Western Australia

Marine Oil Pollution Risk Assessment

Pilbara Zone Report

Prepared for Department of Transport

by Navigatus Consulting

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Department of Transport Western Australia

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Outputs in this Series

Web

Interactive web map application: http://wamopra.navigatusconsulting.com/login

Data

GIS attribute tables for DoT internal system.

Reports

- Navigatus, 2016 – WAMOPRA Preliminary State-Wide Assessment (*published*)
  - Appendix A – Exposure Results by Category
  - Appendix B – Web Based Interface
- **WAMOPRA Pilbara Zone Report (*this report*)**
- WAMOPRA Mid-West Zone Report (*in preparation*)
- WAMOPRA Swan Zone Report (*in preparation*)
- WAMOPRA Kimberley Zone Report (*scheduled FY 2018*)
- WAMOPRA South West Zone Report (*scheduled FY 2018*)
- WAMOPRA South Coast Zone Report (*scheduled FY 2018*)

1. Introduction

1.1. Overview

The Western Australian Department of Transport (DoT) is currently running a programme of work looking at matters around marine oil spills. One component of the work is the Western Australia Marine Oil Pollution Risk Assessment (WAMOPRA).

The WAMOPRA is being undertaken in two stages. In Stage One, Navigatus undertook a preliminary state-wide exposure assessment. Stage Two builds on the work developed in Stage One. It consists of specific zone-by-zone assessments and involves incorporating protection priorities and navigational hazard to create a full risk profile.

This document should be considered a companion report to the WAMOPRA web map application: http://wamopra.navigatusconsulting.com/. It summarises the context, methodology and results for the Pilbara Risk Assessment Zone. The other zones are: Kimberley, Midwest, Swan, South West and South Coast.

1.2. Programme Background

The purpose of the overall WAMOPRA programme is to build an assessment of the oil spill risk in Western Australian State waters. This assessment considers regional, national and international data for maritime activity and marine oil spills, current and future levels of activity and protection priorities including environmental sensitivities.

To undertake the WAMOPRA, DoT has commissioned two consultancies. Navigatus Consulting Limited is engaged to collect and analyse information on potential marine oil pollution exposure and build a risk model. Navigatus has special expertise in this field and have undertaken similar work in Victoria and New Zealand (Navigatus 2015).

The second consultant, Advisian, is collecting environmental data to identify protection priorities in the event of a marine oil spill. Protection Priority data is fed into the risk model developed by Navigatus to create a picture of oil spill risk including likelihood and consequence.

The results will guide oil spill contingency planning and will enable future resource allocations for oil spill response to take account of the level of identified risk. The main purpose of the risk profile is to inform:

- Decisions about resource allocation.
- Identification of areas where management is required to reduce risk.
- Evaluation of whether there is adequate spill response capability in areas of high risk.

Other requirements include:

- Fulfil obligations under WestPlan MOP.
- Ensure Western Australia is up to date with world standards in oil spill response.
- Complement the Oil Spill Response Atlas as a decision-making tool.

2. Scope

2.1. Pilbara Zone

This report summarises the context, methodology and results for the Pilbara Risk Assessment Zone. It builds on the work undertaken in the preliminary state-wide assessment. The geographical extents of the Pilbara Zone shoreline are shown in Figure 2.1 along with the other zones.

Figure 2.1 - Marine Oil Pollution Risk Assessment Zones

The primary output of this assessment is the web map application located at: http://wamopra.navigatusconsulting.com. GIS attribute tables are also held by DoT for use in internal systems. This report is a companion report to the website. Outputs in this report are in the form of heat maps, charts and tables.

2.2. Report Outline

The remainder of this report is structured as follows:

- **Context** – a brief overview of the contextual background informing the WAMOPRA. This includes shipping trends, the current state of the offshore petroleum industry and discussion of short and long-term scenarios.
- **Data Sources** – a summary of the data sources used in the WAMOPRA. As the Pilbara Zone report builds on the preliminary state-wide assessment some data sources are already discussed in the Stage One report. In these cases a shorter summary is provided and the reader is referred to the Stage One report.
- **Methodology** – a summary of the methodology used to develop the WAMOPRA. As with the data sources section there are elements of the methodology which are covered in the Stage One report. In these cases a shorter summary is provided and the reader is referred to the Stage One report.
- **Results** – a presentation of the various results produced by the WAMOPRA:
  - *Exposure* – outputs relating to exposure, i.e. the expected amount of oil in a given shoreline or sea location. Includes breakdown by vessel types and spill sizes. Exposure is combined with protection priorities to produce the Pilbara risk profile.
  - *Protection Priorities* – the primary output shown is a heat map of the overall protection priority ratings for the Pilbara Zone as provided by Advisian. These ratings are combined with exposure to produce the Pilbara risk profile.
  - *Risk Profile* – the primary output shown is a heat map which combines exposure and protection priorities to form a full risk profile. The risk profile is the primary risk output in this report and is the synthesis of all inputs into the WAMOPRA.
  - *Sub-Zone Drill Down* – a short section on each of four sub-zones within the Pilbara Zone (refer Section 5.2 for an explanation of sub-zones). A table is presented for each sub-zone which shows, for each of the shoreline cells in that sub-zone: cell name, overall risk rating, protection priorities ratings, a brief description of the overall protection priority rating and a brief comment on the key drivers of shoreline exposure. The key benefit of these tables is allowing trends in risk drivers to be seen across multiple cells.
- **Discussion** – an interpretation of the results with a focus on identifying key risk areas and risk drivers.
- **Summary** – summary of the key findings.

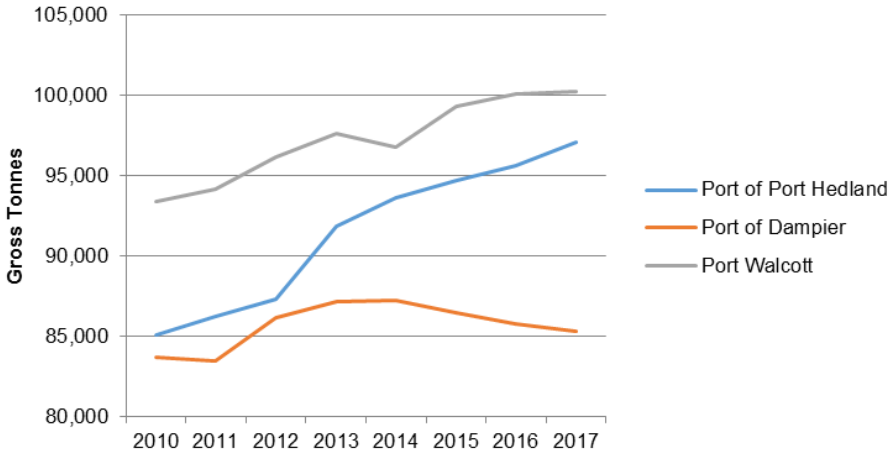
3. Context

3.1. Vessel Trends

Vessel Size

There is a general trend in shipping towards larger vessels as industry strives to realise gains from economies-of-scale. The Port of Port Hedland and the Port of Dampier are two of the world's largest bulk export ports. These areas see the highest levels of bulk carrier activity in Western Australia. To illustrate this, Figure 3.1 shows the change in average size of bulk carriers visiting the top three ports by bulk carrier visits.

Figure 3.1 - Average Bulk Carrier Size, 2010 – 2017



Data source: AMSA

Vessel Age

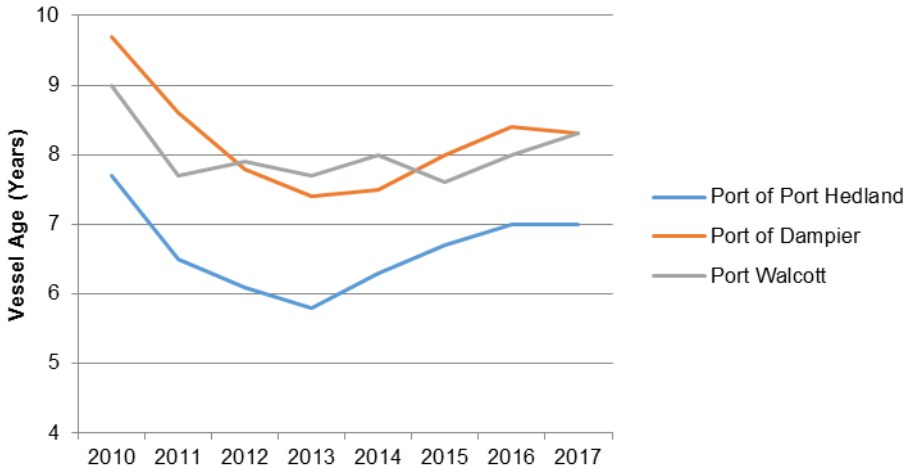
Vessel age is another factor to consider and has been identified by AMSA as one of the key predictive factors in overall vessel safety. Figure 3.2 shows the average vessel age for all vessels greater than 100 gross tonnes visiting the top three major ports.

Figure 3.2 - Average Vessel Age, All Vessels, 2010 - 2017 (AMSA)

Data source: AMSA

Figure 3.3 shows the average vessel age for bulk carrier vessels visiting the three major ports.

Figure 3.3 - Average Vessel Age, Bulk Carriers, 2010 - 2017

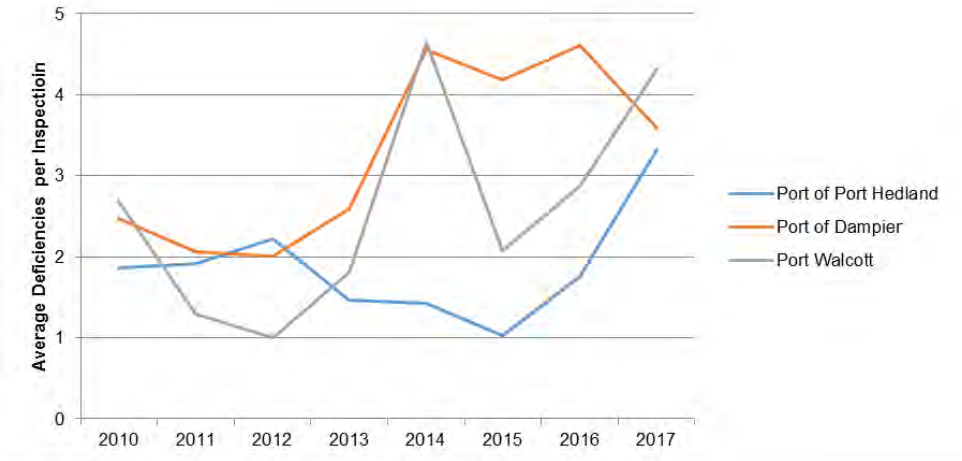


Data source: AMSA

Vessel Deficiencies

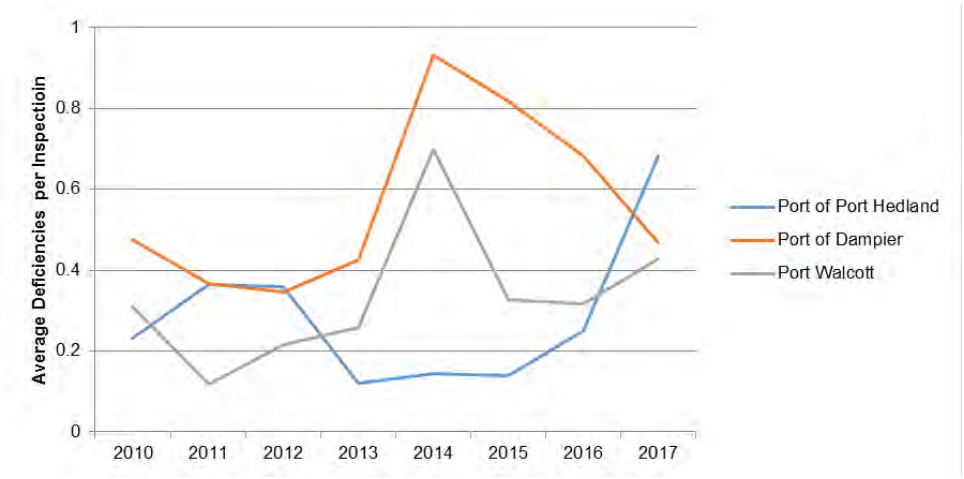
AMSA collects data on the numbers of vessel deficiencies found by the Port State Controls and Flag State Control inspections. Figure 3.4 shows the average number of deficiencies found per inspection at the ports.

Figure 3.4 – Average Deficiencies per Inspection



There are around 30 major deficiency categories in the AMSA data. These categories cover a wide range of administrative, procedural, structural and operational factors. Figure 3.5 shows the average number of deficiencies per inspection categorised as ‘Safety of Navigation’ at the ports.

Figure 3.5 – Average 'Safety of Navigation' Deficiencies per Inspection



3.2. Vessel Routes

Bulk carrier vessels dominate activity in the Pilbara region. However, another major export for the Pilbara region is liquefied natural gas (LNG). This is currently exported through the Port of Dampier. The Wheatstone Natural Gas Project is a major LNG facility under construction in Ashburton North, next to Onslow and proximate to gas resources in the Western Carnarvon Basin. Progression of this project will result in an increased number of LNG tankers transiting offshore. A potential route and exposure impact (which was explored in Stage One) is shown in Figure 3.6.

Figure 3.6 - Potential LNG Tanker Route

Another recent development is the introduction of the Pilbara Express Line. The Pilbara Express Line is a new dedicated service which will operate exclusively between Singapore and Dampier. The service will operate with a multi-purpose vessel for containerised, breakbulk and roll-on/roll-off cargo.

Proposed coal exports to India from the Port of Abbot Point (located in Queensland) may result in some increased traffic in the far north of the offshore Pilbara zone. However this traffic will be a significant distance from land and is therefore not likely to have any impact on the shoreline risk profile.

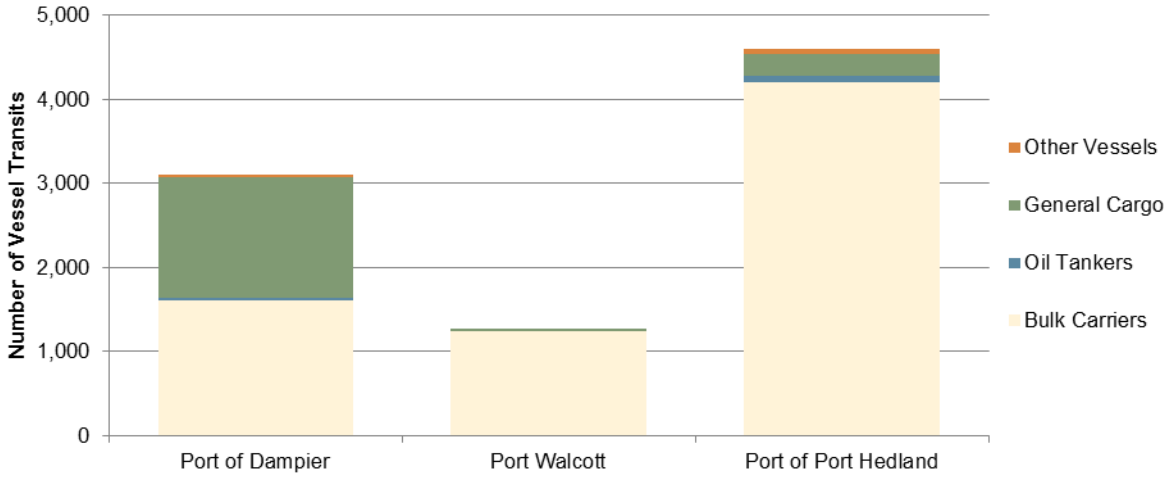
Other trends such as changes from heavy bunker fuels to distillate fuels in response to IMO regulations are discussed in the state-wide report. It is not expected these will have an immediate effect on the Pilbara risk profile.

3.3. Major Ports

Overview

The following sections contain contextual information for the three major ports in the Pilbara region. As an indication of activity levels at these ports, Figure 3.7 shows the numbers of transits[1] by different vessel types Port Hedland, Port Walcott and Dampier Port. These ports are all frequented by bulk carriers. Port Hedland and Port of Dampier also have high numbers of visits by a range of other commercial vessels.

Figure 3.7 – Annual Vessel Transits to and from Ports



The report also contains discussion of the Port of Ashburton, Onslow and Wheatstone. This area sees lower activity levels but is undergoing significant developments.

Port of Port Hedland

Port Hedland has been developed as a major iron ore and salt exporter and for the servicing of offshore oil and gas rigs. Other uses include exports of manganese, copper concentrates, livestock and industrial tourism (cruise ships).

Port Hedland has separate inward and outward navigational routes. Deep-draught vessels which need to use the main fairway approach inward enter the port through a dredged channel, the seaward end of which lies 22 nautical miles (40.7km) NNW off the coast at the harbour entrance. These vessels require marshalling and extended pilotage.

The channel width is generally greater than 200m, narrowing to 162m in the Newman and Goldsworthy straights and 205m at Hunt Point. Anchorage areas are to the west and east of Cape Legendre.

[1] A transit is defined as a single movement. A ship visiting a port will usually comprise two transits.

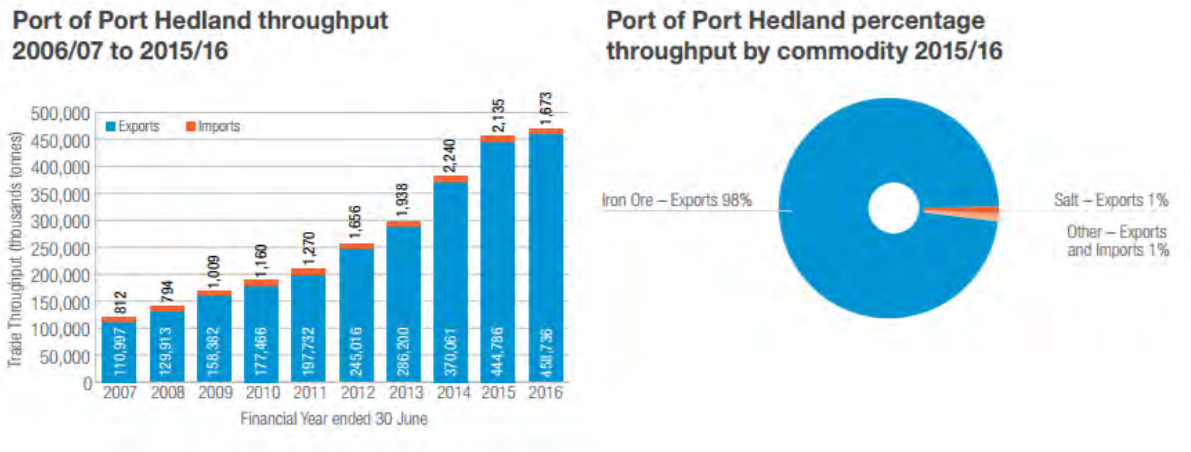
Port Hedland has a mean spring tidal range of about 5.5 metres and a mean neap tidal range of about 1.3 metres. The port is occasionally closed due to large northerly swells during cyclones which may occur between November and April *(Admiralty Sailing Directions Australian Pilot Volume 1).*

Other key contextual elements relating to the Port of Port Hedland are:

- Deep-water inner harbour.
- World's largest bulk commodities export port.
- Focus on facilitating trade for the resource sector.
- The large tidal range experienced in Port Hedland together with the long channel length means it is necessary to carefully manage vessel sailing drafts. This has resulted in an ongoing dredging programme in conjunction with marine technology such as the Dynamic Under Keel Clearance system to maximise vessel draughts.
- Pilbara Port Authority is progressing with a two-year, $120 million Channel Risk and Optimisation Project (CROP) designed to reduce the risk of an obstruction in the Port Hedland shipping channel and allow port users to further maximise loading of product onto their vessels.
- CROP involves a new emergency passing lane, provision of a deep-water refuge zone and improved use of existing deeper depths along Port Hedland's 42km channel. The project will allow disabled vessels to safely anchor in the deep water refuge zone, enabling other vessels to continue to navigate in and out of the port, which ensures continuity of port operations.
- CROP also involves targeted dredging of the channel, resulting in an ability to fully realise the existing channel depth, allowing port users to further optimise the use of their draft restricted vessels.
- In addition to CROP, Pilbara Ports Authority has commenced development of an Integrated Marine Operations Centre and Channel Marker Replacement program. The primary aid to navigation along the 42km shipping channel and through the harbour entrance is via 70 channel markers. The channel markers outline the channel boundaries and provide visual guidance to vessel pilots using the shipping channel.
- Port Hedland Vessel Traffic Services (VTS) provides a 24 hour, seven day a week Information Service (INS) and a Traffic Organisation Service (TOS) to all vessels navigating within the VTS area. It maintains a comprehensive vessel traffic surface picture, interacting with vessels as required, providing essential information to assist in onboard decision making processes.

Figure 3.8 shows a breakdown of throughput at the Port of Port Hedland.

Figure 3.8 - Port of Port Hedland Throughput



Source: (WA DoT 2016)

References: *(Australian Hydrographic Service & United Kingdom Hydrographic Office 2014; WA DoT 2016; Pilbara Ports Authority 2016a; Pilbara Ports Authority 2015; Pilbara Ports Authority 2016b; AMSA & WA DoT 2011)*

Port Walcott

Port Walcott is in the top five ports in Australia by volume with exports reaching nearly 184 million tonnes in 2015/16. It is situated between the Port Hedland and the Dampier and is principally used for the export of iron ore.

The port is approached from the Shipping Fairway and entered from the anchorage area. Departure from the port is made through the marked channel which leads to Bass Pass

Berthing may take place at any stage of the tide except during the period of spring tides when vessels are required to wait for slack water.

References:*(Rio Tinto 2016; WA DoT 2016; Australian Hydrographic Service & United Kingdom Hydrographic Office 2014)*

Port of Dampier

The Port of Dampier is a busy port and a major iron ore, LNG and salt exporting port. The port is also the main operational base for contractors working on the North West Shelf natural gas project. Dampier has a mean spring tidal range of about 3.7 metres and a mean neap tidal range of about 1 metre.

There are strong currents off the coast especially during springs. However tidal streams are weak within the archipelago.

Dampier is situated in the cyclone belt with an incidence of about three cyclones per year. The season lasts from November to April. The prevailing winds are easterly in winter and south-westerly in summer and can blow for sustained periods at more than 20 knots.

Other key contextual elements relating to Port Dampier are:

- Multi-commodity port.

- Focus on general cargo trading.
- Infrastructure and systems to support marine services sector and resources industry.
- Some congestion challenges and infrastructure that is at or near full capacity
- Growth opportunities include development of a general cargo logistics hub, enhanced supply base and marine services facilities, expansion of the port's fuel and hydrocarbon importation
- Realisation of growth opportunities will depend on global demand for oil and gas and the subsequent effects on exploration drilling in the Carnarvon Basin, potentially leading to discovery of further gas fields.
- Targeting increased cargo volumes and regularity to maximise economies of scale and liner services to South East Asia.

References: *(Australian Hydrographic Service & United Kingdom Hydrographic Office 2014; WA DoT 2016; Pilbara Ports Authority 2016a; Pilbara Ports Authority 2015; Pilbara Ports Authority 2016b; AMSA & WA DoT 2011)*

3.4. Petroleum Industry

Petroleum industry activity in the Pilbara region has been largely defined by lower oil prices. A number of decommissioning activities occurred in the second half of 2016 and the beginning of 2017.

Statistics show that recovery in exploration activity is usually around 18 months after the recovery in oil prices. By this measure, even if the oil price were to recover in the short term, the low level of exploration is likely to continue (DMP 2017).

There is however sufficient LNG demand to drive the development of the Wheatstone Natural Gas Project. As discussed in the state-wide report (Navigatus, 2016) this is a major LNG facility under construction in Ashburton North, next to Port Onslow and proximate to gas resources in the Western Carnarvon Basin. The effect of gas development on oil pollution risk profiles tends to be relatively low as any liquid product quickly dissolves or evaporates.

The majority of petroleum facilities in the Pilbara zone are located a significant distance from the shoreline.

Figure 3.9 and Figure 3.10 show the proportion of production wells and the proportion of overall facilities by oil type respectively in the Pilbara region.

Figure 3.9 - Proportion of Production Wells by Oil Group in Pilbara

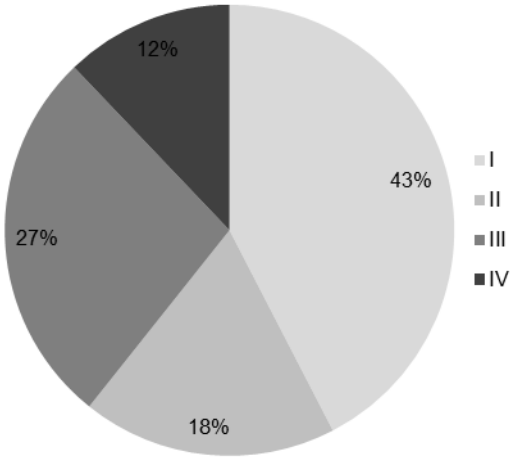
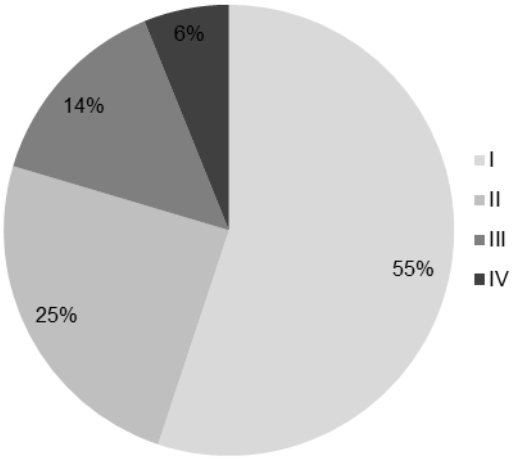


Figure 3.10 - Proportion of Production Facilities by Oil Group in Pilbara



The proportion of both wells and facilities producing condensate (Group I) and light crudes (Group II) is greater than half in the Pilbara region. These oil types are defined as dissolving and do not travel as far as Group III and Group IV oils. This combined with the fact the majority of petroleum facilities in the Pilbara zone are located a significant distance from the shoreline means large shoreline exposure is not expected. Data sources for the above figures and for the Petroleum industry inputs into the WAMOPRA are discussed in Section 4.4.

4. Data Sources

4.1. Overview

The analysis requires a wide range of data inputs, including:

- Vessel activity:
  - Vessel types, routes and number of transits.
  - Vessel cargo types and volumes.
- Ports and marine terminals:
  - Port locations, bunkering and transfers.
- Petroleum industry activity - locations, purpose, phase, oil types and related activity for; wells, platforms, pipelines, FPSOs.
- Spill events:
  - Event occurrence frequencies for vessels and offshore infrastructure.
  - Resulting spill size probability density functions.
- Environmental conditions - wind and current data.
- Oil classifications.

These data sources are discussed in the preliminary state-wide report and a brief outline of vessel activity, petroleum industry data and navigational hazard data is provided below as these data sources have seen updates since the state-wide report.

4.2. Vessel Activity

Vessel activity inputs in the model are primarily based on Automatic Identification System (AIS) data which is collected and held by AMSA. Navigatus commissioned AMSA to interrogate the AIS information system and provide three years of processed data in a suitable format for further pre-processing and incorporation into the model. The steps taken by AMSA were:

- Filter data set for relevant geographic scope and three-year time period from 2013 to 2015.
- Use ship inspections ('ShipSys') database to populate vessel type and size information missing from AIS data.
- Use GIS tool to convert individual AIS 'point' reports to 'line' voyages based on report time.

The resulting data was then provided to Navigatus and a density analysis was undertaken on the vessel tracks. This determined the number of vessel transits per year through each 10km hexagon sea cell for each vessel type/size category. The process included grouping vessels into the following categories for the WAMOPRA outputs:

- Bulk Carriers
- Chemical Tankers
- General Cargo
- Container
- Gas Carrier

- MODUs FPSOs Transit
- Commercial
- Oil Tankers
- Passenger

The use of AIS data to populate vessel activity information is further described in the state-wide report (Navigatus, 2016). This stage also saw the incorporation of vessels closer to shoreline and outside of traditional shipping routes. An algorithm was used on AIS data to simulate the presence of vessels off track as well as coastal operations of smaller vessels whose behaviour is less predictable. Vessels smaller than 100GT are not considered in the analysis for the following reasons:

- Smaller vessel activity is typically more erratic and unpredictable.
- Below this size vessels tend to store fuel in separate tanks rather than against the hull so are less likely to spill in the event of a collision.
- To reduce the 'noise' from small vessels which do not have the potential to add significantly to the risk profile (although, as discussed in Section 6.2 spill responders will typically respond to spills from smaller vessels with greater frequency than larger vessels).

4.3. Navigational Hazard

This stage of the WAMOPRA incorporated a navigational hazard factor. This was determined through the following formats:

- Examination of navigation charts and the Australian Pilot *(Admiralty Sailing Directions Australian Pilot Volume 1).*
- A workshop with expert mariners who are familiar with the Western Australian coastline facilitated by Navigatus and held in Fremantle.
- Interviews with WA State Harbourmasters and Harbourmasters of Port Hedland and Dampier conducted by Navigatus in Fremantle and in the respective ports.

The development of the navigational hazard ratings and incorporation into the model are outlined in the Methodology section.

4.4. Petroleum Industry

Western Australian petroleum producers were contacted with a request to provide data for the WAMOPRA. Operators were asked to fill out a questionnaire designed to gather information on offshore petroleum assets and activities. The primary focus was to capture the location, status and product type of offshore assets that each organisation operates. Operators were also asked to provide contextual comments relating activity levels at wells and the number of exploration and development wells drilled per year.

As mentioned above, the Stage Two assessment involved moving from public data sources of petroleum activities from prior years to acquisition of information directly from operators about current and future operations. Key differences from the data used in Stage One are:

- Product types are lighter than those originally input into the model. There is a greater proportion of facilities producing gas and condensate (Group I), as well as Group II oils. These oils are defined as dissolving and do not travel as far as Group III and Group IV oils. The change in oil types from the data used in the state-wide

assessment may be due to the natural progression of fields over time as product is extracted. The Wheatstone LNG project also means there are more gas facilities coming on board. These have been included in the current analysis.

- Some producing facilities have been decommissioned or suspended. This is due to a combination of lower oil prices and facilities being towards the end of their producing lifespan.
- There was a notable reduction in exploration activity compared to the public data sets used in Stage One which were based on earlier years. This is a result of three years of lower oil prices. As noted in Section 3.4 exploration activity tends to rebound around 18 months after oil prices recover. Therefore, the profile resulting from these inputs remains relevant for the near to medium term future.

Data was obtained from operators on the basis that individual operators would not be identified in the outputs of this study due to commercial sensitivities.

5. Methodology

5.1. Overview

The following sections outline key elements of the WAMOPRA methodology, or elements that have been introduced or modified in Stage Two. These include:

- Spatial Framework – the spatial basis for the WAMOPRA modelling and outputs.
- Navigational Hazard
- Exposure and Risk – an explanation of two key output measures, how they are defined and displayed.
- Limitations – a brief note on the limitations of the WAMOPRA given its primary use as a strategic-level tool.

5.2. Spatial Framework

The model is based on two layers of cells; shoreline cells and a hexagonal sea cell grid.

Shoreline cells are used for visualising shoreline risk and exposure. The shoreline cell layer consists of cells which are 20km long (along the coast) by 10km wide (seaward extent) and which are compliant with shoreline features and shape.

The shoreline cells display exposure, protection priorities and risk for shoreline areas that could credibly be affected by contact with, or proximity to, either floating or dissolving oil. Therefore, the 10km width is a nominal distance, rather than representing the true seaward extent of oil impact, and primarily set for visualisation purposes.

There are 62 shoreline cells in the Pilbara region. For the purposes of this report, shoreline cells are also grouped into four ‘sub-zones’ to facilitate comparisons between wider areas in the Pilbara zone.

The four sub-zones from West to East are: WA10, WA11.West, WA11.East and WA12. The shoreline cells and sub-zones within the Pilbara zone are shown in Figure 5.1.

The hexagon grid is an underlying system of 10km hexagon cells representing open water ocean areas. It is used for visualising and analysing activity and exposure. The grid covers all of WA’s shoreline and extends approximately 200-300km seaward off all shorelines. It enables modelling of potential oil release, oil dispersion and the likelihood of reaching shore. The grid does not include Christmas Island.

The grid is used for storing vessel activity information, positions of offshore elements and environmental factors of the modelling. This system includes flags for cells representing ports and harbours to account for vessel related activity, oil-handling-processes and constrained waterways. The hexagon grid is also the basis of Navigatus modelling of oil dispersion, with the geometry enabling the computational efficiency needed for such a large geographic area.

The state-wide report contains additional information on the shoreline and hexagon cells.

Figure 5.1 - Pilbara Shoreline Cells and Sub-Zones

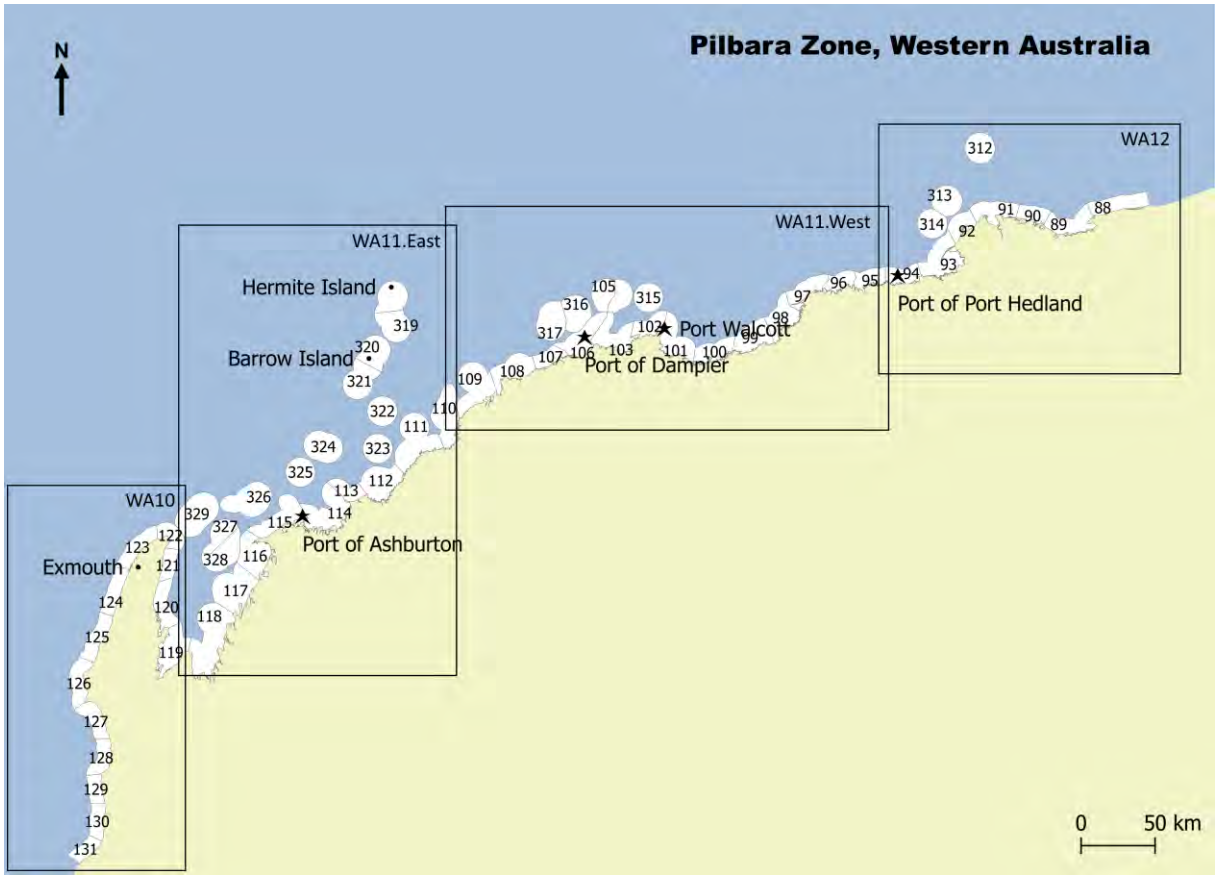


Table 5.1 – Cell identity numbers to names listing

Cell ID	Cell Name	Cell ID	
88	Shoonta Well - Cooraidegel Well coast	118	Hope Point - Locker Point (D)
89	Condini Landing - Mulla Mulla Creek	119	Learmonth - Point Lefroy
90	Yan Well coast - Condini Landing (A)	120	Bundegi - Shothole Canyon N (A)
91	Yan Well coast - Condini Landing (B)	121	Bundegi - Shothole Canyon N (B)
92	Wattle Well coast - Yan Well coast (A)	122	Vlamingh Head - North West Cape
93	Wattle Well coast - Yan Well coast (B)	123	Low Point - Vlamingh Head (A)
94	Beebingara Creek coast E - Wattle Well coast	124	Low Point - Vlamingh Head (B)
95	Turner River NE foreland - Beebingara Creek coast E (A)	125	Osprey Bay - Low Point
96	Turner River NE foreland - Beebingara Creek coast E (B)	126	Winderabandi Point - Osprey Bay
97	Cape Thouin - Turner River NE foreland	127	Coast Hill - Point Cloates
98	Cape Cossigny - Cape Thouin	128	Point Maud - Coast Hill (A)
99	Sherlock coast - Cape Cossigny (A)	129	Point Maud - Coast Hill (B)
100	Sherlock coast - Cape Cossigny (B)	130	Alison Point - Point Maud
101	Cape Lambert - Sherlock coast (A)	131	Gnarraloo Bay - Alison Point (A)
102	Cape Lambert - Sherlock coast (B)	312	Yan Well coast - Condini Landing (C)
103	West Intercourse Island - Dolphin Island N point (A)	313	Wattle Well coast - Yan Well coast (C)
104	West Intercourse Island - Dolphin Island N	314	Wattle Well coast - Yan Well coast (D)

	point (B)		
105	West Intercourse Island - Dolphin Island N point (C)	315	Dolphin Island N point - Cinders Rd coast
106	West Intercourse Island - Dolphin Island N point (D)	316	West Intercourse Island - Dolphin Island N point (F)
107	West Intercourse Island - Dolphin Island N point (E)	317	West Intercourse Island - Dolphin Island N point (G)
108	Pelican Point - West Intercourse Island	318	Barrow Island and Montebello Islands (A)
109	James Point - Cape Preston	319	Barrow Island and Montebello Islands (B)
110	Mount Salt coast W - James Point	320	Barrow Island and Montebello Islands (C)
111	Peter Creek coast E - Mount Salt coast W	321	Barrow Island and Montebello Islands (D)
112	Weld Island coast S - Peter Creek coast E	322	Barrow Island and Montebello Islands (E)
113	Coolgra Point W - Yardie Landing (A)	323	Yardie Landing - Weld Island coast S (A)
114	Coolgra Point W - Yardie Landing (B)	324	Yardie Landing - Weld Island coast S (B)
115	Hope Point - Locker Point (A)	325	Coolgra Point W - Yardie Landing (C)
116	Hope Point - Locker Point (B)	326	Baresand Point - Entrance Point E
117	Hope Point - Locker Point (C)		

5.3. Navigational Hazard

Overview

The overall navigational hazard factor is comprised of the following factors:

- **Physical Features** – in particular submerged and non-drying features. Considerations include likelihood of groundings, collisions, ease of navigation using radar.
- **Complexity** – reflects multifaceted operations / mix of vessel types and activities as well as environmental conditions such as wind, currents, swell and lee shore.
- **Activity Density** – this includes number of vessel movements and other marine activities.

These factors are combined to form an overall navigational hazard rating.

The navigational hazard for each cell around the Western Australia coastline was rated as minor, moderate, significant, major or critical for each of the above factors according to Table 5.2.

Table 5.2 - Rating System and Values

Issue Rating	Description	Value Assigned
Critical	Expected to lead to a future incident.	25
Major	Expected to be a key factor in contributing to an incident.	16
Significant	Individually controllable, but in combination with other factors could contribute to an incident.	9
Moderate	A factor that can be managed in normal operations.	4
Minor	Well within normal operation to manage or respond to (minor matter).	1

The following describes how each of the factors was determined:

Physical: Physical hazards were identified in workshops with expert mariners. All non-surface physical features have the potential to be hazardous should a vessel be in the close vicinity. To account for this all shoreline areas received a higher default rating than open sea areas (Low instead of Very Low) and subsequent efforts were focussed around areas with higher traffic density, e.g. ports.

Complexity: Complexity ratings were identified in workshops with expert mariners. The complexity rating includes the complexity of approach operations as well as environmental conditions wind, currents, swell and lee shore.

Activity Density: The model uses annual vessel transits through a cell as a key input for calculating exposure and risk. This is an arithmetic calculation and increases linearly as transits increase (e.g. two transits give rise to twice the risk of one transit).

However, as shipping density increases other factors come into play such as the interaction between ships. These interactions can mean higher risk of collision, lower margins of error and the potential need for evasive manoeuvring. Overall, this results in a further increase in risk. This additional risk is captured in the model through the activity density rating.

Strictly the number of vessel transits is incorporated only once in the model, however, the activity density measure represents the risk through the interaction between ships. Activity density was determined based on vessel tracks generated from AIS data.

Synthesis of Hazard Factors

The three separate factors are combined to form an overall Navigational Hazard Rating. This is determined by summing the individual rating values as shown in Table 5.3.

Table 5.3 - Overall Navigational Hazard Ratings

Sum of Individual Factors	Overall Rating	Overall Value	Risk Modifier	Display Colour
>30	Very High	25	25/9 = 2.78	
21-30	High	16	16/9 = 1.78	
11-20	Moderate	9	9/9 = 1	
6-10	Low	4	4/9 = 0.44	
<=5	Very Low	1	1/9 = 0.11	

In the WAMOPRA model, each vessel type in a given cell is assigned a base accident / spill rate. This base accident rate is adjusted up or down according to the navigational hazard in the area. To do this the base accident rate in each cell is multiplied by a modifier (Risk Modifier above). The modifier is normalised to the 'Moderate' level to reflect that operational safety in Western Australia is high relative to global standards.

5.4. Exposure and Risk

Key measures of output are exposure and risk. The first step in calculating risk is determining exposure. Exposure can be considered statistically as the total 'expected' amount of spilled oil that would be spilled in or arrive at a given cell in an 'average' one year period.

Fundamentally exposure is based on:

- Likelihood of a vessel being present (number of transits per year) OR presence of offshore petroleum infrastructure.
- Likelihood of a spill event (e.g. grounding, collision, well blowout) conditional on the above.
- Likelihood of different spill size possibilities (ranging from 1 tonne through to 500,000 tonnes) conditional on the above.
- Movement of oil (taking into account wind, currents and degradation) conditional on the above.

Exposure is presented according to the following continuous scale:

Figure 5.2 - Exposure Scale

In turn, risk is determined by combining exposure with protection priorities in the following manner:

Figure 5.3 - Calculation of Risk

Risk outputs are provided for each shoreline cell on a five step scale ranging from very low to very high. The risk scales are shown in Figure 5.4.

Figure 5.4 - Risk Scales

The information presented assesses the risk and exposure for all sources of oil that may end up on the shore in that cell. Some of the oil may originate from spills in other nearby cells, or from more distant seaward sources.

Shoreline risk and exposure outputs are for areas within state waters only.

5.5. Limitations

The WAMOPRA study has the following key limitations:

- The study was carried out at a level of detail appropriate for a strategic level study. The range of spill sizes considered was 1 tonne up to 500,000 tonnes and the physical discrimination for impacts was based upon a 20km coastline distance and 10km hexagonal open water cells.
- The calculated risk profile is built upon available local and global information. Analysis cannot predict specific future events, only likely outcomes over time based on the balance of probabilities. This study is based upon the data available – either via public sources, or as supplied by stakeholders - and the quality of the findings is determined in part by the quality of that data.

6. Results

6.1. Navigational Hazard Results

Navigational Hazard Factors

The results for the individual physical, complexity and activity density factors are shown respectively in Figure 6.1, Figure 6.2 and Figure 6.3. The overall navigational hazard heat map is shown and discussed in the following section. Note that in each of the heat maps navigational hazard information for hexagon cells outside of the Pilbara region is not shown.

Figure 6.1 – Physical Hazard Ratings

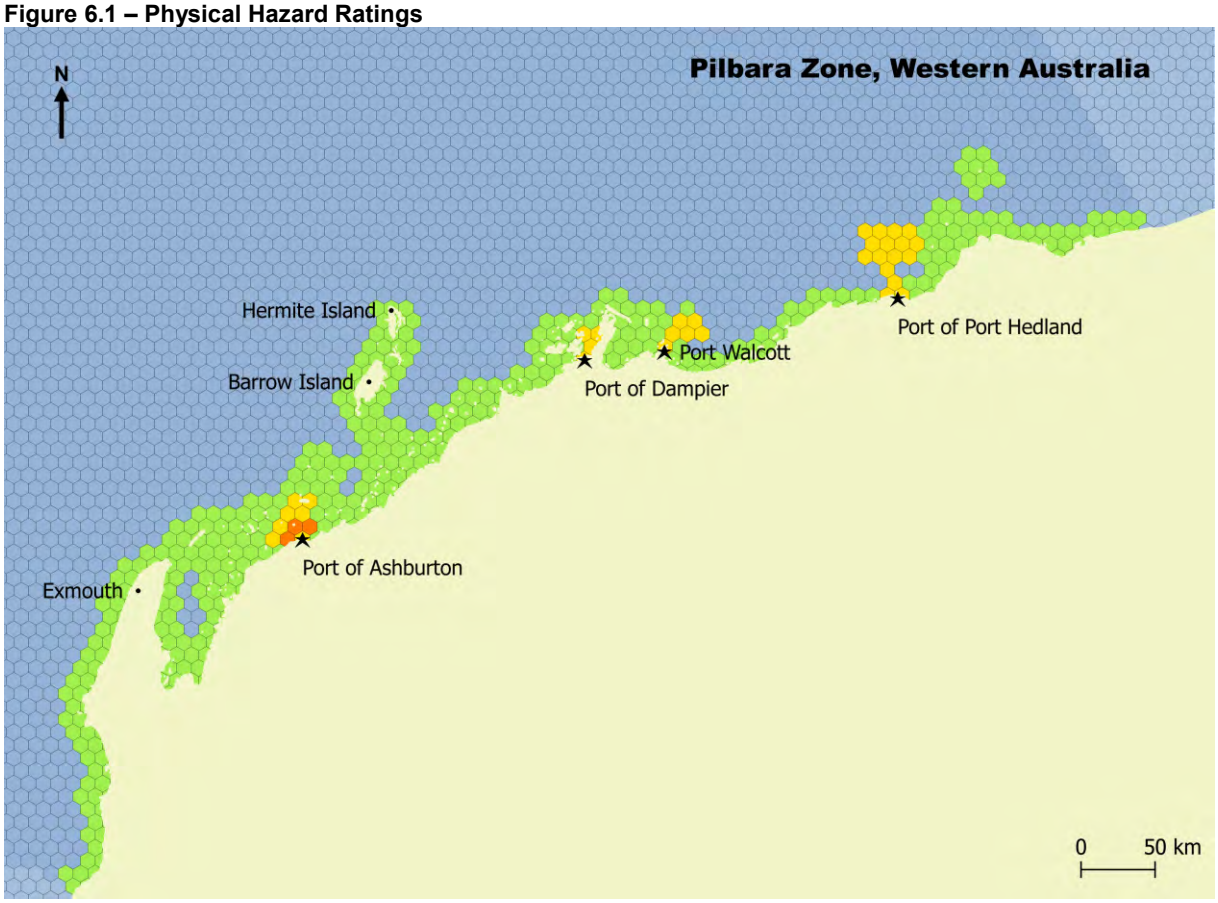


Figure 6.2 – Complexity Ratings

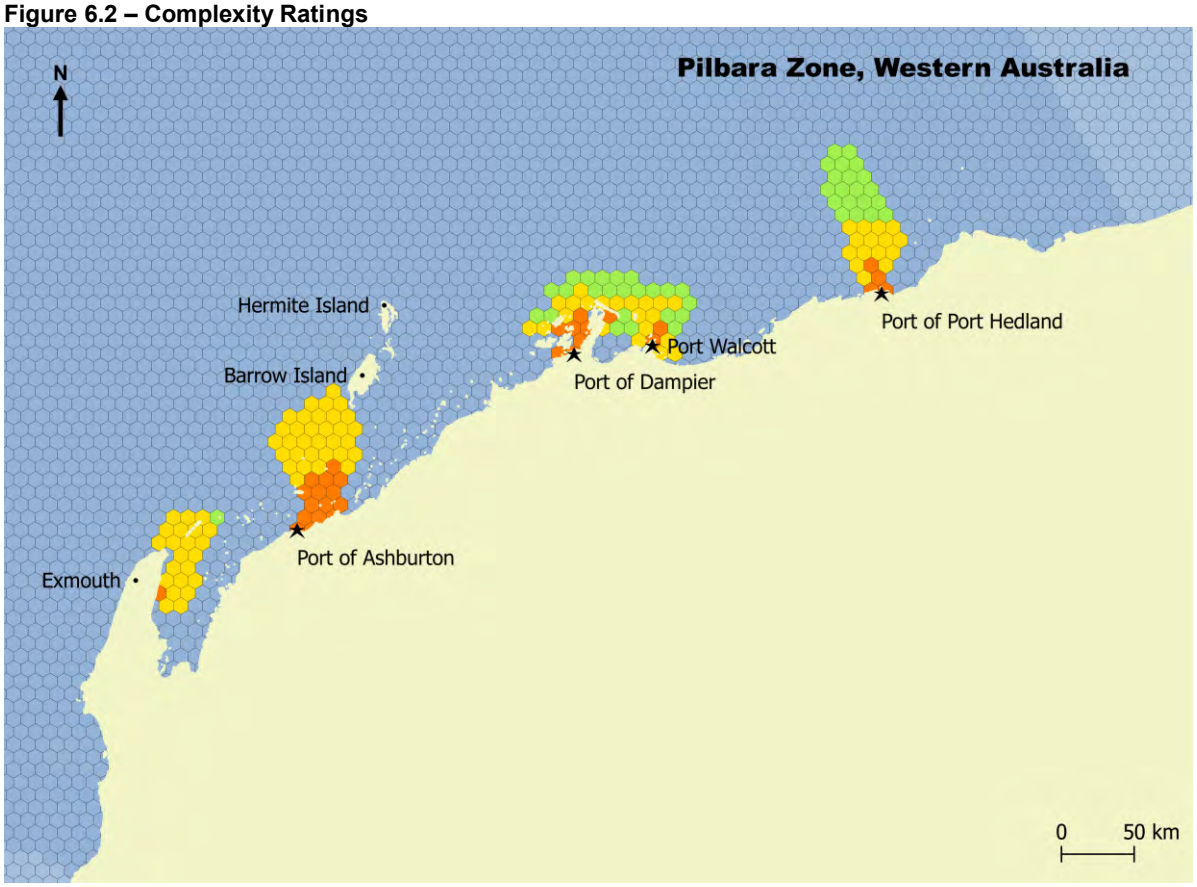
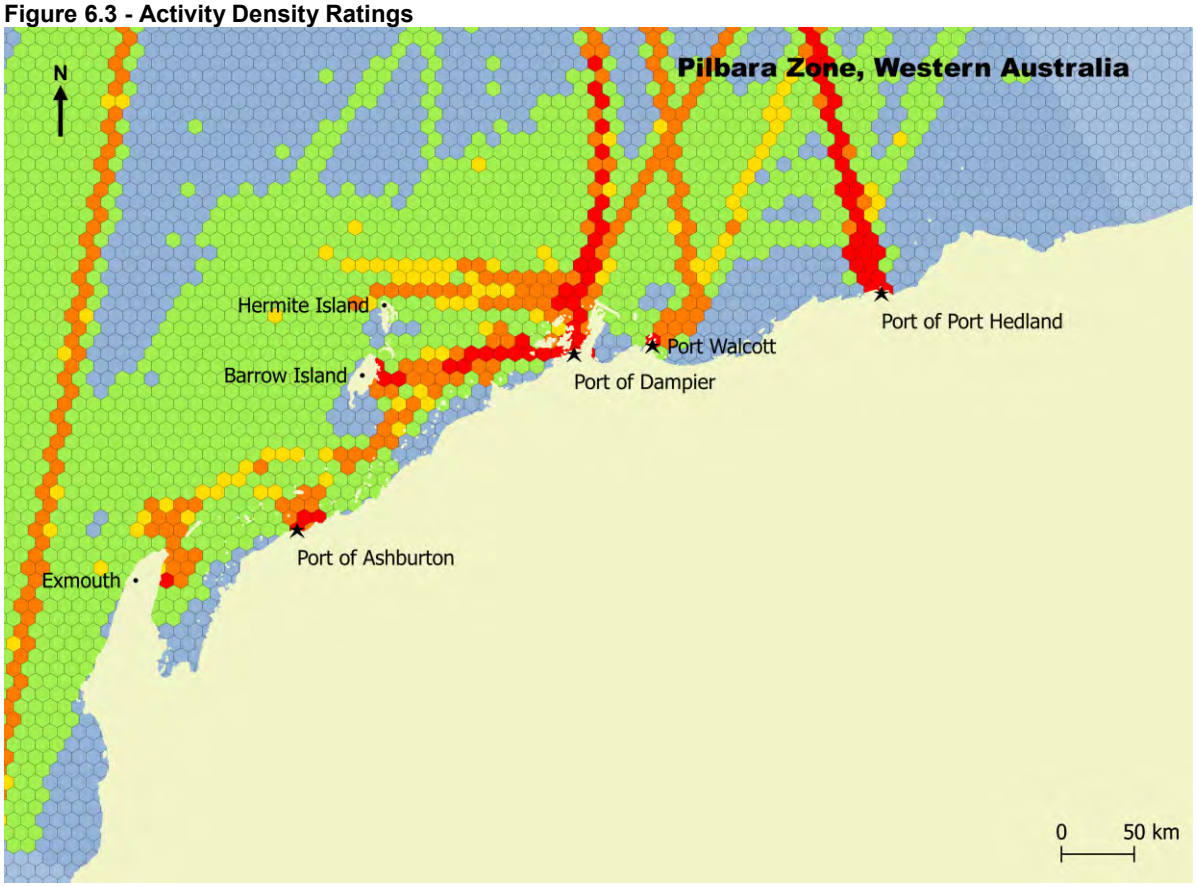


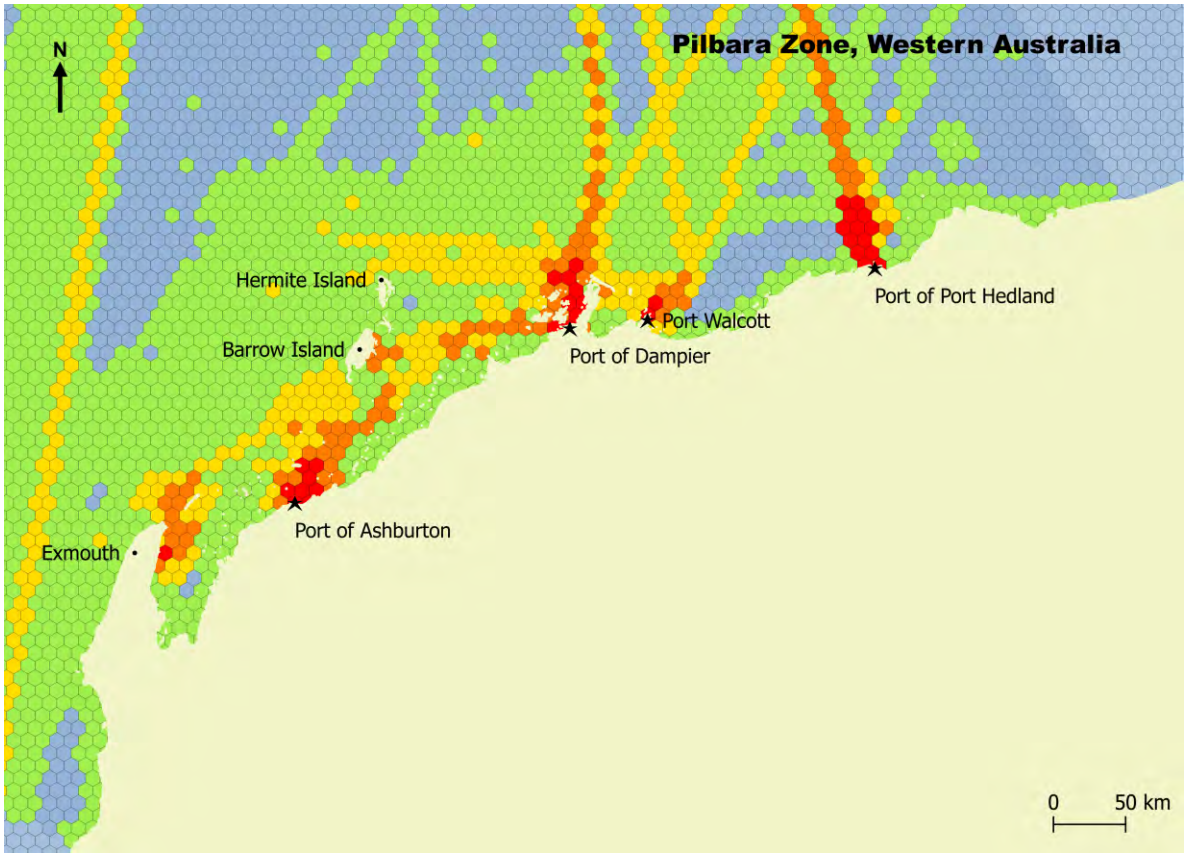
Figure 6.3 - Activity Density Ratings



Overall Navigational Hazard

The combination of the three factors produces an overall rating as described in Section 5.3. This overall navigational hazard rating is shown in Figure 6.4 and a brief description of the driving factors for each major port area is provided below.

Figure 6.4 - Overall Navigational Hazard Ratings



Port of Port Hedland and Approach

Contextual comments for the Port of Port Hedland can be found in Section 3.3. Navigational hazard ratings for the Port of Port Hedland and approach are driven by:

- Single, long deep-water channel approach.
- Constrained time window for departures and arrivals of deep draught vessels.
- Multiple vessels managed in one orchestrated operation.
- Constrained turning room in the port area.
- At times significant number of large anchored vessels in the anchorage areas to the east and west of the channel.

These factors result in individual factor ratings ranging from moderate through to major for physical and complexity categories and ranging up to critical for activity density. Overall this results in very high levels of navigational hazard for the Port of Port Hedland and approach. However, it is noted that the advanced operational management of Port of Port Hedland and approach reflects the inherent challenges associated with a major export facility. As noted in the Section 3.3 the Pilbara Ports authority is implementing and maintaining a range of operational safety enhancements.

Port Walcott

Contextual comments for Port Walcott can be found in Section 3.3. Navigational hazard ratings for Port Walcott and approach are driven by:

- Deep draught vessels constrained to winding channel.
- Anchorages largely to the east.
- Limited turning area in the port area for deep draught vessels.
- Mixed operational activity.

Tide is less of a factor than for Port Hedland.

These factors resulted in individual factor ratings ranging from moderate through to significant for physical and complexity categories on approach with the port itself being rated major. Activity density ranged up to major. Overall this results in high levels of navigational hazard for Port Walcott and approach.

Port of Dampier

Contextual comments for the Port of Dampier can be found in Section 3.3. Navigational hazard ratings for the Port of Dampier and approach are driven by:

- Channel approach.
- Wide range of vessel types.
- Multiple convergent channels supporting multiple jetty and port facilities.
- Multiple facility owners and operators.
- Multiple maritime service providers and related on water activities.
- Overall port activity not centrally orchestrated (unlike at Port Hedland which is run by a single organisation).

These factors result in individual factor ratings ranging from moderate through to major for physical and complexity categories and ranging up to critical for activity density. Overall this results in very high levels of navigational hazard for the Port of Dampier and approach.

Port of Ashburton / Onslow / Wheatstone Area

Navigational hazard at the Port of Ashburton and surrounding area, including Onslow and the Wheatstone development, is driven by:

- Considerable development underway resulting in changing activity patterns.
- Potential conflict between vessels operating from each port.
- New petroleum industry developments, i.e. the Wheatstone project and resulting activity.
- Proposals for multiple new ports.
- Multiple reefs in the vicinity.

These factors result in individual factor ratings ranging from moderate through to major for physical and complexity categories and ranging up to critical for activity density. Overall this results in very high levels of navigational hazard for the Port of Ashburton and surrounding area.

6.2. Oil Exposure

Overview

Exposure represents the likely volume of oil that could arrive at a given area, taking into account both the size of spill and the probability of spill (including the influence of navigational hazard). While the likelihood of any particular spill is low, exposure allows the contribution of different sources to the risk profile to be compared.

The oil exposure in both the shoreline and hexagon cells is dominated by floating oils, although dissolving oils are likely to increase in the future. Oil exposure can be viewed by floating or dissolving oils at the web map application: http://wamopra.navigatusconsulting.com

In this section results are presented for exposure to both shoreline cells and hexagon cells.

Shoreline Exposure

Figure 6.5 shows the shoreline exposure profile for the Pilbara zone.

Figure 6.5 - Shoreline Exposure

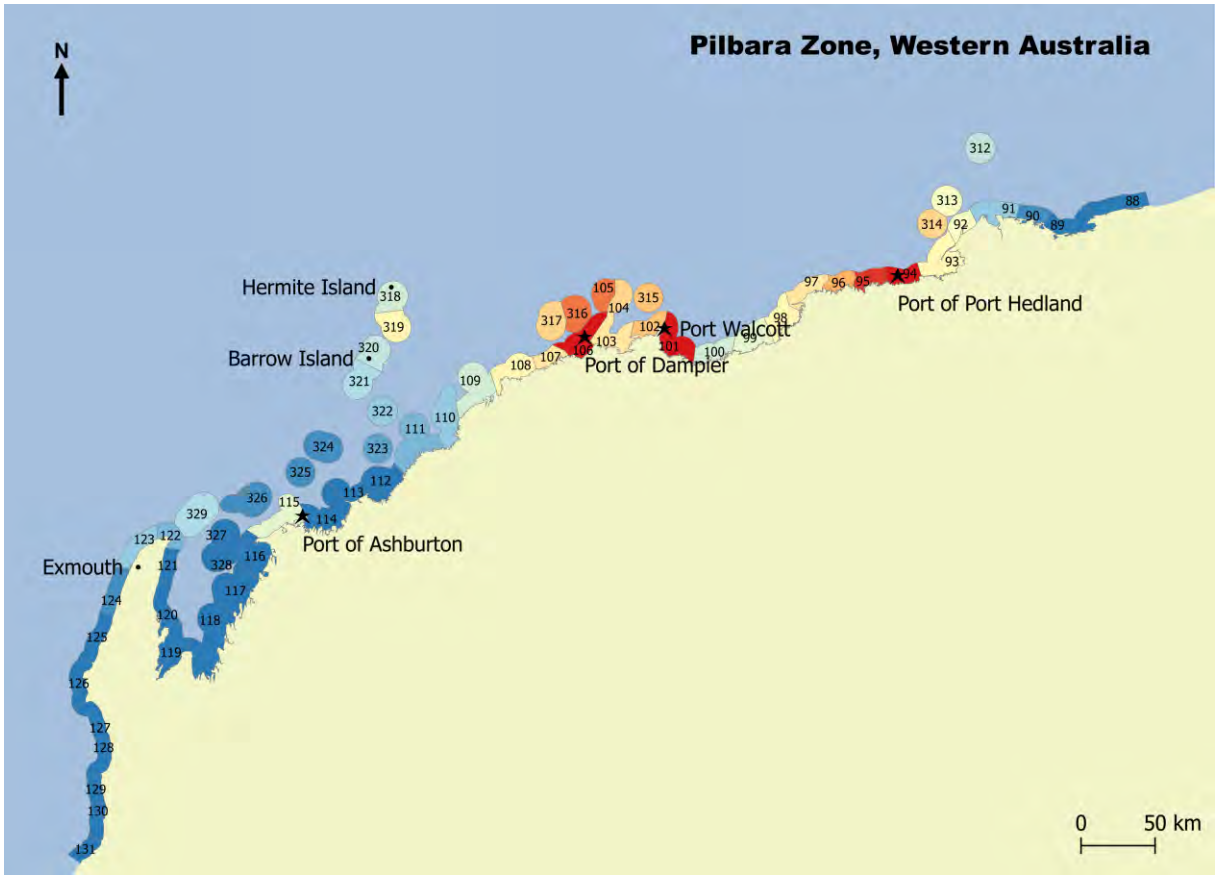


Figure 6.6 shows the proportion of shoreline exposure generated by each spill size band. Over half of the oil expected to arrive at the Pilbara shoreline is due to potential spills in the 500 – 5,000 tonne band.

Figure 6.6 – Proportion of Shoreline Exposure by Spill Size (tonnes)

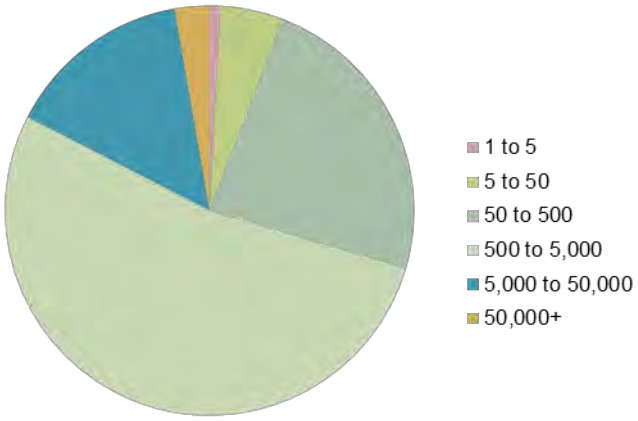


Figure 6.7 is similar to the above in that it shows the proportion of shoreline exposure generated by each spill size band. However, this measure of exposure is further broken down by sub-zone.

Figure 6.7 – Pilbara Shoreline Exposure by Spill Size (tonnes) and Sub-Zone

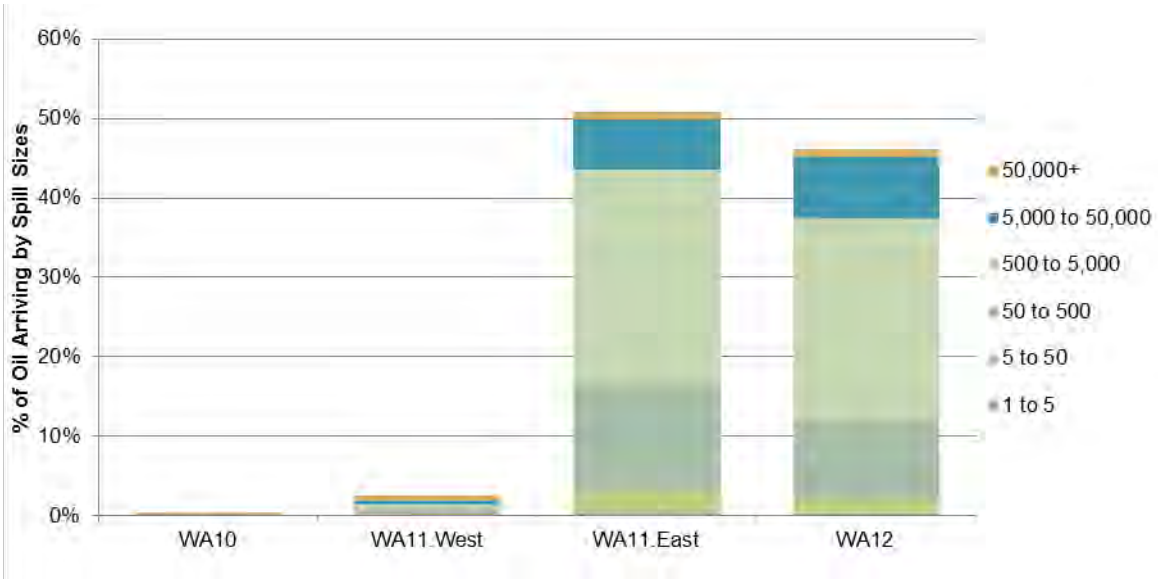
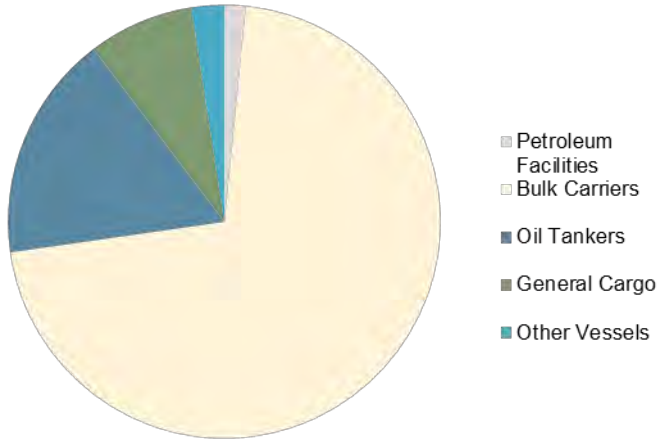


Figure 6.8 shows the proportion of shoreline exposure generated by each spill source. More than half of the oil statistically expected to arrive at the Pilbara shoreline is due to potential spills from bulk carriers.

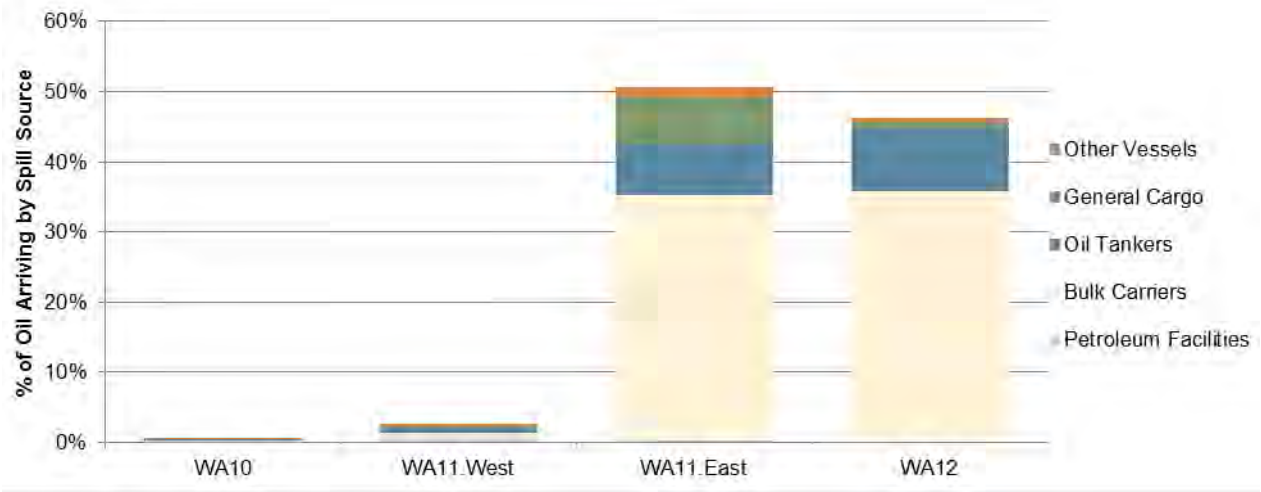
Figure 6.8 – Proportion of Shoreline Exposure by Source (tonnes)



Note that the Other Vessels category consists of a range of commercial vessels and well as chemical tankers, gas carriers and passenger vessels.

Figure 6.9 is similar to the above in that it shows the proportion of shoreline exposure generated by each spill source. However, this measure of exposure is further broken down by sub-zone.

Figure 6.9 – Pilbara Shoreline Exposure by Source and Sub-Zone



There is very low shoreline exposure in the western part of Pilbara (WA10 and WA11.West). In the WA11.West sub-zone exposure is largely driven by the low likelihood, high impact potential for spill events from offshore petroleum facilities such as wells, however, these are a significant distance from the shoreline and spills are more likely to be of condensate of light crude oils.

Exposure in the WA11.East sub-zone is driven by medium to large spills. This is the result of large numbers of bulk carrier vessels. The WA12 sub-zone in the eastern part of Pilbara also has a high level of exposure which is driven primarily by bulk carriers visiting Port Hedland.

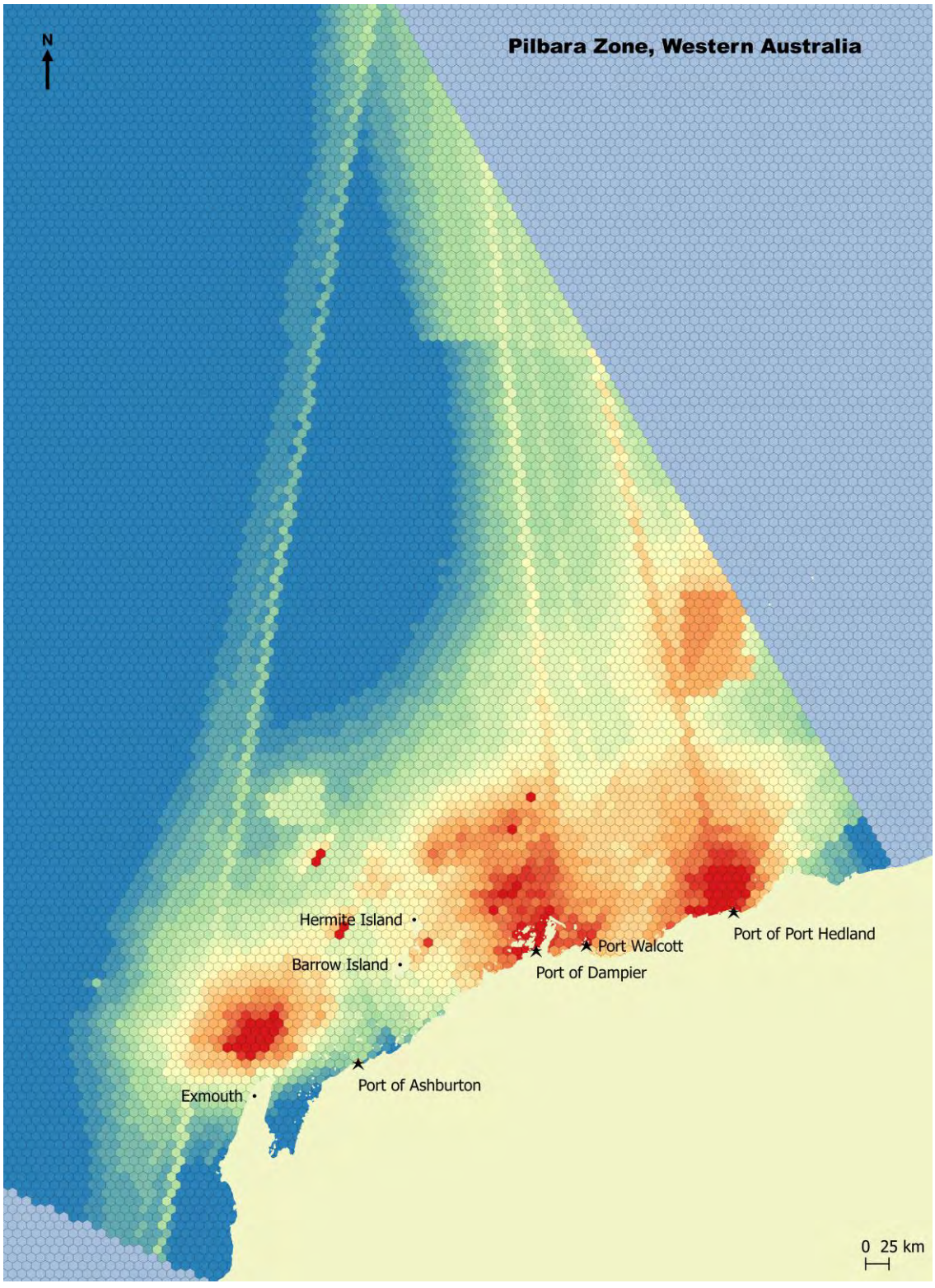
Overall the contribution of petroleum facilities to shoreline exposure is small in the Pilbara region despite this area having a high concentration of activity relative to the rest of Western Australia. This is a result of facilities being located at significant distances from the shoreline and producing primarily gas and condensate or light crude oils.

There has also been a low level of exploration activity as a result of lower oil prices as discussed in Section 3.4. Nonetheless, potential spills from petroleum facilities remain a significant source of offshore sea cell exposure as discussed in the following section.

Sea Cell Exposure

Figure 6.10 shows the exposure profile for the hexagon sea cells within the Pilbara zone. No data is shown for areas outside the Pilbara zone.

Figure 6.10 - Exposure Profile



Key for Exposure

Figure 6.11 shows the proportion of offshore exposure generated by each spill size band. The majority of exposure in the Pilbara zone is due to rare but very large spills. These spills are more likely to occur a significant distance from the shore.

Figure 6.11 – Proportion of Hexagon Cell Exposure by Spill Size (tonnes)

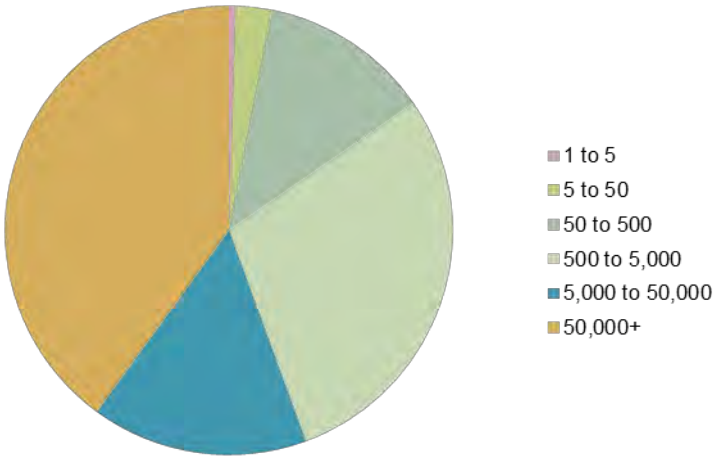
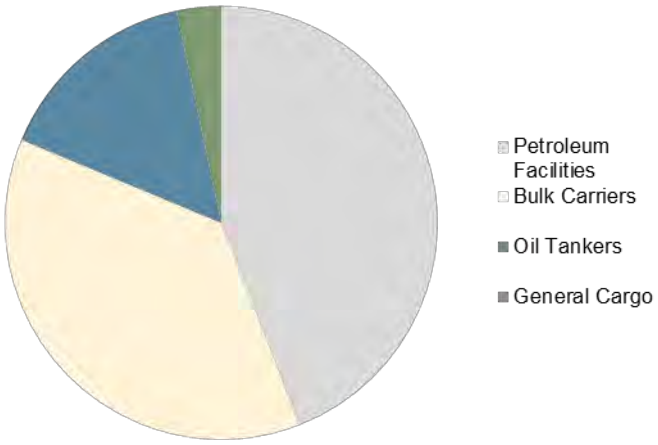


Figure 6.12 shows the proportion of offshore exposure generated by each spill source. The majority of exposure in the Pilbara zone is due to potential spills from petroleum facilities and bulk carriers.

Figure 6.12 – Proportion of Hexagon Cell Exposure by Source (tonnes)



Note that the Other Vessels category consists of a range of commercial vessels and well as chemical tankers, gas carriers and passenger vessels.

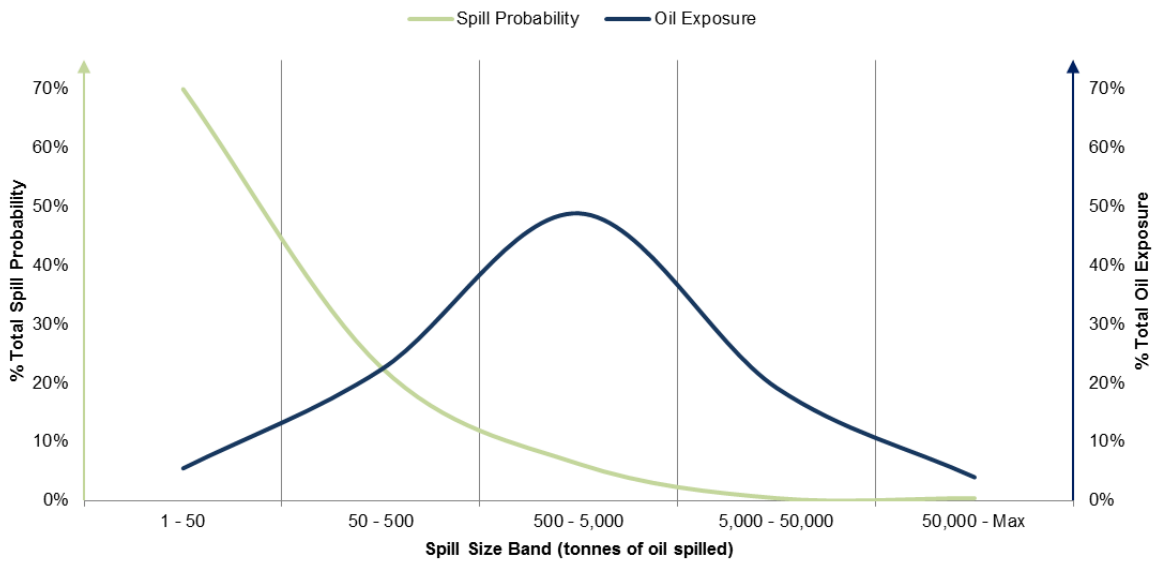
Exposure and Probability

The previous sections find that oil spill exposure in the Pilbara region is largely driven by spills in the 500 to 5,000 tonne band. This would seemingly conflict with the typical experience of an oil spill responder who is likely to attend smaller spill events more frequently. Yet the result is sound because exposure takes into account both the likelihood and size of spills. Exposure is the expectation of how much oil will arrive at a given area over a very long period of time.

Although smaller spills are much more frequent, over a very long time period, the majority of oil spilled in the Pilbara region is statistically likely to come from larger incidents.

This is conceptually illustrated in Figure 6.13. This chart shows relative spill probability (in green) and relative oil exposure (in blue) for different spill size bands. Spill probability is very high in the first spill size band. After the first band, spill probability decreases rapidly as spill size increases. Put simply; smaller spills are more frequent than larger spills.

Figure 6.13 – Conceptual Comparison of Spill Probability vs. Expected Oil



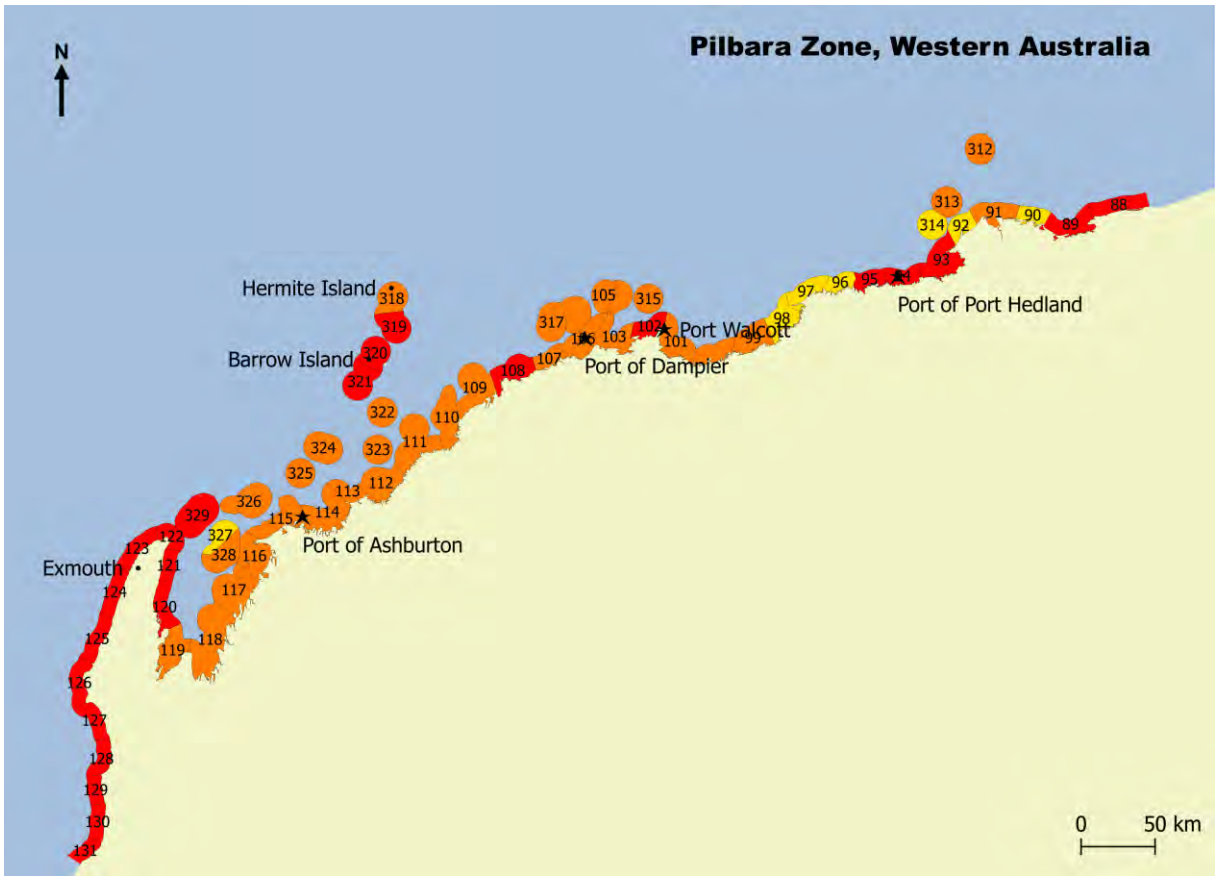
On the other hand, relative oil exposure (the blue curve) is very low for smaller spill sizes. Although these spills are more frequent, their contribution to the statistically expected amount of oil is small. As spill size increases the contribution to total exposure also increases, peaking at the 500 to 5,000 spill size band and then decreasing.

This leaves spill responders with the challenge of regularly dealing with small spills while also ensuring adequate training, capability and resources to respond effectively to larger spills.

6.3. Protection Priority Results

Protection Priority data was developed by Advisian and is fed into the risk model developed by Navigatus to create a picture of oil spill risk including likelihood and consequence. Figure 6.14 shows the overall ranking for Protection Priorities in the Pilbara zone.

Figure 6.14 - Protection Priorities Overall Rankings



Key

Very Low	Low	Moderate	High	Very High

A sample of protection priority data is shown for major ports in Table 6.1. The table is based on Protection Priority data provided by Advisian. It shows the *overall* protection priorities ratings and comments for each of the selected ports. Ratings and comments are provided for potential spills of floating oils (e.g. bunker fuel) and dissolving oils (e.g. diesel).

Information on protection priorities can be viewed at the web map application: http://wamopra.navigatusconsulting.com as well as in the Sub-Zone Drill Down sections of this report. The Pilbara zone report prepared by Advisian for the Department of Transport (Advisian 2017) should be consulted for more context and information.

Table 6.1 - Port Comparison of Protection Priorities (based on Advisian 2017 data)

Port	Protection Priorities Floating Ranking	Protection Priorities Dissolved Ranking	Protection Priorities Overall Ranking	Brief Description for Spills of Floating Oils	Brief Description for Spills of Dissolved Oils	Data Sources
Port Hedland	**Very High**	**Very High**	**Very High**	Port Hedland Port*	Port Hedland Port*	DPI Port Authorities (25 October 2010)
Port Walcott	**High**	**High**	**High**	Protected fauna (reptiles, mammals), Broadscale saltmarsh, Port Walcott	Broadscale saltmarsh, Port Walcott	DotE SNES (22 February 2017), DPaW Protected Fauna (2 March 2017), DotE BIA (26 April 2016), DPaW Marine Habitats dataset (May 2015), DPI Port Authorities (25 October 2010)
Port of Dampier	**High**	**High**	**High**	Protected fauna (birds, mammals, reptiles), Nature Reserve (Unnamed WA36915)(IUCN IA), broadscale mangals, broadscale saltmarsh, Indigenous Listed place: Dampier Archipelago (including Burrup Peninsula), Dampier Port	Broadscale saltmarsh, broadscale coral reef (subtidal), Indigenous Listed place: Dampier Archipelago (including Burrup Peninsula), Dampier Port	DotE SNES (22 February 2017), DPaW Protected Fauna (2 March 2017), DotE BIA (26 April 2016), DotE CAPAD - Terrestrial (30 June 2014) with DPaW update (30 June 2016), DPaW Marine Habitats dataset (May 2015), DotE National Heritage (Public) (22 January 2016), DPI Port Authorities (25 October 2010)
Port of Ashburton	**High**	**High**	**High**	Protected fauna (reptiles), Ashburton Port Area	Ashburton Port Area	DotE SNES (22 February 2017), DPaW Protected Fauna (2 March 2017), DotE BIA (26 April 2016), DPI Port Authorities (25 October 2010)

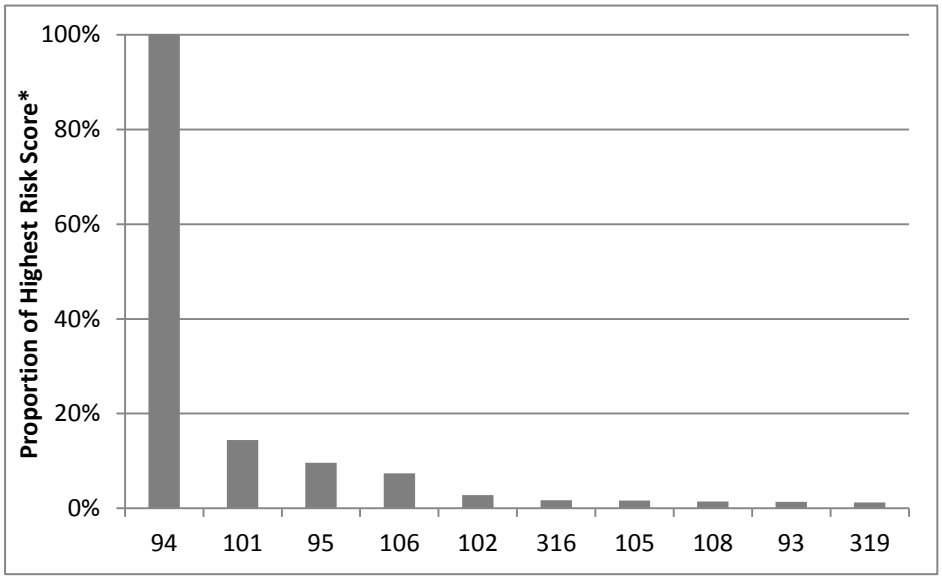
*The comment ‘Port Hedland Port’ refers to the economic importance of the port as a protection priority.

6.4. Pilbara Risk Profile Results

This section contains the main risk results for the Pilbara zone. Figure 6.16 shows a heat map of risk ratings in each of the Pilbara zone shoreline cells.

Risk ratings in the heat map in Figure 6.16 are determined relative to the risk score in the *second* highest shoreline cell (ID 101). This decision was made as the highest risk cell (ID 94) would otherwise dominate the risk profile reducing the level of discrimination in other areas (see Figure 6.15).

Figure 6.15 - Pilbara Risk Profile (ten highest shoreline cells)



This section also contains a column chart showing relative risk[2] between each of the shoreline cells and another column chart showing relative risk between the top three major ports.

[2] The relative risk scores presented in Figure 6.17 are indexed to the second highest cell in the Pilbara Zone and so are not directly comparable to other zones. However, in general the risk results are presented relative across all zones (for example, the risk as shown in the heat maps).

Figure 6.16 - Pilbara Risk Profile Heat Map

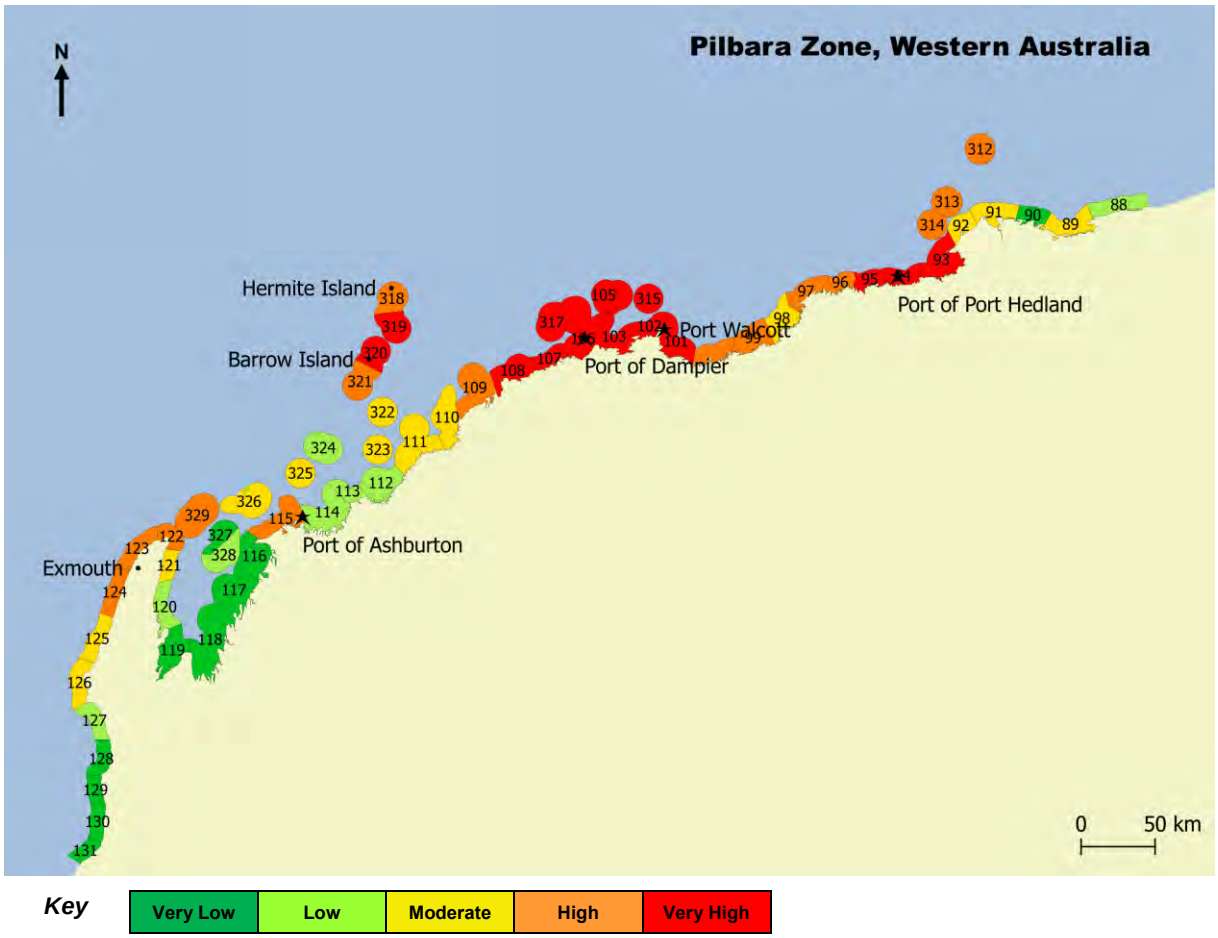
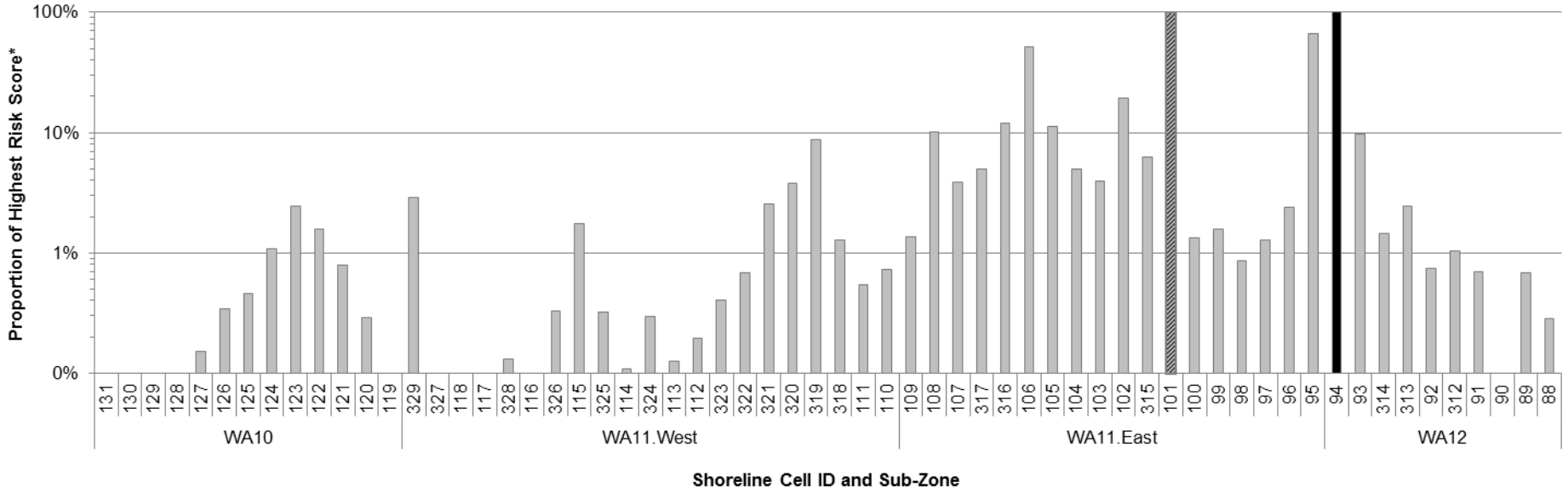


Figure 6.17 shows a column chart of relative risk scores for each of the shoreline cells.

The black column represents shoreline cell ID 94, the cell with the highest risk score. This column extends beyond the maximum limit of the chart's vertical axis. Rather, risk is shown relative to the second highest cell (ID 101) which is distinguished by a striped pattern fill.

Figure 6.17 - Pilbara Risk Profile Relative Risk Scores



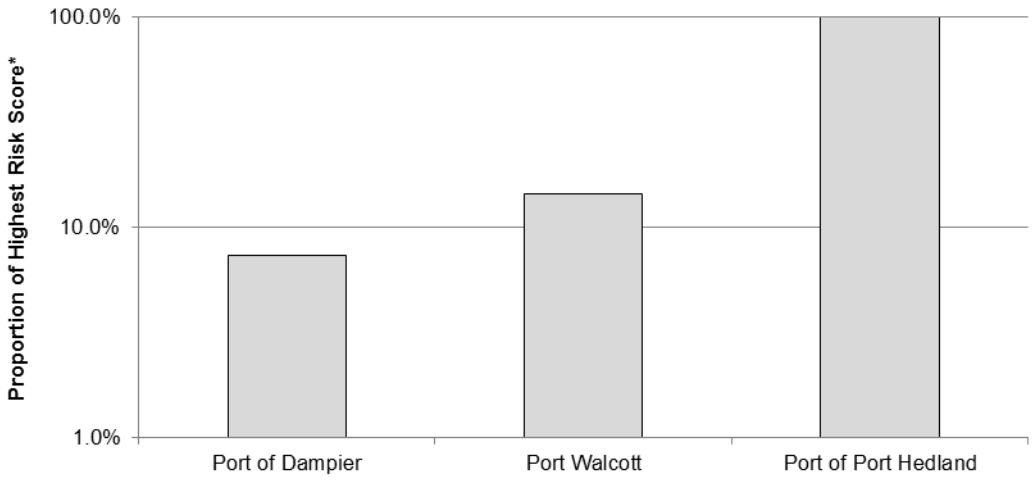
* Note use of log scale. As with the heat map, risk is shown relative to the second highest cell.

The four cells with the highest risk levels are:

1. ID #94 *Port Hedland* (Beebingara Creek coast E – Wattle Well coast)
2. ID #101 *Port Walcott* (Cape Lambert – Sherlock coast (A))
3. ID #95 *next to Port Hedland* - (Turner River NE foreland – Beebingara Creek coast E (A))
4. ID #106 *Port Dampier* (West Intercourse Island – Dolphin Island N point (D)

Figure 6.18 shows the relative oil spill risk between major port areas. Risk is shown as a proportion of the risk score for the highest risk port being Port Hedland.

Figure 6.18 - Relative Oil Spill Risk between Ports



*Note use of log scale.

The Wheatstone project will affect risk further west of the above ports. However, the effect of gas development on oil pollution risk profiles tends to be relatively low as any liquid product quickly dissolves or evaporates. There will be an increase in gas carrier vessels transiting to and from the area. As modelled in Stage One, this is not expected to significantly alter the risk profile although there is uncertainty of the extent to which traffic will increase.

6.5. Sub-Zone Drill Down

Overview

The following sections contain a brief drill-down summary on each of the four sub-zones within the Pilbara Zone (refer Section 5.2 for definition of sub-zones).

Cell counts and heat maps are presented for each of the sub-zones. A summary table is also presented for each sub-zone. The key benefit of these tables is to allow trends in risk drivers to be seen across multiple cells. The tables contain the following fields:

- **ID** – the shoreline cell identification number.
- **Name** – the name assigned to the shoreline cell.
- **Overall Risk Rating** – the primary measure of risk – shown on a five-step rating scale which ranges from Very Low to Very High.
- **Exposure** – represented as a colour on a continuous spectrum which transitions from blue – yellow – red as the level of exposure increases.
- **Overall Protection Priorities Rating** – as determined by Advisian, shown on a five-step rating scale which ranges from Very Low to Very High.
- **Protected Fauna; Protection Areas; Heritage; Economic; Social Amenity Recreation** – these fields show the ratings for each of the protection priority categories as determined by Advisian. The ratings are shown on a five-step rating scale which ranges from Very Low to Very High. In some cases the Advisian data contains an 'N/A' where no features were included in the assessment and no rating was given for that particular category. This 'N/A' is shown in the summary table.
- **Brief Description of Overall Protection Priority Rating** – the protection priorities attribute table provided by Advisian contains a brief overall comment for spills of floating oils and spills of dissolving oils in each shoreline cell. This field represents each of the unique features mentioned in the two overall comments. It is intended to provide a brief overview of key protection priorities in the shoreline cell.
- **Key Drivers of Shoreline Exposure** – this field lists the potential spill sources which contribute most to the risk profile in the given shoreline cell.

WA10 Sub-Zone Summary

Figure 6.19 shows the count of each cell rating within the WA10 Sub-Zone. Figure 6.20 depicts these cell ratings on a heat map.

Figure 6.19 - WA10 Sub-Zone Cell Counts

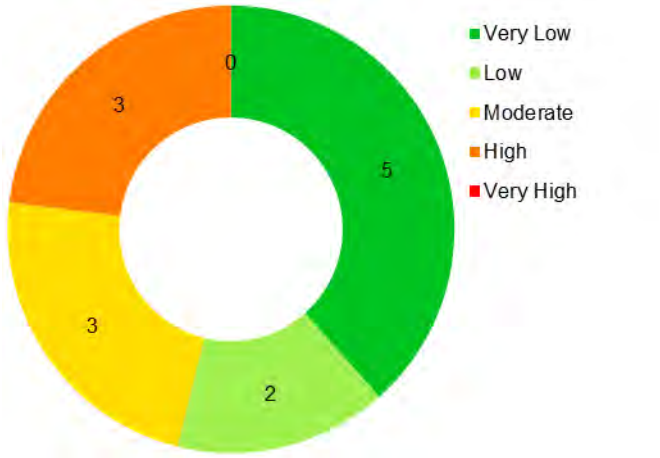
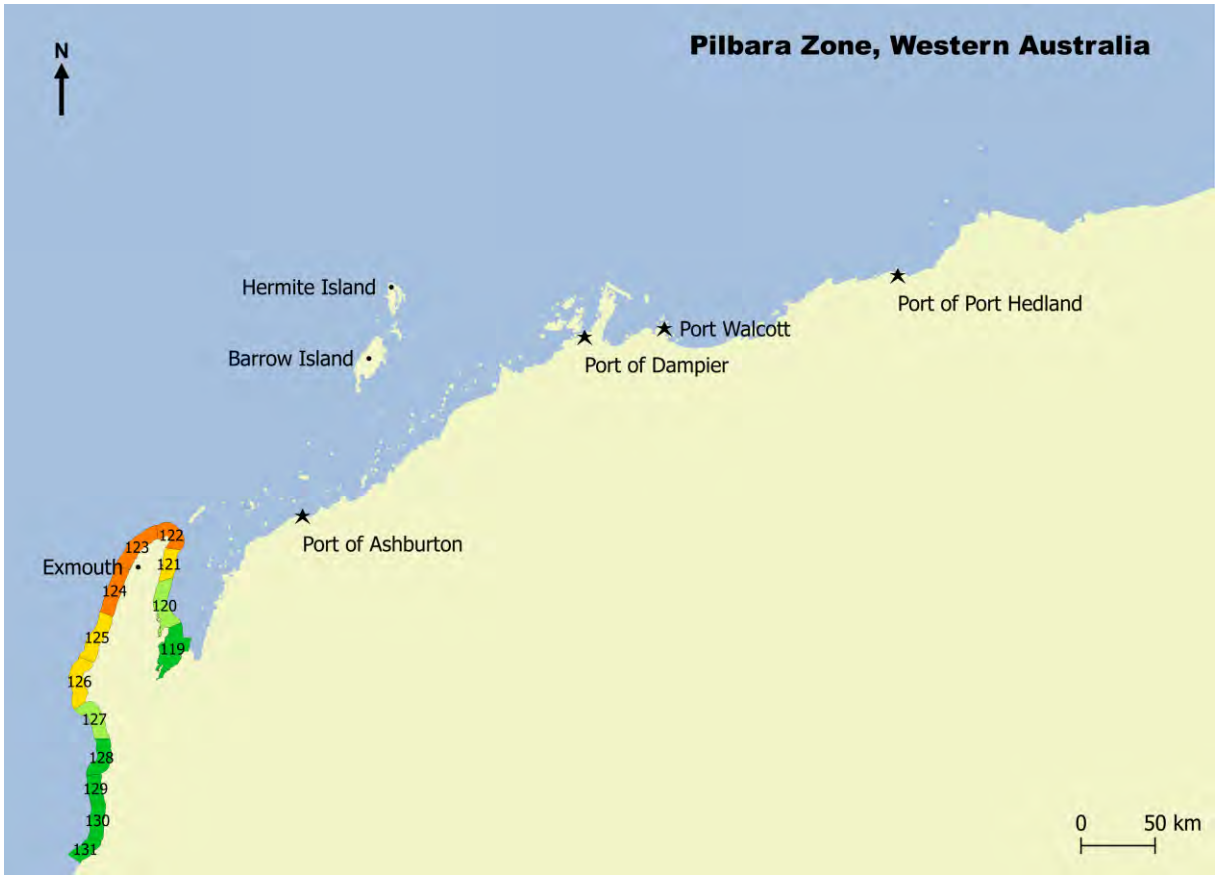


Figure 6.20 - WA10 Sub-Zone Risk Profile



Despite high levels of environmental sensitivity the overall risk in this sub-zone is low. The table on the following page summarises risk and protection priority information for this sub-zone.

WA10 Summary Table

ID	Name	Overall Risk Rating	Exposure	Overall Protection Priorities Rating	Protected Fauna	Protection Areas	Heritage	Economic	Social Amenity Recreation	Brief Description of Overall Protection Priority Rating	Key Drivers of Shoreline Exposure
119	Learmonth - Point Lefroy	Very Low		High			N/A		N/A	*Nature Reserve (Whitmore, Roberts, Doole Islands and Sandalwood Landing), important wetlands (Cape Range Subterranean Waterways)*	*Petroleum Facilities, Oil Tankers*
120	Bundegi - Shothole Canyon N (A)	Low		Very High					N/A	*Protected fauna (reptiles), Important wetlands (Cape Range Subterranean Waterways)*	*Petroleum Facilities, Oil Tankers*
121	Bundegi - Shothole Canyon N (B)	Moderate		Very High						*World Heritage Area (The Ningaloo Coast)*	*Petroleum Facilities, Other Vessels, Oil Tankers*
122	Vlamingh Head - North West Cape	High		Very High						*World Heritage Area (The Ningaloo Coast)*	*Petroleum Facilities, Oil Tankers*
123	Low Point - Vlamingh Head (A)	High		Very High						*World Heritage Area (The Ningaloo Coast)*	*Petroleum Facilities, Oil Tankers*
124	Low Point - Vlamingh Head (B)	High		Very High						*World Heritage Area (The Ningaloo Coast)*	*Petroleum Facilities, Oil Tankers*
125	Osprey Bay - Low Point	Moderate		Very High						*World Heritage Area (The Ningaloo Coast)*	*Petroleum Facilities, Oil Tankers*
126	Winderabandi Point - Osprey Bay	Moderate		Very High						*World Heritage Area (The Ningaloo Coast)*	*Oil Tankers, Petroleum Facilities*
127	Coast Hill - Point Cloates	Low		Very High						*World Heritage Area (The Ningaloo Coast)*	*Petroleum Facilities, Oil Tankers*
128	Point Maud - Coast Hill (A)	Very Low		Very High						*World Heritage Area (The Ningaloo Coast)*	*Petroleum Facilities, Oil Tankers*
129	Point Maud - Coast Hill (B)	Very Low		Very High						*World Heritage Area (The Ningaloo Coast)*	*Petroleum Facilities, Oil Tankers*
130	Alison Point - Point Maud	Very Low		Very High						*World Heritage Area (The Ningaloo Coast)*	*Oil Tankers, Petroleum Facilities, Bulk Carriers*
131	Gnarraloo Bay - Alison Point (A)	Very Low		Very High						*World Heritage Area (The Ningaloo Coast)*	*Oil Tankers, Petroleum Facilities, Bulk Carriers*

Key for Risk and Protection Priorities

Very Low	Low	Moderate	High	Very High

Key for Exposure

Lowest — Highest

WA11.West Sub-Zone Summary

Figure 6.21 shows the count of each cell rating within the WA10 Sub-Zone. Figure 6.22 depicts these cell ratings on a heat map.

Figure 6.21 - WA11.West Sub-Zone Cell Counts

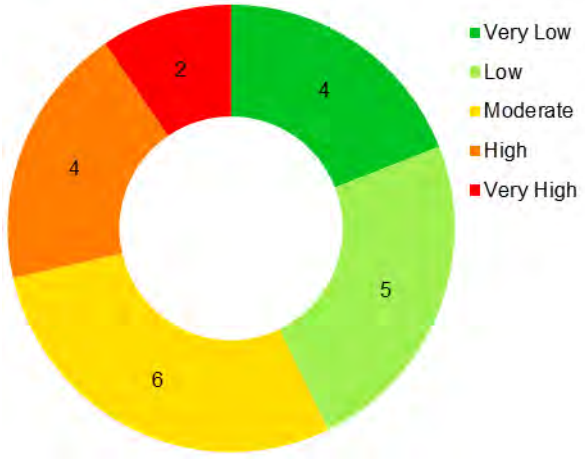
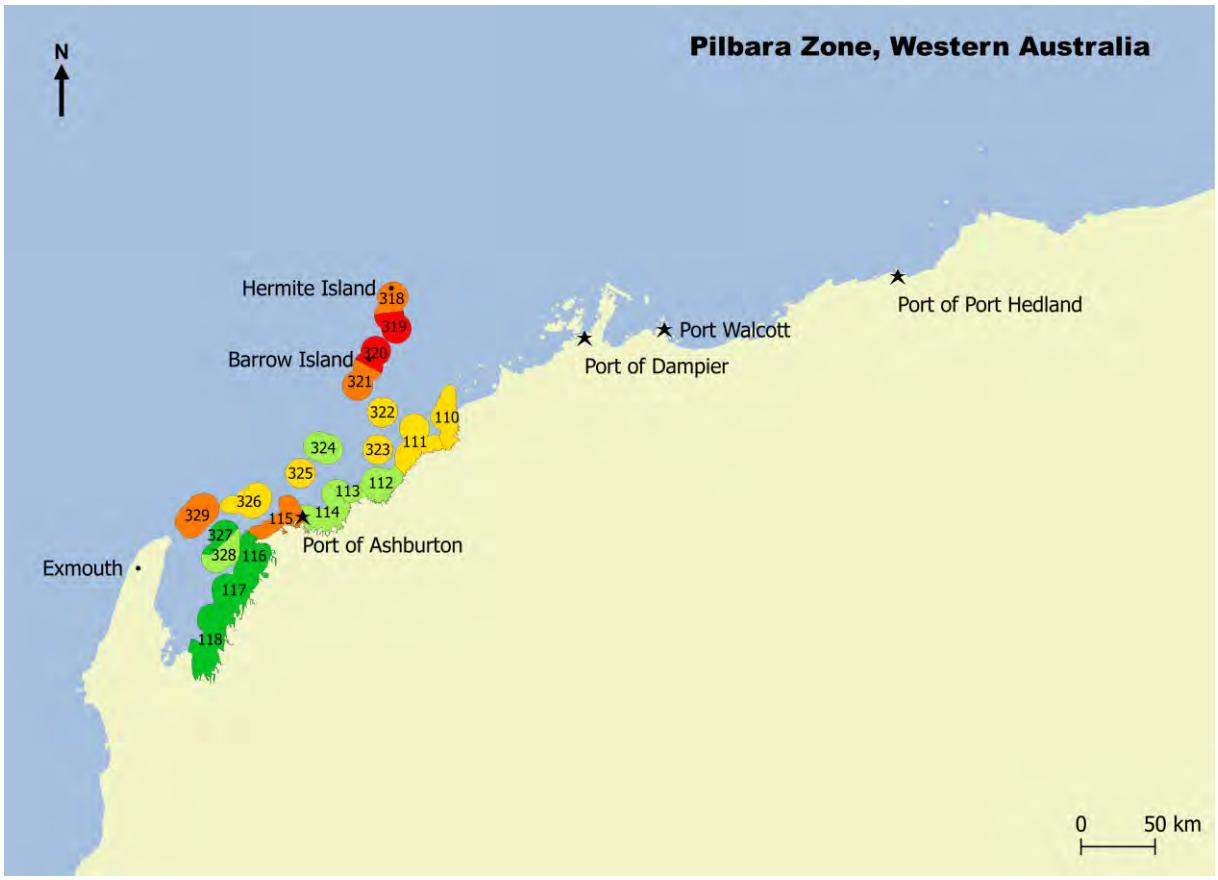


Figure 6.22 - WA11.West Sub-Zone Risk Profile



The risk in this sub-zone is relatively low. The table on the following page summarises the risk and protection priority information for this sub-zone.

WA11.West Summary Table

ID	Name	Overall Risk Rating	Exposure	Overall Protection Priorities Rating	Protected Fauna	Protection Areas	Heritage	Economic	Social Amenity Recreation	Brief Description of Overall Protection Priority Rating	Key Drivers of Shoreline Exposure
110	Mount Salt coast W - James Point	Moderate		High					N/A	Protected fauna (reptiles), Nature Reserve (Great Sandy Island)(IUCN IA), exposed tidal flats, mangroves (1000-3000 ha), sheltered tidal flats (>3000 ha)	Bulk Carriers, General Cargo, Oil Tankers
111	Peter Creek coast E - Mount Salt coast W	Moderate		High			N/A		N/A	Nature Reserve (Great Sandy Island, North Sandy Island, Weld Island)(IUCN IA), exposed tidal flats, mangroves (1000-3000 ha), (sheltered tidal flats >3000 ha)	Bulk Carriers, General Cargo, Oil Tankers
112	Weld Island coast S - Peter Creek coast E	Low		High					N/A	Nature Reserve (Little Rocky Island, Weld Island)(IUCN IA), mangroves (>3000 ha)	Bulk Carriers, Petroleum Facilities, General Cargo, Oil Tankers
113	Coolgra Point W - Yardie Landing (A)	Low		High			N/A		N/A	Port of Onslow	Petroleum Facilities, Other Vessels
114	Coolgra Point W - Yardie Landing (B)	Low		High						Protected fauna (birds, reptiles), Ashburton Port Area	Petroleum Facilities, Other Vessels, General Cargo
115	Hope Point - Locker Point (A)	High		High						Protected fauna (reptiles), Ashburton Port Area	Other Vessels, General Cargo
116	Hope Point - Locker Point (B)	Very Low		High			N/A		N/A	Important wetlands (Exmouth Gulf East)	Petroleum Facilities, Other Vessels
117	Hope Point - Locker Point (C)	Very Low		High			N/A		N/A	Nature Reserve (Tent Island, Burnside and Simpson Island)(IUCN IA), important wetlands (Exmouth Gulf East), mangroves (>3000 ha)	Petroleum Facilities, Oil Tankers
118	Hope Point - Locker Point (D)	Very Low		High			N/A		N/A	Protected fauna (birds, reptiles), Nature Reserve (Whalebone Island), important wetlands (Exmouth Gulf East), mangroves (>3000 ha)	Petroleum Facilities, Oil Tankers
318	Barrow Island and Montebello Islands (A)	High		High						Protected fauna (birds, reptiles, mammals), Marine Park (Montebello Islands)(IUCN IA), broadscale mangals,	Petroleum Facilities, Oil Tankers, Bulk Carriers
319	Barrow Island and Montebello Islands (B)	Very High		Very High						Port of Barrow Island	Petroleum Facilities
320	Barrow Island and Montebello Islands (C)	Very High		Very High						Port of Barrow Island	Petroleum Facilities, General Cargo, Bulk Carriers, Oil Tankers
321	Barrow Island and Montebello Islands (D)	High		Very High						Port of Barrow Island	Bulk Carriers, Petroleum Facilities, General Cargo, Oil Tankers

ID	Name	Overall Risk Rating	Exposure	Overall Protection Priorities Rating	Protected Fauna	Protection Areas	Heritage	Economic	Social Amenity Recreation	Brief Description of Overall Protection Priority Rating	Key Drivers of Shoreline Exposure
322	Barrow Island and Montebello Islands (E)	Moderate		High						*Protected fauna (mammals), Nature Reserve (Great Sandy Island)(IUCN IA), Broadscale coral reef (intertidal, subtidal), Natural Nominated place: Barrow Island and the Montebello-Barrow Islands Marine Conservation Reserves*	*Bulk Carriers, Petroleum Facilities, General Cargo, Oil Tankers*
323	Yardie Landing - Weld Island coast S (A)	Moderate		High			N/A		N/A	*Nature Reserve (Great Sandy Island)(IUCN IA), Exposed tidal flats*	*Bulk Carriers, Petroleum Facilities, General Cargo, Oil Tankers*
324	Yardie Landing - Weld Island coast S (B)	Low		High			N/A		N/A	*Nature Reserve (Airlie Island)(IUCN IA), Port of Onslow*	*Petroleum Facilities, Other Vessels, General Cargo, Oil Tankers*
325	Coolgra Point W - Yardie Landing (C)	Moderate		High			N/A		N/A	*Nature Reserve (Thevenard Island)(IUCN IA), Ashburton Port Area*	*Petroleum Facilities, Oil Tankers, Other Vessels, General Cargo*
326	Baresand Point - Entrance Point E	Moderate		High			N/A		N/A	*Protected fauna (reptiles), Nature Reserve (Serrurier Island, Bessieres Island, Round Island)(IUCN IA)*	*Petroleum Facilities, Oil Tankers*
327	Hope Point - Locker Point (E)	Very Low		Moderate		N/A	N/A		N/A	*Protected fauna (reptiles, mammals)*	*Petroleum Facilities, Oil Tankers*
328	Hope Point - Locker Point (F)	Low		High			N/A		N/A	*Nature Reserve (Gnandaroo Island, Rocky Island, Victor Island, Y Island, Muiron Islands)(IUCN IA)*	*Petroleum Facilities, Other Vessels, General Cargo, Oil Tankers*
329	Locker Point - Baresand Point	High		Very High						*World Heritage Area (The Ningaloo Coast)*	*Oil Tankers, Petroleum Facilities*

Key

Very Low	Low	Moderate	High	Very High

Key for Exposure

Lowest — Highest

WA11.East Sub-Zone Summary

This is overall the second highest risk sub-zone in the Pilbara region, the highest number of 'very high' ratings (Figure 6.23). Figure 6.24 depicts these cell ratings on a heat map.

Figure 6.23 – WA11.East Sub-Zone Cell Counts

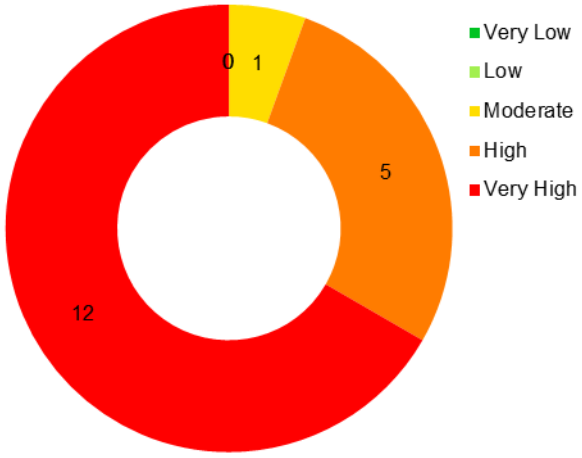
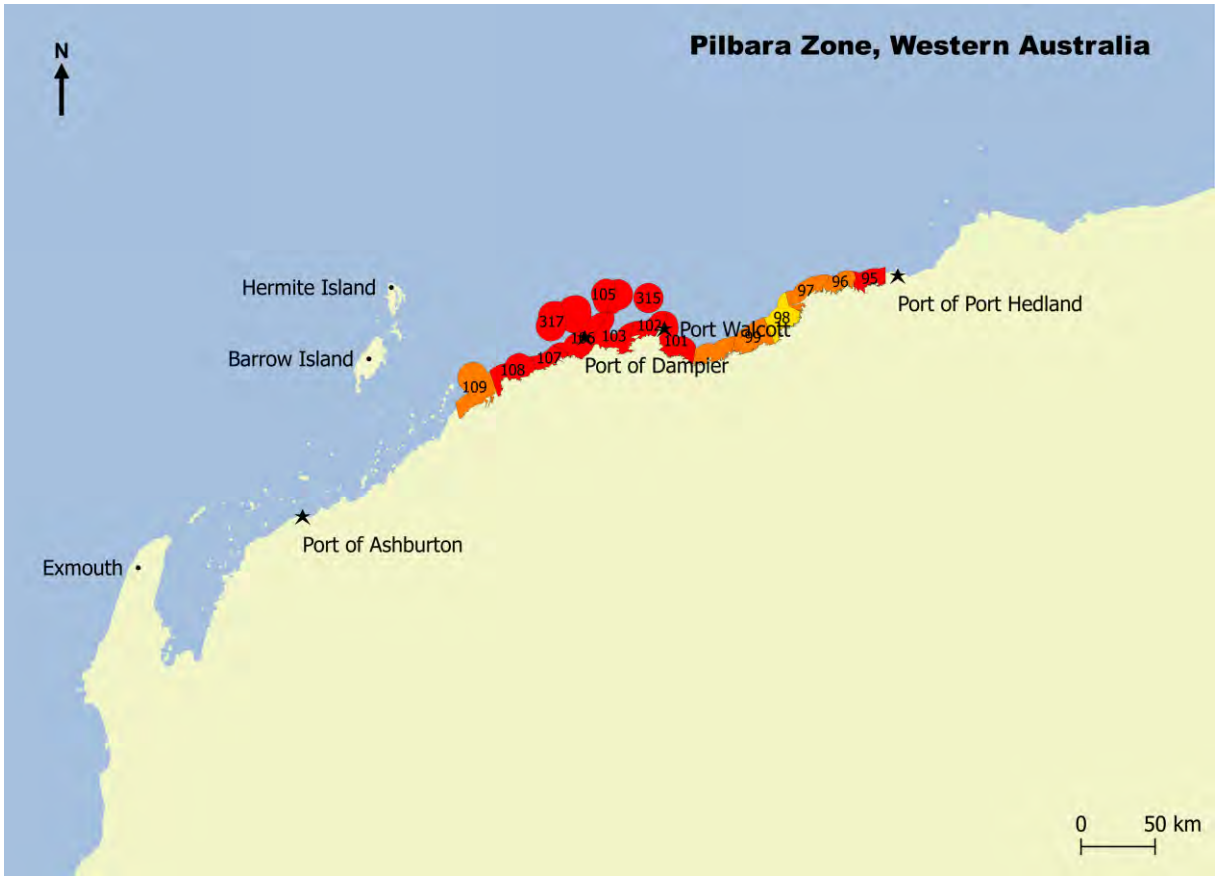


Figure 6.24 - WA11.East Sub-Zone Risk Profile



The highest rated cells in this sub-zone are driven by activity and sensitivity in Port Dampier (106) Port Walcott (101) and proximity to Port Hedland (95). The table on the following page summarises the risk and protection priority information for this sub-zone.

WA11.East Summary Table

ID	Name	Overall Risk Rating	Exposure	Overall Protection Priorities Rating	Protected Fauna	Protection Areas	Heritage	Economic	Social Amenity Recreation	Brief Description of Overall Protection Priority Rating	Key Drivers of Shoreline Exposure
95	Turner River NE foreland - Beebingara Creek coast E (A)	Very High		Very High						*Port Hedland Port*	*Bulk Carriers, Oil Tankers*
96	Turner River NE foreland - Beebingara Creek coast E (B)	High		Moderate			N/A		N/A	*Protected fauna (reptiles, mammals), exposed tidal flats, mangroves (1000-3000 ha), sheltered tidal flats (>3000 ha)*	*Bulk Carriers, Oil Tankers*
97	Cape Thouin - Turner River NE foreland	High		Moderate			N/A		N/A	*Protected fauna (reptiles, mammals), Exposed tidal flats*	*Bulk Carriers, Oil Tankers*
98	Cape Cossigny - Cape Thouin	Moderate		Moderate			N/A		N/A	*Protected fauna (reptiles, mammals), Exposed tidal flats, mangroves (1000-3000 ha), sheltered tidal flats (>3000 ha)*	*Bulk Carriers, Oil Tankers*
99	Sherlock coast - Cape Cossigny (A)	High		High						*Protected fauna (birds), Exposed tidal flats, sheltered rocky shores, mangroves (1000-3000 ha), sheltered tidal flats*	*Bulk Carriers, Oil Tankers*
100	Sherlock coast - Cape Cossigny (B)	High		High			N/A			*Protected fauna (birds), Port Walcott*	*Bulk Carriers, Oil Tankers*
101	Cape Lambert - Sherlock coast (A)	Very High		High						*Protected fauna (reptiles, mammals), Broadscale saltmarsh, Port Walcott*	*Bulk Carriers, General Cargo, Oil Tankers*
102	Cape Lambert - Sherlock coast (B)	Very High		Very High			N/A			*Protected fauna (reptiles), Broadscale saltmarsh, Port Walcott*	*Bulk Carriers*
103	West Intercourse Island - Dolphin Island N point (A)	Very High		High						*Protected fauna (birds, reptiles), Nature Reserve (Unnamed WA36915)(IUCN IA), broadscale saltmarsh, broadscale coral reef (intertidal, subtidal), Indigenous Listed place: Dampier Archipelago (including Burrup Peninsula), Dampier Port*	*Bulk Carriers, Oil Tankers, General Cargo*
104	West Intercourse Island - Dolphin Island N point (B)	Very High		High						*Protected fauna (mammals, reptiles), Nature Reserve (Unnamed WA36915)(IUCN IA), broadscale saltmarsh, broadscale coral reef (intertidal, subtidal) Indigenous Listed place: Dampier Archipelago (including Burrup Peninsula), Port Walcott*	*Bulk Carriers, Oil Tankers, General Cargo*
105	West Intercourse Island - Dolphin Island N point (C)	Very High		High						*Protected fauna (mammals, reptiles), Nature Reserve (Unnamed WA36915)(IUCN IA), broadscale mangals, broadscale saltmarsh, broadscale coral reef (intertidal, subtidal), Indigenous Listed place : Dampier Archipelago (including Burrup Peninsula), Dampier Port*	*Bulk Carriers, Oil Tankers, General Cargo*
106	West Intercourse Island - Dolphin Island N point (D)	Very High		High						*Protected fauna (birds, mammals, reptiles), Nature Reserve (Unnamed WA36915)(IUCN IA), broadscale mangals, broadscale saltmarsh, broadscale coral reef (subtidal, intertidal), Indigenous Listed place: Dampier Archipelago (including Burrup Peninsula), Dampier Port*	*Bulk Carriers*

ID	Name	Overall Risk Rating	Exposure	Overall Protection Priorities Rating	Protected Fauna	Protection Areas	Heritage	Economic	Social Amenity Recreation	Brief Description of Overall Protection Priority Rating	Key Drivers of Shoreline Exposure
107	West Intercourse Island - Dolphin Island N point (E)	Very High		High						*Protected fauna (reptiles), Broadscale saltmarsh, broadscale coral reef (intertidal, subtidal), Indigenous Listed place: Dampier Archipelago (including Burrup Peninsula)*	*Bulk Carriers, General Cargo, Oil Tankers*
108	Pelican Point - West Intercourse Island	Very High		Very High			N/A			*Port of Cape Preston*	*Bulk Carriers, General Cargo, Oil Tankers*
109	James Point - Cape Preston	High		High					N/A	*Nature Reserve (Great Sandy Island)(IUCN IA), broadscale saltmarsh, broadscale coral reef (intertidal, subtidal)*	*Bulk Carriers, General Cargo, Oil Tankers*
315	Dolphin Island N point - Cinders Rd coast	Very High		High			N/A		N/A	*Nature Reserve (Unnamed WA36913)(IUCN IA), Broadscale coral reef (intertidal), broadscale coral reef (subtidal), Port Walcott*	*Bulk Carriers*
316	West Intercourse Island - Dolphin Island N point (F)	Very High		High					N/A	*Protected fauna (reptiles), Nature Reserve (Unnamed WA36915)(IUCN IA), Broadscale coral reef (intertidal, subtidal), Indigenous Listed place: Dampier Archipelago (including Burrup Peninsula), Dampier Port*	*Bulk Carriers, Oil Tankers, General Cargo*
317	West Intercourse Island - Dolphin Island N point (G)	Very High		High					N/A	*Protected fauna (reptiles), Nature Reserve (Unnamed WA36915)(IUCN IA), Broadscale coral reef (intertidal, subtidal), Indigenous Listed place: Dampier Archipelago (including Burrup Peninsula), Dampier Port*	*Bulk Carriers, Oil Tankers, General Cargo*

Key

Very Low	Low	Moderate	High	Very High

Key for Exposure

Lowest — Highest

WA12 Sub-Zone Summary

This is overall the highest risk sub-zone in the Pilbara region. Risk in this sub-zone is dominated by Port Hedland which sees the highest level of activity in the Pilbara region and has a 'very high' Protection Priority rating. Although other sub-zones have a higher proportion of cells rated 'high' or 'very high', the level of risk in Port Hedland is such that the sub-zone still has the highest overall risk.

Figure 6.25 shows the cell counts for each risk rating in this sub-zone and Figure 6.26 depicts these cell ratings on a heat map.

Figure 6.25 - WA12 Sub-Zone Cell Counts

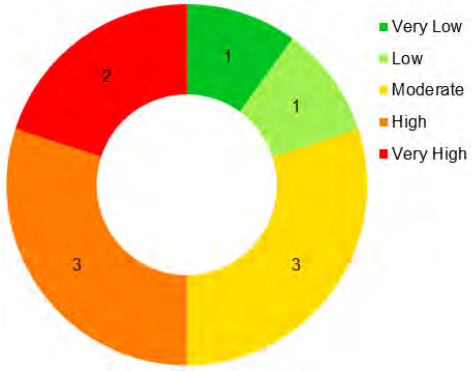
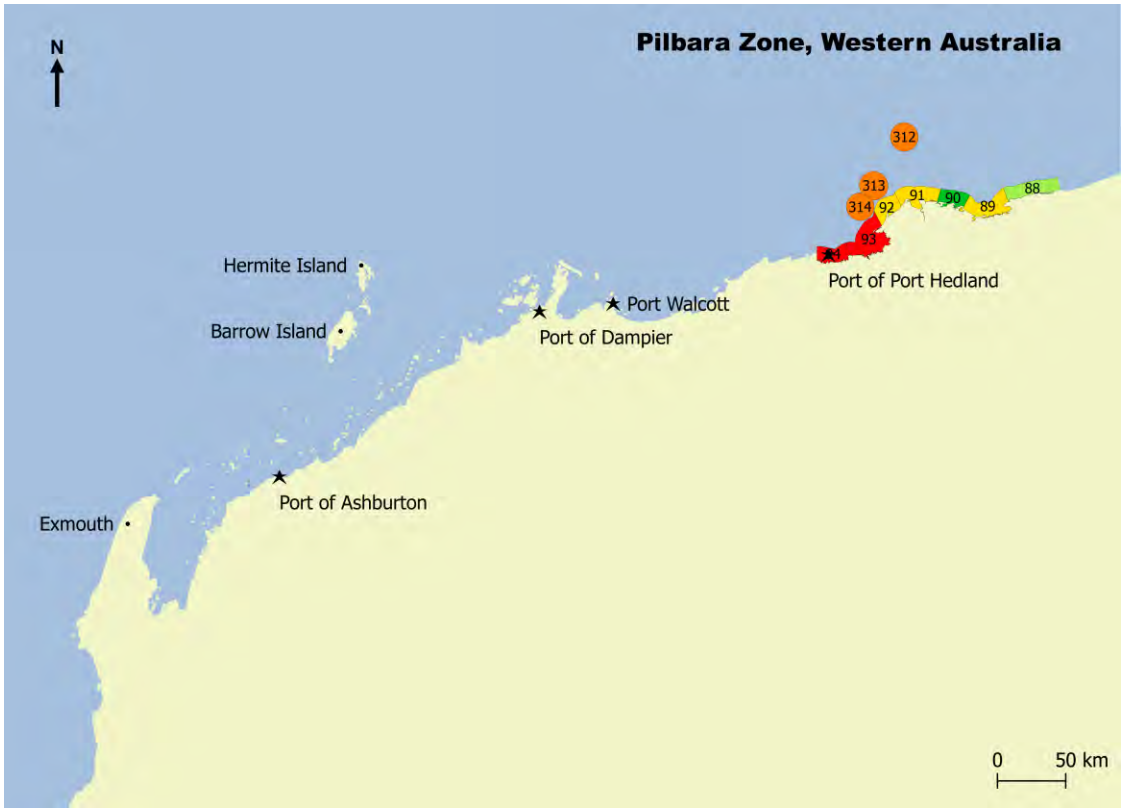


Figure 6.26 – WA12 Sub-Zone Risk Profile



The table on the following page summarises the risk and protection priority information for this sub-zone.

WA12 Summary Table

ID	Name	Overall Risk Rating	Exposure	Overall Protection Priorities Rating	Protected Fauna	Protection Areas	Heritage	Economic	Social Amenity Recreation	Brief Description of Overall Protection Priority Rating	Key Drivers of Shoreline Exposure
88	Shoonta Well - Cooraidegel Well coast	Low		Very High			N/A			*RAMSAR Wetland (Eighty-mile Beach)*	*Bulk Carriers, Oil Tankers*
89	Condini Landing - Mulla Mulla Creek	Moderate		Very High						*RAMSAR Wetland (Eighty Mile Beach)*	*Bulk Carriers, Oil Tankers*
90	Yan Well coast - Condini Landing (A)	Very Low		Moderate						*Protected fauna (birds, reptiles, mammals), exposed tidal flats, Eighty Mile Beach Pearling*	*Bulk Carriers, Oil Tankers*
91	Yan Well coast - Condini Landing (B)	Moderate		High			N/A		N/A	*Important wetlands (De Grey River)*	*Bulk Carriers, Oil Tankers*
92	Wattle Well coast - Yan Well coast (A)	Moderate		Moderate			N/A		N/A	*Protected fauna (reptiles, mammals), Exposed tidal flats*	*Bulk Carriers, Oil Tankers*
93	Wattle Well coast - Yan Well coast (B)	Very High		Very High			N/A		N/A	*Port Hedland Port*	*Bulk Carriers, Oil Tankers*
94	Beebingara Creek coast E - Wattle Well coast	Very High		Very High						*Port Hedland Port*	*Bulk Carriers, Oil Tankers*
312	Yan Well coast - Condini Landing (C)	High		High			N/A			*Nature Reserve (Bedout Island)(IUCN IA)*	*Bulk Carriers, Oil Tankers*
313	Wattle Well coast - Yan Well coast (C)	High		High					N/A	*Nature Reserve (North Turtle Island)(IUCN IA)*	*Bulk Carriers, Oil Tankers*
314	Wattle Well coast - Yan Well coast (D)	High		Moderate					N/A	*Protected fauna (reptiles, mammals, fish), Mangroves (<1000 ha), Commonwealth protected shipwreck: Mary B*	*Bulk Carriers, Oil Tankers*

Key

Very Low	Low	Moderate	High	Very High

Key for Exposure

7. Conclusion

The WAMOPRA combines regional, national and international data for maritime activity and marine oil spills, levels of activity and protection priorities including environmental sensitivities to develop an overview of oil spill risk in the Pilbara zone. This report summarises the context, methodology and results for the Pilbara Risk Assessment Zone. It builds on the work undertaken in the preliminary state-wide assessment.

From an oil spill risk assessment perspective, distinctive features of the Pilbara zone include: scale, exceptional ecological values, large scale export facilities and shipping activity from mineral sector activities and challenging logistics due to remoteness.

The highest risk areas are around Port Hedland, Port Walcott and Dampier Port, where there is a high level of shipping traffic combined with high protection priorities. In particular, the number of bulk carriers visiting ports in this area is a key driver of risk. The resulting high activity density is compounded by the constraints of channel approaches. Other factors include:

- In Port Hedland there is a constrained time window for departures and arrivals of deep draught vessels which results in multiple vessels being managed in a single orchestrated operation.
- The Port of Port Hedland and Port Walcott both have limited turning area in the port area for deep draught vessels.
- Port Walcott and the Port of Dampier both see a relatively broad mix of operational activity which results in added complexity.
- The Port of Dampier has multiple convergent channels supporting multiple jetty and port facilities which are managed by different operators. This adds complexity as overall port activity is not able to be centrally orchestrated.

The western-most part of Pilbara, around Exmouth, has very high protection priorities but lower exposure, resulting in overall lower risk.

The effect of petroleum facilities on shoreline risk is small in the Pilbara region despite this area having a high concentration of activity relative to the rest of Western Australia. This is a result of facilities being located at significant distances from the shoreline and producing primarily gas and condensate or light crude oils. There has also been a low level of recent exploration activity as a result of lower oil prices. Nonetheless, potential spills from petroleum facilities remain a significant source of offshore sea cell exposure.

The Wheatstone project will affect risk further west of the aforementioned ports. However, the effect of gas development on oil pollution risk profiles tends to be relatively low as any liquid product quickly dissolves or evaporates. There will be an increase in gas carrier vessels transiting to and from the area. As modelled in Stage One, this is not expected to significantly alter the risk profile although there is uncertainty of the extent to which traffic will increase.

This companion report summarises the WAMOPRA results for the Pilbara Risk Assessment Zone. Further risk outputs are available via an interactive website at http://wamopra.navigatusconsulting.com (contact Team Leader Planning and Public Information for username and password).

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