	31	2.6
Light goods vehicles	50	7.8	0.8
Heavy goods vehicles	45	10	1.8
All motor vehicles	92	14	1.3

This table shows that the likelihood of all casualty accidents involving heavy goods vehicles is 4.5×10^{-7} per vehicle km, approximately half of the total accident rate target for NSW. These estimates are consistent with each other and are considered appropriate for this study.

III.3.1. LPG Tankers

DNV Technica (c1996) compared various sources of leak frequency data for LPG road tankers, and developed a fault tree model to take account of the main influences. Table III.3.2 gives the failure case frequencies for a road tanker with passive fire protection.

Table III.3.2 LPG Road Tanker Leak Frequencies

FAILURE CASE	LEAK FREQUENCY (per loaded vehicle km)
BLEVE	2.7×10^{-12}
Cold rupture	2.6×10^{-9}
Large liquid leak	1.8×10^{-8}
Large vapour leak	2.1×10^{-9}
Brief liquid leak	6.8×10^{-9}
TOTAL	3.0×10^{-8}

This table shows that the likelihood of a leak from a tanker carrying LPG is approximately 4% of the total accident frequency. This is a consistent estimate of likelihood with the UK and NSW data.

III.3.1.1. Application

The data in Table III.3.2 has been applied in the analysis of the transportation of Class 2.1 and 2.3 flammable and toxic gases.

The likelihood of a leak of Class 2.1 or Class 2.3 material from a truck carrying those classes of material is based on the information in Table III.3.2 and assumed leak sizes.

The likelihood of a 25 mm leak has been based on the likelihood of a brief liquid leak (6.8×10^{-9} per vehicle km). The likelihood of a 100 mm leak has been based on the likelihood of a large liquid leak (1.8×10^{-8} per vehicle km). The likelihood of a rupture of the isotainer has been based on the likelihood of cold rupture (2.6×10^{-9} per vehicle km).

The same leak likelihoods have been applied to the transport of a shipping container with cylinders or drums on board. Thus no allowance has been made for the additional protection provided by the shipping container.

III.4. ATMOSPHERIC STORAGE TANKS

III.4.1. Summary

The best available estimate of fire frequencies for open-top floating roof tanks comes from the LASTFIRE (1997) study. For fixed roof tanks, the best available estimate is from a Technica study for tank operators in Singapore (Technica Report C1998). For tanks with both fixed and internal floating roof, the frequencies of appropriate fire/explosion types have been selected from the other tank types as summarised in Table III.4.1.

Table III.4.1 Atmospheric Storage Tank Fire Frequencies

TYPE OF FIRE	FLOATING ROOF TANK (per tank year)	FIXED ROOF TANK (per tank year)	FIXED PLUS INTERNAL FLOATING ROOF TANK (per tank year)
Rim seal fire	1.6×10^{-3}		1.6×10^{-3}
Full surface fire on roof	1.2×10^{-4}		
Internal explosion and full surface fire		9×10^{-5}	9×10^{-5}
Internal explosion without fire		2.5×10^{-5}	2.5×10^{-5}
Vent fire		9×10^{-5}	
Small bund fire	9×10^{-5}	9×10^{-5}	9×10^{-5}

III.5. REFERENCES

ACDS 1991, *Major Hazard Aspects of the Transport of Dangerous Substances*, Advisory Committee on Dangerous Substances, Health & Safety Commission, HMSO.

DNV Technica, 1980, *Risk Assessment of Liquid Chlorine Transport*, Water Supplies Department, Government of Hong Kong, June 1980, Project C1918.

DNV Technica c1996, *Quantitative Risk Assessment of the Transport of LPG and Naphtha in Hong Kong - Methodology Report*, Electrical & Mechanical Services Department, Hong Kong Government**,** Project C6124.

DNV, 1996, *Comparative QRA of road tunnels*, Civil & Civic, October 1996, Project 2216.

DNV RiskNet, 2001, Offshore QRA Methods.

DNV, 1993, *Port Safety Study QRA*, Fremantle Port Authority, September 1993 Project A1020.

APPENDIX IV

TRANSPORTATION RISK ANALYSIS

TRANSPORTATION RISK ANALYSIS

CONTENTS

IV.1. INTRODUCTION.. 1
IV.2. HAZARD IDENTIFICATION 2
IV.3. LIKELIHOOD OF ROAD TRANSPORTATION ACCIDENTS 3
IV.3.1. Introduction.. 3
IV.3.2. Leaks from Flammable Liquid Tankers.................. 3
IV.3.3. Explosives Transportation Incident Analysis 3
IV.4. DANGEROUS GOODS VEHICLE MOVEMENTS PER YEAR 6
IV.5. METHODOLOGY... 7
IV.6. TRADE ANALYSIS.. 8
IV.7. RISK RESULTS - TRANSPORTATION 10
IV.8. RISK ASSESSMENT 11
IV.9. CONCLUSIONS.. 12
IV.10. REFERENCES... 13

IV.1. INTRODUCTION

This appendix presents a review of the dangerous goods transportation for the expansion to the container terminal at Port Botany being undertaken by Sydney Ports. SEPP 33 requires a transportation study to be undertaken when the number of dangerous goods movements to or from the site is above a threshold (DUAP 1994). This threshold is exceeded for the container terminal and thus this transportation study has been undertaken.

This study considers the routes used by trucks and rail cars carrying dangerous goods to and from the site and assesses the risks to nearby residents and other road users. There is a significant difference between the activities on the container terminal, compared to typical industrial sites. The goods that are handled on the site are always owned by others. The facility operator neither owns the goods, or the trucks or the ships used to transport them but only supplies a service in unloading or loading ships or trucks. This limits the controls that the operator has over the routes used by trucks either travelling to or from the site. However, as there are typical routes that are used by trucks travelling to and from the site, these routes have been assessed.

The draft Route Selection guidance note published by DUAP (1995) provides "an overall integrated framework for the assessment of road transport routes for the transportation of hazardous materials" (p1). Thus, as 96% of containers transported to or from the container terminal carry no dangerous goods, this study is restricted to the 4% of container movements that do contain dangerous goods.

A risk assessment of the risk due to dangerous goods transport handled by Port Botany to the land lining the main transportation routes out of the port has been undertaken.

IV.2. HAZARD IDENTIFICATION

Detailed hazard identification was undertaken for the assessment of the import and export of dangerous goods at the Port Botany Container Terminal in Appendix II. Reference has been made to the hazards identified in Appendix II for the analysis of the risk due to transportation of dangerous goods to and from the Terminal.

Thus the hazards associated with transportation of dangerous goods from the terminal are associated with flammable gases, liquids and solids, explosives and oxidising agents, and toxic gases.

Incidents associated with explosions, fires or releases of these materials could cause hazards to people either on the roads or near to the roads.

IV.3. LIKELIHOOD OF ROAD TRANSPORTATION ACCIDENTS

IV.3.1. Introduction

This section presents a small selection of available data, drawn from NSW, UK and Hong Kong sources on the likelihood of incidents initiated by road accidents on the dangerous goods leaving or travelling to the Port Botany site.

IV.3.2. Leaks from Flammable Liquid Tankers

The best available estimate of leak frequencies from tankers carrying non-pressurised liquids is given by ACDS (1991), based on spills from UK motor spirit tankers (Table IV.3.1).

Table IV.3.1 Liquid Tanker Leak Frequencies

SPILL SIZE	LEAK FREQUENCY (per loaded vehicle km)
5 – 15 kg	6.0×10^{-9}
15 – 150 kg	2.6×10^{-8}
150 – 1500 kg	7.0×10^{-9}
> 1500 kg	2.1×10^{-8}
TOTAL	6.0×10^{-8}

IV.3.3. Explosives Transportation Incident Analysis

3.3.1. Background

The detonation of Class 1 Dangerous Goods (explosives) when transported by road can be caused by the following mechanisms:

- Spontaneous fire.
- Fire after vehicle crash.
- Impact in a crash.
- Detonation due to explosives being in an unsafe condition.

For crash and non-crash fires, detonation requires a fire to start the fire to spread to the explosive load and detonation to occur once the load is engulfed by the fire.

In the case of impact, the explosives can be detonated immediately due to the crash impact or after being spilt onto the road and crushed by other vehicles.

3.3.2. Development of Explosives Detonation Frequency

The following sections describe how the explosive detonation frequency was developed.

Detonation on Impact

Trials have been conducted on cartridge explosives by dropping on to a hard flat surface from a height of over 11m. A total of 1150 drops were performed without a single initiation (See Appendix II.1). Cartridge explosives are considered a Medium

Impact Risk (See Appendix I.1) explosive which are generally sensitive to the type of impacts experiences in typical road accidents. Based on the above test a probability of detonation of the explosives in the event of an accident is estimated at 0.001.

Detonation due to Fire

There is limited data on the probability on detonation of explosives during a fire. Data sheets referenced in the DNV Technica Hong Kong Explosives Transportation QRA Report (See Appendix II.2), describe tests undertaken where loads of explosives were engulfed by fire without explosion. However, explosions under these circumstances are considered a realistic possibility, therefore a probability of detonation of 0.1 is estimated as in previous studies (See Appendix II.3).

Accident Involvement Frequencies

Data on the rate of medium to heavy vehicle accident per kilometre was sought from the Road and traffic Authority (RTA) of New South Wales. Information provided to DNV included details on the number of heavy vehicle accidents on New South Wales roads, along with the number of registered heavy vehicles. The heavy vehicle accident rate has a target maximum value of 8×10^{-7} per km.

Due to uncertainties in the NSW data, reference has been made to the UK heavy goods vehicles (over 3.5 te) accident rate per vehicle kilometre. The UK accident and fire data was considered appropriate for use in this study given the close similarity between the UK and Australia in relation to elements considered as main contributors to the frequency of road accidents, and vehicle fires. The accident rate in NSW and the UK for heavy vehicles was also similar (8×10^{-7} p.a. compared to 6×10^{-7} p.a.).

Elements considered as main contributors to vehicle accidents include:

- Vehicle design and loading.
- Driving standard for both the Dangerous Goods vehicle and other drivers.
- Quality of roads, surface type and design.
- Safety management standards, driver training, maintenance procedures.
- Traffic densities.

The base incident frequencies (See Appendix I.2) for heavy goods vehicle accidents in Table IV.3.2 were applied in the analysis.

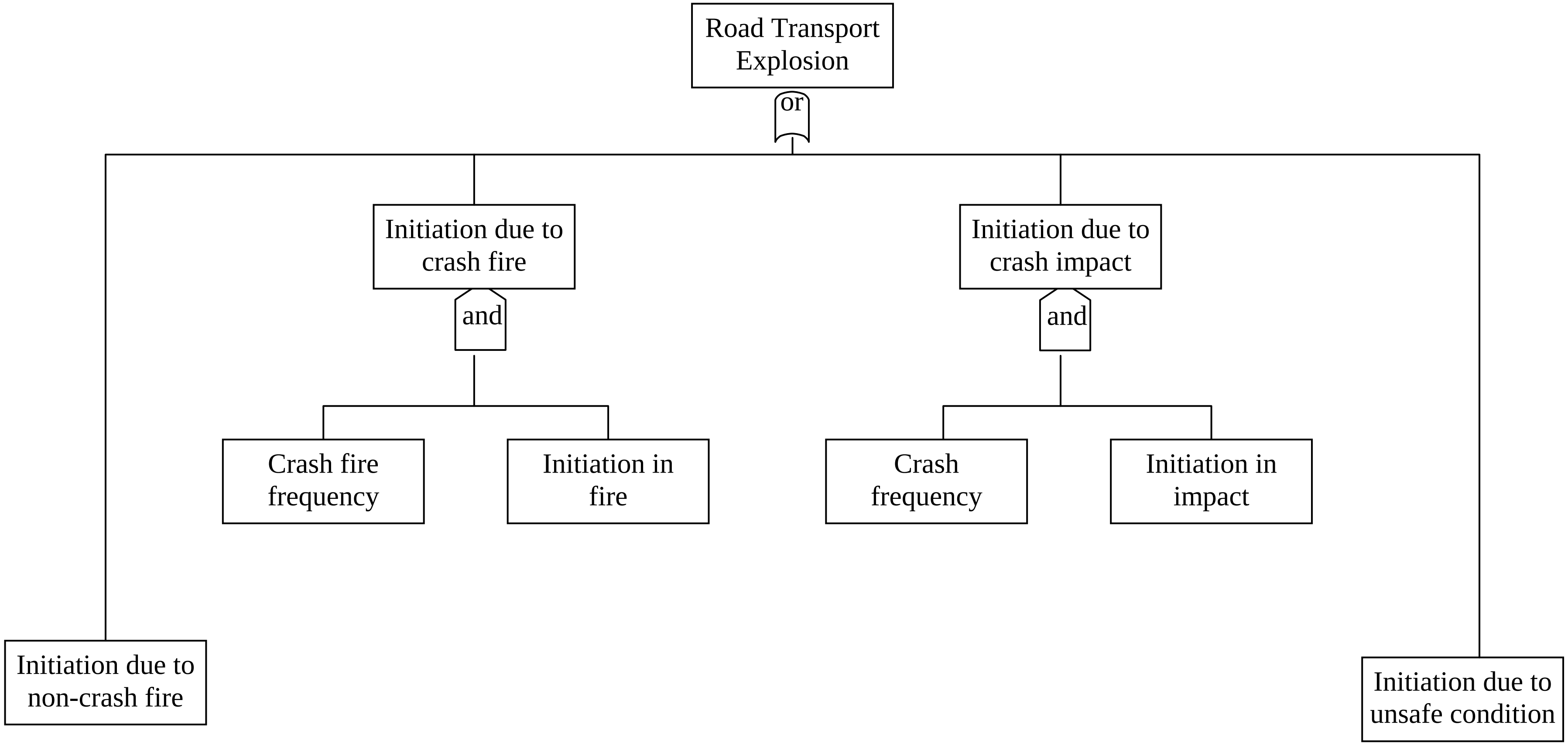
Table IV.3.2 Summary of Basic Incident Frequencies

EVENT	FREQUENCY (per km)
Accident Involvement	6.20×10^{-7}
Crash Fire	2.60×10^{-10} (1 in 2400 accidents)
Non-crash Fire	1.40×10^{-8} (independent of accidents rate)

3.3.3. Explosive Initiation Incident Frequencies

Based on the fault tree in Figure IV.3.1 an explosion initiation frequency of 4.1×10^{-9} per vehicle km has been applied in the analysis.

Figure IV.3.1 Explosive Incident Fault Tree



IV.4. DANGEROUS GOODS VEHICLE MOVEMENTS PER YEAR

An analysis of the dangerous goods movements per year is presented in section 6 of the main report. Based on the breakdown per road and rail route into and out of the Port Botany Terminal presented in Table 6.7, the dangerous goods trade figures estimated in Section 6 of the main report have been distributed along each of these routes.

IV.5. METHODOLOGY

This section describes the methodology applied in the review of the existing transportation routes from the proposed and existing Port Botany Container Terminals.

Using the inputs to the risk analysis of the port operations, a transportation risk model was developed. The model included the transportation of all dangerous goods with the potential for fatal impacts to the surrounding population lining the route and the road users sharing the roads with the dangerous goods vehicle.

The model estimated the risk based on the future throughput of the entire port, not just the expansion being proposed. Thus the total number of TEU included in this transport study was 3.4 million p.a., whereas the number of TEU assessed for site incidents was 1.5 million p.a.

Using DNV's SAFETI risk assessment software a range of potential incident scenarios for each of the dangerous goods classes was modelled along the main routes along which dangerous goods are transported.

Risk results were generated from SAFETI in the form of individual fatality risk contours.

An assessment of the risk results was undertaken using the risk criteria for land use planning from fixed installations in New South Wales published in the Hazardous Industry Planning Advisory Paper No. 4 (1990).

IV.6. TRADE ANALYSIS

A throughput for Port Botany of 3.4 Million TEUs has been used as the basis for the assessment of the risk due to dangerous goods transport.

Table IV.6.1 Summary of Port Botany Total DG Movements [1]

Class	Sub Class	No of Movements per Year					Totals
		<1 T	1 - 5T	5 - 10T	10 – 24T	24 - 30T	
1	1	19	0	0	0	0	19
	2	8	0	0	0	0	8
	3	69	15	23	84	0	191
	4	667	133	15	53	4	873
2	0	5491	2153	1269	861	0	9774
	1	2183	610	663	560	0	4016
	2	1608	366	271	450	103	2797
	3	400	141	84	160	0	785
3	0	4980	1254	412	1204	111	7960
	1	1791	545	133	408	11	2888
	2	8372	1715	633	1155	130	12003
	3	7770	2427	1101	2366	438	14103
4	1	774	191	213	2195	27	3399
	2	133	27	65	187	4	415
	3	202	80	50	1581	88	2001
5	1	1940	503	145	6699	229	9515
	2	183	95	15	23	0	316
6	1	2694	888	274	6634	697	11188
7	0	4	0	0	88	0	91
8	0	7354	2648	1002	4702	274	15981
9	0	2667	1440	2004	4352	194	10658
	Totals	49308	15231	8372	33761	2309	108980

Note: 1. Not all DG trade is electronically reported, however all *red line* DG's are required to be included in the electronic manifest.

Table 6.2 Summary of Port Botany Total Class 2.3 and Hydrogen Fluoride Movements

Class	Sub Class	DG	No of Movements					Totals
			<1 T	1 - 5T	5 - 10T	10 - 24T	24 – 100T	
2	3	Chlorine	30	8	4	72	0	114
		Sulphur Dioxide	69	4	8	4	0	84
		Other Class 2.3	301	130	72	84	0	587
		Total Class 2.3	400	141	84	160	0	785
8	0	Hydrogen Fluoride	8	23	0	30	15	84

.

Table IV.6.3 Summary of Dangerous Goods Movements Modelled in the PHA – Port Botany Throughput 3.4M TEUs

Dangerous Goods Class	Description	Representative Material	Unit Size and Number of Movements		
			NEQ < 1 tonne	NEQ 2 Tonnes	NEQ 12 Tonnes
1	Explosives	TNT	Screened out	188	143
				1 Tonnes	20 Tonnes
2.1	Flammable Gases	Propane	Screened out		252[2]
2.2	Non-flammable Gases		Screened out		
2.3	Toxic Gases	Chlorine	Screened out	84	0
		Sulphur Dioxide	Screened out	73	11
		Ammonia [1]	Screened out	202	386
3	Flammable Liquids	Hexane	Screened out	Screened out	5922
4.1	Flammable Solids	As per Class 3	Screened out		
4.2	Spontaneously Combustible		Screened out		
4.3	Dangerous When Wet	As per Class 3	Screened out		
5.1	Oxidising Materials	Ammonium Nitrate	Screened out	649	6930
5.2	Organic Peroxides		Screened out		
6.1	Toxic Materials		Screened out		
7	Radioactive Materials		Please refer to qualitative analysis		
8	Corrosive Materials	Hydrogen Fluoride	Screened out	29	45
9	Miscellaneous Materials		Screened out		

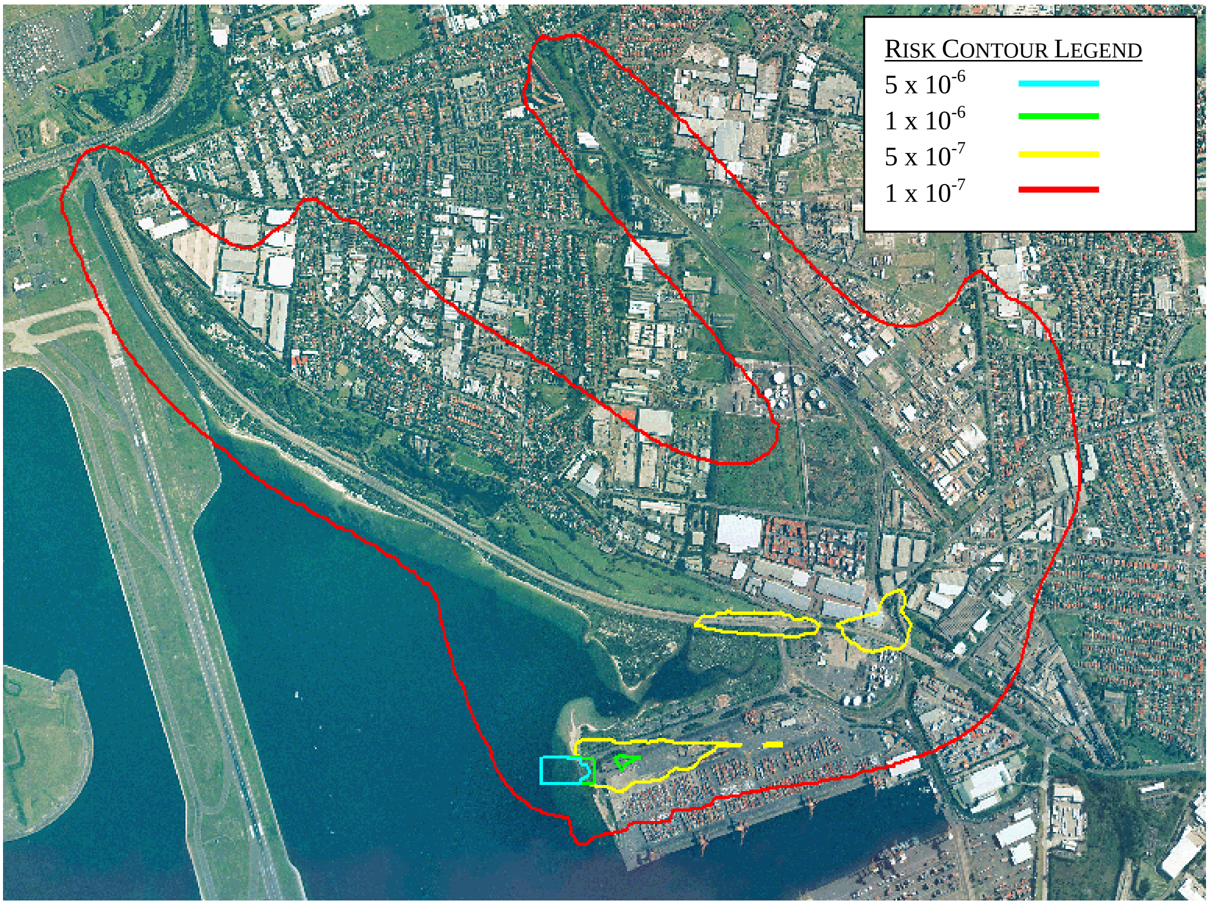
Notes:

1. Ammonia referenced as a representative material for all other Class 2.3 materials excluding Chlorine and Sulphur Dioxide due to their high toxic properties.
2. Only isotainers have been modelled as 20 tonnes movements. Trade involving more than 10 tonnes of flammable gases carried in a Package Type other than a tank (rectangular or cylindrical) have been assumed to be multiple numbers of smaller vessels together in a single container. In the event of a incident involving such as container it has been assumed that only a single vessel will be involved initially and that any potential escalation scenario will again only involve one other vessel of a similar type and size.

IV.7. RISK RESULTS - TRANSPORTATION

This section presents the transportation risk results for the current and future trade levels from the proposed and existing Port Botany container terminals. The risk results are presented in the form of individual risk contours for the entire local Botany area.

Figure IV.7.1 Transportation Risk Contour 3.4M TEUs



The risk contour in Figure IV.7.1 is characterised by the transport routes defined in the model. Dominant are the rail route through the centre of the figure and Foreshore Rd along the coast line towards the airport runway. High risk levels are shown in the yellow contours where the road and rail routes intersect and along the rear of the existing Patrick terminal where the rail line for the port expansion will be extended.

The risk due to the transportation of dangerous goods along Military Road is not shown on the contour due to the absence of movements in Chlorine and the limited number of movements using the route.

IV.8. RISK ASSESSMENT

The risk contours is Figure IV.7.1 show that the maximum fatality risk along a road carrying dangerous goods in containers to or from Port Botany is less than 5×10^{-7} p.a. This level of risk is less than the lowest risk criteria used for risk surrounding industrial premises and is less than 1% of the existing risk to road users due to road crashes not associated with dangerous goods.

Based on the results (Figure IV.7.1), the forecast combined dangerous goods trade imposes a risk to the land surrounding the transport routes of less than 5 in 10 million per year (5×10^{-7}). For the assessment of fixed installations in New South Wales, an acceptable limit of risk for residential area exposure of one in a million per year (1×10^{-6}) has been adopted.

These risk results should also be considered in line with other risks faced by road users and people living in the residences along the road route. The fatality risk due to all home accidents to people in general is 1 in a million per year (1×10^{-6} p.a.). The fatality risk to all people using roads is 1 in ten thousand per year (1×10^{-4} p.a.). Thus, the fatality risk to residents from dangerous goods movements in containers along roads outside their residences is less than one-tenth the risk of fatality from all other accidents. Similarly, the risk to road users due to dangerous goods movement through Port Botany is only one thousandth of the risk to other road accidents.

IV.9. CONCLUSIONS

The preferred road transportation route for dangerous goods to or from Port Botany is along Foreshores Rd except for the movements of dangerous goods to or from the Botany industry (dominated by exports of chlorine from the Orica site in Beauchamp Road and Denison St). It should be noted, these exports of chlorine no longer occur.

Given that the risk results for the proposed future case remain a fraction of the acceptable risk level for residential populations, the risk due to the transportation of dangerous goods to and from Port Botany should be considered acceptable.

IV.10.REFERENCES

ACDS 1991, *Major Hazard Aspects of the Transport of Dangerous Substances*, Advisory Committee on Dangerous Substances, Health & Safety Commission, HMSO.

Department of Urban Affairs and Planning 1998, *City South Freight Strategy*, DJA Maunsell.

DNV Technica, 1980, *Risk Assessment of Liquid Chlorine Transport*, Water Supplies Department, Government of Hong Kong, June 1980, Project C1918.

DNV Technica c1996, *Quantitative Risk Assessment of the Transport of LPG and Naphtha in Hong Kong - Methodology Report*, Electrical & Mechanical Services Department, Hong Kong Government**,** Project C6124.

DNV, 1996, *Comparative QRA of road tunnels*, Civil & Civic, October 1996, Project 2216.

DNV RiskNet, 2001, Offshore QRA Methods.

DNV, 1993, *Port Safety Study QRA*, Fremantle Port Authority, September 1993 Project A1020.

DUAP, 1994, *Applying SEPP 33 Hazardous and Offensive Development Application Guidelines,* Department of Urban Affairs and Planning.

DUAP, 1995, *Route Selection Guidelines for land use and environmental safety planning for hazardous materials – road transport considerations*, Final Draft, 10/11/95

DUAP, 1990, *Risk Criteria for Land Use Safety Planning,* Department of Urban Affairs and Planning

Sydney Ports Corporation, 2000, *Metropolitan Sydney International Container Origin/Destination Analysis,* August 2000.

Sydney Port Corporation, 2002. *Traffic Movement Analysis, Truck Numbers Spreadsheet. Presented in Minutes of Meeting between DNV and Sydney Ports, September 2002.*