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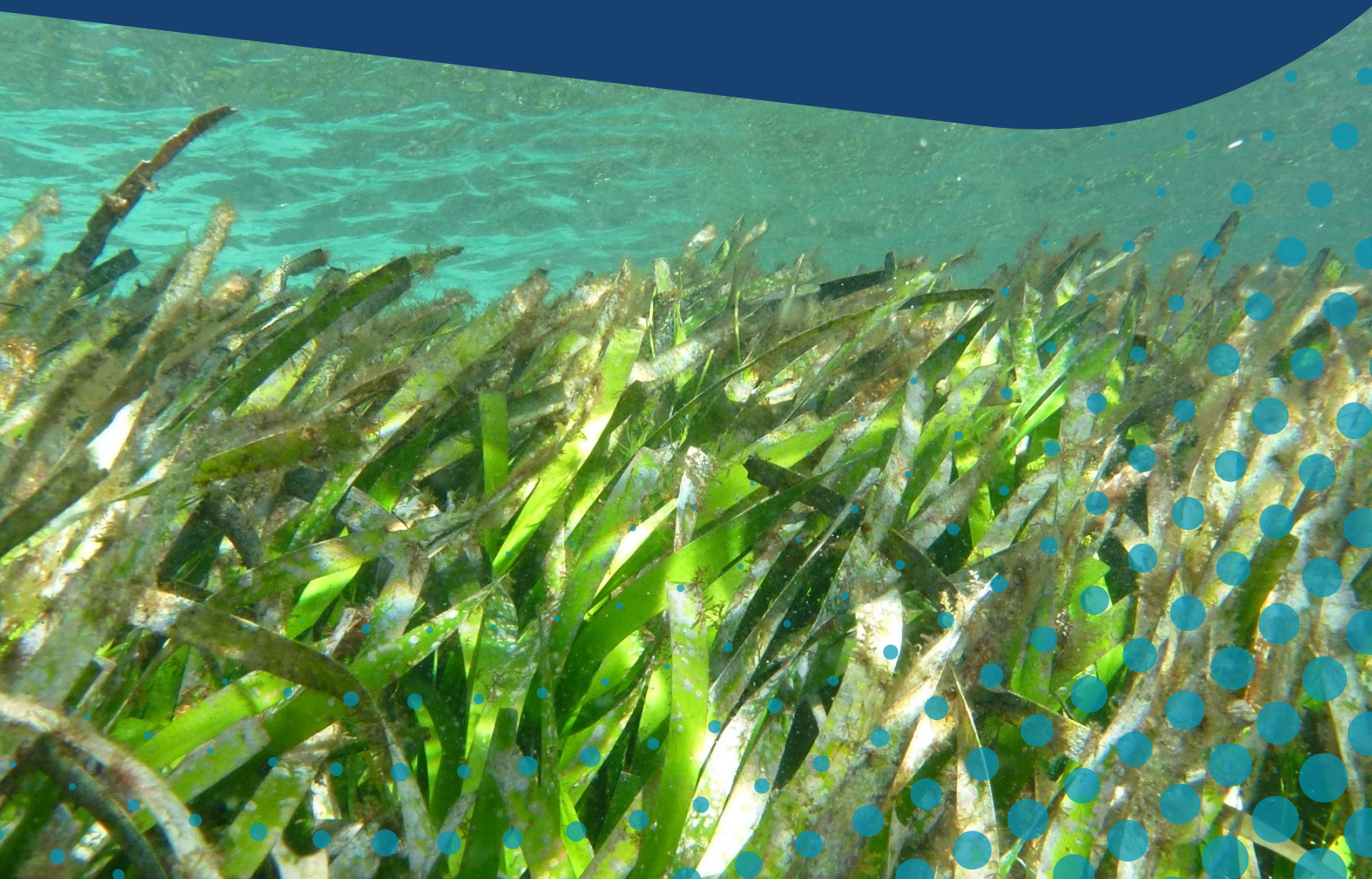
Literature Review and Preliminary Risk Assessment of the Marine Environment for the Westport Port and Environs Strategy

October 2019



WAMSI Literature Review and Preliminary Risk Assessment of the Marine Environment for the Westport Port and Environs Strategy

As part of the State Government's Westport Program, the Western Australian Marine Science Institution (WAMSI) was engaged to complete this report to inform Westport's option evaluation process for the location of WA's future container port and ongoing environmental planning.

At the time of writing the report, three potential locations for the new port were proposed: Fremantle Inner Harbour, Fremantle Outer Harbour (Kwinana) and the Port of Bunbury.

The purpose of the report was to conduct a literature review and subsequently use this knowledge to perform a preliminary risk assessment on the marine environmental and social values of all three locations. There were two overarching goals of the literature review and the preliminary risk assessment:

1. to support decision-making on the best location for a port
2. to identify the gaps in knowledge that could be the target of future research programs

The WAMSI literature review and preliminary risk assessment made no recommendations on where a port should be located and this review was one of many inputs informing the assessment of where to locate the port.

The findings in this report provided the basis for Westport's $13.5million investment for WAMSI to deliver a three-year environmental research and modelling program that fills important knowledge gaps about Cockburn Sounds' ecosystem.

WAMSI is pleased to be leading the WAMSI Westport Marine Science Program which will:

- establish environmental baselines and improve understanding of key ecological processes;
- help shape the concept designs and operational planning for the new port;
- inform mitigation strategies; and
- complete on-ground ecosystem restoration trials to inform a long-term restoration plan.

This partnership will ensure high quality, transparent and inclusive science will be undertaken by an independent provider.

WAMSI is committed to sharing its research and findings as this work progresses.

Literature Review and Preliminary Risk Assessment of the Marine Environment for the Westport Port and Environs Strategy

by:
Western Australia Marine Science Institution
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Cover

Seagrass *Posidonia australis* (Photograph: A. Rossen)

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Purpose and approach

The Westport Taskforce (Westport) is developing a plan to guide the Government on the long-term development of Perth's freight network. With a focus on the ports at Fremantle, Kwinana and Bunbury, Westport is assessing Perth and surrounding regions' trade and supply chain infrastructure to ensure the demands of a growing population can be met for the next 50 years and beyond.

This report presents the results of a literature review and preliminary risk assessment on the marine environmental and social values for Fremantle, Kwinana and Bunbury ports and surrounds.
Specifically, this report:

- refines the accuracy of the Westport Environmental Work Stream's initial assessment (EWS Stage One Progress Report November 2018)
- assesses the risk of harbour development, climate change, other industrial and urban development separately and combined as a cumulative risk
- identifies opportunities for avoiding and mitigating risks and/or improving environmental and social values in the vicinity of each port
- identifies key information gaps that could be the target of future research programs

Important findings from the literature review

Fremantle:

- Environmental
  - Fremantle benefits from reports documenting the after effects of dredging that occurred in 2010 in the Inner Harbour, which provided useful insight for future dredging campaigns
  - Bottlenose dolphins have been one of the most studied species in the area, particularly in relation to underwater noise associated with port operations
  - Fairy terns have made their home in vicinity to the port, with breeding populations regularly occurring at the sanctuary at Rous Head
- Social
  - There are a number of registered heritage sites occurring in and around the port footprint, one of the most important of which is the Swan River, which is registered as a mythological aboriginal heritage site, and one of the largest is the 'Indian Ocean' mythological site
  - Recreational fishing is important within the Inner Harbour as well as the Swan River estuary and adjacent coast
  - The Inner Harbour is also a major thoroughfare for a lot of recreational boating heading offshore to access oceanic waters and the offshore islands and returning to river-based marinas and boat ramps
  - Tourism, commercial fisheries and aquaculture operate within the Inner Harbour and surrounds and the number of cruise ships visiting Fremantle has increased in recent years

Kwinana:

- Environmental
  - Significant information for the Kwinana area comes from the annual monitoring of Cockburn Sound and the State of Environment reports issued by the Cockburn Sound Management Council
  - Seagrass is the most intensively studied habitat as thousands of hectares of seagrass were lost following wastewater and industrial outflow release into Cockburn Sound from the 50s to the 70s
  - Water quality has improved but localised issues still remain
  - Benthic habitats, particularly seagrass, and the sheltered nature of Cockburn Sound provide regionally significant spawning and nursery areas for species such as e.g. pink snapper, blue swimmer crabs and southern garfish

  - A significant number of studies have investigated foraging habits, population dynamics and anthropogenic stresses on resident populations of little penguins and bottlenose dolphins
- Social
  - Cockburn Sound has 31 listed maritime heritage sites and several listed mythological and aboriginal heritage sites, the largest of which is the 'Indian Ocean' mythological site
  - Recreational fishing is one of the most important 'social and community' values in Cockburn Sound and commercial fishing also occurs, though licenses have been in decline since 1990
  - Mussel aquaculture is a significant industry operating in Cockburn Sound, but has faced declines in mussel growth due to rising sea temperatures, predation and decreased nutrient levels.
  - Tourism is important at Rockingham with diving and dolphin encounters being some popular options

Bunbury:

- Environmental
  - Water quality at some localised areas (i.e. inner and outer harbour) is an issue, and turbidity is high in Koombana Bay, particularly during winter and spring
  - Bottlenose dolphins have been intensively studied within Koombana Bay and surrounds with a particular focus on population dynamics and foraging
  - Koombana Bay and Leschenault Inlet are regionally significant spawning and nursery areas for whitebait and King George whiting respectively
  - Leschenault Estuary and Inlet are regionally significant nursery areas for blue swimmer crabs
- Social
  - The Leschenault Estuary and Preston River are significant aboriginal mythological sites
  - Koombana Bay and Leschenault Inlet are important contemporary sites for fishing and recreation
  - Koombana Bay has remnants of 13 ship wrecks as well as several other maritime and historical sites
  - Recreational fishing is one of the most important social and community values in the region, and occurs throughout Koombana Bay, Leschenault Inlet and Leschenault Estuary
  - Tourism is important for Bunbury with diving and dolphin encounters being some popular options
  - Commercial fishing occurs outside of Koombana Bay, though some low level fishing for baitfish occurs at certain times of the year along the beaches of the Bay

Findings of the Risk Assessment and possible preliminary mitigation measures for each port

The literature review was used to inform a risk assessment of potential issues arising for each identified value. The risk assessment was performed using a formal qualitative risk approach (consequence x likelihood), which assigns a level of risk ranging from 'low' to 'extreme'. The suggested mitigation measures should be viewed as preliminary only, as these were determined in the absence of any conceptual or engineering design information and advice on feasibility of suggested measures.

Fremantle

Fremantle was the area of interest with the lowest number of high risks scores, which largely reflects historical changes, its existing status as a major working port and a highly engineered environment. In total, three high risks relating to harbour development were given to the values of biological diversity, bottlenose dolphins and commercial fishing. If an increase in throughput of Fremantle Inner Harbour was to occur, preliminary mitigation measures that may help to lower these high risks include:

- Adopting PIANC Working with Nature principles that avoid significant habitat loss, include engineering niche areas for species and foraging and engineering walls of built structures to promote growth of native species
- Ensure continuation of the State Wide Array Surveillance Program (SWASP) and regular reporting
- Avoiding noisy dredging operations and port maintenance (i.e. pile driving) during the breeding season when dolphins are socialising and calving, and engage Marine Mammal Observers during dredging operations

- Engineering fish/fisher friendly shoreline structures
- Avoiding dredging during peak fish and invertebrate spawning and migration periods through the Inner Harbour
- Establishing new seagrass meadows on shallow sandy banks offshore, adjacent the harbour and upstream of the Inner Harbour to help avoid a lag in ecosystem functioning. Establishing new seagrass meadows is difficult so allowing an appropriate time frame for establishment needs to be considered

Kwinana

The number of high risks related to harbour development was greatest for Kwinana, totalling 14 high risks for environmental and social values. The values at risk include integral functioning ecosystem, biological diversity, water quality, seagrass, fairy terns, little penguins, bottlenose dolphins, migratory shorebirds and seabirds, pink snapper, high quality water for desalination, seafood quality, tourism, commercial fishing and aquaculture. If an expansion of the Outer Harbour in Cockburn Sound was to occur, preliminary mitigation measures that may help to lower these high risks include:

- Adopting PIANC Working with Nature principles which include engineering port structures and niche habitats to improve ecosystem functioning
- Rehabilitating existing seagrass meadows in the near future and establishing new seagrass meadows on shallow sandy banks in Cockburn Sound would help to prevent a lag in ecosystem functioning and increase benthic primary productivity locally. Establishing new seagrass meadows is difficult so allowing an appropriate time frame for establishment needs to be considered
- Ensure continuation of the State Wide Array Surveillance Program (SWASP) for introduced marine pests and regular reporting
- Filling in unused dredged depressions on Success and Parmelia Banks with sandy dredge spoil could create shallow sandy banks suitable for establishment of new seagrass meadows
- Improved management of groundwater, storm water and run-off into Cockburn Sound to minimise nutrient input
- Implementing additional dredge management measures i.e. dredging without overflow and discharging sediments safely, considering tidal movements and water circulation, avoiding winter when seagrass most vulnerable to low light, avoiding pink snapper spawning and larval growth period
- Design port to minimise vessel movement i.e. less turning and manoeuvring which would limit disturbance to sediments
- Having first strike response kits in place with the capability to deal with any size oil spill (level 2/3)
- Incorporating protected seabird friendly sanctuary areas within the harbour boundaries
- Limiting the loss of Kwinana Shelf habitat or creating additional niche foraging habitats for dolphins
- Removing contaminated sediments to reduce potential for bioaccumulation through the food chain and improve sediment and water quality
- Avoiding noisy dredging operations and port maintenance (i.e. pile driving) during the breeding season when dolphins are socialising and calving, and engage Marine Mammal Observers during dredging operations
- Avoiding dredging and high vessel use near industrial intake pipes, or redirect intake pipes
- Engineering fish/fisher friendly structures
- Creating areas conducive to mussel spat collection and mussel grow out

Bunbury

Bunbury had a total of 12 high risks for environmental and social values that would be associated with harbour development. These values include biological diversity, water quality, seagrass, fairy terns, bottlenose dolphins, little penguins, pouched lampreys, migratory shorebirds and seabirds, whitebait, Aboriginal heritage, seafood quality and tourism. If an expansion of Bunbury Port was to occur in Koombana Bay, preliminary mitigation measures that may help to lower these high risks include:

- Adopting PIANC Working with Nature principles which includes engineering niche habitats for species and foraging, as well as designing walls of built structures to promote growth of native species
- Implementing additional monitoring measures to reduce incidence of marine pests
- Adopting low impact dredging methods to excavate basalt
- Managing storm water and run-off to reduce nutrient input into Leschenault Inlet and Koombana Bay
- Implementing additional dredge management measures i.e. dredging without overflow and discharging sediments safely, considering tidal movements and water circulation, avoiding winter when seagrass most vulnerable to low light, avoiding dredging during peak spawning and nursery periods for fish and invertebrates
- Design port to minimise vessel movement i.e. less turning and manoeuvring which would limit disturbance to sediments
- Having first strike response kits in place with the capability to deal with any size oil spill (level 2/3)
- Upgrading the wastewater capture system of the existing port to prevent contamination of Preston River and Vittoria Bay
- Rehabilitation of seagrass meadows outside of Koombana Bay in the near future to prevent a lag effect in ecosystem functioning. Establishing new seagrass meadows is difficult so allowing an appropriate time frame for establishment needs to be considered
- Incorporating protected bird friendly areas within the harbour boundaries
- Removing contaminated sediments to reduce bioaccumulation
- Redirection of the Preston River back into Vittoria Bay rather than truncation
- Avoiding noisy dredging operations and port maintenance (i.e. pile driving) during the breeding season when dolphins are socialising and calving. Engage Marine Mammal Observers during development and dredging operations and include an exclusion zone around any blasting/fracturing operations, though these operations should be avoided if possible.

Information gaps

A prioritised list of significant information gaps that could direct future work and that are applicable for the marine environments of all three areas of interest, include:

- Updated measurements on surface water drainage, groundwater nutrient concentrations, flux and contaminants
- Hydrodynamic modelling inclusive of groundwater flows, recent and localised wave and wind climate data, and influence of dredged channels
- The impact of copper-based coatings or other TBT-replacement coatings for vessels on the marine environment
- Contemporary contaminant sources and pathways and consideration of emerging potential contaminant risks
- Routine widespread monitoring of contaminants, refinement of trigger values and inclusion of reference sites
- Effects of PFAS and other contaminants (i.e. mercury) on marine food webs
- Level of plastic contamination (e.g. microplastics, debris) and attached pollutants
- Further investigation into the role of microphytobenthos in soft sediments
- The level of resilience of coastal environment and key marine ecological components (e.g. communities of plankton, fish, seagrass, benthic macroinvertebrates), including responses to climate change
- Bioaccumulation of contaminants in marine life e.g. seabirds, fishes, sea lions
- Establishing routine monitoring of fish and invertebrate communities with the purpose of detecting temporal trends and shifts in composition in relation to environmental conditions
- Impact of specific sediment type, shape and size from each of the port areas on larval fish
- Causes of recruitment variation in blue swimmer crabs including impacts of recent marine heatwaves

- Integrative models to better understand the interactions within and between ecological and social components of the marine environment, helping decision-makers to more fully understand what the key ecosystem levers are and where future management action should be targeted
- Modelling of coastal processes and sediment transport along shorelines that is calibrated against local sediment budgets and that can inform effective coastal planning
- Development of ecological models that allow scenario testing and that can be coupled with contemporary decision support models

In addition to the above list, prioritised gaps that could direct future work for each port area include:

Kwinana

- Year-round water quality measurements to capture seasonal variations
- Routine widespread monitoring of contaminants, refinement of trigger values and inclusion of reference sites
- Knowledge of cause(s) and pressure-response pathways associated with decreasing seagrass shoot density trends in Cockburn Sound e.g. potential sulphide intrusion into root systems
- Regular mapping of seagrass meadows at the site level and entire Cockburn Sound and determination of the best monitoring methods to detect changes in seagrass health
- The broad scale efficacy of seagrass restoration efforts across Cockburn Sound to better understand the local parameters and regional factors influencing seagrass restoration success rates (including effects of climate change)
- Experimentation into development of artificial niche foraging habitats for dolphins?
- Measurements of dissolved oxygen in sediments and fluctuations between day and night
- Identification of specific migratory shorebird and seabird sites and identification of suitable alternative sites for climate changed induced shifts
- Factors affecting recruitment and spawning variation, changes in growth and stock productivity, and increased predation by sharks on pink snapper

Bunbury

- Year-round water quality measurements to capture seasonal variations
- Identification of specific migratory shorebird and seabird sites and identification of suitable alternative sites for climate change induced shifts
- Population and ecological studies on the giant cuttlefish that dolphins specialise in feeding on in Bunbury

Recommendations for next steps

Next steps to be considered for the Westport Port and Environs Strategy include:

- Development of a research framework to deal with the gaps identified above, which would include a better understanding of government, industry, indigenous and community values and a process for determining future research directions, e.g. the WAMSI framework to implement 'Blueprint for Marine Science 2050' priorities
- Investigate the feasibility of potential mitigation measures and identifying additional measures that may help to lower the risk of impact of harbour development in the three areas of interest. To do this, subject matter experts and engineering advice should be sought to ensure mitigation measures are worked into the design and management frameworks of harbour development
- Comprehensive risk analysis of environmental and social values based on more detailed harbour concepts and engagement with stakeholders and engineers

NB: The outputs from this report were based on a rapid assessment of currently available literature and without knowledge on definite port footprints and specific engineering designs or project descriptions. This report is subject to, and must be read in conjunction with, the limitations, assumptions and qualifications contained throughout the report.

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Terms, acronyms, abbreviations and units

ACAAR	Australian Centre for Applied Aquaculture Research
AH Act	Aboriginal Heritage Act
BMT	BMT Group Ltd
CAMBA	China –Australia Migratory Bird Agreement
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CSMC	Cockburn Sound Management Committee
CS	Cockburn Sound
DBCA	Department of Biodiversity, Conservation and Attractions
DPIRD	Department of Primary Industries and Regional Development
DPSIR Report	Driver-Forces-Pressures-State-Impacts-Responses Report
DWER	Department of Water and Environmental Regulation
ENSO	El Nino - Southern Oscillation
EPA	Environmental Protection Authority (now DWER)
EPBC Act	Environment Protection and Biodiversity Conservation Act
EWS	Westport Environmental Working Stream
FRDC	Fisheries Research and Development Corporation
Fremantle SLSC	Fremantle Surf Life Saving Club
GHD	GHD Consulting Company
HMAS Stirling	Her Majesty's Australian Ship Stirling
JAMBA	Japan –Australia Migratory Bird Agreement
KB	Koombana Bay
MAFRL	Marine and Freshwater Research Laboratory
Mg/l	Milligrams per litre
PCB	Polychlorinated Biphenyl
PFAS	Poly-fluoroalkyl substances
PIANC	Permanent International Association of Navigation Congresses - World Association for Waterborne Transport Infrastructure
RPS	RPS Consulting
SDOOL	Sepia Depression Ocean Outlet Landline
SKM	SKM Consulting
TBT	Tributyltin
UWA	The University of Western Australia
WA	Western Australia
WAMSI	Western Australian Marine Science Institution
WASQAP	Western Australian Shellfish Quality Assurance Program

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1 Introduction

The Westport Taskforce is developing a plan to guide the Government on the long-term development of Perth's freight network. With a focus on the ports at Fremantle, Kwinana and Bunbury, the Westport Taskforce is assessing Perth and surrounding regions' trade and supply chain infrastructure to ensure the demands of a growing population can be met for the next 50 years and beyond. The options for future port expansion considered by the Westport Taskforce include an increase in throughput of Fremantle Inner Harbour; an expansion of the Outer Harbour with a new container port in Cockburn Sound; and/or an expansion of Bunbury Port. This report focuses on the marine environments of these three areas of interest.

1.1 Context

1.1.1 Fremantle

The Fremantle Inner Harbour is situated where the Swan River Estuary mouth meets the Indian Ocean. It was officially opened in 1897, after development that included the removal of a rock bar at the mouth of the Swan River. The removal of the rock bar significantly changed the aquatic environment of the estuary from its natural state. In combination with other pressures such as dredging, growth in shipping operations and eutrophication issues from land clearing, agriculture and development further upstream, the marine environment of the Inner Harbour, as well as the estuary, cannot be regarded as a pristine environment (EPA 2009, SKM 2009c, Kelsey et al. 2010). The estuary has experienced an increase in fish kills, cyanobacterial blooms, red tides and accumulation of organic matter in the bottom sediments over the past few decades. The sediments of the Inner Harbour are similar to other working ports, with contaminants such as heavy metals often exceeding background concentrations.

The Inner Harbour has undergone three harbour deepening campaigns since the original construction to 9.2 m in the 1890s (SKM 2009c). The harbour was dredged to 11 m in the 1920s, from 11 m to 13 m in 1988 and from 13 m to 14.7 m in 2010, which also involved dredging of the Entrance Channel. The additional footprint associated with the Inner Harbour includes Gage Roads, the Deep Water Channel and Rous Head. Gage Roads is a natural offshore depression used as an anchorage for vessels waiting to enter the port and, as a result, sediments and benthic communities are continually disturbed in the region (SKM 2009c). The Deep Water Channel, which was dredged for the first time in 2010, is used as a shipping channel and is largely a sandy sediment environment supporting patches of macroalgae and seagrass (Oceanica Consulting 2013). Rous Head was built on reclaimed land made from previously dredged materials and is now an important working port (Northport) and container storage facility. It also supports a small fairy tern breeding sanctuary area which is locally important (Fremantle Ports 2018).

1.1.2 Kwinana

The Fremantle Outer Harbour area extends south of the Fremantle Inner Harbour into Cockburn Sound, and includes facilities such as the Alcoa Alumina and BP Oil Refinery Jetties, Kwinana Bulk Terminal Bulk Jetty, and CBH Kwinana Grain Terminal. In conjunction with Outer Harbour operations, there has been significant industrial development along the eastern margin of Cockburn Sound including the Perth Seawater Desalinisation Plant and Australian Marine Complex. Up until the late 1970s, residential and industrial effluent was released directly into Cockburn Sound, including wastewater contaminated with hydrocarbons and nutrients (BMT 2018). In the early 1970s, the Garden Island Causeway was built using a 3.3 km solid rock-fill wall to connect Garden Island to the mainland in order to establish the Royal Australian Navy base, HMAS Stirling, on Garden Island. The Causeway reduced some natural water exchange across the shallow sill between the southwestern section of Cockburn Sound and the ocean. Pollution, specifically nutrient enrichment, caused a deterioration of the marine environment and, ultimately, widespread loss of seagrass. In the two decades between the mid-60s and mid-80s approximately 77% of seagrass habitat was lost from Cockburn Sound (Kendrick et al. 2002, BMT 2018).

Since the early 1980s, significant effort by both Government and industry have gone towards improving water quality and trying to restore health in Cockburn Sound. This includes the diversion of wastewater and some industrial outflow to 4 km offshore of Point Peron via the Sepia Depression Ocean Outlet Landline. The Cockburn Sound Management Council was formed in 2000 and oversees annual monitoring and improvements to the health of the Sound. However, despite water quality improving over time, seagrass has not recovered (CSMC 2017; 2018, BMT 2018).

The seagrass meadows, sandy basins and protected waters of Cockburn Sound are regionally important as spawning and nursery areas for several commercially and recreationally fished species, such as blue swimmer crabs and pink snapper (Wakefield 2010, Crisafulli 2018, CSMC 2018). The Sound also provides important foraging grounds for resident populations of little penguins and dolphins (Cannell et al. 2016, Cannell 2017, Chabanne et al. 2017). As a result, fishing, tourism and recreational activities are popular in Cockburn Sound and the region is significant for indigenous culture and heritage as well as maritime heritage. A combination of recreational use, heavy industrial activity, port operations, aquaculture, and Australian Navy operations result in Cockburn Sound being the most intensively used marine environment along the Western Australian coastline (BMT 2018).

1.1.3 Bunbury

The Port of Bunbury is situated in Koombana Bay, adjacent to the Leschenault Estuary, and largely services the bulk shipping export needs of the south-west of Western Australia. Outer Harbour operations commenced in 1864 with the construction of the heritage listed Bunbury Timber Jetty and expanded in the 1960s with the inclusion of land backed berths. The Inner Harbour was constructed in the 1970s and involved cutting off a southern section of the Leschenault Estuary to create the Leschenault Inlet. Following completion of the Inner Harbour in 1976, a channel was excavated at Point MacLeod, known as 'The Plug', to allow water circulation and a thoroughfare for vessels between Leschenault Inlet and Koombana Bay. Additional modifications to the Leschenault Estuary have included the creation of a new opening to the ocean via 'The Cut' in 1952, and realignment of the Preston River into the Estuary during Inner Harbour construction in the 70s.

The Leschenault Inlet has fundamentally changed from an estuarine system to a marine embayment, due to separation from the main estuary and the lack of freshwater (McKenna 2004, PLACE Laboratory 2013, GHD 2017a)). After 'The Cut' was made, the Leschenault Estuary changed from tide dominated to wave dominated and from well mixed to a salt-wedge partially mixed environment with a higher risk of habitat loss due to sedimentation. Despite these significant modifications, Koombana Bay, the Estuary and Inlet still provide favourable habitats for important fish species, crabs, dolphins, little penguins and migratory shorebirds (Cannell 2017; pers.comm., Manlik et al. 2018 Sprogis et al 2018, Christine Taylor pers. comm.).

1.2 Overview of current state of environment and key pressures

1.2.1 Fremantle

The key pressures facing the environment of the Fremantle Inner Harbour and surrounds stem from an increase in human activity. These are summarised below.

- The risk of more introduced marine pests establishing in Fremantle marine and estuarine waters increases with increasing vessel traffic (Bridgwood and McDonald 2014). With a warming ocean and increase in marine heatwaves, some marine species are likely to be negatively impacted if they cannot shift their distributions, while the marine and estuarine communities in general may become more tropicalised and support the establishment of competing species. Since 2010, introduced marine pests have been monitored under the State Wide Array Surveillance Program (SWASP) and reports are completed twice a year.
- There is only one exchange channel between the estuary and the ocean for marine life and increased usage of the port could interrupt important migratory and recruitment behaviours for crustaceans, fishes and dolphins (SKM 2009c).

- Coastal erosion, inundation and flooding are all high concerns for the Inner Harbour, surrounding coastlines and the estuary, which will add pressure to coastline developments and pose risks to important shoreline habitats and associated fauna and flora (GHD 2017, M. P. Rogers 2018).

1.2.2 Kwinana

The current state of the environment of Cockburn Sound and key pressures are detailed in the *Cockburn Sound-Drivers-Pressures-State-Impacts-Responses Assessment 2017 Final Report* (BMT 2018) and is summarised here.

- Heavy industrial use, residential developments and public amenities line the coast of Cockburn Sound which have significantly modified the coastal environment.
- Contaminated sediments still occur in localised regions and per- and poly-fluoroalkyl substances (PFAS) has become a relatively recent concern but, overall, sediment quality is considered acceptable.
- Concerted efforts have seen water quality continue to improve over time and is currently at a high standard for recreational and industrial purposes. Water quality and associated phytoplankton blooms are still an issue in some areas, such as the southern section of Cockburn Sound.
- Despite improved water quality and an increase in the extent of seagrass meadows, there is still evidence of seagrass declining at some sites based on shoot density measurements, and other factors need to be investigated.
- A combination of habitat loss and degradation, and environmental influences such as marine heatwaves, has seen a decline in some commercial and recreational fisheries, including garfish, herring, crabs and mussels. Conversely, catches for squid, octopus and snapper are considered stable, and snapper stocks received some assistance with the help of a restocking project following a 2015 fish kill incident.
- Resident dolphin and little penguin populations which use Cockburn Sound for foraging and nursing are currently considered relatively stable.

The key pressures facing Cockburn Sound are all human-induced and are likely to further accumulate with future coastal developments associated with human population growth. These include the following:

- Groundwater discharging into Cockburn Sound is the main source of nutrients and legacy issues remain from agricultural and industrial contamination.
- The risk of more introduced marine pests establishing in Cockburn Sound and surrounds increases with increasing vessel traffic.
- Commercial and recreational fishing, alongside climate change and the increased incidence of marine heatwaves, have the potential to impact on already declining and currently stable fish stocks, particularly those species that rely on the conditions of Cockburn Sound.
- Under a changing climate, inundation and erosion from sea level rise and the increased frequency of extreme weather events will add pressure to coastline developments and wash away important shoreline habitats for fauna and flora.

1.2.3 Bunbury

The most recent environmental information on Koombana Bay and surrounds is detailed in the *Inner Harbour Structure Plan: Strategic Public Environmental Review* (GHD 2017) and is summarised here.

- Most of the Koombana Bay coastline, the Leschenault Inlet and the eastern margin of the Leschenault Estuary are lined with industrial, commercial and residential developments with some areas facing erosion issues due to insufficient setback.
- Water quality is sometimes hampered by seasonally variable nutrients levels, and contaminants have been recorded in the water column, in mussel tissues, and in sediments in and around port operations and Koombana Bay.
- Koombana Bay, the Leschenault Inlet and Leschenault Estuary are turbid environments, and outflow from the estuary into Koombana Bay can further elevate turbidity, particularly during winter, where plumes can spread out of the Bay.

- There is little benthic macrophyte growth in the bay and it largely supports microalgae species that live on or within the sediments along with some filter feeders. Macroalgae and seagrasses are found throughout the Leschenault Estuary where one of the main restrictions to seagrass distribution is light availability.
- The Leschenault Inlet has the most well-developed mangroves and currently they occupy all available suitable habitat.
- Whitebait and Australian herring are under pressure, whereas the most popular fished species, the blue swimmer crab, is considered sustainable, though no commercial fishing of crabs in Koombana Bay and Leschenault Estuary is permitted.
- The Preston River Delta supports a regionally significant site for migratory shorebirds, and McKinnon Point on the Outer Harbour supports successful breeding colonies of fairy terns.
- The resident dolphin population is at risk of decline if reproductive rates do not improve.

The key pressures facing the Koombana Bay region are similar to Kwinana and are human-induced and likely to accumulate with future coastal developments such as port, marina and industrial expansion. These include the following:

- Potential acid sulphate soils have been identified in the region and are at risk of exposure with development and realignment of the Preston River.
- Future realignment or truncation of the Preston River would also significantly impact on the delta and jeopardise a regionally significant migratory shorebird site (GHD 2017b).
- An increase in vessel traffic to the port increases the risk of introduced marine pests establishing and competing with native populations.
- An increase in marine heatwaves, commercial and recreational fishing and declining health of the Leschenault Estuary have the potential to impact on already declining and currently stable fish stocks.
- Inundation and erosion from sea level rise and the increased frequency of extreme weather events will add pressure to coastline developments with insufficient setback and pose risks to important shoreline habitats and associated fauna and flora.

1.3 Purpose of this report

WAMSI was engaged by the Department of Transport's Westport Taskforce Environmental Working Stream (EWS) to complete a synthesis of knowledge pertaining to the marine environments for the three proposed locations of port expansion: Fremantle, Kwinana and Bunbury. The purpose of the report was to conduct a literature review and subsequently use this knowledge to perform a risk assessment on the marine environmental and social values identified for Fremantle, Kwinana and Bunbury. Both the literature review and the risk assessment could then be used to identify the gaps in knowledge that could be the target of future research programs. The aims of the report are:

- to report on state of environment and key pressure points
- to ensure relevant environmental information for each area of interest is identified, collated, reviewed and available to inform EWS outputs with a focus on the environmental and social values initially identified by the EWS (Table 1)
- to ensure relevant monitoring datasets have been identified
- to refine and improve the accuracy of the EWS value/concern/confidence tables to enable a comparison between options for port expansion – both environmental and social values
- to identify and prioritise key information gaps and make recommendations
- to opportunistically identify opportunities (for avoiding, mitigating impacts and for improving on environmental/ social values) as part of the stakeholder consultation process

Table 1: Marine and estuarine environmental and social values identified in an initial assessment by EWS.

Category	Sub-category	Relevant specifics
Environmental values		
Integral functioning ecosystem		
Sheltered marine ecological community		
Biological diversity		
High level of water quality		
High level of sediment quality		
Significant benthic communities and habitats	Seagrass	
Listed and significant fauna	Threatened fauna	Australian sea lion, fairy tern, other
	Priority & specially protected fauna	
	Migratory birds	
	Iconic fauna	Little penguins, bottlenose dolphins
Regionally significant spawning / nursery area	Pink snapper, whitebait, King George whiting, garfish, blue swimmer crab	
Marine reserves (existing and proposed)		Shoalwater Islands Marine Park, Swan Estuary Marine Park, Leschenault Regional Park
Social values		
Heritage	Aboriginal, Maritime & historic	
Public health	High quality source water for desalination, Recreational water quality, Seafood quality safe for eating	
Social and community	Recreational fishing, Recreational boating access, Marina facilities, Educational & scientific values, Landscape and visual amenity	
Business, industry & commercial	Tourism (including ferries and cruise ships), Commercial fisheries, Aquaculture, Suitable quality water for industrial use, Assimilation of wastewater	

(EWS Stage One Progress Report November 2018)

1.4 Scope of this report

This report focuses on published and unpublished studies from scientific journals, technical reports and grey literature. Where there were limited sources of information for some values, information from websites, presentations and media releases have also been included. This report is not an exhaustive study however it does satisfy the aims and scope. The marine and estuarine values presented in this report were those originally identified by the EWS, and some additional values were included if they were considered in the scope of the three areas of interest. The term 'regionally significant' in reference to nursery areas or migratory pathways means that the marine environment of the location (e.g. Fremantle, Kwinana, Bunbury) is regionally significant and marine fauna migrate specifically to use the location and, if there was an impact on the habitat, there would be a significant impact to the population. Information on migratory seabirds and shorebirds is only partially presented in this review, as it was recognised as a value that needed further clarification and investigation. For reviewing and assessing marine and estuarine values related to climate change, consideration was generally given to medium term (2050) and long term (2100) predictions.

The spatial extent of this marine and estuarine focused review covers oceanic waters through to the high tide mark of coasts and estuaries. Beaches, dune systems and rocky cliffs were not generally included. For the three areas of interest, the following areas were included in the literature search:

- Fremantle: Inner Harbour out to Gage Roads, and approximately 3km to the north and south of the Entrance Channel. Upstream of the Swan Estuary to the Swan Yacht Club, and further if relevant for the value
- Kwinana: Cockburn Sound, Parmelia and Success Banks, Shoalwater Islands Marine Park and the Sepia Depression Ocean Outlet Landline (SDOOL) located 4 km south-west of Point Peron shoreline
- Bunbury: Koombana Bay and up to 5km north and west, Leschenault Inlet, Leschenault Estuary (mostly southern region) and Preston River (lower reaches).

NatureMap and the Threatened and Priority Listed Species Database (Department of Biodiversity, Conservation and Attractions) as well as the Protected Matters Search Tool (EPBC 1999) were searched for any listed species that were known to occur regularly in the three locations of interest. Occasional occurrences of larger megafauna such as turtles, sharks and whales were not included in the risk assessments, except for Humpback whales which occur regularly along the coast close to the Port of Fremantle.

The assessment of risks and the recommendations made in this report are based on the information reviewed at the date of preparation of the report. The services undertaken by WAMSI in preparing this report were limited to those specifically detailed in the report and are subject to the purpose and scope limitations set out in the report.

1.5 Limitations

The limitations of this report should be considered when drawing conclusions, and are as follows:

- This report represents a rapid assessment within a short time-frame
- To avoid stakeholder fatigue, information was gathered from stakeholders (Appendix 1) rather than duplicating a large community engagement program currently being undertaken by another Westport team. Several stakeholders were identified and contacted for any relevant information in relation to marine and estuarine values. It is recognised that there are an abundance of stakeholders with interest and information on the three locations, and efforts should be made to engage with as many as possible throughout the Westport Project
- The report represents a high-level preliminary discussion on the most important values and issues
- The risk assessments were based on very generalised locations of possible harbour footprints (see Figure 1, Figure 2, Figuire 3). The Westport process is an adaptive and evolving process to come up with the best outcomes and solutions for the three areas of interest. **The design and the footprint of any additional infrastructure is still unknown. Therefore, the assessments of risks in this document were based on a commonly used qualitative process based on the likelihood and consequence of an outcome of an event becoming a high, medium or low risk. It is worth remembering that the negative outcome from the event is being assessed rather than the event itself.**

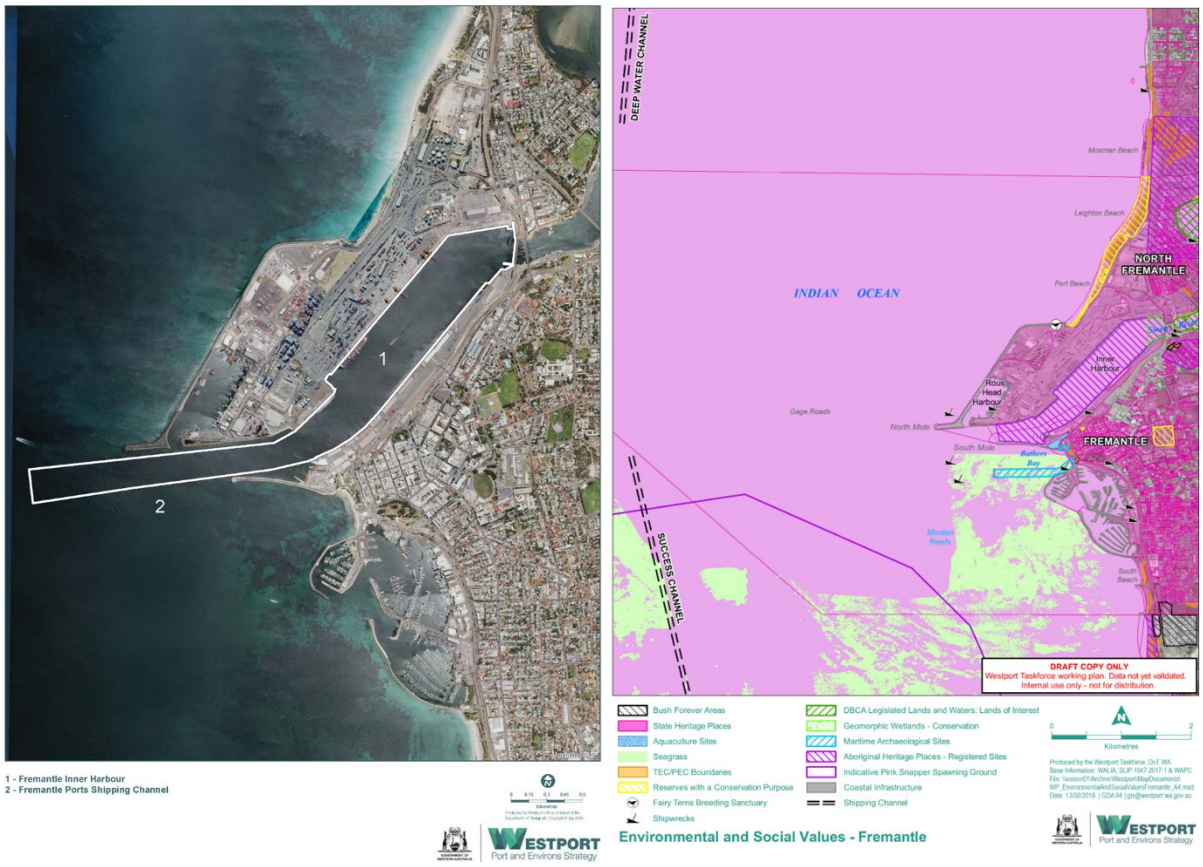


Figure 1: Proposed harbour footprint that was considered in the risk assessment process for Fremantle (left) and a draft map of environmental and social values (right).

Map on the left sourced from Westport Environmental Work Stream Technical Report 2018. Note not all environmental and social values are shown.

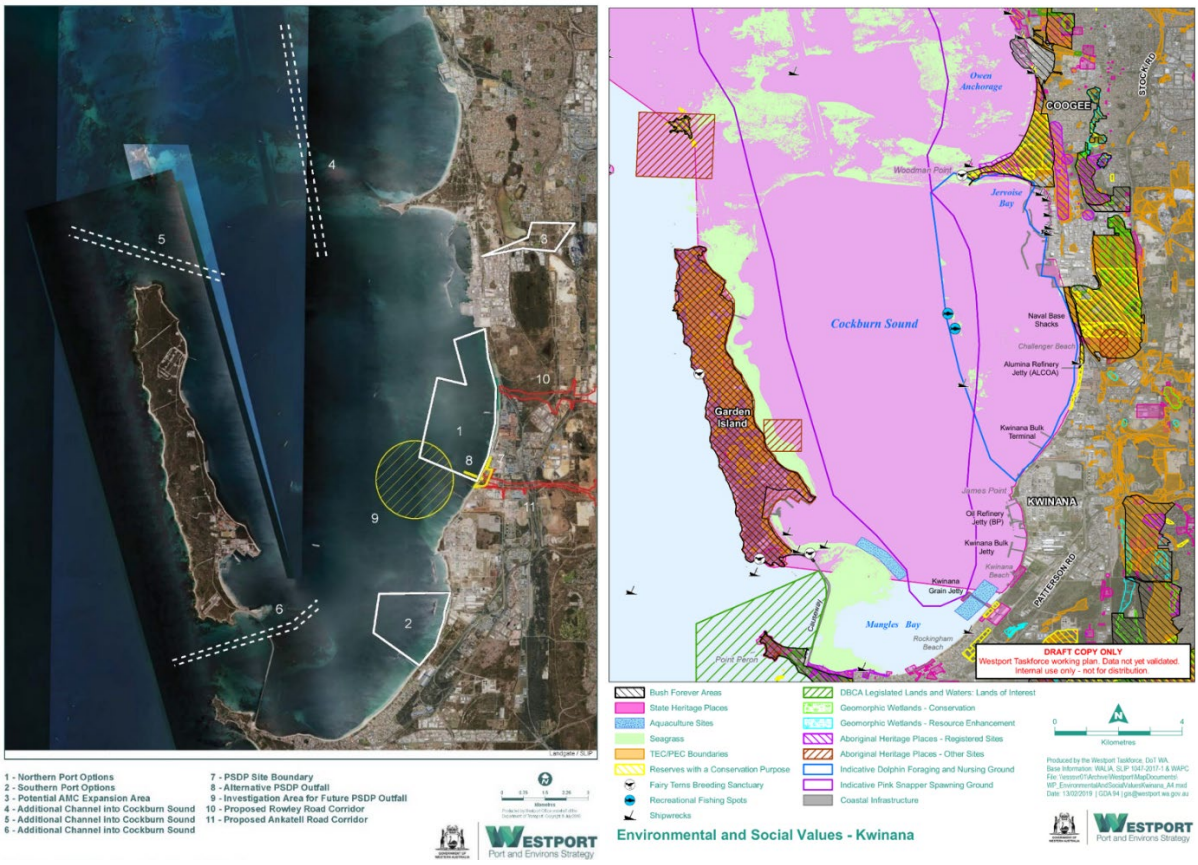


Figure 2: Proposed harbour footprint and additional pressures that were considered in the risk assessment process for Kwinana (left) and a draft map of environmental and social values (right).

Figure on the left sourced from Westport Environmental Work Stream Technical Report 2018. Note only option 1 and 4 were assessed in relation to harbour development as options 2 and 6 are no longer considered (left), and not all environmental and social values are shown (right).

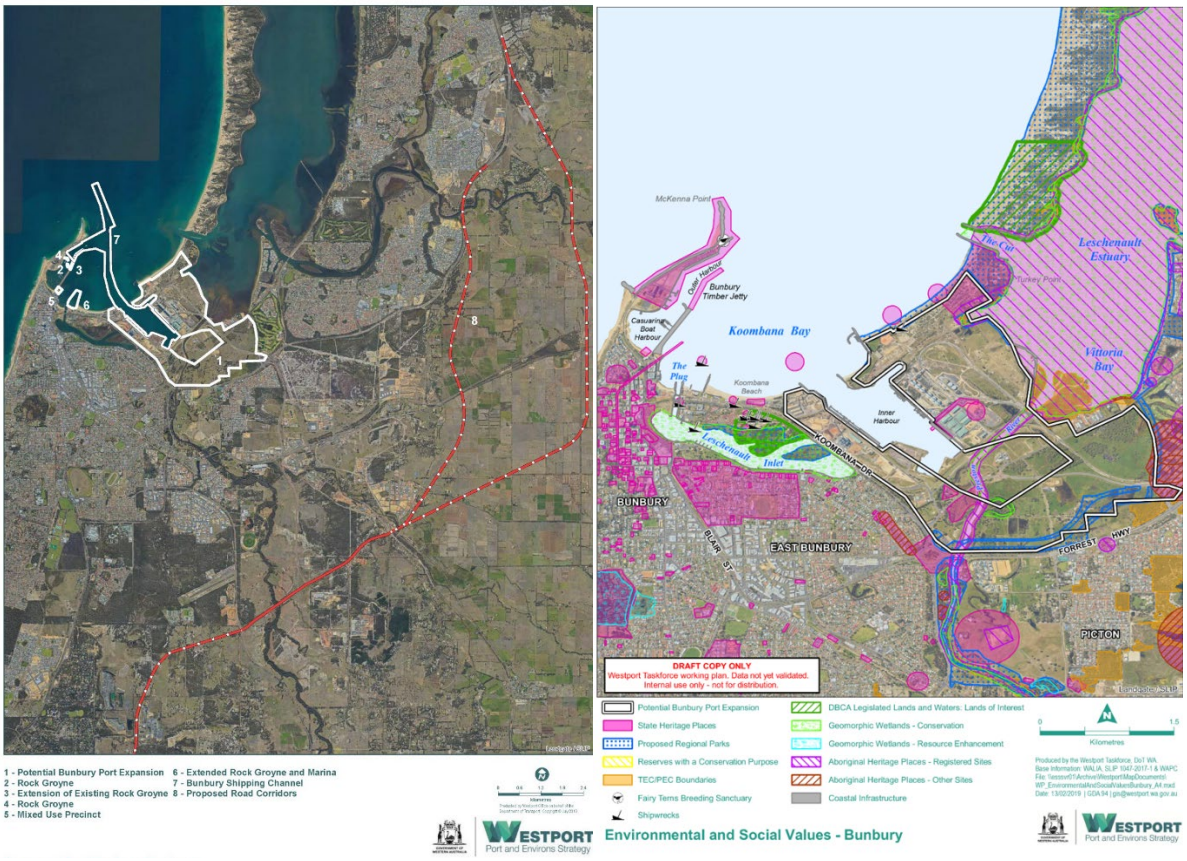
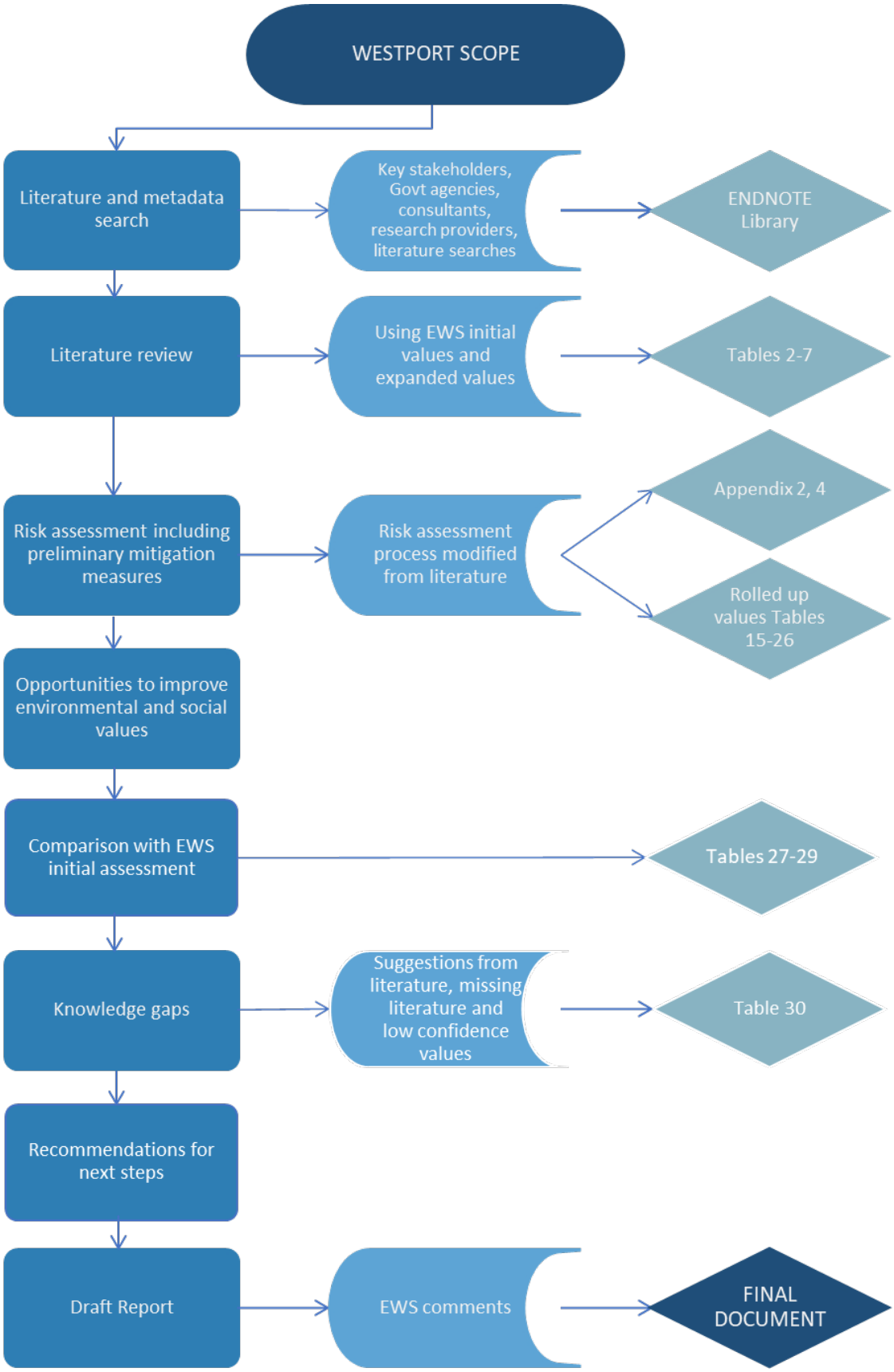


Figure 3: Proposed harbour footprint that was considered in the risk assessment process for Bunbury (left) and a draft map of environmental and social values (right).

Figure on the left sourced from Westport Environmental Work Stream Technical Report 2018. Note not all environmental and social values are shown.

1.6 Layout of this report



2 Review of existing literature

A review of published and unpublished studies, technical reports and grey literature was performed for the purposes of 1) improving data confidence in the values identified by EWS and 2) identifying any additional values of significance for Fremantle, Kwinana and Bunbury. The literature review is extensive, but by no means exhaustive.

2.1 Fremantle

2.1.1 Environmental values

The full suite of literature reviewed for marine and estuarine *environmental values* for Fremantle is given in Table 2. Reports documenting the after effects of dredging that occurred in 2010 in the Inner Harbour provided particularly useful insight for future dredging campaigns. Bottlenose dolphins have been one of the most studied species in the area, particularly in relation to underwater noise associated with port operations. Fairy terns have also made their home in vicinity to the port, with breeding populations regularly occurring at the sanctuary at Rous Head. It is recognised that more fish and invertebrate species would migrate through the Inner Harbour, than those currently listed in Table 2. The species listed were largely those identified as key fishery stocks in *Review of fishery resources and status of key fishery stocks in the Swan-Canning Estuary* (Smith 2006).

Additional environmental values identified for Fremantle include:

- Significant benthic communities and habitats: seagrass
    - Seagrass meadows occur directly to the north, south and west of the port entrance, as well as in the Swan Estuary
- Significant benthic communities and habitats: other
    - Hall Bank Reef (coral reef) and Minden Reefs (rocky reef) occur in proximity to the entrance of the Inner Harbour
- Priority and specially protected fauna: humpback whales
    - Humpback whales, listed as vulnerable under the EPBC Act, spend time resting with calves in waters adjacent to the harbour entrance
- Regionally significant migratory pathways
    - Species migrate both ways through the Inner Harbour to access the Swan Estuary or coastal waters in order to complete their life cycles e.g. blue swimmer crabs, Australian herring, western king prawns and black mussels
- Coastal processes
    - Erosion and inundation occurring at localised areas e.g. Port Beach neighbouring the existing Fremantle Port is considered in the literature as ‘extreme risk’ for inundation, which may also encroach on port jurisdiction

2.1.2 Social values

The full suite of literature reviewed for marine and estuarine *social values* for Fremantle is given in Table 3. There are a number of registered heritage sites occurring in and around the port footprint, one of the most important of which is the Swan River, which is registered as a mythological aboriginal heritage site. Recreational fishing is one of the most popular ‘social and community’ values within the Inner Harbour as well as further upstream in the estuary and coastal waters surrounding the harbour entrance. The Inner Harbour is also the gateway for a lot of recreational boating. Tourism, commercial fisheries and aquaculture all operate immediately within the Inner Harbour or surrounds and are currently doing so alongside a major operating port. No additional social values were identified for Fremantle.

Table 2: Literature review of marine and estuarine environmental values for Fremantle

Ref#	Marine and estuarine environmental values	Description of value	References
1	Integral functioning ecosystem		
		• The marine environment of the port area has been subject to large scale and ongoing shipping and dredging since the late 1890s and cannot be regarded as a pristine environment; the ecology has been significantly modified due to the removal of the bar and dredging • This estuary and catchment have undergone substantial anthropogenic change since European settlement and is now classified as highly modified system • Estuary has experienced an increase in eutrophication, fish kills, cyanobacterial blooms, red tides and accumulation of organic matter in the bottom sediments over the past few decades	Kelsey et al. (2010) Environmental Protection Authority (2009) SKM (2009c)
2	Biological diversity		
2.1	Fish assemblages	• Fish species migrate seasonally between the Swan River and the Indian Ocean via the Inner Harbour • Using fish communities for estuarine health index found the ecological condition in the estuary in 2018 was considered good-fair for nearshore and fair-good for offshore waters. Health for nearshore waters has been relatively consistent since 2011. However, in 2017, severe hypoxia affected the estuary in autumn • Multi-frequency echosounders and baited remote underwater video systems have been used to map fish distributions and benthic habitat in the Inner Harbour in March 2017. Small aggregations of fish were found near the wharf walls and other topographic features. Dominant species identified from initial video analysis included weeping toadfish (*Torquigener pleurogramma*), tarwhine (*Rhabdosargus sarba*), and western butterfish (*Pentapodus vitta*)	Hallett (2018) Hallett (2017) Salgado-Kent et al. (2017) Hallett (2016) Hallett and Tweedley (2015) SKM (2009c)
2.2	Demersal and benthic communities	• The use of Gage Roads as an anchorage for the port continually disturbs sediments and only ephemeral marine biota occur in the area • Crustacean species migrate seasonally between the Swan River and the Indian Ocean via the Inner Harbour • Invertebrates inhabiting the soft sediments of the Inner Harbour include: echinoderms, crustaceans, gastropod and bivalve molluscs and many worms • Infaunal community at Gage Roads comprised of: annelids, molluscs, crustaceans, echinoderms, sipunculids and nemerteans. Crustaceans, molluscs and annelids dominated the community • Wharf pylons, rock walls/breakwaters and benthic debris of the Inner Harbour provide habitat for sponges, ascidians, tube worms, anemones, mussels and barnacles, urchins, sea stars and other echinoderms, crabs, nudibranchs and many gastropod species • Three species of barnacles occur in high abundance on wharf pylons and hard substrates in the Inner Harbour. They are important for estuarine health as they filter plankton and provide food for fish and crabs	Environmental Protection Authority (2009) SKM (2009c) SKM (2006a)
2.3	Invasive species	• Introduced streaked goby, *Acentrogobius pflaumii*, has been documented in Cockburn Sound and Swan River, but effects, if any, on environment have not yet been determined • 79% of potentially introduced marine pests are considered compatible with the marine environment of Fremantle Port (incl. Cockburn Sound) based on currently known habitat preferences • Majority of vessel to Fremantle Port (incl. Cockburn Sound) are international and considered low risk for invasion. however, moderate and high-risk vessels tend to stay longer • Dredge vessels stay longer in Fremantle Port (incl. Cockburn Sound), but are less common, than cargo vessels; dredge, mobile offshore drilling/floating production units and Navy vessels are considered high risk; followed by medium risk vessels of barges, commercial fishing vessels, research vessels and tugs • Greatest risk to Fremantle Port (incl. Cockburn Sound) are vessels from Singapore and Indonesia, which could potentially introduce the invasive species- *Caulerpa taxifolia* (invasive strain) • Port Adelaide is the greatest domestic risk to Fremantle Port (incl. Cockburn Sound) due to a high compatibility of pests and high frequency of vessels entering Fremantle Port • 50 introduced marine species have been documented for the Fremantle Port area (incl. Cockburn Sound); many have not been documented since initial sightings; include hydroids, molluscs, polychaetes, ascidians and fish • 2007 study found *Scaeochlamys livida* (Eastern Australian scallop) and *Sabella spallanzanii* (European fan worm) in the Inner Harbour; listed in the top 10 world's detrimental invaders • Introduced marine pests are monitored and managed by DPIRD under the Fisheries Act and in cooperation with Fremantle Port Authority through implementation of the State Wide Array Surveillance Program (SWASP). The program has been implemented in Fremantle since 2010 and monitoring reports are completed twice a year (Fremantle Port Authority pers.comm. 2019)	Bridgwood and McDonald (2014) Maddern and Morrison (2009) McDonald and Wells (2009) Huisman et al. (2008)

Ref#	Marine and estuarine environmental values	Description of value	References
3	High level of water quality		
3.1	Nutrients	• Water quality in the Inner Harbour and river mouth is influenced by the Swan River and catchment, as well as Cockburn Sound and Port operations • Inner Harbour receives nutrient-rich estuarine waters between winter and spring • 2009 review- Fremantle Ports' Marine Quality Monitoring Program shows nutrient levels in the Inner Harbour are generally below the ANZECC/ARMCANZ guidelines, though phosphorus has shown elevated levels • Predictive modelling shows the maximum acceptable load to the Swan and Canning rivers per year is 130 tonnes of total nitrogen and 14 tonnes of total phosphorus • Avon River contributes more flow and nitrogen load to the estuaries than the coastal catchments	Kelsey et al. (2010) SKM (2009c) Swan River Trust (2009)
3.2	Chlorophyll a/ phytoplankton	• 2009 review- Inner Harbour, Rous Head and the Outer Harbour sites included in the Marine Quality Monitoring Program show chlorophyll *a, b, c* and phaeophytin *a* levels were below detection limits • Phytoplankton blooms in the Swan Estuary have been increasing in frequency and density and typically occur in summer and autumn when there are higher temperatures, low river flows, better water clarity, and elevated nutrient concentrations • The toxic dinoflagellate bloom in 2003 caused the death of ~ 300,000 fish; fish kills have occurred from other phytoplankton blooms in 1983, 1992, 1994, 2000, 2005	Hallett et al. (2016) Cottingham et al. (2014) Place et al. (2012) SKM (2009c) Swan River Trust (2009) Twomey and John (2001)
3.3	Light attenuation/ turbidity	• Predicted sediment plumes from dredging campaigns were found to be short lived and restricted spatially due to current and wind patterns • Turbidity and suspended sediment concentrations typically decrease with distance offshore from port • Surface sediments in the Entrance Channel are generally fine to coarse sand with a few patches of coarser sediment, varying sizes of cemented sand occurs in the surface layers of the Deep Water Channel and Gage Roads acts as a sink for soft sediments • After phase 1 of Inner Harbour dredging in 2010, the management trigger for water clarity was sometimes exceeded at Preston Point beach monitoring location, and after phase 2, it was frequently exceeded. Water clarity was also affected once after phase 2 at Bathers Beach, Fremantle Surf Living Saving Club and Port Beach	Oceanica Consulting (2011b) Oceanica Consulting (2010b) Environmental Protection Authority (2009) SKM (2009c) Fugro (2006)
3.4	Dissolved oxygen	• Marine Quality Monitoring Program shows dissolved oxygen in Inner Harbour waters ranges between 80–120% saturation • Dredging of the port in 2010/11 did not trigger any exceedances for dissolved oxygen guidelines • The upper reaches of the Canning River and Swan River receive artificial oxygenation to help remediate for poor water quality	Department of Water (2015) Oceanica Consulting (2011b) Oceanica Consulting (2010b) SKM (2009c)
3.5	Temperature	• Marine Quality Monitoring Program shows temperature for the Inner Harbour has an obvious pattern of higher water temperature in summer and lower water temperature in winter	SKM (2009c)
3.6	Salinity	• Marine Quality Monitoring Program shows salinity of the Inner Harbour is similar to seawater in summer and brackish in winter • Salinity patterns in the Swan River and Inner Harbour are likely to be impacted by reduced rainfall under a drying climate	M. P. Rogers & Associates (2018) SKM (2009c) Swan River Trust Technical Advisory Panel (2007)
3.7	pH	• Marine Quality Monitoring Program shows the pH of Inner Harbour waters has remained close to that of seawater across sampling years (7.8–8.3) • For Australia, a pH decrease of 0.12 to 0.32 is projected by the year 2090 which will increase ocean acidification	M. P. Rogers & Associates (2018) CSIRO and Bureau of Meteorology (2015) SKM (2009)
3.8	Contaminants/ toxicants	• There have been elevated levels of copper in the Inner Harbour in the past, however this has now been reduced to below recommended guidelines since 2003 due to maintenance dredging of contaminated sediments • After phase 1 and phase 2 of the port dredging campaign in 2010, toxicants did not exceed trigger levels in water or mussels when monitored in 2010 and 2011 • Swan, East Fremantle and Perth Flying Squadron yacht clubs had the highest levels of TBT in mussel tissue and growth rates may be affected • Results from a 2013 study did not find significant contamination of estuarine waters (not close to port) by PCBs or any of the other targeted organic contaminants	Fisher (2013) Oceanica Consulting (2011b) Oceanica Consulting (2010b) SKM (2009) Oceanica Consulting (2007b)

Ref#	Marine and estuarine environmental values	Description of value	References
3.9	Groundwater	• Groundwater beneath North Quay and Victoria Quay flow towards the Inner Harbour, and to the Indian Ocean for Victoria Quay • The foreshore of Port Beach and Leighton is contaminated and requires remediation for petroleum hydrocarbons in the groundwater before any further land use is considered.	GHD (2017b) Fremantle Ports (2016)
3.10	Hydrology	• The port area is protected to an extent from swells by the islands and reefs between Garden Island and Rottnest Island, winds typically drive sea conditions • Increase in intensity and frequency of storm/ rainfall events under a changing climate is likely to affect flood flows from the Swan/Canning catchments through to the Port • Removal of rock bar (1987) and harbour basin expansion altered tidal dynamics within the estuary	M. P. Rogers & Associates (2018) SKM (2009c)
4	High level of sediment quality		
4.1	Contaminants	• Metal, PCB, pesticide TBT and polycyclic aromatic hydrocarbon concentrations sampled around Inner Harbour and Rous Head following dredging phases in 2010/11 were within the ranges previously documented prior to dredging, and where some exceedances were measured, they did not exceed re-sampling measures. • Samples of surface sediments from the Inner Harbour showed elevated levels of TBT, Mercury, pesticides, organochlorides and polycyclic aromatic hydrocarbons, which were well above National Oceans Disposal Guidelines for Dredged Material screening levels (reported in 2009); testing of sediments indicates that contaminants may not be released from sediments at levels which may affect the marine environment, except for arsenic which is of concern as it was found to be easily mobilised from sediments • Sediment samples from the Entrance and Deep Water Channel did not exceed National Oceans Disposal Guidelines for Dredged Material screening levels for metals, organochlorine pesticides, total PCBs (reported in 2009); Polycyclic aromatic hydrocarbon concentrations were above screening levels for some sites; TBT exceeded guidelines in the Entrance Channel • All contaminants were below guidelines for Gage Roads (reported in 2009) • Organochlorine pesticides were more common in sediments than in surface waters during a 2009 baseline study in the Swan Canning catchment drainage system • TBT levels were elevated in 2007 at the majority of yacht club sites in the estuary and there is indication that TBT concentrations at some clubs may be causing adverse ecological effects	Oceanica Consulting (2011b) Oceanica Consulting (2010a) Environmental Protection Authority (2009) Nice (2009) SKM (2009c) Oceanica Consulting (2007b)
4.2	Acid sulphate soils	• Sediments in the Swan River and Inner Harbour are potential acid sulphate soils	SKM (2009c)
5	Significant benthic communities and habitats		
5.1	Seagrass	• Seagrass meadows occur directly to the north, south and further west of the port entrance, as well as in the estuary • Seagrass patches occurred at varying densities along the Deep Water Channel and include eight species • After phase 1 of 2010 dredging which removed sand from the Inner Harbour, Entrance Channel and Deep Water Channel and placed at Rous Head, no significant declines in seagrass health at monitoring sites were detected except at one seagrass reference site. After phase 2, 21 out of 24 seagrass sites did not show significant declines in mean shoot density. The two sites that did show significant declines were offshore of Rous Head (the reclamation area) and south of the Entrance Channel. This had been attributed more to natural variability than lack of light. After the dredging campaign was completed, a comparison of habitat maps using satellite imagery saw an estimated net gain of 48 ha of seagrass within the 'Gage Roads management unit' • It is estimated that 47 ha has already been lost in the past, prior to 2010 dredging, in the 'Gage Roads management unit' • Small patches of Halophila, *Posidonia* and *Amphibolis* occur at the Rous Head, but no dense meadows • *Halophila* is the dominant seagrass in the estuary. The closest site monitored for seagrass to the port is Rocky Bay and also has *Zostera muelleri.* Between 2012-13, % cover of seagrass at Rocky Bay increased from 27% to 51%. The deepest seagrass grows at this site is ~3.5m • From boat based video surveys in 2011, small seagrass patches are found just upstream from the Stirling Hwy bridge • Peak biomass of seagrass (Halophila) in the Swan-Canning estuary is around February • The iconic black swan *Cygnus atratus* feeds on *Halophila ovalis* and *Ruppia megacarpa* in the estuary, and is reported to consume up to 25% of the daily production of *Halophila*	Oceanica Consulting (2011b) Oceanica Consulting (2010b) Environmental Protection Authority (2009) SKM (2009c) Forbes and Kilminster (2014) Kilminster and Forbes (2014) Choney (2012) Eklöf et al. (2009)

Ref#	Marine and estuarine environmental values	Description of value	References
5.2	Coral reefs	• Hall Bank Reef is situated ~3 km north-west of Rous Head • Hall Bank has ~16 species and is dominated by scleractinian corals; Rottnest and Abrolhos are identified as potential source communities for corals occurring at Hall Bank • Hall Bank has the highest levels of coral cover ever recorded this far south despite experiencing relatively lower sea temperatures and higher turbidity • *Goniastrea australensis* occurs at Hall Bank and is primarily a sub-tropical species that is uncommon at low latitudes • The high density of urchins, *Centrostephanus tenuispinus,* maintains the absence of macroalgae of Hall Bank, and commercially and recreationally fished species such as baldchin, trevally and lobster occur here • Predictive modelling of total suspended solids and sediment loading for the 2010 dredging proposal of port area and channels did not show that Hall Bank would be affected; after dredging of the port and channels in 2010, no impacts to corals were measured	Baird and Thomson (2018) Thilakarathna (2017) Oceanica Consulting (2011b) Oceanica Consulting (2010b) Thomson and Frisch (2010) Environmental Protection Authority (2009) SKM (2009c)
5.3	Rocky reefs	• Minden Reefs is approximately 2k south of the Fremantle Harbour entrance at ~8m depth, and is a limestone rocky reef surrounded by sandy plains and seagrasses • A survey of Minden Reefs in autumn 2013 found 12 species of hard coral, 4 species of octocorals, 27 sponge species, 48 mollusc species, 34 crustacean species, 16 echinoderms species and 46 different fishes • The northern side of Minden Reefs was dominated by turf algae and kelp, while the southern portion was dominated by seagrasses (*Posidonia* and *Halophila*); coral cover was greatest for the southern side • Minden Reefs is rarely visited by divers in comparison to other reefs i.e. Rottnest • Minden Reef is subject to a high sediment regime with a lot of abiotic materials on the reef i.e. sand, silt, rock, wreckage • One new species of sponge barnacle was identified and collected at Minden Reefs, which is the first record of the genus in Australian waters. The xanthid crab, *Zalasius dromiaeformis*, also found at the reef is the first record for WA, and range extensions from the tropics also occurred for some species • Highly sought-after endemic cowrie molluscs occur at Minden Reef and are monitored by a group of professional collectors and have occurred on the reef for at least 25 years	Richards et al. (2016)
5.4	Macroalgae	• Seasonal growth of macroalgae occurs on exposed areas of pavement at Rous Head • Macroalgae found on limestone pavement outcrops in the Deep Water Channel • Gage Roads tends to accumulate wrack of algae and seagrass • After the dredging campaign in 2010/11 was completed, a comparison of habitat maps using satellite imagery saw an estimated net gain of 8 ha of macroalgae within the 'Gage Roads management unit'	Oceanica 2011b SKM (2009c)
6	Listed and significant fauna		
6.1	Fairy Tern (*Sternula nereis*)	• Listed as vulnerable under the EPBC Act • Rous Head Project (Fremantle Ports; PIANC Working with Nature Award) successfully attracted breeding colonies in 2014/15/16 • Reclaimed land was set aside to provide habitat for fairy terns • Relatively high breeding success from 90 adult pairs in 2013/14 to 250 adult pairs in 2017/18, and ~ 220 pairs 2018/19 • Blue sprats and flying fish important in diet	Fremantle Ports (2018) de Vos (2016) Dunlop (n.d.)

Ref#	Marine and estuarine environmental values	Description of value	References
6.2	Bottlenose dolphins (*Tursiops aduncus*)	• Protected under the EPBC Act • 14 adult, seven juveniles and four dolphin calves are residents in the Swan-Canning River and use the river system daily showing strong, very long term site fidelity • The Swan Canning Riverpark community is a sink within a source-sink dynamic system. The genetic flow is asymmetric with flow from Owen Anchorage (the source) to the Swan Canning Riverpark. The reverse flow of genes from the Swan Canning Riverpark to Owen Anchorage is very limited. Connection through the inner harbour is critical for the survival of the dolphin community in the Swan Canning Riverpark • The inner harbour has been identified as a seasonal hotspot that is strongly linked with foraging behaviour • Anthropogenic underwater noise from vessels and port operations is prevalent in Fremantle Inner Harbour and has potential to mask communication between dolphins when noise is elevated for frequencies overlapping with dolphins; vessels and snapping shrimp are the most prevalent sound sources across dolphin habitat in the river and port areas • During periods of high vessel traffic in the inner harbour, resting and socialising groups significantly increased their average speed and time spent socialising significantly shortened. Socialising is important for the maintenance of conspecific relationships, calf play, and mating opportunities, and impacts in resting states can affect stress levels and health of dolphins • Pile driving for port maintenance coincided with fewer dolphin detections in the inner harbour during that time • Dolphins that died in the Swan-Canning in 2009 were found to have organic contaminants in their blubber (dieldrin, DDE and PCBs), and these contaminants were also detected in blubber biopsy samples from living free-ranging dolphins	River Guardians (2018) Chabanne (2017) Chabanne et al. (2017b) Marley et al. (2017a) Marley et al. (2017b) Marley et al. (2017c) Marley et al. (2017d) Paiva et al. (2015) Swan River Trust (2015) Chabanne et al. (2012) Salgado-Kent et al. (2012) Holyoake et al. (2011) Holyoake et al. (2010)
6.3	Whales	• Humpback females and calves are often seen resting in the waters between Rottnest and the Fremantle coast from Sep-Nov during their southerly migration • Depending on the timing of dredging campaigns and if dredging was to occur in the Deep Water Channel, there could be an impact on Humpback whale migration • Humpback whales are listed as vulnerable under EPBC Act • Southern right whales are occasionally seen in the coastal metropolitan waters between May-Sep • Southern right whales listed as endangered under EPBC Act	Environmental Protection Authority (2009) SKM (2009c) Jenner et al. (2001)
6.4	Migratory shorebirds and seabirds	• Between Fremantle and Rockingham, 21 listed migratory shorebirds under international agreements have been recorded. 7 have a conservation listing (i.e. endangered or vulnerable) • Estimates of intertidal habitat loss due to sea level rise predictions show seven internationally important sites in south-west Australia at risk of 26% loss with 50cm rise to 97% loss with 300cm rise. Allow room to move upshore in management plans (doesn't specifically mention Fremantle as one of the seven internationally important sites) • Between Fremantle and Rockingham, 15 listed seabirds under international agreements, 4 have a conservation listing (i.e. endangered or vulnerable) • Crested tern: the autumn/winter breeding population in the Fremantle area disappeared in the 1990s, which may have been due to two catastrophic Pilchard *Sardinops sagax* fish kills in 1995 and 1997 that removed their preferred prey resources	Birdife Australia (2018) Weller and Warren (2017); Department of Environment and Energy (2018) Hansen et al. (2016) Department of the Environment and Energy (2016) Iwamura et al. (2013) Dunlop (1985a); Dunlop (1985b)
7	Regionally significant spawning/nursery area		
		• Yellowtail flathead (*Platycephalus endrachtensis*), estuary cobbler (*Cnidoglanis macrocephalus*) and yellowtail grunter (*Amniataba caudavittata*) occupy the Swan Estuary waters and are discrete self-replenishing stocks with limited capacity to recover if stocks are depleted • Black bream (*Acanthopagrus butcheri*) typically spawn in the upper reaches of the Swan Estuary and in the middle to upper reaches as adults and juveniles. They spend their whole life cycle in the estuary and would have limited capacity to recover if stocks are depleted	Smith (2006) Wise et al. (1994)
8	Regionally significant migratory pathway		
8.1	Yellowfin whiting *(Sillago schomburgkii*)	• Larval stages recruit into the estuary during flood tides; adults typically found in open sandy areas and juveniles in seagrass habitat, but both stages can also occur in estuaries- typically the lower reaches • A single stock supports south-west region	Smith (2006) Kanandjembo et al. (2001) Kailola et al. (1993)

Ref#	Marine and estuarine environmental values	Description of value	References
8.2	Blue swimmer crab *(Portunus armatus)*	• Majority of spawning crabs thought to come from Cockburn Sound • Found in the lower reaches of estuary year round and can move upstream • After mating in summer, females migrate to ocean waters to spawn	Smith (2006) Potter et al. (1983)
8.3	Whitebait (*Hyperlophus vittatus*)	• Late autumn and spring peaks in abundance of larvae have occurred in the lower Swan Estuary and is influenced by the hydrology of the estuary	Gaughan et al. (1996) Neira and Potter (1992) Gaughan et al. (1990)
8.4	Australian herring (*Arripis georgianus*)	• Adults migrate from the estuary to coastal waters to spawn during winter • Form part of a widespread south-west stock and it's thought that local disturbance would have little impact on use of the estuary	Smith (2006)
8.5	Perth herring (*Nematalosa vlaminghi*)	• Migrate from the ocean to lower and middle reaches of the Swan River during spring, then to the upper reaches to spawn in summer • Distribution throughout the Swan is linked with salinity • Population is an isolated breeding stock and recovery would be limited if the stock were to be depleted; evidence shows that stocks have already been reduced and may still be declining	Smith (2006) Chubb and Potter (1986)
8.6	Sea mullet (*Mugil cephalus*)	• Migrate downstream to lower and middle reaches of estuary during spring/summer, then migrate to ocean during autumn/winter • Widespread south-western regional stock	Smith (2006) Chubb et al. (1981)
8.7	Yelloweye mullet (*Aldrichetta forsteri*)	• Adults migrate from estuary to coastal waters to spawn from April to August and post larval stages migrate into the estuary from May- September • Mixing of stocks occurs across the south-west	Smith (2006)
8.8	Mulloway (*Argyrosomus japonicus*)	• Restocked in the Swan River in 2013 • Migration occurs through the Inner Harbour and juveniles rely on estuaries and near shore environments • Mulloway mainly spawn during late spring and early summer. Has been known to spawn around boat wrecks in the lower Swan River Estuary • They are croakers and grunters so may be impacted by underwater noise as migrating through Inner Harbour • Poor water quality and loss of benthic primary producers can reduce the abundance of prey species for mulloway • Sedimentation can impact on juveniles feeding by filling holes used to ambush prey	Parsons et al. (2009) Farmer et al. (2005) Dr Fiona Valesini pers. comm. Swan River Trust n.d.
8.9	Prawns	• Western school prawns (*Metapenaeus dalli*) spawn in middle to lower estuary from Nov-April (mainly November to February when water temperatures are >18 °C and salinity >25). Abundances of western school prawns in nearshore estuary waters show strong seasonal patterns in abundance, with greatest abundances occurring in late austral spring and summer months and lowest abundances (very few to no individuals) occurring between late autumn and winter. In offshore estuary waters, densities were greatest from autumn to winter • Very low densities of western school prawns are found in the entrance channel of the estuary (around Fremantle traffic bridge) • Western school prawns are distributed in relation to salinity and sea surface temperature • Western school prawns form a discrete, self-replenishing breeding stock with limited capacity to recover • Western school prawns were found to prefer fine sediments for fast and easy burial • Western king prawn (*Penaeus latisulcatus*) spawn in oceanic waters and migrate into the estuary in spring and summer via tides. Individuals remain in estuary for ~1yr and migrate back to the ocean once mature • Commercial and recreational fishing of prawns were key fisheries in the estuary, but stocks declined likely due to overfishing, recruitment failure and environmental changes, which ceased commercial fishing in the 70s and significantly reduced recreational fishing activity • Prawn restocking from cultured juveniles (*M. dalli*) was undertaken in 2015/16 to help recovery of the stock	Crisp et al. (2018) Jenkins et al. (2017) Tweedley et al. (2017) Bennett (2014) Smithwick et al. (2011) Smith et al. (2007) Smith (2006)
8.10	Black mussel (*Mytilus planulatus*)	• This edible species is most common in the lower reaches of the estuary • Larvae enter the estuary from the ocean in spring	SKM (2009c)
8.11	Other fish species	• Small tooth flounder (*Pseudorhombus jenynsii*) is assumed to have a single stock over the south-west region. Juveniles occur in lower reaches of estuary but move upstream. Spawning occurs in marine waters and larvae are recruited into the estuary during flood tides • Juveniles of tailor (*Pomatomus saltatrix*) recruit to sheltered coastal waters and the estuary and remain there until mature.	Smith (2006) Wise et al. (1994)

Ref#	Marine and estuarine environmental values	Description of value	References
9	Swan Estuary Marine Park		
		• Includes waters of Alfred Cove, Milyu and Pelican Point • The park/locations are considered an important feeding ground for trans-equatorial migratory wading birds • Marine park has a diverse assemblage of aquatic biota • Seagrass beds occur within the park and help contribute to energy flows, primary production and sediment stabilisation	SKM (2009c) Department of Conservation and Land Management (1999)
10	Coastal processes		
		• South Mole and Fishing Boat Harbour considered high risk for inundation • Sea level rise will mean a direct loss of beach at Bathers Beach as there is no room to migrate upshore and beach nourishment would be needed • Port Beach (popular with beach users) undergoes seasonal erosion and accretion; sediment is transported away during summer and accreted during winter storms • For short term modelling of climate change, erosion at Port Beach will affect the carpark, dunes and parts of the road. In the medium term, Fremantle Port will be impacted as well as industrial lots and more of Port Beach. Long term, erosion will impact all of Port Beach • Inundation at Port Beach in the short and medium term is restricted to the width of the beach, but longer term, inundation is likely to affect the foredune and car parking areas • Risk levels for Port Beach are listed as 'Extreme' with risk treatment required • The most recent analysis (2018) of climate change impacts on Fremantle Port infrastructure and operations finds a number of high to very high risks mostly associated with se level rise e.g., Inner Harbour berths, roads, land improvements, seawalls and breakwaters. It is proposed that tidal currents within the Inner Harbour won't be directly influenced by climate change, but changes in the hydrodynamics of the Swan River may cause a small decrease in tidal currents • The foreshores of the Swan Estuary are susceptible to inundation as a result of coastal flooding, i.e. tides, surges and wave action, as there is a lack of sufficient setback of infrastructure • Sediment is transported north along the metropolitan coastline during summer and south during winter	M. P. Rogers & Associates (2018) GHD (2017b) BMT Oceanica (2014a) SKM (2009c) Swan River Trust (2008)

Table 3: Literature review of marine and estuarine social values for Fremantle.

Ref#	Marine and estuarine social values	Description of value	References
1	Heritage		
1.1	Aboriginal	• Registered mythological sites within Fremantle Harbour area include the Swan River (S02548/3536) and Indian Ocean (S02169/3776) • The Indian Ocean site includes waters out to Rottnest Island and down to Cockburn Sound and relate to the creation of islands, particularly Rottnest. • "Other Heritage Place" listings include Fremantle: Manjaree near South Mole which is a camp/meeting/named place (S02703/3421), and Fremantle: Arthur Head, a camp site (S02167/3774)	Department for Planning Lands and Heritage (2018)
1.2	Maritime/historic	• Inner Harbour is listed as a heritage site (#22531) due to still being a 19th century working industrial port, its role in WWII, and the formation of the Maritime Union of Australia- which is one of the strongest unions in the country. It is also considered a National Historical Engineering Landmark • Eight ship wrecks are present in and around the port area	Heritage Council (2018)
2	Public health		
2.1	Recreational water quality	• The foreshore of Port Beach and Leighton is contaminated and requires remediation for petroleum hydrocarbons in the groundwater; safe for recreational use, but further land use would be restricted • Based on bacteria monitoring, South Beach, Bathers Beach, Port Beach and Leighton Beach are considered safe for swimming most of the time	Department of Health (2018) GHD (2017b)
2.2	Seafood quality	• The Department of Health recommends only eating shellfish harvested commercially under strict monitoring programs and does not recommend eating shellfish that are caught in the estuary • Fish are safe to consume from the estuary and a study on black bream in 2013 found very low levels of metal and organic contaminants and were still considered safe for consumption	Department of Biodiversity Conservation and Attractions (2018) Department of Health (2010)
3	Social and community		
3.1	Recreational fishing	• Port development/dredging may disrupt recreational fishing in the inner harbour/entrance • Rous Head is a popular fishing spot • Common species targeted include: tailor, whiting, Australian herring, black bream, flathead, trumpeter, blue swimmer crabs and prawns • Minor species include: flounder, tarwhine, mulloway, yellow-eye mullet, yellowtail scad, butterfish and trevally • The weeping toadfish *Torquigener pleurogramma* are most frequently caught in the estuary by fishers • Swan Estuary Marine Park supports fish that are targeted by recreational fishers • Recreational prawning was a favoured iconic pastime in the Swan Canning Estuary, such as for the Christmas period, and engaged over 50,000 people in the 1980s. However, stocks declined over time (since the 1970s) likely due to overfishing, recruitment failure and environmental changes. Prawns were restocked from cultured juveniles in 2015/16	Jenkins et al. (2017) Tweedley et al. (2017) Smithwick et al. (2011) Environmental Protection Authority (2009) Smith et al. (2007) Smith (2006) Brearley and Hodgkin (2005) Malseed and Sumner (2001) Department of Conservation and Land Management (1999)
3.2	Recreational swimming	• South Beach, Bathers Beach, Port Beach and Leighton Beach are popular for swimming	Department of Health (2018)
3.3	Recreational boating access	• Anchoring is not permitted in the Inner Harbour and Entrance Channel; these areas serve as a link between the estuary and coastal waters • Recreational boating is important in the stretch between Fremantle and Rottnest Island • Boating is popular throughout the Swan Canning Riverpark	Department of Transport (2018) SKM (2009c)
3.4	Marina facilities	• Challenger Harbour Fremantle: 64 public boat pens, 3 jetties and a connecting boardwalk • Fremantle Fishing Boat Harbour: 350 plus commercial and recreational pens, 5 jetties (excludes leased jetties), 3 wharves and fuelling facilities • Additional boat ramp facilities in East Fremantle and Mosman Park	Department of Transport (2018) Department of Transport (2017a) Department of Transport (2017b)
3.5	Educational and scientific values	• Swan Estuary Marine Park provides a space for bird watching and artistic pursuits • Education providers utilise the Swan Estuary Marine Park for studies on intertidal biology, waterbirds and history • Locations within the Swan Estuary Marine Park provide reference sites for broader studies on waterbird populations in the river and estuary system • Dolphin Watch, Prawn Watch and River Guardians are all conservation activities the public can get involved with	Department of Parks and Wildlife (2015) Department of Conservation and Land Management (1999)

Ref#	Marine and estuarine social values	Description of value	References
3.6	Landscape and visual amenity	• Visual amenity will be impacted during any dredging campaigns due to the visibility of sediment plumes along the coast • The waters if the Inner Harbour have low aesthetic quality, but coastal waters north and south of the port have high aesthetic quality • Swan Estuary Marine Park provides ideal sightseeing opportunities • Water clarity was reduced at Preston Beach after phase 1 and phase 2 dredging of the Inner Harbour in 2010, and had some limited impact on water clarity at Port Beach, Fremantle SLSC and Bathers Beach • Future estimated erosion at Bathers Beach and Arthurs Head would likely reduce visual amenity and enjoyment of the landscape	BMT Oceanica (2014a) Oceanica Consulting (2011b) Oceanica Consulting (2010b) Environmental Protection Authority (2009) SKM (2009c)
4	Business, industry and commercial		
4.1	Tourism (including ferries and cruise ships)	• 43 cruise ships visited Fremantle in 2017-18, with 83,352 passengers generating $238 million • Tourism WA identified watching the sunset over the water and walking as the top two coastal activities for tourists. Bather Beach right next to the port is the only place in Perth where visitors can legally consume alcohol on the beach • Future estimated erosion at Bathers Beach and Arthurs Head would likely reduce economic activity as the beach would likely disappear over time	City of Fremantle (2018) BMT Oceanica (2014a)
4.2	Commercial fisheries	• Commercial fisheries are not operating heavily in the port, Deep Water Channel or Gage Roads, however commercially fished species do use the harbour and estuary during their life cycles • Fremantle Octopus fishery operates in the vicinity of Gage Roads and the Deep-Water Channel • West Coast Estuarine Managed Fishery operates in the Swan-Canning at Melville, Perth and lower Canning waters; a small number of operator's fish and target blue swimmer crabs, sea mullet, Perth herring black bream and yelloweye mullet	SKM (2009c) Department of Fisheries (2007) Brearley and Hodgkin (2005)
4.3	Aquaculture	• South Metropolitan TAFE's Australian Centre for Applied Aquaculture Research (ACAAR) uses water from the Inner Harbour • The ACAAR has supported projects such as restocking of prawns in the Swan Estuary • The research sector of ACAAR is recognised nationally and internationally • Site operations of the aquaculture training facilities of South Metropolitan TAFE and ACAAR are subject to lease agreements with the Fremantle Port Authority • Average of 63 student enrolments per year in aquaculture courses at South Metropolitan TAFE	Tweedley et al. (2017) Australian Venture Consultants (2016)

2.2 Kwinana

2.2.1 Environmental values

The full suite of literature reviewed for marine and estuarine *environmental values* for Kwinana is given in Table 4. Significant information for the Kwinana area comes from the annual monitoring of Cockburn Sound and the State of Environment reports issued by the Cockburn Sound Management Council. Some aspects of biological diversity have been studied at points in time, but lack of continuous data prohibits assessments of any change over time. Invasive species is also a concern for biological diversity. Seagrass is the most intensively studied habitat to date, however information on seagrass health is not conclusive given some areas show meadows extending into deeper water and some areas show shoot density decreasing. Water quality has improved but localised issues still remain. The benthic habitats, particularly seagrass, and the sheltered nature of Cockburn Sound provide regionally significant spawning and nursery areas for several species such as pink snapper, blue swimmer crabs and southern garfish. Resident populations of little penguins and bottlenose dolphins occur in and around Cockburn Sound, and a significant number of studies have investigated foraging habits, population dynamics and anthropogenic stresses.

Additional environmental values identified for Kwinana include:

- Significant benthic communities and habitats: other
    - Coral colonies and soft sediment habitats are found in Cockburn Sound
- Regionally significant spawning / nursery area: whitebait
    - High abundances of whitebait eggs have been found in Cockburn Sound
- Coastal processes
    - Erosion and inundation are issues for localised areas, e.g. Palm Beach and Kwinana Bulk Terminal

2.2.2 Social values

The full suite of literature reviewed for marine and estuarine *social values* for Kwinana is given in Table 5. Cockburn Sound has 31 listed maritime heritage sites and several listed mythological and aboriginal heritage sites, the largest of which is the 'Indian Ocean' mythological site that includes the waters of Cockburn Sound north to Fremantle and west to Rottnest Island. Recreational fishing is one of the most popular 'social and community' values in Cockburn Sound and public support was a significant factor in raising enough funds to release hatchery reared juvenile pink snapper back into Cockburn Sound after the 2015 fish kill incident. Commercial fishing also occurs in Cockburn Sound though licenses have been in decline since 1990. Mussel aquaculture is a significant industry operating in Cockburn Sound but has also faced declines in mussel growth due to rising sea temperatures, predation and decreased nutrient levels. Recreational activities typically operate within the southern region of Cockburn Sound around Mangels Bay.

Additional social values identified for Kwinana (and Rockingham) include:

- Social and community: water sports
    - Kayaking, water skiing, wind and kite surfing are some of the water sports occurring in Cockburn Sound
- Business, industry and commercial: tourism
    - Numerous adventure and wildlife packages based at Rockingham are offered in Cockburn Sound

Table 4: Literature review of marine and estuarine environmental values for Kwinana.

Ref#	Marine and estuarine environmental values	Description of value	References
1	Integral functioning ecosystem		
		• Encompasses biodiversity, biomass, abundance, food chains and nutrient cycling • Cockburn Sound was characterised as a system modified by historic nutrient enrichment (eutrophication) and seagrass loss • Since European habitation, the following have declined in Cockburn Sound: habitat complexity (96%), biomass of benthic primary producers (92%), biomass of benthic secondary producers (50%) (offset somewhat by new unvegetated sediments in <10 m water depth, dredge spoil reef and rock wall), benthic invertebrate diversity (29%), benthic secondary production (30%) (incl. a 68% reduction in water filtering capacity), and abundance benthic invertebrates (9%) • Primary production in Cockburn Sound is phytoplankton dominated • It is estimated that the nitrogen turnover rate across the Sound is ~5% higher than the pre-European habitation, due to the higher production rates of phytoplankton, but that sediment turnover across the Sound is 8% lower due to loss of fauna performing bioturbation of sediments	BMT (2018) Cockburn Sound Management Council (2018) Cockburn Sound Management Council (2016) Department of Environmental Protection (1996)
2	Sheltered marine ecological community		
		• South-west coast has only a few sheltered nearshore marine embayments • Most intensively used marine embayment along the WA coast • Has undergone industrial development, dredging and construction of the Garden Island Causeway • Garden Island provides protection from winds and swells	Cockburn Sound Management Council (2018) Government of Western Australia (2015)
3	Biological diversity		
3.1	Fish assemblages	• Broadscale ecological investigations examining fish communities and their health within Cockburn Sound has received little attention, and temporal trends or comparisons are difficult • ~ 130 species of fish are estimated to exist in Cockburn Sound • Fish abundance and diversity was found to be greater for limestone outcrops, seagrass meadows and dredge channels vs rock walls and the sandy basin and banks of Cockburn Sound for both traps and baited video methods • Seagrass wrack was positively associated with abundance, diversity and biomass of plant-associated fish species, and diversity of omnivorous fish species in Cockburn Sound • A 2007 spring study found larval fish abundance to be significantly higher in Cockburn Sound in comparison to Warnbro Sound, Owen Anchorage and Five Fathom Bank. Warnbro Sound had the next highest concentration. Five Fathom Bank significantly less diverse at family level • A 1994 study reported Cockburn Sound to have a distinctive fish community compared to adjacent waters due to the presence of large abundances of the tropical fish species: *Apogon rueppellii, Pentapodus vitta*, and *Monacanthus chinensis*. These fish are more often associated with seagrass meadows, but can also occupy adjacent rocky reefs • A trawl survey found snapper and blue swimmer crab were found to be well distributed across Cockburn Sound, and not significantly correlated with particular sites • 2011 marine heatwave saw the persistence of some tropical species, i.e. *Siganus* sp and *Psammoperca waigiensis*. in Cockburn Sound until the 2013/2014 summer	BMT (2018) Lenanton et al. (2017) Wakefield et al. (2013) Breheny et al. (2012) Sampey et al. (2011) Strategen (2011) Vanderklift and Jacoby (2003) Hutchins (1994) Dybdahl 1979)- to obtain
3.2	Demersal and benthic communities	• In 2006, 188 species of benthic macrofauna were identified; polychaetes and molluscs were the most abundant and continued to be abundant in 2008 and 2013 • A comparison of three benthic macrofauna studies (1978, 1993 and 2006) found a change in species abundances, distribution and diversity. A further comparison between 2006 and 2008 of the same sites found abundance, richness and diversity of macrobenthic fauna to be lower in 2008 than 2006, and this was more pronounced to the north of CS than the centre or south areas There was also a measurable shift in sediment characteristics in the north. This change was considered to be a regional effect rather than a result of desalination operations • Sea cucumbers, sea squirts and sea stars decrease in abundance from north to south of Cockburn Sound (2006, 2008, 2013), while horseshoe worms and sea pens increased • ~ 14 large crustacean and mollusc species are estimated to exist in Cockburn Sound • Trawl survey methods found north Garden Island and Owen Anchorage to have highest species richness (~ 47 species, max of 56), which declined further south in Cockburn Sound i.e. Mangles Bay (~27 species, lowest 24). This gradient may be related to the differences in sediment from calcareous sand and shelly gravel (north) to thick grey mud (south), and from lower nutrients (north) to higher nutrients (south). North Garden Island was dominated by a few species, whereas Owen Anchorage had a more even spread across different species • Jervoise Bay (contains hard substrate for things to attach) and Owen Anchorage (not as affected by water quality and there's more seagrass) had community assemblages that were significantly different from other sites in Cockburn Sound based on abundance data from trawls	Yeo et al. (2015) Oceanica Consulting (2013) Yeo et al. (2013) GHD (2012) Langdon et al. (2011) Sampey et al. (2011) Strategen (2011) Oceanica Consulting (2009) Johnston et al. (2008)

Ref#	Marine and estuarine environmental values	Description of value	References
		• Though comparisons of communities are difficult based on different trawl methods used across studies, Cockburn Sound was found to have a low abundance and biomass on average compared to other areas surveyed along the Western Australian coastline. • The following species may be suitable indicator species for epibenthic and demersal communities in Cockburn Sound: *Belosquilla laevis* (mantis shrimp), *Cercodema anceps* (sea cucumber), *Colochirus quadrangularis* (sea cucumber), *Melicertus latisulcatus* (Western King Prawn), *Portunus armatus* (blue swimmer crab), *Parequula melbournensis* (silverbelly fish), *Pentapodus vitta* (Western butterfish), *and Pseudocalliurichthys goodladi* (long-spine dragonet) • 222 species from six major invertebrate phyla were identified in the 90s in a benthic community study. • In relation to deep basin fauna- northern Cockburn Sound was identified as an 'undisturbed' (anthropogenic and natural) region, while the middle and southern end were considered 'moderately' disturbed most likely due to toxic contaminants. Warnbro Sound northern region was considered 'undisturbed', while the south was 'moderately' disturbed due to build-up of detrital organic material • In the 90s, benthic filter feeders had a higher biomass along the eastern and southern shorelines in Cockburn Sound, and biomass and diversity was higher in *Posidonia* meadows • 28 species of cnidarians, 75 species of echinoderms, 276 species of molluscs were identified in surveys in the 50s and 70s • In the past, dredge spoil was disposed on the Kwinana Shelf and created a 'Dredge spoil' reef habitat which now supports a diverse habitat of algae, seagrass (patchy *Halophila*) and corals • Large aggregations of the grazing urchin *Heliocidaris erythrogramma* has caused significant grazing scars in seagrass meadows in the past • The reproductive biology and movement patterns of the sand dollar, *Peronella lesueuri*, have been examined	Oceanica Consulting (2007a)* Oceanica Consulting (2005) Department of Environmental Protection (1996)
3.3	Plankton	• Estimates of zooplankton grazing rates and secondary production, critical for understanding pelagic food web dynamics, have not yet been measured in Cockburn Sound. • 124 zooplankton species identified from Cockburn and Warnbro Sound between 1992-94, with Arthropoda (e.g. decapods, isopods, amphipods, copepods) taxa accounting for over 70%. • Copepods most abundant- across three families. Mainly small copepods thus are most likely to be grazing heavily on phytoplankton than other zooplankton. Copepods and cladocerans were most abundant when diatoms dominated phytoplankton assemblages • ~70% taxa were common to both Cockburn and Warnbro Sounds. Abundance typically greater in Cockburn Sound than Warnbro Sound, and was highest in Jervoise Bay and lowest in the north-west corner of the Sound • Seasonality of occurrence of zooplankton, and copepods typically peaked in spring, summer, and also autumn for Cockburn Sound • Radiolarian blooms occurred during winter months in the 90s • Diatoms were the most abundant group among the large phytoplankton fraction sampled (microphytoplankton) in the nitrogen limited, clear waters of Cockburn Sound and its surroundings during both the late-winter and late spring • Based on the flushing times of CS (11-30 days), a 10-fold increase in the abundance of diatoms is estimated to take between 2-11 days. The CS phytoplankton community likely reflects that of a semi-enclosed marine embayment compared to offshore of Garden Island where the community is likely influenced by phytoplankton transported by currents from the broader coastal region. However, during winter (2012) the dominance of coastal chain forming diatoms in CS (such as *Leptocylindrus*) may be due to pulses of nutrient input and turbulence creating favourable conditions for growth	BMT (2018) Machado (2013) Department of Environmental Protection (1996)
3.4	Invasive species	• Invasive species is a key pressure associated with shipping activities in Cockburn Sound • Seasonal and annual monitoring for introduced marine pests is conducted by DPIRD, Fremantle Ports and Department of Defence. The State Wide Array Surveillance Program (SWASP) for introduced marine pests has been implemented in Fremantle since 2010 and monitoring reports are completed twice a year (Fremantle Port Authority pers.comm. 2019) • There are 46 introduced marine species in Cockburn Sound, four of which are considered pests: Asian date mussel/bag (*Arcuatula senhousia*), European fanworm (*Sabella spallanzanii*), colonial ascidian (*Didemnum pellucidum*), toxic dinoflagellate (*Alexandrium catenella*) • Introduced streaked goby, *Acentrogobius pflaumii*, has been documented in Cockburn Sound and Swan River, but effects, if any, on environment have not yet been determined • Cockburn Sound considered ideal suited for invasive pests due to large areas of disturbed habitat with no vegetation and a high abundance of phytoplankton for food • 79% of potentially introduced marine pests are considered compatible with the marine environment of Fremantle Port (incl. Cockburn Sound) based on currently known habitat preferences • Majority of vessels to Fremantle Port (incl. Cockburn Sound) are international and considered low risk for invasion, however, moderate and high-risk vessels tend to stay longer • Dredge vessels stay longer in Fremantle Port (incl. Cockburn Sound), but are less common, than cargo vessels; dredge, mobile offshore drilling/floating production units and Navy vessels are considered high risk; followed by medium risk vessels of barges, commercial fishing vessels, research vessels and tugs • Greatest risk to Fremantle Port (incl. Cockburn Sound) are vessels from Singapore and Indonesia, which could potentially introduce the invasive species- *Caulerpa taxifolia* (invasive strain) • Port Adelaide is the greatest domestic risk to Fremantle Port (incl. Cockburn Sound) due to a high compatibility of pests and high frequency of vessels entering Fremantle Port	BMT (2018) Bridgwood and McDonald (2014) Maddern and Morrison (2009) McDonald and Wells (2009) Enzer Marine Environmental Consulting (2008) Huisman et al. (2008) Department of Environmental Protection (1996)

Ref#	Marine and estuarine environmental values	Description of value	References
		• 50 introduced marine species have been documented for the Fremantle Port area (incl. Cockburn Sound); many have not been documented since initial sightings; include hydroids, molluscs, polychaetes, ascidians and fish • Inoculation risk to Fremantle Port area (incl. Cockburn Sound) is considered medium to high	
4	High level of water quality		
4.1	Nutrients	• Nutrient levels have improved in Cockburn Sound since the 1980's after the redirection of point sources of wastewater and industrial discharge to the Sepia Depression Ocean Outlet Landline. Between 1983-2017: o total phosphorus declined since early 80's but has remained the same over the past 11 years. Variability between sites within years has also decreased over time o filterable reactive phosphorus declined since early 80's but has remained the same over the past 11 years o nitrogen has generally decreased since monitoring began. Variability between sites within years has also decreased over time. 2015/16 concentrations not significantly different from most previous years since 1992 o Nitrate-nitrite concentrations highest in early 80's but has recorded lowest concentrations since 2006/07 to present. 2016/2017 not significantly different to concentrations from 2006/07 to 2015/16. Variability between sites within years has also decreased over time o Ammonium concentrations have declined, 2016/17 not significantly different to 2015/16 and 2009/10, but significantly lower to years prior to 2009/10 (measured during non-river flow). Variability between sites within years has also decreased over time. • Most water quality sites in Cockburn Sound currently do not exceed nutrient enrichment levels, except for Jervois Bay Northern Harbour and Mangles Bay (nitrogen and phosphorus for Kwinana Beach sites also showing elevated values) • Jervois Bay Northern Harbour construction finished in 1997, after which point sources for nitrogen were removed. The design created a "bathtub" effect with long resident flushing times of ~ 9 days with sources of nutrients stemming from groundwater and anthropogenic uses. Nutrient levels are anticipated to decrease over time by natural attenuation (2012)	Cockburn Sound Management Council (2017) Cockburn Sound Management Council (2016) Greenwood et al. (2016) Keesing et al. (2016) Government of Western Australia (2015) McFarlane (2015) Cockburn Sound Management Council (2012) D.A. Lord & Associates and PPK Environment and Infrastructure (2001)
4.2	Chlorophyll a/ phytoplankton	• Generally, chlorophyll *a* spatial trends are consistent with nutrients, where highest concentrations are usually found towards the south-east of Cockburn Sound (with the exception of Jervoise Bay Northern Harbour) • Jervoise Bay Northern Harbour has consistently had high concentrations of phytoplankton and chlorophyll *a* • 1983-2017- Median chlorophyll *a* concentrations in Cockburn Sound generally increased from the 1980s to the 1990s, remained high in the early 2000s, decreased during the mid-2000s, increased between 2010–11 and 2012–13 and then decreased again • > 300 known phytoplankton species in Cockburn Sound from four main groups: diatoms (Bacillariophyta), dinoflagellates (Dinophyta), silicoflagellates (Dictyochophyceae), and blue-green algae (Cyanophyta)- majority were temperate marine species • In the early 90s, phytoplankton abundance was greatest in Cockburn Sound and lowest at Sepia Depression • Western Australian Shellfish Quality Assurance Program monitors phytoplankton for toxic species twice monthly at Southern Flats and Kwinana Grain Terminal • Pelagic primary production has not been directly measured within Cockburn Sound • Over the duration of the CSMC monitoring program there has been an increase in the occurrence of higher chlorophyll *a* concentrations reported at Warnbro reference stations • Peaks in Chaetoceros (diatom) cell densities have been increasing in intensity and frequency since 2005, which is also consistent with climate change. This diatom (*Chaetoceros danicus*) contributed to the fish kill incident in 2015 in Cockburn Sound	BMT (2018) Cockburn Sound Management Council (2018) Cockburn Sound Management Council (2017) Cockburn Sound Management Council (2016) Department of Health (2016) Helleren (2016) Keesing et al. (2016) Cockburn Sound Management Council (2012) Department of Environmental Protection (1996)

Ref#	Marine and estuarine environmental values	Description of value	References
4.3	Light attenuation/ turbidity	• In Cockburn Sound between 1983-2017, light attenuation has shown a general downward trend and light availability is considered adequate for seagrass growth given growth has extended deeper and is growing near its depth limit • Higher levels of nutrients in the southern section of Cockburn Sound and Jervoise Bay Northern Harbour have meant that light attenuation guidelines are exceeded there. The southern region of Cockburn Sound experiences poor flushing which exacerbates the issue • Light reaching the seabed in most parts of Cockburn Sound (excl. nearshore shallows) are at, or below, the minimum light requirement for seagrass growth of 11% (Duarte 1991) • Surveys before and after dredging by Cockburn Cement of Parmelia Bank (2006) and Success Bank (2007) showed a negative impact on water clarity and light availability immediately after dredging, however, water quality recovered to 60-75% after 5-6 hours. • Method of dredging by Cockburn Cement results in plumes dispersing over wide distances so that impacts are minimal for any one site • Dredge spoil in Cockburn Sound is calcarenite, which when dredged is unlikely to increase biological oxygen demand in the water column, but there may be oxygen absorption by the natural silt particles • Concentration of suspended solids along with exposure time are both significant in determining the effects of turbidity on fish • Particle shape can have differing effects on fish, i.e. smooth (better) vs angular (worse), and natural sediments are typically less damaging that mineral sediments; calcarenite in Cockburn Sound is a mineral sediment • Larger particles cause more damage in fish than smaller particles, though larger particles are suspended in the water column for less time	Cockburn Sound Management Council (2017) Keesing et al. (2016) Oceanica Consulting (2011a) Partridge et al. (2009a); Partridge et al. (2009b) Newcombe and Jensen (1996) Duarte (1991) Buermann et al. (1997) Appleby and Scarratt (1989)
4.4	Dissolved oxygen	• Dissolved oxygen is consistently measured during the non-river flow (summer) season in Cockburn Sound • Overall, dissolved oxygen concentrations have improved since the 70's and waters are considered generally well mixed and well oxygenated • During extreme weather events and some periods during late summer and autumn, bottom waters can become stratified and depleted of oxygen for short periods • For the majority of Cockburn Sound, dissolved oxygen is above 90%- achieves management guidelines • Some occurrences of lower dissolved oxygen concentrations (60-90%) and also of dissolved oxygen concentrations less than the environmental quality standard of 60% in some bottom waters in the south and east of Cockburn Sound and Jervoise Bay Northern Harbour • These low dissolved oxygen occurrences were not always associated with fish kills etc., however, low dissolved oxygen combined with high sea surface temperatures and a diatom bloom were considered the cause of the 2015 fish kill of ~2000 fish and invertebrates	BMT (2018) Cockburn Sound Management Council (2018) Cockburn Sound Management Council (2017) Cockburn Sound Management Council (2016) Keesing et al. (2016) Department of Fisheries (2016)
4.5	Temperature	• Surface and bottom water temperatures are measured during the non-river flow (summer) season annually in Cockburn Sound, and at selected sites year-round (e.g. Mangles Bay, Alcoa Jetty, Naval Ammunition Jetty) • Environmental quality guidelines for temperature are met annually • Cockburn Sound is experiencing an increase in water temperatures similar to that of other sites off the WA coastline- this is attributed to climate change • Surface waters are increasing at a rate of 0.0325 ± 95% CI 0.016°C per year, and bottom waters of 0.0295 ± 95% CI 0.014°C per year. By 2060, water temperature is expected to be 1.3°C warmer in Cockburn Sound than present • Can expect a lengthening of the warm season with climate change in south-western Australia • 2010/2011 marine heatwave event influenced temperatures in Cockburn Sound with a significant increase recorded compared with adjacent years. Marine heatwaves have increased in duration and frequency • Trends in temperature in Cockburn Sound will be influenced by variability in the El Niño-Southern Oscillation variability	BMT (2018) Cockburn Sound Management Council (2017) Cockburn Sound Management Council (2016) Keesing et al. (2016) Caputi et al. (2009)

Ref#	Marine and estuarine environmental values	Description of value	References
4.6	Salinity	• Surface and bottom salinity are measured during the non-river flow (summer) season annually in Cockburn Sound and typically meets environment guidelines • Brine discharge occurs on eastern portion of Cockburn Sound from the Perth Seawater Desalination Plant, and two sites in close proximity to the outlet have regularly exceeded the environmental quality guidelines for salinity in bottom waters since the plant's establishment- these are considered localised occurrences • Heavy rainfall in January-February 2017 caused flooding in both the Avon and Swan River catchments which resulted in a large plume of turbid fresh water extending well into Cockburn Sound, lowering surface salinities and increasing light attenuation. Flow from the Swan River is expected to reduce under a drying climate	BMT (2018) Cockburn Sound Management Council (2017) Cockburn Sound Management Council (2016)
4.7	pH	• Surface and bottom pH are measured during the non-river flow (summer) season annually in Cockburn Sound and typically meets environment guidelines • In Cockburn Sound, measurements of pH have been recorded since 2005 and range from 8.10 to 8.31 in surface waters. However, these records are of insufficient duration and accuracy to allow for an evaluation of climate-induced pH changes in Cockburn Sound waters	BMT (2018) Cockburn Sound Management Council (2017) Cockburn Sound Management Council (2016)
4.8	Contaminants/ toxicants	• Contaminant inventories were compiled in 1993, 1998 and reviewed in 2001 and 2008. No routine monitoring of contaminants is undertaken in Cockburn Sound • 2008 Contaminants in Water study showed that concentrations of all potential contaminants that have environmental quality criteria were below the guideline values for moderate and high ecological protection areas in Cockburn Sound • The few sites (i.e. Kwinana Bulk Terminal/ Jetty and Mangles Bay) monitored for toxicants (excl. PFAS) in recent years- 2016-2017 have not exceeded guidelines • Department of Defence ceased using firefighting chemicals containing per- and poly-fluoroalkyl substances (PFAS) after 2003 • Potentially contaminated PFAS sites are investigated and managed as part of a National PFAS Investigation and Management Program • PFAS could enter the primary production cycle through filtration/ingestion of impacted groundwater and has the potential to biomagnify and bioaccumulate through the food chain • Garden Island groundwater and surface water within all identified source areas exceeded adopted ecological guidelines for PFAS and pose a risk to the ecology of Cockburn Sound and the Indian Ocean • There is evidence that a pesticide/herbicide plume sourced from the former Chemical Industries Kwinana site has migrated southwards and is now within 1 km of Cockburn Sound, potentially more, which may have localised effects. No monitoring has occurred around other pesticide/herbicide manufacturing sites (such as Bayer Crop Science) • In the 70s, heavy metals were detected in 12 sampled teleost species in Cockburn Sound, but levels were below health standards and were much lower than levels in mussel tissues. • Depending on the type of hydrocarbons spilled into the marine environment, they can either be floating, entrained or dissolved and can cause smothering, toxicity or ecological change. The Swan region (includes Cockburn Sound) is considered a high-risk area to oil spills. Smaller spills are much more frequent than larger spills, however the majority of spills in the Swan region is more likely to come from larger incidents	BMT (2018) HEPA (2018) Navigatus (2018) RPS Australia West (2018) Advisian (2017) Cockburn Sound Management Council (2016) Parsons Brinckerhoff Australia (2009) Trefry et al. (2006) Plaskett and Potter (1979)
4.9	Groundwater	• Groundwater from Jandakot Mound, Safety Bay Mound and Garden Island (minor volumes) discharges to Cockburn Sound. Flow points are located north of Woodman Point to the southern end of Kwinana Beach, as well as to the south and west of the Sound • Since the reduction of direct wastewater output into Cockburn Sound, groundwater was then the main source of nutrients into the Sound. Contamination and nutrient loading of groundwater has likely peaked and will gradually reduce over time • Thirteen high priority plumes (groundwater point source pollution risks) were identified in Cockburn Sound in a 2006 CSIRO report based on data supplied by industry. These occurred along the eastern margin and Garden Island • Legacy issues remain from agricultural and industrial contamination of groundwater and between 13.6 and 27.5 GL of groundwater is discharged into the Sound each year • Managed Aquifer Recharge sites further inland would mean a longer residence time and increased attenuation of phosphorus and nitrogen before discharge into the Sound • Calculations of nutrient loads into the Sound should incorporate estimates of chemically and biologically mediated reactions that can occur when there is slow flow rate, low oxygen concentrations and high organic carbon- nitrification/denitrification reactions can reduce the nitrogen load into the Sound • There is no systematic monitoring of groundwater quality near the coast or DWER monitoring bores • Reduced nutrient loads into Cockburn Sounds via groundwater is likely under a drier climate	BMT (2018) Keesing et al. (2016) McFarlane (2015) GHD (2013) Loveless and Oldham (2009) Smith et al. (2009) Loveless et al. (2008) Davidson and Yu (2006) Trefry et al. (2006) Smith & Nield (2003) Taniguchi et al. (2003)

Ref#	Marine and estuarine environmental values	Description of value	References
			D.A. Lord & Associates and PPK Environment and Infrastructure (2001)
4.10	Hydrology	• Poor flushing of the southern region of Cockburn Sound results in lower water quality, lower dissolved oxygen waters, and is suggested to have helped cause the 2015 Fish Kill together with unusually high sea surface temperatures and diatom bloom • Currently, average flushing times for each season are 37d for Autumn, 22d for Winter, 28d during a winter storm, and 44 d during summer. Estimated that removal of causeway would improve summer flushing to 22d • During the 'winter-spring' regime, waters are less dense in Cockburn Sound and surrounds due to river input and solar heating. During the 'summer' regime, river flows are minor and increased nearshore heating and evaporation reduces cross shelf density differences. During the 'autumn' regime, nearshore waters are denser due to evaporation and nearshore cooling during early winter • Modelling of hydrology in relation to the past proposed Kwinana Quays development on the eastern shelf found no impacts to residual currents for the whole of the Sound, but did so for the eastern shelf, particularly reduced velocities in the central and southern regions of the eastern shelf if island reclamation and a causeway were built • During the summer, an anticlockwise gyre in the northern Cockburn Sound basin generates a northern flow of water along the eastern margin, and a net northward flow of water also flows from the southern basin along the eastern margin • Previous modelling studies estimated that the Garden Island causeway reduced natural flushing of Cockburn Sound by ~40%, and by removing the causeway, flushing would be significantly improved for the southern region of Cockburn Sound. • A WAMSI workshop (2018) on the benefits and impacts of the Garden Island Causeway noted that the shallow sill (~5m) would restrict the physical mixing of water in the southern end of Cockburn Sound. There was disagreement over what extent removal of the Causeway, and increased exchange with the shelf, would have on improving water and sediment quality	WAMSI (2018) Department of Fisheries (2016) Coastal Zone Management and Damara WA (2010) Harris and Antenucci (2009) Asia Pacific Applied Sciences Association (2004) Cockburn Sound Management Council (2003) D. A. Lord & Associates (2002) Department of Environmental Protection (1996)
5	High level of sediment quality		
5.1	Contaminants	• TBT, used in the past as antifoulant for vessels, can accumulate in organisms and become toxic e.g. imposex in shellfish and disruption of ionic regulation in fish • Imposex of gastropods was present at sites in Cockburn Sound during the last survey in 2006 and when present, it is considered an exceedance of sediment TBT environmental quality guidelines. Broadscale surveys of TBT in sediments have not been completed since 2006, though in Jervoise Bay southern harbour it was last reported that imposex had reduced from 100% to 86% (2009), and for Woodman Point, there was a reduction from 62% to 33% (2011) • TBT and breakdown products have been found in tissues of dead little penguins, though TBT cannot definitely be labelled as the cause of death • TBT contaminated sediments can be resuspended and released back into the water column from wave action, dredging, propeller wash, etc. • Elevated concentrations of TBT are expected in bottom sediments of Jervoise Bay northern and southern harbour, Careening Bay, Kwinana Bulk Terminal and James Point • There are no environmental quality guidelines for the breakdown products if TBT (dibutyltin-DBT and monobutyltin- MBT) and in the 2016/17 sampling period, significant concentrations of MBT (final product of TBT) were found at Kwinana Bulk Terminal and Jetty • Only certain sites in Cockburn Sound, such as Kwinana Bulk Terminal and Jetty, are sampled annually for sediment contaminants. Contaminants usually do not exceed guidelines • Last widespread survey of toxicants in sediments was conducted in 2006- contaminants did not exceed guidelines except for mercury at Kwinana Bulk Jetty and TBT at Careening Bay • PFAS in sediments within the stormwater sump at the Garden Island Fire Station could leach into Cockburn Sound or the Indian Ocean and impact marine life	BMT (2018) RPS Australia West (2018) Cockburn Sound Management Council (2017) Cockburn Sound Management Council (2016) GHD (2012) Cockburn Sound Management Council (2012) Cockburn Sound Management Council (2006) Department of Water (2006) Oceanica Consulting (2006)

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5.2	Nutrients	• Sediments in Cockburn Sound have a high organic load due to slow circulation leading to a long-term build up of nutrients • Nutrients are resupplied to the water column through biological activity and biogeochemical processes • Recycling of nutrients from sediments fuels phytoplankton production, which reduces light levels to below 10% of surface irradiance in some areas • Estimates of nutrient cycling in the marine sediments in Cockburn Sound are up to 1950 tonnes/year (2001)	Greenwood et al. (2016) Keesing et al. (2016) Li et al. (2013) D.A. Lord & Associates and PPK Environment and Infrastructure (2001)
5.3	Acid sulphate soils	• Initial analyses from samples collected around the eastern margin of CS revealed all samples to be potential acid sulphate soils, but acid formation is unlikely given the sufficient neutralising capacity of the sediments	GHD (2012) Oceanica 2009*
6	Significant benthic communities and habitats		
6.1	Seagrass	• Seagrass cover in Cockburn Sound declined from 4200 ha in 1954 to 900 ha in 1978- which corresponds to the period of time when wastewater and industrial outflow were released directly into the Sound • Seagrass meadows are most extensive in the western (Garden Island) and southern (Southern Flats) regions of Cockburn Sound • The most recent (2018) analysis of seagrass meadow extent shows a seagrass cover of 965 ha (2017) across the whole Sound, which is a gain of 244 ha since 1999 that mostly occurred at Southern Flats and eastern offshore areas of Cockburn Sound • A 40 ha gain occurred between 2012-2017 which was largely attributed by an increase in cover at the north-east of Garden Island. During this same time period, some loss was observed to the east of the Sound, but overall cover is still higher than it was in 1999 • Currently, only 22.6% of benthic environment, that is less than 10 m in depth, has seagrass • The increase in seagrass cover over the past 20 years has not been reflected in seagrass shoot density measurements, so even though an increase in seagrass cover coincides with improved water quality, it is believed that other environmental factors are at play that are prohibiting the increase in seagrass shoot densities across the Sound; no significant increases in shoot density were measured for any site during the 2016/17 sampling period and 'legacy problems' may be preventing seagrass recovery • A possible cause of decline causing dieback in meadows could be sulphide intrusion. Rhizome tissues of *Posidonia sinuosa* were low in oxygen at night at sites in Cockburn Sound, which could be making them vulnerable to sulphide intrusion • Isotopic analyses on *Posidonia sinuosa* tissues indicate sulphide stress at sites that have experienced seagrass declines. Analyses of seagrass from Garden Island and Warnbro Sound suggest sulphide intrusion *may* be causing declines in these areas. • Marine heatwave effects on Amphibolis antarctica seagrass in Shark Bay included a long-term reduction in below ground biomass, which was not as clearly visible as above ground leaf biomass, and this needs to be considered for areas with seagrass for future marine heatwaves. *Amphibolis* is more vulnerable to change because it doesn't have the stored reserves in big rhizomes like *Posidonia* does • The mean lower depth limits of seagrass meadows have increased significantly at Garden Island South and Woodman Point over the 17 years that the sites have been monitored (from 8m to 11m), however, in recent years, shallower depth limits and potential thinning of meadows at these locations has been recorded. Reduced light and increased turbidity were recorded during the 2017 sampling season which could negatively impact lower depth limits of meadows. Garden Island north and Warnbro have remained stable in lower depth limits of meadows. This suggests water quality and light availability are adequate for seagrass to grow at their depth limits • Warnbro Sound reference sites for which Cockburn Sound seagrass measurements are compared to have been significantly declining in shoot density • Newly dredged slopes by Cockburn Cement in Owen Anchorage are estimated to stabilise after 3 years where slopes can then be colonised by seagrasses • Tranplantion experiments have occurred for *Posidonia sinuosa* and *Amphibolis griffithii* at various locations throught the Sound, including Southern Flats and Success Bank	Cambridge pers. comm. (2019) Hovey and Fraser (2018) Olsen et al. (2018) Cockburn Sound Management Council (2017) Fraser and Kendrick (2017) Cockburn Sound Management Council (2016) Fraser et al. (2016a) Fraser et al. (2016b) Fraser et al. (2014) Mohring and Rule (2014) Mohring and Rule (2013a); Mohring and Rule (2013b) Sinclair et al. (2013) Verduin et al. (2012) Dapson (2011) Lavery and McMahon (2011) Oceanica Consulting (2011a) Pederson et al. (2004); Oceanica Consulting (2011a) Horn et al. (2009) Paling et al. (2007) Paling et al. (2001) Paling et al. (2000) Cambridge and McComb (1984)

Ref#	Marine and estuarine environmental values	Description of value	References
6.2	Coral reefs	• 50 hard coral colonies were found at two separate sites within Cockburn Sound; largely form the Faviidae family • No long-term monitoring has been conducted for corals in Cockburn Sound • Coral assemblages comprised of up to 16 species have been found on rubble banks along eastern margin of Cockburn Sound • *Goniopora norfolkensis* has been found in Cockburn Sound and is a documented range extension from Barrow Island- though not many colonies have been found	GHD (2012) Thomson (2010); Thomson and Frisch (2010) Cockburn Sound Management Council (2006) Veron and Marsh (1988)
6.3	Rocky reefs	• A rocky reef community of algae, sponge, crayfish and octopi have established on the Garden Island Causeway	Cockburn Sound Management Council (2003) D. A. Lord & Associates (2002)
6.4	Soft sediment	• Microphytobenthos (microscopic algae) is a key benthic primary producer on soft sediments within Cockburn Sound, and is considered the most dominant over the eastern shelf and accounts for 77% of carbon turnover by benthic producers; it is typically the major contributor to productivity in coastal shelf waters and estuaries • Microphytobenthos can help to stabilise sediments and reduce erosion	GHD (2012) Jordon (2009) Consalvey et al. (2004) de Deckere et al. (2001)
7	Listed and significant fauna		
7.1	Fairy Tern (*Sternula nereis*)	• Listed as vulnerable under the EPBC Act • Nesting and pre-breeding aggregation sites occur in Cockburn Sound • Nesting sites have been found on Carnac Island and Garden Island and spit (and Rottnest Island). Parkin Point serves as a night roost. Some vehicle collisions with terns, but otherwise relatively secure sites • The erosion of sand bars has caused pre-breeding aggregations of terns to abandon sites (e.g. Penguin I. Rockingham) • New sand banks have connected the mainland to previously secure islands, which has allowed access to domestic dogs and feral predators such as foxes and Black Rats (e.g. Tern Island in Safety Bay) • Terns have a similar diet to little penguins and use the same foraging habitats • Elevated levels of various contaminants around southwestern Australia, including mercury in Cockburn Sound and selenium in the Albany waterways, have been measured in terns	Dunlop (2018) Dunlop (2015) Dunlop et al. (2013) Dunlop (n.d.)
7.2	Little penguins (*Eudyptula minor*)	• Protected under the Wildlife Conservation Act of WA and listed in EPBC Act • There are colonies of little penguins on Garden Island, Penguin Island and Carnac Island • Core foraging areas include Cockburn Sound, the west side of Garden Island, Warnbro Sound, Comet Bay, Lake Clifton-Binningup, Koombana Bay, Bunbury and Geographe Bay • Penguin Island penguins that nest on the north-east side of Penguin Island feed in Cockburn Sound during the incubation stage of breeding and enter/exit the Sound from the north • Garden Island penguins feed within Cockburn Sound during the whole breeding cycle and enter the Sound from the areas adjacent to their nest sites on the eastern margins of Garden Island • Garden Island penguins have a higher breeding success rate than Penguin Island (in 2015) which indicates food resources were adequate for the number of breeding pairs and tracking data has shown that they always forage within Cockburn Sound • Southern foraging locations are important for when prey is limited closer to the colonies • Penguin Island colony is considered regionally threatened. The foraging zone is within < 30km from Penguin Island during chick rearing, and anywhere from 30-200 km during incubation. • Garden Island Penguins feed within 5km of the island, typically within the southern half of Cockburn Sound • Penguins feed on a range of fish species including white bait, pilchards, anchovy, blue sprat, scaly mackerel, occasionally garfish however diet is not as well known for Garden Island penguins compared to Penguin Island penguins, but limited data shows that they feed on a similar suite of species • For Penguin Island penguins, whitebait generally comprise a large proportion of the diet of adult penguins during chick-rearing, and pilchards typically predominate the diet in autumn and early winter. During the 2010/2011 marine heatwave, there were no whitebait in the diet	Western Australian Planning Commission (2018) Cannell (2017) unpub. data Cannell et al. (2016) Cockburn Sound Management Council (2016) Cannell et al. (2012) Chiaradia et al. (2007) Klomp and Wooller (1988)

Ref#	Marine and estuarine environmental values	Description of value	References
		• Trauma from watercraft and starvation are the two highest causes of mortality from Penguin Island, Garden Island and south to 34°19'S • Starvation and availability of prey is likely linked to Leeuwin Current strength and increased water temperatures, which in turn influences breeding success. Also consider other environmental variables such as rainfall • TBT persistent in sediments at Cockburn Sound and could be an ongoing problem for little penguins and other seabirds through bioaccumulation • Seagrass meadows and floating wrack are important for the fish that little penguin consume • There are limited areas where little penguins can forage • Penguins from PI and GI are genetically distinct to penguins in the south-west of WA and elsewhere • A report on Mangles Bay Marina (2018) noted concerns that dredging and disturbance to sediments would stir up mercury and heavy metals which would accumulate in penguins through the food chain	
7.3	Bottlenose dolphins (*Tursiops aduncus*)	• Protected under the EPBC Act • Resident populations of dolphins utilise Owen Anchorage and Cockburn Sound and exhibit strong and long-term site fidelity • Cockburn Sound community is a sink within a source-sink dynamic system. The genetic flow is asymmetric with flow from Owen Anchorage (the source) to Cockburn Sound. Limited exchange occurs from Cockburn Sound to Owen Anchorage. Maintaining the Owen Anchorage community Is essential for the survival of Cockburn Sound dolphins, as well as, and the Swan Canning dolphins • Resident dolphin population of Cockburn Sound is estimated to be ~74 individuals • The strong, long-term association of dolphins with Cockburn Sound and Kwinana Shelf suggest that dolphins may not be able to compensate for a major loss of habitat on the Kwinana Shelf, as the characteristics of this habitat are absent in nearby areas • Shallow sand areas and seagrass meadows in Owen Anchorage likely to support a broad range of prey species for dolphins • Dredging operations, if focused on unvegetated areas, are likely to only have a localised effect on the prey available to dolphins. Further, it is unlikely that transport vessels will impact dolphins due to the slow speed, and dolphins don't appear to be attracted to dredging operations • Kwinana shelf to the east of Cockburn Sound is a core area for foraging and is also a nursery area. Foraging aggregations of dolphins and seabirds have been observed in Cockburn Sound in past surveys (2000-2001), most of the 62 aggregations occurred over Kwinana Shelf or adjacent to the shelf • Illegal feeding of dolphins occurs in Cockburn Sound by recreational users/fishers- individuals were more likely to become conditioned if they spent more time in high boat density areas and if they spent more time with other conditioned dolphins. Dolphins engage in "risky" behaviours during illegal feeding interactions, increasing their risk to boat strikes and entanglement in fishing gear- which has been documents for individuals in the Sound • In a 2000/2001 survey of the sound, dolphins were found to forage more so along the shelf edge and shelf and dolphins with calves tended to forage more on the shelf. Foraging was the most common activity observed for dolphins in Cockburn Sound, as opposed to resting. Foraging was consistent throughout the day with an increase in the early hours of the afternoon, which was similar to the pied cormorant	Chabanne et al. (2017) Chabanne et al. (2017a); Chabanne et al. (2017b) Donaldson et al. (2012) Donaldson et al. (2010) Finn and Calver (2008); Finn et al. (2008) Finn (2005) Watterson (2001)
7.4	Australian Sea lions (*Neophoca cinerea)*	• The Australian sea lion, endemic to Western and South Australia, is classified as Vulnerable by EPBC and is listed as endangered on the IUCN Red List of threatened species. • West coast population of sea lions is stable but small due to past impacts of commercial sealing and colonization; there has been reduction in the number of breeding sites over time. • The impacts of fishery-related mortality on this species is unknown; some commercial fisheries have reported low levels of bycatch • Historical records (Freycinet 1807) documented breeding populations on Rottnest and Garden Island, which have disappeared over time, and now are considered 'haul out' sites only. Breeding still occurs further north, such as at the Abrolhos Islands • Seal and Carnac Islands are two of the most used hall out sites in the Perth metro area, with over 30 individuals documented during peak haul out periods. July-Aug and Dec-Jan were found to be peak haul out periods and haul out numbers increased with increasing air temperature (up to 21°C) and decreased with increasing tide height • An analysis of scat samples from south-west WA found Chondrichthyes made up the largest proportion of prey (46%) in samples from Shoalwater Bay (n=10), including but not limited to stingarees, wobbegongs and carpet sharks. Scats also comprised DNA of ray finned fishes, octopus, cuttlefish, gastropods and crustaceans. Considered to be opportunistic feeders • Sea lions haul out where the environment is most suitable, so static marine reserves that only protect a portion of beach or island may not be effective in preventing human disturbances • Behavioural responses of sea lions to vessels and people were assessed at Seal Island and Carnac Island and severe responses of 'aggressive' and 'retreat' were observed at Carnac and most likely occurred due to the approach of people < 10 m from animals. Distance of vessel and people played a major role in eliciting responses in *N. cinerea*, but types of activities were also contributors • Using whisker spot patterns to identify individuals to get a better understanding of the populations has not proven successful to date	Berry et al. (2017) Osterrieder et al. (2017a) Osterrieder et al. (2017b) Osterrieder (2016) Osterrieder et al. (2015a) Osterrieder et al. (2015b) Campbell et al. (2008) Salgado Kent and Crabtree (2008) Campbell (2005) Gales and Costa (1997) Gales et al. (1994) Gales et al. (1992) Abbott (1979)

Ref#	Marine and estuarine environmental values	Description of value	References
		• Accidental catch of sea lion pups was occurring in some areas of the rock lobster fishery. This led to the mandatory inclusion of sea lion exclusion devices on pots in these areas (Jurien Bay, Abrolhos Islands) • Population size in Perth metro area is unknown, and only 16% of the total sea lion population occurs in WA (~2030 individuals)	
7.5	Migratory shorebirds and seabirds	• Between Fremantle and Rockingham, 21 listed migratory shorebirds under international agreements have been recorded. Seven have a conservation listing (i.e. endangered or vulnerable) • Between Fremantle and Rockingham, 15 listed seabirds under international agreements, four have a conservation listing (i.e. endangered or vulnerable) • Garden Island is listed as an internationally important migratory shorebird site • Estimates of intertidal habitat loss due to sea level rise predictions show seven internationally important sites in south-west Australia at risk of 26% loss with 50cm rise to 97% loss with 300cm rise. Allow room to move upshore in management plans (doesn't specifically say Garden Island in seven) • Roseate tern: tropical species recognised under JAMBA and CAMBA international agreements. Have been recorded in Warnbro, Rottnest Island, Shoalwater Bay and Cockburn Sound in past (50's, 80's, 90's), so with future warming, more colonies may be established • Bridled terns: tropical species recognised under JAMBA and CAMBA international agreements. Colonies of bridled terns have been growing since their recorded presence in Safety Bay area in 1901, and colonies have been documented for Penguin Island and Rottnest Island. Bridled Terns started to breed on Penguin Island only after 1950 and breeding pairs have increased to at least 3000-4000 pairs, which breed annually in three sub-colonies. Birds from the Penguin Island population are thought to feed up to 80 km from the island, over mid and outer shelf waters- no specific records of feeding in Cockburn Sound • Desertion (such as from human disturbance) and predation of eggs by skinks were important factors on Penguin Island • Bridled terns banded on Penguin Island have been found in Celebes Sea • Brown noddy: tropical species recognised under JAMBA and CAMBA international agreements. Brown Noddies were prospecting Penguin Island in the 2003/04, 2004/05, 2005/06 and 2006/07, but not in 2007/08 season • Crested tern: tropical species recognised under JAMBA international agreements. Autumn/winter breeding component of the Crested Tern population in the Fremantle area disappeared sometime in the 1990s and may have been a result of the two catastrophic Pilchard *Sardinops sagax* fish kills in 1995 and 1997 that removed their preferred prey resources. Large colonies exist on Rottnest Island • The pied cormorant, silver gull, Australasian gannet, little penguin, crested tern and Australian pelican were the seabirds present throughout the Cockburn Sound during a survey of seabirds and marine mammals in 2000/2001. Pied cormorants were found to forage more in seagrass beds and the deep basin but did forage in all habitats in the Sound. Silver gulls tended to forage in the seagrass beds and on the shelf. Little penguins were observed more frequently in the deep basin but foraging was not directly observed. Gannets preferred the deep basin for foraging. Crested terns were observed along the east shore and not on the shelf. Pelicans were observed foraging mainly on the east shore but were also observed in seagrass beds and the deep basin. Seabirds were segregated so it is unlikely there was high competition for food. Pied cormorant foraging overlapped with dolphin foraging. Resting was the most commonly observed activity for seabirds in Cockburn, as opposed to foraging activity	Birdife Australia (2018) Department of Environment and Energy (2018) Labbé (2017) Weller and Warren (2017) Department of the Environment and Energy (2016) Hansen et al. (2016) Iwamura et al. (2013) Labbe´ et al. (2013) Dunlop (2009) Bamford et al. (2008) Watterson (2001) Garavanta and Wooller (2000) Dunlop (1997) Dunlop and Jenkins (1994) Dunlop & Johnstone 1994 Wooller et al. (1991) Dunlop (1985a); Dunlop (1985b) Kim Onton pers. comm. DBCA
8	Regionally significant spawning / nursery area		
8.1	King George Whiting (*Sillaginodes punctatus*)	• Occupies three habitats during its life cycle: nearshore nursery areas, deeper waters in marine embayments and offshore reefs • Fishery considered sustainable and adequate for the West Coast Bioregion • Mangles Bay an important nursery for 0+ whiting where they settle in waters < 1.5m deep, but not necessarily associated with seagrass • Port Phillip Bay, Vic study found little evidence of a relationship between seagrass biomass cover and recruitment levels- though recognised that % cover is only one characteristic of seagrass habitat • Unknown whether Leeuwin Current facilitates transport of KGW or if a more localised population • Small individuals feed on copepods and amphipods, and with increasing size, amphipods, copepods, polychaetes and gastropods, algae and sipunculid worms were found	Gaughan and Santoro (2018) Brown et al. (2013) Hyndes et al. (1998) Jenkins et al. (1996) Potter et al. (1996)
8.2	Blue swimmer crab *(Portunus armatus)*	• Fishery has been closed in Cockburn Sound since 2014 to allow stocks to recover • Declines in abundance are believed to be substantially attributable to environmental changes, rather than fishing and a strong correlation has been found between lower water temperatures and reduced recruitment success • Considered as high risk to climate change • The overall stock for WA is considered resilient to climate change given the large latitudinal range of occurrence, but changes are likely for individual stocks at certain locations • Spawning doesn't occur year-round like in more tropical environments i.e. Shark Bay	Cockburn Sound Management Council (2018) Gaughan and Santoro (2018) Caputi et al. (2015)

Ref#	Marine and estuarine environmental values	Description of value	References
		• Maturation generally occurs in less than 12 months in Cockburn Sound and legal catch size is attained after 14-18 months • Cockburn Sound stocks are considered independent of other stocks and there is unlikely to be pronounced recruitment from outside the Sound • Mangles Bay, James Point and Jervoise Bay are the best recruitment sites for 0+, likely due to more seagrass cover • Sub adults 1+ found throughout Cockburn Sound and don't appear to favour particular sites • Assessment of the damage caused to seagrass meadows from recreational fishers wading through water to scoop net is needed. Traps pose a low risk to seagrass meadows through minimal habitat damage	Fletcher and Santoro (2015) Johnston et al. (2011a); Johnston et al. (2011b) de Lestang et al. (2010) de Lestang et al. (2003) Chaplin et al. (2001)
8.3	Pink snapper (*Pagrus auratus*)	• Entry and departure from Cockburn Sound follows annual, lunar, diel and oceanographic cycles, i.e. spawning peaks when water temperatures are between 19-21°C (November) • Pink snapper migrating into Cockburn Sound for spawning mainly occurs through the northern entrance • Given the strong relationship between water temperature and gonadal maturation, migration and spawning, warming waters may influence these behaviours, and marine heatwaves may have more rapid effects on spawning success • Adults are likely to be more resilient to climate change than juveniles. Snapper are highly mobile and have a wide distribution and broad diet so may be able to respond to warming • Migrating and pre-spawning pink snapper arrive before the fishing closure, and are fished, which is likely to impact spawning aggregation biomass. Most leave the Sound before the end of the closure • Fish may not return in consecutive years, but do exhibit spawning site philopatry • Pink snapper an indicator species for demersal fisheries • Cockburn Sound has been identified as an important nursery area for spawning aggregations since 1971; seagrass meadows are important as foraging and nursery grounds for Pink Snapper • Spawning also takes place in Owen Anchorage and Warnbro Sound • Next closest locations for spawning aggregations are Carnarvon, Shark Bay and Augusta • Spawning occurs between September and January, usually peaking in November and occurs mainly in the north-east to east in early period of spawning, then to middle, north and west of the Sound • Recfishwest coordinated the release of ~100 000 juvenile pink snapper into Cockburn Sound over two successive seasons (summer 2016 and summer 2017) after the 2015 fish kill, that included pink snapper • Any disruptions to spawning needs to consider effects to recruitment to adult population on lower west coast of Australia • Juvenile pink snapper can be found in higher abundances in the dredged channels of Cockburn Sound, and to a lesser extent, the limestone outcrop habitats • Larval pink snapper occurred in higher concentrations in Warnbro Sound, then Cockburn Sound, then Owen Anchorage in Spring 2007 • An experiment replicating dredge sediment suspensions found calcarenite sediment did adhere to pink snapper eggs but did not cause them to sink. This finding suggested that if suspended solids from dredge projects were high enough to adhere to eggs, it likely won't negatively impact buoyancy or hatch rate. Dredge sediments did impact pre-feeding larvae with mouths open, which were less tolerant of suspended sediments, and had a higher mortality in comparison to closed mouth larvae. Mortality of larvae increased with increased exposure time to suspended sediments. 15 days post hatch, the increased turbidity in the water due to sediments decreased ingestion of copepod larvae by pink snapper larvae	BMT (2018) Crisafulli et al. (2018) Caputi et al. (2015) Wakefield et al. (2013) Breheny et al. (2012) Wakefield (2010) Partridge and Michael (2010) Partridge et al. (2009a) Johnston et al. (2008)
8.4	Whitebait (*Hyperlophus vittatus*)	• High concentrations of eggs were found in Cockburn Sound and Warnbro Sound in November 93, which indicates that major spawning events may happen in addition to the usual winter spawning period • Higher abundances of eggs have been found in sheltered embayments such as Cockburn Sound and Koombana Bay in comparison to unsheltered sites (except Warnbro Sound) • 2011 marine heatwave may have negatively impacted spawning for the West Coast Bioregion, which resulted in lower catches in following years • Part of the coastal fishery between Fremantle and Bunbury • Considered sustainable-adequate (breeding stocks are adequate or recovering)	BMT (2018) Fletcher et al. (2017) Gaughan et al. (1996)

Ref#	Marine and estuarine environmental values	Description of value	References
8.5	Southern garfish (*Hyporhamphus melanochir*)	• Indicator species for nearshore finfish resources • Cockburn Sound hosts WA's largest Southern garfish fishery • Considered seagrass dependant- seagrass forms part of diet and garfish eggs are attached to leave blades • Stocks have been declining since 1990's and the fishery is vulnerable to collapse if it has a single year of poor recruitment • Stock currently closed to fishing to allow recovery and considered unsustainable (breeding stocks are not adequate or recovering) and inadequate (additional actions needed to confirm if breeding stocks are adequate or recovering) in the West Coast Bioregion • Cockburn Sound's stock should be managed as a discrete stock. There is limited dispersal so limited mixing between populations (which are <60km apart), and if the stock is lost, it may take a long time to recover because it won't be replenished by other stocks • Recreational catch is estimated to be larger than commercial catch and Cockburn Sound produces ~80% of commercial landings and 50% recreational landings of garfish in the West Coast Bioregion • 2011 marine heatwave had a negative impact on stocks	Cockburn Sound Management Council (2018) Gaughan and Santoro (2018) Smith et al. (2017)
9	Shoalwater Islands Marine Park		
		• Gazetted in 1990 as Class A Reserve • Mixture of tropical and temperate species due to the influence of the Leeuwin Current • Habitats include seagrass meadows, macroalgal limestone reefs, and the Warnbro Sound silty basin; seagrasses included mostly *Posidonia*, *Amphibolis*, *Halophil ovalis* and *Heterozostera tasmanica* • Large populations of Roe's abalone occur on the intertidal reef platforms • The Park provides important habitat for little penguins, dolphins, sea lions, as well as occasional occurrences of southern right and humpback whales • Erosion of Point Peron has been a concern in recent years • Sand is extracted from the sand trap west of the Garden Island causeway to prevent sedimentation at the boat launching facility; sand is used for beach renourishment of Penguin Island, Warnbro Sound and Kwinana beaches • Chain of islands and reefs provides a lot of protection from wave action • Under SSW winds, water from the Peel Harvey Estuary enters the marine park, and under north-west winds, waters from Cockburn Sound and Sepia Depression enter the park. • Commercial fishing occurs as well as mussel farming • Inappropriately designed moorings in Safety Bay and Mangles Bay have caused localised damage to seagrass	Department of Transport (2009) Department of Environment and Conservation (2006) D'Adamo et al. (1995a); D'Adamo et al. (1995b)
10	Coastal processes		
		• Local erosion in Cockburn Sound is likely largely attributed to cross-shore sediment transport during storm events • An estimate of constant rate of erosion is ~1.16 m y^{-1} • Because Cockburn Sound is sheltered, no substantial erosion due to increased sea level is expected within the next century • Inundation from rising sea levels is not expected for much of the coast due to high dunes and topography • Success and Parmelia Bank supply sediments to the coastline and could act to replenish eroded regions • Before the construction of the Garden Island Causeway, sand was naturally transported east along Mangles Bay; now sand accretes to the west of the causeway • Woodman Point, the coast between James Point and Kwinana Industrial strip, north of Catherine Point and Careening Bay are expected to experience increased erosion with increased sea level rise • Garden Island north of Colpoys Point, Palm Beach and the Kwinana Bulk Terminal are areas of acute erosion • Southern Cockburn Sound, Rockingham shore, Woodman Point, some areas of the Australian Marine Complex are considered to have a high level of present inundation hazard • James Point, BP Australia and Verve Energy areas are expected to have future inundation issues • The most recent analysis (2018) of climate change impacts on Fremantle Port infrastructure and operations (including Outer Harbour in Cockburn Sound) finds a number of high to very high risks mostly associated with sea level rise e.g., Kwinana Bulk Jetty and operations and Kwinana Bulk Terminal. Tidal currents are unlikely to change in the Outer Harbour area of Cockburn Sound as climate change will not influence astronomical tides	BMT (2018) M. P. Rogers & Associates (2018) Stead (2016) M. P. Rogers and Associates (2015) BMT Oceanica (2014a) Coastal Zone Management et al. (2013) Department of Transport (2009) Waterman (2006) Jones et al. (2005) Masselink and Pattiaratchi (2001)

Ref#	Marine and estuarine environmental values	Description of value	References
		• Sea level rise and increased storm events will eventually outweigh sediment supply, resulting in erosion in the Sound • Changes in dominant wave direction, within the sheltered waters for Owen Anchorage and Cockburn Sound can cause different coastal responses, such as southward sediment flux at James Point after the Garden Island Causeway was constructed. The offshore breakwaters off James Point are likely to be less effective in stabilising the shore with rising sea levels • The Garden Island Causeway and Woodman Point groyne have significantly impacted the longshore sediment transport from the west and south of Cockburn Sound respectively and other smaller artificial structures (i.e. jetties, breakwaters) influences local sediment transport and may cause shoreline instabilities in surrounding areas • Sediment pathways are unlikely to change significantly with rising sea levels, though the rates of sediment transport are likely to change	
11	*Historical reports and papers*		
		A series of consultancy reports, government reports, environmental assessments, theses and scientific papers documenting various aspects of the hydrological, marine ecological and coastal morphological research were generated for Cockburn Sound, from 1967 to 1995. Some of these reports are held by the Department of Defence (Defence Infrastructure Leeuwin Barracks) and Peter Waterman. *Research between 1969-1972 by Peter Waterman and Environmental Resources of Australia collected hydrological data between Cape Peron and Garden Island prior to the construction of the Garden Island causeway.* ***NB:** These reports, papers and theses are mentioned here and included in the Additional References list for completeness, but they were not available at the time the preliminary risk assessments were completed.*	

Table 5: Literature review of marine and estuarine social values for Kwinana

Ref#	Marine and estuarine environmental values	Description of value	References
1	Heritage		
1.1	Aboriginal	• Noongar people form one of the largest cultural groups in Australia and are the traditional owners of the south-west region of WA • There are currently no criteria to assess the maintenance of indigenous cultural and spiritual values within Cockburn Sound • Cockburn Sound and waters to the north are part of the mythological 'Indian Ocean' Aboriginal heritage site (S02169/3776) relating to the creation of islands, particularly Rottnest • Registered mythological sites within the Kwinana region include: Woodman Point (#15841), Rotary Park lining Mangles Bay (S02625/ 3471) • Registered historical sites within the Kwinana region include Robb Jetty Camp (S02207/ 3707) • Coogee and Woodman Point beaches have been important places for social interaction and recreation for local families and visitors. • Shoalwater Islands Marine Park has been used for fishing and hunting, and there are several sites within the park that are registered Aboriginal sites e.g. Mooribirdup Hunting and Fishing Areas (#22890), Mooribirdup Burial Site (#22889), Mersey Point Burial (#22891) • For listed 'Other Heritage Places', artefacts and scatter have been found at Garden Island 1 (S02097/ 3827), Garden Island 2 (S02098/3828), and the whole island itself is listed as an Artefacts/Scatter, Historical, Midden/Scatter, Mythological site (#18417) • Listed 'Other Heritage Places' for artefacts and scatter include Fisherman's Head, Point Peron (#20293) • Listed 'Other Heritage Places' include Carnac Island as a mythological site (#20863) • No specific monitoring programs are in place that focus on cultural and spiritual values of Cockburn Sound • Currently four native title claims for the Cockburn Sound area: Gnaala Karla Booja, Whadjuk People, Swan River People 2, Single Noongar Claim (Area 1)	BMT (2018) Cockburn Sound Management Council (2018) Department for Planning Lands and Heritage (2018) National Native Title Tribunal (2017) Stocker et al. (2016) Botting et al. (2009) Ecoscape (Australia) (2009) Fisher Research (2008) Department of Environment and Conservation (2006)
1.2	Maritime/historic	• C.Y. O'Connor's work on the Fremantle Port and pipeline to Kalgoorlie is commemorated by the 'Horse and Rider' sculpture off C.Y.O'Connor beach • Cockburn Sound and surrounds has 31 listed maritime heritage sites • There is a registered heritage and conservation site to the north east of Garden Island- Cockburn Sound Anti-Submarine Boom Remnant (#17789), which is a rare remnant from WWII • Shipwrecks and other maritime artefacts can act as artificial reefs for marine life; this can help to maintain or improve biodiversity, but also face pressures such as diving and snorkelling • Many jetties in Owen Anchorage and Cockburn Sound were built prior to 1987 before the Inner Fremantle Port was established • Ship building and repairing has occurred in Cockburn Sound since 1829, and a large-scale industry was established in Jervoise Bay in the 1980's which has grown into the Australian Maritime Complex; the largest marine industry in Australia	BMT (2018) Western Australian Museum (2018) Botting et al. (2009) Ecoscape (Australia) (2009) Heritage Council (2018)
2	Public health		
2.1	High quality source water for desalination	• PSDP has been producing drinking water since Nov 2006 and produces 18% of water supply requirements • Some minor exceedances of guidelines for intake water • Temperature, pH, dissolved oxygen and hydrocarbons are continuously monitored in real time near the intake pipe • Bacteria (*E. coli*), suspended solids, boron and bromide are sampled for on a regular basis	BMT (2018) Cockburn Sound Management Council (2018) Water Corporation (2018) Environmental Protection Authority (2017)
2.2	Recreational water quality	• Swimming and water sports in Cockburn Sound has been considered safe since 2009 • Swimming is considered safe and of 'good' grade for most beaches in Cockburn Sound; Jervoise Bay Beach, Naval Base, Kwinana Beach and North Hymus considered "good/fair"; Educational Dept. camp considered 'fair' • Potential faecal contaminant sources are few • Bacteria levels are safe for swimming most of the time • Water cleanliness has been achieved through improvements to storm water drainage and alternate outfalls for industrial discharge	Cockburn Sound Management Council (2018) Department of Health (2018)

Ref#	Marine and estuarine environmental values	Description of value	References
2.3	Seafood quality	• Shellfish from approved and conditionally approved harvesters are considered safe for human consumption • Quality assurance monitoring is not performed for wild shellfish or fish	Cockburn Sound Management Council (2018) Department of Health (2016) Department of Health (2010)
3	Social and community		
3.1	Recreational fishing	• Garden Island causeway provides protected conditions for fishing • Hatchery-reared juvenile pink snapper were released in to Cockburn Sound to benefit stocks and fishing after the 2015 fish kill; funding came from Recfishwest and crowd-sourcing • Shore based fishing is often focused around jetties and northern Cockburn Sound • Boast based fishing occurs across Cockburn Sound but is more concentrated in Mangles Bay, Cape Peron and in the northern entrance waters • 50% of the total finfish catch (excluding baitfish) and 60% of the blue swimmer crab catch is taken by recreational fishers • Most of the recreational crab catch occurs around Mangles Bay, Southern Flats, Woodman Point and other shallow margins • Mangles Bay Fishing Club has its own boat ramp and jetty facilities and is a popular club with a waiting list for membership • Gloomy octopus considered a highly productive and adequate fishery, and rated as low risk to climate change • Seasonal bursts of western king prawns occur in Cockburn Sound but not a target for commercial fishing. No research has been conducted into Western King Prawn biological stock structure in Western Australia, and status in those states is therefore reported at the management unit level. Was proposed that recruitment of prawns into Cockburn Sound comes from offshore stocks that spawn in the warmer waters of the Leeuwin Current • Australian herring is an indicator species for nearshore finfish resources. WA herring stock is considered under pressure in the West Coast Bioregion and is recovering. Spawning occurs during late May and early June in the south west. Females spawn more than once in a breeding season. The distribution of juveniles and adult spawning stocks are believed to be influenced by the strength of Leeuwin Current. Considered resilient to climate change given their wide range of habitat use, wide latitudinal range and a variable opportunistic diet • Tailor are predominantly a recreational fishery in the West Coast Bioregion. Considered adequate (breeding stocks are adequate or recovering). A single stock occurs between Onslow and Esperance. Recruitment is linked to environmental factors	BMT (2018) Cockburn Sound Management Council (2018) Crisafulli et al. (2018) Gaughan and Santoro (2018) Wise and Molony (2018) Partridge et al. (2017) Smith et al. (2013b); Smith et al. (2013c) Sumner and Lai (2012) Botting et al. (2009) Johnston et al 2008 Johnston et al. (2008) Fletcher and Santoro (2007) Cockburn Sound Management Council (2003) D. A. Lord & Associates (2002) Potter et al. (1991) Penn (1980) Penn (1976) Penn (1975)
3.2	Recreational swimming	• A study of beach use of Rockingham and Challenger beaches in 2005 found 35-42% of visitation was for swimming, and 16-18% of visitation to those specific beaches were because of the swimming conditions • Most popular swimming beaches include West Beach at Woodman Point, Kwinana Beach, Rockingham Beach and Palm Beach	BMT (2018) Eliot et al. (2005) Q & A Communications (2005b) Blackweir & Beckley (2004)
3.3	Recreational water sports	• Sports include: water skiing, kayaking, parasailing, windsurfing and kitesurfing • Typically concentrated around Mangles Bay, Palm Beach, Point Peron and Woodman Point (Q & A Communications, 2005d), or to the north around Woodman Point (GHD, 2009b)	GHD (2012) GHD (2009b) Q & A Communications (2005a)
3.4	Recreational boating access	• High concentration of boating in Mangles Bay and southern areas compared to the rest of Cockburn Sound; boat launching and mooring facilities are located here • Estimated increase in recreational boats of 77% between 2006- 2025, which means increased pressures associated with usage of available moorings and boat ramps • Garden Island causeway provides protection for Cape Peron Boat Ramp and moorings • Recreational boats can land and picnic on northern beaches of Garden Island, and can use mooring areas to stay overnight on the boat only • Public boat launching facilities in Cockburn Sound include Woodman Point, the Sutton Road boat ramp at Challenger Beach, Kwinana Beach, Palm Beach and Cape Peron; Woodman Point and Cape Peron have highest usage	BMT (2018) Botting et al. (2009) Department for Planning and Infrastructure (2009) Cockburn Sound Management Council (2003) D. A. Lord & Associates (2002)

Ref#	Marine and estuarine environmental values	Description of value	References
3.5	Marina facilities	• The Woodman Point Recreational Boating Precinct has eight boat ramps, jetties and a floating pontoon • Port Coogee has pens, fuelling jetty and pontoons • Mangles Bay Marina was proposed and rejected in 2018 due to public opposition	Western Australian Planning Commission (2018) Department of Transport (2017c)
3.6	Educational and scientific values	• Illegal feeding of dolphins in Cockburn Sound has resulted in differences in behaviour than observed by researchers in other locations • Visitors to sea lion haul out locations, i.e. Carnac Island, supported the idea of more educational information as well as enforcement by rangers; there was a high expectation to view sea lions on the island	Christiansen et al. (2016) Orsini and Newsome (2005)
3.7	Landscape and visual amenity	• Grey sands at Owen Anchorage are a result of natural processes and not contamination • Palm Beach, Mangles Bay and Kwinana beach have undergone beach nourishment to manage shoreline erosion • Visual amenity of the waters of Cockburn Sound are assessed every year during summer, and include an assessment of: nuisance organisms, dead animals, water clarity, water colour, natural water reflectance, surface films of petrochemicals, marine debris, odour and fish tainting • 2015 fish kill incident was concerning for the public, but fish tainting information is not routinely measured during monitoring programs • Looking out from Cockburn Sound, views are expansive and visual elements include the ocean horizon line and Garden Island; considered to have very high scenic quality	BMT (2018) GHD (2012) Oceanica Consulting and The University of Western Australia (2011) GHD (2009a)
4	Business, industry and commercial		
4.1	Tourism (including ferries and cruise ships)	• Shoalwater Islands Marine Park is important for commercial tour operators including diving, boat tours, wildlife and nature observing • Rockingham Wild Encounters offers swim with dolphin packages that depart from the Rockingham foreshore • Other tourist activities occurring within and around Cockburn Sound include: Penguin Island/ferry/wildlife cruise, glass bottom boats, adventure cruises, sea kayak tours, stand up paddle boarding, kite boarding, diving, jet skiing tours	Department of Environment and Conservation (2006)
4.2	Commercial fisheries	• Six managed fisheries operate in Cockburn Sound: CS line and pot, CS fish net, CS crab, CS mussel, West Coast beach bait and West Coast purse seine • South West trawl managed fishery for prawns considered sustainable, but not commercially fished in CS • There has been a decline in commercial fishing licenses for Cockburn Sound since 1990 • Most commercial fishing catches have decreased in Cockburn Sound likely due to environmental conditions, rules and restrictions, supply and demand, and gear and effort changes • Australian herring is an indicator species for nearshore finfish resources. WA herring stock is considered under pressure in the West Coast Bioregion and is recovering. Herring are fished in Cockburn Sound and catch rates have continued to increase since 2012/13. This increase is likely to be driven by external market influences and decreased opportunity to target garfish. Overall, the time series of catch rates do not suggest evidence of any substantial change in the herring abundance over the past three decades. Australian herring comprise a single breeding stock across southern Australia, which spawns in Western Australia; strong evidence that Australian herring migrate westwards from South Australia to south-western Australia during the summer of the third year of life. All life cycles are found in south-west Australia. Spawning occurs during late May and early June in the south west. Females spawn more than once in a breeding season. The distribution of juveniles and adult spawning stocks are believed to be influenced by the strength of Leeuwin Current. Herring considered resilient to climate change given their wide range of habitat use, wide latitudinal range and a variable opportunistic diet	BMT (2018) Wise and Molony (2018) Fletcher et al. (2017) Fletcher and Santoro (2007) Caputi et al. (2015) Smith and Brown (2014) Smith et al. (2013b) Fletcher and Santoro (2011) Botting et al. (2009) Fairclough et al. (2000a) Fairclough et al. (2000b)
4.3	Aquaculture	• Mussel aquaculture in Western Australia began in Cockburn Sound in 1988. Currently three lease areas for mussel aquaculture: north Garden Island (not active), Kwinana Grain Jetty and Southern Flats • Sheltered conditions of Cockburn Sound are ideal and Southern Flats is the main mussel farming area • Mussel production has decreased and is attributed to decreased nutrient levels, warmer water, reduced recruitment and predation. It is estimated that snapper consumed between 120-140 tonnes of mussels during 2.5 weeks in 2016. Mussel production has decreased to 200t in recent years, from 700t in early 2000s • Increased development will mean increased resource sharing within the sheltered waters of Cockburn Sound, and likely increased pressures on aquaculture operations. • A closed zone for mussel harvesting was established around the outflow of the SDOOL (4km off Point Peron) due to elevated bacteria levels, but the wastewater outflow is not considered to pose a risk to Cockburn Sound • Mussels feed on phytoplankton readily available in the Sound and no other food is added • Genetics of the mussels in Cockburn Sound were found to have a mixture of introduced and native haplotypes, so any future translocation of spat from the east coast (if needed) is unlikely to have impacts on the native WA population	BMT (2018) Cockburn Sound Management Council (2018) Gaughan and Santoro (2018) Dias et al. (2014) Botting et al. (2009) Lawrence and How (2007)

Ref#	Marine and estuarine environmental values	Description of value	References
		• White sea squirts have invaded the WA coast and have caused problems for mussel farms in Cockburn Sound	
4.4	Suitable quality water for industrial use	• The guidelines in place for measuring water quality for the Perth Seawater Desalination Plant are considered suitable for other industrial water needs • The Kwinana Water Reclamation Plant accesses secondary treated effluent from the SDOOL and processes it further to provide high quality water to industry in place of scheme water • Any impacts to hydrology and flushing times may influence the suitability of water for industrial use	BMT (2018) Botting et al. (2009) Oceanica Consulting and M. P. Rogers & Associates (2006)
4.5	Assimilation of wastewater	• Five industrial point sources of nutrients enter Cockburn Sound (Western Power, BP Refinery, Tiwest Joint Venture, Wesfarmers CSBP, Mintech Chemical Industries (Millennium Chemicals)) (uncertain which point sources are still current), and two emergency outfalls (Water Corporation) Discharge has been considerably lessened in recent decades due to environmental regulation. • Wastewater effluent tends to form a buoyant and nutrient rich plume • Sites along the Perth coastline that are influenced by wastewater effluent discharges (SDOOL, Whitfords Lagoon) showed relatively higher abundance of diatoms • The CS phytoplankton community likely reflects that of a semi-enclosed marine embayment compared to offshore of Garden Island where the community is likely influenced by phytoplankton transported by currents from the broader coastal region. However, during winter (2012) the dominance of coastal chain forming diatoms in CS (such as *Leptocylindrus*) may be due to pulses of nutrient input and turbulence creating favourable conditions for growth	Machado (2013) Thompson and Waite (2003) D.A. Lord & Associates and PPK Environment and Infrastructure (2001)

2.3 Bunbury

2.3.1 Environmental values

The full suite of literature reviewed for marine and estuarine *environmental values* for Bunbury is given in Table 6. Most of the studies on communities and species diversity have occurred in the Leschenault Estuary and some parts of Koombana Bay, and invasive species has been assessed as a risk for the region. Water quality at some localised areas (i.e. inner and outer harbour) is an issue, and turbidity is high in Koombana Bay due to outflow of estuarine waters via The Cut and the presence of a nepheloid (sediment) layer during winter and spring. As a result, benthic habitats are limited to soft sediments and some small patches of non-meadow forming seagrass species but do occur in extensive meadows just outside of Koombana Bay. Bottlenose dolphins have been intensively studied within Koombana Bay and surrounds with a particular focus on population dynamics and foraging. Koombana Bay and Leschenault Inlet are regionally significant spawning and nursery areas for whitebait and King George whiting, respectively.

Additional environmental values identified for Bunbury include:

- Significant benthic communities and habitats: mangroves
    - Mangroves are occurring at their most southern limits and occur in Leschenault Inlet and some parts of Leschenault Estuary
    - This value was initially included under terrestrial environmental values
- Significant benthic communities and habitats: other
    - Less dominant benthic habitats included rocky reefs, sponge gardens, mud flats and artificial reefs
- Listed and significant fauna: Iconic fauna: Little penguins
    - Koombana Bay is noted as a core foraging ground for penguins originating from Penguin Island
- Regionally significant migratory pathways
    - Species migrate in and out of Leschenault Estuary to complete their life cycles, and entry via The Cut is adjacent to Koombana Bay
    - Blue swimmer crabs use the Leschenault Estuary to spawn
- Coastal processes
    - Bunbury is considered one of the most vulnerable locations to erosions in the south-west

2.3.2 Social values

The full suite of literature reviewed for marine and estuarine *social values* for Bunbury is given in Table 7. The Leschenault Estuary and Preston River are significant aboriginal mythological sites, and Koombana Bay and Leschenault Inlet are important contemporary sites for fishing and recreation. Koombana Bay has remnants of 13 ship wrecks as well as several other maritime and historically listed sites. Recreational fishing is one of the most significant social and community values in the region, and occurs throughout Koombana Bay, Leschenault Inlet and Leschenault Estuary. Leschenault Inlet is also popular for other recreational uses such as swimming, boating and landscape appeal. Tourism is important for Bunbury with diving and dolphin encounters being some popular options, and the most recent tourism development strategy for Bunbury includes developing a new marina that can facilitate cruise ships. Commercial fishing occurs around Koombana Bay, but some restrictions are in place within Koombana Bay itself.

Additional social values identified for Bunbury include:

- Social and community: water sports
    - Water sports are popular in the Leschenault Inlet and other locations with several clubs operating on the foreshores of the Leschenault Inlet

Table 6: Literature review of marine and estuarine environmental values for Bunbury.

Ref#	Marine and estuarine environmental values	Description of value	References
1	Integral functioning ecosystem		
		• The Leschenault Inlet has fundamentally changed from an estuarine system to a marine embayment, due to separation from the main estuary and the lack of freshwater; this has in turn resulted in more marine flora and fauna assemblages • After The Cut was made, the Leschenault Estuary changed from tide dominated to wave dominated, from moderate sediment trapping efficiency to high, from high to low turbidity, from well mixed to salt/wedge partially mixed and now has a higher risk of habitat loss due to sedimentation • Koombana Bay is predominately characterised by a bare sand with low biotic cover which supports microalgae species living on the surface or within sediments. Lack of primary producer habitat is attributed to elevated turbidity and frequent storm events depositing organic material during winter and spring • The Koombana Bay marine environment is influenced by river flows pushing turbid waters from the Estuary through 'The Cut' during winter	GHD (2017a) PLACE Laboratory (2013) Wave Solutions (2012) Department of Water (2007) McKenna (2004)
2	Sheltered ecological community		
		• Koombana Bay is partially protected by a breakwater that extends seaward from Point Casuarina. Historically, the embayment was formed by a basalt rock outcrop off Point Casurina and submerged reef extending in a north-east direction • Koombana Bay is protected from prevailing offshore SW and W waves	GHD (2017a) RPS (2015)
3	Biological diversity		
3.1	Fish assemblages	• Using three fishing gear methods between 2008-2010 in the Bunbury region (Koombana Bay, Leschenault Estuary and coastal waters), abundance of fish was double in summer compared to winter, and abundance was greatest in the estuary and Koombana Bay compared to open coast. 62 species were documented with sandy sprat and weeping toadfish being the most abundant species • Underwater noise from dredging may cause avoidance behaviour by fishes and elasmobranchs; sudden impulses such as from blasting have been known to burst swim bladders and cause fish kills • Leschenault Estuary is commonly fished recreationally for mullet, silver bream, tailor, sea garfish, striped perch, roach, whitebait and anchovy, as well as king prawns • Flathead pygmy stargazer (Lesueurina platycephala), yelloweye mullet (Aldrichetta forsteri), southern school whiting (Sillago bassensis) and the prickly toad fish (Contusus brevicaudas) account for over 70% of the fish species found in the shallows of Koombana Bay • Twenty-seven species of protected or listed fish may occur within or adjacent to the port and Koombana Bay; including three threatened shark species and a Priority 2 listed sea dragon • Some estuarine fishes such as Western Hardyhead, the Swan River Goby and the South-western Goby, were found upstream in the Preston River in a 2006 survey	GHD (2017a) McCluskey et al. (2016) Hugues-dit-Ciles et al. (2012) Morgan and Beatty (2006) Potter et al. (2000b) Potter et al. (1997)
3.2	Demersal and benthic communities	• There was a measurable reduction in molluscs, polychaetes worms and small benthic and epibenthic crustaceans between 1982-1997 in the Leschenault Estuary; no recent studies have been undertaken • Faunal diversity and abundance during a snapshot survey of the Leschenault Inlet in May 2005 was low in comparison with the Estuary • Small benthic crustacean populations in the Leschenault Estuary typically showed a peak in abundance during summer; abundance and diversity is linked to environmental conditions, and populations have showed a decline in abundance and change in species composition as the estuary environment has changed	Department of Water (2007) Semeniuk (2000) Wurm and Semeniuk (2000)

Ref#	Marine and estuarine environmental values	Description of value	References
3.3	Invasive species	• Risk of receiving an invasive species is high, though inoculation risk is considered low, as the majority of vessels were low risk with short durations 83% of potential introduced marine pests are compatible with the marine environment of Bunbury Port • Dredge vessels stay longer but are less frequent than bulk cargo vessels • Most vessels come from international locations but are considered low risk and have a short duration • Vessels from Japan pose the greatest risk, and Japan has 4 of the most detrimental introduced species (out of 100) • Vessels from Adelaide Port pose the greatest domestic risk due to frequency of visits and compatibility of pests to the marine environment • Currently 24 introduced species in Bunbury Port, including hydroids, molluscs, polychaetes, ascidians and fish • Regular surveys were undertaken in the outer harbour, Koombana Bay and inner harbour from 1995-2012 • Bunbury Port Authority is required to survey dredge spoil ground to make sure invasive pests have not become established; the pest dinoflagellate, *Alexandrium cf. catenella*, was found at the spoil ground in 2014 but requires a more positive identification • Invasive species are monitored and managed by DPIRD under the Fisheries Act	GHD (2017a) MAFRL (2015a) Bridgwood and McDonald (2014) Huisman et al. (2008) McDonald (2008)
4	High level of water quality		
4.1	Nutrients	• Koombana Bay has seasonally variable nutrient concentrations, where levels peak in winter due to stormwater from residential catchments draining into the Leschenault Estuary • The shipping channel into the harbour is a trap for decaying organic matter such as seagrass and macroalgae, and as a result, high nutrient levels are measured in the inner and outer harbour • Nitrogen and phosphorus have been recorded above acceptable load targets for LE and coastline; most effective management practice to reduce nutrient loads is fertiliser management in the catchment • Monitoring of the Leschenault Inlet commenced in 1995 and total nitrogen, total phosphorus, nitrate, nitrite, ammonium and filtered reactive phosphorus levels are considered low; nutrients are likely dissipated through high tidal exchange	RPS (2014) PLACE Laboratory (2013) Hugues-dit-Ciles et al. (2012) Kelsey (2010) Department of Water (2007)
4.2	Chlorophyll a/ phytoplankton	• Chlorophyll a levels have exceeded the guidelines at Inner Harbour surface waters and dredge material placement ground bottom waters in 2002, and Inner and Outer Harbour in 2004 • No phytoplankton blooms have been recorded in the Leschenault Inlet since monitoring commenced in 1995 • Chlorophyll and phytoplankton levels are below guidelines and not of concern • Marine and estuarine diatoms can dominant the Leschenault Estuary for most of the year	Wave Solutions (2012e) Department of Water (2007) Hosja and Deeley (2000)
4.3	Light attenuation/turbidity	• In the Leschenault Inlet, light attenuation is considered relatively consistent and below guidelines • Modelling of dredge suspended sediments from the extension of the Inner Harbour shows sediments entering Koombana Bay, Leschenault Inlet and Estuary and nearshore areas up to 8km north of The Cut; spread would be greater during winter than summer. This modelling involves removal of existing soil and sediments to achieve a depth of ~ 12.6 m, and does not include dredging to 16 m or removal of basalt rock • If Preston River mouth is realigned, then turbidity is expected to directly impact macroalgae, though recovery of macroalgae is likely • Turbidity levels are variable across Koombana Bay, and influenced by tidal exchange, river inflows, wind, wave height, re-suspension of bottom sediments and the distinct nepheloid layer (sediment layer) that is persistent close to the seafloor during winter and spring • Outflow of water from the Leschenault Estuary, particularly during winter, causes elevated turbidity across the whole of Koombana Bay as well as up to 10km offshore and north and south- this is most likely why seagrass does not grow extensively in Koombana Bay, and why meadows occur so far from the coast • In the Leschenault Inlet, turbidity is considered relatively consistent and below concerning guidelines, though turbid waters can enter from Koombana Bay during winter	GHD (2017a) RPS (2015) Wave Solutions (2012e) Department of Water (2007) Babcock et al. (2006)
4.4	Dissolved oxygen	• Koombana Bay mean dissolved oxygen levels measured in 2011 ranged from 7.1 to 8.3 mg/L • In the Leschenault Inlet, dissolved oxygen is considered relatively consistent and below concerning guidelines • Dissolved oxygen in the Leschenault Estuary are generally good with concentrations usually over 5mg/L	Wave Solutions (2012e) Department of Water (2007)
4.5	Temperature	• In the Leschenault Inlet, temperature is considered relatively consistent and below concerning guidelines	Department of Water (2007)

Ref#	Marine and estuarine environmental values	Description of value	References
4.6	Salinity	• Koombana Bay can experience a slightly less saline surface water layer due to fresh water input from Collie and Preston River into the Leschenault Estuary and, in turn, into the Bay via The Cut. This would be most obvious during winter when river inputs are greatest • Under a changing climate, the Leschenault Estuary is at risk of increased salinity due to decreased rainfall • In the Leschenault Inlet, salinity is considered relatively consistent and below concerning guidelines	PLACE Laboratory (2013) Wave Solutions (2012e) Department of Water (2007) Potter and Lestang, 2000
4.7	pH	• There was little variation (<0.1 pH units) in pH, measured in 2011, for Koombana Bay or proposed offshore disposal locations; averaged 8.1 and 8.2 pH units respectively • In the Leschenault Inlet, pH is considered relatively consistent and below concerning guidelines	Wave Solutions (2012e) Department of Water (2007)
4.8	Contaminants/ toxicants	• It is considered unlikely that port operations at Berth 8 have impacted the water quality and contamination of Preston River or Vittoria Bay; a waste water capture system was constructed in 2009 and is believed to be effectively capturing contaminated sediments. Prior to 2009, water was discharged directly into the Inner Harbour via an uncontrolled partly open system. Contaminants such as arsenic, cobalt, copper and zinc detected in the waste water capture system are possibly sourced from Berth 8 operations • Aluminium and selenium levels in seawater typically exceed guidelines at all testing sites in and around Koombana Bay (but the trigger value is of low reliability) • Mussel tissue concentrations of copper, selenium and zinc have, at all sites, exceed the food guideline values at some point in time. However, this is a human consumption risk and does not indicate an ecological risk. Arsenic is also present • Contaminant status of the port remained relatively stable until Nov 2009 when Newmont Boddington Gold started to export copper, which may impact this stability	GHD (2016) MAFRL (2016, 2015b, 2014b, 2013) 360 Environmental (2013) SKM (2011a); SKM (2011b) SKM (2010a); SKM (2010b) SKM (2009b) SKM (2008)
4.9	Groundwater	• Groundwater flow into Koombana Bay can increase nutrient loadings • Dewatering close to the coast will likely result in saline waters migrating inland, and may expose acid sulphate soils	GHD (2017a) RPS (2014)
4.10	Hydrology	• Tides in the Bunbury area are micro-tidal and generally has a single tidal cycle on most days • During summer, a north easterly coastal current flows across the northern edge of Koombana Bay and then flows north along the coast without entering the Bay • Movement of surface waters is usually north-east in Koombana Bay, with very limited south-west flow apart from a southward surface current over the shipping channel in summer • For deeper waters during summer, there is movement towards the inner harbour • Deep channel flushing of the inner harbour occurs with upwelled channel waters reach the surface and flow north with prevailing southerly winds • Flushing times for Koombana Bay are estimated to be 4-6 days and for the inner harbour 40-90 days • Modelled results for the realignment of the Preston River mouth for port expansion found that the impact of the realignment of the Preston River on hydrodynamic conditions at The Cut will most likely be negligible	GHD (2017a) Worley Parsons Consulting (2015) Wave Solutions (2012e)
5	High level of sediment quality		
5.1	Contaminants	• Sediment quality in Koombana Bay is unknown, because no sediment studies have been referenced, and studies are usually focused on port operational areas and dredge spoil grounds Leschenault Peninsula may have contaminated sediments due to a historical pipeline carry waste water through the region • Arsenic is naturally occurring in coastal waters and sediment transport into the Inner Harbour has resulted in Arsenic detection in the Harbour • Copper and zinc have shown signs of enrichment in the vicinity of Berth 8 since copper concentrate started to be exported and may be indicative of a spill. However, all metals/metalloids detected are not considered to be bioavailable and contact with seawater is expected to occur as a pulse with no significant ecotoxicological effects • TBT at all sites in and around the Port and Koombana Bay were below detection in 2011 but have been measured above screening and maximum levels at some Inner Harbour sites in 2010 • Preston River has had elevated levels of copper and mercury in the past (2014), but overall, the wastewater capture system is considered effective in capturing and containing contaminants to mitigate impacts on Preston River and Vittoria Bay • Aluminium levels in sediments have been recorded at 19 times higher in the Inner Harbour compared with reference sites and most likely due to alumina dust from port operations • Three registered contamination sites in Bunbury Port region: Old Bunbury Power Station; Inner Harbour sediments below the water line; and Caustic soda tanks behind Berth 4. The Inner Harbour sediments were reported as a contaminated site in 2007 due to elevated TBT levels in sediment	GHD (2017a) Western Australian Planning Commission (2017) GHD (2016) MAFRL (2016) 360 Environmental (2014) PLACE Laboratory (2013) Newmont Asia Pacific (2012b) Simpson et al. (2011) SKM (2011a); SKM (2011b) SKM (2010a); SKM (2010b) SKM (2009b)

Ref#	Marine and estuarine environmental values	Description of value	References
		• The sediments of the Leschenault Inlet contain heavy metals, which had likely accumulated from storm water discharge into the Inlet; mud substrates were found to contain the highest amounts of contaminants/pollutants and it appears to be sediment type rather than distance from drain outfalls that determines contaminant concentrations • The mangrove areas in the Leschenault Inlet are considered a contaminated site due to excessive levels of radiation from deposition of mineral sands tailings; considered suitable for recreational purposes, but may be problematic with more intensive land use	SKM (2008) BGM Management Company (2009) Department of Water (2007)
5.2	Nutrients	• Sediments in the shipping channel contain up to 30% organic matter and high nutrient levels	SKM (2009a) SKM (2001)
5.3	Acid sulphate soils	• Oxidation of acid sulphate soils (naturally occurring under water logged conditions) can cause surface and groundwater to become acidic, which may in turn mobilise heavy metals. Realignment of the Preston River has potential to expose acid sulphate soils • Dewatering close to the coast will likely result in saline waters migrating inland, and may expose acid sulphate soils • Leschenault Inlet likely to have acid sulphate soils occurring >2m below surface • Leschenault Estuary system is listed as an area of concern in WA for acid sulphate soils	GHD (2017a) Kilminster et al. (2011) Parsons Brinckerhoff (2008) Department of Environment (2006)*
6	Significant benthic communities and habitats		
6.1	Seagrass	• No significant seagrass meadows have been observed in Koombana Bay, but some low cover of non-meadow forming seagrass has been documented inshore waters of Koombana Bay • Several seagrass species (*Posidonia* spp., *Amphibolis* spp., *Thalassodendron pachyrhizum* and *Halophila ovalis*) occur outside of the Port and Koombana Bay region, in depths of 9m or deeper. • *Halophila ovalis* is a significant primary producer species in the Leschenault Estuary • Sedimentation in the Leschenault Estuary has caused seagrass loss in the past and although sedimentation is a natural process here, it can be accelerated due to surrounding land changes • No seagrass has been identified in the Leschenault Inlet	RPS (2015) Wave Solutions (2012) Parsons Brinckerhoff (2012) Wave Solutions (2011) Oceanica Consulting (2008) Department of Water (2007) Department of Environment (2004) Hillman et al. (2000)
6.2	Mangroves	• Relictual white mangroves are found throughout the Leschenault Inlet and in some parts of the Leschenault Estuary. The mangroves occurring in Bunbury are at their southern limit, thus environmental effects on these mangroves may be amplified or exacerbated. The mangrove community in the Leschenault Inlet is classified as a Priority 1 Priority Ecological Community for Western Australia • Increased salinity since the excavation of The Cut and blocking of Preston River delta may be the reason for the slow expansion of Avicennia populations, and the slow general increase in height • Mangroves are turbidity tolerant so would likely be unaffected by increases in suspended sediments	GHD (2017a) Department of Water (2007) Semeniuk et al. (2000b)
6.3	Rocky reefs	• One patch of reef (~15ha) has been recorded on the north-eastern margin of Koombana Bay. The dominant biota on the reef was foliose algae with some canopy algae • The reef is considered an extension of the inshore Geographe Bay benthic habitat and is not considered as unique habitat in Koombana Bay	GHD (2017a) RPS (2015) Wave Solutions (2012)
6.4	Soft sediment	• Koombana Bay is dominated by sand, and has relatively low biotic cover (<2%) of turf and foliose algae and supports microalgae growth	GHD (2017a) Wave Solutions (2012)
6.5	Sponge gardens	• Sponge gardens have not been observed in Koombana Bay, but do occur on reef areas just north of the Bay and The Cut. The occurrence of sponges here is likely due to high current speeds and nutrient rich waters flowing out from the Estuary	Wave Solutions (2012)
6.6	Mudflats	• 100+ species of aquatic invertebrates, birds and fish have been recorded in the mudflats, tidal channels, mangroves and samphire saltmarsh of the Leschenault Inlet	PLACE Laboratory (2013)

Ref#	Marine and estuarine environmental values	Description of value	References
6.7	Artificial reefs	• Artificial reef installed in 17 m of water less than 5km west of Koombana Bay in 2013 • Aim of artificial reef is to enhance recreational fishing opportunities for pink snapper, silver (skipjack) trevally and Samson fish; all three target species have been found regularly at the reef • Since establishment, the number of species observed on the reefs has grown; 52 species of fish recorded during May 2015 survey, and ~130 species occurring in the natural areas around the reef • Abundance on the reef has been increasing slowly, though abundance and diversity increases have been less than that observed for the artificial reef deployed off Dunsborough at the same time	Fletcher and Santoro (2015)
7	Listed and significant fauna		
7.1	Fairy Tern (*Sternula nereis*)	• Listed as vulnerable under the EPBC Act • Migratory and nest colonially so they may not nest in the area when conditions, prey abundance etc. is not suitable. This may lead them to nest in different locations around the Leschenault Estuary from year to year • A successful breeding colony of 70 pairs was observed at the Outer Harbour (McKinnon Pt) in December 2015 and 2017, which nest from November onwards. This is believed to be the main nesting site in the area as the beach is protected from beach users and 4wd. No nesting was detected here in 2016, though terns were observed flying around the outer harbour area • In the past, 200 pairs were observed on Barr Island (2007/08) and also occurred on the Leschenault Peninsula in Dec/Jan. These areas may be used as alternative or second breeding attempt sites as these two sites are rarely successful due to tides/storms washing away nests, 4wd access and disturbance from predators and public. • Some breeding attempts were made in dunes north of The Cut but most likely failed due to human disturbance • Rising sea and estuary water levels, as well as erosion will significantly influence populations	Taylor pers. comm. 2018 Dunlop (2015) Dunlop (n.d.)
7.2	Little penguins (*Eudyptula minor*)	• Protected under the Wildlife Conservation Act of WA • Koombana Bay identified as a core foraging area, along with Cockburn Sound, west of Garden Island, Lake Clifton-Binningup, and Geographe Bay. • Data on little penguins was obtained over an eight year study between 2008-2009, 2013-2018 from tags attached to penguins during both incubation and chick rearing from Penguin Island. The home range for tagged penguins extended across ~230 km from Two Rocks/Yanchep to Cape Clairault near Yallingup • Bunbury/ Koombana Bay is a consistently important area for foraging when prey availability is limited closer to the Penguin Island colony • Every year of tagging data shows that penguins use the Bunbury/Geographe Bay area for foraging • Following moult, penguins are likely heading south for 2-3 months	Cannell (2017) Cannell pers.comm.(2019)
7.3	Bottlenose dolphins (*Tursiops aduncus*)	• Protected under the EPBC Act • Koombana Bay and surround have a resident dolphin population of around ~260 individuals, but the population is forecast to decline, i.e. Bunbury was forecasted to have 38 (SE 0.6) dolphins after 100 years – an 83% decline (not including potential migrants) • In Bunbury, the peak breeding season is late summer/early autumn, and this is associated with an increase in dolphin abundance within the study area. Dolphins also have a high a probability of return into the area in relation to the breeding season. During the summer/autumn calving season, females used a hotpot on the lee-side of an artificial groyne, adjacent to Leschenault Estuary and Koombana Bay • During summer, both male and female dolphins were concentrated close to the coast, with a high use area in Koombana Bay; Adult females also increased their use of the Leschenault Estuary during cooler seasons, especially winter • Bunbury dolphins have limited gene flow with adjacent populations. Evidence shows that, historically, dolphins were dispersing out of Bunbury rather than into Bunbury. The population is at risk of decline if reproductive levels do not increase or if immigration does not occur. Other dolphin populations, such as off Perth, would also be at risk of decline if low reproductive rates of Bunbury dolphins resulted in no more dolphins dispersing out of Bunbury. • The Leschenault Estuary has a high abundance, biomass and quality of prey in comparison to open waters; high quality prey optimizes foraging and likely encourages small home ranges in Bunbury. The dolphin mother and calf pairs that remain in Koombana Bay and Leschenault Estuary year-round may be sustained by the higher quality prey in the winter months	Manlik et al. (2018) Sprogis et al. (2018) GHD (2017a) Manlik et al. (2016) McCluskey et al. (2016) Sprogis et al. (2016a) Sprogis et al. (2016b) Smith et al. (2016) Smith and Sprogis (2016) Sprogis (2015) Smith et al. (2013a) Smith (2012) SKM (2011) Coulthard (2006)

Ref#	Marine and estuarine environmental values	Description of value	References
		• Dolphins exhibit a specialised feeding behaviour on giant cuttlefish (*Sepia apama*) in the coastal waters of Bunbury, but little ecological information is known about the giant cuttlefish population here and if it is affected by brine water discharge from the desalination plant; females were mostly observed feeding on cuttlefish and they may supplement their diets with cuttlefish for gestation and lactation • There is evidence to show dolphin abundance in Bunbury is significantly influenced by ENSO events e.g. an El nino event occurred across winter 2009 which saw lower dolphin abundance (high temporary emigration rates) from coastal areas: e.g. Buffalo Beach, Koombana Bay, Leschenault Estuary, Back Beach. This was coupled with a negative anomaly in sea surface temperature and an above average rainfall which may have caused a shift in dolphin prey distribution • Based on a threat likelihood for Bunbury dolphins, food provisioning and tourism are listed as having a 'high' level of impact with a 'medium' level of probability, and entanglement in fishing gear is listed as having a 'medium' level of impact with a 'high' level of probability. Coastal development and loss of habitat is a 'high' probability of occurrence, but a 'low' impact • Using photo ID methods from 2007-2013, individual dolphins with smaller home ranges were most often sighted in Koombana Bay, Leschenault Estuary or riverine waters, whereas those individuals with larger home ranges were more often observed in open water habitat • Modelling predicts that marine mammals would have to be within 1 m of dredging operations to have temporary hearing loss • After previous dredging in the port area, marine mammals did not appear affected by the temporary increase in suspended sediments	
7.4	Migratory shorebirds and seabirds	• 22 listed migratory birds under international agreements have been recorded for Bunbury region, incl. Leschenault Estuary, and eight of these have conservation listings • Inner Harbour has low levels of waterbird use; three shorebird species were recorded during a survey of the Inner Harbour in 2008, including one migrator- Common Sandpiper • Preston River delta is considered a regionally significant shorebird site; 43% of *waterbirds* were recorded here in 2008 • Proposed truncation of Preston River into the Inner Harbour instead of realignment into the estuary would impact on the Preston River delta and would likely remove significant migratory wading bird habitat • 70 species (all birds) have been recorded in the Leschenault Inlet • Species protected under the EPBC Act that occur in Leschenault Estuary region: Eastern curlew (critically endangered), Curlew sandpiper (critically endangered), Great knot (critically endangered), red knot (endangered), greater sand plover (vulnerable) • Estimates of intertidal habitat loss due to sea level rise predictions show seven internationally important sites in south-west Australia at risk of 26% loss with 50cm rise to 97% loss with 300cm rise (doesn't specifically say Bunbury region). Allow room to move upshore in management plans • Leschenault Estuary not currently listed as a Nationally important wetland (considered nationally important if supports 0.1 per cent of the flyway population of a single species of migratory shorebird, or 2000 migratory shorebirds, or 15 migratory shorebird species); a survey done 1987/88 counted 6385 waterbirds comprising ~17 species listed under international agreements • Leschenault Estuary added to Annual Shorebirds 2020 count in 2016; the estuary is used year-round but greatest numbers occur in mid spring and summer • Bioaccumulation of chemicals and competition for food with invasive species are potential concerns • Bunbury region incl. LE have six listed migratory or protected seabirds under international agreements. One species, Flesh-footed Shearwater, is listed as Vulnerable in WA • Pacific Golden Plover: Documented from Leschenault Inlet. Peel Harvey Inlet and Princess Royal Harbour are considered most important sites in the south-west. Found in a diverse range of habitats • Shy albatross: May occur in the Bunbury region. Major threats to the shy albatross include incidental capture and mortality in commercial fishing gear	Birdife Australia (2018) Department of Environment and Energy (2018) Birdlife WA (2017) Department of the Environment and Energy (2017); GHD (2017a); GHD (2017c) Weller and Warren (2017) Department of the Environment and Energy (2016) Department of the Environment (2015) Hansen et al. (2016) Iwamura et al. (2013) Singor (2012) Wave Solutions (2012i) Bennelongia (2008a); Bennelongia (2008b) Raines et al. (2000)
7.5	Pouched Lamprey (*Geotria australis*)	• Priority 3 listed species under Wildlife Conservation Act of WA and poorly known listed species • Known to occur in the region • Part of its life cycle is spent at sea and part of it involves entering freshwater rivers and moving upstream during winter and spring to spawn • Modification or removal of the Preston River mouth in the Leschenault Estuary could impact in the lamprey's ability to migrate upstream • This anadromous species moves upstream by climbing rocks and other surfaces using their sucking mouths	Parks and Wildlife Service (2018) Fishes of Australia (2018) GHD (2017a); GHD (2017c)

Ref#	Marine and estuarine environmental values	Description of value	References
7.6	Carter's Freshwater Mussel (*Westralunio carteri*)	• Endemic to south-west Australia and is the only large freshwater mussel found here; listed as Threatened under the Wildlife Conservation Act of WA (1950) • Low tolerance of saline waters • Has been recorded in the Preston River, but recent studies (2015) found no evidence of live or dead mussels from the mouth of the river to further upstream	GHD (2017a) GHD (2015)
8	Regionally significant spawning / nursery area		
8.1	King George Whiting (*Sillaginodes punctatus*)	• Leschenault Inlet an important nursery for 0+ whiting • Present in relatively high numbers in the Inlet but not in adjacent marine waters like Koombana Bay • Comprises 20% of total whiting catch	Brown et al. (2013) Potter et al. (1996)
8.2	Whitebait (*Hyperlophus vittatus*)	• Most likely spawning in Koombana Bay and using Leschenault Estuary as a nursery • Relatively low catches recorded since 2009/10 • Reduced distribution and 2011 heatwave impacts suggest environmental limitations- reduced spawning success in winter of 2011 which resulted in low catches and catch rates • Rated as having a high risk to climate change • Classified as unsustainable (breeding stocks are not adequate or recovering) and inadequate (additional actions needed to confirm if breeding stocks are adequate or recovering) • Coastal currents influence spawning and recruitment behaviour- Leeuwin Current and Capes Current	Gaughan and Santoro (2018) Lenanton et al. (2009) Dr Fiona Valesini pers.comm.
9	Regionally significant migratory pathway		
9.1	Blue swimmer crab *(Portunus armatus)*	• Mandurah to Bunbury is a developing fishery- classified as sustainable • Bunbury Harbour crab deaths in 2016 exhibited shell disease (which is naturally occurring for crustaceans) and deaths may have resulted from a combination of stressors (i.e. water quality) making crabs more susceptible to the infection • Female crabs move out of Leschenault Estuary to spawn in Koombana Bay in spring/early summer • Recreational fishing still allowed, but no commercial fishing in the estuary • Leschenault Inlet is a popular crabbing spot and there has been public concern that the numbers have decreased over time; stocks can significantly fluctuate with a range of environmental influences • Over 80% of boat-based fishing effort is on blue swimmer crabs in the Leschenault Estuary	Gaughan and Santoro (2018) GHD (2017a) Bunbury Mail- Nathan Harrison pers comm (2016) PLACE Laboratory (2013) Malseed et al. (2000) Potter and De Lestang (2000)

Ref#	Marine and estuarine environmental values	Description of value	References
10	Leschenault Regional Park		
		• Macrophyte distribution in the Leschenault Estuary consists predominantly of seagrasses and a combination of green, brown, and red macroalgal species • Leschenault Estuary is predominantly wave driven • Estuaries that occur within the Leeuwin Naturaliste Bioregion, like the Leschenault Estuary, are considered high risk for nutrient run off and acid sulphate soils • Five rivers drain into the Leschenault Estuary, along with runoff from adjacent lands • A primary aim of the park is to protect native fringing vegetation • The estuary is showing signs of stress, such as excessive algal growth, anoxia, fish kills and odour in the northern region of the estuary • The park has high conservation and recreation values and includes some of the ecological linkages identified in the Greater Bunbury Region Ecological Linkage Plan • The estuary and rivers provide important scenic backdrops and waterways with views of the water are highly sought after • Impacts due to storms and coastal erosion from climate change are recognised as needing management within the park • Some of the common waders include: Pied oystercatcher (*Haematopus longirostris*), Grey plover (*Pluvialis squatarola*), Banded stilt (*Cladorhyncus leucocphalus*), White faced heron (*Egretta novaehollandiae*), Rufous night heron (*Nycticorax caledonicus*), Straw necked ibis (*Threskiornis spinicollis*), Yellow billed spoonbill (*Platalea flavipes*), Great Egret (*Egretta alba*) • Leschenault Estuary is thought to be globally significant in terms of the high richness of foraminifera species- 118 recorded so far; exceeds most other marine environments.	GHD (2017a) Fletcher and Santoro (2012) Hugues-dit-Ciles et al. (2012) Department of Water (2007) Hillman et al. (2000) Semeniuk et al. (2000a)
11	Coastal processes		
		• Coast between Bunbury and Mandurah is the most vulnerable to erosion in the south-west • Climate models find that the Leschenault Peninsula will offer protection from erosion until it is itself eroded in the year 2100. • There is a predicted increased flooding risk for the Leschenault Estuary • Koombana Beach is influenced by waves and varying water levels, and is under significant pressure from erosion, particularly the eastern section of the beach that's closest to the inner harbour; this has potential risks for port operations and the Dolphin Discovery Centre • Recovery of the beach after storm events is uneven, with accumulation of sediments occurring to the west of the beach • Koombana Yacht Club groyne is in extremely poor condition • Risk of inundation to the Leschenault Inlet with rising sea levels and flooding • More than 50% of accumulated sediment in Koombana Bay is fine silt and comes from the Leschenault Estuary via The Cut	Western Australian Planning Commission (2017) McCormack et al. (2014) PLACE Laboratory (2013) ACIL Tasman (2012) Department of Climate Change (2009) SKM (2001)

Table 7: Literature review of marine and estuarine social values for Bunbury.

Ref#	Marine and estuarine environmental values	Description of value	References
1	Heritage		
1.1	Aboriginal	• Registered mythological sites within Bunbury area (Koombana Bay) include the Collie River Waugul (incl. Leschenault Estuary) (#16713), Preston River (#19795). • Collie River Waugul also a registered Natural Area and Water Source site and Collie River Waugal 1 is listed as a "Other Heritage Place" (#36737) • The Leschenault area was home to the Wardandi people before European settlement. Leschenault Inlet and Koombana Bay are important contemporary areas for the Nyungar community to fish and recreate and there is concern over the effects of increased development	Department for Planning Lands and Heritage (2018) Western Australian Planning Commission (2017) Wooltorton (2013) Landcorp (2008)
1.2	Maritime/ historic	• Heritage listed: Bunbury Timber Jetty (outer harbour jetty) (#03402), Leschenault Homestead (#00344), Bunbury Shoreline (Koombana Bay) (#02500, #05655), Jetty Crane, Causeway (#03379), Dolphin Discovery Centre (#04259), Original Railway Route (#05494), Flood Gates Strom Surge Barrier (#5674), Military Camp (#5675; Point McCleod), Jetty Public Baths 1, 2, 3 (#06599, #06685, #06700), Breakwater (Casuarina Point; #06602) • Koombana Bay has remnants of 13 ship wrecks, 12 of which are in close proximity to the Leschenault Inlet	Heritage Council (2018) PLACE Laboratory (2013) Landcorp (2008)
2	Public health		
2.1	Recreational water quality	• Based on bacteria monitoring, beaches are considered safe for swimming most of the time	Department of Health (2018)
2.2	Seafood quality	• Mussel tissue concentrations of copper, selenium and zinc have, at all sites, exceeded the food guideline values at some point in time and is a human consumption risk	MAFRL (2016), MAFRL (2013); MAFRL (2014a); MAFRL (2015b)
3	Social and community		
3.1	Recreational fishing	• Leschenault Inlet is used for fishing and crabbing and Leschenault Estuary for crabbing and prawning; over 80% of boat-based fishing effort is on blue swimmer crabs • Other fishing related activities in the Leschenault Estuary can increase localised erosion and degradation of the shoreline, such as: digging for worms (polychaetes), trampling shoreline vegetation, disposing of bait and catch remains, and general litter • Yellowfin whiting comprises 75% of total whiting catch • Australian herring are fished in Koombana Bay, and through a combination of environmental factors and fishing pressure, the WA herring stock in the West Coast Bioregion is under pressure and needs to improve. Catch rates seem to be increasing but are still relatively low in comparison to past rates • Fishing for rock lobster occurs outside of Koombana Bay, generally to the north rather than directly inside (depending on where boundary of KB is cut off)	DPIRD Bunbury Office (2019) Wise and Molony (2018) Brown et al. (2013) PLACE Laboratory (2013) Smith et al. (2013b) Beckwith Environmental Planning (2009) McKenna (2004) Malseed et al. (2000)
3.2	Recreational swimming	• Three recreational beaches in the Koombana Bay/ port area: Koombana Beach, Ski Beach, Jetty Baths	Department of Health (2018)
3.3	Recreational water sports	• The Leschenault Inlet is popular for canoeing, kayaking and sailing and several water sports clubs have leased land on foreshore which is used for recreating and socializing. Other water sports include wind surfing, dragon boating, paddle boarding and model boats	PLACE Laboratory (2013) Beckwith Environmental Planning (2009)
3.4	Recreational boating access	• Leschenault Inlet has two boat launching facilities and Leschenault estuary has four boat launching facilities • Koombana Bay has one boat launching facility in the Casuarina Boat Harbour	Department of Transport (2018) PLACE Laboratory (2013) McKenna (2004)
3.5	Marina facilities	• Casuarina Boat Harbour: service jetty, two public boat ramps, 48 recreational and five commercial boat pens, swing moorings and a slipway, parking for casual use vehicles and boat trailers	Department of Transport (2017)

Ref#	Marine and estuarine environmental values	Description of value	References
3.6	Educational and scientific values	• Bird watching amenities and educational signs are established in the Leschenault Inlet, around the mangrove conservation area • Popular bird watching sites include The Cut and Preston River mouth • The Leschenault Ribbons of Blue program provides educational activities for students in the Inlet and included macro-invertebrate sampling and mangrove walks • Bunbury Sea Scouts has facilities on the southern foreshore of the Leschenault Inlet	PLACE Laboratory (2013) Beckwith Environmental Planning (2009)
3.7	Landscape and visual amenity	• Scenic boardwalk through the mangroves of the Leschenault Inlet; walk trail is used by walkers and cyclists and is wheelchair accessible. Birds can be seen feeding on the mudflats and shallows of the Inlet • Koombana Bay visited by locals and tourists, which would have a direct view of the port	Birdlife WA (2017) PLACE Laboratory (2013) Beckwith Environmental Planning (2009)
4	Business, industry and commercial		
4.1	Tourism (including ferries and cruise ships)	• Dolphin Discovery Centre was established in 1994 • Most recent tourism development strategy (2015-2019) includes developing a new marina in Bunbury that can facilitate cruise ships, dive boats and dolphin cruises • Three dive operators in Bunbury and the Lena wreck is popular for divers	Dolphin Discovery Centre 2018 EVOLVE Strategic Solutions (2015)
4.2	Commercial fisheries	• The Port of Bunbury does not permit commercial or recreational fishing within the Inner and Outer Harbours due to safety concerns and shipping operations • A low level of fishing occurs at certain times of the year close to the beaches of Koombana Bay- i.e. when whiting and herring are in abundance • Commonwealth and state-wide fisheries operate in the vicinity of Bunbury Port however specific reports for the Bunbury region are difficult to estimate as data is collated for the state or region • The Mandurah to Bunbury Developing Crab Fishery operates in the area. Commercial fishing was previously allowed in Koombana Bay and Leschenault Estuary, but is now prohibited • Geographe Bay is important for harvesting saucer scallops • Western and demersal gillnet and longline fisheries operate in the coastal region off Bunbury and includes catches of a range of shark species. • Southern rock lobster is targeted in the wider Bunbury region • Significant catches of West Australia's pilchard and greenlip and brown lip abalone are processed in this Bunbury region • Estuarine coastal fisheries in the Bunbury region target pilchard, Australian herring, black bream, cobbler, western Australian salmon, scaley mackerel, white bait and southern garfish	DPIRD Bunbury Office pers.comm. (2019) GHD (2017a) Bunbury Port Authority (2012)

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2.4 Metadata collation

A collation of metadata records obtained from the literature that were considered relevant for harbour planning and development in the three locations of interest are provided in Table 8. This collation of metadata is not exhaustive and more relevant datasets may become available through stakeholder engagement.

Table 8: Metadata details for relevant data sets that could be incorporated into harbour planning and development in Fremantle, Kwinana and Bunbury.

Fremantle	Spatial	Held by
Benthic habitat maps	Yes	SKM and Oceanica (now BMT)
Predicted dredge plume contours	Yes	SKM
Predicted Cumulative sediments loads	Yes	SKM
Predicted benthic primary producer habitat loss unmitigated	Yes	SKM
Minden Reefs species list	No	Zoe Richards, Western Australian Museum
Erosion and inundation areas	?	BMT Oceanica
Short term inundation and erosion of Port Beach	Yes	GHD
Distribution of seagrass in the Swan Canning Estuary	Yes	Department of Water
Kwinana	**Spatial**	**Held by**
Coastal modification in Cockburn Sound	Yes	BMT
Mooring Scars and seagrass loss across years in Mangles Bay	Yes	BMT
Recreational fishing effort in Cockburn Sound during 2005–2006	Yes	BMT
Recreational crabbing effort in Cockburn Sound during 2005–2006	Yes	BMT
Estimates of coastal inundation and erosion along the Rockingham coastline following a sea level rise of 0.5 m by 2070	Yes	BMT
Surface light reaching seabed in Cockburn Sound	Yes	John Keesing CSIRO/ Cockburn Sound Management Council/ Department of Water
Habitat maps	Yes	BMT, UWA/DWER (2018)
Infauna abundance	Yes	BMT/ Water Corporation
Foraging distribution of little penguins during breeding	Yes	Belinda Cannell, UWA
Dolphin sightings Gage Roads, Swan Canning, OA and CS	Yes	Delphine Chabanne, Murdoch University
Dolphin foraging and aggregations	Yes	Hugh Finn/ BMT?
Major point sources of groundwater contamination	Yes	BMT
Modelling of sediment movement on eastern shelf of Cockburn Sound	?	MP Rogers and Associates
Public boat ramp usage during summer	?	Department of Planning, Lands and Heritage, Department of Transport
CSMC Sounding Out 2009 report has a metadata collation for all spatially available data		
Coastal Zone Management and Damara 2010 have inventory lists		
Bunbury	**Spatial**	**Held by**
Surficial sediment: particle size distribution in Koombana Bay	Yes	Wave Solutions/ Fusion GIS
Modelled seagrass distribution and biota distribution for Koombana Bay and around Bunbury	Yes	Wave Solutions/ Fusion GIS
Dolphin sightings along coast, Koombana Bay and Leschenault Estuary	Yes	Dolphin Discovery Centre
Contaminated sites around Port and Leschenault Peninsula	Yes	Western Australian Planning Commission
Little penguin tracks in Koombana Bay	Yes	Belinda Cannell, UWA
6 month sampling of marine sediments, sea water and biota within the Inner Harbour	No	Newmont
Modelled suspended fine sediments from dredging in inner harbour	Yes	GHD, Bunbury Port Authority
Seagrass monitoring 3 times annually around Waste water treatment plant outfall	?	Water Corporation
Surface and groundwater quality database that incl sites close to Koombana Bay	?	Department of Water- Water Information Database (WIN)
Predicted flushing times of Inner Harbour and Outer harbour	Yes	Wave Solutions
CTD profiles in around Koombana Bay in 2011 Jul-Aug	?	Wave Solutions
Passive acoustic loggers around Port to measure dolphin occurrence	?	Wave Solutions

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3 Assessment of marine and estuarine values and risks

A risk assessment was performed for marine and estuarine environmental and social values for Fremantle, Kwinana and Bunbury. The reference numbers provided in the risk tables link to the literature review tables in Section 2. The risk assessment process was conducted in three stages for each location in order to address cumulative risks for each area and risks associated directly with harbour development.

> *Stage 1*: Expanded risk assessment of issues that are occurring, or could occur, for sub-values of the overarching values listed in Table 1 as well as the additional values identified under section 2 (Appendix 2).
>
> *Stage 2*: Assignment of synthesised 'rolled up' issues that are occurring, or could occur, for the overarching values listed in Table 1 as well as the additional values identified under section 2 (Appendix 3).
>
> *Stage 3*: A preliminary unmitigated and mitigated risk assessment for synthesised issues that separate into different activities ('harbour development', 'climate change', 'other industrial and urban growth'), as well as an assessment of the current risk and cumulative risk (Appendix 4).

Stage 3 Preliminary unmitigated and mitigated risk assessments can only be considered as a preliminary draft because they were determined in the absence of any conceptual or engineering design information. It is recommended that subject matter experts are consulted for high risk values in collaboration with engineers who can inform on feasible and effective mitigation measures. Mitigation measures relate to the capabilities of Westport only rather than measures unrelated to harbour development. Use of any tables or text labelled as 'preliminary' outside of this document must explicitly state that the work is preliminary and a draft and must state the recommendations outlined above.

The activities included in *Stage 3 Preliminary unmitigated and mitigated risk assessments* aim to identify the direct impacts of harbour development and other impacts that need to be considered when assessing the cumulative impact. The activities are defined as:

- Harbour development: inclusive of construction and operational phases, harbour infrastructure and shipping channels for the proposed harbour locations
- Climate change: initial broad assessments made based on medium (2050) and long term (2100) predictions and assuming worst case scenario.
- Other industrial and urban growth: assumes definite growth over time and inclusion of any known future developments in the area

Assessment of risks that considered harbour development were guided by the proposed harbour footprints provided in the EWS Technical Report for Fremantle (Fig. 1), Kwinana (Fig. 2) and Bunbury (Fig. 3). The current understanding at the time this report was written is that options 2 and 6 are no longer considered as harbour options for Kwinana and therefore were not considered in the risk assessment. The exact footprint of the harbour option for Kwinana, i.e. land backed or not land backed, is also not known. In addition, sites for potential dumping of dredge spoil were not identified in time for completion of this report and were not considered in the risk assessment.

3.1 Risk assessment procedure and definitions

The literature review was used to inform a risk assessment of potential issues arising for each identified value. The risk assessment was performed using a formal qualitative risk approach (consequence x likelihood), which assigns a level of risk to the issue. The consequence ratings ranged from 'negligible' to 'severe' and are defined in Table 9. The likelihood rating scale ranged from 'rare' to 'almost certain' and ratings are defined in Table 10. The consequence-likelihood approach and rating scales are based upon the Australian & New Zealand and International Standard Risk Analysis (Standards Australia, 2000, 2004; ISO 31000:2018) and is a commonly used approach, such as for ecosystem based fisheries management in Western Australia (Fletcher et al. 2011).

The risk scores assigned to each activity and each value in *Stage 3 Preliminary unmitigated and mitigated risk assessment* were guided by taking an 'average' of the consequence and likelihood scores assigned in the *Stage 1 Expanded risk assessment of issues*. For example, four expanded issues and risks were assigned for biological diversity in Fremantle in relation to harbour development: major x unlikely, moderate x possible, minor x unlikely and major x likely. The final risk score given to harbour development in relation to biological diversity was major x possible = High. Cumulative risk was determined by adding up or taking the highest scores of the consequence and likelihood scores, i.e. if there were two 'possible' and two 'likely' scores for likelihood for the current risk and each of the three activities, then 'likely' would be used in calculating the cumulative risk, whereas four 'likely' scores would probably result in an 'almost certain' score for the likelihood of that issue. Current risk was assessed by considering what the consequence and likelihood of the issue would be currently and within the next year.

Table 9: Categories and definitions of consequence for marine and estuarine environmental and social values.

Marine and estuarine environmental values	
Negligible (1)	No measurable impact on value, or within natural variation
Minor (2)	Reversible impact on value at a localised scale OR a measurable impact on value at a regional, system or population scale that does not result in any loss of the value
Moderate (3)	Irreversible loss of value at a localised scale OR there is a reversible impact on the value at a regional, system or population scale.
Major (4)	Impact on value at a regional, system or population scale and the severity of the impact may not allow for recovery of the value to the same pre-impact condition
Severe (5)	Significant and irreversible/irrecoverable impact on value at a regional, system or population scale with no prospect of recovery
Marine and estuarine social values	
Negligible (1)	No measurable impact on value
Minor (2)	Minor impact on value (e.g. in spatial extent or quality) but not affecting continued use/enjoyment/cultural significance at a local or regional level
Moderate (3)	Impact on value with an adverse effect on continued use/enjoyment/cultural significance at a local level – some displacement of people/users
Major (4)	Significant impact on value with an adverse effect on continued use/enjoyment/cultural significance at a local and regional level – significant displacement of people/users
Severe (5)	Substantial loss or alteration of value, displacement of most people/users

Adapted from Fletcher et al 2011 Ecosystem Based Fisheries Management case study report West Coast Bioregion and Department of Environment and Energy Risk assessment for environmental management of the marine environment

Table 10: Categories and definitions of likelihood for marine and estuarine environmental and social values.

Marine and estuarine values	
Rare (1)	May occur in exceptional circumstances
Unlikely (2)	Will probably not occur
Possible (3)	Could occur at some point
Likely (4)	Will probably occur
Almost certain (5)	Expected to occur

Adapted from Department of Environment and Energy Risk assessment for environmental management of the marine environment 2018: https://parksaustralia.gov.au/marine/management/resources/scientific-publications/risk-assessment-environmental-management-marine-environment/

From the consequence and likelihood ratings assigned to each issue, the risk matrix shown in Table 11 was used to determine the overall risk level for each potential environmental and social issue. The risk level for each issue is calculated as the consequence score x likelihood score, with possible values ranging between 1-25. There are four risk levels ranging from 'low' to 'extreme', and these are detailed in Table 12, along with the suggested management response.

Table 11: Risk assessment matrix for marine and estuarine environmental and social values.

			Consequence				
			Negligible	Minor	Moderate	Major	Severe
			1	2	3	4	5
Likelihood	Rare	1	1	2	3	4	5
	Unlikely	2	2	4	6	8	10
	Possible	3	3	6	9	12	15
	Likely	4	4	8	12	16	20
	Almost certain	5	5*	10	15	20	25

Risk	1-4	Low	5-9	Medium	10-16	High	20-25	Extreme

*A negligible consequence and almost certain likelihood of an impact (1x5=5) would logically be given a low risk rating, but a severe consequence that has a rare likelihood should not be considered low risk (5x1=5). *Adapted from Fletcher et al 2011 Ecosystem Based Fisheries Management case study report West Coast Bioregion*

Table 12: Risk categories, descriptions and management responses for marine and estuarine environmental and social values.

Risk Category	Risk Value	Description	Management response
Low	1-4	Acceptable, no control measures required	No response required
Medium	5-9	Acceptable provided risk control measures are in place	Will require regular monitoring and/or management
High	10-16	Not desirable, strong risk control measures and/or planning required if value is to be maintained	Will require comprehensive monitoring and management
Extreme	20-25	Value is likely to be lost unless significant additional control measures and/or *offsets are applied	Requires decision on whether value is to be protected

*Offset implies replacing like for like to keep the value in the system. *Adapted from Fletcher et al 2011 Ecosystem Based Fisheries Management case study report West Coast Bioregion*

Each environmental and social value was assigned a significance rating based on the rating scale, shown in Table 13. Each environmental and social value was also assigned a level of data confidence based upon the availability of data or information to support the assessment. The levels of confidence for identified values are presented in Table 14.

Table 13: Categories and definitions of significance for marine and estuarine environmental and social values.

Marine and estuarine environmental values		
Low	**Medium**	**High**
Local significance	Regional significance	State significance
Marine and estuarine social values		
Low	**Medium**	**High**
Asset/value widely distributed in the area. May have some level of degradation. People can access other similar assets or values can be managed with minor interventions.	Only facility/amenity of its type in the local area, in good condition. Popular value to local community and people from the broader area.	Unique or rare, only facility/amenity of its type. Irreplaceable assets/values. Used regularly by many people from across the region/state.
Of local importance only	Of local as well regional importance	Of local as well as state/national importance

Adapted from GHD 2017 Infrastructure Victoria: Second Container Port Advice, Environment & Social Advice

Table 14: Categories and definitions of data confidence for marine and estuarine environmental and social values.

Marine and estuarine environmental values		
Low	**Medium**	**High**
Data and information is limited on: presence, numbers, pressure-response relationships, status and/or another relevant area of understanding	Data and information is available but not sufficient for a high degree of confidence. Some data is lacking on: presence, numbers, pressure-response relationships, status and/or another relevant area of understanding	Data and information is available and sufficient for a high degree of confidence
Marine and estuarine social values		
Low	**Medium**	**High**
Data and information is limited on: local/regional significance, popularity (number of users), potential for impacts on public health & wellbeing, uniqueness	Data and information is available but not sufficient for a high degree of confidence. Some data is lacking on: local/regional significance, popularity (number of users), potential for impacts on public health & wellbeing, uniqueness	Data and information is available and sufficient for a high degree of confidence

3.2 Fremantle

3.2.1 Environmental values

A total of 53 issues were assessed for *Stage 1 expanded issues and risks* for Fremantle, which comprised of 19 high, 31 medium and three low risks (Appendix 2). Eight of the high risk issues related to water quality, and in particular, impacts on hydrology, nutrients, light attenuation due to dredging, contamination due to oil/fuel spills and impacts of climate change on salinity, temperature and pH. Bioaccumulation of contaminants was considered a high risk for resident bottlenose dolphins and loss of shoreline habitat was a high risk for fairy terns. The risk of an increase in invasive species was high due an increase in vessel visitation and Fremantle having suitable environmental conditions for establishment. Perth herring migrate through the Inner Harbour and due to being an isolated breeding stock, increasing salinity and impacts of dredging were considered as high risks, as was increasing salinity for western school prawns. Increasing water temperature was a high risk for seagrass meadows occurring along the Fremantle coast. Degradation of the Swan Estuary Marine Park from increased development was considered as high risk due to the estuary already being highly modified and under stress further upstream. Inundation and erosion of coastal areas, the Swan Estuary and Port Beach adjacent to port operations were all given high risk scores.

To reiterate, this report represents a rapid assessment within a short time-frame of the most important environmental values for Fremantle. The risk assessments were based on very generalised locations of possible harbour footprints and it is recognised that further stakeholder engagement is required to refine the risk assessment.

3.2.1.1 Cumulative pressures

A synthesis of the issues identified for Fremantle in *Stage 1 Expanded issues and risks* resulted in 14 'rolled up' issues (Appendix 3) that were used in *Stage 3 preliminary unmitigated and mitigated risk assessment* (Appendix 4). A summarised table of the preliminary unmitigated and mitigated risks is given in Table 15. Climate change was the activity with the highest risks, which was considered to impact significantly on water quality, seagrass habitats, listed and significant fauna, regionally significant spawning/nursery areas, regionally significant migratory pathways, the Swan Estuary Marine Park, and coastal processes. Other industrial and urban growth was associated with medium and low risks only and was more likely to have impacts on the estuary further upstream than within the vicinity of the port. Harbour development posed a high risk for biological diversity and resident bottlenose dolphins and a medium risk for all other issues. Overall, there were 11 issues where the cumulative pressure risk score was considered high.

Table 15: Summarised preliminary unmitigated and mitigated risk assessment for marine and estuarine environmental values in Fremantle.

Full table showing risk evaluation in Appendix 4.

Ref#	Issue	Current risk	Activity	Future unmitigated risk and justification		Future harbour development mitigated risk	
Environmental value: Integral functioning ecosystem							
1	Decrease in current ecosystem functioning within and around port footprint with increased use and development	M (8)	Harbour development	M (8)	Environment already highly modified and degraded from previous development and eutrophication in the estuary is an ongoing problem further upstream. Already a working port with vessel traffic so may not expect major declines in current ecosystem functioning if expansion happened. Climate change would change the functioning, but not necessarily cause a decrease if new species adapt to new conditions.	Use PIANC Working with Nature principles, as has already been done with past development in the port, to engineer port structures and niche habitats. Rehabilitate seagrass meadows that may be impacted by port development now to avoid a lag in ecosystem functioning.	L (4)
			Climate change	M (6)			M (6)
			Other industrial and urban growth	M (8)			M (8)
			Cumulative pressure	*M (8)*	*Environment already highly modified and degraded from previous development and eutrophication in the estuary is an ongoing problem further upstream. Currently has risks associated with a working port such as turbidity, contamination and oil spills.*		*M (8)*
Environmental value: Biological diversity							
2	Decrease in species diversity due to reduction of suitable habitat, invasive species and altered environmental conditions	M (6)	Harbour development	H (12)	Invasive species from increased vessel traffic could outcompete native species, and there are already invasive species in the area. Port expansion could cause localised habitat loss, but mobile animals could move to other suitable areas if available. Fish species migrate seasonally between the Swan River and the Indian Ocean via the Inner Harbour. Many species spend all life cycle stages in the estuary and would have limited capacity to recover from disturbances. Already an operating port so expansion may not have a big impact. Only short lived marine biota occur in the anchorage area of Gage Roads due to continual disturbance from vessels and anchors, however increased vessel traffic may not allow enough time for some ephemeral species to survive long enough to reproduce. Removal or maintenance of artificial substrates within the inner harbour may temporarily reduce diversity of invertebrates i.e. barnacles and may temporarily reduce localised water quality due to decreased filtering capacity. Tropicalisation may not necessarily decrease biological diversity, as new species will be inhabiting the area and some current species may have time to gradually adapt.	Use PIANC working with nature principles to engineer ecological niche areas for valuable species. Ensure continuation of the State Wide Array Surveillance Program (SWASP) for marine pests and regular reporting (invasive species are monitored and managed by DPIRD under the Fisheries Act). Engineer walls of built structures to be native species friendly in order to reduce establishment of invasive.	M (6)
			Climate change	M (6)			M (6)
			Other industrial and urban growth	M (6)			M (6)
			Cumulative pressure	*H (16)*	*Invasive species could impact system wide functioning and cause declines or local extinctions of populations.*		*M (9)*

Ref#	Issue	Current risk	Activity	Future unmitigated risk and justification		Future harbour development mitigated risk	
Environmental value: High level of water quality							
3	Decrease in quality of water due to increased development and altered environmental conditions	M (9)	Harbour development	M (9)	Port expansion and operation could increase nutrients and contaminants in the water column from run-off. Likely to be more resuspension of sediments with high nutrient and contaminant loading. Increased nutrients and warmer temperatures may cause toxic phytoplankton blooms in the lower reaches of estuary as well as potential dead zones due to increases oxygen consumption. Dredging and continual propeller wash would increase turbidity, though already a turbid environment and operating port. More vessels would increase the risk of oil and fuel spills. Increased nutrient levels discharged into the Inner Harbour and surrounds from groundwater. Increased circulation of the Swan Estuary (lower reaches) and migration of higher salinity concentrations upstream with deeper dredge channel. Salinity patterns in the Swan and inner harbour are also likely to be impacted by reduced rainfall under a drying climate. Climate change may also increase the incidence of flooding and increase acidification of the water. Increased incidence of flooding will increase discharges of fresher and turbid water plumes from the Swan Canning catchment.	Better management of groundwater, storm water and run off to reduce nutrients. Additional dredge management options should be considered e.g. timing around high flushing periods. Dredge without overflow and discharge sediments safely. Design port to minimise vessel movement i.e. less turning and manoeuvring which would limit disturbance to sediments. Check maintenance records of vessels before port entry to reduce risk of oil spill and have first strike response kits in place to respond to level 2/3 oil spills as a minimum. Increase vigilance with management of fuel transfers. Engineer structures to prevent coastal erosion or salt wedge migration if hydrology is changed from deeper shipping channel.	L (4)
			Climate change	H (12)			H (12)
			Other industrial and urban growth	M (9)			M (9)
			Cumulative pressure	*H (12)*	*Already an impacted environment but does not mean increased use of the area would have negligible impacts. Industrial and urban growth will likely put more pressure on the estuary, which could flow downstream.*		*H (12)*
Environmental value: High level of sediment quality							
4	Decrease in quality of sediments due to increased development	H (12)	Harbour development	M (9)	Likely increase in contamination of sediments with increased shipping and port operations. Port would facilitate cargo and container shipping rather than mineral exports, so load spills unlikely. There is a risk of exposing acid sulphate soils during development as Swan River and Inner Harbour have potential acid sulphate soils. Has not been exposed with previous development. Other industrial and urban growth likely to have more impact on sediment quality further upstream rather than in the Inner Harbour or coast.	Remove contaminated sediments created from port operations. Test for potential acid sulphate soils before developing port infrastructure.	L (4)
			Climate change				
			Other industrial and urban growth	L (4)			L (4)
			Cumulative pressure	*H (12)*	*Currently localised areas of contaminated sediments- such as in the Inner Harbour, and likely to increase with increasing operations.*		*L (4)*
Environmental value: Significant benthic communities and habitats- Seagrass							
5.1	Reduction in seagrass biomass and extent due to increased development and altered environmental conditions	M (6)	Harbour development	M (9)	Seagrass meadows occur directly to the north, south and further west of the port entrance, as well as in the estuary, and dredging and increased turbidity from vessel use may impact meadows. No significant declines in seagrass from dredging in 2010 were recorded. More area for sediments to disperse out of the inner harbour entrance. Already an area of high vessel traffic. Increased incidence of marine heatwaves may cause decrease in seagrass biomass which occurred in Shark Bay. Other industrial and urban growth likely to have more impact on seagrass quality further upstream rather than in the Inner Harbour or coast.	Manage dredging operations for tidal movements and water circulation. If conditions allow, use a silt screen during dredging. Additional dredge management options should be considered to protect benthic producers e.g. avoid winter when seagrass most vulnerable to low light. Avoid removal of seagrass meadows or rehabilitate new areas for seagrass colonisation now to prevent a lag effect in ecosystem functioning. Design port to minimise vessel movement i.e. less turning and manoeuvring which would limit disturbance to sediments.	L (4)
			Climate change	H (16)			H (16)
			Other industrial and urban growth	L (4)			L (4)
			Cumulative pressure	*H (16)*	*Climate change likely to have the greatest future impact on seagrass meadows off coast.*		*H (16)*

Ref#	Issue	Current risk	Activity	Future unmitigated risk and justification		Future harbour development mitigated risk	
Environmental value: Significant benthic communities and habitats- Other							
5.2 **5.3** **5.4**	Degradation of other benthic communities due to increased development	L (4)	Harbour development	M (9)	Degradation of Hall Bank coral community could occur with spread of suspended sediments from dredging, though this did not occur with 2010 dredging. Minden Reef already subject to a high sediment regime with a lot of abiotic materials being deposited on the reef i.e. sand, silt, rock, wreckage. Loss of macroalgae habitats could occur with port expansion as macroalgae is found on limestone pavement outcrops in the Deep Water Channel. Macroalgae can re-establish relatively quickly. Human disturbance may have some impact of reefs, but they are less frequently visited compared to other reefs i.e. Rottnest.	Design port to minimise vessel movement i.e. less turning and manoeuvring which would limit disturbance to sediments. Manage dredge plume for tidal movements and water circulation. Periodically clean Minden Reef of abiotic materials associated with port operations.	L (4)
			Climate change				
			Other industrial and urban growth	L (4)			L (4)
			Cumulative pressure	*M (9)*	*Limited information to assess climate change impacts.*		*L (4)*
Environmental value: Listed and significant fauna- Fairy terns							
6.1	Decline in abundance and breeding success of fairy terns due to impacts on habitat and prey species	M (6)	Harbour development	M (9)	Loss of shoreline habitat due to development and/or sea level rise. Successful breeding colony at Rous Head. Port expansion not likely to remove more coastline. Lack of nesting sites would impact the population. Bioaccumulation of contaminants through the food chain could negatively affect survival and/or breeding success. TBT is being reduced, though there is potential for other contaminants to impact populations. Port operations my increase contaminants in the water and sediments, though terns may be less likely to ingest contaminated fish given the open coastline. Other industrial and urban growth may disturb nesting sites. Very built up coastline already. Urban growth would increase risk of entanglement in fishing gear and rubbish. Rising sea temperatures would influence distribution of prey.	Use PIANC Working with Nature principles to incorporate protected bird friendly areas for current and future use. Areas of contaminated sediments could be removed and contamination of the water column heavily regulated to reduce bioaccumulation.	L (4)
			Climate change	H (12)			H (12)
			Other industrial and urban growth	M (6)			M (6)
			Cumulative pressure	*H (12)*	*Listed as vulnerable under EPBC. Feral predators also pose a risk to fairy tern abundance. Any impacts to nesting sites would have an influence on the overall population- i.e. mating opportunities.*		*H (12)*
Environmental value: Listed and significant fauna- Bottlenose dolphins							
6.2	Decline in resident and other populations due to a decline in foraging habitat, prey species and anthropogenic influences i.e. boat strikes, fishing entanglements and underwater noise	M (9)	Harbour development	H (12)	Increase in underwater noise from development and construction could deter dolphins from their usual habitats and interrupt communications between dolphins. Noises can be short lived or intermittent. The inner harbour has been identified as a seasonal hotspot that is strongly linked with foraging behaviour and this would be at risk with port expansion. Deepening of the channel and increased vessel use may impact in these hotspots. Bioaccumulation of contaminants through the food chain may negatively affect survival and/or breeding success as dolphins that died in the Swan-Canning in 2009 were found to have organic contaminants in their blubber. Death was not definitely attributed to contaminants. Boat strikes and entanglement in fishing gear has been noted for nearby regions and is likely to occur with urban growth. The genetic flow is asymmetric with flow from Owen Anchorage (the source) to the Swan Canning Riverpark. Connection through the inner harbour is critical for the survival of the community in the Swan Canning Riverpark.	Use PIANC Working with Nature principles to create niche areas for dolphins to forage and design structures that would reduce the loss of foraging habitat in the Inner Harbour. Avoid conducting noisy dredging operations and port maintenance (i.e. pile driving) during the breeding season when animals are socialising and calving. Engage Marine Mammal Observers to observe the occurrence of dolphins during the time development is occurring.	M (6)
			Climate change	H (12)			H (12)
			Other industrial and urban growth	M (9)			M (9)
			Cumulative pressure	*H (12)*	*Accumulate pressures may cause dolphins to limit transitions/access between Swan Canning Riverpark and adjacent waters, more so than cause direct death to dolphins, and would impact the value being present in Swan Canning Riverpark.*		*H (12)*

Ref#	Issue	Current risk	Activity		Future unmitigated risk and justification	Future harbour development mitigated risk	
Environmental value: Listed and significant fauna- whales							
6.3	Decrease in humpback whale occurrence due to port operations	L (2)	Harbour development	M (9)	Humpback females and calves are often seen resting in the waters between Rottnest and the Fremantle coast from Sep-Nov during their southerly migration. Increased vessel traffic and dredging could deter whales or increase vessel strikes. Noise from dredging could also deter whales or interrupt communications.	Avoid noisy dredging operations during time of migration off Fremantle. Limit the spread of vessel movements entering and leaving the port.	L (4)
			Climate change				
			Other industrial and urban growth	L (4)			L (4)
			Cumulative pressure	*M (9)*	*Migration occurs every year and impacts are more likely to affect calves.*		*L (4)*
Environmental value: Listed and significant fauna- migratory shorebirds and seabirds							
6.4	Decline in abundance and breeding success due to impacts on habitat and prey species	L (4)	Harbour development	M (9)	Sea level rise could inundate important shoreline habitat. Increased coastal development could remove important habitat, though areas around port are heavily developed already. Port expansion not likely to remove additional sections of coastline. Bioaccumulation of contaminants through the food chain could negatively affect survival and/or breeding success, though an open coast reduces risk of ingesting contaminate prey. Birds largely nesting on nearby islands. There would be localised loses of suitable habitat but this may flow on to impact the population as a whole if another suitable habitat is not available. Rising sea temperatures would influence distribution of prey. Urban growth would increase risk of entanglement in fishing gear and rubbish.	Use PIANC Working with Nature principles to create niche areas for birds to forage and incorporate coastal stretches for birds to nest and move up shore as sea level rises. Areas of contaminated sediments could be removed to reduce risk of bioaccumulation.	L (4)
			Climate change	H (12)			H (12)
			Other industrial and urban growth	M (9)			M (9)
			Cumulative pressure	*H (16)*	*Coastal development and human disturbance may impact on birds using coastal areas. Popular sites for seabirds and shorebirds include surrounding islands, but it is unknown if stretches of mainland coastline in vicinity of port are also significant. Migratory birds frequent the same or similar locations year after year due to reliable conditions, so any impacts to known forging or nesting sites may have greater implications for migration.*		*H (12)*
Environmental value: Regionally significant spawning / nursery area							
7	Fish species that spend their whole life cycles in the estuary (i.e. yellowtail flathead, black bream) may be negatively impacted by habitat degradation and environmental changes	M (6)	Harbour development	M (9)	Discrete self-replenishing stocks will have limited capacity to recover if stocks are depleted. Already an operating port and species still occurring, but there may be some risk of impacting populations occurring in the estuary if port expansion impacts water quality. Deepening the channel may further high salinity waters upstream and impact some fish species, as would a drying climate. Impacts from other urban and industrial growth more likely upstream of port. Black bream mainly spawning upstream and using the middle to upper estuary as juveniles and adults.	Use PIANC Working with Nature principles to create fish friendly habitat. Manage dredge plume for tidal movements and water circulation. Install a silt screen.	L (4)
			Climate change	H (12)			H (12)
			Other industrial and urban growth	L (4)			L (4)
			Cumulative pressure	*H (16)*	*Estuary currently under stress from eutrophication which would have some impact on fish populations. Fish not directly occurring in the port area, but there could be impacts that flow upstream.*		*H (12)*

Ref#	Issue	Current risk	Activity	Future unmitigated risk and justification		Future harbour development mitigated risk	
Environmental value: Regionally significant migratory pathways							
8	Negative impacts from increased development to fish and invertebrate species that migrate to and from estuary and oceanic waters to complete their lifecycle	M (6)	Harbour development	M (9)	Suspended sediments and noise from dredging and vessels may impact on larval recruitment and adult migration between the open coast and the Estuary, as well as spawning in coastal waters. Increasing salinity from lower rainfall may impact on the distribution of fish throughout the estuary. Habitat degradation from port operations may reduce abundances of some species in the lower reaches of the estuary. Impacts from other urban and industrial growth more likely upstream of port.	Time dredging operations to avoid peak recruitment, migration and spawning periods. Install a silt screen to limit spread of sediments. Design port to minimise vessel movement i.e. less turning and manoeuvring which would limit disturbance to sediments.	L (4)
			Climate change	H (12)			H (12)
			Other industrial and urban growth	L (4)			L (4)
			Cumulative pressure	*H (12)*	*Many different species to consider and each would have different tolerances to impacts. Already an operating port and fish are currently moving between environments.*		*H (12)*
Environmental value: Swan Estuary Marine Park							
9	Degradation of marine park through upstream flow on effects of increased development and environmental change	M (6)	Harbour development	M (9)	Port operates right in the mouth of the estuary but has been doing so for a long time. Environment already highly modified from previous development of the inner harbour and deepening the channel may cause more saline waters to move further upstream. Eutrophication in the estuary is an ongoing problem that has largely stemmed from upstream impacts. Impacts from other urban and industrial growth more likely upstream of port. Reduced rainfall will increase salinity in the estuary.	Use PIANC Working with Nature principles to create niche habitats that will benefit species using the marine park. Manage dredge plume for tidal movements and water circulation. Install a silt screen. Have first strike response kits in place to respond to level 2/3 oil spills as a minimum.	L (4)
			Climate change	H (12)			H (12)
			Other industrial and urban growth	L (4)			L (4)
			Cumulative pressure	*H (12)*	*Climate change and upstream impacts likely pose most risk to the Marine Park.*		*H (12)*
Environmental value: Coastal processes							
10	Increased erosion and inundation of shorelines from rising sea levels, storms and changes to sediment transport	M (9)	Harbour development	M (9)	Deepening of channel may cause some changes to sediment transport. Inundation and erosion of coastal use areas (e.g. South Mole, Bathers Beach) is likely due to sea level rise. Inundation of foreshores of Swan Estuary due to coastal flooding. Insufficient setback of infrastructure along the foreshores of the estuary and inundation from coastal flooding is a risk. Fremantle Port expected to be impacted by erosion at Port Beach in the medium term. Port Beach listed as 'extreme' risk for erosion.	Use PIANC Working with Nature principles to engineer long lasting solutions for coastal erosion if shipping channel has a significant impact on sediment transport.	L (4)
			Climate change	H (12)			H (12)
			Other industrial and urban growth				
			Cumulative pressure	*H (12)*	*Coastal erosion and inundation already affecting localised areas.*		*H (12)*

3.2.1.2 Harbour development pressures

A summary of harbour development related issues and risks for environmental values in Fremantle is given in Table 16. Biological diversity was assigned a high risk in relation to harbour development due to an increase in introduced species, localised habitat loss from harbour expansion and continual disturbance to ephemeral species in the anchorage areas of Gage Roads. The risk may be lowered to medium if preliminary mitigation measures include the adoption of PIANC Working with Nature principles to engineer niche areas and walls of built structures to promote growth of native species, as well as implementing additional monitoring measures to reduce incidence of marine pests. Bottlenose dolphins were given a high risk in relation to harbour development due to a combination of increased underwater noise impacting on behaviours, loss of favoured foraging habitat in the Inner Harbour and bioaccumulation of contaminants. The risk could be lowered to medium if PIANC Working with Nature principles were adopted and included creation of niche foraging areas or avoidance of habitat loss, and if noisy operations were reduced during the breeding season and stopped when dolphins were present in the vicinity of operations. The medium risks assigned for all other harbour development related issues could all be reduced to low if the preliminary suggested mitigation measures were adopted (Table 16).

Table 16: Summarised preliminary unmitigated and mitigated risk assessment of marine and estuarine environmental values in relation to harbour development in Fremantle.

Full table in Appendix 4.

Ref#	Issue	Harbour development unmitigated risk and justification		Harbour development mitigation and risk	
Environmental value: Integral functioning ecosystem					
1	Decrease in current ecosystem functioning within and around port footprint with increased use and development	M (8)	Environment already highly modified and degraded from previous development and eutrophication in the estuary is an ongoing problem further upstream. Already a working port with vessel traffic so may not expect major declines in current ecosystem functioning if expansion happened.	Use PIANC Working with Nature principles, as has already been done with past development in the port, to engineer port structures and niche habitats. Rehabilitate seagrass meadows that may be impacted by port development now to avoid a lag in ecosystem functioning.	L (4)
Environmental value: Biological diversity					
2	Decrease in species diversity due to reduction of suitable habitat, invasive species and altered environmental conditions	H (12)	Invasive species from increased vessel traffic could outcompete native species, and there are already invasive species in the area. Port expansion could cause localised habitat loss, but mobile animals could move to other suitable areas if available. Fish species migrate seasonally between the Swan River and the Indian Ocean via the Inner Harbour. Many species spend all life cycle stages in the estuary and would have limited capacity to recover from disturbances. Already an operating port so expansion may not have a big impact. Only short lived marine biota occur in the anchorage area of Gage Roads due to continual disturbance from vessels and anchors, however increased vessel traffic may not allow enough time for some ephemeral species to survive long enough to reproduce. Removal or maintenance of artificial substrates within the inner harbour may temporarily reduce diversity of invertebrates i.e. barnacles and may temporarily reduce localised water quality due to decreased filtering capacity.	Use PIANC working with nature principles to engineer ecological niche areas for valuable species. Ensure continuation of the State Wide Array Surveillance Program (SWASP) for marine pests and regular reporting (invasive species are monitored and managed by DPIRD under the Fisheries Act). Engineer walls of built structures to be native species friendly in order to reduce establishment of invasive.	M (6)
Environmental value: High level of water quality					
3	Decrease in quality of water due to increased development and altered environmental conditions	M (9)	Port expansion and operation could increase nutrients and contaminants in the water column from run-off. Likely to be more resuspension of sediments with high nutrient and contaminant loading. Increased nutrients and warmer temperatures may cause toxic phytoplankton blooms in the lower reaches of estuary as well as potential dead zones due to increased oxygen consumption. Dredging and continual propeller wash would increase turbidity, though already a turbid environment and operating port. More vessels would increase the risk of oil and fuel spills. Increased nutrient levels discharged into the Inner Harbour and surrounds from groundwater. Increased circulation of the Swan Estuary (lower reaches) and migration of higher salinity concentrations upstream with deeper dredge channel.	Better management of groundwater, storm water and run off to reduce nutrients. Additional dredge management options should be considered e.g. timing around high flushing periods. Dredge without overflow and discharge sediments safely Design port to minimise vessel movement i.e. less turning and manoeuvring which would limit disturbance to sediments. Check maintenance records of vessels before port entry to reduce risk of oil spill and have first strike response kits in place to respond to level 2/3 oil spills as a minimum. Increase vigilance with management of fuel transfers. Engineer structures to prevent coastal erosion or salt wedge migration if hydrology is changed from deeper shipping channel.	L (4)
Environmental value: High level of sediment quality					
4	Decrease in quality of sediments due to increased development	M (9)	Likely increase in contamination of sediments with increased shipping and port operations. Port would facilitate cargo and container shipping rather than mineral exports, so load spills unlikely. There is a risk of exposing acid sulphate soils during development as Swan River and Inner Harbour have potential acid sulphate soils. Has not been exposed with previous development.	Remove contaminated sediments created from port operations. Regulatory frameworks are in place to test for acid sulphate soils and ensure issues are managed appropriately.	L (4)

Ref#	Issue	Harbour development unmitigated risk and justification		Harbour development mitigation and risk	
Environmental value: Significant benthic communities and habitats- Seagrass					
5.1	Reduction in seagrass biomass and extent due to increased development and altered environmental conditions	M (9)	Seagrass meadows occur directly to the north, south and further west of the port entrance, as well as in the estuary, and dredging and increased turbidity from vessel use may impact meadows. No significant declines in seagrass from dredging in 2010 were recorded. More area for sediments to disperse out of the inner harbour entrance. Already an area of high vessel traffic.	Manage dredging operations for tidal movements and water circulation. If conditions allow, use a silt screen during dredging. Additional dredge management options should be considered to protect benthic producers e.g. avoid winter when seagrass most vulnerable to low light. Avoid removal of seagrass meadows or rehabilitate new areas for seagrass colonisation now to prevent a lag effect in ecosystem functioning. Design port to minimise vessel movement i.e. less turning and manoeuvring which would limit disturbance to sediments.	L (4)
Environmental value: Significant benthic communities and habitats- Other					
5.2 5.3 5.4	Degradation of other benthic communities due to increased development	M (9)	Degradation of Hall Bank coral community could occur with spread of suspended sediments from dredging, though this did not occur with 2010 dredging. Minden Reef already subject to a high sediment regime with a lot of abiotic materials being deposited on the reef i.e. sand, silt, rock, wreckage. Loss of macroalgae habitats could occur with port expansion as macroalgae is found on limestone pavement outcrops in the Deep Water Channel. Macroalgae can re-establish relatively quickly.	Design port to minimise vessel movement i.e. less turning and manoeuvring which would limit disturbance to sediments. Manage dredge plume for tidal movements and water circulation. Periodically clean Minden Reef of abiotic materials associated with port operations.	L (4)
Environmental value: Listed and significant fauna- Fairy terns					
6.1	Decline in abundance and breeding success of fairy terns due to impacts on habitat and prey species	M (9)	Loss of shoreline habitat due to development. Successful breeding colony at Rous Head. Port expansion not likely to remove more coastline. Lack of nesting sites would impact the population. Bioaccumulation of contaminants through the food chain could negatively affect survival and/or breeding success. TBT is being reduced, though there is potential for other contaminants to impact populations. Port operations my increase contaminants in the water and sediments, though terns may be less likely to ingest contaminated fish given the open coastline.	Use PIANC Working with Nature principles to incorporate protected bird friendly areas for current and future use. Areas of contaminated sediments could be removed and contamination of the water column heavily regulated to reduce bioaccumulation.	L (4)
Environmental value: Listed and significant fauna- Bottlenose dolphins					
6.2	Decline in resident and other populations due to a decline in foraging habitat, prey species and anthropogenic influences i.e. boat strikes, fishing entanglements and underwater noise	H (12)	Increase in underwater noise from development and construction could deter dolphins from their usual habitats and interrupt communications between dolphins. Noises can be short lived or intermittent. The inner harbour has been identified as a seasonal hotspot that is strongly linked with foraging behaviour and this would be at risk with port expansion. Deepening of the channel and increased vessel use may impact in these hotspots. Bioaccumulation of contaminants through the food chain may negatively affect survival and/or breeding success as dolphins that died in the Swan-Canning in 2009 were found to have organic contaminants in their blubber. Death was not definitely attributed to contaminants. The genetic flow is asymmetric with flow from Owen Anchorage (the source) to the Swan Canning Riverpark. Connection through the inner harbour is critical for the survival of the community in the Swan Canning Riverpark.	Use PIANC Working with Nature principles to create niche areas for dolphins to forage and design structures that would reduce the loss of foraging habitat in the Inner Harbour. Avoid conducting noisy dredging operations and port maintenance (i.e. pile driving) during the breeding season when animals are socialising and calving. Engage Marine Mammal Observers to observe the occurrence of dolphins during the time development is occurring.	M (6)
Environmental value: Listed and significant fauna- whales					
6.3	Decrease in humpback whale occurrence due to port operations	M (9)	Humpback females and calves are often seen resting in the waters between Rottnest and the Fremantle coast from Sep-Nov during their southerly migration. Increased vessel traffic and dredging could deter whales or increase vessel strikes. Noise from dredging could also deter whales or interrupt communications.	Avoid noisy dredging operations during time of migration off Fremantle. Limit the spread of vessel movements entering and leaving the port.	L (4)
Environmental value: Listed and significant fauna- migratory shorebirds and seabirds					
6.4	Decline in abundance and breeding success due to impacts on habitat and prey species	M (9)	Port expansion not likely to remove additional sections of coastline. Bioaccumulation of contaminants through the food chain could negatively affect survival and/or breeding success, though an open coast reduces risk of ingesting contaminate prey. Birds largely nesting on nearby islands.	Use PIANC Working with Nature principles to create niche areas for birds to forage and incorporate coastal stretches for birds to nest and move up shore as sea level rises. Areas of contaminated sediments could be removed to reduce risk of bioaccumulation.	L (4)

Ref#	Issue	Harbour development unmitigated risk and justification		Harbour development mitigation and risk	
Environmental value: Regionally significant spawning / nursery area					
7	Fish species that spend their whole life cycles in the estuary (i.e. yellowtail flathead, black bream) may be negatively impacted by habitat degradation and environmental changes	M (9)	Discrete self-replenishing stocks will have limited capacity to recover if stocks are depleted. Already an operating port and species still occurring, but there may be some risk of impacting populations occurring in the estuary if port expansion impacts water quality. Deepening the channel may further saline waters upstream and impact some fish species. Black bream mainly spawning upstream and using the middle to upper estuary as juveniles and adults.	Use PIANC Working with Nature principles to create fish friendly habitat. Manage dredge plume for tidal movements and water circulation. Install a silt screen.	L (4)
Environmental value: Regionally significant migratory pathways					
8	Negative impacts from increased development to fish and invertebrate species that migrate to and from estuary and oceanic waters to complete their lifecycle	M (9)	Suspended sediments and noise from dredging and vessels may impact on larval recruitment and adult migration between the open coast and the Estuary, as well as spawning in coastal waters. Habitat degradation from port operations may reduce abundances of some species in the lower reaches of the estuary.	Time dredging operations to avoid peak recruitment, migration and spawning periods. Install a silt screen to limit spread of sediments. Design port to minimise vessel movement i.e. less turning and manoeuvring which would limit disturbance to sediments.	L (4)
Environmental value: Swan Estuary Marine Park					
9	Degradation of marine park through upstream flow on effects of increased development and environmental change	M (9)	Port operates right in the mouth of the estuary but has been doing so for a long time. Environment already highly modified from previous development of the inner harbour and deepening the channel may cause more saline waters to move further upstream.	Use PIANC Working with Nature principles to create niche habitats that will benefit species using the marine park. Manage dredge plume for tidal movements and water circulation. Install a silt screen. Have first strike response kits in place to respond to level 2/3 oil spills as a minimum.	L (4)
Environmental value: Coastal processes					
10	Increased erosion and inundation of shorelines from rising sea levels, storms and changes to sediment transport	M (9)	Depending of channel may cause some changes to sediment transport. Fremantle Port expected to be impacted by erosion at Port Beach in the medium term. Port Beach listed as 'extreme' risk for erosion.	Use PIANC Working with Nature principles to engineer long lasting solutions for coastal erosion if shipping channel has a significant impact on sediment transport.	L (4)

3.2.2 Social values

A total of 17 issues were assessed for *Stage 1 expanded issues and risks* for Fremantle, which comprised of seven high, nine medium and one low risk (Appendix 2). Four of the of the high risk issues related to recreational and commercial fishing, and in particular, impacts fishing spots and a suitable environment for fished species. Increased turbidity from dredge plumes posed a high risk for recreational swimming, and erosion at popular beaches, such as Bathers Beach and Arthurs Head posed a high risk to landscape/visual amenity and tourism.

This report represents a rapid assessment within a short time-frame of the most important social values for Fremantle. The risk assessments were based on very generalised locations of possible harbour footprints and it is recognised that further stakeholder engagement is required to refine the risk assessment.

3.2.2.1 Cumulative pressures

A synthesis of the social issues identified for Fremantle in *Stage 1 Expanded issues and risks* resulted in 13 'rolled up' issues (Appendix 3) that were used in *Stage 3 preliminary unmitigated and mitigated risk assessment* (Appendix 4). A summarised table of the preliminary unmitigated and mitigated risks is given in Table 17. Most risks to social values were considered low to medium. Climate change posed a high risk to recreational and commercial fishing due to shifts in the distribution of fished species, as well as to landscape/visual amenity and tourism due to the impacts of erosion and inundation of the coastline. Harbour development posed a high risk to commercial fisheries, and a medium risk to most other values. Overall, there were four issues where the cumulative pressure risk score was considered high.

Table 17: Summarised preliminary unmitigated and mitigated risk assessment for marine and estuarine social values in Fremantle.

Full table showing risk evaluation in Appendix 4.

Ref#	Issue	Risk	Activity	Future unmitigated risk and justification		Future Harbour development mitigated and risk	
Social value: Heritage- Aboriginal							
1.1	Loss or degradation of important heritage sites with increased development	L (2)	Harbour development	M (6)	Valued sites occur adjacent to port footprint. The Swan River is a registered mythological site and the health of the river may be impacted on with increased use and development. However, the Swan River is already an impacted system from past port construction. Sea level rise could inundate or erode some popular gathering areas.	Remove contaminated sediments associated with port operation. Dredge without overflow and discharge sediments safely. Use a silt screen if conditions permit and time dredging operations to avoid spread of sediments upstream as much as possible. Design port to minimise vessel movement i.e. less turning and manoeuvring which would limit disturbance to sediments.	L (4)
			Climate change	M (9)			M (9)
			Other industrial and urban growth	L (4)			L (4)
			Cumulative pressure	*M (9)*	*Already a heavily developed region.*		*M (9)*
Social value: Heritage- Maritime/historic							
1.2	Loss or degradation of important historical sites with increased development	L (2)	Harbour development	L (4)	No registered sites occur directly in expanded port footprint, but they do occur in the vicinity.	No mitigation.	L (4)
			Climate change	L (4)			L (4)
			Other industrial and urban growth	L (4)			L (4)
			Cumulative pressure	*L (4)*	*Already a heavily developed region and further development unlikely to have a significant impact on registered sites.*		*L (4)*
Social value: Public health- Recreational water quality							
2.1	Increased safety concerns for primary and secondary contact with water due to decreased water quality	L (2)	Harbour development	M (6)	Recreational water quality expected to meet relevant environmental quality guidelines and remain safe due to mixing with oceanic waters and dispersal of any contaminants etc. Poor water quality extending upstream of port may impact on recreational water use and swimming off river beaches. Based on bacteria monitoring, South Beach, Bathers Beach, Port Beach and Leighton Beach are considered safe for swimming most of the time. Other industrial and urban growth more likely to impact on water quality further upstream.	Remove contaminated sediments associated with port operation. Dredge without overflow and discharge sediments safely. Time dredging operations with water circulation to avoid spread of sediments. Use a silt screen if conditions permit. Design port to minimise vessel movement i.e. less turning and manoeuvring which would limit disturbance to sediments. Monitor water quality regularly to detect any health concerns.	L (4)
			Climate change				
			Other industrial and urban growth	L (4)			L (4)
			Cumulative pressure	*M (6)*	*Perceptions of water quality would change with each person. The Estuary and coastal areas are popular recreational areas which have been occurring alongside a major operating port.*		*L (4)*

Ref#	Issue	Risk	Activity	Future unmitigated risk and justification		Future Harbour development mitigated and risk	
Social value: Public health- Seafood quality							
2.2	Decrease in health of shellfish and fish with increased contamination in waters and sediments	M (6)	Harbour development	M (9)	The Department of Health does not recommend eating shellfish outside of commercial harvesting. Fish such as black bream have very low levels of contaminants and are currently considered safe to eat. Though, over time, this may continue to accumulate to unsafe levels if contaminant levels are increased in the environment. Decrease in seafood quality would impact on favourite past times and social gatherings. Contamination may increase with port construction and operation, though contaminants may disperse and dilute with exchange with oceanic waters. Would reduce recreational and commercial fishing as well as aquaculture if contamination levels exceeded guidelines. May cause death and wash up of marine life. Seafood quality more likely to be affected upstream rather than in coastal waters. Other industrial and urban growth more likely to impact on seafood quality further upstream, though these effects may flow downstream.	Remove contaminated sediments associated with port operation. Dredge without overflow and discharge sediments safely. Design port to minimise vessel movement i.e. less turning and manoeuvring which would limit disturbance to sediments. Monitor water quality regularly to detect any health concerns.	L (4)
			Climate change				
			Other industrial and urban growth	M (9)			M (9)
			Cumulative pressure	*M (9)*	*Already an operating port. Contaminants already found in some species.*		*M (9)*
Social value: Social and community: Recreational fishing							
3.1	Decrease in recreational fishing due to restrictions around port area and the loss of popular fished species due to impacts to migration pathway	M (9)	Harbour development	M (9)	Reduction or loss of popular fished species in the estuary due to interruptions in migration/recruitment into/out of the estuary during dredging campaigns. Depends on timing of dredging. Only one entry/exit point for fish exchanging between the ocean and estuary. Fishing important to many people in the estuary. Port expansion may cause temporary exclusion zones due to safety reasons and will impact on fishing popular species in the inner harbour (i.e. mackerel, squid, snapper, tailor), as well as at South Mole, North Mole, Rous Head and north and south of the entrance. Rising sea temperatures may cause shifts in fish distributions. Other industrial and urban growth more likely to impact on fishing further upstream, though these effects may flow downstream.	Use PIANC Working with Nature principles to engineer ecological niche areas for valuable species, as well as fisher friendly structures. Avoid dredging during spawning and migrations periods as well as peak fishing periods around the Inner Harbour. Rehabilitate seagrass meadows now to avoid a lag in ecosystem functioning, if port is predicted to impact on coastal meadows.	L (4)
			Climate change	H (12)			H (12)
			Other industrial and urban growth	M (9)			M (9)
			Cumulative pressure	*H (16)*	*Recreational fishing is a strong social value in the region. Current risks to recreational fishing likely higher in the Estuary than along the coastline.*		*H (12)*
Social value: Social and community: Recreational swimming							
3.2	Increased turbidity at popular swimming beaches from dredge plumes	L (4)	Harbour development	M (9)	No swimming beaches will be directly removed in proposed port expansion footprint, though some impacts may still occur to prevent swimming i.e. turbidity. People would likely avoid swimming due to aesthetics of turbid water, or perceived low health and safety. Would be temporary. After dredging of the port and channels in 2010, water clarity was affected at Preston Point beach, Bathers Beach, Fremantle SLSC and Port Beach. Sea level rise and erosion could impact access points for beaches that are used for swimming.	Time dredging operations with water circulation to avoid spread of sediments. Use a silt screen if conditions permit. Design port to minimise vessel movement i.e. less turning and manoeuvring which would limit disturbance to sediments.	L (4)
			Climate change	M (6)			M (6)
			Other industrial and urban growth	L (4)			L (4)
			Cumulative pressure	*M (9)*	*Swimming currently considered safe for beaches along coasts and in the river, and there are multiple beaches to access for the purposes of swimming.*		*M (6)*
Social value: Social and community: Recreational boating access							
3.3	Delays in passage through entrance channel during dredging/expansion works	Low (3)	Harbour development	M (6)	Entry/exit may be restricted to a narrow band during dredging and cause a bottleneck of recreational vessels during high peak times. Only temporary.	Avoid dredging operations during peak boating periods, i.e. summer, and give notice to boat users about the potential time delays in passage through Inner Harbour.	L (4)
			Climate change	L (4)			L (4)
			Other industrial and urban growth	L (4)			L (4)
			Cumulative pressure	*M (6)*	*Climate change have impacts for boat ramps further upstream, but not in area considered for port footprint.*		*L (4)*

Ref#	Issue	Risk	Activity	Future unmitigated risk and justification		Future Harbour development mitigated and risk	
Social value: Social and community: Marina facilities							
3.4	Reduced use of marina facilities with increased development	L (2)	Harbour development	M (6)	Increased water turbidity at marinas may occur due to dredging and increased vessel use and may be perceived as a reduction in quality. Depends on water flow and timing of dredging. Port expansion footprint does not remove any marina facilities. Sea level rise and erosion may impact on some marine facilities.	Time dredging operations with water circulation to avoid spread of sediments. Use a silt screen if conditions permit. Design port to minimise vessel movement i.e. less turning and manoeuvring which would limit disturbance to sediments.	L (4)
			Climate change	M (9)			M (9)
			Other industrial and urban growth	L (4)			L (4)
			Cumulative pressure	*M (9)*	*Marinas likely to be upgraded over time rather than removed due to other further development. Climate change likely biggest threat if there is insufficient set back of coastal structures or lack of protection from erosion and sea level rise.*		*M (9)*
Social value: Social and community: Educational and scientific values							
3.5	Decline in educational experiences due to degradation of estuarine habitats with increased use of the development in inner harbour.	L (2)	Harbour development	M (9)	Habitat either side of the inner harbour may degrade over time with increased development if not managed sufficiently. May impact participation in citizen science activities occurring in the estuary. May degrade reference sites for scientific studies. May deter educational groups visiting parts of the estuary. Other industrial and urban growth more likely to impact on value further upstream, though these effects may flow downstream.	Adopt PIANC Working with Nature principles maintain a functioning ecosystem.	L (4)
			Climate change	L (4)			L (4)
			Other industrial and urban growth	L (4)			L (4)
			Cumulative pressure	*M (9)*	*Already a heavily developed area and value is still important and ongoing. Climate change won't necessarily cause a decline in experiences.*		*L (4)*
Social value: Social and community: Landscape and visual amenity							
3.6	Less visitation due to increased development negatively impacting on the landscape and visual amenity	L (4)	Harbour development	M (9)	Less scenic enjoyment due to sightings of dredge plumes and increased vessel traffic. Only temporary, however may leave a negative impression on tourists and cruise ships entering the harbour. Erosion at Bathers Beach and Arthurs Head would reduce visual amenity and enjoyment of the landscape. Bathers Beach is popular with locals and tourists due to the range of amenities available right near the beach.	Manage dredging with water circulation to reduce spread of plumes. Use a silt curtain if allowable. Avoid dredging during peak tourism periods.	L (4)
			Climate change	H (12)			H (12)
			Other industrial and urban growth	L (4)			L (4)
			Cumulative pressure	*H (12)*	*Attractions of Fremantle will vary per person. Port already operating and obvious in the landscape.*		*H (12)*
Social value: Business, industry and commercial: Tourism							
4.1	Loss of tourism due to increased development, loss of marine life and environmental change	L (4)	Harbour development	M (6)	Reduced aesthetic quality during dredging campaigns/expansion works for passengers on cruise ships entering the port. Less scenic enjoyment due to sightings of dredge plumes and increased vessel traffic. Only temporary, however may leave a negative impression on tourists and cruise ships entering the harbour. Erosion at Bathers Beach and Arthurs Head would reduce visual amenity and enjoyment of the landscape. Bathers Beach is popular with locals and tourists due to the range of amenities available right near the beach. Other industrial and urban growth could contribute to poor water quality and habitat degradation further upstream but could also attract more tourists due to increased facilities.	Adopt PIANC Working with Nature principles to maintain a functioning ecosystem. Manage dredging with water circulation to reduce spread of plumes. Use a silt curtain if allowable. Avoid dredging during peak tourism periods.	L (4)
			Climate change	H (12)			H (12)
			Other industrial and urban growth	L (4)			L (4)
			Cumulative pressure	*H (12)*	*Tourism is a major economic driver for Fremantle, and the port footprint occurs right in the hub of popular activities for tourists. Although, it is already an operating port and Fremantle is also popular for its maritime attractions.*		*H (12)*

Ref#	Issue	Risk	Activity	Future unmitigated risk and justification		Future Harbour development mitigated and risk	
Social value: Business, industry and commercial: Commercial fisheries							
4.2	Decrease in commercial catches due to interruption to migration/recruitment of fishes through the entrance channel during dredging/expansion works	M (6)	Harbour development	H (12)	Commercial fisheries are not operating heavily in the port, Deep Water Channel or Gage Roads, however commercially fished species do use the harbour and estuary during their life cycles, which may be impacted upon with port expansion. Seagrass meadows may be impacted by increased turbidity from dredging and vessel use. Other industrial and urban growth could contribute to poor water quality and habitat degradation further upstream. Climate change would influence the distributions of fished species.	Use PIANC Working with Nature principles to engineer ecological niche areas for valuable species, as well as fisher friendly structures. Avoid dredging during spawning and migration periods. Rehabilitate seagrass meadows now to avoid a lag in ecosystem functioning, if port is predicted to impact on coastal meadows.	L (4)
			Climate change	H (12)			H (12)
			Other industrial and urban growth	M (9)			M (9)
			Cumulative pressure	*H (16)*	*Fisheries operating in the region would rely on a healthy estuarine environment and coastal environment i.e. seagrass meadows.*		*H (12)*
Social value: Business, industry and commercial: Aquaculture							
4.3	Reduced water quality of the Inner Harbour would impact on intake water for aquaculture operations	L (4)	Harbour development	M (9)	Australian Centre for Applied Aquaculture Research uses water from the Inner Harbour. Expansion of the port may reduce water quality and it could become costly to treat or filter intake water to use for aquaculture tanks. Already an operating port.	Avoid dredging during aquaculture water intake operations. Design port to minimise vessel movements and reduce turbidity. Remove contaminated sediments.	L (4)
			Climate change	L (4)			L (4)
			Other industrial and urban growth	L (4)			L (4)
			Cumulative pressure	*M (9)*	*The ACAAR has supported projects such as restocking of prawns in the Swan Estuary. The research sector of ACAAR is recognised nationally and internationally.*		*L (4)*

3.2.2.2 Harbour development pressures

A summary of harbour development related issues and risks for social values in Fremantle is given in Table 18. Commercial fisheries was assigned a high risk in relation to harbour development due to the potential impact the activity may have on fished species that migrate through the Inner Harbour, using the estuary and coastal areas to complete their life cycles. This includes a potential impact to the nearby seagrass meadows from dredging. The risk could be reduced to a low risk if ecological niche areas were engineered for important species, as well as fisher friendly structures considered. It is also recommended that dredging during peak spawning and migration periods is avoided and that establishment of new seagrass meadows could help to avoid a lag in ecosystem functioning. The medium risks assigned for all other harbour development related issues could all be reduced to low if the suggested mitigation measures were feasible and adopted (Table 18).

Table 18: Summarised preliminary unmitigated and mitigated risk assessment of marine and estuarine social values in relation to harbour development in Fremantle.

Full table in Appendix 4.

Ref#	Issue	Harbour development risk and justification		Harbour development mitigation and risk	
Social value: Heritage- Aboriginal					
1.1	Loss or degradation of important heritage sites with increased development	M (6)	Valued sites occur adjacent to port footprint. The Swan River is a registered mythological site and the health of the river may be impacted on with increased use and development. However, the Swan River is already an impacted system from past port construction.	Remove contaminated sediments associated with port operation. Dredge without overflow and discharge sediments safely. Use a silt screen if conditions permit and time dredging operations to avoid spread of sediments upstream as much as possible. Design port to minimise vessel movement i.e. less turning and manoeuvring which would limit disturbance to sediments.	L (4)
Social value: Heritage- Maritime/historic					
1.2	Loss or degradation of important historical sites with increased development	L (4)	No registered sites occur directly in expanded port footprint, but they do occur in the vicinity.	No mitigation.	L (4)
Social value: Public health- Recreational water quality					
2.1	Increased safety concerns for primary and secondary contact with water due to decreased water quality	M (6)	Recreational water quality expected to remain safe due to mixing with oceanic waters and dispersal of any contaminants etc. Based on bacteria monitoring, South Beach, Bathers Beach, Port Beach and Leighton Beach are considered safe for swimming most of the time.	Remove contaminated sediments associated with port operation. Dredge without overflow and discharge sediments safely. Time dredging operations with water circulation to avoid spread of sediments. Use a silt screen if conditions permit. Design port to minimise vessel movement i.e. less turning and manoeuvring which would limit disturbance to sediments. Monitor water quality regularly to detect any health concerns.	L (4)
Social value: Public health- Seafood quality					
2.2	Decrease in health of shellfish and fish with increased contamination in waters and sediments	M (9)	Eating shellfish is not recommended outside of commercial harvesting. Fish such as black bream already have very low levels of contaminants and over time this may continue to accumulate to unsafe levels if contaminant levels are increased. Decrease in seafood quality would impact on favourite past times and social gatherings. Contamination may increase with port construction and operation, though contaminants may disperse and dilute with exchange with oceanic waters. Would reduce recreational and commercial fishing as well as aquaculture if contamination levels exceeded guidelines. May cause death and wash up of marine life. Seafood quality more likely to be affected upstream rather than in coastal waters.	Remove contaminated sediments associated with port operation. Dredge without overflow and discharge sediments safely. Design port to minimise vessel movement i.e. less turning and manoeuvring which would limit disturbance to sediments. Monitor water quality regularly to detect any health concerns.	L (4)
Social value: Social and community: Recreational fishing					
3.1	Decrease in recreational fishing due to restrictions around port area and the loss of popular fished species due to impacts to migration pathway	M (9)	Reduction or loss of popular fished species in the estuary due to interruptions in migration/recruitment into/out of the estuary during dredging campaigns. Depends on timing of dredging. Only one entry/exit point for fish exchanging between the ocean and estuary. Fishing important to many people in the estuary. Port expansion may cause temporary exclusion zones due to safety reasons and will impact on fishing popular species in the inner harbour (i.e. mackerel, squid, snapper, tailor), as well as at South Mole, North Mole, Rous Head and north and south of the entrance.	Use PIANC Working with Nature principles to engineer ecological niche areas for valuable species, as well as fisher friendly structures. Avoid dredging during spawning and migrations periods as well as peak fishing periods around the Inner Harbour. Rehabilitate seagrass meadows now to avoid a lag in ecosystem functioning, if port is predicted to impact on coastal meadows.	L (4)
Social value: Social and community: Recreational swimming					
3.2	Increased turbidity at popular swimming beaches from dredge plumes	M (9)	No swimming beaches will be directly removed in proposed port expansion footprint, though some impacts may still occur to prevent swimming i.e. turbidity. People would likely avoid swimming due to aesthetics of turbid water, or perceived low health and safety. Would be temporary. After dredging of the port and channels in 2010, water clarity was affected at Preston Point beach, Bathers Beach, Fremantle SLSC and Port Beach.	Time dredging operations with water circulation to avoid spread of sediments. Use a silt screen if conditions permit. Design port to minimise vessel movement i.e. less turning and manoeuvring which would limit disturbance to sediments.	L (4)

Ref#	Issue	Harbour development risk and justification		Harbour development mitigation and risk	
Social value: Social and community: Recreational boating access					
3.3	Delays in passage through entrance channel during dredging/expansion works	M (6)	Entry/exit may be restricted to a narrow band during dredging and cause a bottleneck of recreational vessels during high peak times. Only temporary.	Avoid dredging operations during peak boating periods, i.e. summer, and give notice to boat users about the potential time delays in passage through Inner Harbour.	L (4)
Social value: Social and community: Marina facilities					
3.4	Reduced use of marina facilities with increased development	M (6)	Increased water turbidity at marinas may occur due to dredging and increased vessel use and may be perceived as a reduction in quality. Depends on water flow and timing of dredging. Port expansion footprint does not remove any marina facilities.	Time dredging operations with water circulation to avoid spread of sediments. Use a silt screen if conditions permit. Design port to minimise vessel movement i.e. less turning and manoeuvring which would limit disturbance to sediments.	L (4)
Social value: Social and community: Educational and scientific values					
3.5	Decline in educational experiences due to degradation of estuarine habitats with increased use of the development in inner harbour.	M (9)	Habitat either side of the inner harbour may degrade over time with increased development if not managed sufficiently. May impact participation in citizen science activities occurring in the estuary. May degrade reference sites for scientific studies. May deter educational groups visiting parts of the estuary.	Adopt PIANC Working with Nature principles maintain a functioning ecosystem.	L (4)
Social value: Social and community: Landscape and visual amenity					
3.6	Less visitation due to increased development negatively impacting on the landscape and visual amenity	M (9)	Less scenic enjoyment due to sightings of dredge plumes and increased vessel traffic. Only temporary, however may leave a negative impression on tourists and cruise ships entering the harbour.	Manage dredging with water circulation to reduce spread of plumes. Use a silt curtain if allowable. Avoid dredging during peak tourism periods.	L (4)
Social value: Business, industry and commercial: Tourism					
4.1	Loss of tourism due to increased development, loss of marine life and environmental change	M (6)	Reduced aesthetic quality during dredging campaigns/expansion works for passengers on cruise ships entering the port. Less scenic enjoyment due to sightings of dredge plumes and increased vessel traffic. Only temporary, however may leave a negative impression on tourists and cruise ships entering the harbour.	Adopt PIANC Working with Nature principles to maintain a functioning ecosystem. Manage dredging with water circulation to reduce spread of plumes. Use a silt curtain if allowable. Avoid dredging during peak tourism periods.	L (4)
Social value: Business, industry and commercial: Commercial fisheries					
4.2	Decrease in commercial catches due to interruption to migration/recruitment of fishes through the entrance channel during dredging/expansion works	H (12)	Commercial fisheries are not operating heavily in the port, Deep Water Channel or Gage Roads, however commercially fished species do use the harbour and estuary during their life cycles, which may be impacted upon with port expansion. Seagrass meadows may be impacted by increased turbidity from dredging and vessel use.	Use PIANC Working with Nature principles to engineer ecological niche areas for valuable species, as well as fisher friendly structures. Avoid dredging during spawning and migration periods. Establish new seagrass meadows now to avoid a lag in ecosystem functioning, if port is predicted to impact on coastal meadows.	L (4)
Social value: Business, industry and commercial: Aquaculture					
4.3	Reduced water quality of the Inner Harbour would impact on intake water for aquaculture operations	M (9)	Australian Centre for Applied Aquaculture Research uses water from the Inner Harbour. Expansion of the port may reduce water quality and it could become costly to treat or filter intake water to use for aquaculture tanks. Already an operating port.	Avoid dredging during aquaculture water intake operations. Design port to minimise vessel movements and reduce turbidity. Remove contaminated sediments.	L (4)

3.3 Kwinana

3.3.1 Environmental values

A total of 66 environmental issues were assessed for *Stage 1 expanded issues and risks* for Kwinana, which comprised of 38 high, 28 medium and two low risks (Appendix 2). Overarching all of the issues is an integral functioning ecosystem, which was given a high risk in the face of increased use and development in Cockburn Sound. Ten of the high risk issues related to water quality, and in particular, impacts on nutrients and light attenuation/turbidity due to dredging, contamination due to oil/fuel spills, brine discharge increasing salinity in localised areas, poor flushing along the eastern and southern regions of Cockburn Sound, legacy issues from groundwater and impacts of climate change on temperature, pH and dissolved oxygen. Twelve high risks were assigned to listed and significant fauna and included loss of important habitat (i.e. Kwinana Shelf and shorelines) for bottlenose dolphins, little penguins, fairy terns and migratory birds, loss of life in due to an increase in vessel strikes and entanglement in fishing gear and starvation due to decreased prey abundance. Nine high risks related to species in which Cockburn Sound is a regionally significant spawning/nursery area, such as pink snapper, southern garfish, whitebait and blue swimmer crabs. Marine heatwaves, loss of seagrass and altered hydrological conditions were the issues identified for these species. Marine heatwaves were also identified as a high risk for seagrass meadows, along with poor water quality facilitating sulphide intrusion and poor light availability from dredging and propeller wash limiting growth. The risk of an increase in invasive species was high due an increase in vessel visitation and Cockburn Sound having suitable environmental conditions for establishment. Inundation and erosion of localised areas in Cockburn Sound and Shoalwater Islands Marine Park was considered a high risk under a changing climate.

This report represents a rapid assessment within a short time-frame of the most important environmental values for Kwinana. The risk assessments were based on very generalised locations of possible harbour footprints and it is recognised that further stakeholder engagement is required to refine the risk assessment.

3.3.1.1 Cumulative pressures

A synthesis of the issues identified for Kwinana in *Stage 1 Expanded issues and risks* resulted in 20 ‘rolled up’ issues (Appendix 3) that were used in *Stage 3 preliminary unmitigated and mitigated risk assessment* (Appendix 4). A summarised table of the preliminary unmitigated and mitigated risks is given in Table 19. Most of the high risks were associated with climate change which had impacts on water quality, seagrass habitat, listed and significant fauna, regionally significant spawning/nursery areas, Shoalwater Islands Marine Park and coastal processes. Harbour development was associated with nine high risks in relation to integral ecosystem functioning, biological diversity, water quality, seagrass habitat, listed and significant fauna and regionally significant spawning/nursery area. Other industrial and urban growth posed a high risk for integral functioning ecosystem, water quality and little penguins. Overall, there were 14 issues where the cumulative pressure risk score was considered high, and for water quality the cumulative pressure was considered extreme.

Table 19: Summarised preliminary unmitigated and mitigated risk assessment for marine and estuarine environmental values in Kwinana.

Full table showing risk evaluation in Appendix 4.

Ref #	Issue	Current risk	Activity	Risk	Future unmitigated risk and justification	Future harbour development mitigated risk	
Environmental value: Integral functioning ecosystem							
1	Decrease in ecosystem functioning with increased use and development in Cockburn Sound	H (12)	Harbour development	H (12)	Region has improved over time but has not fully recovered from significant impacts on ecosystem functioning. Localised losses of ecosystem functioning are currently occurring. Port construction would reduce available habitat for marine life e.g. Kwinana Shelf, and proposed channel would remove seagrass. Water quality may deteriorate with increased use of CS. Climate change would change the functioning, but not necessarily cause a *decrease* if new species adapt to new conditions.	Use PIANC Working with Nature principles to engineer port structures and niche habitats. Rehabilitate seagrass meadows now before development occurs to avoid a lag in ecosystem functioning.	M (8)
			Climate change	M (6)			M (6)
			Other industrial and urban growth	H (12)			H (12)
			Cumulative pressure	*H (16)*	*The 2018 DPSIR report states "[CS] will be characterised by overlapping residential, commercial and industrial development footprints leading to cumulative impacts and further declines in abundance and diversity of key biota, if not appropriately considered and managed".*		H (12)
Environmental value: Sheltered marine ecological community							
2	Alteration to the sheltered nature of Cockburn Sound where dredge channels and built structures may impact on calm waters	L (1)	Harbour development	M (9)	No modifications to Garden Island Causeway, however new dredge channels may significantly impact on circulation in some parts of the Sound. Built structures may impact circulation on a localised scale, potentially causing stagnate waters or re-directing water flow. Any changes to or impacts of circulation would vary seasonally.	Engineer port structures to reduce stagnate waters.	L (4)
			Climate change				
			Other industrial and urban growth	M (9)			M (9)
			Cumulative pressure	*M (9)*	*Unknown if channel is a definite between Garden and Carnac Island, as this channel likely to have more impact on CS than the port shipping channel.*		*M (9)*
Environmental value: Biological diversity							
3	Decrease in species diversity due to reduction of suitable habitat, invasive species and altered environmental conditions	M (9)	Harbour development	H (16)	Invasive species from increased vessel traffic could outcompete native species, and there are already invasive species in Cockburn Sound. Evidence that dredge channels provide suitable habitat for fishes, but so do seagrass meadows and limestone outcrops which may be impacted by dredging and port development. Port and other development likely to cause localised habitat loss, but mobile animals could move to other suitable areas if available in Cockburn Sound (however, nursery areas may be affected). Northern Cockburn Sound and Owen Anchorage have highest benthic diversity, which is also in footprint of proposed port and other dredging channels. Tropicalisation may not necessarily decrease biological diversity, as new species will be entering Cockburn Sound and some current species may have time to gradually adapt. Cockburn Sound already has a distinctive fish community due to the presence of large abundances of the tropical fish species.	Use PIANC working with nature principles to engineer ecological niche areas for valuable species. Fill in unused dredged depressions on Success and Parmelia Banks with sandy dredge spoil to create shallow sandy banks suitable for establishment of new seagrass meadows. Ensure continuation of the State Wide Array Surveillance Program (SWASP) for marine pests and regular reporting (invasive species are monitored and managed by DPIRD under the Fisheries Act). Engineer walls of built structures to be native species friendly in order to reduce establishment of invasive.	M (9)
			Climate change	M (6)			M (6)
			Other industrial and urban growth	M (9)			M (9)
			Cumulative pressure	*H (16)*	*Invasive species could impact system wide functioning and cause declines or local extinctions of populations.*		*M (9)*

Ref #	Issue	Current risk	Activity	Risk	Future unmitigated risk and justification	Future harbour development mitigated risk	
Environmental value: High level of water quality							
4	Decrease in quality of water due to increased development and altered environmental conditions	High (15)	Harbour development	High (15)	Port development and operation could increase nutrients and contaminants in the water column from run-off and resuspension of sediments with high nutrient and contaminant loading. Dredging and continual propeller wash would increase turbidity. More vessels in CS also increases the risk of oil and fuel spills. Climate change will elevate temperatures inside CS, which could contribute to more frequent toxic phytoplankton blooms as well as potential dead zones due to increases oxygen consumption. Climate change may also increase the incidence of flooding and increase acidification of the water. Other industrial and urban growth could increase the contamination of groundwater with excess nutrients and contaminants, which would then increase legacy issues for CS. Brine discharge from current and future desalination plants could negatively affect marine life.	Better management of groundwater, storm water and run off to reduce nutrients entering CS. Additional dredge management options should be considered e.g. timing around high flushing periods. Dredge without overflow and discharge sediments safely. Design port to minimise vessel movement i.e. less turning and manoeuvring which would limit disturbance to sediments. Check maintenance records of vessels before port entry to reduce risk of oil spill and have first strike response kits in place to respond to level 2/3 oil spills as a minimum. Increase vigilance with management of fuel transfers. Engineer structures to prevent coastal erosion if hydrology is changed from additional shipping channel.	M (8)
			Climate change	H (12)			H (12)
			Other industrial and urban growth	H (12)			H (12)
			Cumulative pressure	*E (20)*	*Currently localised areas with poor water quality, despite the system as a whole generally improving since the majority of industrial outflow was diverted to the SDOOL. Poor flushing, particularly in the southern regions of CS contributes to poor water quality. Development in CS is the cause of the water quality issues experienced currently and, in the past, thus future development would likely impact on water quality as well.*		*H (16)*
Environmental value: High level of sediment quality							
5	Decrease in quality of sediments due to increased development	H (12)	Harbour development	M (9)	Likely increase in contamination of sediments with increased shipping and port operations. No widespread surveys conducted since 2006 but expected elevated levels in footprint of port e.g. Kwinana Bulk Jetty and James Point. Due to poor flushing in Cockburn Sound sediments have a high organic load. Unless re-suspended, may be adequately supplying food for infauna, which also means biological oxygen demand will increase. There is a risk of exposing acid sulphate soils during development, particularly along eastern margin. However acid formation is unlikely given the sufficient neutralising capacity of the sediments. Nutrients from groundwater could settle in sediments.	Remove contaminated sediments created from port operations. Additional shipping channel may improve flushing and reduce nutrient loads in sediments. Test for potential acid sulphate soils before developing port infrastructure.	L (4)
			Climate change				
			Other industrial and urban growth	M (9)			M (9)
			Cumulative pressure	*H (12)*	*Localised areas of contaminated sediments already in CS and there are relatively new concerns about PFAS leaching into CS from contaminated areas on Garden Island. High organic load of sediments will remain high as long as flushing is poor and there are elevated nutrients in the water column.*		*M (9)*
Environmental value: Significant benthic communities and habitats- Seagrass							
6.1	Reduction in seagrass biomass and extent due to increased development and altered environmental conditions	H (12)	Harbour development	H (12)	Some removal of seagrass meadows could occur dredged shipping channel, but meadows not occurring along eastern margin where port infrastructure is likely. Prolonged reduction in photosynthesis due to poor light and sedimentation of meadows would cause a reduction in further growth and loss of current meadows. Turbidity will be high during dredging and from increased vessel use in the area. Dredged sediments may spread widely and impact seagrass on a wider scale if environmental conditions become unpredictable- this has happened elsewhere. Increased incidence of marine heatwaves may cause decrease in seagrass biomass, which has occurred at Shark Bay. Most seagrass meadows occurring along western and southern margins, so may be less likely at risk with increased industrial and urban growth. Though increased recreational vessel use in the already popular southern margins may increase nutrient loading from sewage dumping.	Manage dredging operations for tidal movements and water circulation. If conditions allow, use a silt screen during dredging. Additional dredge management options should be considered to protect benthic producers e.g. avoid winter when seagrass most vulnerable to low light. Avoid removal of seagrass meadows or rehabilitate new areas for seagrass colonisation now to prevent a lag effect in ecosystem functioning. Design port to minimise vessel movement i.e. less turning and manoeuvring which would limit disturbance to sediments.	M (9)
			Climate change	H (16)			H (16)
			Other industrial and urban growth	M (9)			M (9)
			Cumulative pressure	*H (16)*	*The 2018 DPSIR report states "Seagrass extent has increased appreciably since 2008, by ~130 hectares (ha), although health indicators suggest a continued decline [in shoot density] in some long-term monitoring sites, despite improved water quality". There is likely reduced seagrass growth due to sulphide intrusion facilitated by low dissolved oxygen levels and low light levels.*		*H (16)*

Ref #	Issue	Current risk	Activity	Risk	Future unmitigated risk and justification	Future harbour development mitigated risk	
Environmental value: Significant benthic communities and habitats- Other							
6.2 6.3 6.4	Degradation of other benthic communities due to increased development	M (6)	Harbour development	M (6)	Corals and rocky reef occur in Cockburn Sound, but not dominant habitats. These less dominant habitats could be removed during port or other development. Corals may also be smothered by dredged sediments. There would be continual disturbance to soft sediments and communities with vessel traffic which may decrease primary productivity and destabilise sediments due to the loss of microphytobenthos.	Use PIANC Working with Nature principles to engineer port structures that consider benthic communities in immediate vicinity, or engineer habitats to replace those removed through port development. Design port to minimise vessel movement i.e. less turning and manoeuvring which would limit disturbance to sediments.	L (4)
			Climate change				
			Other industrial and urban growth	M (6)			M (6)
			Cumulative pressure	*M (6)*	*Vessel use would cause some disturbance to soft sediment communities. Limited information to assess climate change impacts.*		*M (6)*
Environmental value: Listed and significant fauna- Fairy terns							
7.1	Decline in abundance and breeding success of fairy terns due to impacts on habitat and prey species	M (6)	Harbour development	H (12)	Loss of shoreline habitat due to development and/or sea level rise. Popular nesting spots have not been identified for eastern margin where port and other development most likely. Over time risk will increase with sea level rise. Lack of nesting sites would impact the population, so development on eastern margin may remove future nesting sites if sea level rise removes current sites. Bioaccumulation of contaminants through the food chain could negatively affect survival and/or breeding success. TBT is being reduced, though there is potential for other contaminants to impact populations. Port operations my increase contaminants in the water and sediments. Disturbance to current nesting sites possible due to human disturbance. Urban growth would increase risk of entanglement in fishing gear and rubbish.	Use PIANC Working with Nature principles to incorporate protected bird friendly areas for current and future use. Areas of contaminated sediments could be removed and contamination of the water column heavily regulated to reduce bioaccumulation.	M (6)
			Climate change	H (12)			H (12)
			Other industrial and urban growth	M (9)			M (9)
			Cumulative pressure	*H (12)*	*Feral predators also pose a risk to fairy tern abundance on nearby islands that can become connected to the mainland with sandbars. Current nesting sites around CS are considered secure, though impacts to other nesting sites close by would have some influence on the overall population- i.e. mating opportunities.*		*H (12)*
Environmental value: Listed and significant fauna- Little penguins							
7.2	Decline in abundance and breeding success of little penguins due to a decline in foraging habitat and prey species, as well as increased collisions with recreational vessels	H (10)	Harbour development	H (16)	Loss of habitat for foraging, particularly along Kwinana Shelf which is in port footprint, could negatively impact on populations. Starvation identified as one of the top two causes of death for penguins in the region, which can occur from reduced prey abundance from habitat degradation and/or sea temperatures. Tropical species could move in to replace lost species. Trauma from watercraft identified as one of the top two causes of death. Port footprint would compress the same number of recreational boats into a smaller area. Bioaccumulation of contaminants through the food chain could negatively affect survival and/or breeding success. Contaminants have been found in dead penguins but have not been identified as the definite cause of death. TBT use would be decreasing over time but would remain high in sediments and other contaminants could also impact populations. Urban growth would increase risk of entanglement in fishing gear and rubbish.	Use PIANC Working with Nature principles to create niche areas for prey species that also restricts recreational vessel use, as well as structures that would reduce the loss of Kwinana Shelf habitat. Reduce recreational boat speeds in a large area around the port which would lessen the risk overall for penguins if they use those areas. Given that the port footprint would condense recreational vessel use into a smaller area, educational programs could be developed for boat users. Areas of contaminated sediments could be removed to reduce risk of bioaccumulation. Restricted vessel routes and speed limits. Conduct regular surveys of shoreline to look for dead penguins and perform necropsies to determine cause of death. Reduce removal of wrack and damage to seagrass meadows. Reduce underwater noise pollution. Conduct boat cleaning above water line.	M (9)
			Climate change	H (12)			H (12)
			Other industrial and urban growth	H (16)			H (12)
			Cumulative pressure	*H (16)*	*Common causes of death already known and relate to further development and use of CS, as well as climate change. Some years have already experienced low breeding success. Increased vessel traffic and speed is a major risk and one that is hard to manage.*		*H (12)*

Ref #	Issue	Current risk	Activity	Risk	Future unmitigated risk and justification	Future harbour development mitigated risk	
Environmental value: Listed and significant fauna- Bottlenose dolphins							
7.3	Decline in resident and other populations due to a decline in foraging habitat, prey species and anthropogenic influences i.e. boat strikes, fishing entanglements and underwater noise	M (6)	Harbour development	H (16)	Loss of habitat, particularly along Kwinana Shelf which is used for foraging and a nursery, could negatively impact on resident dolphin populations. It has been suggested that dolphins would not be able to compensate for the loss of habitat on the Kwinana Shelf. Increased recreational use of the Kwinana area could increase illegal feeding of dolphins, increasing the risk of boat strikes and entanglement in fishing gear; this has been documented for CS. Increase in underwater noise from development and construction could deter dolphins from their usual habitats and interrupt communications between dolphins. Climate change would likely cause shifts in prey distributions, and this dolphins, or dolphins may adjust to new tropical species.	Use PIANC Working with Nature principles to create niche areas for dolphins to forage and design structures that would reduce the loss of Kwinana Shelf habitat. Avoid conducting noisy dredging operations and port maintenance (i.e. pile driving) during the breeding season when animals are socialising and calving. Engage Marine Mammal Observers to observe the occurrence of dolphins during the time development is occurring.	M (8)
			Climate change	H (12)			H (12)
			Other industrial and urban growth	M (9)			M (9)
			Cumulative pressure	*H (16)*	*Accumulated pressures may cause dolphins to leave CS, more so than cause direct death to dolphins, and would impact the value being present in CS.*		*H (12)*
Environmental value: Listed and significant fauna- Australian sea lion							
7.4	Lack of suitable haul out sites due to changing environmental conditions and anthropogenic disturbance	M (6)	Harbour development	L (4)	Additional haul out locations may be limited in Kwinana (due to development) if current haul out sites become unsuitable with a changing climate. Sea lions haul out where the environment is most suitable. Haul out locations are currently on islands, none have been identified for the mainland coasts of Cockburn Sound. Increase in disturbance at haul out sites of Carnac and Seal Island may be likely with increased recreational and large vessel traffic. Large vessels already operate in CS and sea lions may have become accustomed to their presence.	Restrict proximity of vessels to current haul out sites. Use PIANC Working with Nature principles and include potential haul out locations to maximise choice if sea lions need to shift from islands.	L (2)
			Climate change	M (9)			M (9)
			Other industrial and urban growth	M (9)			M (6)
			Cumulative pressure	*M (9)*	*No breeding populations around CS, only haul out locations. Even though haul out sites are not directly in CS, sea lions occur adjacent to CS and may still use the area for foraging. Also listed as Vulnerable under the EPBC Act.*		*M (9)*
Environmental value: Listed and significant fauna- migratory shorebirds and seabirds							
7.5	Decline in abundance and breeding success due to impacts on habitat and prey species	M (6)	Harbour development	H (12)	Sea level rise could inundate important shoreline habitat. Increased coastal development could remove important habitat. Bioaccumulation of contaminants through the food chain could negatively affect survival and/or breeding success. Starvation could occur like it does for penguins due to decreased food supply resulting from habitat degradation and rising sea temperatures. Birds would likely also feed outside of Cockburn Sound. Urban growth would increase risk of entanglement in fishing gear and rubbish.	Use PIANC Working with Nature principles to create niche areas for birds to forage and incorporate coastal stretches for birds to nest and move up shore as sea level rises. Areas of contaminated sediments could be removed to reduce risk of bioaccumulation.	M (6)
			Climate change	H (12)			H (12)
			Other industrial and urban growth	M (9)			M (9)
			Cumulative pressure	*H (16)*	*Coastal development and human disturbance may impact on birds using coastal areas. Popular sites for seabirds and shorebirds include surrounding islands, but it is unknown if stretches of mainland coastline are also significant. Death from starvation would have impacts at a population level. Migratory birds frequent the same or similar locations year after year due to reliable conditions, so any impacts to known forging or nesting sites may have greater implications for migration.*		*H (12)*

Ref #	Issue	Current risk	Activity	Risk	Future unmitigated risk and justification	Future harbour development mitigated risk	
Environmental value: Regionally significant spawning / nursery area- King George whiting							
8.1	Decline in abundance and loss of nursery area due to environmental changes and loss of habitat	L (2)	Harbour development	L (4)	Loss of habitat will negatively impact important nursery areas. Mangles Bay is an important nursery. Seagrass meadows occur here but it is unknown whether this is directly related to the occurrence of whiting in the area. Other seagrass areas not specifically mentioned as nursery areas, so may or may not be exclusive to Mangles Bay. Impacts to younger life stages would be felt at a population level. Unknown if future developments will occur in Mangles Bay, but the port footprint does not include the Bay and has limited direct removal of seagrass. Decline in water quality, including turbidity, may impact upon nursery areas if sediments spread.	Use PIANC Working with Nature principles to create fish friendly habitat which could be used as nursery areas. Do not dredge during peak nursery use in case suspended sediments spread with unfavourable conditions.	L (4)
			Climate change				
			Other industrial and urban growth	M (6)			M (6)
			Cumulative pressure	*M (6)*	*Fishery overall is currently considered sustainable and adequate. Any impacts to Mangles Bay may see disappearance of nursery areas in CS. Unknown what impacts climate change will have, so it is likely that the risk to the species will increase with more knowledge.*		*M (6)*
Environmental value: Regionally significant spawning / nursery area- Blue swimmer crab							
8.2	Decline in abundance and loss of nursery area due to environmental changes and loss of seagrass habitat	H (12)	Harbour development	M (9)	Current low abundances in CS attributed substantially to impacts of the 2011 marine heatwave and flooding events. Fishery remains closed to allow recovery. Loss of seagrass will negatively impact on recruitment. Mangles Bay, James Point and Jervoise Bay are the best recruitment sites for 0+, likely due to more seagrass cover. Port footprint will most likely not directly occur in these three areas, but some seagrass will likely be destroyed in shipping channel and turbidity from dredging and ship traffic may affect important seagrass areas. Crabs are mobile and could move to where conditions are more favourable.	Use PIANC Working with Nature principles to create crab friendly habitat and rehabilitate seagrass meadows now to prevent a lag in ecosystem functioning. Manage dredge and vessel generated turbidity to have least impact on seagrass meadows.	L (4)
			Climate change	H (16)			H (16)
			Other industrial and urban growth	M (9)			M (9)
			Cumulative pressure	*H (16)*	*Already a population under stress due to environmental influences.*		*H (16)*
Environmental value: Regionally significant spawning / nursery area- Pink snapper							
8.3	Decline in abundance and loss of significant spawning area due to loss of habitat, increase in suspended sediments and changing environmental conditions	M (9)	Harbour development	H (12)	Increasing temperatures may cause declines in abundance or alter shifts in spawning peaks and maturation as spawning is documented to occur within a certain temperature range. Dredged materials could impact the survival rates of larval stages and studies show mortality of larvae increased with increased exposure time to suspended sediments. Suspended sediments from dredging and vessel use would also impact seagrass meadows which are important for snapper. Spawning also takes place in surrounding bays outside of CS, though CS has been a nursery area since 1971. Loss of habitat could decrease the use of CS as a nursery area. Altered hydrological conditions from additional shipping channel may influence egg dispersal and survival. Any impacts to spawning or juvenile stages will influence adult population. Increased nutrients in the water column could increase the occurrence of toxic blooms that lead to fish kills. Overfishing may reduce population to unsustainable levels.	Use PIANC Working with Nature principles to create fish friendly habitat. Plan dredging to avoid snapper spawning and larval growth and design port to minimise vessel movement i.e. less turning and manoeuvring which would limit disturbance to sediments. Rehabilitate seagrass meadows now to avoid a lag in ecosystem functioning as some seagrass would likely be removed or impacted upon during port construction and operation. Engineer shipping channel to balance improved flushing with transport of eggs outside of CS.	M (6)
			Climate change	H (12)			H (12)
			Other industrial and urban growth	M (9)			M (9)
			Cumulative pressure	*H (16)*	*Pink snapper were restocked after 2015 fish kill incident. Eggs and larvae are sensitive to suspended sediments and spawning events are sensitive to environmental conditions, so a combination of these pressures in the future may cause a significant impact on the population in CS.*		*H (12)*

Ref #	Issue	Current risk	Activity	Risk	Future unmitigated risk and justification	Future harbour development mitigated risk	
Environmental value: Regionally significant spawning / nursery area- Whitebait							
8.4	Loss of favourable spawning area due to changes in environmental conditions	M (9)	Harbour development	M (9)	An increase in marine heatwaves would negatively impact spawning and lower catches resulted in the years following the 2011 marine heatwave. Altered hydrological conditions from additional channels (port and other channels) may influence egg dispersal and survival. Eggs are transported via water movement, and increased flushing may transport eggs out of nursery areas where they would be less protected.	Engineer shipping channel to balance improved flushing with transport of eggs outside of CS.	M (6)
			Climate change	H (16)			H (16)
			Other industrial and urban growth	M (9)			M (9)
			Cumulative pressure	*H (16)*	*Climate change impacts would likely be the greatest threat to whitebait in CS.*		*H (16)*
Environmental value: Regionally significant spawning / nursery area- Southern garfish							
8.5	Decline in abundance and loss of nursery area due to environmental changes and loss of seagrass habitat	H (12)	Harbour development	M (9)	Loss of seagrass would reduce feeding opportunities and decrease survival of eggs as garfish feed on seagrass and attach eggs to seagrass blades in Cockburn Sound. Some seagrass will likely be destroyed in shipping channel and turbidity from dredging and ship traffic may affect important seagrass areas. An increase in marine heatwaves would negatively impact stocks as the 2011 marine heatwave had a negative impact. Industrial and urban growth may contribute to poor water quality which would impact seagrass.	Use PIANC Working with Nature principles to create fish friendly habitat and potential nursery areas. Rehabilitate seagrass meadows now to avoid a lag in ecosystem functioning as some seagrass would likely be removed or impacted upon during port construction and operation. Do not dredge during peak egg and nursery periods in case suspended sediments spread with unfavourable conditions. Design port to minimise vessel movement i.e. less turning and manoeuvring which would limit disturbance to sediments. Shipping channel may help to increase flushing times and improve water quality and seagrass growth in some parts of CS.	L (4)
			Climate change	H (16)			H (16)
			Other industrial and urban growth	M (9)			M (9)
			Cumulative pressure	*H (16)*	*Stocks have been declining since 1990's and the fishery is vulnerable to collapse if it has a single year of poor recruitment.*		*H (16)*
Environmental value: Shoalwater Islands Marine Park							
9	Degradation of marine park due to flow on effects of poor water quality and declining biodiversity, as well as erosion of shorelines	M (8)	Harbour development	M (9)	Due to close proximity, impacts on water quality and marine biota in Cockburn Sound would have flow on affects to the marine park. Port operations and other industrial and urban growth may contribute to poor water quality. Majority of park mixes with open coastal waters which would help water quality. Increased erosion of the shorelines is a concern for the park and beach renourishment already occurs. Inappropriately designed moorings in Safety Bay and Mangles Bay have caused localised damage to seagrass. Tropicalisation of the region will likely occur with increasing temperatures but not necessarily cause degradation.	Use PIANC Working with Nature principles to engineer ecological niche areas for valuable species that use both CS and marine park. Reduce impacts to water quality as much as possible.	L (4)
			Climate change	H (12)			H (12)
			Other industrial and urban growth	M (9)			M (9)
			Cumulative pressure	*H (12)*	*The Park provides important habitat for little penguins, dolphins, sea lions, as well as occasional occurrences of southern right and humpback whales. Park has its own restrictions in place to help protect values.*		*H (12)*

Ref #	Issue	Current risk	Activity	Risk	Future unmitigated risk and justification	Future harbour development mitigated risk	
Environmental value: Coastal processes							
10	Increased erosion and inundation of shorelines from rising sea levels, storms and changes to sediment transport	M (8)	Harbour development	M (9)	Increased erosion and inundation at localised points within Cockburn Sound with increasing sea levels and storms. Changes to hydrological conditions may change alongshore sediment transport and erode shorelines. Already documented from the construction of Causeway, groynes and rock walls. Hydrological conditions may change with additional shipping channels	Use PIANC Working with Nature principles to engineer long lasting solutions for coastal erosion if shipping channel has a significant impact on sediment transport.	L (4)
			Climate change	H (12)			H (12)
			Other industrial and urban growth	M (9)			M (9)
			Cumulative pressure	*H (12)*	*Coastal erosion and inundation already affecting localised areas around CS.*		*H (12)*

3.3.1.2 Harbour development pressures

A summary of harbour development related issues and risks for environmental values in Kwinana is given in Table 20. As Cockburn Sound has not fully recovered from significant impacts on ecosystem functioning, a high risk was assigned to the value of integral functioning ecosystem in relation to harbour development. This high risk could be lowered to a medium risk if PIANC Working with Nature principles were adopted and included engineering port structures and niche habitats to improve ecosystem functioning. Rehabilitation of seagrass meadows in the near future would also help to prevent a lag in ecosystem functioning if harbour development was to occur in Cockburn Sound. Establishing new seagrass meadows is difficult so allowing an appropriate time frame for establishment needs to be considered.

Biological diversity was assigned a high risk in relation to harbour development due to an increase in introduced species and localised habitat loss from harbour development. The risk could be lowered to medium if mitigation measures include the adoption of PIANC Working with Nature principles to engineer niche areas and walls of built structures to promote growth of native species, as well as implementing additional monitoring measures to reduce incidence of marine pests. Filling in unused dredged depressions on Success and Parmelia Banks with sandy dredge spoil could help to create shallow sandy banks suitable for establishment of new seagrass meadows.

Water quality was given a high risk due to a potential increase in nutrients and contaminants in the water column from run-off and resuspension of sediments from harbour development and operation. The increase in nutrients together with increasing water temperatures could also cause more frequent toxic phytoplankton blooms. There is also an increased risk of oil and fuel spills within and around Cockburn Sound with increased vessel traffic. Some mitigation measures which may reduce the risk to a medium include such measures as improving the management of groundwater, storm water and run-off, additional dredge management considerations, minimising vessel movement through port design and having first strike response kits in place to deal with level 2/3 oil spills.

Reduction in seagrass biomass and extent was given a high risk in relation to harbour development largely due to the impact dredging and vessel movement within Cockburn Sound could have on light availability. A medium risk could be assigned if mitigation measures included additional management of dredging operations for tidal movements and water circulation and avoiding winter when seagrass most vulnerable to low light. The harbour could also be designed to minimise vessel movement in an attempt to reduce turbidity. Rehabilitation of seagrass meadow could also begin now to prevent a lag effect in ecosystem functioning.

Fairy terns, little penguins, bottlenose dolphins and migratory birds were considered to be at high risk of decline largely due to loss of habitat for foraging and nesting (i.e. Kwinana Shelf), bioaccumulation of contaminants through the food chain, and in addition for dolphins, an increase in underwater noise from harbour development and operation which could impact on communications and socialisation. Mitigation measures which could help to lower the risk to these listed and significant fauna include incorporating protected bird friendly areas within the harbour boundaries, limiting the loss of Kwinana Shelf habitat or creating additional niche foraging areas, removing contaminated sediments to reduce bioaccumulation. To further reduce the risk to bottlenose dolphins, noisy operations could be avoided during the breeding season when animals are socialising and calving, and Marine Mammal Observers could be engaged during development.

Cockburn Sound is a regionally important spawning and nursery area for pink snapper. The risk to pink snapper is high in relation to harbour development as dredged materials may impact on survival rates of eggs and larvae as well as impact on favoured seagrass habitat. In addition, alteration of hydrological conditions could influence the dispersal of eggs and an increase in nutrients could increase toxic phytoplankton blooms which could lead to fish kills. The high risk could be lowered to a medium risk if PIANC Working with Nature principles were adopted and included the creation of niche habitats favourable to pink snapper.

Dredging could be timed to avoid pink snapper spawning and larval growth and the harbour designed to minimise vessel movement and reduce disturbance to sediments. Seagrass meadows could also be rehabilitated in the near future to avoid a lag in ecosystem functioning.

Table 20: Summarised preliminary unmitigated and mitigated risk assessment of marine and estuarine environmental values in relation to harbour development in Kwinana.

Full table in Appendix 4.

Ref#	Issue	Harbour development risk and justification		Harbour development mitigation and risk	
Environmental value: Integral functioning ecosystem					
1	Decrease in ecosystem functioning with increased use and development in Cockburn Sound	H (12)	Region has improved over time but has not fully recovered from significant impacts on ecosystem functioning. Localised losses of ecosystem functioning are currently occurring. Port construction would reduce available habitat for marine life e.g. Kwinana Shelf, and proposed channel would remove seagrass.	Use PIANC Working with Nature principles to engineer port structures and niche habitats. Rehabilitate seagrass meadows now before development occurs to avoid a lag in ecosystem functioning.	M (8)
Environmental value: Sheltered marine ecological community					
2	Alteration to the sheltered nature of Cockburn Sound where dredge channels and built structures may impact on calm waters	M (9)	No modifications to Garden Island Causeway, however new dredge channel may significantly impact on circulation in some parts of the Sound. Built structures may impact circulation on a localised scale, potentially causing stagnate waters or re-directing water flow. Any changes to or impacts of circulation would vary seasonally.	Engineer port structures to reduce stagnate waters.	L (4)
Environmental value: Biological diversity					
3	Decrease in species diversity due to reduction of suitable habitat, invasive species and altered environmental conditions	H (16)	Invasive species from increased vessel traffic could outcompete native species, and there are already invasive species in Cockburn Sound. Evidence that dredge channels provide suitable habitat for fishes, but so do seagrass meadows and limestone outcrops which may be impacted by dredging and port development. Port likely to cause localised habitat loss, but mobile animals could move to other suitable areas if available in Cockburn Sound (however, nursery areas may be affected). Northern Cockburn Sound and Owen Anchorage have highest benthic diversity, which is also in footprint of proposed port shipping channel.	Use PIANC working with nature principles to engineer ecological niche areas for valuable species. Fill in unused dredged depressions on Success and Parmelia Banks with sandy dredge spoil to create shallow sandy banks suitable for establishment of new seagrass meadows. Ensure continuation of the State Wide Array Surveillance Program (SWASP) for marine pests and regular reporting (invasive species are monitored and managed by DPIRD under the Fisheries Act). Engineer walls of built structures to be native species friendly in order to reduce establishment of invasive.	M (9)
Environmental value: High level of water quality					
4	Decrease in quality of water due to increased development and altered environmental conditions	H (15)	Port development and operation could increase nutrients and contaminants in the water column from run-off and resuspension of sediments with high nutrient and contaminant loading. Dredging and continual propeller wash would increase turbidity. More vessels in CS also increases the risk of oil and fuel spills. Increased nutrients and elevated temperatures inside CS could contribute to more frequent toxic phytoplankton blooms as well as potential dead zones due to increases oxygen consumption.	Better management of groundwater, storm water and run off to reduce nutrients entering CS. Additional dredge management options should be considered e.g. timing around high flushing periods. Dredge without overflow and discharge sediments safely. Design port to minimise vessel movement i.e. less turning and manoeuvring which would limit disturbance to sediments. Check maintenance records of vessels before port entry to reduce risk of oil spill and have first strike response kits in place to respond to level 2/3 oil spills as a minimum. Increase vigilance with management of fuel transfers. Engineer structures to prevent coastal erosion if hydrology is changed from additional shipping channel.	M (8)
Environmental value: High level of sediment quality					
5	Decrease in quality of sediments due to increased development	M (9)	Likely increase in contamination of sediments with increased shipping and port operations. No widespread surveys conducted since 2006 but expected elevated levels in footprint of port e.g. Kwinana Bulk Jetty and James Point. Cockburn Sound would facilitate cargo and container shipping rather than mineral exports, so load spills unlikely. Due to poor flushing in Cockburn Sound sediments have a high organic load. Unless re-suspended, may be adequately supplying food for infauna, which also means biological oxygen demand will increase. There is a risk of exposing acid sulphate soils during development, particularly along eastern margin. However acid formation is unlikely given the sufficient neutralising capacity of the sediments. Nutrients from groundwater could settle in sediments.	Remove contaminated sediments created from port operations. Additional shipping channel may improve flushing and reduce nutrient loads in sediments. Test for potential acid sulphate soils before developing port infrastructure.	L (4)

Ref#	Issue	Harbour development risk and justification		Harbour development mitigation and risk	
Environmental value: Significant benthic communities and habitats- Seagrass					
6.1	Reduction in seagrass biomass and extent due to increased development and altered environmental conditions	H (12)	Some removal of seagrass meadows could occur dredged shipping channel, but meadows not occurring along eastern margin where port infrastructure is likely. Prolonged reduction in photosynthesis due to poor light and sedimentation of meadows would cause a reduction in further growth and loss of current meadows. Turbidity will be high during dredging and from increased vessel use in the area. Dredged sediments may spread widely and impact seagrass on a wider scale if environmental conditions become unpredictable- this has happened elsewhere.	Manage dredging operations for tidal movements and water circulation. If conditions allow, use a silt screen during dredging. Additional dredge management options should be considered to protect benthic producers e.g. avoid winter when seagrass most vulnerable to low light. Avoid removal of seagrass meadows or rehabilitate new areas for seagrass colonisation now to prevent a lag effect in ecosystem functioning. Design port to minimise vessel movement i.e. less turning and manoeuvring which would limit disturbance to sediments.	M (9)
Environmental value: Significant benthic communities and habitats- Other					
6.2 6.3 6.4	Degradation of other benthic communities due to increased development	M (6)	Corals and rocky reef occur in Cockburn Sound, but not dominant habitats. These less dominant habitats could be removed during port or other development. Corals may also be smothered by dredged sediments. There would be continual disturbance to soft sediments and communities with vessel traffic which may decrease primary productivity and destabilise sediments due to the loss of microphytobenthos.	Use PIANC Working with Nature principles to engineer port structures that consider benthic communities in immediate vicinity, or engineer habitats to replace those removed through port development. Design port to minimise vessel movement i.e. less turning and manoeuvring which would limit disturbance to sediments.	L (4)
Environmental value: Listed and significant fauna- Fairy terns					
7.1	Decline in abundance and breeding success of fairy terns due to impacts on habitat and prey species	H (12)	Loss of shoreline habitat due to development and/or sea level rise. Popular nesting spots have not been identified for eastern margin where port and other development most likely. Lack of nesting sites would impact the population, so development on eastern margin may remove future nesting sites if sea level rise removes current sites. Bioaccumulation of contaminants through the food chain could negatively affect survival and/or breeding success. TBT is being reduced, though there is potential for other contaminants to impact populations. Port operations my increase contaminants in the water and sediments.	Use PIANC Working with Nature principles to incorporate protected bird friendly areas for current and future use. Areas of contaminated sediments could be removed and contamination of the water column heavily regulated to reduce bioaccumulation.	M (6)
Environmental value: Listed and significant fauna- Little penguins					
7.2	Decline in abundance and breeding success of little penguins due to a decline in foraging habitat and prey species, as well as increased collisions with recreational vessels	H (16)	Loss of habitat for foraging, particularly along Kwinana Shelf which is in port footprint, could negatively impact on populations. Starvation identified as one of the top two causes of death for penguins in the region, which can occur from reduced prey abundance from habitat degradation and/or sea temperatures. Tropical species could move in to replace lost species. Trauma from watercraft identified as one of the top two causes of death. Port footprint would compress the same number of recreational boats into a smaller area. Bioaccumulation of contaminants through the food chain could negatively affect survival and/or breeding success. Contaminants have been found in dead penguins but have not been identified as the definite cause of death. TBT use would be decreasing over time but would remain high in sediments and other contaminants could also impact populations.	Use PIANC Working with Nature principles to create niche areas for prey species that also restricts recreational vessel use, as well as structures that would reduce the loss of Kwinana Shelf habitat. Reduce recreational boat speeds in a large area around the port which would lessen the risk overall for penguins if they use those areas. Given that the port footprint would condense recreational vessel use into a smaller area, educational programs could be developed for boat users. Areas of contaminated sediments could be removed to reduce risk of bioaccumulation. Restricted vessel routes and speed limits. Conduct regular surveys of shoreline to look for dead penguins and perform necropsies to determine cause of death. Reduce removal of wrack and damage to seagrass meadows. Conduct boat cleaning above water line. Reduce underwater noise pollution.	M (9)
Environmental value: Listed and significant fauna- Bottlenose dolphins					
7.3	Decline in resident and other populations due to a decline in foraging habitat, prey species and anthropogenic influences i.e. boat strikes, fishing entanglements and underwater noise	H (16)	Loss of habitat, particularly along Kwinana Shelf which is used for foraging and a nursery, could negatively impact on resident dolphin populations. It has been suggested that dolphins would not be able to compensate for the loss of habitat on the Kwinana Shelf. Increase in underwater noise from development and construction could deter dolphins from their usual habitats and interrupt communications between dolphins.	Use PIANC Working with Nature principles to create niche areas for dolphins to forage and design structures that would reduce the loss of Kwinana Shelf habitat. Avoid conducting noisy dredging operations and port maintenance (i.e. pile driving) during the breeding season when animals are socialising and calving. Engage Marine Mammal Observers to observe the occurrence of dolphins during the time development is occurring.	M (8)

Ref#	Issue	Harbour development risk and justification		Harbour development mitigation and risk	
Environmental value: Listed and significant fauna- Australian sea lion					
7.4	Lack of suitable haul out sites due to changing environmental conditions and anthropogenic disturbance	L (4)	Additional haul out locations may be limited in Kwinana (due to development) if current haul out sites become unsuitable with a changing climate. Sea lions haul out where the environment is most suitable. Haul out locations are currently on islands, none have been identified for the mainland coasts of Cockburn Sound. Increase in disturbance at haul out sites of Carnac and Seal Island may be likely with increased large vessel traffic. Large vessels already operate in CS and sea lions may have become accustomed to their presence.	Restrict proximity of vessels to current haul out sites. Use PIANC Working with Nature principles and include potential haul out locations to maximise choice is sea lions need to shift from islands.	L (2)
Environmental value: Listed and significant fauna- migratory shorebirds and seabirds					
7.5	Decline in abundance and breeding success due to impacts on habitat and prey species	H (12)	Increased coastal development could remove important habitat. Bioaccumulation of contaminants through the food chain could negatively affect survival and/or breeding success. Starvation could occur like it does for penguins due to decreased food supply resulting from habitat degradation. Birds would likely also feed outside of Cockburn Sound.	Use PIANC Working with Nature principles to create niche areas for birds to forage and incorporate coastal stretches for birds to nest and move up shore as sea level rises. Areas of contaminated sediments could be removed to reduce risk of bioaccumulation.	M (6)
Environmental value: Regionally significant spawning / nursery area- King George whiting					
8.1	Decline in abundance and loss of nursery area due to environmental changes and loss of habitat	L (4)	Loss of habitat will negatively impact important nursery areas. Mangles Bay is an important nursery. Seagrass meadows occur here but it is unknown whether this is directly related to the occurrence of whiting in the area. Other seagrass areas not specifically mentioned as nursery areas, so may or may not be exclusive to Mangles Bay. Impacts to younger life stages would be felt at a population level. Port footprint does not include the Bay and has limited direct removal of seagrass. Decline in water quality, including turbidity, may impact upon nursery areas if sediments spread.	Use PIANC Working with Nature principles to create fish friendly habitat which could be used as nursery areas. Do not dredge during peak nursery use in case suspended sediments spread with unfavourable conditions.	L (4)
Environmental value: Regionally significant spawning / nursery area- Blue swimmer crab					
8.2	Decline in abundance and loss of nursery area due to environmental changes and loss of seagrass habitat	M (9)	Fishery remains closed to allow recovery. Loss of seagrass will negatively impact on recruitment. Mangles Bay, James Point and Jervoise Bay are the best recruitment sites for 0+, likely due to more seagrass cover. Port footprint will most likely not directly occur in these three areas, but some seagrass will likely be destroyed in shipping channel and turbidity from dredging and ship traffic may affect important seagrass areas. Crabs are mobile and could move to where conditions are more favourable.	Use PIANC Working with Nature principles to create crab friendly habitat and rehabilitate seagrass meadows now to prevent a lag in ecosystem functioning. Manage dredge and vessel generated turbidity to have least impact on seagrass meadows.	L (4)
Environmental value: Regionally significant spawning / nursery area- Pink snapper					
8.3	Decline in abundance and loss of significant spawning area due to loss of habitat, increase in suspended sediments and changing environmental conditions	H (12)	Dredged materials could impact the survival rates of larval stages and studies show mortality of larvae increased with increased exposure time to suspended sediments. Suspended sediments from dredging and vessel use would also impact seagrass meadows which are important for snapper. Spawning also takes place in surrounding bays outside of CS, though CS has been a nursery area since 1971. Loss of habitat could decrease the use of CS as a nursery area. Altered hydrological conditions from additional shipping channel may influence egg dispersal and survival. Any impacts to spawning or juvenile stages will influence adult population. Increased nutrients in the water column could increase the occurrence of toxic blooms that lead to fish kills.	Use PIANC Working with Nature principles to create fish friendly habitat. Plan dredging to avoid snapper spawning and larval growth and design port to minimise vessel movement and reduce sediment disturbance. Rehabilitate seagrass meadows now to avoid a lag in ecosystem functioning as some seagrass would likely be removed or impacted upon during port construction and operation. Engineer shipping channel to balance improved flushing with transport of eggs outside of CS.	M (6)
Environmental value: Regionally significant spawning / nursery area- Whitebait					
8.4	Loss of favourable spawning area due to changes in environmental conditions	M (9)	Altered hydrological conditions from additional channel may influence egg dispersal and survival. Eggs are transported via water movement, and increased flushing may transport eggs out of nursery areas where they would be less protected.	Engineer shipping channel to balance improved flushing with transport of eggs outside of CS.	M (6)

Ref#	Issue	Harbour development risk and justification		Harbour development mitigation and risk	
Environmental value: Regionally significant spawning / nursery area- Southern garfish					
8.5	Decline in abundance and loss of nursery area due to environmental changes and loss of seagrass habitat	M (9)	Loss of seagrass would reduce feeding opportunities and decrease survival of eggs as garfish feed on seagrass and attach eggs to seagrass blades in Cockburn Sound. Some seagrass will likely be destroyed in shipping channel and turbidity from dredging and ship traffic may affect important seagrass areas.	Use PIANC Working with Nature principles to create fish friendly habitat and potential nursery areas. Rehabilitate seagrass meadows now to avoid a lag in ecosystem functioning as some seagrass would likely be removed or impacted upon during port construction and operation. Do not dredge during peak egg and nursery periods in case suspended sediments spread with unfavourable conditions. Design shipping channel and port to minimise vessel movement and reduce turbidity. Shipping channel may help to increase flushing times and improve water quality and seagrass growth in some parts of CS.	L (4)
Environmental value: Shoalwater Islands Marine Park					
9	Degradation of marine park due to flow on effects of poor water quality and declining biodiversity, as well as erosion of shorelines	M (9)	Due to close proximity, impacts on water quality and marine biota in Cockburn Sound would have flow on affects to the marine park. Port operations and other industrial and urban growth may contribute to poor water quality. Majority of park mixes with open coastal waters which would help water quality.	Use PIANC Working with Nature principles to engineer ecological niche areas for valuable species that use both CS and marine park. Reduce impacts to water quality as much as possible.	L (4)
Environmental value: Coastal processes					
10	Increased erosion and inundation of shorelines from rising sea levels, storms and changes to sediment transport	M (9)	Increased erosion and inundation at localised points within Cockburn Sound with increasing sea levels and storms. Changes to hydrological conditions may change alongshore sediment transport and erode shorelines. Already documented from the construction of Causeway, groynes and rock walls. Hydrological conditions may change with additional shipping channel.	Use PIANC Working with Nature principles to engineer long lasting solutions for coastal erosion if shipping channel has a significant impact on sediment transport.	L (4)

3.3.2 Social values

A total of 27 social issues were assessed for *Stage 1 expanded issues and risks* for Kwinana, which comprised of 10 high, 13 medium and four low risks (Appendix 2). Three of the of the high risk issues related to public health and potential for poor water quality to negatively impact on source water for desalination, recreational water contact and seafood quality. The remaining eight high risks related to business, industry and commercial values. Loss of habitat and marine life could impact on tourism and commercial fishing and poor water quality could impact on water quality for industrial use. In addition, growth of mussels in aquaculture could potentially be impacted by reduced nutrients, marine invasive species, contamination of tissues and warming waters.

This report represents a rapid assessment within a short time-frame of the most important social values for Kwinana. The risk assessments were based on very generalised locations of possible harbour footprints and it is recognised that further stakeholder engagement is required to refine the risk assessment.

3.3.2.1 Cumulative pressures

A synthesis of the social issues identified for Kwinana in *Stage 1 Expanded issues and risks* resulted in 17 'rolled up' issues (Appendix 3) that were used in *Stage 3 preliminary unmitigated and mitigated risk assessment* (Appendix 4). A summarised table of the preliminary unmitigated and mitigated risks is given in Table 21. Harbour development posed the most high risks out of the three activities and included negative impacts to the quality of water used for desalination, health of seafood, tourism, commercial fishing and aquaculture. Climate change was associated with high risks to recreational fishing, commercial fisheries, and aquaculture due to the impacts of warming sea temperatures. Other industrial and urban growth posed a high risk to the quality of seafood. Overall, there were six issues where the cumulative pressure risk score was considered high.

3.3.2.2 Harbour development pressures

A summary of harbour development related issues and risks for social values in Kwinana is given in Table 22. An increase in contamination and suspended sediments in the water column from dredging and vessel use posed a high risk for source water for desalination as well as recreational water quality and seafood quality. These high risks could be lowered to medium risks if dredging and high vessel use was avoided near intake pipes, or if pipes were moved away from harbour operations, and if dredging occurred without overflow and timed to avoid spread of sediments with water circulation. Contaminated sediments could also be removed to improve water quality and the harbour designed to minimise vessel movement in order to reduce suspended sediments.

Harbour development posed a high risk to tourism because of the potential loss of marine life and habitat, and in particular, if the Kwinana Shelf is lost and negatively impacts bottlenose dolphin abundance and occurrence, then businesses like Rockingham Wild Encounters would likely lose tourists. Adopting PIANC Working with Nature principles during harbour development could help to maintain a functioning ecosystem, and together with limiting the loss of habitat along Kwinana Shelf could help to reduce the high risk to a medium risk.

Commercial fisheries was assigned a high risk in relation to harbour development due to an increase in rules and restriction within the area and low catch rates from loss of habitat. Some possible mitigation measures to reduce the risk to a medium risk could include engineering ecological niche areas and fisher friendly structures, avoiding dredging during spawning periods and rehabilitating seagrass meadows in the near future to avoid a lag in ecosystem functioning.

Mussel farming was given a high risk in relation to harbour development due to the potential reduction in nutrients (and in turn plankton which mussels feed on) with improved water flow and quality, an increase risk of introduced marine pests impacting on mussel growth and an increase in contaminants which could cause health concerns for mussel consumption. Possible mitigation measured include creating areas conducive to mussel spat collection and mussel grow out, removing contaminated sediments and implementing additional monitoring measures to reduce incidence of marine pests.

Table 21: Summarised preliminary unmitigated and mitigated risk assessment for marine and estuarine social values in Kwinana.

Full table showing risk evaluation in Appendix 4.

Ref#	Issue	Current risk	Activity	Future unmitigated risk and justification		Future harbour development mitigated risk	
Social value: Heritage- Aboriginal							
1.1	Loss or degradation of important heritage sites with increased development	L (2)	Harbour development	L (4)	Valued sites occur around the coastlines of Cockburn Sound and on Garden Island, but not directly in port footprint. Cockburn Sound and waters to the north are part of the mythological 'Indian Ocean' aboriginal heritage site. However, degradation to these areas could occur from increased use and development. Sea level rise may impact on some coastal sites.	Avoid port construction on important aboriginal sites	L (4)
			Climate change	M (9)			M (9)
			Other industrial and urban growth	M (9)			M (9)
			Cumulative pressure	*M (9)*	*Valued sites occur around the coastlines of Cockburn Sound and on Garden Island.*		*M (9)*
Social value: Heritage- Maritime/historic							
1.2	Loss or degradation of important historical sites with increased development	L (2)	Harbour development	M (6)	One shipwreck in proposed port footprint and degradation to other sites areas could occur from increased use and development in CS. Sea level rise and erosion may impact on some sites along coastline.	Engineer port structures around shipwrecks.	L (4)
			Climate change	M (9)			M (9)
			Other industrial and urban growth	L (4)			L (4)
			Cumulative pressure	*M (9)*			*M (9)*
Social value: Public health- High quality source water for desalination							
2.1	Negative impact on drinking water supply due to declining water quality in Cockburn Sound	M (6)	Harbour development	H (12)	Potential decrease in water quality with increased use of CS. Expensive to treat/filter water or source water elsewhere if CS becomes unsuitable i.e. increased contamination, suspended sediments. Potentially more frequent maintenance (resulting in a loss of productivity and increase in cost) and potentially an increase in unplanned shutdowns (e.g. in response to elevated hydrocarbon concentration) to prevent damage. Could potentially cost the community more money for water. Other industrial and urban growth likely to influence groundwater flow into CS which would impact on source water.	Avoid dredging and high vessel use near intake pipe or move intake pipe to a more suitable location. Adopt engineering solutions that will reduce the frequency of maintenance and shutdowns.	M (6)
			Climate change				
			Other industrial and urban growth	M (9)			M (9)
			Cumulative pressure	H (12)	*Only one intake pipe in CS.*		*M (9)*
Social value: Public health- Recreational water quality							
2.2	Increased safety concerns for primary and secondary contact with water due to decreased water quality	L (2)	Harbour development	M (8)	Many people swim or use CS for water sports or leisure. Some beaches have a current rating of 'fair' that may get worse with increased use of CS.	Time dredging operations with water circulation to avoid spread of sediments. Use a silt screen if conditions permit. Design port to minimise vessel movement i.e. less turning and manoeuvring which would limit disturbance to sediments. Monitor water quality regularly to detect any health concerns.	L (4)
			Climate change				
			Other industrial and urban growth	L (4)			L (4)

Ref#	Issue	Current risk	Activity	Future unmitigated risk and justification		Future harbour development mitigated risk	
			Cumulative pressure	*M (8)*	*Perceptions of water quality would change with each person.*		*L (4)*
Social value: Public health- Seafood quality							
2.3	Decrease in health of shellfish and fish with increased contamination in waters and sediments	M (6)	Harbour development	H (12)	Contamination may increase with port construction and operation. Quality assurance monitoring is not performed for wild shellfish or fish. Would reduce recreational and commercial fishing as well as aquaculture if contamination levels exceeded guidelines. Would impact on favourite past times and social gatherings. May cause death and wash up of marine life. Concerns over PFAS entering the water column and food chain.	Remove contaminated sediments associated with port operation. Dredge without overflow and discharge sediments safely. Design port to minimise vessel movement i.e. less turning and manoeuvring which would limit disturbance to sediments.	M (6)
			Climate change				
			Other industrial and urban growth	H (12)			H (12)
			Cumulative pressure	*H (12)*	*A lot of fishing occurs in CS and no widespread health issues have been reported or linked to seafood in CS.*		*H (12)*
Social value: Social and community: Recreational fishing							
3.1	Decrease in recreational fishing due to restrictions around port area and the loss of popular fished species i.e. pink snapper, crabs with loss of habitat	H (12)	Harbour development	M (9)	Most boat based fishing is concentrated in the south of Cockburn Sound and northern waters, rather than the eastern margin where development may occur. Most shore based fishing is focused around jetties and to the north of Cockburn Sound. Some displacement in area of port development, but fishers could move to surrounding areas. Development could degrade current favoured habitats for fish and crabs, particularly seagrass beds. Climate change impacts may change fish patterns and distributions.	Use PIANC Working with Nature principles to engineer ecological niche areas for valuable species, as well as fisher friendly structures. Avoid dredging during spawning periods. Rehabilitate seagrass meadows now to avoid a lag in ecosystem functioning.	L (4)
			Climate change	H (12)			H (12)
			Other industrial and urban growth	M (9)			M (9)
			Cumulative pressure	*H (16)*	*Cockburn Sound is popular for fishing and even underwent the costly restocking of juvenile snapper after many were killed in 2015. A lot of time and money spent keeping the sound maintained for activities such as fishing. Blue swimmer crab fishing is still closed to allow stocks to recover.*		*H (12)*
Social value: Social and community: Recreational swimming							
3.2	Loss of popular swimming beaches with increased development i.e. Kwinana/ Challenger Beach	L (4)	Harbour development	M (9)	Depending on final port footprint, some popular swimming beaches may be removed. CS has other beaches for swimmers to utilise. Other industrial development may disturb swimming beaches. Sea level rise and erosion could impact access points for beaches that are used for swimming.	Create access to another stretch of beach in the vicinity of Kwinana Beach, or design port structures around beach so that it can still be used.	L (4)
			Climate change	M (6)			M (6)
			Other industrial and urban growth	M (6)			M (6)
			Cumulative pressure	M (9)	*Swimming currently considered safe in CS, and there are multiple beaches to access for the purposes of swimming.*		*M (6)*
Social value: Social and community: Recreational water sports							
3.3	Decrease in water sports with increased development	Low (3)	Harbour development	M (8)	Sports would likely only be displaced along the eastern margin of CS, and in shipping channels, and water sports are typically centred around the south of the sound and Woodman Point. May be restrictions on use put in place with increasing vessel traffic.	Designate new recreational areas specifically for water sports.	L (4)
			Climate change				
			Other industrial and urban growth	L (4)			L (4)

Ref#	Issue	Current risk	Activity	Future unmitigated risk and justification		Future harbour development mitigated risk	
			Cumulative pressure	*M (8)*	*Water sports popular in CS and surrounding bays.*		*L (4)*
Social value: Social and community: Recreational boating access							
3.4	Loss of boat ramps with increased development i.e. Challenger Beach boat ramp	Low (3)	Harbour development	M (9)	Depending on final port footprint, access to eastern margin boat ramps such as Challenger Beach boat ramp may be lost. Recreational boat use expected to grow over time. Other boat ramps out of port footprint are more popular to use. Sea level rise and erosion may impact on some boat ramps.	If a boat ramp is removed, engineer access to a new boat ramp in a similar location that is long lasting under climate change.	L (4)
			Climate change	M (9)			M (9)
			Other industrial and urban growth	L (4)			L (4)
			Cumulative pressure	*M (9)*	*Erosion is likely to impact boat ramps before sea level rise does.*		*M (9)*
Social value: Social and community: Marina facilities							
3.5	Reduced use of marina facilities with increased development	L (2)	Harbour development	L (4)	Marina facilities not in port footprint, so should have limited impact, apart from increased vessel traffic in and around CS. Quality of marina may decline with increased use and development. Sea level rise and erosion may impact on some boat ramps.	No mitigation	L (4)
			Climate change	M (9)			M (9)
			Other industrial and urban growth	L (4)			L (4)
			Cumulative pressure	M (9)	*Marinas likely to be upgraded over time rather than removed. Climate change likely biggest threat if there is insufficient set back of coastal structures.*		M (9)
Social value: Social and community: Educational and scientific values							
3.6	Reduced research and educational opportunities due to further development degrading the functioning ecosystem	L (2)	Harbour development	M (9)	Port footprint, and other development, could interrupt widespread/comprehensive research in CS and may impact on the collection of long time series data. Increased use and development in CS may cause educational operators to relocate to new sites due to a degraded and unhealthy ecosystem. Other industrial and urban growth could contribute to poor water quality and habitat degradation in CS. Climate change would not necessarily degrade or reduce opportunities.	Adopt PIANC Working with Nature principles maintain a functioning ecosystem. Grant permits to access certain regions of port if established study sites exist.	L (4)
			Climate change	L (4)			L (4)
			Other industrial and urban growth	M (9)			M (9)
			Cumulative pressure	*M (9)*	*Port development would be the biggest threat to this value.*		*M (9)*
Social value: Social and community: Landscape and visual amenity							
3.7	Less visitation due to increased development negatively impacting on the landscape and visual amenity	M (6)	Harbour development	M (9)	Erosion will reduce visual amenity and access at popular beaches and coastlines- Palm Beach, Mangles Bay and Kwinana beach already undergone beach nourishment to manage shoreline erosion. Increased sightings of marine life kills due to decreased water quality from increased development. Lack of visitation due to obstruction of expansive views of the ocean horizon with large vessels and/or built structures, as well as sightings of temporary dredge turbid plumes. Some vessel use of the area already.	Manage dredging with water circulation to reduce spread of plumes. Use a silt curtain if allowable.	M (9)
			Climate change	M (9)			M (9)
			Other industrial and urban growth	L (4)			L (4)

Ref#	Issue	Current risk	Activity	Future unmitigated risk and justification		Future harbour development mitigated risk	
			Cumulative pressure	*M (9)*	*Attractions of CS will vary per person. Port would be the biggest infrastructure project that would impact on visual amenity.*		*M (9)*
Social value: Business, industry and commercial: Tourism							
4.1	Loss of tourism due to restrictions around port area and the loss of marine life and habitat with increased development	L (4)	Harbour development	H (12)	Loss of marine life and habitat degradation due to increased development would reduce wildlife tourism i.e. any impacts to dolphins would significantly impact Rockingham Wild Encounters. Tourist activities would be displaced with port development along the eastern margin of CS and in shipping channels. The southern end of the sound most popular for tourist activities e.g. water sports hire, diving. Other industrial and urban growth could contribute to poor water quality and habitat degradation in CS.	Adopt PIANC Working with Nature principles to maintain a functioning ecosystem.	M (6)
			Climate change	L (4)			L (4)
			Other industrial and urban growth	M (9)			M (9)
			Cumulative pressure	*H (12)*	*Tourism popular around Rockingham and southern CS. Direct and indirect effects of development on tourism.*		*M (9)*
Social value: Business, industry and commercial: Commercial fisheries							
4.2	Decrease in commercial fishing due to an increase in rules and restrictions and lower catch rates from habitat loss and degradation with increased development	H (16)	Harbour development	H (12)	Increased rules and restrictions could lead to a further decrease in commercial fishing in CS. Further development could cause loss/degradation of habitat resulting in low catch rates. Climate change likely to impact distributions of fished species. Other industrial and urban growth could contribute to poor water quality and habitat degradation in CS.	Use PIANC Working with Nature principles to engineer ecological niche areas for valuable species, as well as fisher friendly structures. Avoid dredging during spawning periods. Rehabilitate seagrass meadows now to avoid a lag in ecosystem functioning.	M (6)
			Climate change	H (12)			H (12)
			Other industrial and urban growth	M (9)			M (9)
			Cumulative pressure	*H (16)*	*Commercial fishing has already been impacted by development in Cockburn Sound and there has been a decline in licenses since the 1990s.*		*H (12)*
Social value: Business, industry and commercial: Aquaculture							
4.3	Loss of mussel aquaculture due to increased development and changing environmental conditions	H (12)	Harbour development	H (12)	Reduction of nutrients in CS due would reduce food available for mussel growth, and this may occur with the shipping channel increasing flushing rates. Increased vessel visitation would increase risk of introduced marine pests that could negatively impact mussel growth and sales. Availability of contaminants in the water column would increase and could cause health concerns in farmed mussels. Increase in water temperatures may negatively affect mussel growth as is thought to be a contributing cause of decline in the last 10 years. Other industrial and urban growth could contribute to poor water quality. Any additional channels could also impact flushing of nutrients.	Use PIANC guidelines to create areas conducive to spat collection and mussel grow out. Implement additional monitoring measures to reduce incidence of marine pests. Remove contaminated sediments.	M (9)
			Climate change	H (12)			H (12)
			Other industrial and urban growth	M (9)			M (9)
			Cumulative pressure	*H (16)*	*Mussel production has decreased and is attributed to decreased nutrient levels, warmer water, reduced recruitment and predation.*		*H (12)*
Social value: Business, industry and commercial: Suitable quality water for industrial use							
4.4	Reduced water quality due to increased development will impact industrial use	L (4)	Harbour development	L (4)	Potential decrease in water quality with increased use of CS. Expensive to treat/filter water or source water elsewhere if CS becomes unsuitable i.e. increased contamination, suspended sediments. Industrial water quality generally means a level of quality that allows it to be used as cool water and thus it is unlikely that water quality is reduced to such an extent it is no longer suitable for industrial use. Other industrial and urban growth likely to influence groundwater flow into CS which would impact on source water.	Avoid dredging and high vessel use near intake pipe or move intake pipes to more suitable locations.	L (4)
			Climate change				
			Other industrial and urban growth	L (4)			L (4)
			Cumulative pressure	L (4)	*Intake pipes would occur along eastern margin of CS.*		L (4)

Ref#	Issue	Current risk	Activity		Future unmitigated risk and justification	Future harbour development mitigated risk	
Social value: Business, industry and commercial: Assimilation of wastewater							
4.5	Decreased water quality around outfall pipes due to wastewater operations	M (6)	Harbour development	M (9)	Contaminants and nutrients would increase with increased development. Port infrastructure and shipping channel may impact water circulation and wastewater assimilation close to the coast. A structure in this environment may reduce local flushing with consequences for assimilating effluent from existing wastewater outfalls. Possible use of emergency outfalls in CS with population growth.	Engineer port structures to prevent stagnate waters near coast. Move outfall pipes further offshore.	L (4)
			Climate change				
			Other industrial and urban growth	M (9)			M (9)
			Cumulative pressure	*M (9)*	*Outfall pipes would likely increase with increased development but may be directed to SDOOL.*		*M (9)*

Table 22: Summarised preliminary unmitigated and mitigated risk assessment of marine and estuarine social values in relation to harbour development in Kwinana.

Full table in Appendix 4.

Ref#	Issue	Harbour development risk and justification		Harbour development mitigation and risk	
Social value: Heritage- Aboriginal					
1.1	Loss or degradation of important heritage sites with increased development	L (4)	Valued sites occur around the coastlines of Cockburn Sound and on Garden Island, but not directly in port footprint. Cockburn Sound and waters to the north are part of the mythological 'Indian Ocean' aboriginal heritage site. Loss/degradation of sites would likely be avoided at all opportunities. Backlash from community if valued sites were impacted significantly.	Avoid port construction on important aboriginal sites	L (4)
Social value: Heritage- Maritime/historic					
1.2	Loss or degradation of important historical sites with increased development	M (6)	One shipwreck in proposed port footprint and degradation to other sites areas could occur from increased use and development in CS. Loss/degradation of sites would likely be avoided at all opportunities. Backlash from community if valued sites were impacted significantly.	Engineer port structures around shipwrecks.	L (4)
Social value: Public health- High quality source water for desalination					
2.1	Negative impact on drinking water supply due to declining water quality in Cockburn Sound	H (12)	Potential decrease in water quality with increased use of CS. Expensive to treat/filter water or source water elsewhere if CS becomes unsuitable i.e. increased contamination, suspended sediments. Potentially more frequent maintenance (resulting in a loss of productivity and increase in cost) and potentially an increase in unplanned shutdowns (e.g. in response to elevated hydrocarbon concentration) to prevent damage. Could potentially cost the community more money for water	Avoid dredging and high vessel use near intake pipe or move intake pipe to a more suitable location. Adopt engineering solutions that will reduce the frequency of maintenance and shutdowns.	M (6)
Social value: Public health- Recreational water quality					
2.2	Increased safety concerns for primary and secondary contact with water due to decreased water quality	H (12)	Many people swim or use CS for water sports or leisure. Some beaches have a current rating of 'fair' that may get worse with increased development and use of CS.	Time dredging operations with water circulation to avoid spread of sediments. Use a silt screen if conditions permit. Design port to minimise vessel movement i.e. less turning and manoeuvring which would limit disturbance to sediments. Monitor water quality regularly to detect any health concerns.	M (6)
Social value: Public health- Seafood quality					
2.3	Decrease in health of shellfish and fish with increased contamination in waters and sediments	H (12)	Contamination may increase with port construction and operation. Quality assurance monitoring is not performed for wild shellfish or fish. Would reduce recreational and commercial fishing as well as aquaculture if contamination levels exceeded guidelines. Would impact on favourite past times and social gatherings. May cause death and wash up of marine life.	Remove contaminated sediments associated with port operation. Dredge without overflow and discharge sediments safely. Design port to minimise vessel movement i.e. less turning and manoeuvring which would limit disturbance to sediments.	M (6)
Social value: Social and community: Recreational fishing					
3.1	Decrease in recreational fishing due to restrictions around port area and the loss of popular fished species i.e. pink snapper, crabs with loss of habitat	M (9)	Most boat based fishing is concentrated in the south of Cockburn Sound and northern waters, rather than the eastern margin where development may occur. Most shore based fishing is focused around jetties and to the north of Cockburn Sound. Some displacement in area of port development, but fishers could move to surrounding areas. Development could degrade current favoured habitats for fish and crabs, particularly seagrass beds.	Use PIANC Working with Nature principles to engineer ecological niche areas for valuable species, as well as fisher friendly structures. Avoid dredging during spawning periods. Rehabilitate seagrass meadows now to avoid a lag in ecosystem functioning.	L (4)
Social value: Social and community: Recreational swimming					
3.2	Loss of popular swimming beaches with increased development i.e. Kwinana/ Challenger Beach	M (9)	Depending on final port footprint, some popular swimming beaches may be removed. CS has other beaches for swimmers to utilise.	Create access to another stretch of beach in the vicinity of Kwinana Beach, or design port structures around beach so that it can still be used.	L (4)

Ref#	Issue	Harbour development risk and justification		Harbour development mitigation and risk	
Social value: Social and community: Recreational water sports					
3.3	Decrease in water sports with increased development	M (8)	Sports would likely only be displaced along the eastern margin of CS, and in shipping channels, and water sports are typically centred around the south of the sound and Woodman Point. May be restrictions on use put in place with increasing vessel traffic.	Designate new recreational areas specifically for water sports.	L (4)
Social value: Social and community: Recreational boating access					
3.4	Loss of boat ramps with increased development i.e. Challenger Beach boat ramp	M (9)	Depending on final port footprint, access to eastern margin boat ramps such as Challenger Beach boat ramp may be lost. Recreational boat use expected to grow over time. Other boat ramps out of port footprint are more popular to use.	If a boat ramp is removed, engineer access to a new boat ramp in a similar location that is long lasting under climate change.	L (4)
Social value: Social and community: Marina facilities					
3.5	Reduced use of marina facilities with increased development	L (4)	Marina facilities not in port footprint, so should have limited impact, apart from increased vessel traffic in and around CS. Quality of marina may decline with increased use and development.	No mitigation	L (4)
Social value: Social and community: Educational and scientific values					
3.6	Reduced research and educational opportunities due to further development degrading the functioning ecosystem	M (9)	Port footprint could interrupt widespread/comprehensive research in CS and may impact on the collection of long time series data. Increased use and development in CS may cause educational operators to relocate to new sites due to a degraded and unhealthy ecosystem.	Adopt PIANC Working with Nature principles maintain a functioning ecosystem. Grant permits to access certain regions of port if established study sites exist.	L (4)
Social value: Social and community: Landscape and visual amenity					
3.7	Less visitation due to increased development negatively impacting on the landscape and visual amenity	M (9)	Increased sightings of marine life kills due to decreased water quality from increased development. Lack of visitation due to obstruction of expansive views of the ocean horizon with large vessels and/or built structures, as well as sightings of temporary dredge turbid plumes. Some vessel use of the area already.	Manage dredging with water circulation to reduce spread of plumes. Use a silt curtain if allowable.	M (9)
Social value: Business, industry and commercial: Tourism					
4.1	Loss of tourism due to restrictions around port area and the loss of marine life and habitat with increased development	H (12)	Loss of marine life and habitat degradation due to increased development would reduce wildlife tourism i.e. any impacts to dolphins would significantly impact Rockingham Wild Encounters. Tourist activities would be displaced with port development along the eastern margin of CS and in shipping channels. The southern end of the sound most popular for tourist activities e.g. water sports hire, diving.	Adopt PIANC Working with Nature principles to maintain a functioning ecosystem.	M (6)
Social value: Business, industry and commercial: Commercial fisheries					
4.2	Decrease in commercial fishing due to an increase in rules and restrictions and lower catch rates from habitat loss and degradation with increased development	H (12)	Increased rules and restrictions could lead to a further decrease in commercial fishing in CS. Further development could cause loss/degradation of habitat resulting in low catch rates.	Use PIANC Working with Nature principles to engineer ecological niche areas for valuable species, as well as fisher friendly structures. Avoid dredging during spawning periods. Rehabilitate seagrass meadows now to avoid a lag in ecosystem functioning.	M (6)
Social value: Business, industry and commercial: Aquaculture					
4.3	Loss of mussel aquaculture due to increased development and changing environmental conditions	H (12)	Reduction of nutrients in CS due would reduce food available for mussel growth, and this may occur with the shipping channel increasing flushing rates. Increased vessel visitation would increase risk of introduced marine pests that could negatively impact mussel growth and sales. Availability of contaminants in the water column would increase and could cause health concerns in farmed mussels.	Use PIANC guidelines to create areas conducive to spat collection and mussel grow out. Implement additional monitoring measures to reduce incidence of marine pests. Remove contaminated sediments.	M (9)

Ref#	Issue	Harbour development risk and justification		Harbour development mitigation and risk	
Social value: Business, industry and commercial: Suitable quality water for industrial use					
4.4	Reduced water quality due to increased development will impact industrial use	L (4)	Potential decrease in water quality with increased use of CS. Expensive to treat/filter water or source water elsewhere if CS becomes unsuitable i.e. increased contamination, suspended sediments.	Avoid dredging and high vessel use near intake pipe or move intake pipes to more suitable locations.	L (4)
Social value: Business, industry and commercial: Assimilation of wastewater					
4.5	Decreased water quality around outfall pipes due to wastewater operations	M (9)	Contaminants and nutrients would increase with increased development. Port infrastructure and shipping channel may impact water circulation and wastewater assimilation close to the coast. A structure in this environment may reduce local flushing with consequences for assimilating effluent from existing wastewater outfalls.	Engineer port structures to prevent stagnate waters near coast. Move outfall pipes further offshore.	L (4)

3.4 Bunbury

3.4.1 Environmental values

A total of 63 environmental issues were assessed for *Stage 1 expanded issues and risks* for Bunbury, which comprised of 29 high, 31 medium and three low risks (Appendix 2). Integral functioning ecosystem was given a high risk in the face of increased use and development in Koombana Bay as the system has already undergone changes as outlined in Section 1.1.3. Eight high risk issues related to water quality and included impacts on light attenuation/turbidity due to dredging and shipping traffic, contamination due to oil/fuel spills, increased nutrients from groundwater and impacts of climate change on temperature, salinity, pH and dissolved oxygen. Ten high risks were assigned to listed and significant fauna. Fairy terns are at risk of losing shoreline habitat with increasing sea level and development, and other migratory birds are at risk of losing regionally important habitat if the Preston River Delta is modified or truncated. Bioaccumulation of contaminants pose a high risk for fairy terns, little penguins, migratory birds and bottlenose dolphins. In addition, bottlenose dolphins are also at risk of increased entanglement in fishing gear and climate change. Impacts to the Preston River, such as truncation or increasing salinity, pose a high risk to the priority 3 listed ouched lamprey and threatened Carter's freshwater mussel. Increased development in the Koombana Bay region poses a high risk to a regionally significant spawning/nursery area for whitebait, while marine heatwaves pose a threat to whitebait and blue swimmer crabs. Marine heatwaves are also a high risk for seagrass meadows just outside of Koombana Bay. The risk of an increase in invasive species was high due an increase in vessel visitation and Koombana Bay having suitable environmental conditions for establishment. Coastal erosion and inundation are high risks for areas of Koombana Bay and the Leschenault Regional Park and, in addition, increasing salinity and increased stress causing algal blooms is also a high risk for the Park.

This report represents a rapid assessment within a short time-frame of the most important environmental values for Bunbury. The risk assessments were based on very generalised locations of possible harbour footprints and it is recognised that further stakeholder engagement is required to refine the risk assessment.

3.4.1.1 Cumulative pressures

A synthesis of the environmental issues identified for Bunbury in *Stage 1 Expanded issues and risks* resulted in 19 'rolled up' issues (Appendix 3) that were used in *Stage 3 preliminary unmitigated and mitigated risk assessment* (Appendix 4). A summarised table of the preliminary unmitigated and mitigated risks is given in Table 23. Almost half of the high risks (10) were associated with climate change which had impacts on water quality, seagrass habitat, listed and significant fauna, regionally significant spawning/nursery areas, regionally significant migratory pathways, Leschenault Regional Park and coastal processes. Harbour development was associated with nine eight risks in relation to biological diversity, water quality, seagrass habitat, listed and significant fauna and regionally significant spawning/nursery area. Other industrial and urban growth posed a high risk for regionally significant spawning/nursery area and the Leschenault Regional Park. Overall, there were 17 issues where the cumulative pressure risk score was considered high.

3.4.1.2 Harbour development pressures

A summary of harbour development related issues and risks for environmental values in Bunbury is given in Table 24. Biological diversity was assigned a high risk in relation to harbour development due to an increase in introduced species, blasting of basalt damaging or killing fish, and localised habitat loss from harbour development. Mitigation measures that could lower the risk to medium include the adoption of PIANC Working with Nature principles to engineer niche areas and walls of built structures to promote growth of native species, as well as implementing additional monitoring measures to reduce incidence of marine pests. Adopting low impact dredging methods to excavate basalt would have less of an impact on underwater noise and fish species than use of explosives.

A combination of harbour development and operation, resuspension of sediment and accumulation of wrack in shipping channels pose a high risk to water quality due to a potential increase in nutrients and contaminants in the water column. The increase in nutrients together with increasing water temperatures may also cause toxic phytoplankton blooms in the region though, to date, have been uncommon.

There is also an increased risk of oil and fuel spills within and around Koombana Bay with increased vessel traffic. The risk to water quality may be lowered to a medium if mitigation measures include managing storm water and run-off, additional dredge management considerations (i.e. timing, no overflow), minimising vessel movement through harbour design, having first strike response kits in place to deal with level 2/3 oil spills and upgrading the wastewater capture system to prevent contamination of Preston River and Vittoria Bay

Reduction in seagrass biomass and extent was given a high risk in relation to harbour development due to the impacts of dredging and vessel movement on light availability. The risk may be lowered to a medium if mitigation measures included additional management of dredging operations for tidal movements and water circulation and avoiding winter when seagrass most vulnerable to low light, as well as designing the harbour to minimise vessel movement and turbidity. Rehabilitation of seagrass meadow may help to prevent a lag effect in ecosystem functioning. Establishing new seagrass meadows is difficult so allowing an appropriate time frame for establishment needs to be considered.

Fairy terns, bottlenose dolphins, little penguins and migratory birds were considered to be at high risk of decline largely due to loss of habitat for foraging and nesting and bioaccumulation of contaminants through the food chain. In addition for migratory birds and the pouched lamprey, the truncation of Preston River would result in the loss of the regionally important Preston River Delta. Dolphins will also likely be impacted by an increase in underwater noise from harbour development and operations which could impact on communications and socialisation. Mitigation measures which could help to lower the risk to these listed and significant fauna include incorporating protected bird friendly areas within the harbour boundaries, creating niche areas ideal for foraging and removing contaminated sediments to reduce bioaccumulation. Redirection of the Preston River back into Vittoria Bay would still disrupt the current delta, but likely less so than truncating the river into the Inner Harbour. Lastly, noisy operations could be avoided during the bottlenose dolphin breeding season when animals are socialising and calving, and Marine Mammal Observers could be engaged during development.

Koombana Bay is a regionally important spawning and nursery areas for whitebait and harbour development poses a high risk as development may result in poor water quality which may cause a reduction in abundance and occurrence. Possible mitigation measures that may reduce the high risks to medium risks would include adopting PIANC Working with Nature principles and including the creation of fish friendly habitats, avoiding dredging during peak spawning and nursery periods, and limiting the nutrients and contaminants entering the system.

Table 23: Summarised preliminary unmitigated and mitigated risk assessment for marine and estuarine environmental values in Bunbury.

Full table showing risk evaluation in Appendix 4.

Ref#	Issue	Current risk	Activity	Future unmitigated risk and justification		Future harbour development mitigated risk	
Environmental value: Integral functioning ecosystem							
1	Decrease in ecosystem functioning with increased use and development in Koombana Bay	M (9)	Harbour development	M (9)	Port construction would not likely affect marine life in KB specifically as there is limited marine life currently present due to high turbidity. However marine life would migrate through KB to each the Inlet and Estuary. Already an operating port, but further expansion may impact on water and sediment quality and indirectly on the Inlet and Estuary. Climate change would change the functioning, but not necessarily cause a *decrease* if new species adapt to new conditions. As Bunbury becomes more populated, industrial and urban pressures on KB and surrounds would likely grow.	Use PIANC Working with Nature principles to engineer port structures and niche habitats, as well as keeping migration routes to and from the Inlet and Estuary relatively undisturbed.	L (4)
			Climate change	M (6)			M (6)
			Other industrial and urban growth	M (9)			M (9)
			Cumulative pressure	*H (12)*	*System has already undergone significant changes due to modifications to the coast- largely Leschenault Inlet and Estuary.*		*M (9)*
Environmental value: Sheltered marine ecological community							
2	Alteration to the sheltered nature of Koombana Bay where dredge channels and built structures may impact on marine biota that depend on calmer waters	L (1)	Harbour development	M (9)	Development planned for inside of outer harbour and a dredge channel would be needed which may change circulation. Built structures may impact circulation on a localised scale, potentially causing stagnate waters or re-directing water flow. Any changes to or impacts of circulation would vary seasonally. Other industrial growth may influence localised flow if protruding from coast.	Engineer port structures to reduce stagnate waters.	L (4)
			Climate change				
			Other industrial and urban growth	L (4)			L (4)
			Cumulative pressure	*M (9)*	*Flushing times for Koombana Bay are estimated to be 4-6 days and for the inner harbour 40-90 days, so shipping channel may shorten flushing times.*		*L (4)*
Environmental value: Biological diversity							
3	Decrease in species diversity due to reduction of suitable habitat, invasive species and altered environmental conditions	L (4)	Harbour development	H (12)	Invasive species from increased vessel traffic could outcompete native species, and there are already invasive species in the area. In KB, most fish species are found in the shallows, which is where development would occur. Intense impulses and sudden noises from blasting/fracturing of the basalt layer to achieve 16 m depth could burst fish swim bladders, cause haemorrhaging, kidney damage and rupture to the body cavity. Temporal trends in abundance or diversity are not clear due to limited monitoring. Tropicalisation may not necessarily decrease biological diversity, as new species will be entering KB and some current species may have time to gradually adapt. Shipping channel would be likely to continually disturb benthos through prop wash, and if dredging occurs, benthic communities would be directly impacted.	Use PIANC working with nature principles to engineer ecological niche areas for valuable species. Implement additional monitoring measures to reduce incidence of marine pests. Engineer walls of built structures to be native species friendly in order to reduce establishment of invasive (invasive species are monitored and managed by DPIRD under the Fisheries Act). Adopting low impact dredging methods to excavate basalt.	M (9)
			Climate change	M (6)			M (6)
			Other industrial and urban growth	L (4)			L (4)
			Cumulative pressure	*H (12)*	*Invasive species could impact system wide functioning and cause declines or local extinctions of populations. Leschenault Inlet has relatively low diversity compared with the once connected Leschenault Estuary. Species diversity in KB is relatively low due to high turbidity and lack of benthic producers. Leschenault Estuary is thought to be globally significant in terms of the high richness of foraminifera species.*		*M (9)*

Ref#	Issue	Current risk	Activity	Future unmitigated risk and justification		Future harbour development mitigated risk	
Environmental value: High level of water quality							
4	Decrease in quality of water due to increased development and altered environmental conditions	H (12)	Harbour development	H (12)	Port development and operation could increase nutrients and contaminants in the water column from run-off and resuspension of sediments with high nutrient and contaminant loading. Decayed material collects in current dredge channel and is thought to be cause of increased nutrient levels in harbour waters. Dredging, fracturing of the basalt layer and continual propeller wash would exacerbate turbidity in an already turbid environment. More vessels in KB also increases the risk of oil and fuel spills. Climate change will elevate temperatures inside KB, which could contribute to frequent toxic phytoplankton blooms as well as potential dead zones due to increases oxygen consumption. No phytoplankton blooms recorded in Koombana Bay since 1995 monitoring began. Climate change may also increase the incidence of flooding and increase acidification of the water. Other industrial and urban growth could increase the contamination of groundwater with excess nutrients and contaminants, which would then increase legacy issues for KB and Estuary.	Better management of groundwater, storm water and run off to reduce nutrients entering into LI and KB. Additional dredge management options should be considered e.g. timing around high flushing periods or consideration of nepheloid layer in KB and outflow from Estuary during winter and spring. Dredge without overflow and discharge sediments safely. Design port to minimise vessel movement i.e. less turning and manoeuvring which would limit disturbance to sediments. Check maintenance records of vessels before port entry to reduce risk of oil spill and have first strike response kits in place to respond to level 2/3 oil spills as a minimum. Increased vigilance with management of fuel transfers. Upgrade waste water capture system or put in a second capture system to capture any remaining contaminants that may flow to Preston River and Vittoria Bay. Engineer structures to prevent coastal erosion if hydrology is changed from additional shipping channel.	M (6)
			Climate change	H (12)			H (12)
			Other industrial and urban growth	M (9)			M (9)
			Cumulative pressure	*H (16)*	*Currently localised areas with poor water quality due to modifications to the coast and current operating port. The Estuary is considered to be under stress due to water quality and environmental change. Urban and industrial growth would increase groundwater contamination and nutrient loading, that would then enter into KB and the Estuary.*		*H (12)*
Environmental value: High level of sediment quality							
5	Decrease in quality of sediments due to increased development	H (12)	Harbour development	M (9)	Likely increase in contamination of sediments with increased shipping and port operations. Bunbury would facilitate mineral exports, so load spills are possible and copper has been elevated in the inner harbour since copper concentrate exports started. Larger shipping channel may accumulate more decaying wrack and increase nutrient loading in the sediments There is a risk of exposing acid sulphate soils during development, and potential soils have been identified for the Leschenault Inlet and Estuary, but unknown for direct port footprint.	Remove contaminated sediments created from port operations. Larger shipping channel may improve flushing and reduce nutrient loads in sediments. Test for potential acid sulphate soils before developing port infrastructure.	L (4)
			Climate change				
			Other industrial and urban growth	M (9)			M (9)
			Cumulative pressure	*H (12)*	*Localised areas of contaminated sediments already in KB. Additional pressures would add to this.*		*M (9)*
Environmental value: Significant benthic communities and habitats- Seagrass							
6.1	Reduction in seagrass biomass and extent due to increased development and altered environmental conditions	M (6)	Harbour development	H (12)	Spread of suspended sediments from dredging and vessel movement may reach and impact on seagrass meadows outside of KB. Outflow of turbid plumes from the estuary can spread 10 km offshore during winter. Modelling of dredge suspended sediments from the inner harbour shows sediments entering Koombana Bay, Leschenault Inlet and Estuary and nearshore areas up to 8km north of The Cut; spread would be greater during winter than summer and concentrations would likely dissipate with increased distance from port. Increased incidence of marine heatwaves may cause decrease in seagrass biomass which occurred at Shark Bay. Some non-meadow forming patches of seagrass in KB which may be affected by development and increased nutrients in the system.	Manage dredging operations for tidal movements and water circulation. If conditions allow, use a silt screen during dredging. Additional dredge management options should be considered to protect benthic producers e.g. avoid winter when seagrass most vulnerable to low light. Rehabilitate new areas for seagrass colonisation now if predictions show a potential impact on meadows outside of KB. Design port to minimise vessel movement i.e. less turning and manoeuvring which would limit disturbance to sediments.	M (9)
			Climate change	H (16)			H (16)
			Other industrial and urban growth	L (4)			L (4)
			Cumulative pressure	*H (16)*	*Even though meadows occur outside of KB, port development and operation still have the potential to impact. Climate change would likely have the most significant impact over time.*		*H (16)*

Ref#	Issue	Current risk	Activity		Future unmitigated risk and justification	Future harbour development mitigated risk	
Environmental value: Significant benthic communities and habitats- Mangroves							
6.2	Degradation of mangrove habitat due to increased development and changing environmental conditions	M (6)	Harbour development	M (8)	Further increases in salinity in Leschenault Inlet due to less storm water input may cease growth or degrade mangroves as it is believed to be the current cause of slow expansion since the excavation of The Cut and the blocking of Preston River delta. Conversely, warming of waters may see an increase in the occurrence of mangroves as far south as Bunbury. Development may cause degradation to mangrove habitat and reduce biodiversity as a whole in the Inlet. The mangrove area and mudflats have over 100+ species. Port footprint does not directly remove mangrove habitat but does sit adjacent to mangroves in the Inlet. Mangroves cope with turbidity well. Other development could occur around the Inlet that may impact upon mangroves. Mangroves so far appear to be coping with an operating port, however if it did have an impact, it would affect the population rather than a small localised patch because the mangroves in the Inlet are clustered together. Some patches of mangroves occur in the Estuary.	Use PIANC Working with Nature principles to ensure current mangrove habitat remains in place and additional room for expansion is allowed for.	Low 4)
			Climate change	M (9)			M (9)
			Other industrial and urban growth	M (8)			Low 4)
			Cumulative pressure	*H (12)*	*Mangroves in Leschenault Inlet are already surrounded by development and appear to be coping. However, they are occurring at their southern limit so any impacts are likely to be exacerbated.*		*M (9)*
Environmental value: Significant benthic communities and habitats- Other							
6.3 6.4 6.5 6.6 6.7	Degradation of other benthic communities due to increased development	L (4)	Harbour development	M (9)	Rocky reef on eastern margin of KB may be negatively impacted if further development occurred, however dominant biota is foliose and canopy algae which would be able to recover relatively quickly. A decline in primary productivity (e.g. microphytobenthos or turf algae) for soft sediments in KB may occur due to increased turbidity and sediment disturbance. Sponges may be negatively impacted if there is a reduction in water quality, including turbidity and sedimentation, which could spread to sponge gardens north of KB. A decrease in biodiversity of mud flats could occur due to degradation or removal of habitat. A decline of artificial reef habitat west of KB could occur due to spread of suspended sediments from dredging, however foundation artificial reef would still remain for marine life to re-establish. Increased vessel traffic may deter fishes from artificial reef though fish may return to artificial structure during periods of low vessel traffic or adjust their behaviours. Other development may have an impact on mudflats such as in Inlet.	Use PIANC Working with Nature principles to create niche habitat areas. Manage dredge and turbidity plumes and for tidal movements and water circulation to reduce risk of spreading to surrounding habitats.	L (4)
			Climate change				
			Other industrial and urban growth	M (9)			M (6)
			Cumulative pressure	*M (9)*	*Not enough information to assess climate change impacts on mentioned benthic communities though it is likely to play a role in future scenarios.*		*M (6)*
Environmental value: Listed and significant fauna- Fairy terns							
7.1	Decline in abundance and breeding success of fairy terns due to impacts on habitat and prey species	M (6)	Harbour development	H (12)	Loss of shoreline habitat due to development and/or sea level rise. Preferred nesting spot is likely McKenna Pt within the current outer harbour and proposed port development lies adjacent to the area. Over time risk will increase with sea level rise. Lack of nesting sites would impact the population. Bioaccumulation of contaminants through the food chain could negatively affect survival and/or breeding success. TBT is being reduced, though there is potential for other contaminants to impact populations. Port operations my increase contaminants in the water and sediments. Other sites include Barr Island and Leschenault Peninsular and these sites are impacted by human disturbances e.g. 4WD, beach users and predators. Urban growth would increase risk of entanglement in fishing gear and rubbish.	Use PIANC Working with Nature principles to incorporate protected bird friendly areas for current and future use. Develop a temporary or permanent nesting sanctuary at McKenna Point free of human disturbance and development. Areas of contaminated sediments could be removed and contamination of the water column heavily regulated to reduce bioaccumulation.	M (6)
			Climate change	H (12)			H (12)
			Other industrial and urban growth	M (9)			M (9)
			Cumulative pressure	*H (16)*	*Feral predators also pose a risk to fairy tern abundance. Impacts to nesting sites would influence the overall population- i.e. mating opportunities.*		*H (12)*

Ref#	Issue	Current risk	Activity	Future unmitigated risk and justification		Future harbour development mitigated risk	
Environmental value: Listed and significant fauna- Little penguins							
7.2	Decline in abundance and breeding success of little penguins due to a decline in foraging habitat and prey species, as well as increased collisions with recreational vessels	L (4)	Harbour development	H (16)	Penguin Island penguins have consistently been tracked down to coastal area adjacent to Bunbury from Kwinana region as KB is a core foraging area. No breeding colonies in Bunbury. Bioaccumulation of contaminants through the food chain could affect survival and/or breeding success. Increase in deaths from collisions with increasing recreational boat traffic is possible given it is a top cause of death. Warming sea temperatures would influence the distribution of prey. Penguins have been shown to utilise the area in years where there has been above average sea surface temperature. Urban growth would increase risk of entanglement in fishing gear and rubbish and increased collisions.	Use PIANC Working with Nature principles during port design. Areas of contaminated sediments could be removed during port development and when levels exceed guidelines in order to reduce bioaccumulation. Reduce recreational boat speeds in a large area around the port which would lessen the risk overall for penguins if they use those areas. Given that the port footprint would condense recreational vessel use into a smaller area, educational programs could be developed for boat users. Restrict vessel routes and speed limits. Conduct regular surveys of shoreline to look for dead penguins and perform necropsies to determine cause of death. Reduce removal of wrack and damage to seagrass meadows. Conduct boat cleaning above water line. Reduce underwater noise pollution.	M (9)
			Climate change	M (8)			M (8)
			Other industrial and urban growth	M (6)			M (6)
			Cumulative pressure	*H (16)*	*Risks are lower for penguins in KB as penguins are only temporarily visiting the region. If future colonies establish due to climate change then risks would increase.*		*M (9)*
Environmental value: Listed and significant fauna- Bottlenose dolphins							
7.3	Decline in resident and other populations due to a decline in foraging habitat, prey species and anthropogenic influences i.e. boat strikes, fishing entanglements and underwater noise	H (16)	Harbour development	H (12)	High quality of prey items that resident dolphins target may decline due to loss of habitat or contamination. Dolphins use KB and the Estuary foraging. Increase in underwater noise from development and construction could deter dolphins from their usual habitats and interrupt communications between dolphins. Use of explosives to blast the basalt layer would produce intense impulses and sudden noises that would contribute significantly to the impacts of underwater noise on dolphins. Dolphin abundances may decline and movement patterns altered for the Bunbury area under a changing climate. Increased tourism and feeding of dolphins could increase vessel strikes as well as increased risk of entanglement in fishing gear with increased recreational use of Koombana Bay.	Use PIANC Working with Nature principles to create niche areas for dolphins to forage and design structures of port that do not interrupt passage of dolphins to favoured areas. Avoid conducting noisy dredging operations and port maintenance (i.e. pile driving) during the breeding season when animals are socialising and calving. Include an appropriate exclusion zone around blasting operations. Engage Marine Mammal Observers to observe the occurrence of dolphins during the time development is occurring. Adopt low impact dredging methods to excavate basalt. Implement speed restrictions throughout most of Koombana Bay for all vessels.	M (6)
			Climate change	H (12)			H (12)
			Other industrial and urban growth	M (9)			M (9)
			Cumulative pressure	*H (16)*	*The Bunbury population is currently forecast to decline. Accumulated pressures may cause dolphins to avoid KB and surrounds, more so than cause direct death to dolphins, and would impact the value being present.*		*H (12)*
Environmental value: Listed and significant fauna- migratory shorebirds and seabirds							
7.4	Decline in abundance and breeding success due to impacts on habitat and prey species	M (6)	Harbour development	H (12)	Sea level rise could inundate important shoreline habitat. Increased coastal development could remove important habitat. Bioaccumulation of contaminants through the food chain could negatively affect survival and/or breeding success. Loss, degradation, or complete removal of Preston River Delta could reduce the regional significance of the location for birds. Rising sea temperatures would influence distribution of prey. Urban growth would increase risk of entanglement in fishing gear and rubbish.	Use PIANC Working with Nature principles to create niche areas for birds to forage and incorporate coastal stretches for birds to nest and move up shore as sea level rises. Areas of contaminated sediments could be removed to reduce risk of bioaccumulation. Redirect Preston River back into Vittoria Bay rather than truncate into the Inner Harbour.	M (9)
			Climate change	H (12)			H (12)
			Other industrial and urban growth	M (9)			M (9)
			Cumulative pressure	*H (16)*	*Coastal development and human disturbance may impact on birds using coastal areas. Migratory birds frequent the same or similar locations year after year due to reliable conditions, so any impacts to known forging or nesting sites may have greater implications for migration.*		*H (12)*

Ref#	Issue	Current risk	Activity	Future unmitigated risk and justification		Future harbour development mitigated risk	
Environmental value: Listed and significant fauna- Pouched lamprey							
7.5	Loss, degradation, or complete removal of Preston River Delta could reduce access to river and spawning opportunities in freshwater sources	M (6)	Harbour development	H (12)	Development may alter the current state of the delta. Truncation of the river into the inner harbour instead of redirection into Vittoria Bay has been proposed. Redirection would cause some disruption to the lampreys using the delta for access to Preston River, but may be more a 'medium' risk as lampreys may adjust to new conditions.	Redirect Preston River back into Vittoria Bay rather than truncate into the Inner Harbour.	M (9)
			Climate change				
			Other industrial and urban growth				
			Cumulative pressure	*H (12)*	*Priority 3 listed species under Wildlife Conservation Act of WA (not under imminent threat). Unknown what impacts climate change will have, so it is likely that the risk to the species will increase with more knowledge.*		*M (9)*
Environmental value: Listed and significant fauna- Carter's Freshwater Mussel							
7.6	Further decline in abundance and occurrence of mussels due to reduced water quality (e.g. contamination) of the Preston River and environmental change	H (12)	Westport related development	M (6)	No mussels have been found in the Preston River in recent surveys. There is a risk that port expansion may impact on Preston River, though contamination of the river is already managed through a waste water capture system. Preston River may be at risk of becoming more saline under a drying climate, and mussels have a low tolerance of saline waters.	Upgrade waste water capture system or put in a second capture system to ensure high water quality in the Preston River.	L (4)
			Climate change	H (12)			H (12)
			Other industrial and urban growth	M (6)			M (6)
			Cumulative pressure	*H (12)*	*Threatened species under Wildlife Conservation Act of WA. Low tolerance of saline waters so likely that occurrence is limited in lower reaches of Preston River. Unknown what impacts climate change will have, so it is likely that the risk to the species will increase with more knowledge.*		*H (12)*
Environmental value: Regionally significant spawning / nursery area- King George whiting							
8.1	Decline in abundance and loss of nursery area due to environmental changes and loss of habitat	L (2)	Harbour development	M (9)	Leschenault Inlet not directly in the footprint of the port, but there may be some degradation to Leschenault Inlet habitat, i.e. reduced water quality, which may negatively impact on an important nursery area. However, the Inlet is listed as a Priority 1 Priority Ecological Community for Western Australian due to the presence of relictual mangroves and therefor avoiding impacts to the Inlet from future development is strived for.	Use PIANC Working with Nature principles to create fish friendly habitat which could be used as nursery areas. Do not dredge during peak nursery use in case suspended sediments spread with unfavourable conditions. Minimise impacts to water quality in the Inlet.	M (6)
			Climate change				
			Other industrial and urban growth	H (12)			H (12)
			Cumulative pressure	*H (12)*	*Unknown what impacts climate change will have, so it is likely that the risk to the species will increase with more knowledge.*		*H (12)*
Environmental value: Regionally significant spawning / nursery area- Whitebait							
8.2	Loss of favourable spawning and nursery areas due to changes in environmental conditions	M (9)	Harbour development	H (12)	Koombana Bay likely used as a spawning ground and Leschenault Estuary as a nursery ground. The added pressures of poor water quality from increased development may contribute to a decline in abundance. An increase in marine heatwaves would negatively impact spawning as reduced distribution and 2011 heatwave impacts suggest environmental limitations. There was reduced spawning success in winter of 2011 which resulted in low catches and catch rates. Rated as high risk to climate change.	Use PIANC Working with Nature principles to create fish friendly habitat. Do not dredge during peak spawning periods. Manage runoff to limit nutrients and contaminants entering the water.	M (6)
			Climate change	H (16)			H (16)
			Other industrial and urban growth	M (9)			M (9)
			Cumulative pressure	*H (16)*	*Classified as unsustainable and inadequate. Climate change impacts would likely be the greatest threat to whitebait.*		*H (16)*

Ref#	Issue	Current risk	Activity	Future unmitigated risk and justification		Future harbour development mitigated risk	
Environmental value: Regionally significant migratory pathway: Blue swimmer crab							
9.1	Decline in abundance and loss of nursery area due to environmental changes, reduced water quality and increased development	M (9)	Harbour development	M (9)	Environmental factors can influence abundances and is believed to be a cause of decline for stocks in Cockburn Sound. Reduced water quality can stress crabs making them more prone to infections such as shell disease, which was the cause of crab deaths in 2016. Reduced water quality may occur with increased use and development in KB. Increased urban and industrial growth would likely place more stress on water quality.	Use PIANC Working with Nature principles to create crab friendly habitat. Manage dredge and vessel generated turbidity to have least impact on surrounding habitats and spawning locations such as the Estuary.	M (6)
			Climate change	H (16)			H (16)
			Other industrial and urban growth	M (9)			M (9)
			Cumulative pressure	*H (16)*	*Climate change likely to be one of the biggest threats. Some concerns over declines in abundance in the Inlet.*		*H (16)*
Environmental value: Leschenault Regional Park							
10	Degradation of park due effects of poor water quality and declining ecosystem function, as well as environmental change	H (12)	Harbour development	M (9)	Increase stress on the estuary will increase the occurrence of algal blooms and fish kills. Reduced water quality from port operations may impact the Estuary. Impacts due to storms and coastal erosion from climate change are recognised as needing management within the park. Storm events and erosion predicted to increase under a changing climate. Fertiliser use is one of the biggest contributors to high nutrient levels. Salinity expected to increase under a drying climate, though incidences of flooding which is predicted to increase may help to alleviate some of this.	Use PIANC Working with Nature principles to engineer ecological niche areas for valuable species that use both KB and the Estuary. Reduce impacts to water quality such as timing of dredging to reduce transport of sediments into the Estuary.	L (4)
			Climate change	H (14)			H (14)
			Other industrial and urban growth	H (12)			H (12)
			Cumulative pressure	*H (14)*	*Estuary already showing signs of stress in the northern regions with algal blooms. Has adapted to being a wave dominated environment since The Cut was made. Salinity expected to increase under a drying climate.*		*H (14)*
Environmental value: Coastal processes							
11	Increased erosion and inundation of shorelines from rising sea levels, storms and changes to sediment transport	H (12)	Harbour development	L (2)	Koombana Beach and Yacht Club Groyne already face erosion issues. Risk of inundation to the Leschenault Inlet with rising sea levels and flooding. Stormwater pipes enter into the Inlet and could cause temporary flooding.		L (2)
			Climate change	H (12)			H (12)
			Other industrial and urban growth	L (2)			L (2)
			Cumulative pressure	*H (12)*	*Bunbury listed as one of the most vulnerable locations to erosion in the south-west.*		*H (12)*

Table 24: Summarised preliminary unmitigated and mitigated risk assessment of marine and estuarine environmental values in relation to harbour development in Kwinana.

Full table in Appendix 4.

Ref#	Issue	Harbour development risk and justification		Harbour development mitigation and risk	
Environmental value: Integral functioning ecosystem					
1	Decrease in ecosystem functioning with increased use and development in Koombana Bay	M (9)	Port construction would not likely affect marine life in KB specifically as there is limited marine life currently present due to high turbidity. However marine life would migrate through KB to each the Inlet and Estuary. Already an operating port, but further expansion may impact on water and sediment quality and indirectly on the Inlet and Estuary.	Use PIANC Working with Nature principles to engineer port structures and niche habitats, as well as keeping migration routes to and from the Inlet and Estuary relatively undisturbed.	L (4)
Environmental value: Sheltered marine ecological community					
2	Alteration to the sheltered nature of Koombana Bay where dredge channels and built structures may impact on marine biota that depend on calmer waters	M (9)	Development planned for inside of outer harbour and a dredge channel would be needed which may change circulation. Built structures may impact circulation on a localised scale, potentially causing stagnate waters or re-directing water flow. Any changes to or impacts of circulation would vary seasonally.	Engineer port structures to reduce stagnate waters.	L (4)
Environmental value: Biological diversity					
3	Decrease in species diversity due to reduction of suitable habitat, invasive species and altered environmental conditions	H (12)	Invasive species from increased vessel traffic could outcompete native species, and there are already invasive species in the area. In KB, most fish species are found in the shallows, which is where development would occur. Fish are mobile so they could move to other suitable areas if available. Temporal trends in abundance or diversity are not clear due to limited monitoring. Shipping channel would be likely to continually disturb benthos through prop wash, and if dredging occurs, benthic communities would be directly impacted.	Use PIANC working with nature principles to engineer ecological niche areas for valuable species. Implement additional monitoring measures to reduce incidence of marine pests (invasive species are monitored and managed by DPIRD under the Fisheries Act). Engineer walls of built structures to be native species friendly in order to reduce establishment of invasive.	M (9)
Environmental value: High level of water quality					
4	Decrease in quality of water due to increased development and altered environmental conditions	H (12)	Port development and operation could increase nutrients and contaminants in the water column from run-off and resuspension of sediments with high nutrient and contaminant loading. Decayed material collects in current dredge channel and is thought to be cause of increased nutrient levels in harbour waters. Dredging and continual propeller wash would increase turbidity, though KB is already a turbid environment. More vessels in KB also increases the risk of oil and fuel spills. No phytoplankton blooms recorded in Koombana Bay since 1995 monitoring began.	Better management of groundwater, storm water and run off to reduce nutrients entering LI and KB. Additional dredge management options should be considered e.g. timing around high flushing periods or consideration of nepheloid layer in KB and outflow from Estuary during winter and spring. Dredge without overflow and discharge sediments safely. Design port to minimise vessel movement i.e. less turning and manoeuvring which would limit disturbance to sediments. Check maintenance records of vessels before port entry to reduce risk of oil spill and have first strike response kits in place to respond to level 2/3 oil spills as a minimum. Increased vigilance with management of fuel transfers. Upgrade waste water capture system or put in a second capture system to capture any remaining contaminants that may flow to Preston River and Vittoria Bay. Engineer structures to prevent coastal erosion if hydrology is changed from additional shipping channel.	M (6)
Environmental value: High level of sediment quality					
5	Decrease in quality of sediments due to increased development	M (9)	Likely increase in contamination of sediments with increased shipping and port operations. Bunbury would facilitate **mineral** exports, so load spills are possible and copper has been elevated in the inner harbour since copper concentrate exports started. Larger shipping channel may accumulate more decaying wrack and increase nutrient loading in the sediments There is a risk of exposing acid sulphate soils during development, and potential soils have been identified for the Leschenault Inlet and Estuary, but unknown for direct port footprint.	Remove contaminated sediments created from port operations. Larger shipping channel may improve flushing and reduce nutrient loads in sediments. Test for potential acid sulphate soils before developing port infrastructure.	L (4)

Ref#	Issue	Harbour development risk and justification		Harbour development mitigation and risk	
Environmental value: Significant benthic communities and habitats- Seagrass					
6.1	Reduction in seagrass biomass and extent due to increased development and altered environmental conditions	H (12)	Spread of suspended sediments from dredging and vessel movement may reach and impact on seagrass meadows outside of KB. Outflow of turbid plumes from the estuary can spread 10 km offshore during winter. Modelling of dredge suspended sediments from the inner harbour shows sediments entering Koombana Bay, Leschenault Inlet and Estuary and nearshore areas up to 8km north of The Cut; spread would be greater during winter than summer and concentrations would likely dissipate with increased distance from port. Increased incidence of marine heatwaves may cause decrease in seagrass biomass which occurred at Shark Bay. Some non-meadow forming patches of seagrass in KB which may be affected by development and increased nutrients in the system.	Manage dredging operations for tidal movements and water circulation. If conditions allow, use a silt screen during dredging. Additional dredge management options should be considered to protect benthic producers e.g. avoid winter when seagrass most vulnerable to low light. Rehabilitate new areas for seagrass colonisation now if predictions show a potential impact on meadows outside of KB. Design port to minimise vessel movement i.e. less turning and manoeuvring which would limit disturbance to sediments.	M (9)
Environmental value: Significant benthic communities and habitats- Mangroves					
6.2	Degradation of mangrove habitat due to increased development and changing environmental conditions	M (8)	Development may cause degradation to mangrove habitat and reduce biodiversity as a whole in the Inlet. The mangrove area and mudflats have over 100+ species. Port footprint does not directly remove mangrove habitat but does sit adjacent to mangroves in the Inlet. Mangroves cope with turbidity well. Mangroves so far appear to be coping with an operating port, however if it did have an impact, it would affect the population rather than a small localised patch because the mangroves in the Inlet are clustered together. Some patches of mangroves occur in the Estuary.	Use PIANC Working with Nature principles to ensure current mangrove habitat remains in place and additional room for expansion is allowed for.	Low 4)
Environmental value: Significant benthic communities and habitats- Other					
6.3 6.4 6.5 6.6 6.7	Degradation of other benthic communities due to increased development	M (9)	Rocky reef on eastern margin of KB may be negatively impacted if further development occurred, however dominant biota is foliose and canopy algae which would be able to recover relatively quickly. A decline in primary productivity (e.g. microphytobenthos or turf algae) for soft sediments in KB may occur due to increased turbidity and sediment disturbance. Sponges may be negatively impacted if there is a reduction in water quality, including turbidity and sedimentation, which could spread to sponge gardens north of KB. A decrease in biodiversity of mud flats could occur due to degradation or removal of habitat. A decline of artificial reef habitat west of KB could occur due to spread of suspended sediments from dredging, however foundation artificial reef would still remain for marine life to re-establish. Increased vessel traffic may deter fishes from artificial reef though fish may return to artificial structure during periods of low vessel traffic or adjust their behaviours.	Use PIANC Working with Nature principles to create niche habitat areas. Manage dredge and turbidity plumes and for tidal movements and water circulation to reduce risk of spreading to surrounding habitats.	L (4)
Environmental value: Listed and significant fauna- Fairy terns					
7.1	Decline in abundance and breeding success of fairy terns due to impacts on habitat and prey species	H (12)	Loss of shoreline habitat due to development and/or sea level rise. Preferred nesting spot is likely McKenna Pt within the current outer harbour and proposed port development lies adjacent to the area. Lack of nesting sites would impact the population. Bioaccumulation of contaminants through the food chain could negatively affect survival and/or breeding success. TBT is being reduced, though there is potential for other contaminants to impact populations. Port operations my increase contaminants in the water and sediments.	Use PIANC Working with Nature principles to incorporate protected bird friendly areas for current and future use. Develop a temporary or permanent nesting sanctuary at McKenna Point free of human disturbance and development. Areas of contaminated sediments could be removed and contamination of the water column heavily regulated to reduce bioaccumulation.	M (6)

Ref#	Issue	Harbour development risk and justification		Harbour development mitigation and risk	
Environmental value: Listed and significant fauna- Little penguins					
7.2	Decline in abundance and breeding success of little penguins due to a decline in foraging habitat and prey species, as well as increased collisions with recreational vessels	H (16)	Penguins have been tracked down to Bunbury from Kwinana region as KB is a core foraging area. No breeding colonies in Bunbury. Bioaccumulation of contaminants through the food chain could affect survival and/or breeding success.	Use PIANC Working with Nature principles during port design. Areas of contaminated sediments could be removed during port development and when levels exceed guidelines in order to reduce bioaccumulation. Reduce recreational boat speeds in a large area around the port which would lessen the risk overall for penguins if they use those areas. Given that the port footprint would condense recreational vessel use into a smaller area, educational programs could be developed for boat users. Restrict vessel routes and speed limits. Conduct regular surveys of shoreline to look for dead penguins and perform necropsies to determine cause of death. Reduce removal of wrack and damage to seagrass meadows. Conduct boat cleaning above water line. Reduce underwater noise pollution.	M (9)
Environmental value: Listed and significant fauna- Bottlenose dolphins					
7.3	Decline in resident and other populations due to a decline in foraging habitat, prey species and anthropogenic influences i.e. boat strikes, fishing entanglements and underwater noise	H (12)	High quality of prey items that resident dolphins target may decline due to loss of habitat or contamination. Dolphins use KB and the Estuary for foraging. Increase in underwater noise from development and construction could deter dolphins from their usual habitats and interrupt communications between dolphins.	Use PIANC Working with Nature principles to create niche areas for dolphins to forage and design structures of port that do not interrupt passage of dolphins to favoured areas. Avoid conducting noisy dredging operations and port maintenance (i.e. pile driving) during the breeding season when animals are socialising and calving. Engage Marine Mammal Observers to observe the occurrence of dolphins during the time development is occurring. Implement speed restrictions throughout most of Koombana Bay for all vessels.	M (6)
Environmental value: Listed and significant fauna- migratory shorebirds and seabirds					
7.4	Decline in abundance and breeding success due to impacts on habitat and prey species	H (12)	Increased coastal development could remove important habitat. Bioaccumulation of contaminants through the food chain could negatively affect survival and/or breeding success. Loss, degradation, or complete removal of Preston River Delta could reduce the regional significance of the location for birds.	Use PIANC Working with Nature principles to create niche areas for birds to forage and incorporate coastal stretches for birds to nest and move up shore as sea level rises. Areas of contaminated sediments could be removed to reduce risk of bioaccumulation. Redirect Preston River back into Vittoria Bay rather than truncate into the Inner Harbour.	M (9)
Environmental value: Listed and significant fauna- Pouched lamprey					
7.5	Loss, degradation, or complete removal of Preston River Delta could reduce access to river and spawning opportunities in freshwater sources	H (12)	Development may alter the current state of the delta. Truncation of the river into the inner harbour instead of redirection into Vittoria Bay has been proposed. Redirection would cause some disruption to the lampreys using the delta for access to Preston River, but may be more a 'medium' risk as lampreys may adjust to new conditions.	Redirect Preston River back into Vittoria Bay rather than truncate into the Inner Harbour.	M (9)
Environmental value: Listed and significant fauna- Carter's Freshwater Mussel					
7.6	Further decline in abundance and occurrence of mussels due to reduced water quality (e.g. contamination) of the Preston River and environmental change	M (6)	No mussels have been found in the Preston River in recent surveys. There is a risk that port expansion may impact on Preston River, though contamination of the river is already managed through a waste water capture system.	Upgrade waste water capture system or put in a second capture system to ensure high water quality in the Preston River.	L (4)

Ref#	Issue	Harbour development risk and justification		Harbour development mitigation and risk	
Environmental value: Regionally significant spawning / nursery area- King George whiting					
8.1	Decline in abundance and loss of nursery area due to environmental changes and loss of habitat	M (9)	Leschenault Inlet not directly in the footprint of the port, but there may be some degradation to Leschenault Inlet habitat, i.e. reduced water quality, which may negatively impact on an important nursery area. However, the Inlet is listed as a Priority 1 Priority Ecological Community for Western Australian due to the presence of relictual mangroves and therefor avoiding impacts to the Inlet from future development is strived for.	Use PIANC Working with Nature principles to create fish friendly habitat which could be used as nursery areas. Do not dredge during peak nursery use in case suspended sediments spread with unfavourable conditions.	M (6)
Environmental value: Regionally significant spawning / nursery area- Whitebait					
8.2	Loss of favourable spawning and nursery areas due to changes in environmental conditions	H (12)	Koombana Bay likely used as a spawning ground and Leschenault Estuary as a nursery ground. The added pressures of poor water quality from increased development may contribute to a decline in abundance.	Use PIANC Working with Nature principles to create fish friendly habitat. Do not dredge during peak spawning periods. Manage runoff to limit nutrients and contaminants entering the water.	M (6)
Environmental value: Regionally significant migratory pathway: Blue swimmer crab					
9.1	Decline in abundance and loss of nursery area due to environmental changes, reduced water quality and increased development	M (9)	Environmental factors can influence abundances and is believed to be a cause of decline for stocks in Cockburn Sound. Reduced water quality can stress crabs making them more prone to infections such as shell disease, which was the cause of crab deaths in 2016. Reduced water quality may occur with increased use and development in KB. Increased urban and industrial growth would likely place more stress on water quality.	Use PIANC Working with Nature principles to create crab friendly habitat. Manage dredge and vessel generated turbidity to have least impact on surrounding habitats and spawning locations such as the Estuary.	M (6)
Environmental value: Leschenault Regional Park					
10	Degradation of park due effects of poor water quality and declining ecosystem function, as well as environmental change	M (9)	Increase stress on the estuary will increase the occurrence of algal blooms and fish kills. Reduced water quality from port operations may impact the Estuary.	Use PIANC Working with Nature principles to engineer ecological niche areas for valuable species that use both KB and the Estuary. Reduce impacts to water quality such as timing of dredging to reduce transport of sediments into the Estuary.	L (4)
Environmental value: Coastal processes					
11	Increased erosion and inundation of shorelines from rising sea levels, storms and changes to sediment transport	L (2)	Koombana Beach and Yacht Club Groyne already face erosion issues and may impact on port operations.		L (2)

3.4.2 Social values

A total of 18 social issues were assessed for *Stage 1 expanded issues and risks* for Bunbury, which comprised of six high, ten medium and two low risks (Appendix 2). Loss or degradation of important aboriginal heritage sites due to increased development was considered high. Two high risk issues related to public health and potential for poor water quality to negatively impact recreational water contact and seafood quality. Recreational and commercial fishing were considered to be high risk due to loss of habitat with increased development. Loss of habitat and marine life also poses a high risk to tourism in the region.

This report represents a rapid assessment within a short time-frame of the most important social values for Bunbury. The risk assessments were based on very generalised locations of possible harbour footprints and it is recognised that further stakeholder engagement is required to refine the risk assessment.

3.4.2.1 Cumulative pressures

A synthesis of the social issues identified for Bunbury in *Stage 1 Expanded issues and risks* resulted in 13 'rolled up' issues (Appendix 3) that were used in *Stage 3 preliminary unmitigated and mitigated risk assessment* (Appendix 4). A summarised table of the preliminary unmitigated and mitigated risks is given in Table 25. Most of the issues assessed were low to medium risk. Climate change poses a high risk to aboriginal heritage, recreational fishing, and commercial fishing. Harbour development also poses a high risk to aboriginal heritage, as well as seafood quality and tourism. No high risks were associated with other industrial and urban growth. Overall, there were five issues where the cumulative pressure risk score was considered high.

3.4.2.2 Harbour development pressures

A summary of harbour development related issues and risks for social values in Bunbury is given in Table 26. Alteration to the Preston River with harbour development, which is a registered aboriginal heritage site, poses a high risk to aboriginal heritage. Mitigation measures would only lower the risk to a medium as some modification to Preston River would be needed with development, but these modifications could be minimised and truncation avoided. An increase in contaminants in the water column from dredging and vessel use posed a high risk for seafood quality. Possible mitigation to lower the risk to a medium could include dredging without overflow and discharging sediments safely, removing contaminated sediments and designing the harbour to minimise vessel movement and suspended sediments. Harbour development poses a high risk to tourism if there is loss to marine life and habitat which, in particular, would impact on the Dolphin Discovery Centre if resident dolphins were displaced. If PIANC Working with Nature principles were adopted, harbour development could have limited impact on ecosystem functioning and dolphin populations and, combined with reducing noisy activities during times of peak dolphin use, could reduce the high risk to a medium risk.

Table 25: Summarised preliminary unmitigated and mitigated risk assessment for marine and estuarine social values in Bunbury.

Full table showing risk evaluation in Appendix 4.

Ref#	Issue	Current Risk	Activity	Future unmitigated risk and justification		Future harbour development mitigated risk	
Social value: Heritage- Aboriginal							
1.1	Loss or degradation of important heritage sites with increased development	L (2)	Harbour development	H (12)	Leschenault Inlet and Koombana Bay are important contemporary areas for the Nyungar community. Leschenault Estuary, Koombana Bay and Preston River are all registered mythological sites. Alteration to Preston River would impact a mythological site, and current port footprint would directly cut across the river. Degradation to these areas could occur from increased use and development. Sea level rise could inundate some popular gathering areas.	Avoid port construction on important aboriginal sites or engineer built structures to incorporate sites and access to sites. Minimise modifications to Preston River.	M (8)
			Climate change	H (12)			H (12)
			Other industrial and urban growth	M (6)			M (6)
			Cumulative pressure	H (12)	*Port development would be the biggest threat to this value due to the size and ongoing operations it would bring to the area.*		H (12)
Social value: Heritage- Maritime/historic							
1.2	Loss or degradation of important historical sites with increased development	L (2)	Harbour development	M (8)	One registered site occurs directly within port footprint and others occurring in immediate vicinity. Sea level rise could inundate some shore based sites.	Engineer port structures around shipwreck.	L (4)
			Climate change	M (8)			M (8)
			Other industrial and urban growth	L (4)			L (4)
			Cumulative pressure	*M (8)*	*Quite a lot of registered sites occur right in KB and surrounds.*		*M (8)*
Social value: Public health- Recreational water quality							
2.1	Increased safety concerns for primary and secondary contact with water due to decreased water quality	L (2)	Harbour development	M (8)	People use in Koombana Bay and Leschenault Inlet for water sports or leisure.	Time dredging operations with water circulation to avoid spread of sediments. Use a silt screen if conditions permit. Design port to minimise vessel movement i.e. less turning and manoeuvring which would limit disturbance to sediments. Monitor water quality regularly to detect any health concerns.	L (4)
			Climate change				
			Other industrial and urban growth	L (4)			L (4)
			Cumulative pressure	*M (8)*	*Perceptions of water quality would change with each person.*		*M (6)*
Social value: Public health- Seafood quality							
2.2	Decrease in health of shellfish and fish with increased contamination in waters and sediments	M (9)	Harbour development	H (12)	Mussel tissue concentrations of copper, selenium and zinc have, at all sites, exceeded the food guideline values at some point in time and is a human consumption risk. Contamination may increase with port construction and operation. Quality assurance monitoring is not performed for wild shellfish or fish. Would reduce recreational and commercial fishing as well as aquaculture if contamination levels exceeded guidelines. Would impact on favourite past times and social gatherings. May cause death and wash up of marine life.	Remove contaminated sediments associated with port operation. Dredge without overflow and discharge sediments safely Design port to minimise vessel movement i.e. less turning and manoeuvring which would limit disturbance to sediments.	M (6)
			Climate change				
			Other industrial and urban growth	M (9)			M (9)
			Cumulative pressure	*H (12)*	*Food guidelines have been exceeded already for mussels under current use of KB.*		*M (9)*

Ref#	Issue	Current Risk	Activity		Future unmitigated risk and justification	Future harbour development mitigated risk	
Social value: Social and community: Recreational fishing							
3.1	Decrease in recreational fishing with increased development	M (9)	Harbour development	M (9)	Decrease of recreational fishing with port development due to restrictions. Some fishing would take place in Koombana Bay but is more popular in the Leschenault Estuary and the Inlet. Degradation of Leschenault Inlet could occur with port development. Concerns over reducing abundance of crabs in the Inlet. Rising sea temperatures likely to shift fish distributions. Industrial and urban growth could contribute to poor water quality and decline in fish abundances over time.	Use PIANC Working with Nature principles to engineer ecological niche areas for valuable species, as well as fisher friendly structures. Avoid dredging during spawning periods. Rehabilitate seagrass meadows now to avoid a lag in ecosystem functioning, if port is predicted to impact on coastal meadows.	L (4)
			Climate change	H (12)			H (12)
			Other industrial and urban growth	M (9)			M (9)
			Cumulative pressure	*H (16)*	*Recreational fishing is a strong social value in Bunbury.*		*H (12)*
Social value: Social and community: Recreational swimming							
3.2	Degradation of swimming beaches due to increased development	L (4)	Harbour development	M (9)	Koombana Beach, Ski Beach, Jetty Baths are popular for swimming and are in the vicinity, but not directly in the port footprint. People would likely avoid swimming due to aesthetics of turbid water, or perceived low health and safety. Would be temporary. Other industrial development may disturb swimming beaches. Sea level rise and erosion could impact access points for beaches that are used for swimming.	Time dredging operations with water circulation to avoid spread of sediments. Use a silt screen if conditions permit. Design port to minimise vessel movement i.e. less turning and manoeuvring which would limit disturbance to sediments.	L (4)
			Climate change	M (6)			M (6)
			Other industrial and urban growth	L (4)			L (4)
			Cumulative pressure	M (9)	*Swimming currently considered safe in KB, and there are multiple beaches to access for the purposes of swimming.*		*M (6)*
Social value: Social and community: Recreational water sports							
3.3	Decrease in water sports with increased development and environmental change	Low (3)	Harbour development	L (4)	Leschenault Inlet most popular for recreational sports. Could still be used for sports despite turbidity or lower water quality. Footprint of port does not directly impact on Inlet. Water sports in KB would likely be restricted to certain areas. Several water sports clubs have leased land on the foreshore of the Inlet, which would be at risk from sea level rise due to insufficient set back.	Designate new recreational areas specifically for water sports if port development removes access to favoured areas.	L (2)
			Climate change	M (9)			M (9)
			Other industrial and urban growth	L (4)			L (4)
			Cumulative pressure	*M (9)*	*Water sports popular in Leschenault Inlet*		*M (9)*
Social value: Social and community: Recreational boating access							
3.4	Flooding occurrences via storm water outfalls may impact on boat ramps in Leschenault Inlet	Low (3)	Harbour development	L (2)	Port footprint does not remove current boat access. Temporary flooding in the Inlet will impact access and may be an increased risk long term with increased sea level.	No mitigation.	L (2)
			Climate change	M (9)			M (9)
			Other industrial and urban growth	L (4)			L (4)
			Cumulative pressure	*M (9)*			*M (9)*

Ref#	Issue	Current Risk	Activity		Future unmitigated risk and justification	Future harbour development mitigated risk	
Social value: Social and community: Marina facilities							
3.5	Reduced use of marina facilities with increased development	L (2)	Harbour development	L (4)	Depends on structures built and shipping channel- current footprint indicates rock groynes will be built near the Casuarina harbour. Potential restrictions on Casuarina Boat Harbour entry and exit with increased port development. Quality of marina may decline with increased use and development. Sea level rise and erosion may impact on some marine facilities.	Ensure ease of access to marina with port development.	L (4)
			Climate change	M (9)			M (9)
			Other industrial and urban growth	L (4)			L (4)
			Cumulative pressure	M (9)	*Marinas likely to be upgraded over time rather than removed due to other further development. Climate change likely biggest threat if there is insufficient set back of coastal structures.*		M (9)
Social value: Social and community: Educational and scientific values							
3.6	Degradation of mangrove habitat would impact educational experiences and value for scientific purposes	L (2)	Harbour development	M (9)	Habitat may degrade over time with increased development if not managed sufficiently. Potential loss of birds and reduction in bird watching. Salinity in Inlet likely to increase under climate change which may cease growth of mangroves.	Adopt PIANC Working with Nature principles maintain a functioning mangrove ecosystem.	L (4)
			Climate change	M (6)			M (6)
			Other industrial and urban growth	M (9)			M (9)
			Cumulative pressure	*M (9)*	*Mangroves are completely surrounded by development.*		*M (9)*
Social value: Social and community: Landscape and visual amenity							
3.7	Less visitation due to increased development negatively impacting on the landscape and visual amenity	L (4)	Harbour development	M (9)	Scenic boardwalk through mangrove habitat may lose scenic quality if habitat is degraded with increased development. Lack of visitation to Bunbury due to obstruction of expansive views of the ocean horizon with large vessels and/or building and structures, as well as sightings of dredge plumes. Increase in vessel traffic will occur if operations expand, and the shipping channel spreads right across Koombana Bay. Some vessels already operating in the bay. Erosion may reduce visual amenity and access at popular beaches and coastlines, such as Koombana Beach.	Manage dredging with water circulation to reduce spread of plumes. Use a silt curtain if allowable.	M (6)
			Climate change	M (9)			M (9)
			Other industrial and urban growth	L (4)			L (4)
			Cumulative pressure	*M (9)*	*Attractions of KB will vary per person. Port would be the biggest infrastructure project that would impact on visual amenity.*		*M (9)*
Social value: Business, industry and commercial: Tourism							
4.1	Loss of tourism due to increased development, loss of marine life and environmental change	L (4)	Harbour development	H (12)	Reduced wildlife tourism due to loss of marine life and habitat degradation. Dolphin Discovery Centre would be significantly impacted if resident dolphin populations were displaced by loss of habitat or noisy operations. Displacement of tourist activities with port development could occur, though a lot of tourist activities would occur in the Inlet. Increased erosion of Koombana Beach may leave a negative impression. Other industrial and urban growth could contribute to poor water quality and habitat degradation in KB and surrounds, though likely to also attract more tourists. Most recent tourism development strategy for Bunbury (2015-2019) includes developing a new marina that can facilitate cruise ships, dive boats and dolphin cruises.	Adopt PIANC Working with Nature principles to maintain a functioning ecosystem and avoid noisy operations during periods of high dolphin use.	M (6)
			Climate change	L (4)			L (4)
			Other industrial and urban growth	L (4)			L (4)
			Cumulative pressure	*H (12)*	*Tourism is continually growing for Bunbury.*		M (6)

Ref#	Issue	Current Risk	Activity	Future unmitigated risk and justification		Future harbour development mitigated risk	
Social value: Business, industry and commercial: Commercial fisheries							
4.2	Decrease in commercial fishing due to habitat loss and degradation with increased development, as well as environmental change	M (9)	Westport related development	M (9)	No commercial fishing allowed in the inner or outer harbour areas due to current port operations. If Leschenault Estuary or Inlet are affected by further development in the area, this may reduce fish stocks which use coastal areas during their life cycle. Climate change would influence the distributions of fished species.	Use PIANC Working with Nature principles to engineer ecological niche areas for valuable species, as well as fisher friendly structures. Design port so that migration pathways are not disturbed. Avoid dredging during spawning periods. Rehabilitate seagrass meadows now to avoid a lag in ecosystem functioning, if port is predicted to impact on coastal meadows.	L (4)
			Climate change	H (12)			H (12)
			Other industrial and urban growth	M (9)			M (9)
			Cumulative pressure	*H (16)*	*Many different species are targeted in the Bunbury region, including species that rely on the Leschenault Estuary.*		*H (12)*

Table 26: Summarised preliminary unmitigated and mitigated risk assessment of marine and estuarine social values in relation to harbour development in Bunbury.

Full table in Appendix 4.

Ref#	Issue	Harbour development risk and justification		Harbour development mitigation and risk	
Social value: Heritage- Aboriginal					
1.1	Loss or degradation of important heritage sites with increased development	H (12)	Leschenault Inlet and Koombana Bay are important contemporary areas for the Nyungar community. Leschenault Estuary, Koombana Bay and Preston River are all registered mythological sites. Alteration to Preston River would impact a mythological site, and current port footprint would directly cut across the river.	Avoid port construction on important aboriginal sites or engineer built structures to incorporate sites and access to sites. Minimise modifications to Preston River.	M (8)
Social value: Heritage- Maritime/historic					
1.2	Loss or degradation of important historical sites with increased development	M (8)	One registered site occurs directly within port footprint and others occurring in immediate vicinity.	Engineer port structures around shipwreck.	L (4)
Social value: Public health- Recreational water quality					
2.1	Increased safety concerns for primary and secondary contact with water due to decreased water quality	M (8)	People use in Koombana Bay and Leschenault Inlet for water sports or leisure.	Time dredging operations with water circulation to avoid spread of sediments. Use a silt screen if conditions permit. Design port to minimise vessel movement i.e. less turning and manoeuvring which would limit disturbance to sediments. Monitor water quality regularly to detect any health concerns.	L (4)
Social value: Public health- Seafood quality					
2.2	Decrease in health of shellfish and fish with increased contamination in waters and sediments	H (12)	Mussel tissue concentrations of copper, selenium and zinc have, at all sites, exceeded the food guideline values at some point in time and is a human consumption risk. Contamination may increase with port construction and operation. Quality assurance monitoring is not performed for wild shellfish or fish. Would reduce recreational and commercial fishing as well as aquaculture if contamination levels exceeded guidelines. Would impact on favourite past times and social gatherings. May cause death and wash up of marine life.	Remove contaminated sediments associated with port operation. Dredge without overflow and discharge sediments safely. Design port to minimise vessel movement i.e. less turning and manoeuvring which would limit disturbance to sediments.	M (6)
Social value: Social and community: Recreational fishing					
3.1	Decrease in recreational fishing with increased development	M (9)	Decrease of recreational fishing with port development due to restrictions. Some fishing would take place in Koombana Bay but is more popular in the Leschenault Estuary and the Inlet. Degradation of Leschenault Inlet could occur with port development. Concerns over reducing abundance of crabs in the Inlet.	Use PIANC Working with Nature principles to engineer ecological niche areas for valuable species, as well as fisher friendly structures. Avoid dredging during spawning periods. Rehabilitate seagrass meadows now to avoid a lag in ecosystem functioning, if port is predicted to impact on coastal meadows.	L (4)
Social value: Social and community: Recreational swimming					
3.2	Degradation of swimming beaches due to increased development	M (9)	Koombana Beach, Ski Beach, Jetty Baths are popular for swimming and are in the vicinity, but not directly in the port footprint. People would likely avoid swimming due to aesthetics of turbid water, or perceived low health and safety. Would be temporary.	Time dredging operations with water circulation to avoid spread of sediments. Use a silt screen if conditions permit. Design port to minimise vessel movement i.e. less turning and manoeuvring which would limit disturbance to sediments.	L (4)
Social value: Social and community: Recreational water sports					
3.3	Decrease in water sports with increased development and environmental change	L (4)	Leschenault Inlet most popular for recreational sports. Could still be used for sports despite turbidity or lower water quality. Footprint of port does not directly impact on Inlet. Water sports in KB would likely be restricted to certain areas.	Designate new recreational areas specifically for water sports if port development removes access to favoured areas.	L (2)

Ref#	Issue	Harbour development risk and justification		Harbour development mitigation and risk	
Social value: Social and community: Recreational boating access					
3.4	Flooding occurrences via storm water outfalls may impact on boat ramps in Leschenault Inlet	L (2)	Port footprint does not remove current boat access.	No mitigation.	L (2)
Social value: Social and community: Marina facilities					
3.5	Reduced use of marina facilities with increased development	L (4)	Depends on structures built and shipping channel- current footprint indicates rock groynes will be built near the Casurina harbour. Potential restrictions on Casurina Boat Harbour entry and exit with increased port development. Quality of marina may decline with increased use and development.	Ensure ease of access to marina with port development.	L (4)
Social value: Social and community: Educational and scientific values					
3.6	Degradation of mangrove habitat would impact educational experiences and value for scientific purposes	M (9)	Habitat may degrade over time with increased development if not managed sufficiently. Potential loss of birds and reduction in bird watching.	Adopt PIANC Working with Nature principles maintain a functioning mangrove ecosystem.	L (4)
Social value: Social and community: Landscape and visual amenity					
3.7	Less visitation due to increased development negatively impacting on the landscape and visual amenity	M (9)	Scenic boardwalk through mangrove habitat may lose scenic quality if habitat is degraded with increased development. Lack of visitation to Bunbury due to obstruction of expansive views of the ocean horizon with large vessels and/or building and structures, as well as sightings of dredge plumes. Increase in vessel traffic will occur if operations expand, and the shipping channel spreads right across Koombana Bay. Some vessels already operating in the bay.	Manage dredging with water circulation to reduce spread of plumes. Use a silt curtain if allowable.	M (6)
Social value: Business, industry and commercial: Tourism					
4.1	Loss of tourism due to increased development, loss of marine life and environmental change	H (12)	Reduced wildlife tourism due to loss of marine life and habitat degradation. Dolphin Discovery Centre would be significantly impacted if resident dolphin populations were displaced by loss of habitat or noisy operations. Displacement of tourist activities with port development could occur, though a lot of tourist activities would occur in the Inlet.	Adopt PIANC Working with Nature principles to maintain a functioning ecosystem and avoid noisy operations during periods of high dolphin use.	M (6)
Social value: Business, industry and commercial: Commercial fisheries					
4.2	Decrease in commercial fishing due to habitat loss and degradation with increased development, as well as environmental change	M (9)	No commercial fishing allowed in the inner or outer harbour areas due to current port operations. If Leschenault Estuary or Inlet are affected by further development in the area, this may reduce fish stocks which use coastal areas during their life cycle.	Use PIANC Working with Nature principles to engineer ecological niche areas for valuable species, as well as fisher friendly structures. Design port so that migration pathways are not disturbed. Avoid dredging during spawning periods. Rehabilitate seagrass meadows now to avoid a lag in ecosystem functioning, if port is predicted to impact on coastal meadows.	L (4)

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4 Opportunities to improve environmental and social values

Unmitigated risk scores for environmental and social values presented in Tables 15-26 from Sections 3.2, 3.3 and 3.4 were largely determined from the literature presented in Section 2. To improve the confidence around the unmitigated risks assigned to values, and whether or not 'worst case' scenarios are being assumed, subject matter experts should be engaged for each of the values identified. Engagement will help to:

- Identify missing data and studies that could help to improve data confidence
- Refine justifications and risk scores for the identified issues
- Identify new issues that are critical to consider in order to improve the outcome for environmental and social values

The mitigation measures and the associated mitigated risk scores provided in Section 3 are preliminary and include the following assumptions:

- The mitigated risk score is reliant on the mitigation measures being implemented successfully
- The mitigation measures are within the capabilities of Westport

Mitigation measures were determined in the absence of stakeholder engagement and any conceptual or engineering design information. A significant opportunity to improve environmental and social values would include investigating the feasibility of potential mitigation measures and identifying additional measures that may help to lower the risk of impact of harbour development in the three areas of interest. To do this, subject matter experts and engineering advice should be sought to ensure mitigation measures are worked into the design and management frameworks of harbour development.

Engineering and stakeholder advice sought for future port concepts in the three areas of interest should follow the PIANC Working with Nature approach to ensure mutually beneficial solutions are achieved for both the marine environment and its users. PIANC Working with Nature principles highlight that solutions should move beyond the usual approach of just minimising ecological harm. For already degraded environments, adopting future infrastructure that would improve the condition of the environment could only benefit marine life and the commercial and recreational users that rely on it. A local example of the Working with Nature approach can be seen for the successful fairy tern sanctuary at Rous Head which was created from reclaimed land using dredge spoil from Fremantle Port channel deepening.

Harbour development may also provide an opportunity to improve environmental and social values beyond the three areas of interest. For example, in consideration of the past proposed Kwinana Quay offshore port facility, GHD (2012) and SKM (2008) identified that project enhancement opportunities could include alternative and recycled construction materials, sustainable waste management, reduction of greenhouse gas emissions and carbon footprint, renewable energy sources and energy efficiency, and storm water and wastewater re-use. If these additional opportunities consider the marine environment, i.e. establishing more seagrass meadows to trap carbon, then they could potentially benefit environmental and social values further.

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5 Comparison with EWS initial assessment

A key objective of this report was to refine the accuracy of the environmental and social values and confidence tables presented in the EWS Stage One Progress Report (November 2018). The values included and 'levels of concern' assessed for each value in the EWS Stage One Progress Report were preliminary, and further refinement is necessary in order to effectively compare options for port expansion. A comparison between the values assessed in the EWS Stage One Progress Report and those assessed in this report are given for Fremantle (Table 27), Kwinana (Table 28) and Bunbury (Table 29). Consideration needs to be given to the definitions used in the EWS Stage One Progress Report, as these differ from the definitions used in this report.

The definitions used in the EWS initial assessment include:

- Category = category of importance, with "1" indicating the value is present (or applies) and "2" indicating the value is recognised as important
- Level of concern= "Low" for values that are not deemed to be at risk of impact, "Moderate" for values that may be at risk of impact and require further investigation and "High" for values that are likely to be at risk of impact and will be prioritised for further investigation
- Confidence = Level of confidence with "Low" indicating a low level of confidence in the assigned level of concern, due to a poor understanding of the relevant risks, "Moderate" indicating a moderate level of confidence in the assigned level of concern, due to a reasonable understanding of the relevant risks and "High" indicating a high level of confidence in the assigned level of concern, due to a good understanding of the relevant risks

5.1 Fremantle

Eleven environmental values were initially assessed by the EWS for Fremantle and comprised of five medium and six low levels of concern (Table 27). Fourteen environmental values were considered in the follow-up assessment and comprised of 11 high and three medium risks for cumulative impacts, but only two high risks and 12 medium risks for harbour development impacts. After mitigation, most harbour development related risks were reduced to low risks. After considering the literature presented in section 2.1.1, data confidence remained the same or lower for all values when compared to the initial assessment of confidence by the EWS. All values had a data confidence of medium to high, except for migratory shorebirds and seabirds which was low.

Thirteen social values were initially assessed by the EWS for Fremantle and comprised of one medium and 12 low levels of concern (Table 27). The same values were considered in the follow up assessment and included four high and eight medium risks for cumulative impacts, but only one high and 12 medium risks associated with harbour development. Mitigation measures helped to reduce all harbour development risks to low, except for recreational water quality, which remained a medium risk. The literature presented in section 2.1.2 resulted in the data confidence of most values being lowered to a medium level of confidence when compared to the initial EWS assessment. No social values had a low level of data confidence for Fremantle.

Table 27: Comparison of initial and follow up assessments for environmental and social values identified for Fremantle.

Harb. dev. = harbour development, cat. = category of significance (1 or 2), sig. = significance of value (low, med, high), conf. = confidence in data when assigning risk.

	Initial assessment			Follow up assessment					
Environmental values	Cat.	Conf.	Level of Concern	Sig.	Conf.	Harb. dev. risk	Cumulative risk	Mitigated risk	Comments
Integral functioning ecosystem	1	H	L	H	M-H	M	M	L	
Sheltered marine ecological community									
Biological diversity	1	H	L	H	M	H	H	M	
High level of water quality	1	M	L	M	M	M	H	L	
High level of sediment quality	1	M	M	M	M-H	M	H	L	
Significant benthic communities and habitats									
Seagrass habitat				H	M	M	H	L	Seagrass meadows present in all directions surrounding the Inner Harbour
Other				L	M	M	M	L	Includes coral reefs, rocky reefs, macroalgae
Listed and significant fauna									
Threatened fauna									
Australian sealion	1	H	L						
Fairy tern	2	H	L	H	M	M	H	L	
Other threatened fauna	2	M	L-M						
Priority & specially protected fauna	2	M	L-M	H	M	M	M	L	Humpback whales
Migratory birds	2	M	L-M	H	M	M	H	L	
Iconic fauna									
Bottlenose dolphins	2	H	M	H	M-H	H	H	M	
Regionally significant spawning / nursery area									
Other				M	M	M	H	L	Fish species that complete their whole life cycles in the Swan Estuary (i.e. yellowtail flathead, black bream)
Regionally significant migratory pathways				M	M	M	H	L	Fish and invertebrate species that migrate to and from estuary and oceanic waters to complete their lifecycle
Marine reserves (existing and proposed)									
Swan Estuary Marine Park	2	H	L	H	M	M	H	L	
Coastal processes				M	M-H	M	H	L	Climate change impacts such as erosion and inundation

Social values	Initial assessment			Follow up assessment					Comments
	Cat.	Conf.	Level of Concern	Sig.	Conf.	Harb. dev. risk	Cumulative risk	Mitigated risk	
Heritage									
Aboriginal	2	H	L	M	H	M	M	L	
Maritime & historic	2	H	L	M	H	L	L	L	
Public health									
Recreational water quality	2	H	L	M	M	M	M	M	
Seafood quality safe for eating	2	M	L	H	M	M	M	L	
Social and community									
Recreational fishing	2	H	L	M	M-H	M	H	L	
Recreational swimming	1	H	L	L	M	M	M	L	
Recreational boating access	2	H	L	L	M	M	M	L	
Marina facilities	2	H	L	M	M	M	M	L	
Educational & scientific values	1	H	L	H	M	M	M	L	
Landscape and visual amenity	1	H	L	M	M	M	H	L	
Business, industry & commercial									
Tourism	2	H	L	H	M	M	H	L	
Commercial fisheries	1	H	L	H	M	H	H	L	
Aquaculture	2	M	M	H	M	M	M	L	

Table 28: Comparison of initial and follow up assessments for environmental and social values identified for Kwinana.

Harb. dev. = harbour development, cat. = category of significance (1 or 2), sig. = significance of value (low, med, high), conf. = confidence in data when assigning risk.

Environmental values	Initial assessment			Follow up assessment					Comments
	Cat.	Conf.	Level of Concern	Sig.	Conf.	Harb. dev. risk	Cumulative risk	Mitigated risk	
Integral functioning ecosystem	2	L	M-H	H	M	H	H	M	
Sheltered marine ecological community	2	H	L	H	M	M	M	L	
Biological diversity	2	M	H	H	L-M	H	H	M	
High level of water quality	2	M	H	M	M-H	H	E	M	
High level of sediment quality	2	M	L	M	L-M	M	H	L	
Significant benthic communities and habitats									
Seagrass habitat	2	M	H	H	M-H	H	H	M	
Other				L	L	M	M	L	Corals, rocky reef and soft sediments
Listed and significant fauna									
Threatened fauna									
Australian sealion	1	H	L	H	L-M	L	M	L	
Fairy tern	2	M	L	H	L-M	H	H	M	
Other threatened fauna	2	M	L-M						No other fauna (other than birds) identified
Priority & specially protected fauna	2	M	L-M						No other fauna (other than birds) identified
Migratory birds	2	M	L-M	H	L	H	H	M	
Iconic fauna									
Little penguins	2	L	H	H	M-H	H	H	M	
Bottlenose dolphins	2	L	H	H	M-H	H	H	M	
Regionally significant spawning / nursery area									
Pink snapper	2	L	H	H	M	H	H	M	
Whitebait				M	L-M	M	H	M	High abundances of eggs have been found
King George whiting	1	L	M	H	H	L	M	L	
Garfish	1	L	M	H	M-H	M	H	L	
Blue swimmer crab	1	M	M	H	M-H	M	H	L	
Marine reserves (existing and proposed):									
Shoalwater Islands Marine Park	2	H	M	H	M	M	H	L	
Coastal processes				M	M	M	H	L	Climate change impacts such as erosion and inundation

Social values	Initial assessment			Follow up assessment					Comments
	Cat.	Conf.	Level of Concern	Sig,	Conf.	Harb. dev. risk	Cumulative risk	Mitigated risk	
Heritage									
Aboriginal	2	H	L	M	H	L	M	L	
Maritime & historic	2	M	L	M	H	M	M	L	
Public health									
High quality source water for desalination	2	M	H	H	M-H	H	H	M	
Recreational water quality	2	H	L	M	M-H	M	M	L	
Seafood quality safe for eating	2	L	L	H	M-H	H	H	M	
Social and community									
Recreational fishing	2	H	H	M	M-H	M	H	L	
Recreational swimming	2	H	L	L	H	M	M	L	
Recreational water sports				L	M	M	M	L	Water sports popular in CS and surrounding bays.
Recreational boating access	2	H	M	L	H	M	M	L	
Marina facilities	2	H	L	M	M-H	L	M	L	
Educational & scientific values	2	H	L	H	M	M	M	L	
Landscape and visual amenity	1	H	M	M	M-H	M	M	M	
Business, industry & commercial									
Tourism				H	M-H	H	H	M	Tourism popular around Rockingham and southern CS.
Commercial fisheries	2	M	H	H	M-H	H	H	M	
Aquaculture	1	M	M	H	M-H	H	H	M	
Suitable quality water for industrial use	2	H	L	H	M-H	L	L	L	
Assimilation of wastewater	2	M	M	M	L-M	M	M	L	

Table 29: Comparison of initial and follow up assessments for environmental and social values identified for Bunbury.

Harb. dev. = harbour development, cat. = category of significance (1 or 2), sig. = significance of value (low, med, high), conf. = confidence in data when assigning risk.

Environmental values	Initial assessment			Follow up assessment					Comments
	Cat.	Conf.	Level of Concern	Sig.	Conf.	Harb. dev. Risk	Cumulative risk	Mitigated Risk	
Integral functioning ecosystem	2	M	L	H	L-M	M	H	L	
Sheltered marine ecological community	2	M	L	M	M	M	M	L	
Biological diversity	2	M	M	H	M	H	H	M	
High level of water quality	2	H	M-H	M	M-H	H	H	M	
High level of sediment quality	2	M	M	M	M	M	H	L	
Significant benthic communities and habitats									
Seagrass habitat	2	L	L	H	L-M	H	H	M	
Mangroves	2	M	M	L	M	M	H	L	Occur in Leschenault Inlet and parts of estuary. Initially included in terrestrial environmental values.
Other				L	L-M	M	M	L	Rocky reef, sponge gardens, soft sediments, mud flats, artificial reefs.
Listed and significant fauna									
Threatened fauna									
Fairy tern	2	M	L	H	L-M	H	H	M	
Other threatened fauna	2	M	L-M	M	L-M	M	H	L	Carter's freshwater mussel.
Priority & specially protected fauna	2	M	L-M	M	L	H	H	M	Pouched lamprey- Priority 3.
Migratory birds	2	L	L-H	H	L-M	H	H	M	
Iconic fauna									
Little penguins				H	M	H	H	M	Koombana Bay is a core foraging area for little penguins
Bottlenose dolphins	2	M	H	H	M	H	H	M	
Regionally significant spawning / nursery area									
Whitebait	1	L	M	M	L-M	H	H	M	
King George whiting				H	M	M	H	M	Leschenault Inlet an important nursery for 0+ whiting
Regionally significant migratory pathways				M	L-M	M	H	M	Blue swimmer crabs migrate into Leschenault Estuary to spawn.
Marine reserves (existing and proposed):									
Leschenault Regional Park	2	M	L	H	M	M	H	L	
Coastal processes				M	L-M	L	H	L	Climate change impacts such as erosion and inundation.

Social values	Initial assessment			Follow up assessment					Comments
	Cat.	Conf.	Level of Concern	Sig.	Conf.	Harb. dev. risk	Cumulative risk	Mitigated risk	
Heritage									
Aboriginal	2	M	H	M	H	H	H	M	
Maritime & historic	2	M	M	M	H	M	M	L	
Public health									
Recreational water quality	2	M	L	M	M	M	M	L	
Seafood quality safe for eating	2	L	L	H	M	H	H	M	
Social and community									
Recreational fishing	2	M	L	M	M	M	H	L	
Recreational swimming	1	H	L	L	M	M	M	L	
Recreational water sports				L	L-M	L	M	L	Recreational water sports occurs in the Leschenault Inlet and parts of KB
Recreational boating access	2	H	L	L	M	L	M	L	
Marina facilities	2	H	L	M	M	L	M	L	
Educational & scientific values	2	H	L	H	M	M	M	L	
Landscape and visual amenity	1	H	M	M	M	M	M	M	
Business, industry & commercial									
Tourism	2	M	M	H	M	H	H	M	
Commercial fisheries	1	M	L	H	M	M	H	L	

5.2 Kwinana

Eighteen environmental values were initially assessed for Kwinana by the EWS and included seven high, seven medium and four low levels of concern (Table 28). Nineteen values were considered in the follow up assessment and comprised one extreme, 14 high and four medium risks for cumulative impacts, and nine high, eight medium and two low risks for harbour development impacts. After mitigation, harbour development risks were all low to medium. The literature provided in section 2.2.1 improved the data confidence for integral functioning ecosystem, little penguins, bottlenose dolphins, pink snapper, King George whiting and garfish when compared with the initial assessment. Benthic communities other than seagrass, migratory shorebirds and seabirds have low data confidence, and low to medium confidence was assigned to biological diversity, sediment quality, Australian sea lions, fairy terns and whitebait.

Fifteen social values were initially assessed by the EWS and included three high, four medium and eight low levels of concern (Table 28). Seventeen values were considered in the follow up assessment and included eight high and nine medium risks for cumulative impacts, and six high, eight medium and two low risks for harbour development impacts. Mitigation measures resulted in ten medium and seven low risks. The literature presented in section 2.2.2 improved the data confidence for maritime and historic heritage and seafood quality when compared to the initial EWS assessment. No social values had a low level of data confidence for Kwinana, though assimilation of wastewater was considered to have low-medium data confidence.

5.3 Bunbury

The EWS initially assessed thirteen environmental values for Bunbury which included three high, five medium and five low levels of concern (Table 29). In the follow up assessment, 19 values were considered and included 17 high and three medium risks for cumulative impacts and eight high, ten medium and one low risk associated with harbour development impacts. Mitigation measures reduced all harbour related risks to low and medium. After considering the literature presented in section 2.3.1, data confidence remained the same or lower for all values when compared to the initial assessment of confidence by the EWS. Benthic communities other than seagrass and mangroves and the pouched lamprey were considered to have low data confidence around the risk ratings. Several more values were given low-medium confidence ratings.

Twelve social values were initially assessed by the EWS for Bunbury and comprised of one high, three medium and eight low levels of concern (Table 29). Thirteen values were considered in the follow up assessment and included five high and eight medium risks for cumulative impacts and three high, seven medium and three low risks for harbour development impacts. After mitigation, harbour development related risks were lowered to mostly low risks, with the exception of aboriginal heritage, seafood quality, landscape and visual amenity and tourism, which were assessed as having medium risks. The literature presented in section 2.3.2 helped to improve data confidence from medium to high for aboriginal and maritime/historic heritage, and from low to medium for seafood quality. All values were considered to have medium or high data confidence, with the exception of recreational water sports which was low – medium.

5.4 Conclusion

The environmental and social values, significance of values, data confidence and risk assessments presented in this report are considered more accurate than the assessments presented in the EWS Stage One Progress Report (November 2018). The assessments in this report are supported by an extensive literature review of the marine environment for all three areas of interest and were further supported through consultation with stakeholders. The number of values assessed as having an unmitigated high risk for all three areas of interest were greater in this report. Data confidence for most values remained the same or lower for Fremantle, generally improved for Kwinana, and remained the same or lower for Bunbury.

6 Knowledge gaps to direct future work

The knowledge gaps compiled in Table 30 come from a combination of specific suggestions from the literature, review of the low data confidence listings for the identified values, and an analysis of what was missing from the literature review presented in this report. These gaps can be used to direct future work to improve our understanding of the marine environment for Fremantle, Kwinana and Bunbury and are not specific to harbour development. For Cockburn Sound, Kwinana, many suggestions on missing information and future studies came from the recent Cockburn Sound-Drivers-Pressures-State-Impacts-Responses Assessment 2017 (BMT 2018). Most of the gaps identified are applicable for all three areas of interest. It is recognised that the gaps listed are extensive but not exhaustive, and consultation with stakeholders would likely refine and identify additional gaps in knowledge.

The prioritised list of significant gaps that are applicable for *all three areas* of interest are highlighted in Table 30, and include:

- Updated measurements on surface water drainage, groundwater nutrient concentrations, flux and contaminants
- Hydrodynamic modelling inclusive of groundwater flows, recent and localised wave and wind climate data, and influence of dredged channels
- The impact of copper-based coatings or other TBT-replacement coatings for vessels on the marine environment
- Contemporary contaminant sources and pathways and consideration of emerging potential contaminant risks
- Routine widespread monitoring of contaminants, refinement of trigger values and inclusion of reference sites
- Effects of PFAS and other contaminants (i.e. mercury) on marine food webs
- Level of plastic contamination (e.g. microplastics, debris) and attached pollutants
- Further investigation into the role of microphytobenthos in soft sediments
- The level of resilience of coastal environment and key marine ecological components (e.g. communities of plankton, fish, seagrass, benthic macroinvertebrates), including responses to climate change
- Bioaccumulation of contaminants in marine life e.g. seabirds, fishes, sea lions
- Establishing routine monitoring of fish and invertebrate communities with the purpose of detecting temporal trends and shifts in composition in relation to environmental conditions
- Impact of specific sediment type, shape and size from each of the port areas on larval fish
- Causes of recruitment variation in blue swimmer crabs including impacts of recent marine heatwaves
- Integrative models to better understand the interactions within and between ecological and social components of the marine environment, helping decision-makers to more fully understand what the key ecosystem levers are and where future management action should be targeted
- Modelling of coastal processes and sediment transport along shorelines that is calibrated against local sediment budgets and that can inform effective coastal planning
- Development of ecological models that allow scenario testing and that can be coupled with contemporary decision support models

In addition to the above list, prioritised gaps are also specified for each area of interest in Table 30 and include:

Fremantle

- Is the Inner Harbour habitat specifically utilised (i.e. foraging) by fish species migrating between the estuary and ocean?

Kwinana

- Year-round water quality measurements to capture seasonal variations

- Routine widespread monitoring of contaminants, refinement of trigger values and inclusion of reference sites
- Knowledge of cause(s) and pressure-response pathways associated with decreasing seagrass shoot density trends in Cockburn Sound e.g. potential sulphide intrusion into root systems
- Regular mapping of seagrass meadows at the site level and entire Cockburn Sound and determination of the best monitoring methods to detect changes in seagrass health
- The broad scale efficacy of seagrass restoration efforts across Cockburn Sound to better understand the local parameters and regional factors influencing seagrass restoration success rates (including effects of climate change)
- Experimentation into development of artificial niche foraging habitats for dolphins?
- Measurements of dissolved oxygen in sediments and fluctuations between day and night
- Identification of specific migratory shorebird and seabird sites and identification of suitable alternative sites for climate changed induced shifts
- Factors affecting recruitment and spawning variation, changes in growth and stock productivity, and increased predation by sharks on pink snapper

Bunbury

- Year-round water quality measurements to capture seasonal variations
- Identification of specific migratory shorebird and seabird sites and identification of suitable alternative sites for climate change induced shifts
- Population and ecological studies on the giant cuttlefish that dolphins specialise in feeding on in Bunbury

7 Recommendations for next steps

This report presents a high-level review and preliminary risk assessment of environmental and social values for Fremantle, Kwinana and Bunbury. The recommendations provided in this section will improve understanding of the risks facing these three environments and will also provide additional information that may affect the findings in this report.

Next steps to be considered for the Westport Port and Environs Strategy include:

- Development of a research framework to deal with the gaps identified in Section 5, which would include a better understanding of government, industry, Indigenous and community values and a process for determining future research directions, e.g. the WAMSI framework to implement 'Blueprint for Marine Science 2050' priorities
- Investigate the feasibility of potential mitigation measures and identifying additional measures that may help to lower the risk of impact of harbour development in the three areas of interest. To do this, subject matter experts and engineering advice should be sought to ensure mitigation measures are worked into the design and management frameworks of harbour development.
- Comprehensive risk analysis of environmental and social values based on more detailed harbour concepts and engagement with stakeholders and engineers

Table 30: Knowledge gaps in the marine environment compiled from specific suggestions from the literature, review of the low data confidence listings for the identified values, and an analysis of what was missing from the literature review.

Light grey shading indicates gaps that are common across more than one location, and coloured shading relates to each area of interest. Bolded text are those knowledge gaps that are considered priorities.

FREMANTLE	KWINANA	BUNBURY
WATER AND SEDIMENT QUALITY		
• **Updated measurements on groundwater nutrient concentrations and contaminants** • Direct measurements and quantification of phytoplankton productivity • Accurate and regular pH measurements to assess ocean acidification • Rates of sediment denitrification and nutrient fluxes • **Hydrodynamic modelling inclusive of groundwater flows, recent and localised wave and wind climate data, and influence of dredges channels** • **The impact of copper-based coatings or other TBT-replacement coatings for vessels on the marine environment** • **Contemporary contaminant sources and pathways and consideration of emerging potential contaminant risks** • Establishment of environmental quality guidelines for the breakdown products if TBT (dibutyltin-DBT and monobutyltin- MBT) • **Level of plastic contamination (e.g. microplastics, debris) and attached pollutants** • **Effects of PFAS on marine food webs** • **Routine widespread monitoring of contaminants, refinement of trigger values and inclusion of reference sites**		
	• **Year-round water quality measurements to capture seasonal variations**	
	• **Measurements of dissolved oxygen in sediments and fluctuations between day and night** • Analysis of the WASQAP long-term phytoplankton dataset to evaluate temporal dynamics and potential shifts in phytoplankton abundance and composition • Monitoring of water quality around other pesticide/herbicide manufacturing sites (such as Bayer Crop Science)	• Leschenault Inlet has only had snapshot studies performed to date • Water quality data needs to be collected directly from the drainage outlets and studies undertaken to determine what pollutants are entering the Leschenault Inlet from the drainage systems and impacts on the Inlet ecosystem including the benthic communities
MARINE COMMUNITIES		
• Further identification of suitable indicator species to assess health of benthic, demersal, pelagic and coastal communities • **Further investigation into the role of microphytobenthos in soft sediments** • Estimates of zooplankton grazing rates and secondary production for understanding pelagic food web dynamics • **The level of resilience of coastal environment and key marine ecological components (e.g. communities of plankton, fish, seagrass, benthic macroinvertebrates), including responses to climate change** • **Bioaccumulation of contaminants in marine life e.g. seabirds, fishes, sea lions** • Population size and movement patterns of Australian sea lions • Information on the impacts of species removal on ecosystems and associated food webs • What is the current rate of tropicalisation by marine species extending south, and what are the projections into the future with consideration of sheltered embayments and estuaries • **Establishing routine monitoring of fish and invertebrate communities with the purpose of detecting temporal trends and shifts in composition in relation to environmental conditions** • Biodiversity of fish communities and their ecological roles (not fisheries based) • **Impact of specific sediment type, shape, size from the areas of interest on larval fish** • Susceptibility of fish and crabs to disease when stressed under poor water quality • Feasibility of artificial seagrass meadows and the positive and negative ecosystem benefits		
	• **Identification of specific migratory shorebird and seabird sites and identification of suitable alternative sites for climate change induced shifts**	

FREMANTLE	KWINANA	BUNBURY
	• The impact of industrial seawater intakes on larval and juvenile fish and other biota • Monitoring for coral assemblages to assess changes in health of Cockburn Sound • **Knowledge of definite cause(s) and pressure-response pathways associated with downward shoot density trends in Cockburn Sound e.g. potential sulphide intrusion** • **Regular mapping of seagrass meadows at the site level and entire Cockburn Sound** • **The broad scale efficacy of seagrass restoration efforts across Cockburn Sound to better understand the local parameters and regional factors influencing seagrass restoration success rates (including effects of climate change)** • **Experimentation into development of artificial niche foraging habitats for dolphins** • Use of Cockburn Sound as a foraging ground for sea lions • Further investigation into the diet of Garden Island little penguins • Modelling the shift in little penguin prey species with changing environmental conditions • Effects of brine discharge on marine communities	• **Population and ecological studies on the giant cuttlefish that dolphins specialise in feeding on in Bunbury** • Regional importance of the Preston River to the priority 3 listed pouched lamprey
FISHERIES		
• **Causes of recruitment variation in blue swimmer crabs including impacts of the recent heatwave** • Environmental effects on recruitment of octopus • Tolerance of tailor and pilchard eggs and larvae to changing environmental conditions • Factors affecting recruitment variation in Australian herring • Biological stock structure and effects of increasing temperatures on king prawns		
	• **Factors affecting recruitment and spawning variation, changes in growth and stock productivity, and increased predation by sharks on pink snapper** • The sustainability of commercial and recreational fisheries and aquaculture production	
SOCIAL		
• Development of environmental quality criteria to measure whether cultural and spiritual values are being protected • Characterisation of the contemporary visitation and use of beaches and the coastal environment • **Integrative models to better understand the interactions within and between ecological and social components of the marine environment, helping decision-makers to more fully understand what the key ecosystem levers are and where future management action should be targeted**		
CLIMATE CHANGE AND COASTAL PROCESSES		
• **Modelling of coastal processes and sediment transport along shorelines that is calibrated against local sediment budgets to inform effective coastal planning**		

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10 Appendices

Appendix 1

Table 1: Stakeholders consulted during the literature review and risk assessment phases of this report.

Stakeholders	Contact	Outcome
BMT	Rob De Roach	Rob away on extended leave
CSCA		Filled in a form for request of spatial layers for erosion and inundation- no response
CSIRO	John Keesing	Provided discussion around water quality in Cockburn Sound
CSMC	Kateryna Longley	Advised to direct requests to Tina Runnion
Curtin University	Sylvia Osterreider (sea lions)	Sent through additional sea lion literature
DBCA Bunbury	Christine Taylor	Provided information on fairy terns in the Bunbury region
DPIRD (Fisheries)	Various	Requested reports via Hans and his contacts at Fisheries
DWER	Tina Runnion	Loaned older reports not available online
Kwinana Industries Council	Chris Oughton	No other reports to provide other than what is available online. Recommended old reports are obsolete, all work done through a third party like CSMC
Murdoch University	Fiona Valesini (fish)*	Sent through link to relevant FRDC report and provided preliminary incite of the risks associated with fishes
	Claire Greenwell (birds)	Sent through seabird/shorebird reports and journal articles for south-west
	Kate Sprogis (dolphins)	Brief exchange over phone
	Delphine Chabanne (dolphins)*	Preliminary revision of issues and risks identified for dolphins
	James Tweedley (fish)	Sent through some prawn literature
South West Catchments Council	Jenelle Bowles	Jenelle sent a list of literature to choose from. Requests sent back but no response from Jenelle.
UWA	Belinda Cannell (penguins)*	Preliminary review of assessment and literature on little penguins
	Marion Cambridge (seagrass)*	Preliminary review of seagrass issues and risks
Water Corporation	Bree Atkinson	Sent through requested reports
Westport	Hans Kemps	Provided relevant reports, mostly from port authorities

Stakeholders were contacted for the purposes of obtaining grey literature and/or reviewing sections of the report relevant to their specialised area of research.

*Subject matter experts all stressed that it was hard to give concrete advice without knowing more about the port development footprints and indirect effects resulting from hydrological changes.

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Appendix 2

Table 1: Expanded issues and risk assessment relating to marine and estuarine environmental values for Fremantle.

Ref#	Value	Issue	Conseq.	Likeli.	Risk	Data confidence	Justification
1	Integral functioning ecosystem	Decrease in current ecosystem functioning within and around port footprint with increased use and development	Minor (2)	Likely (4)	Med (8)	Med/high	Environment already highly modified and degraded from previous development and eutrophication in the estuary is an ongoing problem further upstream. Already a working port with vessel traffic so may not expect major declines in current ecosystem functioning if expansion happened.
2	Biological diversity	Decrease in biological diversity due to increasing sea temperatures and distribution shifts of species	Minor (2)	Possible (3)	Med (6)	Low	Tropicalisation may not necessarily decrease biological diversity, as new species will be inhabiting the area and some current species may have time to gradually adapt. It is almost certain to change community compositions. Climate change is an external driver.
2.1	Biological diversity: fish assemblages	Reduction in fish abundance/biodiversity from habitat degradation	Major (4)	Unlikely (2)	Med (8)	Low/med	Fish species migrate seasonally between the Swan River and the Indian Ocean via the Inner Harbour. Many species spend all life cycle stages in the estuary and would have limited capacity to recover from disturbances. Already an operating port so expansion may not have a big impact.
2.2	Biological diversity: demersal and benthic communities	Reduction in biodiversity of demersal and benthic communities from habitat degradation	Moderate (3)	Possible (3)	Med (9)	Low/med	Already a degraded system due to current port operations. Only short lived marine biota occur in the anchorage area of Gage Roads due to continual disturbance from vessels and anchors. Increased vessel traffic may not allow enough time for some ephemeral species to survive long enough to reproduce.
2.3	Biological diversity: invasive species	Increased risk of introduced marine pests with increasing vessel traffic	Major (4)	Likely (4)	High (16)	High	Already marine pests documented in Swan Estuary and Fremantle Port area. Environment considered compatible for 79% of potentially introduced species.
3.1	High level of water quality: nutrients	Elevated nutrient levels with increased use and development of Fremantle Port	Moderate (3)	Unlikely (2)	Med (6)	Med	Already an impacted system due to current port operations. Elevated nutrients from inner harbour would be flushed out with tides but may affect surrounding areas. Surrounding environment would have adjusted or are already influenced by altered nutrient levels due to presence of port.
3.2	High level of water quality: Chl a/ phytoplankton	Increased nutrients and warmer temperatures may cause toxic phytoplankton blooms in the estuary	Moderate (3)	Likely (4)	High (12)	Med/high	Phytoplankton blooms in the estuary have been increasing in frequency and density and fish kills have resulted. This may influence downstream health.
3.3	High level of water quality: light attenuation/turbidity	Increased light attenuation from increased turbidity as a result of dredging (construction)	Moderate (3)	Almost certain (5)	High (15)	Med/high	Dredging will occur with port development. Inner Harbour already a turbid environment. Turbidity will improve over time, thus light attenuation is reversible itself, but the impact it has on marine biota may not be. Spread of suspended sediments would depend on port footprint and water circulation.
3.3	High level of water quality: light attenuation/turbidity	Increased light attenuation from increased turbidity as a result resuspended sediments from increased shipping traffic (operational)	Moderate (3)	Likely (4)	High (12)	Med/high	Continued resuspension of fine sediments and inorganic material from large propeller wash i.e. ships and tugs. Not as severe as dredging. Already an operational port. Concentrations of suspended sediments may not be as severe as dredging, but they would be long-lived and constant. Spread of suspended sediments would depend on port footprint and water circulation.
3.4	High level of water quality: dissolved oxygen	Decreased dissolved oxygen due to increasing temperatures which may cause temporary or permanent dead zones	Major (4)	Unlikely (2)	Med (8)	Low	Warmer temperatures promote faster algae growth and oxygen consumption. Dependant on the speed of ocean warming and is hard to predict. Entrance channel would mix with oceanic waters, but low oxygen could occur further upstream.

Ref#	Value	Issue	Conseq.	Likeli.	Risk	Data confidence	Justification
3.5	High level of water quality: temperature	Increased incidence of marine heatwave events that could cause stress and death to marine life	Major (4)	Likely (4)	High (16)	Med	Over time could increase to 'Extreme' risk depending on speed of warming and frequency of heatwaves.
3.6	High level of water quality: salinity	Increased incidence of flooding will increase discharges of fresher and turbid water plumes from the Swan Canning catchment	Moderate (3)	Possible (3)	Med (9)	Med	The extent of influence of plumes into Owen Anchorage and Cockburn Sound would be dependent on any alterations to hydrology. Hard to predict the future rates of occurrence of flooding. Last flooding event to reach Cockburn Sound was early 2017.
3.6	High level of water quality: salinity	Salinity patterns in the Swan and inner harbour are likely to be impacted by reduced rainfall under a drying climate	Major (4)	Possible (3)	High (12)	Low/med	A more saline environment would change the marine communities in the estuary, and potentially the species migrating through the entrance channel.
3.7	High level of water quality: ph	Increase in pH may cause acidification and negatively impact calcareous organisms	Major (4)	Possible (3)	High (12)	Low/med	Acidification is occurring elsewhere. Limited temporal data for region to detect trends and make predictions.
3.8	High level of water quality: contaminants	Resupply of contaminants to water column through re-suspension of sediments	Moderate (3)	Possible (3)	Med (9)	Med/high	High levels of contaminants in sediments of Inner Harbour. Testing of sediments indicates that contaminants may not be released from sediments at levels which may affect the marine environment, except for arsenic. After phase 1 and phase 2 of the port dredging campaign in 2010, toxicants did not exceed trigger levels in water or mussels when monitored in 2010 and 2011.
3.8	High level of water quality: contaminants	Increased incidence of oil and fuel spills with increased vessel traffic	Major (4)	Likely (4)	High (16)	Low/med	Port expansion in Fremantle would see an increase in vessels in the area. The region is already considered as having a high risk to oil spills. Small spills are more common than larger spills.
3.9	High level of water quality: groundwater	Increased nutrient levels discharged into the Inner Harbour and surrounds from groundwater	Minor (2)	Possible (3)	Med (6)	Low	Groundwater beneath North Quay and Victoria Quay flow towards the Inner Harbour, and to the Indian Ocean for Victoria Quay. Flushing with seawater would disperse nutrients.
3.10	High level of water quality: hydrology	Increased circulation of the Swan Estuary (lower reaches) and migration of higher salinity concentrations upstream with deeper dredge channel	Moderate (3)	Likely (4)	High (12)	Low/med	Removal of rock bar (1987) and harbour basin expansion altered tidal dynamics within the estuary. Salinity concentrations may increase further upstream. Increased circulation may also improve water quality.
4.1	High level of sediment quality: contaminants	Increase in contamination of sediments with increased shipping and port operations	Moderate (3)	Possible (3)	Med (9)	Med/high	Inner Harbour already has elevated levels of contaminants. TBT not used for antifoul anymore. Cargo port and container shipping rather than mineral exports.
4.2	High level of sediment quality: acid sulphate soils	Potential acid sulphate soils could become actual acid sulphate soils during development	Minor (2)	Unlikely (2)	Low (4)	Med	Sediments in the Swan River and Inner Harbour are potential acid sulphate soils. Has not been exposed with previous development.
5.1	Significant benthic communities and habitats: seagrass	Loss of seagrass meadows from dredging channels	Moderate (3)	Possible (3)	Med (9)	Med	Seagrass meadows occur directly to the north, south and further west of the port entrance, as well as in the estuary. Seagrass patches occurred at varying densities along the Deep Water Channel and include eight species.
5.1	Significant benthic communities and habitats: seagrass	Reduced seagrass growth due to poor light availability as a result of dredging and vessel use	Moderate (3)	Possible (3)	Med (9)	Med/high	Seagrass meadows occur directly to the north, south and further west of the port entrance, as well as in the estuary. No significant declines in seagrass from dredging in 2010 were recorded. More area for sediments to disperse out of the inner harbour entrance. Already an area of high vessel traffic.

Ref#	Value	Issue	Conseq.	Likeli.	Risk	Data confidence	Justification
5.1	Significant benthic communities and habitats: seagrass	Increased incidence of marine heatwaves may cause decrease in seagrass biomass	Major (4)	Likely (4)	High (16)	Low	Occurred at Shark Bay for *Antarctica* species; risk is dependent on frequency of marine heatwaves and the magnitude felt for Fremantle. Depends on resilience of the species in a particular location.
5.2	Significant benthic communities and habitats: coral reefs	Degradation of Hall Bank coral community with spread of suspended sediments from dredging	Moderate (3)	Possible (3)	Med (8)	Med	After dredging of the port and channels in 2010, no impacts to corals at Hall Bank were measured, however water clarity was affected at Preston Point beach, Bathers Beach, Fremantle SLSC and Port Beach. No significant losses of coral or seagrass habitat were recorded after previous dredging campaigns.
5.3	Significant benthic communities and habitats: rocky reefs	Degradation of rocky reef communities with increased development e.g. Minden Reef	Moderate (3)	Possible (3)	Med (9)	Med	Minden Reef already subject to a high sediment regime with a lot of abiotic materials being deposited on the reef i.e. sand, silt, rock, wreckage.
5.4	Significant benthic communities and habitats: macroalgae	Loss of macroalgae habitats with increased development	Minor (2)	Unlikely (2)	Low (4)	Med	Macroalgae found on limestone pavement outcrops in the Deep Water Channel. Macroalgae can re-establish relatively quickly.
6.1	Listed and significant fauna: fairy tern	Loss of shoreline habitat due to development and/or sea level rise	Major (4)	Possible (3)	High (12)	Med/high	Over time risk will increase with sea level rise. Successful breeding colony at Rous Head that is offered protection.
6.1	Listed and significant fauna: fairy tern	Bioaccumulation of contaminants through the food chain that would negatively affect survival and/or breeding success	Moderate (3)	Possible (3)	Med (9)	Low	TBT is being reduced. Terns are not bottom feeders but contaminants may accumulate in fish prey. Could impact viability. Port operations may increase contaminants in the water and sediments, though terns may be less likely to ingest contaminated fish given the open coastline.
6.2	Listed and significant fauna: bottlenose dolphins	Increase in underwater noise from development and construction could deter dolphins from their usual habitats and interrupt communications between dolphins	Minor (2)	Likely (4)	Med (8)	High	Dolphins have been documented avoiding noisy areas temporarily and changing their usual behaviours. Dolphins may investigate due to curiousness but depends on the noise. Noises can be short lived or intermittent.
6.2	Listed and significant fauna: bottlenose dolphins	Degradation of foraging hotspots in the Inner Harbour	Moderate (3)	Possible (3)	Med (9)	Med/high	The inner harbour has been identified as a seasonal hotspot that is strongly linked with foraging behaviour. Deepening of the channel and increased vessel use may impact in these hotspots. May degrade over time or remain the same.
6.2	Listed and significant fauna: bottlenose dolphins	Bioaccumulation of contaminants through the food chain that would negatively affect survival and/or breeding success	Major (4)	Possible (3)	High (12)	Low	Dolphins that died in the Swan-Canning in 2009 were found to have organic contaminants in their blubber. Death was not definitely attributed to contaminants.
6.3	Listed and significant fauna: Whales	Decrease in humpback whale occurrence due to port operations	Moderate (3)	Possible (3)	Med (9)	Med	Females and calves are often seen resting in the waters between Rottnest and the Fremantle coast from Sep-Nov during their southerly migration. Increased vessel traffic could deter whales or increase vessel strikes. Noise from dredging could also deter whales or interrupt communications.

Ref#	Value	Issue	Conseq.	Likeli.	Risk	Data confidence	Justification
6.4	Listed and significant fauna: migratory shorebirds and seabirds	Sea level rise could inundate important shoreline habitat	Moderate (3)	Possible (3)	Med (9)	Low	Low data confidence on the location's shorebirds use within the port area. Birds would also make use of nearby islands. Foraging and nesting occurs along the shorelines. There would be localised loses of suitable habitat but this may flow on to impact the population as a whole if other suitable habitat is not available.
7	Regionally significant spawning / nursery area: other fish species	Fish species that spend their whole life cycles in the estuary (i.e. yellowtail flathead, black bream) may be negatively impacted by habitat degradation or alteration	Major (4)	Unlikely (2)	Med (8)	Med	Discrete self-replenishing stocks with limited capacity to recover if stocks are depleted. Already an operating port and species still occurring.
8.1	Regionally significant migratory pathway: yellowfin whiting	Suspended sediments and noise from dredging may impact on larval recruitment into the estuary from coastal waters	Moderate (3)	Possible (3)	Med (9)	Low/med	Inner harbour is the only entry/exit point for migration/recruitment. Dredged sediments may be ingested by larvae and clog gills.
8.2	Regionally significant migratory pathway: blue swimmer crab	Habitat degradation from port operation may reduce abundances in the lower Swan Estuary	Major (4)	Unlikely (2)	Med (8)	Med	Crabs can be found in the lower reaches of the estuary year round. Degradation may occur over time from increased vessel traffic, nutrient loading, contaminants, sediment disturbance, potential oil spills. Stocks may be replenished from Cockburn Sound. Already an operating port that has affected the system, and crabs are still present.
8.2	Regionally significant migratory pathway: blue swimmer crab	Suspended sediments and noise from dredging may impact on adults migrating out of the estuary, and also impact on spawning in coastal waters	Moderate (3)	Possible (3)	Med (9)	Med	Females mate in the estuary in summer. Inner harbour is the only entry/exit point for migration/recruitment. Dredged sediments may spread to surrounding coastal areas where spawning may occur.
8.3	Regionally significant migratory pathway: whitebait	Suspended sediments and noise from dredging may impact on larval stages, which peak in abundance in the lower reaches of the swan estuary	Moderate (3)	Possible (3)	Med (9)	Low/med	Dredged sediments may spread upstream and be ingested by larvae or clog gills. May be restocked by other populations once sediments settle.
8.4	Regionally significant migratory pathway: Australian herring	Suspended sediments and noise from dredging may impact on the migration of adults from the estuary to coastal waters, and also impact on spawning in coastal waters	Moderate (3)	Possible (3)	Med (9)	Low/med	Inner harbour is the only entry/exit point for migration/recruitment. Dredged sediments may spread to surrounding coastal areas where spawning may occur. Form part of a widespread south-west stock and it's thought that local disturbance would have little impact on use of the estuary.
8.5	Regionally significant migratory pathway: Perth herring	Increasing salinity from lower rainfall may impact on the distribution of fish throughout the estuary	Major (4)	Possible (3)	High (12)	Med	Evidence for distribution being linked with salinity. The population is an isolated breeding stock and recovery would be limited if the stock were to be depleted; stocks have already been reduced and may still be declining. Inner harbour is the only entry/exit point for migration/recruitment.

Ref#	Value	Issue	Conseq.	Likeli.	Risk	Data confidence	Justification
8.5	Regionally significant migratory pathway: Perth herring	Suspended sediments and noise from dredging may impact on the migration of adults from oceanic waters into the estuary where they spawn	Major (4)	Possible (3)	High (12)	Med	The population is an isolated breeding stock and recovery would be limited if the stock were to be depleted; stocks have already been reduced and may still be declining. Inner harbour is the only entry/exit point for migration/recruitment.
8.6	Regionally significant migratory pathway: sea mullet	Suspended sediments and noise from dredging may impact on the migration of adults from the estuary to oceanic waters	Moderate (3)	Possible (3)	Med (9)	Low/med	Inner harbour is the only entry/exit point for migration/recruitment.
8.7	Regionally significant migratory pathway: yelloweye mullet	Suspended sediments and noise from dredging may impact on the migration of adults from the estuary to oceanic waters, and also impact on spawning in coastal waters	Moderate (3)	Possible (3)	Med (9)	Low/med	Inner harbour is the only entry/exit point for migration/recruitment. Dredged sediments may spread to surrounding coastal areas where spawning may occur.
8.8	Regionally significant migratory pathway: mulloway	Suspended sediments and noise from dredging may impact on the mulloway occurrence and abundance	Moderate (3)	Possible (3)	Med (9)	Med	Inner harbour is the only entry/exit point for migration/recruitment. Sedimentation of holes may impact upon juvenile feeding. Underwater noise will increase during expansion works which may impact on communications between mulloway (croakers, grunters).
8.9	Regionally significant migratory pathway: prawns	Increasing salinity from lower rainfall and increasing temperatures may impact on the distribution of western school prawns throughout the estuary	Major (4)	Possible (3)	High (12)	High	Western school prawns are distributed in relation to salinity and temperature. An increase in salinity further upstream may allow prawns to utilise more habitat. Climate change is an external driver
8.9	Regionally significant migratory pathway: prawns	Habitat degradation from port operations may reduce abundances of western school prawns in the estuary	Major (4)	Unlikely (2)	Med (8)	Low/med	Western school prawns can be found in the lower to middle reaches of the estuary. Degradation may occur over time from increased vessel traffic, nutrient loading, contaminants, sediment disturbance, potential oil spills. Form a discrete, self-replenishing breeding stock with limited capacity to recover if disturbed. Restocking in 2015/16 was required to assist the recovery of stocks. Already an operating port so effects would be currently felt.
8.9	Regionally significant migratory pathway: prawns	Suspended sediments and noise from dredging may impact on the migration of adult western king prawns from oceanic water into the estuary	Moderate (3)	Possible (3)	Med (9)	Med	Inner harbour is the only entry/exit point for migration/recruitment.
8.10	Regionally significant migratory pathway: black mussels	Suspended sediments from dredging may impact on the larvae that enter the estuary from the ocean	Moderate (3)	Possible (3)	Med (9)	Low/med	Inner harbour is the only entry/exit point for migration/recruitment.

Ref#	Value	Issue	Conseq.	Likeli.	Risk	Data confidence	Justification
8.11	Regionally significant migratory pathway: other fish species	Fish species such as small tooth flounder and tailor use parts of the estuary during their life cycles, which may be affected by suspended sediments from dredging operations	Moderate (3)	Possible (3)	Med (9)	Med	Inner harbour is the only entry/exit point for migration/recruitment.
9	Swan Estuary Marine Park	Degradation of marine park through upstream flow on effects of increased development/port operations	Major (4)	Possible (3)	High (12)	Med	Port operates right in the mouth of the estuary. Environment already highly modified from previous development of the inner harbour, and eutrophication in the estuary is an ongoing problem.
10	Coastal processes	Inundation of coastal use areas (e.g. South Mole, Bathers Beach) due to sea level rise	Moderate (3)	Likely (4)	High (12)	Med	Sea level is predicted to rise over time. Climate change is an external factor.
10	Coastal processes	Inundation of foreshores of Swan Estuary due to coastal flooding	Moderate (3)	Likely (4)	High (12)	Med	Insufficient setback of infrastructure along the foreshores of the estuary. Coastal flooding predicted to increase over time. Climate change is an external factor.
10	Coastal processes	Increased erosion of Port Beach and potential influence on Port operations	Moderate (3)	Likely (4)	High (12)	High	Fremantle Port expected to be impacted by erosion at Port Beach in the medium term. Port Beach listed as 'extreme' risk for erosion.

Table 2: Expanded issues and risk assessment relating to marine and estuarine social values of Fremantle.

Ref#	Value	Issue	Conseq.	Likeli.	Risk	Data confidence	Justification
1.1	Heritage: Aboriginal	Loss or degradation of important heritage sites with increased development	Minor (2)	Possible (3)	Med (6)	High	Loss/degradation of sites would likely be avoided at all opportunities. Backlash from community if valued sites were impacted significantly. Valued sites occur adjacent to port footprint. Degradation of these areas could occur over time with increased use and development.
1.2	Heritage: Maritime/historic	Loss or degradation of important historical sites with increased development	Minor (2)	Unlikely (2)	Low (4)	High	Loss/degradation of sites would likely be avoided at all opportunities. Backlash from community if valued sites were impacted significantly.
2.1	Public health: Recreational water quality	Increased safety concerns for primary and secondary contact with water due to decreased water quality	Minor (2)	Possible (3)	Med (6)	Med	Already an operating port. No beaches directly in the Inner Harbour, and beaches outside the harbour on adjacent coastline may remain safe due to mixing with oceanic water and dispersal of any contaminants. Poor water quality extending upstream of port may impact on recreational water use and swimming off river beaches.
2.2	Public health: Seafood quality	Decrease in health of shellfish and fish with increased contamination in waters and sediments	Moderate (3)	Possible (3)	Med (9)	Med	Eating shellfish is not recommended outside of commercial harvesting. Fish such as black bream already have very low levels of contaminants and over time this may continue to accumulate to unsafe levels if contaminant levels are increased. Decrease in seafood quality would impact on favourite past times and social gatherings.
3.1	Social and community: Recreational fishing	Reduction or loss of popular fished species in the estuary due to interruptions in migration/recruitment into/out of the estuary during dredging campaigns	Major (4)	Possible (3)	High (12)	Med/high	Depends on timing of dredging. Only one entry/exit point for fish exchanging between the ocean and estuary. Fishing important to many people in the estuary.
3.1	Social and community: Recreational fishing	Port expansion and dredging may disrupt popular fishing spots inside and outside of the inner harbour	Moderate (3)	Likely (4)	High (12)	Med/high	Expansion may cause temporary exclusion zones due to safety reasons. Fishing popular in the inner harbour (i.e. mackerel, squid, snapper, tailor), as well as South Mole, North Mole, Rous Head and north and south of the entrance.
3.2	Social and community: Recreational swimming	Increased turbidity at popular swimming beaches from dredge plumes	Moderate (3)	Likely (4)	High (12)	Med	Depends on timing of dredging and hydrology. People would likely avoid swimming due to aesthetics of turbid water, or perceived low health and safety. Would be temporary. After dredging of the port and channels in 2010, water clarity was affected at Preston Point beach, Bathers Beach, Fremantle SLSC and Port Beach.
3.3	Social and community: Recreational boating access	Delays in passage through entrance channel during dredging/expansion works	Minor (2)	Possible (3)	Med (6)	Med	Entry/exit may be restricted to a narrow band and cause a bottleneck during high peak times for boating. Only temporary.
3.4	Social and community: Marina facilities	Increased water turbidity at marinas due to dredging	Minor (2)	Possible (3)	Med (6)	Med	Depends on water flow and timing of dredging.
3.5	Social and community: Educational and scientific values	Decline in educational experiences due to degradation of estuarine habitats with increased use of the port area	Moderate (3)	Possible (3)	Med (9)	Med	May impact participation in citizen science activities. May degrade reference sites for studies. May deter educational groups visiting parts of the estuary.
3.6	Social and community: Landscape and visual amenity	Less scenic enjoyment due to sightings of dredge plumes	Minor (2)	Possible (3)	Med (6)	Med	Only temporary, however may leave a negative impression on tourists.
3.6	Social and community: Landscape and visual amenity	Erosion at Bathers Beach and Arthurs Head would reduce visual amenity and enjoyment of the landscape	Major (4)	Likely (4)	High (16)	Med	Bathers Beach is popular with locals and tourists due to the range of amenities available right near the beach. Bather Beach is the only place in Perth where visitors can legally consume alcohol on the beach, which adds to the attraction.
4.1	Business, industry and commercial: Tourism	Reduced aesthetic quality during dredging campaigns/expansion works for passengers on cruise ships entering the port	Minor (2)	Possible (3)	Med (6)	Med	Depends on timing of port works and cruise ship itinerary.

Ref#	Value	Issue	Conseq.	Likeli.	Risk	Data confidence	Justification
4.1	Business, industry and commercial: Tourism	Reduced economic activity with erosion at Bathers Beach	Major (4)	Likely (4)	High (16)	Med	Bathers Beach is popular with locals and tourists due to the range of amenities available right near the beach. Bather Beach is the only place in Perth where visitors can legally consume alcohol on the beach, which adds to the attraction.
4.2	Business, industry and commercial: Commercial fisheries	Decrease in commercial catches due to interruption to migration/recruitment of fishes through the entrance channel during dredging/expansion works	Major (4)	Possible (3)	High (12)	Med	Commercially fished species use the harbour and estuary during their life cycles.
4.2	Business, industry and commercial: Commercial fisheries	Decrease in commercial catches due to degradation of estuarine habitats with increased use of the port area	Major (4)	Possible (3)	High (12)	Med	West Coast Estuarine Managed Fishery operates in the Swan-Canning at Melville, Perth and lower Canning waters. Commercially fished species use the harbour and estuary during their life cycles.
4.3	Business, industry and commercial: Aquaculture	Reduced water quality of the Inner Harbour would impact on intake water for aquaculture operations	Moderate (3)	Possible (3)	Med (9)	Med	Increased use of the port may reduce water quality. Could become costly to treat or filter intake water to use for aquaculture tanks.

Table 3: Expanded issues and risk assessment relating to marine and estuarine environmental values of Kwinana.

Ref#	Value	Issue	Conseq.	Likeli.	Risk	Data confidence	Justification
1	Integral functioning ecosystem	Decrease in ecosystem functioning with increased use and development in Cockburn Sound	Major (4)	Possible (3)	High (12)	Med	Region has improved but has not fully recovered from significant impacts on ecosystem functioning, so additional stressors may hinder or reverse improvements.
2	Sheltered marine ecological community	Alteration to the sheltered nature of Cockburn Sound where dredge channels and built structures may impact on calm waters	Moderate (3)	Possible (3)	Med (9)	Med	No modifications to Garden Island Causeway, however new dredge channels may significantly impact on circulation in some parts of the Sound. Built structures may impact circulation on a localised scale, potentially causing stagnate waters or re-directing water flow. Any changes to or impacts of circulation would vary seasonally.
3	Biological diversity	Decrease in biological diversity due to increasing sea temperatures and distribution shifts of species	Minor (2)	Likely (4)	Med (8)	Low	Tropicalisation may not necessarily decrease biological diversity, as new species will be entering Cockburn Sound and some current species may have time to gradually adapt. It is almost certain to change community compositions. Cockburn Sound already has a distinctive fish community due to the presence of large abundances of the tropical fish species. Climate change is an external driver.
3.1	Biological diversity: fish assemblages	Reduction in fish abundance/biodiversity from habitat loss	Moderate (3)	Possible (3)	Med (9)	Low/med	Evidence that dredge channels provide suitable habitat for fishes, but so do seagrass meadows and limestone outcrops which may be impacted by dredging and development. Development likely to cause localised habitat loss and fish are mobile so they could move to other suitable areas if available in Cockburn Sound. Temporal trends in abundance or diversity are not clear due to limited monitoring.
3.2	Biological diversity: demersal and benthic communities	Reduction in biodiversity of demersal and benthic communities from habitat loss or degradation	Moderate (3)	Possible (3)	Med (9)	Low	Northern Cockburn Sound and Owen Anchorage have highest benthic diversity, which is also in footprint of proposed dredging channels. Development likely to cause localised habitat loss. Limited and irregular monitoring/data to assess trends.
3.3	Biological diversity: plankton	Decline in nutrient levels will cause a decline in phytoplankton and zooplankton species diversity	Moderate (3)	Possible (3)	Med (9)	Low	Zooplankton feed on phytoplankton which grow at a rate dependant on nutrient availability. Nutrients may be reduced with any alterations to flushing rates i.e. dredge channels. However, increased development and associated outflow or turbidity from vessels may counteract the impact of increased flushing. Phytoplankton and zooplankton grow quickly so declines in abundance and diversity are reversible given the right conditions. Plankton are carried with currents so any impacts would be system wide. Plankton are also prey to other species so impacts would flow through food chain.
3.4	Invasive species	Increase in marine pests with increasing vessel traffic	Major (4)	Likely (4)	High (16)	High	Already marine pests documented in Kwinana, and Cockburn Sound considered ideal suited for invasive pests due to large areas of disturbed habitat with no vegetation and a high abundance of phytoplankton for food.
4.1	High level of water quality: nutrients	Resupply of nutrients to water column through re-suspension of sediments	Moderate (3)	Likely (4)	High (12)	Low/med	Due to poor flushing in Cockburn Sound sediments have a high organic load. Large propeller wash from ships and tugs would cause continued resuspension of fine sediments and inorganic material. Over time, less nutrients would be entrained in sediments and more would be available in the water column.
4.1	High level of water quality: nutrients	Elevated nutrient levels with increased use and development in Cockburn Sound	Moderate (3)	Possible (3)	Med (9)	High	This would depend on any additional infrastructure and allowable discharges from industry into Cockburn Sound. Dredge channels may improve flushing.
4.2	High level of water quality: Chl a/ phytoplankton	Increased nutrients and warmer temperatures may cause more frequent toxic phytoplankton blooms	Moderate (3)	Possible (3)	Med (9)	Med	Dependant on a number of factors, not just nutrients. Higher risk for the southern end of Cockburn Sound where there is limited flushing. Blooms are relatively short lived but do occur. The last major toxic bloom was in 2015 and caused a fish kill.
4.3	High level of water quality: light attenuation/turbidity	Increased light attenuation from increased turbidity as a result of dredging (construction)	Moderate (3)	Almost certain (5)	High (15)	Med/high	Dredging will occur with port development in Cockburn Sound, and likely to be significant. Turbidity will improve over time, thus light attenuation is reversible itself, but the impact it has on marine biota may not be. Spread of suspended sediments would depend on port footprint and water circulation.

Ref#	Value	Issue	Conseq.	Likeli.	Risk	Data confidence	Justification
4.3	High level of water quality: light attenuation/turbidity	Increased light attenuation from increased turbidity as a result of increased shipping traffic (operational)	Moderate (3)	Almost certain (5)	High (15)	Med/high	Continued resuspension of fine sediments and inorganic material from large propeller wash i.e. ships and tugs. Concentrations of suspended sediments may not be as severe as dredging, but they would be long-lived and constant. Spread of suspended sediments would depend on port footprint and water circulation.
4.4	High level of water quality: dissolved oxygen	Decrease in dissolved oxygen in bottom waters to the east and south of Cockburn Sound	Moderate (3)	Possible (3)	Med (9)	Med/high	Already experiences low oxygen concentrations due to poor flushing. Dredging may improve flushing of the eastern and southern regions of Cockburn Sound. Low oxygen in these regions may be facilitating sulphide intrusion in seagrasses
4.4	High level of water quality: dissolved oxygen	Decreased dissolved oxygen due to increasing temperatures which may cause temporary or permanent dead zones	Major (4)	Possible (3)	High (12)	Low	Warmer temperatures promote faster algae growth and oxygen consumption. Dependant on the speed of ocean warming and is hard to predict. Improved flushing of the system from dredging channels may alleviate this risk.
4.5	High level of water quality: temperature	Increased incidence of marine heatwave events that could cause stress and death to marine life	Major (4)	Likely (4)	High (16)	Med	Over time could increase to 'Extreme' risk depending on speed of warming and frequency of heatwaves.
4.6	High level of water quality: salinity	Increased incidence of flooding will increase discharges of fresher and turbid water plumes into Kwinana region from the Swan River	Moderate (3)	Possible (3)	Med (9)	Med	The extent of influence of plumes into Owen Anchorage and Cockburn Sound would be dependent on any alterations to hydrology. Hard to predict the future rates of occurrence of flooding. Last flooding event to reach Cockburn Sound was early 2017. Heavy rainfall events and flooding are likely to occur more frequently under a changing climate.
4.6	High level of water quality: salinity	Negative impacts to marine life from brine discharged into Cockburn Sound	Moderate (3)	Likely (4)	High (12)	Low	High salinity waters near outlets may only be localised and may improve with increased flushing. Limited knowledge on any negative effects to marine life.
4.7	High level of water quality: ph	Increase in pH may cause acidification and negatively impact calcareous organisms	Major (4)	Possible (3)	High (12)	Low	Acidification is occurring elsewhere. Limited temporal data for region to detect trends and make predictions.
4.8	High level of water quality: contaminants	Resupply of contaminants (e.g. TBT and PFAS) to water column through re-suspension of sediments	Moderate (3)	Possible (3)	Med (9)	Low/med	No routine monitoring of contaminates, last monitored in 2008. Plus, no widespread surveys conducted since 2006. Expected elevated levels in footprint of port e.g. Kwinana Bulk Jetty. Limited knowledge on the level of bioaccumulation of toxins in definitely causing death to marine life (e.g. little penguins), but toxins have been found in marine life and have caused imposex in gastropods.
4.8	High level of water quality: contaminants	PFAS impacting marine life through filtration/ingestion of contaminated groundwater	Moderate (3)	Possible (3)	Med (9)	Low	Impacts of PFAS unknown. PFAS contamination has been recorded for Garden Island.
4.8	High level of water quality: contaminants	Increased incidence of oil and fuel spills with increased vessel traffic	Major (4)	Likely (4)	High (16)	Low/med	Port expansion in Cockburn Sound would see an increase in vessels using the area. The region is already considered as having a high risk to oil spills. Small spills are more common than larger spills.
4.9	High level of water quality: groundwater	Increased nutrient levels discharged into Cockburn Sound from groundwater with legacy contamination issues from agriculture and industry	Moderate (3)	Likely (4)	High (12)	Med	Groundwater is the main source of nutrients into Cockburn Sound. No systematic monitoring of groundwater. May increase with industrial expansion if not regulated.

Ref#	Value	Issue	Conseq.	Likeli.	Risk	Data confidence	Justification
4.10	High level of water quality: hydrology	Poor flushing resulting in lower water quality in some areas of Cockburn Sound- i.e. eastern and southern regions	Moderate (3)	Likely (4)	High (12)	Med/High	Flushing may be improved in these areas by having additional dredge channels. Summer flushing times can average 44 days.
4.10	High level of water quality: hydrology	Efforts to improve flushing may increase coastal erosion	Moderate (3)	Possible (3)	Med (9)	Low/med	Modelling only done for removal and modification of Garden Island Causeway, not for dredging in northern Cockburn Sound. Would be a high risk for social values. Changes exacerbated with sea level rise
5.1	High level of sediment quality: contaminants	Increase in contamination of sediments with increased shipping and port operations	Moderate (3)	Possible (3)	Med (9)	Low/med	No widespread surveys conducted since 2006 but expected elevated levels in footprint of port e.g. Kwinana Bulk Jetty. Limited knowledge on the level of bioaccumulation of toxins in definitely causing death to marine life (e.g. little penguins), but toxins have been found in marine life and have caused imposex in gastropods. Cargo port and container shipping rather than mineral exports
5.2	High level of sediment quality: nutrients	High organic load of sediments due to poor flushing	Minor (2)	Likely (4)	Med (8)	Low/med	Due to poor flushing in Cockburn Sound sediments have a high organic load. Unless re-suspended, may be adequately supplying food for infauna. Biological oxygen demand will increase.
5.3	High level of sediment quality: acid sulphate soils	Exposure of acid sulphate soils during development	Minor (2)	Unlikely (2)	Low (4)	Low	Development can expose potential soils to oxygen and create acid sulphate soils. There is potential acid sulphate soils along the eastern margins of Cockburn Sound, however. acid formation is unlikely given the sufficient neutralising capacity of the sediments.
6.1	Significant benthic communities and habitats: seagrass	Loss of seagrass meadows from dredged channels	Moderate (3)	Possible (3)	Med (9)	High	Seagrass meadows not in footprint of port infrastructure on eastern margin, but some loss may occur in footprint of shipping channels.
6.1	Significant benthic communities and habitats: seagrass	Reduced seagrass growth due to poor light availability	Major (4)	Possible (3)	High (12)	High	Prolonged reduction in photosynthesis due to poor light and sedimentation of meadows would cause a reduction in further growth and loss of current meadows. Turbidity will be high during dredging and from increased vessel use in the area. Dredged sediments may spread widely and impact seagrass on a wider scale if environmental conditions become unpredictable- this has happened elsewhere.
6.1	Significant benthic communities and habitats: seagrass	Reduced seagrass growth due to sulphide intrusion facilitated by low dissolved oxygen levels and low light levels	Moderate (3)	Likely (4)	High (12)	Low/med	Sulphide intrusion would occur at night time when DO levels are low, further investigation needed to confirm sulphide intrusion is occurring, though evidence is suggesting so.
6.1	Significant benthic communities and habitats: seagrass	Increased incidence of marine heatwaves may cause decrease in seagrass biomass	Major (4)	Likely (4)	High (16)	Low	Occurred at Shark Bay for Antarctica species; risk is dependent on frequency of marine heatwaves and the magnitude felt for Cockburn Sound and Owen Anchorage. Depends on resilience of the species in a particular location.
6.2	Significant benthic communities and habitats: coral reefs	Loss of coral communities with increased development and dredging	Moderate (3)	Possible (3)	Med (9)	Low	Corals not a dominant habitat in Cockburn Sound so may not significantly impact biodiversity or ecological function. Lack of monitoring to detect any changes in coral abundance or distribution. Unknown if corals colonies are occurring in port footprint.
6.3	Significant benthic communities and habitats: rocky reefs	Loss of rocky reef communities with increased development	Minor (2)	Unlikely (2)	Low (4)	Low/med	Significant marine community on rock wall of Garden Island Causeway, but the causeway is not expected to be modified. May be other rocky reef communities occurring in Cockburn Sound, but not a dominant habitat.

Ref#	Value	Issue	Conseq.	Likeli.	Risk	Data confidence	Justification
6.4	Significant benthic communities and habitats: soft sediments	Continual disturbance to soft sediments would decrease primary productivity and destabilise sediments due to the loss of microphytobenthos	Moderate (3)	Possible (3)	Med (9)	Low	Microphytobenthos grow quickly when conditions are right but continual disturbance may limit suitable conditions for growth. Soft sandy sediment habitats are dominant in Cockburn Sound.
7.1	Listed and significant fauna: fairy tern	Loss of shoreline habitat due to development and/or sea level rise	Major (4)	Possible (3)	High (12)	Med	Over time risk will increase with sea level rise. Risk more likely if there was a southern channel into Cockburn Sound. Lack of nesting sites would affect population.
7.1	Listed and significant fauna: fairy tern	Bioaccumulation of contaminants through the food chain that would negatively affect survival and/or breeding success	Major (4)	Possible (3)	High (12)	Low	TBT is being reduced. Terns are not bottom feeders but contaminants may accumulate in fish prey. Could impact viability.
7.2	Listed and significant fauna: little penguins	Starvation due to decreased food supply resulting from degradation of habitat for fish prey	Major (4)	Possible (3)	High (12)	Low	Starvation already identified as one of the top two causes of death. Population would be affected.
7.2	Listed and significant fauna: little penguins	Starvation due to prey availability being affected by sea temperatures	Major (4)	Possible (3)	High (12)	Low/med	Starvation already identified as one of the top two causes of death. Population would be affected. Tropical species could move in to replace lost species, or penguin population may shift to follow prey shifts.
7.2	Listed and significant fauna: little penguins	Increase in deaths from collisions with increasing recreational boat traffic	Major (4)	Likely (4)	High (16)	High	Trauma from watercraft identified as one of the top two causes of death. Port footprint would compress the same number of recreational boats into a smaller area.
7.2	Listed and significant fauna: little penguins	Bioaccumulation of contaminants through the food chain that would negatively affect survival and/or breeding success	Major (4)	Possible (3)	High (12)	Low	Contaminants have been found in dead penguins but have not been identified as the definite cause of death. TBT use would be decreasing over time but would remain high in sediments.
7.2	Listed and significant fauna: little penguins	Loss of habitat, particularly along Kwinana Shelf which is used for foraging, could negatively impact on populations	Major (4)	Likely (4)	High (16)	Med/high	Kwinana Shelf has been identified as a key foraging area in Cockburn Sound. Kwinana Shelf is likely location of port.
7.3	Listed and significant fauna: bottlenose dolphins	Loss of habitat, particularly along Kwinana Shelf which is used for foraging and a nursery, could negatively impact on resident dolphin populations	Major (4)	Likely (4)	High (16)	Med/high	Dolphins have a long-term association of with Cockburn Sound and Kwinana Shelf. It has been suggested that dolphins would not be able to compensate for the loss of habitat on the Kwinana Shelf, as the characteristics of this habitat are absent in nearby areas. Kwinana Shelf is likely location of port.
7.3	Listed and significant fauna: bottlenose dolphins	Increased recreational use of the Kwinana area could increase illegal feeding of dolphins, increasing the risk of boat strikes and entanglement in fishing gear	Major (4)	Possible (3)	High (12)	Med	Dolphins engage in “risky” behaviours during illegal feeding interactions, increasing their risk to boat strikes and entanglement in fishing gear- which has been documented for individuals in the Sound.

Ref#	Value	Issue	Conseq.	Likeli.	Risk	Data confidence	Justification
7.3	Listed and significant fauna: bottlenose dolphins	Increase in underwater noise from development and construction could deter dolphins from their usual habitats and interrupt communications between dolphins	Minor (2)	Likely (4)	Med (8)	Med	Dolphins have been documented avoiding noisy areas temporarily and changing their usual behaviours. Dolphins may investigate due to curiousness but depends on the noise. Noises can be short lived or intermittent.
7.4	Listed and significant fauna: Australian sea lions	Additional haul out locations may be limited in Kwinana (due to development) if current haul out sites become unsuitable with a changing climate	Moderate (3)	Possible (3)	Med (9)	Low/med	Sea lions haul out where the environment is most suitable i.e. peak haul out periods and haul out numbers increased with increasing air temperature (up to 21°C) and decreased with increasing tide height. Haul out locations are currently on islands, none have been identified for the mainland coasts of Cockburn Sound. If islands become inundated, sea lions may haul up on mainland shorelines. Not breeding colonies.
7.4	Listed and significant fauna: Australian sea lions	Increase in disturbance at haul out sites of Carnac and Seal Island with increased vessel traffic	Moderate (3)	Possible (3)	Med (9)	Low	Sea lions are currently disturbed by recreational users and visitors to Carnac. Unknown impacts of large vessel disturbance.
7.5	Listed and significant fauna: migratory shorebirds and seabirds	Sea level rise could inundate important shoreline habitat	Moderate (3)	Possible (3)	Med (9)	Low/med	Foraging and nesting occurs along the shorelines. There would be localised loses of suitable habitat but this may flow on to impact the population as a whole if another suitable habitat is not available.
7.5	Listed and significant fauna: migratory shorebirds and seabirds	Increased coastal development could remove important habitat	Moderate (3)	Possible (3)	Med (9)	Low/med	If some areas become inundated, then there may be no room to move if other suitable areas have been developed. Unknown if some stretches of shoreline are used more intensely than others.
7.5	Listed and significant fauna: migratory shorebirds and seabirds	Bioaccumulation of contaminants through the food chain that would negatively affect survival and/or breeding success	Major (4)	Possible (3)	High (12)	Low	Contaminants have been documented in other birds, such as penguins and fairy terns. Shorebirds could be feeding on invertebrates that live in contaminated sediments. TBT would decrease over time. Foraging would also occur outside of Cockburn Sound.
7.5	Listed and significant fauna: migratory shorebirds and seabirds	Starvation due to decreased food supply resulting from degradation of habitat for fish prey	Major (4)	Possible (3)	High (12)	Low	Starvation has been a significant threat for little penguins. Decreased food supply leads to increased competition for food, however foraging would also be occurring outside of Cockburn Sound. Unknown how much foraging occurs in Cockburn Sound. Death from starvation would impact the population if frequent.
7.5	Listed and significant fauna: migratory shorebirds and seabirds	Starvation due to prey availability being affected by sea temperatures	Major (4)	Possible (3)	High (12)	Low	Decreased food supply leads to increased competition for food. Birds may adapt to feed on tropical species or shift their distribution to match prey shifts. creased competition for food, however foraging would also be occurring outside of Cockburn Sound. Unknown how much foraging occurs in Cockburn Sound. Death from starvation would impact the population if frequent.

Ref#	Value	Issue	Conseq.	Likeli.	Risk	Data confidence	Justification
8.1	Regionally significant spawning / nursery area: King George whiting	Decline in abundance and loss of nursery area due to loss of habitat	Moderate (3)	Unlikely (2)	Med (6)	High	Mangles Bay is an important nursery. Seagrass meadows occur here but it is unknown whether this is directly related to the occurrence of whiting in the area. Other seagrass areas not specifically mentioned as nursery areas, so may or may not be exclusive to Mangles Bay. Impacts to younger life stages would be felt at a population level. Mangles Bay not currently proposed for port or other developments.
8.2	Regionally significant spawning / nursery area: Blue swimmer crab	Decline in abundance in Cockburn Sound due to environmental impacts, such as marine heatwaves and flooding	Major (4)	Likely (4)	High (16)	Med	Current low abundances attributed substantially to impacts of marine heatwave and flooding events. Fishery remains closed to allow recovery.
8.2	Regionally significant spawning / nursery area: Blue swimmer crab	Loss of seagrass will negatively impact on recruitment	Moderate (3)	Possible (3)	Med (9)	High	Mangles Bay, James Point and Jervoise Bay are the best recruitment sites for 0+, likely due to more seagrass cover. Port footprint will most likely not occur in these three areas, though turbidity from dredging and ship traffic may affect important seagrass areas.
8.3	Regionally significant spawning / nursery area: Pink snapper	Increasing temperatures may cause declines in abundance or alter shifts in spawning peaks and maturation	Major (4)	Possible (3)	High (12)	Med	Spawning is documented to occur within a certain temperature range.
8.3	Regionally significant spawning / nursery area: Pink snapper	Dredged materials could impact the survival rates of larval stages	Moderate (3)	Possible (3)	Med (9)	Med	Dredge sediments did impact pre-feeding larvae with mouths open, which were less tolerant of suspended sediments, and had a higher mortality in comparison to closed mouth larvae. Mortality of larvae increased with increased exposure time to suspended sediments. 15 days post hatch, the increased turbidity in the water due to sediments decreased ingestion of copepod larvae by pink snapper larvae. Mineral suspended sediments found in Cockburn Sound have the potential to be more damaging to fish than natural suspended sediments. Spawning also takes place in surrounding bays.
8.3	Regionally significant spawning / nursery area: Pink snapper	Loss of habitat could decrease the use of Cockburn Sound as a nursery area	Major (4)	Possible (3)	High (12)	Med	Cockburn Sound has been a nursery area since 1971. Any impacts to spawning or juvenile stages will influence adult population. Spawning also takes place in surrounding bays.
8.3	Regionally significant spawning / nursery area: Pink snapper	Altered hydrological conditions may influence egg dispersal and survival	Major (4)	Possible (3)	High (12)	Med	Eggs are transported via water movement, and increased flushing may transport more eggs out of nursery areas, where they would be less protected. Unknown exactly how additional dredge channels would change circulation.
8.4	Regionally significant spawning / nursery area: Whitebait	An increase in marine heatwaves would negatively impact spawning	Major (4)	Likely (4)	High (16)	Low/med	Lower catches resulted in the years following the 2011 marine heatwave.
8.4	Regionally significant spawning / nursery area: Whitebait	Altered hydrological conditions may influence egg dispersal and survival	Moderate (3)	Possible (3)	Med (9)	Med	Eggs are transported via water movement, and increased flushing may transport more eggs out of nursery areas where they would be less protected.

Ref#	Value	Issue	Conseq.	Likeli.	Risk	Data confidence	Justification
8.5	Regionally significant spawning / nursery area: Southern garfish	Loss of seagrass would reduce feeding opportunities and decrease survival of eggs	Major (4)	Possible (3)	High (12)	Med/high	Southern garfish feed on seagrass and attach eggs to seagrass blades in Cockburn Sound.
8.5	Regionally significant spawning / nursery area: Southern garfish	An increase in marine heatwaves would negatively impact stocks	Major (4)	Likely (4)	High (16)	Med/high	2011 marine heatwave had a negative impact on stocks.
9	Shoalwater Islands Marine Park	Reduction in water quality and marine biota in Cockburn Sound would flow on to affect the marine park	Moderate (3)	Possible (3)	Med (9)	Med	Due to close proximity, impacts to Cockburn Sound would have flow on affects to the marine park.
9	Shoalwater Islands Marine Park	Increased erosion of the shorelines with increasing sea level and storms	Moderate (3)	Likely (4)	High (12)	Med/high	Already a concern for the park's shorelines and renourishment already occurs.
10	Coastal processes	Increased erosion and inundation at localised points within Cockburn Sound with increasing sea levels and storms	Moderate (3)	Likely (4)	High (12)	Med/high	Erosion already documented for localised areas.
10	Coastal processes	Changes to hydrological conditions may change alongshore sediment transport and erode shorelines	Moderate (3)	Possible (3)	Med (9)	Med	Already documented from the construction of Causeway, groynes and rock walls. Hydrological conditions may change with additional dredged channels.

Table 4: Expanded issues and risk assessment relating to marine and estuarine social values of Kwinana.

Ref #	Value	Issue	Conseq.	Likeli.	Risk	Data confidence	Justification
1.1	Heritage: Aboriginal	Loss or degradation of important heritage sites with increased development	Minor (2)	Unlikely (2)	Low (4)	High	Loss/degradation of sites would likely be avoided at all opportunities. Backlash from community if valued sites were impacted significantly. Valued sites occur around the coastlines of Cockburn Sound and on Garden Island, but not directly in port footprint. However, degradation to these areas could occur from increased use and development. Cockburn Sound and waters to the north are part of the mythological 'Indian Ocean' aboriginal heritage site.
1.2	Heritage: Maritime/historic	Loss or degradation of important historical sites with increased development	Minor (2)	Unlikely (2)	Low (4)	High	Loss/degradation of sites would likely be avoided at all opportunities. Backlash from community if valued sites were impacted significantly.
2.1	Public health: High quality source water for desalination	Negative impact on drinking water supply due to declining water quality in Cockburn Sound	Major (4)	Possible (3)	High (12)	Med/high	Potential decrease in water quality with increased use of Cockburn Sound. Expensive to treat/filter water or source water elsewhere if Cockburn Sound becomes unsuitable. Could potentially cost the community more money for water.
2.2	Public health: Recreational water quality	Increased safety concerns for primary and secondary contact with water due to decreased water quality	Major (4)	Possible (3)	High (12)	Med/high	Many people swim or use the sound for water sports or leisure. Some beaches have a current rating of 'fair' that may get worse with increased use of the sound.
2.3	Public health: Seafood quality	Decrease in health of shellfish and fish with increased contamination in waters and sediments	Major (4)	Possible (3)	High (12)	Med/high	Would reduce recreational and commercial fishing as well as aquaculture. Would impact on favourite past times and social gatherings. May cause death and wash up of marine life.
3.1	Social and community: Recreational fishing	Decrease of recreational fishing with port development due to restrictions	Minor (2)	Possible (3)	Med (6)	Med	Most boat based fishing is concentrated in the south of Cockburn Sound and northern waters, rather than the eastern margin where development may occur. Most shore based fishing is focused around jetties and to the north of Cockburn Sound. Some displacement in area of port development, but fishers could move to surrounding areas.
3.1	Social and community: Recreational fishing	Reduction or loss of popular fished species i.e. pink snapper and crabs with loss or degradation of habitat in Cockburn Sound	Moderate (3)	Possible (3)	Med (9)	Med/high	Development could degrade current favoured habitats for fish and crabs, particularly seagrass beds. Cockburn Sound is popular for fishing and even underwent the costly restocking of juvenile snapper after many were killed in 2015. A lot of time and money spent keeping the sound maintained for activities such as fishing.
3.2	Social and community: Recreational swimming	Loss of popular swimming beaches with port development i.e. Kwinana/ Challenger Beach	Moderate (3)	Possible (3)	Med (9)	High	Depends on final port footprint. Other beaches for swimmers to utilise.
3.3	Social and community: Recreational water sports	Decrease in water sports with port development	Minor (2)	Possible (3)	Med (6)	Med	Likely only to be displaced along the eastern margin of Cockburn Sound, and in shipping channels, and water sports are typically centred around the south of the sound and Woodman Point. May be restriction put in place with increasing vessel traffic.
3.4	Social and community: Recreational boating access	Loss of boat ramps with increased development i.e. Challenger Beach boat ramp	Moderate (3)	Possible (3)	Med (9)	High	Depends on final port footprint. Recreational boat use expected to grow over time. Other boat ramps out of port footprint are more popular to use.
3.5	Social and community: Marina facilities	Reduced use of marina facilities with increased development	Minor (2)	Unlikely (2)	Low (4)	Med/high	Marina facilities not in port footprint, so should have limited impact, apart from increased vessel traffic in and around Cockburn Sound. Quality of marina may decline with increased use and development.
3.6	Social and community: Educational and scientific values	Restricted access to the marine environment of the port area for research purposes	Minor (2)	Likely (4)	Med (8)	Med	Could interrupt any widespread/comprehensive research in Cockburn Sound. May impact on the collection of long time series data. Could gain access through permits.

Ref #	Value	Issue	Conseq.	Likeli.	Risk	Data confidence	Justification
3.6	Social and community: Educational and scientific values	Unsatisfying educational experiences due to a degraded and unhealthy ecosystem	Moderate (3)	Possible (3)	Med (9)	Med	May cause educational operators to relocate to new sites.
3.7	Social and community: Landscape and visual amenity	Erosion will reduce visual amenity and access at popular beaches and coastlines	Moderate (3)	Possible (3)	Med (9)	Med/high	Palm Beach, Mangles Bay and Kwinana beach already undergone beach nourishment to manage shoreline erosion. This will only get worse with sea level rise and potentially from alterations to the hydrology of the Sound.
3.7	Social and community: Landscape and visual amenity	Increased sightings of marine life kills due to decreased water quality	Moderate (3)	Possible (3)	Med (9)	Med/high	Would be a temporary inconvenience for some beach goers/water users. However, continual kills over time may cause people to avoid areas long term.
3.7	Social and community: Landscape and visual amenity	Lack of visitation due to obstruction of expansive views of the ocean horizon with large vessels and/or building and structures	Moderate (3)	Possible (3)	Med (9)	Med	Would depend on location of development/port. Some vessel use of the area already.
4.1	Business, industry and commercial: Tourism	Reduced wildlife tourism due to loss of marine life and habitat degradation	Major (4)	Possible (3)	High (12)	Med/high	Loss of customers. Any impacts to dolphins would significantly impact Rockingham Wild Encounters.
4.1	Business, industry and commercial: Tourism	Displacement of tourist activities with port development	Major (4)	Unlikely (2)	Med (8)	Med	Only displaced along the eastern margin of Cockburn Sound, and in shipping channels. The southern end of the sound most popular for tourist activities e.g. water sports hire, diving.
4.2	Business, industry and commercial: Commercial fisheries	Increased rules and restrictions leading to a further decrease in commercial fishing in Cockburn Sound	Major (4)	Possible (3)	High (12)	Med	Commercial fishing has already been impacted by development in Cockburn Sound.
4.2	Business, industry and commercial: Commercial fisheries	Loss/degradation of habitat resulting in low catch rates	Major (4)	Possible (3)	High (12)	Med/high	Commercial fishing has already been impacted by development in Cockburn Sound.
4.3	Business, industry and commercial: Aquaculture	Reduction of nutrients would reduce food available for mussel growth	Major (4)	Possible (3)	High (12)	Med/high	Would impact on supplier/buyer relationships locally and regionally. Could cause closure of industry. Changes to circulation could cause reduced nutrients.
4.3	Business, industry and commercial: Aquaculture	Increase in introduced marine pests that would negatively impact mussel growth and sales	Major (4)	Possible (3)	High (12)	Med/high	Would impact on supplier/buyer relationships locally and regionally. Mussel beds already experienced the impact of an introduced colonial ascidian.
4.3	Business, industry and commercial: Aquaculture	Availability of contaminants in the water column would increase and could cause health concerns in farmed mussels	Major (4)	Possible (3)	High (12)	Med/high	Would impact on supplier/buyer relationships locally and regionally.
4.3	Business, industry and commercial: Aquaculture	Increase in water temperatures may negatively affect mussel growth	Major (4)	Possible (3)	High (12)	Med/high	Warmer water in combination with other pressures have affected mussel growth in the last 10 years.

Ref #	Value	Issue	Conseq.	Likeli.	Risk	Data confidence	Justification
4.4	Business, industry and commercial: Suitable quality water for industrial use	Reduced water quality due to increased development will impact industrial use	Minor (2)	Unlikely (2)	Low (4)	Med	Potential decrease in water quality with increased use of CS. Expensive to treat/filter water or source water elsewhere if CS becomes unsuitable i.e. increased contamination, suspended sediments. Industrial water quality generally means a level of quality that allows it to be used as cool water and thus it is unlikely that water quality is reduced to such an extent it is no longer suitable for industrial use. Other industrial and urban growth likely to influence groundwater flow into CS which would impact on source water.
4.5	Business, industry and commercial: Assimilation of wastewater	Decreased water quality around outfall pipes due to wastewater operations	Moderate (3)	Possible (3)	Med (9)	Med	A structure in this environment may reduce local flushing with consequences for assimilating effluent from existing wastewater outfalls.
4.5	Business, industry and commercial: Assimilation of wastewater	Increase in Cockburn Sound emergency outfall use in with an increasing population or issues with SDOOL	Moderate (3)	Unlikely (2)	Med (6)	Low	Possible with population growth or risk of defects over next 50-100 years. A structure in this environment may reduce local flushing with consequences for assimilating effluent from existing wastewater outfalls .

Table 5: Expanded issues and risk assessment relating to marine and estuarine environmental values of Bunbury.

Ref #	Value	Issue	Conseq.	Likeli.	Risk	Data confidence	Justification
1	Integral functioning ecosystem	Decrease in ecosystem functioning with increased use and development in Koombana Bay	Major (4)	Possible (3)	High (12)	Low/med	System has already undergone significant changes due to modifications to the coast.
2	Sheltered marine ecological community	Alteration to the sheltered nature of Koombana Bay where dredge channels and built structures may impact on marine biota that depend on calmer waters	Moderate (3)	Possible (3)	Med (9)	Med	Development planned for inside of outer harbour and a dredge channel would be needed which may change circulation. Built structures may impact circulation on a localised scale, potentially causing stagnate waters or re-directing water flow. Any changes to or impacts of circulation would vary seasonally.
3	Biological diversity	Decrease in biological diversity due to increasing sea temperatures and distribution shifts of species	Minor (2)	Likely (4)	Med (8)	Low	Tropicalisation may not necessarily decrease biological diversity, as new species will be entering Koombana Bay and some current species may have time to gradually adapt. It is almost certain to change community compositions. A shift in the community may or may not change the functioning of the ecosystem as it is known currently. Climate change is an external driver.
3.1	Biological diversity: fish assemblages	Reduction in fish abundance/biodiversity from habitat loss	Moderate (3)	Possible (3)	Med (9)	Low/med	In Koombana Bay, most fish species are found in the shallows, which is where development would occur. Development likely to cause localised habitat loss and fish are mobile so they could move to other suitable areas if available. Temporal trends in abundance or diversity are not clear due to limited monitoring.
3.2	Biological diversity: demersal and benthic communities	Reduction in biodiversity of demersal and benthic communities from habitat loss or degradation	Moderate (3)	Possible (3)	Med (9)	Low/med	Leschenault Inlet has relatively low diversity compared with the once connected Leschenault Estuary. Shipping channel would be likely to continually disturb benthos through prop wash, and if dredging occurs, benthic communities would be directly impacted. Limited and irregular monitoring/data to assess trends.
3.3	Biological diversity: plankton	Decrease in high richness of foraminifera in Leschenault Estuary due to changes in environmental conditions	Minor (2)	Possible (3)	Med (6)	Low	Leschenault Estuary is thought to be globally significant in terms of the high richness of foraminifera species. Can grow quickly when conditions are favourable.
3.4	Biological diversity: invasive species	Increase in marine pest with increasing vessel traffic	Major (4)	Likely (4)	High (16)	Med/high	Already invasive species in the area. 83% of potential introduced marine pests are compatible with the marine environment of Bunbury Port
4.1	High level of water quality: nutrients	Resupply of nutrients to water column through re-suspension of decayed material	Minor (2)	Likely (4)	Med (8)	Med/high	Decayed material collects in dredge channel and is thought to be cause of increased nutrient levels in harbour waters. Continued resuspension of fine sediments and inorganic material from large propeller wash i.e. ships and tugs.
4.1	High level of water quality: nutrients	Elevated nutrient levels with increased use and development around Koombana Bay	Moderate (3)	Possible (3)	Med (9)	Med/high	Limited benthic growth in Koombana Bay that would be affected by increased nutrients, reduced oxygen and light levels. Would depend on any future infrastructure and discharge regulations. Dredged channel may improve flushing.
4.2	High level of water quality: Chl a/ phytoplankton	Increased nutrients and warmer temperatures may cause toxic phytoplankton blooms	Moderate (3)	Unlikely (2)	Med (6)	Med	No phytoplankton blooms recorded in Koombana Bay since 1995 monitoring began but may do if conditions are right.
4.3	High level of water quality: light attenuation/turbidity	Increased light attenuation from increased turbidity as a result of dredging (construction)	Moderate (3)	Likely (4)	High (12)	Med/high	Dredging likely for port expansion. Limited benthic growth in Koombana Bay due to already turbid environment. Turbidity will improve over time, thus light attenuation is reversible itself, but the impact it has on marine biota may not be. Spread of suspended sediments would depend on port footprint and water circulation.
4.3	High level of water quality: light attenuation/turbidity	Increased light attenuation from increased turbidity as a result resuspended sediments from increased shipping traffic (operational)	Moderate (3)	Likely (4)	High (12)	Med/high	Continued resuspension of fine sediments and inorganic material from large propeller wash i.e. ships and tugs. Concentrations of suspended sediments may not be as severe as dredging, but they would be long-lived and constant. Spread of suspended sediments would depend on port footprint and water circulation. KB already a turbid environment.
4.4	High level of water quality: dissolved oxygen	Decrease in dissolved oxygen in Koombana Bay and Inlet due to increasing nutrient load and phytoplankton growth	Moderate (3)	Possible (3)	Med (9)	Low/med	Current concentrations are not concerning.

Ref #	Value	Issue	Conseq.	Likeli.	Risk	Data confidence	Justification
4.4	High level of water quality: dissolved oxygen	Decreased dissolved oxygen due to increasing temperatures which may cause temporary or permanent dead zones	Major (4)	Possible (3)	High (12)	Low	Warmer temperatures promote faster algae growth and oxygen consumption. Dependant on the speed of ocean warming and is hard to predict. Improved flushing of the system from dredged channel may alleviate this risk.
4.5	High level of water quality: temperature	Increased incidence of marine heatwave events that could cause stress and death to marine life	Major (4)	Likely (4)	High (16)	Med	Over time could increase to 'Extreme' risk depending on speed of warming and frequency of heatwaves.
4.6	High level of water quality: salinity	Increased incidence of flooding will increase discharges of fresher and turbid water plumes into Koombana Bay via The Cut	Moderate (3)	Possible (3)	Med (9)	Med/high	Five rivers drain into the Leschenault Estuary. Increased incidence of flooding expected with climate change.
4.6	High level of water quality: salinity	Leschenault Estuary is at risk of increased salinity due to decreasing rainfall	Major (4)	Possible (3)	High (12)	Low/med	A more saline environment would change the marine communities in the estuary.
4.7	High level of water quality: ph	Increase in pH may cause acidification and negatively impact calcareous organisms	Major (4)	Possible (3)	High (12)	Low	Acidification is occurring elsewhere. Limited temporal data for region to detect trends and make predictions.
4.8	High level of water quality: contaminants	Resupply of contaminants to water column through re-suspension of sediments	Moderate (3)	Possible (3)	Med (9)	Med	Elevated levels of contaminants found in sediments, incl. TBT in the inner harbour. Expected elevated levels in footprint of existing port. Limited knowledge on the level of bioaccumulation of toxins in definitely causing death to marine life but can cause problems like imposex in gastropods.
4.8	High level of water quality: contaminants	Increased incidence of oil and fuel spills with increased vessel traffic	Major (4)	Likely (4)	High (16)	Low/med	Port expansion in Bunbury would see an increase in vessels in the area. The region is already considered a risky area for oil spills. Small spills are more common than larger spills.
4.8	High level of water quality: contaminants	Contamination of Preston River and Vittoria Bay with increased development of the port	Moderate (3)	Unlikely (2)	Med (6)	Med	A waste water capture system is in place and is believed to be effectively capturing contaminants.
4.9	High level of water quality: groundwater	Increased nutrient levels discharged into Koombana Bay and Leschenault Estuary via groundwater	Moderate (3)	Likely (4)	High (12)	Low	Fertiliser use is considered a major nutrient source in groundwater.
4.9	High level of water quality: groundwater	Dewatering close to the coast may result in saline waters migrating inland, and may expose acid sulphate soils	Minor (2)	Possible (3)	Med (6)	Med	Future development may include dewatering. Potential acid sulphate soils occur in Leschenault Inlet and Estuary.
4.10	High level of water quality: hydrology	Dredged channels may influence flow patterns and sediment transport	Moderate (3)	Possible (3)	Med (9)	Low/med	Further dredging likely to occur with port development.
5.1	High level of sediment quality: contaminants	Increase in contamination of sediments with increased shipping and port operations	Moderate (3)	Possible (3)	Med (9)	Med/high	Sediments already contaminated, and some elevated levels associated with port operations i.e. copper due to potential copper spill.
5.2	High level of sediment quality: nutrients	Larger shipping channel may accumulate more decaying wrack and increase nutrient loading in the sediments	Minor (2)	Possible (3)	Med (6)	Med	Current shipping channel accumulates decaying wrack and sediments there contain up to 30% organic matter and high nutrient levels.
5.3	High level of sediment quality: acid sulphate soils	Increased risk of exposed acid sulphate soils with development and/or modification of the shorelines	Minor (2)	Unlikely (2)	Low (4)	Med	Potential acid sulphate soils occur in Leschenault Inlet and Estuary. Further development would require modification of the shoreline, but development not necessarily occurring in the Inlet or Estuary. Testing of soils is typically done to test for potential ASS prior to development.

Ref #	Value	Issue	Conseq.	Likeli.	Risk	Data confidence	Justification
6.1	Significant benthic communities and habitats: seagrass	Spread of suspended sediments may reach and impact on seagrass meadows outside of Koombana Bay	Major (4)	Possible (3)	High (12)	Med	Turbid plumes from dredging not long lasting. Outflow of turbid plumes from the estuary can spread 10 km offshore during winter. Modelling of dredge suspended sediments from the inner harbour shows sediments entering Koombana Bay, Leschenault Inlet and Estuary and nearshore areas up to 8km north of The Cut; spread would be greater during winter than summer.
6.1	Significant benthic communities and habitats: seagrass	Increased incidence of marine heatwaves may cause decrease in seagrass biomass	Major (4)	Likely (4)	High (16)	Low	Occurred at Shark Bay for *Antarctica* species; risk is dependent on frequency of marine heatwaves and the magnitude felt for Bunbury. Depends on resilience of the species in a particular location.
6.2	Significant benthic communities and habitats: Mangroves	Further increases in salinity in Leschenault Inlet due to less storm water input may cease expansion of or degrade mangroves	Moderate (3)	Possible (3)	Med (9)	Low/med	Increased salinity since the excavation of The Cut and blocking of Preston River delta may be the reason for the slow expansion of Avicennia populations, and the slow general increase in height. Conversely, warming of waters may see an increase in the occurrence of mangroves as far south as Bunbury.
6.2	Significant benthic communities and habitats: Mangroves	Development may cause degradation to mangrove habitat and reduce biodiversity as a whole in the Inlet	Major (4)	Unlikely (2)	Med (8)	Med/high	The mangrove area and mudflats have over 100+ species. Port footprint does not directly remove mangrove habitat but does sit adjacent to mangroves in the Inlet. Mangroves have a high tolerance to turbidity. Mangroves already surrounded by development and an operating port.
6.3	Significant benthic communities and habitats: rocky reefs	Rocky reef on eastern margin of Koombana Bay may be negatively impacted if further development occurred	Moderate (3)	Possible (3)	Med (9)	Low	Dominant biota on rocky reef is foliose algae and some canopy algae which would be able to recover relatively quickly at new sites or if the current site has returned to a pre-impact state. Shipping channel of expanded port would be in the vicinity of the reef.
6.4	Significant benthic communities and habitats: soft sediments	Decline in primary productivity (e.g. microphytobenthos or turf algae) for soft sediments in Koombana Bay due to increased turbidity and sediment disturbances	Minor (2)	Unlikely (2)	Low (4)	Low	Koombana Bay is already a turbid environment with relatively low biotic cover (mentions of turf and foliose algae but did not account for microphytobenthos which can adapt to periods of low light). Increased vessel traffic may prevent establishment and growth of microphytobenthos, though when conditions are ideal, microphytobenthos would grow quickly.
6.5	Significant benthic communities and habitats: sponge gardens	Sponges may be negatively impacted if there is a reduction in water quality, including turbidity and sedimentation	Moderate (3)	Possible (3)	Med (9)	Low	Sponge gardens do not occur in Koombana Bay but do occur north of The Cut. Dredge plumes are modelled to extend 8 km north of The Cut and may impact sponges.
6.6	Significant benthic communities and habitats: mud flats	Decrease in biodiversity of mud flats due to degradation or removal of habitat	Moderate (3)	Possible (3)	Med (9)	Low	Leschenault Inlet has over 100 species recorded. Mudflats not exclusive to the Inlet.
6.7	Significant benthic communities and habitats: artificial reefs	Decline of artificial reef habitat due to suspended sediments from dredging	Minor (2)	Unlikely (2)	Low (4)	Low/med	Turbid plumes from dredging not long lasting. Modelling of dredged suspended sediments from the inner harbour shows sediments entering Koombana Bay, Leschenault Inlet and Estuary and nearshore areas up to 8km north of The Cut; spread would be greater during winter than summer. Turbid outflow from the estuary during winter can extend 10 km offshore. Foundation artificial reef would still remain for marine life to re-establish.
6.7	Significant benthic communities and habitats: artificial reefs	Increased vessel traffic may deter fishes	Minor (2)	Possible (3)	Med (6)	Low	Fish may return to artificial structure during periods of low vessel traffic and may adjust behaviours i.e. become used to vessels if they are occurring near the reef frequently.
7.1	Listed and significant fauna: fairy tern	Loss of shoreline habitat due to development and/or sea level rise	Major (4)	Possible (3)	High (12)	Med	Over time. risk will increase with sea level rise. Lack of nesting sites would affect population. Breeding occurs in the port area at McKenna Pt.
7.1	Listed and significant fauna: fairy tern	Bioaccumulation of contaminants through the food chain that would negatively affect survival and/or breeding success	Major (4)	Possible (3)	High (12)	Low	TBT is being reduced. Terns are not bottom feeders but contaminants may accumulate in fish prey. Could impact viability.

Ref #	Value	Issue	Conseq.	Likeli.	Risk	Data confidence	Justification
7.2	Listed and significant fauna: little penguins	Bioaccumulation of contaminants through the food chain that would negatively affect survival and/or breeding success	Major (4)	Possible (3)	High (12)	Low	Contaminants have been found in dead penguins around Kwinana but have not been identified as the definite cause of death. TBT would be decreasing over time.
7.2	Listed and significant fauna: little penguins	Increase in deaths from collisions with increasing recreational boat traffic	Moderate (3)	Unlikely (2)	Med (6)	High	Trauma from watercraft identified as one of the top two causes of death for Cockburn Sound. Port footprint would compress the same number of recreational boats into a smaller area. Penguins have been satellite tracked from Kwinana to Bunbury, but the Bunbury area would have a lower abundance of penguins, as penguins are visiting the area and there are no breeding colonies.
7.3	Listed and significant fauna: bottlenose dolphins	Decrease in the high quality of prey items due to loss of prey biodiversity or contamination	Major (4)	Possible (3)	High (12)	Med	The Leschenault Estuary has a high abundance, biomass and quality of prey in comparison to open waters; high quality prey optimizes foraging and likely encourages small home ranges in Bunbury. The dolphin mother and calf pairs that remain in Koombana Bay and Leschenault Estuary year round may be sustained by the higher quality prey in the winter months.
7.3	Listed and significant fauna: bottlenose dolphins	Loss of habitat could negatively impact on resident dolphin populations	Moderate (3)	Possible (3)	Med (9)	Med/high	Threat likelihood already assessed for dolphins in the region and coastal development and loss of habitat is a 'high' probability of occurrence but a 'low' impact.
7.3	Listed and significant fauna: bottlenose dolphins	Increased entanglement in fishing gear with increased recreational use of Koombana Bay	Moderate (3)	Likely (4)	High (12)	Med	Threat likelihood already assessed for dolphins in the region and entanglement in fishing gear is listed as having a 'medium' level of impact with a 'high' level of probability. More of a problem over summer time.
7.3	Listed and significant fauna: bottlenose dolphins	Dolphin abundances may decline and movement patterns altered for the Bunbury area under a changing climate	Major (4)	Possible (3)	High (12)	Low/med	Movement patterns will be dictated by changes to prey distributions. Abundances and movement patterns linked to ENSO events.
7.3	Listed and significant fauna: bottlenose dolphins	Increased tourism and feeding of dolphins could increase vessel strikes	Moderate (3)	Possible (3)	Med (9)	Med	Based on a threat likelihood for Bunbury dolphins, food provisioning and tourism are already assessed as having a 'high' level of impact with a 'medium' level of probability. Dolphin Discovery Centre has been managing their tourism for decades and would likely not increase activities that would cause harm.
7.3	Listed and significant fauna: bottlenose dolphins	Increase in underwater noise from development and construction could deter dolphins from their usual habitats and interrupt communications between dolphins	Minor (2)	Likely (4)	Med (8)	Med	Dolphins have been documented avoiding noisy areas temporarily and changing their usual behaviours. Dolphins may investigate due to curiousness but depends on the noise. Noises can be short lived or intermittent.
7.4	Listed and significant fauna: migratory shorebirds and seabirds	Bioaccumulation of contaminants through the food chain that would negatively affect survival and/or breeding success	Major (4)	Possible (3)	High (12)	Low	Shorebirds could be feeding on invertebrates that live in contaminated sediments. Contaminants have been documented in other birds, such as penguins and fairy terns around Kwinana. TBT would decrease over time. Contaminants have been documented in other birds, such as penguins and fairy terns. Foraging would also occur outside of Koombana Bay.
7.4	Listed and significant fauna: migratory shorebirds and seabirds	Loss, degradation, or complete removal of Preston River Delta could reduce the regional significance of the location	Major (4)	Possible (3)	High (12)	Med	Development may alter the current state of the delta. Truncation of the river into the inner harbour instead of redirection into Vittoria Bay has been proposed. Redirection is also a possibility and this would also cause some disruption to the birds using the delta but may be more a 'medium' risk as birds would likely adjust to new conditions. 43% of waterbirds were recorded at the delta in a 2008 survey.
7.4	Listed and significant fauna: migratory shorebirds and seabirds	Increased coastal development could remove important habitat	Moderate (3)	Possible (3)	Med (9)	Low	Development likely to occur in the region.
7.5	Listed and significant fauna: pouched lamprey	Loss, degradation, or complete removal of Preston River Delta could reduce access to river and spawning opportunities in freshwater sources	Major (4)	Possible (3)	High (12)	Low	Development may alter the current state of the delta. Truncation of the river into the inner harbour instead of redirection into Vittoria Bay has been proposed. Redirection is also a possibility and this would also cause some disruption to the lampreys using the delta for access to Preston River, but may be more a 'medium' risk as lampreys would likely adjust to new conditions.

Ref #	Value	Issue	Conseq.	Likeli.	Risk	Data confidence	Justification
7.6	Listed and significant fauna: Carter's Freshwater Mussel	Reduction of water quality (e.g. contamination) of the Preston River could prevent re-establishment of mussel populations	Moderate (3)	Unlikely (2)	Med (6)	Low/med	Endemic to south-west Australia and is the only large freshwater mussel found here. No mussels have been found in the Preston River in recent surveys, and contamination of the River is managed through a waste water capture system.
7.6	Listed and significant fauna: Carter's Freshwater Mussel	Increased salinity of Preston River under a drying climate	Major (4)	Possible (3)	High (12)	Low/med	Low tolerance of saline waters.
8.1	Regionally significant spawning / nursery area: King George whiting	Degradation to Leschenault Inlet habitat will negatively impact on an important nursery area	Moderate (3)	Possible (3)	Med (9)	Med	Inlet identified as an important nursery. Port footprint not directly removing habitat. But degradation may occur over time due to increased use of Koombana Bay.
8.2	Regionally significant spawning / nursery area: Whitebait	An increase in marine heatwaves would negatively impact spawning	Major (4)	Likely (4)	High (16)	Low/med	Reduced distribution and 2011 heatwave impacts suggest environmental limitations. There was reduced spawning success in winter of 2011 which resulted in low catches and catch rates. Rated as high risk to climate change.
8.2	Regionally significant spawning / nursery area: Whitebait	A decrease in water quality due to increased development may cause a decrease in abundance	Major (4)	Possible (3)	High (12)	Low/med	Reduced distribution and 2011 heatwave impacts suggest environmental limitations. Koombana Bay likely used as a spawning ground and Leschenault Estuary as a nursery ground. The added pressures of poor water quality from increased development may contribute to a decline in abundance.
9.1	Regionally significant migratory pathway: Blue swimmer crab	Decline in abundances due to environmental impacts, such as marine heatwaves	Major (4)	Likely (4)	High (16)	Med	Environmental factors can influence abundances and is believed to be a cause of decline for stocks in Cockburn Sound.
9.1	Regionally significant migratory pathway: Blue swimmer crab	Reduced water quality can stress crabs making them more prone to infections such as shell diseases	Moderate (3)	Possible (3)	Med (9)	Low	Shell disease was the cause of crab deaths in 2016. Reduced water quality may occur with increased use and development in Koombana Bay.
10	Leschenault Regional Park	Increase stress on the estuary will increase the occurrence of algal blooms and fish kills	Moderate (3)	Likely (4)	High (12)	Med	Estuary already under stress and algal blooms and fish kills have occurred towards the northern portion of the estuary. Fertiliser use is one of the biggest contributors to high nutrient levels.
10	Leschenault Regional Park	Increase in salinity of the Estuary under a drying climate	Major (4)	Likely (4)	High (16)	Med	Estuary has already changed from a well-mixed to salt wedge partially mixed environment since The Cut, and less fresh water would be flowing into the estuary as the planet warms.
10	Leschenault Regional Park	Increase in coastal erosion due to an increase in storm events	Moderate (3)	Likely (4)	High (12)	Med	Impacts due to storms and coastal erosion from climate change are recognised as needing management within the park. Storm events and erosion predicted to increase under a changing climate.
11	Coastal processes	Risk of inundation to the Leschenault Inlet with rising sea levels and flooding	Minor (2)	Possible (3)	Med (6)	Low/med	Stormwater pipes enter into the Inlet and could cause temporary flooding.
11	Coastal processes	Risk of erosion and inundation to areas of Koombana Bay with rising sea levels and storms	Moderate (3)	Likely (4)	High (12)	Low/med	Koombana Beach and Yacht Club groyne already impacted.

Table 6: Expanded issues and risk assessment relating to marine and estuarine social values of Bunbury.

Ref#	Value	Issue	Conseq.	Likeli.	Risk	Data confidence	Justification
1.1	Heritage: Aboriginal	Loss or degradation of important heritage sites with increased development	Moderate (3)	Likely (4)	High (12)	High	Leschenault Inlet and Koombana Bay are important contemporary areas for the Nyungar community. Leschenault Estuary, Koombana Bay and Preston River are all registered mythological sites. Alteration to Preston River would impact a mythological site, and current port footprint would directly cut across the river. Degradation to these areas could occur from increased use and development.
1.2	Heritage: Maritime/historic	Loss or degradation of important historical sites with increased development	Minor (2)	Likely (4)	Med (8)	High	One registered site occurs directly within port footprint and others occurring in immediate vicinity.
2.1	Public health: Recreational water quality	Increased safety concerns for primary and secondary contact with water due to decreased water quality	Major (4)	Possible (3)	High (12)	Med	People use in Koombana Bay/ Leschenault Inlet for water sports or leisure.
2.2	Public health: Seafood quality	Decrease in health of shellfish and fish with increased contamination in waters and sediments	Major (4)	Possible (3)	High (12)	Med	Mussel tissue concentrations of copper, selenium and zinc have, at all sites, exceeded the food guideline values at some point in time and is a human consumption risk.
3.1	Social and community: Recreational fishing	Decrease of recreational fishing with port development due to restrictions	Minor (2)	Possible (3)	Med (6)	Med	Some fishing would take place in Koombana Bay but is more popular in the Leschenault Estuary and the Inlet.
3.1	Social and community: Recreational fishing	Degradation of Leschenault Inlet with port development	Major (4)	Possible (3)	High (12)	Med	Leschenault Inlet popular for fishing and crabbing.
3.2	Social and community: Recreational swimming	Degradation of swimming beaches due to port development	Moderate (3)	Possible (3)	Med (9)	Med	Koombana Beach, Ski Beach, Jetty Baths are popular for swimming and are in the vicinity of port footprint. Footprint doesn't directly remove favoured swimming beaches.
3.3	Social and community: Recreational water sports	Displacement of water sports with increased development	Minor (2)	Possible (3)	Med (6)	Low/med	Leschenault Inlet most popular for recreational sports. Could still be used for sports despite turbidity or lower water quality. Footprint of port does not directly impact on Inlet. Water sports in KB would likely be restricted to certain areas.
3.3	Social and community: Recreational water sports	Loss of shoreline infrastructure in Leschenault Inlet with a changing climate	Moderate (3)	Possible (3)	Med (6)	Low/med	Several water sports clubs have leased land on foreshore which is used for recreating and socialising.
3.4	Social and community: Recreational boating access	Flooding occurrences via storm water outfalls may impact on boat ramps in Leschenault Inlet.	Moderate (3)	Possible (3)	Med (9)	Med	Port footprint does not impact current boat access. Temporary flooding in the Inlet will impact access and may be an increased risk long term with increased sea level.
3.5	Social and community: Marina facilities	Reduced use of marina facilities with increased development	Minor (2)	Unlikely (2)	Low (4)	Med	Depends on structures built and shipping channel- current footprint indicates rock groynes will be built near the harbour. Can use other boat launching facilities. Potential restrictions on Casuarina Boat Harbour with increased port development.
3.6	Social and community: Educational and scientific values	Degradation of mangrove habitat would impact educational experiences and value for scientific purposes	Moderate (3)	Possible (3)	Med (9)	Med	Habitat may degrade over time with increased development if not managed sufficiently. Potential loss of birds and reduction in bird watching.
3.7	Social and community: Landscape and visual amenity	Scenic boardwalk through mangrove habitat may lose scenic quality if habitat is degraded with increased development	Moderate (3)	Possible (3)	Med (9)	Med	Habitat may degrade over time with increased developed if not managed sufficiently. Potential loss of birds and reduction in bird watching.
3.7	Social and community: Landscape and visual amenity	Lack of visitation due to obstruction of expansive views of the ocean horizon with large vessels and/or building and structures	Moderate (3)	Possible (3)	Med (9)	Med	Increase in vessel traffic will occur if operations expand, and the shipping channel spreads right across Koombana Bay. Some vessels already operating in the bay.

Ref#	Value	Issue	Conseq.	Likeli.	Risk	Data confidence	Justification
4.1	Business, industry and commercial: Tourism	Reduced wildlife tourism due to loss of marine life and habitat degradation	Major (4)	Possible (3)	High (12)	Med/high	Dolphin Discovery Centre would be significantly impacted if resident dolphin populations were displaced.
4.1	Business, industry and commercial: Tourism	Displacement of tourist activities with port development	Major (4)	Unlikely (2)	Med (8)	Low/med	A lot of tourist activities would occur in the Inlet, but some also in Koombana Bay- which could potentially still occur away from port footprint.
4.1	Business, industry and commercial: Tourism	Increased erosion of Koombana Beach may cause a decrease in tourism	Minor (2)	Unlikely (2)	Low (4)	High	Erosion occurring at some points along the beach. Already a developed area and erosion could cause risk to businesses and the port if not managed.
4.2	Business, industry and commercial: Commercial fisheries	Decrease in commercial fishing due to habitat loss and degradation with increased development, as well as environmental change	Major (4)	Possible (3)	High (12)	Med	No commercial fishing allowed in the inner or outer harbour areas due to current port operations. If Leschenault Estuary or Inlet are affected by further development in the area, this may reduce fish stocks which use coastal areas during their life cycle.

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Appendix 3

Table 1: Synthesised "rolled" up issues (highlighted rows) for marine and estuarine environmental values of Fremantle.

Ref#	Value	Issue
1	**Integral functioning ecosystem**	**Decrease in current ecosystem functioning within and around port footprint with increased use and development**
2	Biological diversity	Decrease in biological diversity due to increasing sea temperatures and distribution shifts of species
2.1	Biological diversity: fish assemblages	Reduction in fish abundance/biodiversity from habitat degradation
2.2	Biological diversity: demersal and benthic communities	Reduction in biodiversity of demersal and benthic communities from habitat degradation
2.3	Biological diversity: invasive species	Increased risk of introduced marine pests with increasing vessel traffic
2	**Biological diversity**	**Decrease in species diversity due to reduction of suitable habitat, invasive species and altered environmental conditions**
3.1	High level of water quality: nutrients	Elevated nutrient levels with increased use and development of Fremantle Port
3.2	High level of water quality: Chl a/ phytoplankton	Increased nutrients and warmer temperatures may cause toxic phytoplankton blooms in the estuary
3.3	High level of water quality: light attenuation/turbidity	Increased light attenuation from increased turbidity as a result of dredging (construction)
3.3	High level of water quality: light attenuation/turbidity	Increased light attenuation from increased turbidity as a result resuspended sediments from increased shipping traffic (operational)
3.4	High level of water quality: dissolved oxygen	Decreased dissolved oxygen due to increasing temperatures which may cause temporary or permanent dead zones
3.5	High level of water quality: temperature	Increased incidence of marine heatwave events that could cause stress and death to marine life
3.6	High level of water quality: salinity	Increased incidence of flooding will increase discharges of fresher and turbid water plumes from the Swan Canning catchment
3.6	High level of water quality: salinity	Salinity patterns in the Swan and inner harbour are likely to be impacted by reduced rainfall under a drying climate
3.7	High level of water quality: ph	Increase in pH may cause acidification and negatively impact calcareous organisms
3.8	High level of water quality: contaminants	Resupply of contaminants to water column through re-suspension of sediments
3.8	High level of water quality: contaminants	Increased incidence of oil and fuel spills with increased vessel traffic
3.9	High level of water quality: groundwater	Increased nutrient levels discharged into the Inner Harbour and surrounds from groundwater
3.10	High level of water quality: hydrology	Increased circulation of the Swan Estuary (lower reaches) and migration of higher salinity concentrations upstream with deeper dredge channel
3	**High level of water quality**	**Decrease in quality of water due to increased development and altered environmental conditions**
4.1	High level of sediment quality: contaminants	Increase in contamination of sediments with increased shipping and port operations
4.2	High level of sediment quality: acid sulphate soils	Potential acid sulphate soils could become actual acid sulphate soils during development
4	**High level of sediment quality**	**Decrease in quality of sediments due to increased development**
5.1	Significant benthic communities and habitats: seagrass	Loss of seagrass meadows from dredging channels
5.1	Significant benthic communities and habitats: seagrass	Reduced seagrass growth due to poor light availability as a result of dredging and vessel use
5.1	Significant benthic communities and habitats: seagrass	Increased incidence of marine heatwaves may cause decrease in seagrass biomass
5.1	**Significant benthic communities and habitats: Seagrass**	**Reduction in seagrass biomass and extent due to increased development and altered environmental conditions**
5.2	Significant benthic communities and habitats: coral reefs	Degradation of Hall Bank coral community with increased development and dredging
5.3	Significant benthic communities and habitats: rocky reefs	Degradation of rocky reef communities with increased development
5.4	Significant benthic communities and habitats: macroalgae	Loss of macroalgae habitats with increased development
5	**Significant benthic communities and habitats: Other**	**Degradation of other benthic communities due to increased development**
6.1	Listed and significant fauna: fairy tern	Loss of shoreline habitat due to development and/or sea level rise

Ref#	Value	Issue
6.1	Listed and significant fauna: fairy tern	Bioaccumulation of contaminants through the food chain that would negatively affect survival and/or breeding success
6.1	**Listed and significant fauna: Fairy terns**	**Decline in abundance and breeding success of fairy terns due to impacts on habitat and prey species**
6.2	Listed and significant fauna: bottlenose dolphins	Increase in underwater noise from development and construction could deter dolphins from their usual habitats and interrupt communications between dolphins
6.2	Listed and significant fauna: bottlenose dolphins	Degradation of foraging hotspots in the Inner Harbour
6.2	Listed and significant fauna: bottlenose dolphins	Bioaccumulation of contaminants through the food chain that would negatively affect survival and/or breeding success
6.2	**Listed and significant fauna: Bottlenose dolphins**	**Decline in resident and other populations due to a decline in foraging habitat, prey species and anthropogenic influences i.e. boat strikes, fishing entanglements and underwater noise**
6.3	**Listed and significant fauna: Whales**	**Decrease in humpback whale occurrence due to port operations**
6.4	Listed and significant fauna: migratory seabirds and shorebirds	Sea level rise could inundate important shoreline habitat
6.4	Listed and significant fauna: migratory seabirds and shorebirds	Sea level rise could inundate important shoreline habitat
6.4	**Listed and significant fauna: Migratory seabirds and shorebirds**	**Decline in abundance and breeding success due to impacts on habitat and prey species**
7	**Regionally significant spawning / nursery area**	**Fish species that spend their whole life cycles in the estuary (i.e. yellowtail flathead, black bream) may be negatively impacted by habitat degradation or alteration**
8.1	Regionally significant migratory pathway: Yellowfin whiting	Suspended sediments and noise from dredging may impact on larval recruitment into the estuary from coastal waters
8.2	Regionally significant migratory pathway: Blue swimmer crab	Habitat degradation may reduce abundances in the lower Swan Estuary
8.2	Regionally significant migratory pathway: Blue swimmer crab	Suspended sediments and noise from dredging may impact on adults migrating out of the estuary, and also impact on spawning in coastal waters
8.3	Regionally significant migratory pathway: Whitebait	Suspended sediments and noise from dredging may impact on larval stages, which peak in abundance in the lower reaches of the swan estuary
8.4	Regionally significant migratory pathway: Australian herring	Suspended sediments and noise from dredging may impact on the migration of adults from the estuary to coastal waters, and also impact on spawning in coastal waters
8.5	Regionally significant migratory pathway: Perth herring	Increasing salinity from lower rainfall may impact on the distribution of fish throughout the estuary
8.5	Regionally significant migratory pathway: Perth herring	Suspended sediments and noise from dredging may impact on the migration of adults from oceanic waters into the estuary where they spawn
8.6	Regionally significant migratory pathway: Sea mullet	Suspended sediments and noise from dredging may impact on the migration of adults from the estuary to oceanic waters
8.7	Regionally significant migratory pathway: Yelloweye mullet	Suspended sediments and noise from dredging may impact on the migration of adults from the estuary to oceanic waters, and also impact on spawning in coastal waters
8.8	Regionally significant migratory pathway: Mulloway	Suspended sediments and noise from dredging may impact on the mulloway occurrence and abundance
8.9	Regionally significant migratory pathway: Prawns	Increasing salinity from lower rainfall and increasing temperatures may impact on the distribution of western school prawns throughout the estuary
8.9	Regionally significant migratory pathway: Prawns	Habitat degradation may reduce abundances of western school prawns in the estuary
8.9	Regionally significant migratory pathway: Prawns	Suspended sediments and noise from dredging may impact on the migration of adult western king prawns from oceanic water into the estuary
8.10	Regionally significant migratory pathway: black mussels	Suspended sediments from dredging may impact on the larvae that enter the estuary from the ocean
8.11	Regionally significant migratory pathway: Other fish species	Fish species such as small tooth flounder and tailor use parts of the estuary during their life cycles, which may be affected by suspended sediments from dredging operations
8	**Regionally significant migratory pathway**	**Negative impacts from increased port use to fish and invertebrate species that migrate to and from estuary and oceanic waters to complete their lifecycle**
9	**Swan Estuary Marine Park**	**Degradation of marine park through upstream flow on effects of increased port operations**
10	Coastal processes	Inundation of popular coastal use areas (e.g. South Mole, Bathers Beach) due to sea level rise
10	Coastal processes	Inundation of foreshores of Swan Estuary due to coastal flooding and loss of infrastructure
10	Coastal processes	Increased erosion of Port Beach and potential influence on Port operations
10	**Coastal processes**	**Increased erosion and inundation of shorelines from rising sea levels, storms and changes to sediment transport**

Table 2: Synthesised "rolled" up issues (highlighted rows) for marine and estuarine social values of Fremantle.

Ref#	Value	Issue
1.1	**Heritage: Aboriginal**	**Loss or degradation of important heritage sites with increased development**
1.2	**Heritage: Maritime/historic**	**Loss or degradation of important historical sites with increased development**
2.1	**Public health: Recreational water quality**	**Increased safety concerns for primary and secondary contact with water due to decreased water quality**
2.2	**Public health: Seafood quality**	**Decrease in health of shellfish and fish with increased contamination in waters and sediments**
3.1	Social and community: Recreational fishing	Reduction or loss of popular fished species in the estuary due to interruptions in migration/recruitment into/out of the estuary during dredging campaigns
3.1	Social and community: Recreational fishing	Port expansion may disrupt popular fishing spots in the inner harbour entrance or Rous Head
3.1	**Social and community: Recreational fishing**	**Decrease in recreational fishing due to restrictions around port area and the loss of popular fished species due to impacts to migration pathway**
3.2	**Social and community: Recreational swimming**	**Increased turbidity at popular swimming beaches from dredge plumes**
3.3	**Social and community: Recreational boating access**	**Delays in passage through entrance channel during dredging/expansion works**
3.4	**Social and community: Marina facilities**	**Marinas may experience increased water turbidity due to increased vessel use and dredging**
3.5	**Social and community: Educational and scientific values**	**Decline in educational experiences due to degradation of estuarine habitats with increased use of the development in inner harbour.**
3.6	Social and community: Landscape and visual amenity	Sightings of dredge plumes off the coast
3.6	Social and community: Landscape and visual amenity	Erosion at Bathers Beach and Arthurs Head would reduce visual amenity and enjoyment of the landscape
3.6	**Social and community: Landscape and visual amenity**	**Less visitation due to increased development negatively impacting on the landscape and visual amenity**
4.1	Business, industry and commercial: Tourism	Reduced aesthetic quality during dredging campaigns/expansion works for passengers on cruise ships entering the port
4.1	Business, industry and commercial: Tourism	Reduced economic activity with erosion at Bathers Beach
4.1	**Business, industry and commercial: Tourism**	**Loss of tourism due to increased development, loss of marine life and environmental change**
4.2	Business, industry and commercial: Commercial fisheries	Decrease in commercial catches due to interruption to migration/recruitment of fishes through the entrance channel during dredging/expansion works
4.2	Business, industry and commercial: Commercial fisheries	Degradation of estuarine habitats with increased use of the port area
4.2	**Business, industry and commercial: Commercial fisheries**	**Decrease in commercial fishing due to impacts on migration pathways of fishes and degradation of estuarine habitats with increased port use**
4.3	**Business, industry and commercial: Aquaculture**	**Reduced water quality of the Inner Harbour would impact on intake water for aquaculture operations**

Table 3: Synthesised "rolled" up issues (highlighted rows) for marine and estuarine environmental values of Kwinana.

Ref#	Value	Issue
1	**Integral functioning ecosystem**	**Decrease in ecosystem functioning with increased use and development in Cockburn Sound**
2	**Sheltered marine ecological community**	**Alteration to the sheltered nature of Cockburn Sound where dredge channels and built structures may impact on calm waters**
3	Biological diversity	Decrease in biological diversity due to increasing sea temperatures and distribution shifts of species
3.1	Biological diversity: fish assemblages	Reduction in fish abundance/biodiversity from habitat loss
3.2	Biological diversity: demersal and benthic communities	Reduction in biodiversity of demersal and benthic communities from habitat loss or degradation
3.3	Biological diversity: plankton	Decline in nutrient levels will cause a decline in phytoplankton and zooplankton species diversity
3.4	Biological diversity: invasive species	Increase in marine pests with increasing vessel traffic
3	**Biological diversity**	**Decrease in species diversity due to reduction of suitable habitat, invasive species and altered environmental conditions**
4.1	High level of water quality: nutrients	Resupply of nutrients to water column through re-suspension of sediments
4.1	High level of water quality: nutrients	Elevated nutrient levels with increased use and development in Cockburn Sound
4.2	High level of water quality: Chl a/ phytoplankton	Increased nutrients and warmer temperatures may cause more frequent toxic phytoplankton blooms
4.3	High level of water quality: light attenuation/turbidity	Increased light attenuation from increased turbidity as a result of dredging (construction)
4.3	High level of water quality: light attenuation/turbidity	Increased light attenuation from increased turbidity as a result of increased shipping traffic (operational)
4.4	High level of water quality: dissolved oxygen	Decrease in dissolved oxygen in bottom waters to the east and south of Cockburn Sound
4.4	High level of water quality: dissolved oxygen	Decreased dissolved oxygen due to increasing temperatures which may cause temporary or permanent dead zones
4.5	High level of water quality: temperature	Increased incidence of marine heatwave events that could cause stress and death to marine life
4.6	High level of water quality: salinity	Increased incidence of flooding will increase discharges of fresher and turbid water plumes into Kwinana region from the Swan River
4.6	High level of water quality: salinity	Negative impacts to marine life from brine discharged into Cockburn Sound
4.7	High level of water quality: ph	Increase in pH may cause acidification and negatively impact calcareous organisms
4.8	High level of water quality: contaminants	Resupply of contaminants (e.g. TBT and PFAS) to water column through re-suspension of sediments
4.8	High level of water quality: contaminants	PFAS impacting marine life through filtration/ingestion of contaminated groundwater
4.8	High level of water quality: contaminants	Increased incidence of oil and fuel spills with increased vessel traffic
4.9	High level of water quality: groundwater	Increased nutrient levels discharged into Cockburn Sound from groundwater with legacy contamination issues from agriculture and industry
4.10	High level of water quality: hydrology	Continued poor flushing resulting in lower water quality in some areas of Cockburn Sound- i.e. eastern and southern regions
4.10	High level of water quality: hydrology	Efforts to improve flushing may increase coastal erosion
4	**High level of water quality**	**Decrease in quality of water due to increased development and altered environmental conditions**
5.1	High level of sediment quality: contaminants	Increase in contamination of sediments with increased shipping and port operations
5.2	High level of sediment quality: nutrients	High organic load of sediments due to poor flushing
5.3	High level of sediment quality: acid sulphate soils	Exposure of acid sulphate soils during development
5	**High level of sediment quality**	**Decrease in quality of sediments due to increased development**
6.1	Significant benthic communities and habitats: seagrass	Loss of seagrass meadows from dredged shipping channels
6.1	Significant benthic communities and habitats: seagrass	Reduced seagrass growth due to dredging activities and poor light availability
6.1	Significant benthic communities and habitats: seagrass	Reduced seagrass growth due to sulphide intrusion facilitated by low dissolved oxygen levels and low light levels

Ref#	Value	Issue
6.1	Significant benthic communities and habitats: seagrass	Increased incidence of marine heatwaves may cause decrease in seagrass biomass
6.1	**Significant benthic communities and habitats: Seagrass**	**Reduction in seagrass biomass and extent due to increased development and altered environmental conditions**
6.2	Significant benthic communities and habitats: coral reefs	Loss of coral communities with increased development and dredging
6.3	Significant benthic communities and habitats: rocky reefs	Loss of rocky reef communities with increased development
6.4	Significant benthic communities and habitats: soft sediments	Continual disturbance to soft sediments would decrease primary productivity and destabilise sediments due to the loss of microphytobenthos
6	**Significant benthic communities and habitats: Other**	**Degradation of other benthic communities due to increased development**
7.1	Listed and significant fauna: fairy tern	Bioaccumulation of contaminants through the food chain that would negatively affect survival and/or breeding success
7.1	Listed and significant fauna: fairy tern	Loss of shoreline habitat due to development and/or sea level rise
7.1	**Listed and significant fauna: Fairy terns**	**Decline in abundance and breeding success of fairy terns due to impacts on habitat and prey species**
7.2	Listed and significant fauna: little penguins	Bioaccumulation of contaminants through the food chain that would negatively affect survival and/or breeding success
7.2	Listed and significant fauna: little penguins	Starvation due to decreased food supply resulting from degradation of habitat for fish prey
7.2	Listed and significant fauna: little penguins	Starvation due to prey availability being affected by sea temperatures
7.2	Listed and significant fauna: little penguins	Increase in deaths from collisions with increasing recreational boat traffic
7.2	Listed and significant fauna: little penguins	Loss of habitat, particularly along Kwinana Shelf which is used for foraging could negatively impact on populations
7.2	**Listed and significant fauna: Little penguins**	**Decline in abundance and breeding success of little penguins due to a decline in foraging habitat and prey species, as well as increased collisions with recreational vessels**
7.3	Listed and significant fauna: bottlenose dolphins	Loss of habitat, particularly along Kwinana Shelf which is used for foraging and a nursery, could negatively impact on resident dolphin populations
7.3	Listed and significant fauna: bottlenose dolphins	Increased recreational use of the Kwinana area could increase illegal feeding of dolphins, increasing the risk of boat strikes and entanglement in fishing gear
7.3	Listed and significant fauna: bottlenose dolphins	Increase in underwater noise from development and construction could deter dolphins from their usual habitats and interrupt communications between dolphins
7.3	**Listed and significant fauna: Bottlenose dolphins**	**Decline in resident and other populations due to a decline in foraging habitat, prey species and anthropogenic influences i.e. boat strikes, fishing entanglements and underwater noise**
7.4	Listed and significant fauna: Australian sea lions	Additional haul out locations may be limited in Kwinana (due to development) if current haul out sites become unsuitable with a changing climate
7.4	Listed and significant fauna: Australian sea lions	Increase in disturbance at haul out sites of Carnac and Seal Island with increased vessel traffic
7.4	**Listed and significant fauna: Australian sea lions**	**Lack of suitable haul out sites due to changing environmental conditions and anthropogenic disturbance**
7.5	Listed and significant fauna: migratory seabirds and shorebirds	Bioaccumulation of contaminants through the food chain that would negatively affect survival and/or breeding success
7.5	Listed and significant fauna: migratory seabirds and shorebirds	Starvation due to decreased food supply resulting from degradation of habitat for fish prey
7.5	Listed and significant fauna: migratory seabirds and shorebirds	Starvation due to prey availability being affected by sea temperatures
7.5	Listed and significant fauna: migratory seabirds and shorebirds	Sea level rise could inundate important shoreline habitat
7.5	Listed and significant fauna: migratory seabirds and shorebirds	Increased development could remove important coastal habitat
7.5	**Listed and significant fauna: Migratory seabirds and shorebirds**	**Decline in abundance and breeding success due to impacts on habitat and prey species**
8.1	**Regionally significant spawning / nursery area: King George whiting**	**Decline in abundance and loss of nursery area due to loss of habitat**
8.2	Regionally significant spawning / nursery area: Blue swimmer crab	Loss of seagrass will negatively impact on recruitment
8.2	Regionally significant spawning / nursery area: Blue swimmer crab	Decline in abundance in Cockburn Sound due to environmental impacts, such as marine heatwaves and flooding
8.2	**Regionally significant spawning / nursery area: Blue swimmer crab**	**Decline in abundance and loss of nursery area due to environmental changes and loss of seagrass habitat**
8.3	Regionally significant spawning / nursery area: Pink snapper	Loss of habitat could decrease the use of Cockburn Sound as a nursery area

Ref#	Value	Issue
8.3	Regionally significant spawning / nursery area: Pink snapper	Increasing temperatures may cause declines in abundance or alter shifts in spawning peaks and maturation
8.3	Regionally significant spawning / nursery area: Pink snapper	Dredged materials could impact the survival rates of larval stages
8.3	Regionally significant spawning / nursery area: Pink snapper	Altered hydrological conditions may influence egg dispersal and survival
8.3	**Regionally significant spawning / nursery area: Pink snapper**	**Decline in abundance and loss of significant spawning area due to loss of habitat, increase in suspended sediments and changing environmental conditions**
8.4	Regionally significant spawning / nursery area: Whitebait	An increase in marine heatwaves would negatively impact spawning
8.4	Regionally significant spawning / nursery area: Whitebait	Altered hydrological conditions may influence egg dispersal and survival
8.4	**Regionally significant spawning / nursery area: Whitebait**	**Loss of favourable spawning area due to changes in environmental conditions**
8.5	Regionally significant spawning / nursery area: Southern garfish	Loss of seagrass would reduce feeding opportunities and decrease survival of eggs
8.5	Regionally significant spawning / nursery area: Southern garfish	An increase in marine heatwaves would negatively impact stocks
8.5	**Regionally significant spawning / nursery area: Southern garfish**	**Decline in abundance and loss of nursery area due to environmental changes and loss of seagrass habitat**
9	Shoalwater Islands Marine Park	Reduction in water quality and marine biota would flow on to affect the marine park
9	Shoalwater Islands Marine Park	Increased erosion of the shorelines with increasing sea level and storms
9	**Shoalwater Islands Marine Park**	**Degradation of marine park due to flow on effects of poor water quality and declining biodiversity, as well as erosion of shorelines**
10	Coastal processes	Increased erosion and inundation at localised points within Cockburn Sound with increasing sea levels and storms
10	Coastal processes	Changes in hydrological conditions may change alongshore sediment transport and erode shorelines
10	**Coastal processes**	**Increased erosion and inundation of shorelines from rising sea levels, storms and changes to sediment transport**

Table 4: Synthesised "rolled" up issues (highlighted rows) for marine and estuarine social values of Kwinana.

Ref#	Value	Issue
1.1	**Heritage: Aboriginal**	**Loss or degradation of important heritage sites with increased development**
1.2	**Heritage: Maritime/historic**	**Loss or degradation of important historical sites with increased development**
2.1	**Public health: High quality source water for desalination**	**Negative impact on drinking water supply due to declining water quality in Cockburn Sound**
2.2	**Public health: Recreational water quality**	**Increased safety concerns for primary and secondary contact with water due to decreased water quality**
2.3	**Public health: Seafood quality**	**Decrease in health of shellfish and fish with increased contamination in waters and sediments**
3.1	Social and community: Recreational fishing	Decrease in recreational fishing with port development due to restrictions
3.1	Social and community: Recreational fishing	Reduction or loss of popular fished species i.e. pink snapper, crabs with loss or degradation of habitat in Cockburn Sound
3.1	**Social and community: Recreational fishing**	**Decrease in recreational fishing due to restrictions around port area and the loss of popular fished species i.e. pink snapper, crabs with loss of habitat**
3.2	**Social and community: Recreational swimming**	**Loss of popular swimming beaches with increased development i.e. Kwinana/ Challenger Beach**
3.3	**Social and community: Recreational water sports**	**Decrease in water sports with increased development**
3.4	**Social and community: Recreational boating access**	**Loss of boat ramps with increased development i.e. Challenger Beach boat ramp**
3.5	**Social and community: Marina facilities**	**Reduced use of marina facilities with increased development**
3.6	Social and community: Educational and scientific values	Restricted access to the marine environment of the port area for research purposes
3.6	Social and community: Educational and scientific values	Dissatisfying educational experiences due to a degraded and unhealthy ecosystem
3.6	**Social and community: Educational and scientific values**	**Reduced research and educational opportunities due to further development degrading the functioning ecosystem**
3.7	Social and community: Landscape and visual amenity	Erosion will reduce visual amenity and access at popular beaches and coastlines
3.7	Social and community: Landscape and visual amenity	Increased sightings of marine life kills due to decreased water quality
3.7	Social and community: Landscape and visual amenity	Obstruction of expansive views of the ocean horizon with large vessels and/or building and structures
3.7	**Social and community: Landscape and visual amenity**	**Less visitation due to increased development negatively impacting on the landscape and visual amenity**
4.1	Business, industry and commercial: Tourism	Reduced wildlife tourism due to loss of marine life and habitat degradation
4.1	Business, industry and commercial: Tourism	Displacement of tourist activities with port development
4.1	**Business, industry and commercial: Tourism**	**Loss of tourism due to restrictions around port area and the loss of marine life and habitat with increased development**
4.2	Business, industry and commercial: Commercial fisheries	Increased rules and restrictions leading to a further decrease in commercial fishing in Cockburn Sound
4.2	Business, industry and commercial: Commercial fisheries	Loss/degradation of habitat resulting in low catch rates
4.2	**Business, industry and commercial: Commercial fisheries**	**Decrease in commercial fishing due to an increase in rules and restrictions and lower catch rates from habitat loss and degradation with increased development**
4.3	Business, industry and commercial: Aquaculture	Reduction of nutrients would reduce food available for mussel growth
4.3	Business, industry and commercial: Aquaculture	Increase in introduced marine pests that would negatively impact mussel growth and sales
4.3	Business, industry and commercial: Aquaculture	Availability of contaminants in the water column would increase and could cause health concerns in farmed mussels
4.3	Business, industry and commercial: Aquaculture	Increase in water temperatures may negatively affect mussel growth
4.3	**Business, industry and commercial: Aquaculture**	**Loss of mussel aquaculture due to increased development and changing environmental conditions**

Ref#	Value	Issue
4.4	**Business, industry and commercial: Suitable quality water for industrial use**	**Reduced water quality due to increased development will impact industrial use**
4.5	Business, industry and commercial: Assimilation of wastewater	Decreased water quality around outfall pipes due to wastewater operations
4.5	Business, industry and commercial: Assimilation of wastewater	Increase in emergency outfall use with an increasing population or issues with SDOOL
4.5	**Business, industry and commercial: Assimilation of wastewater**	**Decreased water quality around outfall pipes due to wastewater operations**

Table 5: Synthesised "rolled" up issues (highlighted rows) for marine and estuarine environmental values of Bunbury.

Ref#	Value	Issue
1	**Integral functioning ecosystem**	**Decrease in ecosystem functioning with increased use and development in Koombana Bay**
2	**Sheltered marine ecological community**	**Alteration to the sheltered nature of Koombana Bay where dredge channels and built structures may impact on marine biota that depend on calmer waters**
3	Biological diversity	Increased warming of waters may cause a shift in the marine communities and habitats with the introduction of more tropical species.
3.1	Biological diversity: fish assemblages	Reduction in fish abundance/biodiversity from habitat loss
3.2	Biological diversity: demersal and benthic communities	Reduction in biodiversity of demersal and benthic communities from habitat loss or degradation
3.3	Biological diversity: plankton	Decrease in high richness of foraminifera in Leschenault Estuary due to changes in environmental conditions
3.4	Biological diversity: invasive species	Increase in marine pest with increasing vessel traffic
3	**Biological diversity**	**Decrease in species diversity due to reduction of suitable habitat, invasive species and altered environmental conditions**
4.1	High level of water quality: nutrients	Resupply of nutrients to water column through re-suspension of decayed material
4.1	High level of water quality: nutrients	Elevated nutrient levels with increased use and development around Koombana Bay
4.2	High level of water quality: Chl a/ phytoplankton	Increased nutrients and warmer temperatures may cause toxic phytoplankton blooms
4.3	High level of water quality: light attenuation/turbidity	Increased light attenuation from increased turbidity as a result of dredging (construction)
4.3	High level of water quality: light attenuation/turbidity	Increased light attenuation from increased turbidity as a result resuspended sediments from increased shipping traffic (operational)
4.3	High level of water quality: light attenuation/turbidity	Suspended sediments from dredging may spread outside of Koombana Bay to seagrass beds as well as into the Leschenault Inlet
4.4	High level of water quality: dissolved oxygen	Decrease in dissolved oxygen in Koombana Bay and Inlet due to increasing nutrient load and phytoplankton growth
4.4	High level of water quality: dissolved oxygen	Decreased dissolved oxygen due to increasing temperatures which may cause temporary or permanent dead zones
4.5	High level of water quality: temperature	Increased incidence of marine heatwave events that could cause stress and death to marine life
4.6	High level of water quality: salinity	Increased incidence of flooding will increase discharges of fresher and turbid water plumes into Koombana Bay via The Cut
4.6	High level of water quality: salinity	Leschenault Estuary is at risk of increased salinity due to decreasing rainfall
4.7	High level of water quality: ph	Increase in pH may cause acidification and negatively impact calcareous organisms
4.8	High level of water quality: contaminants	Resupply of contaminants to water column through re-suspension of sediments
4.8	High level of water quality: contaminants	Increased incidence of oil and fuel spills with increased vessel traffic
4.8	High level of water quality: contaminants	Contamination of Preston River and Vittoria Bay with increased development of the port
4.9	High level of water quality: groundwater	Increased nutrient levels discharged into Koombana Bay and Leschenault Estuary
4.9	High level of water quality: groundwater	Dewatering close to the coast may result in saline waters migrating inland, and may expose acid sulphate soils
4.10	High level of water quality: hydrology	Dredged channels may influence flow patterns and sediment transport
4	**High level of water quality**	**Decrease in quality of water due to increased development and altered environmental conditions**
5.1	High level of sediment quality: contaminants	Increase in contamination of sediments with increased shipping and port operations
5.2	High level of sediment quality: nutrients	Larger shipping channel may accumulate more decaying wrack and increase nutrient loading in the sediments
5.3	High level of sediment quality: acid sulphate soils	Increased risk of exposed acid sulphate soils with development and/or modification of the shorelines
5	**High level of sediment quality**	**Decrease in quality of sediments due to increased development**
6.1	Significant benthic communities and habitats: seagrass	Spread of suspended sediments may reach and impact on seagrass meadows outside of Koombana Bay
6.1	Significant benthic communities and habitats: seagrass	Increased incidence of marine heatwaves may cause decrease in seagrass biomass

Ref#	Value	Issue
6.1	**Significant benthic communities and habitats: Seagrass**	**Reduction in seagrass biomass and extent due to increased development and altered environmental conditions**
6.2	Significant benthic communities and habitats: Mangroves	Further increases in salinity in Leschenault Inlet due to less storm water input may cease expansion of or degrade mangroves
6.2	Significant benthic communities and habitats: Mangroves	Development may cause degradation to mangrove habitat and reduce biodiversity as a whole in the Inlet
6.2	**Significant benthic communities and habitats: Mangroves**	**Degradation of mangrove habitat due to increased development and changing environmental conditions**
6.3	Significant benthic communities and habitats: rocky reefs	Rocky reef on eastern margin of Koombana Bay may be negatively impacted if further development occurred
6.4	Significant benthic communities and habitats: soft sediments	Decline in primary productivity (e.g. microphytobenthos or turf algae) of soft sediments due to increased turbidity and sediment disturbances
6.5	Significant benthic communities and habitats: sponge gardens	Sponges may be negatively impacted if there is a reduction in water quality, including turbidity and sedimentation
6.6	Significant benthic communities and habitats: mud flats	Decrease in biodiversity of mud flats due to degradation or removal of habitat
6.7	Significant benthic communities and habitats: artificial reefs	Decline of artificial reef habitat due to suspended sediments from dredging
6.7	Significant benthic communities and habitats: artificial reefs	Increased vessel traffic may deter fishes
6	**Significant benthic communities and habitats: Other**	**Degradation of other benthic communities due to increased development and altered environmental conditions**
7.1	Listed and significant fauna: fairy tern	Loss of shoreline habitat due to development and/or sea level rise
7.1	Listed and significant fauna: fairy tern	Bioaccumulation of contaminants through the food chain that would negatively affect survival and/or breeding success
7.1	**Listed and significant fauna: Fairy terns**	**Decline in abundance and breeding success of fairy terns due to impacts on habitat and prey species**
7.2	Listed and significant fauna: little penguins	Bioaccumulation of contaminants through the food chain that would negatively affect survival and/or breeding success
7.2	Listed and significant fauna: little penguins	Increase in deaths from collisions with increasing recreational boat traffic
7.2	**Listed and significant fauna: Little penguins**	**Decline in abundance and breeding success of little penguins due to a decline in foraging habitat and prey species, and increased collisions with recreational vessels**
7.3	Listed and significant fauna: bottlenose dolphins	Decrease in the high quality of prey items due to loss of prey biodiversity or contamination
7.3	Listed and significant fauna: bottlenose dolphins	Loss of habitat could negatively impact on resident dolphin populations
7.3	Listed and significant fauna: bottlenose dolphins	Increased entanglement in fishing gear with increased recreational use of Koombana Bay
7.3	Listed and significant fauna: bottlenose dolphins	Dolphin abundances and movement patterns for Bunbury area will be influenced by ENSO events under a changing climate
7.3	Listed and significant fauna: bottlenose dolphins	Increased tourism and feeding of dolphins could increase vessel strikes
7.3	Listed and significant fauna: bottlenose dolphins	Increase in underwater noise from development and construction could deter dolphins from their usual habitats and interrupt communications between dolphins
7.3	**Listed and significant fauna: Bottlenose dolphins**	**Decline in resident and other populations due to a decline in foraging habitat, prey species and anthropogenic influences i.e. boat strikes, fishing entanglements and underwater noise**
7.4	Listed and significant fauna: migratory seabirds and shorebirds	Bioaccumulation of contaminants through the food chain that would negatively affect survival and/or breeding success
7.4	Listed and significant fauna: migratory seabirds and shorebirds	Increased competition for food with invasive species
7.4	Listed and significant fauna: migratory seabirds and shorebirds	Loss, degradation, or complete removal of Preston River Delta could reduce the regional significance of the location
7.4	Listed and significant fauna: migratory seabirds and shorebirds	Increased coastal development could remove important habitat
7.4	**Listed and significant fauna: Migratory seabirds and shorebirds**	**Decline in abundance and breeding success due to impacts on habitat and prey species**
7.5	**Listed and significant fauna: pouched lamprey**	**Loss, degradation, or complete removal of Preston River Delta could reduce access to river and spawning opportunities in freshwater sources**
7.6	Listed and significant fauna: Carter's Freshwater Mussel	Reduction of water quality (e.g. contamination) of the Preston River could prevent re-establishment of mussel populations
7.6	Listed and significant fauna: Carter's Freshwater Mussel	Increased salinity of Preston River under a drying climate would impact the occurrence and distribution of mussels
7.6	**Listed and significant fauna: Carter's Freshwater Mussel**	**Further decline in abundance and occurrence of mussels due to reduced water quality (e.g. contamination) of the Preston River and environmental change**

Ref#	Value	Issue
8.1	**Regionally significant spawning / nursery area: King George whiting**	**Degradation to Leschenault Inlet habitat will negatively impact on important nursery area**
8.2	Regionally significant spawning / nursery area: Whitebait	An increase in marine heatwaves would negatively impact spawning
8.2	Regionally significant spawning / nursery area: Whitebait	A decrease in water quality due to increased development may cause a decrease in abundance
8.2	**Regionally significant spawning / nursery area: Whitebait**	**Loss of favourable spawning area due to changes in environmental conditions**
9.1	Regionally significant migratory pathway: Blue swimmer crab	Increasing temperatures may cause declines in abundance in the localised area of Koombana Bay/ Leschenault Estuary and Inlet
9.1	Regionally significant migratory pathway: Blue swimmer crab	Reduced water quality can stress crabs making them more prone to infections such as shell diseases
9.1	**Regionally significant migratory pathway: Blue swimmer crab**	**Decline in abundance and loss of nursery area due to environmental changes, reduced water quality and increased development**
10	Leschenault Regional Park	Increase stress on the estuary will increase the occurrence of algal blooms and fish kills
10	Leschenault Regional Park	Increase in salinity of the Estuary under a drying climate
10	Leschenault Regional Park	Increase in coastal erosion due to an increase in storm events
10	**Leschenault Regional Park**	**Degradation of park due effects of poor water quality and declining ecosystem function, as well as environmental change**
11	Coastal processes	Risk of inundation to the Leschenault Inlet with rising sea levels and flooding
11	Coastal processes	Risk of erosion and inundation to areas of Koombana Bay with rising sea levels and storms
11	**Coastal processes**	**Increased erosion and inundation of shorelines from rising sea levels, storms and changes to sediment transport**

Table 6: Synthesised “rolled” up issues (highlighted rows) for marine and estuarine social values of Bunbury.

Ref#	Value	Issue
1.1	**Heritage: Aboriginal**	**Loss or degradation of important heritage sites with increased development**
1.2	**Heritage: Maritime/historic**	**Loss or degradation of important historical sites with increased development**
2.1	**Public health: Recreational water quality**	**Increased safety concerns for primary and secondary contact with water due to decreased water quality**
2.2	**Public health: Seafood quality**	**Decrease in health of shellfish and fish with increased contamination in waters and sediments**
3.1	Social and community: Recreational fishing	Displacement of recreational fishing with port development
3.1	Social and community: Recreational fishing	Degradation of Leschenault Inlet with port development
3.1	**Social and community: Recreational fishing**	**Decrease in recreational fishing with increased development**
3.2	**Social and community: Recreational swimming**	**Degradation of swimming beaches due to increased development**
3.3	Social and community: Recreational water sports	Displacement of water sports with increased development
3.3	Social and community: Recreational water sports	Loss of shoreline infrastructure in Leschenault Inlet with a changing climate
3.3	**Social and community: Recreational water sports**	**Decrease in water sports with increased development and environmental change**
3.4	**Social and community: Recreational boating access**	**Flooding occurrences via storm water outfalls may impact on boat ramps in Leschenault Inlet**
3.5	**Social and community: Marina facilities**	**Reduced use of marina facilities with increased development**
3.6	**Social and community: Educational and scientific values**	**Degradation of mangrove habitat would impact educational experiences and value for scientific purposes**
3.7	Social and community: Landscape and visual amenity	Scenic boardwalk through mangrove habitat may lose scenic quality if habitat is degraded with increased development
3.7	Social and community: Landscape and visual amenity	Lack of visitation due to obstruction of expansive views of the ocean horizon with large vessels and/or building and structures
3.7	**Social and community: Landscape and visual amenity**	**Less visitation due to increased development negatively impacting on the landscape and visual amenity**
4.1	Business, industry and commercial: Tourism	Reduced wildlife tourism due to loss of marine life and habitat degradation
4.1	Business, industry and commercial: Tourism	Displacement of tourist activities with port development
4.1	Business, industry and commercial: Tourism	Increased erosion of Koombana Beach
4.1	**Business, industry and commercial: Tourism**	**Loss of tourism due to increased development, loss of marine life and environmental change**
4.2	**Business, industry and commercial: Commercial fisheries**	**Decrease in commercial fishing due to habitat loss and degradation with increased development, as well as environmental change**

Appendix 4

Table 1: Preliminary unmitigated and mitigated risk assessment for marine and estuarine environmental values in Fremantle.

Ref #	Issue	Current risk C	L	R	DC	Future unmitigated risk Activity	C	L	R	Justification	Future harbour development mitigated risk Mitigation	C	L	R	Justification
Environmental value: Integral functioning ecosystem															
1	Decrease in current ecosystem functioning within and around port footprint with increased use and development	2	4	M (8)	M-H	Harbour development	2	4	M (8)	Environment already highly modified and degraded from previous development and eutrophication in the estuary is an ongoing problem further upstream. Already a working port with vessel traffic so may not expect major declines in current ecosystem functioning if expansion happened. Climate change would change the functioning, but not necessarily cause a decrease if new species adapt to new conditions.	Use PIANC Working with Nature principles, as has already been done with past development in the port, to engineer port structures and niche habitats. Rehabilitate seagrass meadows that may be impacted by port development now to avoid a lag in ecosystem functioning.	2	2	L (4)	Rehabilitation of seagrass meadows is a slow process with may take several attempts. Adoption of PIANC principles may improve the system, not just maintain the current state. Niche habitats created need to be suitable for tropical species to inhabit *as well* in order to maintain a functioning, though different, ecosystem.
						Climate change	2	3	M (6)			2	3	M (6)	
						Other industrial and urban growth	2	4	M (8)			2	4	M (8)	
						Cumulative pressure	*2*	*4*	*M (8)*	*Environment already highly modified and degraded from previous development and eutrophication in the estuary is an ongoing problem further upstream. Currently has risks associated with a working port such as turbidity, contamination and oil spills.*		*2*	*4*	*M (8)*	*Uncertainty around climate change impacts. Unsure of the management strategies that other industries would put in place to mitigate against a decrease in ecosystem functioning. Highly urbanised and industrialised surroundings that will grow as the population grows.*
Environmental value: Biological diversity															
2	Decrease in species diversity due to reduction of suitable habitat, invasive species and altered environmental conditions	2	3	M (6)	M	Harbour development	4	3	H (12)	Invasive species from increased vessel traffic could outcompete native species, and there are already invasive species in the area. Port expansion could cause localised habitat loss, but mobile animals could move to other suitable areas if available. Fish species migrate seasonally between the Swan River and the Indian Ocean via the Inner Harbour. Many species spend all life cycle stages in the estuary and would have limited capacity to recover from disturbances. Already an operating port so expansion may not have a big impact. Only short lived marine biota occur in the anchorage area of Gage Roads due to continual disturbance from vessels and anchors, however increased vessel traffic may not allow enough time for some ephemeral species to survive long enough to reproduce. Removal or maintenance of artificial substrates within the inner harbour may temporarily reduce diversity of invertebrates i.e. barnacles and may temporarily reduce localised water quality due to decreased filtering capacity. Tropicalisation may not necessarily decrease biological diversity, as new species will be inhabiting the area and some current species may have time to gradually adapt.	Use PIANC working with nature principles to engineer ecological niche areas for valuable species. Ensure continuation of the State Wide Array Surveillance Program (SWASP) for marine pests and regular reporting (invasive species are monitored and managed by DPIRD under the Fisheries Act). Engineer walls of built structures to be native species friendly in order to reduce establishment of invasive.	3	2	M (6)	Risk of invasive species is still an issue, but early detection may help to localise any negative effects to species diversity.
						Climate change	2	3	M (6)			2	3	M (6)	
						Other industrial and urban growth	2	3	M (6)			2	3	M (6)	

Ref #	Issue	Current risk C	L	R	DC	Future unmitigated risk Activity	C	L	R	Justification	Future harbour development mitigated risk Mitigation	C	L	R	Justification
						Cumulative pressure	*4*	*4*	*H (16)*	*Invasive species could impact system wide functioning and cause declines or local extinctions of populations.*		*3*	*3*	*M (9)*	*Efforts to reduce invasive species would benefit the whole system. Would still have localised patches of habitat destroyed but may not necessarily cause a decline in biodiversity if another similar habitat is available.*
Environmental value: High level of water quality															
3	Decrease in quality of water due to increased development and altered environmental conditions	3	3	M (9)	M	Harbour development	3	3	M (9)	Port expansion and operation could increase nutrients and contaminants in the water column from run-off. Likely to be more resuspension of sediments with high nutrient and contaminant loading. Increased nutrients and warmer temperatures may cause toxic phytoplankton blooms in the lower reaches of estuary as well as potential dead zones due to increases oxygen consumption. Dredging and continual propeller wash would increase turbidity, though already a turbid environment and operating port. More vessels would increase the risk of oil and fuel spills. Increased nutrient levels discharged into the Inner Harbour and surrounds from groundwater. Increased circulation of the Swan Estuary (lower reaches) and migration of higher salinity concentrations upstream with deeper dredge channel. Salinity patterns in the Swan and inner harbour are also likely to be impacted by reduced rainfall under a drying climate. Climate change may also increase the incidence of flooding and increase acidification of the water. Increased incidence of flooding will increase discharges of fresher and turbid water plumes from the Swan Canning catchment.	Better management of groundwater, storm water and run off to reduce nutrients. Additional dredge management options should be considered e.g. timing around high flushing periods. Dredge without overflow and discharge sediments safely. Design port to minimise vessel movement i.e. less turning and manoeuvring which would limit disturbance to sediments. Check maintenance records of vessels before port entry to reduce risk of oil spill and have first strike response kits in place to respond to level 2/3 oil spills as a minimum. Increase vigilance with management of fuel transfers. Engineer structures to prevent coastal erosion or salt wedge migration if hydrology is changed from deeper shipping channel.	2	2	L (4)	There would still be increased turbidity in the footprint of port from operations. Dredging plumes would still occur but sediments may not spread as far. If oil spills are responded to immediately, then impacts could remain localised. Use of chemicals and paints on vessels is regulated by Australian and international standards.
						Climate change	4	3	H (12)			4	3	H (12)	
						Other industrial and urban growth	3	3	M (9)			3	3	M (9)	
						Cumulative pressure	*4*	*3*	*H (12)*	*Already an impacted environment but does not mean increased use of the area would have negligible impacts. Industrial and urban growth will likely put more pressure on the estuary, which could flow downstream.*		*4*	*3*	*H (12)*	*Industrial and urban growth will still continue to grow and put more pressure on the system unless groundwater and any industrial outflows can be heavily regulated. Industrial and urban growth will likely put more pressure on the estuary, which could flow downstream. Climate change is an external driver.*

Ref #	Issue	Current risk C	L	R	DC	Future unmitigated risk Activity	C	L	R	Justification	Future harbour development mitigated risk Mitigation	C	L	R	Justification
Environmental value: High level of sediment quality															
4	Decrease in quality of sediments due to increased development	3	4	H (12)	M-H	Harbour development	3	3	M (9)	Likely increase in contamination of sediments with increased shipping and port operations. Port would facilitate cargo and container shipping rather than mineral exports, so load spills unlikely. There is a risk of exposing acid sulphate soils during development as Swan River and Inner Harbour have potential acid sulphate soils. Has not been exposed with previous development. Other industrial and urban growth likely to have more impact on sediment quality further upstream rather than in the Inner Harbour or coast.	Remove contaminated sediments created from port operations. Test for potential acid sulphate soils before developing port infrastructure.	2	2	L (4)	Use of chemicals and paints on vessels is regulated by Australian and international standards, so not a mitigation measure Westport can use. However, removal of contaminated sediments would help improve sediment quality.
						Climate change									
						Other industrial and urban growth	2	2	L (4)			2	2	L (4)	
						Cumulative pressure	*3*	*4*	*H (12)*	*Currently localised areas of contaminated sediments- such as in the Inner Harbour, and likely to increase with increasing operations.*		*2*	*2*	*L (4)*	*Some areas that have contaminated sediments are in proposed port footprint so could be removed during development.*
Environmental value: Significant benthic communities and habitats- Seagrass															
5.1	Reduction in seagrass biomass and extent due to increased development and altered environmental conditions	2	3	M (6)	M	Westport related development	3	3	M (9)	Seagrass meadows occur directly to the north, south and further west of the port entrance, as well as in the estuary, and dredging and increased turbidity from vessel use may impact meadows. No significant declines in seagrass from dredging in 2010 were recorded. More area for sediments to disperse out of the inner harbour entrance. Already an area of high vessel traffic. Increased incidence of marine heatwaves may cause decrease in seagrass biomass which occurred in Shark Bay. Other industrial and urban growth likely to have more impact on seagrass quality further upstream rather than in the Inner Harbour or coast.	Manage dredging operations for tidal movements and water circulation. If conditions allow, use a silt screen during dredging. Additional dredge management options should be considered to protect benthic producers e.g. avoid winter when seagrass most vulnerable to low light. Avoid removal of seagrass meadows or rehabilitate new areas for seagrass colonisation now to prevent a lag effect in ecosystem functioning. Design port to minimise vessel movement i.e. less turning and manoeuvring which would limit disturbance to sediments.	2	2	L (4)	Current port operations have not wiped out all the meadows occurring in the vicinity of the port, so by mitigating against potential impacts, the risk would be low.
						Climate change	4	4	H (16)			4	4	H (16)	
						Other industrial and urban growth	2	2	L (4)			2	2	L (4)	
						Cumulative pressure	*4*	*4*	*H (16)*	*Climate change likely to have the greatest future impact on seagrass meadows off coast.*		*4*	*4*	*H (16)*	*Climate change impacts are external drivers.*

Ref #	Issue	Current risk C	L	R	DC	Future unmitigated risk Activity	C	L	R	Justification	Future harbour development mitigated risk Mitigation	C	L	R	Justification
Environmental value: Significant benthic communities and habitats- Other															
5.1 5.2 5.3	Degradation of other benthic communities due to increased development	2	2	L (4)	M	Harbour development	3	3	M (9)	Degradation of Hall Bank coral community could occur with spread of suspended sediments from dredging, though this did not occur with 2010 dredging. Minden Reef already subject to a high sediment regime with a lot of abiotic materials being deposited on the reef i.e. sand, silt, rock, wreckage. Loss of macroalgae habitats could occur with port expansion as macroalgae is found on limestone pavement outcrops in the Deep Water Channel. Macroalgae can re-establish relatively quickly. Human disturbance may have some impact of reefs, but they are less frequently visited compared to other reefs i.e. Rottnest.	Design port to minimise vessel movement i.e. less turning and manoeuvring which would limit disturbance to sediments. Manage dredge plume for tidal movements and water circulation. Periodically clean Minden Reef of abiotic materials associated with port operations.	2	2	L (4)	Impacts minimised for currents habitats, which also occur up and down the coast.
						Climate change									
						Other industrial and urban growth	2	2	L (4)			2	2	L (4)	
						Cumulative pressure	*3*	*3*	*M (9)*	*Limited information to assess climate change impacts.*		*2*	*2*	*L (4)*	*Limited information to assess climate change impacts.*
Environmental value: Listed and significant fauna- Fairy terns															
6.1	Decline in abundance and breeding success of fairy terns due to impacts on habitat and prey species	2	3	M (6)	M	Harbour development	3	3	M (9)	Loss of shoreline habitat due to development and/or sea level rise. Successful breeding colony at Rous Head. Port expansion not likely to remove more coastline. Lack of nesting sites would impact the population. Bioaccumulation of contaminants through the food chain could negatively affect survival and/or breeding success. TBT is being reduced, though there is potential for other contaminants to impact populations. Port operations my increase contaminants in the water and sediments, though terns may be less likely to ingest contaminated fish given the open coastline. Other industrial and urban growth may disturb nesting sites. Very built up coastline already. Urban growth would increase risk of entanglement in fishing gear and rubbish. Rising sea temperatures would influence distribution of prey.	Use PIANC Working with Nature principles to incorporate protected bird friendly areas for current and future use. Areas of contaminated sediments could be removed and contamination of the water column heavily regulated to reduce bioaccumulation.	2	2	L (4)	Less chance of ingesting contaminated prey due to open coast and sediment removal.
						Climate change	4	3	H (12)			4	3	H (12)	
						Other industrial and urban growth	2	3	M (6)			2	3	M (6)	
						Cumulative pressure	*4*	*3*	*H (12)*	*Listed as vulnerable under EPBC. Feral predators also pose a risk to fairy tern abundance. Any impacts to nesting sites would have an influence on the overall population- i.e. mating opportunities.*		*4*	*3*	*H (12)*	*Sea level rise is still a major risk to nesting sites and is an external driver.*

Ref #	Issue	Current risk C	L	R	DC	Future unmitigated risk Activity	C	L	R	Justification	Future harbour development mitigated risk Mitigation	C	L	R	Justification
Environmental value: Listed and significant fauna- Bottlenose dolphins															
6.2	Decline in resident and other populations due to a decline in foraging habitat, prey species and anthropogenic influences i.e. boat strikes, fishing entanglements and underwater noise	3	3	M (9)	M-H	Harbour development	4	3	H (12)	Increase in underwater noise from development and construction could deter dolphins from their usual habitats and interrupt communications between dolphins. Noises can be short lived or intermittent. The inner harbour has been identified as a seasonal hotspot that is strongly linked with foraging behaviour and this would be at risk with port expansion. Deepening of the channel and increased vessel use may impact in these hotspots. Bioaccumulation of contaminants through the food chain may negatively affect survival and/or breeding success as dolphins that died in the Swan-Canning in 2009 were found to have organic contaminants in their blubber. Death was not definitely attributed to contaminants. Boat strikes and entanglement in fishing gear has been noted for nearby regions and is likely to occur with urban growth. The genetic flow is asymmetric with flow from Owen Anchorage (the source) to the Swan Canning Riverpark. Connection through the inner harbour is critical for the survival of the community in the Swan Canning Riverpark.	Use PIANC Working with Nature principles to create niche areas for dolphins to forage and design structures that would reduce the loss of foraging habitat in the Inner Harbour. Avoid conducting noisy dredging operations and port maintenance (i.e. pile driving) during the breeding season when animals are socialising and calving. Engage Marine Mammal Observers to observe the occurrence of dolphins during the time development is occurring.	2	3	M (6)	If suitable foraging habitat is still available, then underwater noise would be the concerning impact, which would not be a constant pressure and one that dolphins can avoid temporarily.
						Climate change	4	3	H (12)			4	3	H (12)	
						Other industrial and urban growth	3	3	M (9)			3	3	M (9)	
						Cumulative pressure	*4*	*3*	*H (12)*	*Accumulated pressures may cause dolphins to limit transitions/access between Swan Canning Riverpark and adjacent waters, more so than cause direct death to dolphins, and would impact the value being present in Swan Canning Riverpark*		*4*	*3*	*H (12)*	*Still issues with illegal feeding and vessel strikes which would likely increase with urban growth. Climate change impacts on prey species is an external driver.*
Environmental value: Listed and significant fauna- whales															
6.3	Decrease in humpback whale occurrence due to port operations	1	1	L (2)	M	Harbour development	3	3	M (9)	Humpback females and calves are often seen resting in the waters between Rottnest and the Fremantle coast from Sep-Nov during their southerly migration. Increased vessel traffic and dredging could deter whales or increase vessel strikes. Noise from dredging could also deter whales or interrupt communications.	Avoid noisy dredging operations during time of migration off Fremantle. Limit the spread of vessel movements entering and leaving the port.	2	2	L (4)	Noise and vessel strike risks reduced.
						Climate change									
						Other industrial and urban growth	2	2	L (4)			2	2	L (4)	
						Cumulative pressure	*3*	*3*	*M (9)*	*Migration occurs every year and impacts are more likely to affect calves.*		*2*	*2*	*L (4)*	*Risks reduced overall.*

Ref #	Issue	Current risk C	L	R	DC	Future unmitigated risk Activity	C	L	R	Justification	Future harbour development mitigated risk Mitigation	C	L	R	Justification
Environmental value: Listed and significant fauna- migratory shorebirds and seabirds															
6.4	Decline in abundance and breeding success due to impacts on habitat and prey species	2	2	L (4)	L	Harbour development	3	3	M (9)	Sea level rise could inundate important shoreline habitat. Increased coastal development could remove important habitat, though areas around port are heavily developed already. Port expansion not likely to remove additional sections of coastline. Bioaccumulation of contaminants through the food chain could negatively affect survival and/or breeding success, though an open coast reduces risk of ingesting contaminate prey. Birds largely nesting on nearby islands. There would be localised loses of suitable habitat but this may flow on to impact the population as a whole if other suitable habitat is not available. Rising sea temperatures would influence distribution of prey. Urban growth would increase risk of entanglement in fishing gear and rubbish.	Use PIANC Working with Nature principles to create niche areas for birds to forage and incorporate coastal stretches for birds to nest and move up shore as sea level rises. Areas of contaminated sediments could be removed to reduce risk of bioaccumulation.	2	2	L (4)	Port operations may still cause some temporary or prolonged disturbance to birds using niche areas.
						Climate change	4	3	H (12)			4	3	H (12)	
						Other industrial and urban growth	3	3	M (9)			3	3	M (9)	
						Cumulative pressure	*4*	*4*	*H (16)*	*Coastal development and human disturbance may impact on birds using coastal areas. Popular sites for seabirds and shorebirds include surrounding islands, but it is unknown if stretches of mainland coastline in vicinity of port are also significant. Migratory birds frequent the same or similar locations year after year due to reliable conditions, so any impacts to known forging or nesting sites may have greater implications for migration.*		*4*	*3*	*H (12)*	*Climate change is an external driver and other coastal development and human disturbance may impact on birds using coastal areas.*
Environmental value: Regionally significant spawning / nursery area															
7	Fish species that spend their whole life cycles in the estuary (i.e. yellowtail flathead, black bream) may be negatively impacted by habitat degradation and environmental changes	2	3	M (6)	M	Harbour development	3	3	M (9)	Discrete self-replenishing stocks will have limited capacity to recover if stocks are depleted. Already an operating port and species still occurring, but there may be some risk of impacting populations occurring in the estuary if port expansion impacts water quality. Deepening the channel may further saline waters upstream and impact some fish species, as would a drying climate. Impacts from other urban and industrial growth more likely upstream of port.	Use PIANC Working with Nature principles to create fish friendly habitat. Manage dredge plume for tidal movements and water circulation. Install a silt screen.	2	2	L (4)	
						Climate change	4	3	H (12)			4	3	H (12)	
						Other industrial and urban growth	2	2	L (4)			2	2	L (4)	
						Cumulative pressure	*4*	*4*	*H (16)*	*Estuary currently under stress from eutrophication which would have some impact on fish populations. Fish not directly occurring in the port area, but there could be impacts that flow upstream.*		*4*	*3*	*H (12)*	*Climate change an external driver.*

Ref #	Issue	Current risk C	L	R	DC	Future unmitigated risk Activity	C	L	R	Justification	Future harbour development mitigated risk Mitigation	C	L	R	Justification
Environmental value: Regionally significant migratory pathways															
8	Negative impacts from increased development to fish and invertebrate species that migrate to and from estuary and oceanic waters to complete their lifecycle	2	3	M (6)	M	Harbour development	3	3	M (9)	Suspended sediments and noise from dredging and vessels may impact on larval recruitment and adult migration between the open coast and the Estuary, as well as spawning in coastal waters. Increasing salinity from lower rainfall may impact on the distribution of fish throughout the estuary. Habitat degradation from port operations may reduce abundances of some species in the lower reaches of the estuary. Impacts from other urban and industrial growth more likely upstream of port.	Time dredging operations to avoid peak recruitment, migration and spawning periods. Install a silt screen to limit spread of sediments. Design port to minimise vessel movement i.e. less turning and manoeuvring which would limit disturbance to sediments.	2	2	L (4)	Already an operating port and fish are currently moving between environments, so efforts to mitigate impacts with increased port use would probably be considered a low risk.
						Climate change	4	3	H (12)			4	3	H (12)	
						Other industrial and urban growth	2	2	L (4)			2	2	L (4)	
						Cumulative pressure	*4*	*3*	*H (12)*	*Many different species to consider and each would have different tolerances to impacts. Already an operating port and fish are currently moving between environments.*		*4*	*3*	*H (12)*	*Climate change an external driver.*
Environmental value: Swan Estuary Marine Park															
9	Degradation of marine park through upstream flow on effects of increased development and environmental change	2	3	M (6)	M	Harbour development	3	3	M (9)	Port operates right in the mouth of the estuary but has been doing so for a long time. Environment already highly modified from previous development of the inner harbour and deepening the channel may cause more saline waters to move further upstream. Eutrophication in the estuary is an ongoing problem that has largely stemmed from upstream impacts. Impacts from other urban and industrial growth more likely upstream of port. Reduced rainfall will increase salinity in the estuary.	Use PIANC Working with Nature principles to create niche habitats that will benefit species using the marine park. Manage dredge plume for tidal movements and water circulation. Install a silt screen. Have first strike response kits in place to respond to level 2/3 oil spills as a minimum.	2	2	L (4)	Marine Park not in immediate vicinity of port, so mitigation measures is probably enough to reduce the risk that the port may specifically have.
						Climate change	4	3	H (12)			4	3	H (12)	
						Other industrial and urban growth	2	2	L (4)			2	2	L (4)	
						Cumulative pressure	*4*	*3*	*H (12)*	*Climate change and upstream impacts likely pose most risk to the Marine Park.*		*4*	*3*	*H (12)*	*Climate change an external driver*
Environmental value: Coastal processes															
10	Increased erosion and inundation of shorelines from rising sea levels, storms and changes to sediment transport	3	3	M (9)	M-H	Harbour development	3	3	M (9)	Depending of channel may cause some changes to sediment transport. Inundation and erosion of coastal use areas (e.g. South Mole, Bathers Beach) is likely due to sea level rise. Inundation of foreshores of Swan Estuary due to coastal flooding. Insufficient setback of infrastructure along the foreshores of the estuary and inundation from coastal flooding is a risk. Fremantle Port expected to be impacted by erosion at Port Beach in the medium term. Port Beach listed as 'extreme' risk for erosion.	Use PIANC Working with Nature principles to engineer long lasting solutions for coastal erosion if shipping channel has a significant impact on sediment transport.	2	2	L (4)	Reducing sediment transport would help to reduce erosion.
						Climate change	3	4	H (12)			3	4	H (12)	
						Other industrial and urban growth									
						Cumulative pressure	*3*	*4*	*H (12)*	*Coastal erosion and inundation already affecting localised areas.*		*3*	*4*	*H (12)*	*Climate change an external drivers.*

Table 2: Preliminary unmitigated and mitigated risk assessment for marine and estuarine social values in Fremantle.

Ref #	Issue	Current risk C	L	R	DC	Future unmitigated risk Activity	C	L	R	Justification	Future harbour development mitigated risk Mitigation	C	L	R	Justification
Social value: Heritage- Aboriginal															
1.1	Loss or degradation of important heritage sites with increased development	1	2	L (2)	H	Harbour development	2	3	M (6)	Valued sites occur adjacent to port footprint. The Swan River is a registered mythological site and the health of the river may be impacted on with increased use and development. However, the Swan River is already an impacted system from past port construction. Sea level rise could inundate or erode some popular gathering areas.	Remove contaminated sediments associated with port operation. Dredge without overflow and discharge sediments safely. Use a silt screen if conditions permit and time dredging operations to avoid spread of sediments upstream as much as possible. Design port to minimise vessel movement i.e. less turning and manoeuvring which would limit disturbance to sediments.	2	2	L (4)	Important sites can still be enjoyed.
						Climate change	3	3	M (9)			3	3	M (9)	
						Other industrial and urban growth	2	2	L (4)			2	2	L (4)	
						Cumulative pressure	*3*	*3*	*M (9)*	*Already a heavily developed region.*		*3*	*3*	*M (9)*	*Upstream impacts could degrade the health of the Swan River and Estuary. Climate change an external driver.*
Social value: Heritage- Maritime/historic															
1.2	Loss or degradation of important historical sites with increased development	1	2	L (2)	H	Harbour development	2	2	L (4)	No registered sites occur directly in expanded port footprint, but they do occur in the vicinity.	No mitigation.	2	2	L (4)	
						Climate change	2	2	L (4)			2	2	L (4)	
						Other industrial and urban growth	2	2	L (4)			2	2	L (4)	
						Cumulative pressure	*2*	*2*	*L (4)*	*Already a heavily developed region and further development unlikely to have a significant impact on registered sites.*		*2*	*2*	*L (4)*	

Ref #	Issue	Current risk C	L	R	DC	Future unmitigated risk Activity	C	L	R	Justification	Future harbour development mitigated risk Mitigation	C	L	R	Justification
Social value: Public health- Recreational water quality															
2.1	Increased safety concerns for primary and secondary contact with water due to decreased water quality	2	2	L (2)	M	Harbour development	2	3	M (6)	Recreational water quality expected to remain safe due to mixing with oceanic waters and dispersal of any contaminants etc. Poor water quality extending upstream of port may impact on recreational water use and swimming off river beaches. Based on bacteria monitoring, South Beach, Bathers Beach, Port Beach and Leighton Beach are considered safe for swimming most of the time. Other industrial and urban growth more likely to impact on water quality further upstream.	Remove contaminated sediments associated with port operation. Dredge without overflow and discharge sediments safely. Time dredging operations with water circulation to avoid spread of sediments. Use a silt screen if conditions permit. Design port to minimise vessel movement i.e. less turning and manoeuvring which would limit disturbance to sediments. Monitor water quality regularly to detect any health concerns.	2	2	L (4)	Still may be temporary occurrences of reduced water quality that causes concern for contact with water, but likely not prolonged.
						Climate change									
						Other industrial and urban growth	2	2	L (4)			2	2	L (4)	
						Cumulative pressure	*2*	*3*	*M (6)*	*Perceptions of water quality would change with each person. The Estuary and coastal areas are popular recreational areas which have been occurring alongside a major operating port.*		*2*	*2*	*L (4)*	*Unlikely that recreational water use will become unsafe for public health.*
Social value: Public health- Seafood quality															
2.2	Decrease in health of shellfish and fish with increased contamination in waters and sediments	2	3	M (6)	M	Harbour development	3	3	M (9)	Eating shellfish is not recommended outside of commercial harvesting. Fish such as black bream already have very low levels of contaminants and over time this may continue to accumulate to unsafe levels if contaminant levels are increased. Decrease in seafood quality would impact on favourite past times and social gatherings. Contamination may increase with port construction and operation, though contaminants may disperse and dilute with exchange with oceanic waters. Would reduce recreational and commercial fishing as well as aquaculture if contamination levels exceeded guidelines. May cause death and wash up of marine life. Seafood quality more likely to be affected upstream rather than in coastal waters. Other industrial and urban growth more likely to impact on seafood quality further upstream, though these effects may flow downstream.	Remove contaminated sediments associated with port operation. Dredge without overflow and discharge sediments safely. Design port to minimise vessel movement i.e. less turning and manoeuvring which would limit disturbance to sediments. Monitor water quality regularly to detect any health concerns.	2	2	L (4)	Use of chemicals and paints on vessels is regulated by Australian and international standards.
						Climate change									
						Other industrial and urban growth	3	3	M (9)			3	3	M (9)	
						Cumulative pressure	*3*	*3*	*M (9)*	*Already an operating port. Contaminants already found in some species.*		*3*	*3*	*M (9)*	*Industrial and urban growth could contribute to poor water quality over time.*

Ref #	Issue	Current risk C	L	R	DC	Future unmitigated risk Activity	C	L	R	Justification	Future harbour development mitigated risk Mitigation	C	L	R	Justification
Social value: Social and community: Recreational fishing															
3.1	Decrease in recreational fishing due to restrictions around port area and the loss of popular fished species due to impacts to migration pathway	3	3	M (9)	M-H	Harbour development	4	3	M (9)	Reduction or loss of popular fished species in the estuary due to interruptions in migration/recruitment into/out of the estuary during dredging campaigns. Depends on timing of dredging. Only one entry/exit point for fish exchanging between the ocean and estuary. Fishing important to many people in the estuary. Port expansion may cause temporary exclusion zones due to safety reasons and will impact on fishing popular species in the inner harbour (i.e. mackerel, squid, snapper, tailor), as well as at South Mole, North Mole, Rous Head and north and south of the entrance. Rising sea temperatures may cause shifts in fish distributions. Other industrial and urban growth more likely to impact on fishing further upstream, though these effects may flow downstream.	Use PIANC Working with Nature principles to engineer ecological niche areas for valuable species, as well as fisher friendly structures. Avoid dredging during spawning and migrations periods as well as peak fishing periods around the Inner Harbour. Rehabilitate seagrass meadows now to avoid a lag in ecosystem functioning, if port is predicted to impact on coastal meadows.	2	2	L (4)	PIANC principles may help to improve recreational fishing in Fremantle and surrounds.
						Climate change	4	3	H (12)			4	3	H (12)	
						Other industrial and urban growth	3	3	M (9)			3	3	M (9)	
						Cumulative pressure	*4*	*4*	*H (16)*	*Recreational fishing is a strong social value in the region. Current risks to recreational fishing likely higher in the Estuary than along the coastline.*		*4*	*3*	*H (12)*	*Climate change an external driver. Industrial and urban growth could contribute to poor water quality over time.*
Social value: Social and community: Recreational swimming															
3.2	Increased turbidity at popular swimming beaches from dredge plumes	2	2	L (4)	M	Harbour development	3	3	M (9)	No swimming beaches will be directly removed in proposed port expansion footprint, though some impacts may still occur to prevent swimming i.e. turbidity. People would likely avoid swimming due to aesthetics of turbid water, or perceived low health and safety. Would be temporary. After dredging of the port and channels in 2010, water clarity was affected at Preston Point beach, Bathers Beach, Fremantle SLSC and Port Beach. Sea level rise and erosion could impact access points for beaches that are used for swimming.	Time dredging operations with water circulation to avoid spread of sediments. Use a silt screen if conditions permit. Design port to minimise vessel movement i.e. less turning and manoeuvring which would limit disturbance to sediments.	2	2	L (4)	Beaches are not directly removed so mitigating for good water quality is all that is needed.
						Climate change	2	3	M (6)			2	3	M (6)	
						Other industrial and urban growth	2	2	L (4)			2	2	L (4)	
						Cumulative pressure	*3*	*3*	*M (9)*	*Swimming currently considered safe for beaches along coasts and in the river, and there are multiple beaches to access for the purposes of swimming.*		*2*	*3*	*M (6)*	*Climate change an external driver. Unknown impacts of other industrial and urban growth.*

Ref #	Issue	Current risk C	L	R	DC	Future unmitigated risk Activity	C	L	R	Justification	Future harbour development mitigated risk Mitigation	C	L	R	Justification
Social value: Social and community: Recreational boating access															
3.3	Delays in passage through entrance channel during dredging/expansion works	1	2	Low (3)	M	Harbour development	2	3	M (6)	Entry/exit may be restricted to a narrow band during dredging and cause a bottleneck of recreational vessels during high peak times. Only temporary.	Avoid dredging operations during peak boating periods, i.e. summer, and give notice to boat users about the potential time delays in passage through Inner Harbour.	2	2	L (4)	Will not cause a loss of the value.
						Climate change	2	2	L (4)			2	2	L (4)	
						Other industrial and urban growth	2	2	L (4)			2	2	L (4)	
						Cumulative pressure	*2*	*3*	*M (6)*	*Climate change have impacts for boat ramps further upstream, but not in area considered for port footprint.*		*2*	*2*	*L (4)*	*Will not cause a loss of the value.*
Social value: Social and community: Marina facilities															
3.4	Reduced use of marina facilities with increased development	1	2	L (2)	M	Harbour development	2	3	M (6)	Increased water turbidity at marinas may occur due to dredging and increased vessel use and may be perceived as a reduction in quality. Depends on water flow and timing of dredging. Port expansion footprint does not remove any marina facilities. Sea level rise and erosion may impact on some marine facilities.	Time dredging operations with water circulation to avoid spread of sediments. Use a silt screen if conditions permit. Design port to minimise vessel movement i.e. less turning and manoeuvring which would limit disturbance to sediments.	2	2	L (4)	Still may be temporary impacts to perceived quality of marina- i.e. increased turbidity.
						Climate change	3	3	M (9)			3	3	M (9)	
						Other industrial and urban growth	2	2	L (4)			2	2	L (4)	
						Cumulative pressure	*3*	*3*	*M (9)*	*Marinas likely to be upgraded over time rather than removed due to other further development. Climate change likely biggest threat if there is insufficient set back of coastal structures or lack of protection from erosion and sea level rise.*		*3*	*3*	*M (9)*	*Climate change an external driver.*
Social value: Social and community: Educational and scientific values															
3.5	Decline in educational experiences due to degradation of estuarine habitats with increased use of the development in inner harbour.	1	2	L (2)	M	Harbour development	3	3	M (9)	Habitat either side of the inner harbour may degrade over time with increased development if not managed sufficiently. May impact participation in citizen science activities occurring in the estuary. May degrade reference sites for scientific studies. May deter educational groups visiting parts of the estuary. Other industrial and urban growth more likely to impact on value further upstream, though these effects may flow downstream.	Adopt PIANC Working with Nature principles maintain a functioning ecosystem.	2	2	L (4)	PIANC principles may help to improve the functioning of the ecosystem not just maintain it.
						Climate change	2	2	L (4)			2	2	L (4)	
						Other industrial and urban growth	2	2	L (4)			2	2	L (4)	
						Cumulative pressure	*3*	*3*	*M (9)*	*Already a heavily developed area and value is still important and ongoing. Climate change won't necessarily cause a decline in experiences.*		*2*	*2*	*L (4)*	

Ref #	Issue	Current risk C	L	R	DC	Future unmitigated risk Activity	C	L	R	Justification	Future harbour development mitigated risk Mitigation	C	L	R	Justification
Social value: Social and community: Landscape and visual amenity															
3.6	Less visitation due to increased development negatively impacting on the landscape and visual amenity	2	2	L (4)	M	Harbour development	2	3	M (9)	Less scenic enjoyment due to sightings of dredge plumes and increased vessel traffic. Only temporary, however may leave a negative impression on tourists and cruise ships entering the harbour. Erosion at Bathers Beach and Arthurs Head would reduce visual amenity and enjoyment of the landscape. Bathers Beach is popular with locals and tourists due to the range of amenities available right near the beach.	Manage dredging with water circulation to reduce spread of plumes. Use a silt curtain if allowable. Avoid dredging during peak tourism periods.	2	2	L (4)	Still may displace some users who think Fremantle is too industrialised.
						Climate change	4	3	H (12)			4	3	H (12)	
						Other industrial and urban growth	2	2	L (4)			2	2	L (4)	
						Cumulative pressure	*4*	*3*	*H (12)*	*Attractions of Fremantle will vary per person. Port already operating and obvious in the landscape.*		*4*	*3*	*H (12)*	*Climate change an external driver. Unknown impacts of other industrial and urban growth.*
Social value: Business, industry and commercial: Tourism															
4.1	Loss of tourism due to increased development, loss of marine life and environmental change	2	2	L (4)	M	Harbour development	2	3	M (6)	Reduced aesthetic quality during dredging campaigns/expansion works for passengers on cruise ships entering the port. Less scenic enjoyment due to sightings of dredge plumes and increased vessel traffic. Only temporary, however may leave a negative impression on tourists and cruise ships entering the harbour. Erosion at Bathers Beach and Arthurs Head would reduce visual amenity and enjoyment of the landscape. Bathers Beach is popular with locals and tourists due to the range of amenities available right near the beach. Other industrial and urban growth could contribute to poor water quality and habitat degradation further upstream but could also attract more tourists due to increased facilities.	Adopt PIANC Working with Nature principles to maintain a functioning ecosystem. Manage dredging with water circulation to reduce spread of plumes. Use a silt curtain if allowable. Avoid dredging during peak tourism periods.	2	2	L (4)	Visual amenity may also contribute to customer satisfaction.
						Climate change	4	3	H (12)			4	3	H (12)	
						Other industrial and urban growth	2	2	L (4)			2	2	L (4)	
						Cumulative pressure	*4*	*3*	*H (12)*	*Tourism is a major economic driver for Fremantle, and the port footprint occurs right in the hub of popular activities for tourists. Although, it is already an operating port and Fremantle is also popular for its maritime attractions.*		*4*	*3*	*H (12)*	*Climate change an external driver.*

Ref #	Issue	Current risk C	L	R	DC	Future unmitigated risk Activity	C	L	R	Justification	Future harbour development mitigated risk Mitigation	C	L	R	Justification
Social value: Business, industry and commercial: Commercial fisheries															
4.2	Decrease in commercial catches due to interruption to migration/recruitment of fishes through the entrance channel during dredging/expansion works	2	3	M (6)	M	Harbour development	4	3	H (12)	Commercial fisheries are not operating heavily in the port, Deep Water Channel or Gage Roads, however commercially fished species do use the harbour and estuary during their life cycles, which may be impacted upon with port expansion. Seagrass meadows may be impacted by increased turbidity from dredging and vessel use. Other industrial and urban growth could contribute to poor water quality and habitat degradation further upstream. Climate change would influence the distributions of fished species.	Use PIANC Working with Nature principles to engineer ecological niche areas for valuable species, as well as fisher friendly structures. Avoid dredging during spawning and migration periods. Rehabilitate seagrass meadows now to avoid a lag in ecosystem functioning, if port is predicted to impact on coastal meadows.	2	2	L (4)	PIANC principles may increase the abundance of fished species.
						Climate change	4	3	H (12)			4	3	H (12)	
						Other industrial and urban growth	3	3	M (9)			3	3	M (9)	
						Cumulative pressure	*4*	*4*	*H (16)*	*Fisheries operating in the region would rely on a healthy estuarine environment and coastal environment i.e. seagrass meadows.*		*4*	*3*	*H (12)*	*Climate change an external driver. Unknown impacts of other industrial and urban growth.*
Social value: Business, industry and commercial: Aquaculture															
4.3	Reduced water quality of the Inner Harbour would impact on intake water for aquaculture operations	2	2	L (4)	M	Harbour development	3	3	M (9)	Australian Centre for Applied Aquaculture Research uses water from the Inner Harbour. Expansion of the port may reduce water quality and it could become costly to treat or filter intake water to use for aquaculture tanks. Already an operating port.	Avoid dredging during aquaculture water intake operations. Design port to minimise vessel movements and reduce turbidity. Remove contaminated sediments.	2	2	L (4)	Mitigation would maintain current water quality used for intake.
						Climate change	2	2	L (4)			2	2	L (4)	
						Other industrial and urban growth	2	2	L (4)			2	2	L (4)	
						Cumulative pressure	*3*	*3*	*M (9)*	*The ACAAR has supported projects such as restocking of prawns in the Swan Estuary. The research sector of ACAAR is recognised nationally and internationally.*		*2*	*2*	*L (4)*	*Port expansion likely has the biggest impact on intake water, compared to other activities.*

Table 3: Preliminary unmitigated and mitigated risk assessment for marine and estuarine environmental values in Kwinana.

Ref #	Issue	Current risk C	L	R	DC	Future unmitigated risk Activity	C	L	R	Justification	Future harbour development mitigated risk Mitigation	C	L	R	Justification
Environmental value: Integral functioning ecosystem															
1	Decrease in ecosystem functioning with increased use and development in Cockburn Sound	3	4	H (12)	M	Harbour development	3	4	H (12)	Region has improved over time but has not fully recovered from significant impacts on ecosystem functioning. Localised losses of ecosystem functioning are currently occurring. Port construction would reduce available habitat for marine life e.g. Kwinana Shelf, and proposed channel would remove seagrass. Water quality may deteriorate with increased use of CS. Climate change would change the functioning, but not necessarily cause a *decrease* if new species adapt to new conditions.	Use PIANC Working with Nature principles to engineer port structures and niche habitats. Rehabilitate seagrass meadows now before development occurs to avoid a lag in ecosystem functioning.	2	4	M (8)	Rehabilitation of seagrass meadows is a slow process with may take several attempts. Adoption of PIANC principles may improve the system, not just maintain the current state. Niche habitats created need to be suitable for tropical species to inhabit *as well* in order to maintain a functioning, though different, ecosystem.
						Climate change	2	3	M (6)			2	3	M (6)	
						Other industrial and urban growth	3	4	H (12)			3	4	H (12)	
						Cumulative pressure	*4*	*4*	*H (16)*	*The 2018 DPSIR report states "[CS] will be characterised by overlapping residential, commercial and industrial development footprints leading to cumulative impacts and further declines in abundance and diversity of key biota, if not appropriately considered and managed".*		*3*	*4*	*H (12)*	*Uncertainty around climate change impacts. Unsure of the management strategies that other industries would put in place to mitigate against a decrease in ecosystem functioning. Still nutrient enrichment, seagrass loss and low DO occurring for some parts of CS.*
Environmental value: Sheltered marine ecological community															
2	Alteration to the sheltered nature of Cockburn Sound where dredge channels and built structures may impact on calm waters	1	1	L (1)	M	Harbour development	3	3	M (9)	No modifications to Garden Island Causeway, however new dredge channels may significantly impact on circulation in some parts of the Sound. Built structures may impact circulation on a localised scale, potentially causing stagnate waters or re-directing water flow. Any changes to or impacts of circulation would vary seasonally.	Engineer port structures to reduce stagnate waters.	2	2	L (4)	Still potential impact of shipping channel changing circulation but this may not necessarily be a bad thing for the health of CS.
						Climate change									
						Other industrial and urban growth	3	3	M (9)			3	3	M (9)	
						Cumulative pressure	*3*	*3*	*M (9)*	*Unknown if any additional channels will be dredged and if there would be more of an impact on CS than the port shipping channel.*		*3*	*3*	*M (9)*	*Unknown if any additional channels will be dredged and if there would be more of an impact on CS than the port shipping channel.*

Ref #	Issue	Current risk C	L	R	DC	Future unmitigated risk Activity	C	L	R	Justification	Future harbour development mitigated risk Mitigation	C	L	R	Justification
Environmental value: Biological diversity															
3	Decrease in species diversity due to reduction of suitable habitat, invasive species and altered environmental conditions	3	3	M (9)	L-M	Harbour development	4	4	H (16)	Invasive species from increased vessel traffic could outcompete native species, and there are already invasive species in Cockburn Sound. Evidence that dredge channels provide suitable habitat for fishes, but so do seagrass meadows and limestone outcrops which may be impacted by dredging and port development. Port and other development likely to cause localised habitat loss, but mobile animals could move to other suitable areas if available in Cockburn Sound (however, nursery areas may be affected). Northern Cockburn Sound and Owen Anchorage have highest benthic diversity, which is also in footprint of proposed port dredge channels. Tropicalisation may not necessarily decrease biological diversity, as new species will be entering Cockburn Sound and some current species may have time to gradually adapt. Cockburn Sound already has a distinctive fish community due to the presence of large abundances of the tropical fish species.	Use PIANC working with nature principles to engineer ecological niche areas for valuable species. Fill in unused dredged depressions on Success and Parmelia Banks with sandy dredge spoil to create shallow sandy banks suitable for establishment of new seagrass meadows. Ensure continuation of the State Wide Array Surveillance Program (SWASP) for marine pests and regular reporting (invasive species are monitored and managed by DPIRD under the Fisheries Act). Engineer walls of built structures to be native species friendly in order to reduce establishment of invasive.	3	3	M (9)	Risk of invasive species is still an issue, but early detection may help to localise any negative effects to species diversity.
						Climate change	2	3	M (6)			2	3	M (6)	
						Other industrial and urban growth	3	3	M (9)			3	3	M (9)	
						Cumulative pressure	*4*	*4*	*H (16)*	*Invasive species could impact system wide functioning and cause declines or local extinctions of populations.*		*3*	*3*	*M (9)*	*Efforts to reduce invasive species would benefit the whole system. Would still have localised patches of habitat destroyed with any coastal development but may not necessarily cause a decline in biodiversity if other similar habitat is available.*

Ref #	Issue	Current risk C	L	R	DC	Future unmitigated risk Activity	C	L	R	Justification	Future harbour development mitigated risk Mitigation	C	L	R	Justification
Environmental value: High level of water quality															
4	Decrease in quality of water due to increased development and altered environmental conditions	3	5	H (15)	M-H	Harbour development	3	5	H (15)	Port development and operation could increase nutrients and contaminants in the water column from run-off and resuspension of sediments with high nutrient and contaminant loading. Dredging and continual propeller wash would increase turbidity. More vessels in CS also increases the risk of oil and fuel spills. Climate change will elevate temperatures inside CS, which could contribute to more frequent toxic phytoplankton blooms as well as potential dead zones due to increases oxygen consumption. Climate change may also increase the incidence of flooding and increase acidification of the water. Other industrial and urban growth could increase the contamination of groundwater with excess nutrients and contaminants, which would then increase legacy issues for CS. Brine discharge from current and future desalination plants could negatively affect marine life.	Better management of groundwater, storm water and run off to reduce nutrients entering CS. Additional dredge management options should be considered e.g. timing around high flushing periods. Dredge without overflow and discharge sediments safely. Design port to minimise vessel movement i.e. less turning and manoeuvring which would limit disturbance to sediments. Check maintenance records of vessels before port entry to reduce risk of oil spill and have first strike response kits in place to respond to level 2/3 oil spills as a minimum. Increase vigilance with management of fuel transfers. Engineer structures to prevent coastal erosion if hydrology is changed from additional shipping channel.	2	4	M (8)	There would still be increased turbidity in the footprint of port from operations. Dredging plumes would still occur but sediments may not spread as far. If oil spills are responded to immediately, then impacts could remain localised. Use of chemicals and paints on vessels is regulated by Australian and international standards. Improved flushing of system from additional shipping channel may help to disperse turbid plumes generated from vessel movement.
						Climate change	4	3	H (12)			4	3	H (12)	
						Other industrial and urban growth	3	4	H (12)			3	4	H (12)	
						Cumulative pressure	*4*	*5*	*E (20)*	*Currently localised areas with poor water quality, despite the system as a whole generally improving since the majority of industrial outflow was diverted to the SDOOL. Poor flushing, particularly in the southern regions of CS contributes to poor water quality. Development in CS is the cause of the water quality issues experienced currently and, in the past, thus future development would likely impact on water quality as well.*		*4*	*4*	*H (16)*	*If shipping channel, or any other channels, improved flushing, then this would make improvements on other parts of the system. Industrial and urban growth will still continue to grow, putting more pressure on the system unless groundwater and any industrial outflows into CS can be heavily regulated. Climate change is an external driver.*

Ref #	Issue	Current risk C	L	R	DC	Future unmitigated risk Activity	C	L	R	Justification	Future harbour development mitigated risk Mitigation	C	L	R	Justification
Environmental value: High level of sediment quality															
5	Decrease in quality of sediments due to increased development	3	4	H (12)	L-M	Harbour development	3	3	M (9)	Likely increase in contamination of sediments with increased shipping and port operations. No widespread surveys conducted since 2006 but expected elevated levels in footprint of port e.g. Kwinana Bulk Jetty and James Point. Cockburn Sound would facilitate cargo and container shipping rather than mineral exports, so load spills unlikely. Due to poor flushing in Cockburn Sound sediments have a high organic load. Unless re-suspended, may be adequately supplying food for infauna, which also means biological oxygen demand will increase. There is a risk of exposing acid sulphate soils during development, particularly along eastern margin. However acid formation is unlikely given the sufficient neutralising capacity of the sediments. Nutrients from groundwater could settle in sediments.	Remove contaminated sediments created from port operations. Additional shipping channel may improve flushing and reduce nutrient loads in sediments. Test for potential acid sulphate soils before developing port infrastructure.	2	2	L (4)	Use of chemicals and paints on vessels is regulated by Australian and international standards, so not a mitigation measure Westport can use. However, removal of contaminated sediments would help improve sediment quality.
						Climate change									
						Other industrial and urban growth	3	3	M (9)			3	3	M (9)	
						Cumulative pressure	*3*	*4*	*H (12)*	*Localised areas of contaminated sediments already in CS and there are relatively new concerns about PFAS leaching into CS from contaminated areas on Garden Island. High organic load of sediments will remain high as long as flushing is poor and there are elevated nutrients in the water column.*		*3*	*3*	*M (9)*	*Some areas that have contaminated sediments are in proposed port footprint so could be removed during development. Still potential issues with PFAS contamination. If shipping channel, or any other channels, improved flushing, then this would make improvements on organic loads in sediments.*

Ref #	Issue	Current risk C	L	R	DC	Future unmitigated risk Activity	C	L	R	Justification	Future harbour development mitigated risk Mitigation	C	L	R	Justification
Environmental value: Significant benthic communities and habitats- Seagrass															
6.1	Reduction in seagrass biomass and extent due to increased development and altered environmental conditions	3	4	H (12)	M-H	Harbour development	4	3	H (12)	Some removal of seagrass meadows could occur dredged shipping channel, but meadows not occurring along eastern margin where port infrastructure is likely. Prolonged reduction in photosynthesis due to poor light and sedimentation of meadows would cause a reduction in further growth and loss of current meadows. Turbidity will be high during dredging and from increased vessel use in the area. Dredged sediments may spread widely and impact seagrass on a wider scale if environmental conditions become unpredictable- this has happened elsewhere. Increased incidence of marine heatwaves may cause decrease in seagrass biomass, which has occurred at Shark Bay. Most seagrass meadows occurring along western and southern margins, so may be less likely at risk with increased industrial and urban growth. Though increased recreational vessel use in the already popular southern margins may increase nutrient loading from sewage dumping.	Manage dredging operations for tidal movements and water circulation. If conditions allow, use a silt screen during dredging. Additional dredge management options should be considered to protect benthic producers e.g. avoid winter when seagrass most vulnerable to low light. Avoid removal of seagrass meadows or rehabilitate new areas for seagrass colonisation now to prevent a lag effect in ecosystem functioning. Design port to minimise vessel movement i.e. less turning and manoeuvring which would limit disturbance to sediments.	3	3	M (9)	Still a risk of dredge plume spreading and would still be increased turbidity from vessel use.
						Climate change	4	4	H (16)			4	4	H (16)	
						Other industrial and urban growth	3	3	M (9)			3	3	M (9)	
						Cumulative pressure	*4*	*4*	*H (16)*	*The 2018 DPSIR report states "Seagrass extent has increased appreciably since 2008, by ~130 hectares (ha), although health indicators suggest a continued decline in some long-term monitoring sites, despite improved water quality". There is likely reduced seagrass growth due to sulphide intrusion facilitated by low dissolved oxygen levels and low light levels.*		*4*	*4*	*H (16)*	*Still a potential sulphide intrusion issue. Climate change impacts are external drivers.*
Environmental value: Significant benthic communities and habitats- Other															
6.2 **6.3** **6.4**	Degradation of other benthic communities due to increased development	2	3	M (6)	L	Harbour development	2	3	M (6)	Corals and rocky reef occur in Cockburn Sound, but not dominant habitats. These less dominant habitats could be removed during port or other development. Corals may also be smothered by dredged sediments. There would be continual disturbance to soft sediments and communities with vessel traffic which may decrease primary productivity and destabilise sediments due to the loss of microphytobenthos.	Use PIANC Working with Nature principles to engineer port structures that consider benthic communities in immediate vicinity, or engineer habitats to replace those removed through port development. Design port to minimise vessel movement i.e. less turning and manoeuvring which would limit disturbance to sediments.	2	2	L (4)	Impact minimised for benthic habitats that also occur outside of port footprint.
						Climate change									
						Other industrial and urban growth	2	3	M (6)			2	3	M (6)	
						Cumulative pressure	*2*	*3*	*M (6)*	*Current vessel use would cause some disturbance to soft sediment communities. Limited information to assess climate change impacts.*		*2*	*3*	*M (6)*	*Still potential impacts from other industrial and urban growth.*

Ref #	Issue	Current risk C	L	R	DC	Future unmitigated risk Activity	C	L	R	Justification	Future harbour development mitigated risk Mitigation	C	L	R	Justification
Environmental value: Listed and significant fauna- Fairy terns															
7.1	Decline in abundance and breeding success of fairy terns due to impacts on habitat and prey species	2	3	M (6)	L-M	Harbour development	4	3	H (12)	Loss of shoreline habitat due to development and/or sea level rise. Popular nesting spots have not been identified for eastern margin where port and other development most likely. Over time risk will increase with sea level rise. Lack of nesting sites would impact the population, so development on eastern margin may remove future nesting sites if sea level rise removes current sites. Bioaccumulation of contaminants through the food chain could negatively affect survival and/or breeding success. TBT is being reduced, though there is potential for other contaminants to impact populations. Port operations my increase contaminants in the water and sediments. Disturbance to current nesting sites possible due to human disturbance. Urban growth would increase risk of entanglement in fishing gear and rubbish.	Use PIANC Working with Nature principles to incorporate protected bird friendly areas for current and future use. Areas of contaminated sediments could be removed and contamination of the water column heavily regulated to reduce bioaccumulation.	2	3	M (6)	Still don't know the impacts of bioaccumulation of contaminants, so if this doesn't cause death or reduced breeding success, then risk would be 'low'.
						Climate change	4	3	H (12)			4	3	H (12)	
						Other industrial and urban growth	3	3	M (9)			3	3	M (9)	
						Cumulative pressure	*4*	*3*	*H (12)*	*Feral predators also pose a risk to fairy tern abundance on nearby islands that can become connected to the mainland with sandbars. Current nesting sites around CS are considered secure, though impacts to other nesting sites close by would have some influence on the overall population- i.e. mating opportunities.*		*4*	*3*	*H (12)*	*Sea level rise is still a major risk to nesting sites and is an external driver.*

Ref #	Issue	Current risk C	L	R	DC	Future unmitigated risk Activity	C	L	R	Justification	Future harbour development mitigated risk Mitigation	C	L	R	Justification
Environmental value: Listed and significant fauna- Little penguins															
7.2	Decline in abundance and breeding success of little penguins due to a decline in foraging habitat and prey species, as well as increased collisions with recreational vessels	2	5	H (10)	M-H	Harbour development	4	4	H (16)	Loss of habitat for foraging, particularly along Kwinana Shelf which is in port footprint, could negatively impact on populations. Starvation identified as one of the top two causes of death for penguins in the region, which can occur from reduced prey abundance from habitat degradation and/or sea temperatures. Tropical species could move in to replace lost species. Trauma from watercraft identified as one of the top two causes of death. Port footprint would compress the same number of recreational boats into a smaller area. Bioaccumulation of contaminants through the food chain could negatively affect survival and/or breeding success. Contaminants have been found in dead penguins but have not been identified as the definite cause of death. TBT use would be decreasing over time but would remain high in sediments and other contaminants could also impact populations. Urban growth would increase risk of entanglement in fishing gear and rubbish.	Use PIANC Working with Nature principles to create niche areas for prey species that also restricts recreational vessel use, as well as structures that would reduce the loss of Kwinana Shelf habitat. Reduce recreational boat speeds in a large area around the port which would lessen the risk overall for penguins if they use those areas. Given that the port footprint would condense recreational vessel use into a smaller area, educational programs could be developed for boat users. Areas of contaminated sediments could be removed to reduce risk of bioaccumulation. Restricted vessel routes and speed limits. Conduct regular surveys of shoreline to look for dead penguins and perform necropsies to determine cause of death. Reduce removal of wrack and damage to seagrass meadows. Reduce underwater noise pollution.	3	3	M (9)	Still possibility of having some impacts on penguin populations due to port operations.
						Climate change	3	4	H (12)			3	4	H (12)	
						Other industrial and urban growth	4	4	H (16)			4	4	H (16)	
						Cumulative pressure	*4*	*4*	*H (16)*	*Common causes of death already known and relate to further development and use of CS, as well as climate change. Some years have already experienced low breeding success. Increased vessel traffic and speed is a major risk and one that is hard to manage.*		*4*	*3*	H (12)	*Though Westport could help to reduce vessel speeds and educate boat users given that the port would indirectly contribute to high vessel density, rules would need to be enforced. Rising sea temperatures is an external driver.*

Ref #	Issue	Current risk C	L	R	DC	Future unmitigated risk Activity	C	L	R	Justification	Future harbour development mitigated risk Mitigation	C	L	R	Justification
Environmental value: Listed and significant fauna- Bottlenose dolphins															
7.3	Decline in resident and other populations due to a decline in foraging habitat, prey species and anthropogenic influences i.e. boat strikes, fishing entanglements and underwater noise	2	3	M (6)	M-H	Harbour development	4	4	H (16)	Loss of habitat, particularly along Kwinana Shelf which is used for foraging and a nursery, could negatively impact on resident dolphin populations. It has been suggested that dolphins would not be able to compensate for the loss of habitat on the Kwinana Shelf. Increased recreational use of the Kwinana area could increase illegal feeding of dolphins, increasing the risk of boat strikes and entanglement in fishing gear; this has been documented for CS. Increase in underwater noise from development and construction could deter dolphins from their usual habitats and interrupt communications between dolphins. Climate change would likely cause shifts in prey distributions, and this dolphins, or dolphins may adjust to new tropical species.	Use PIANC Working with Nature principles to create niche areas for dolphins to forage and design structures that would reduce the loss of Kwinana Shelf. Avoid conducting noisy dredging operations and port maintenance (i.e. pile driving) during the breeding season when animals are socialising and calving. Engage Marine Mammal Observers to observe the occurrence of dolphins during the time development is occurring.	2	4	M (8)	If the majority of Kwinana Shelf can remain useful for dolphins, then underwater noise would be the concerning impact, which would not be a constant pressure and one that dolphins can avoid temporarily.
						Climate change	4	3	H (12)			4	3	H (12)	
						Other industrial and urban growth	3	3	M (9)			3	3	M (9)	
						Cumulative pressure	*4*	*4*	*H (16)*	*Accumulated pressures may cause dolphins to leave CS, more so than cause direct death to dolphins, and would impact the value being present in CS.*		*4*	*3*	*H (12)*	*Still issues with illegal feeding and vessel strikes which would likely increase with urban growth. Climate change impacts on prey species is an external driver.*
Environmental value: Listed and significant fauna- Australian sea lion															
7.4	Lack of suitable haul out sites due to changing environmental conditions and anthropogenic disturbance	2	3	M (6)	L-M	Harbour development	2	2	L (4)	Additional haul out locations may be limited in Kwinana (due to development) if current haul out sites become unsuitable with a changing climate. Sea lions haul out where the environment is most suitable. Haul out locations are currently on islands, none have been identified for the mainland coasts of Cockburn Sound. Increase in disturbance at haul out sites of Carnac and Seal Island may be likely with increased recreational and large vessel traffic. Large vessels already operate in CS and sea lions may have become accustomed to their presence.	Restrict proximity of vessels to current haul out sites. Use PIANC Working with Nature principles and include potential haul out locations to maximise choice is sea lions need to shift from islands.	1	2	L (2)	Sea lions do not haul out on the coastal areas near eastern margin of CS, so reducing potential risks that may arise in the future is all that can be done until more is understood about the population.
						Climate change	3	3	M (9)			3	3	M (9)	
						Other industrial and urban growth	3	3	M (9)			2	3	M (6)	
						Cumulative pressure	*3*	*3*	*M (9)*	*No breeding populations around CS, only haul out locations. Even though haul out sites are not directly in CS, sea lions occur adjacent to CS and may still use the area for foraging. Also listed as Vulnerable under the EPBC Act.*		*3*	*3*	*M (9)*	*Restricting proximity of vessels to haul out sites could include recreational vessels. Climate change impacts an external driver.*

Ref #	Issue	Current risk C	L	R	DC	Future unmitigated risk Activity	C	L	R	Justification	Future harbour development mitigated risk Mitigation	C	L	R	Justification
Environmental value: Listed and significant fauna- migratory shorebirds and seabirds															
7.5	Decline in abundance and breeding success due to impacts on habitat and prey species	2	3	M (6)	L	Harbour development	4	3	H (12)	Sea level rise could inundate important shoreline habitat. Increased coastal development could remove important habitat. Bioaccumulation of contaminants through the food chain could negatively affect survival and/or breeding success. Starvation could occur like it does for penguins due to decreased food supply resulting from habitat degradation and rising sea temperatures. Birds would likely also feed outside of Cockburn Sound. Urban growth would increase risk of entanglement in fishing gear and rubbish.	Use PIANC Working with Nature principles to create niche areas for birds to forage and incorporate coastal stretches for birds to nest and move up shore as sea level rises. Areas of contaminated sediments could be removed to reduce risk of bioaccumulation.	2	3	M (6)	Port operations may still cause some temporary or prolonged disturbance to birds using niche areas.
						Climate change	4	3	H (12)			4	3	H (12)	
						Other industrial and urban growth	3	3	M (9)			3	3	M (9)	
						Cumulative pressure	*4*	*4*	*H (16)*	*Coastal development and human disturbance may impact on birds using coastal areas. Popular sites for seabirds and shorebirds include surrounding islands, but it is unknown if stretches of mainland coastline are also significant. Death from starvation would have impacts at a population level. Migratory birds frequent the same or similar locations year after year due to reliable conditions, so any impacts to known forging or nesting sites may have greater implications for migration.*		*4*	*3*	*H (12)*	*Climate change is an external driver and other coastal development and human disturbance may impact on birds using coastal areas.*
Environmental value: Regionally significant spawning / nursery area- King George whiting															
8.1	Decline in abundance and loss of nursery area due to environmental changes and loss of habitat	2	2	L (2)	H	Harbour development	2	2	L (4)	Loss of habitat will negatively impact important nursery areas. Mangles Bay is an important nursery. Seagrass meadows occur here but it is unknown whether this is directly related to the occurrence of whiting in the area. Other seagrass areas not specifically mentioned as nursery areas, so may or may not be exclusive to Mangles Bay. Impacts to younger life stages would be felt at a population level. Unknown if future developments will occur in Mangles Bay, but the port footprint does not include the Bay and has limited direct removal of seagrass. Decline in water quality, including turbidity, may impact upon nursery areas if sediments spread.	Use PIANC Working with Nature principles to create fish friendly habitat which could be used as nursery areas. Do not dredge during peak nursery use in case suspended sediments spread with unfavourable conditions.	2	2	L (4)	No guarantee that whiting will use created nursery areas if they have such a strong relationship with Mangles Bay.
						Climate change									
						Other industrial and urban growth	3	2	M (6)			3	2	M (6)	
						Cumulative pressure	*3*	*2*	*M (6)*	*Fishery overall is currently considered sustainable and adequate. Any impacts to Mangles Bay may see disappearance of nursery areas in CS. Unknown what impacts climate change will have, so it is likely that the risk to the species will increase with more knowledge.*		*3*	*2*	*M (6)*	*Creating nursery areas would benefit the population overall and may provide an alternative if Mangles Bay is impacted by urban and industrial growth. Unknown what impacts climate change will have, so it is likely that the risk to the species will increase with more knowledge.*

Ref #	Issue	Current risk C	L	R	DC	Future unmitigated risk Activity	C	L	R	Justification	Future harbour development mitigated risk Mitigation	C	L	R	Justification
Environmental value: Regionally significant spawning / nursery area- Blue swimmer crab															
8.2	Decline in abundance and loss of nursery area due to environmental changes and loss of seagrass habitat	4	3	H (12)	M-H	Harbour development	3	3	M (9)	Current low abundances in CS attributed substantially to impacts of the 2011 marine heatwave and flooding events. Fishery remains closed to allow recovery. Loss of seagrass will negatively impact on recruitment. Mangles Bay, James Point and Jervoise Bay are the best recruitment sites for 0+, likely due to more seagrass cover. Port footprint will most likely not directly occur in these three areas, but some seagrass will likely be destroyed in shipping channel and turbidity from dredging and ship traffic may affect important seagrass areas. Crabs are mobile and could move to where conditions are more favourable.	Use PIANC Working with Nature principles to create crab friendly habitat and rehabilitate seagrass meadows now to prevent a lag in ecosystem functioning. Manage dredge and vessel generated turbidity to have least impact on seagrass meadows.	2	2	L (4)	Crabs use seagrass and sandy habitats all throughout CS, so crabs could move from turbid areas temporarily.
						Climate change	4	4	H (16)			4	4	H (16)	
						Other industrial and urban growth	3	3	M (9)			3	3	M (9)	
						Cumulative pressure	*4*	*4*	H (16)	*Already a population under stress due to environmental influences.*		*4*	*4*	H (16)	*Climate change is an external driver and crabs are considered a 'high risk' to climate change (DPIRD). Future developments could impact on favoured recruitment sites.*
Environmental value: Regionally significant spawning / nursery area- Pink snapper															
8.3	Decline in abundance and loss of significant spawning area due to loss of habitat, increase in suspended sediments and changing environmental conditions	3	3	M (9)	M	Harbour development	4	3	H (12)	Increasing temperatures may cause declines in abundance or alter shifts in spawning peaks and maturation as spawning is documented to occur within a certain temperature range. Dredged materials could impact the survival rates of larval stages and studies show mortality of larvae increased with increased exposure time to suspended sediments. Suspended sediments from dredging and vessel use would also impact seagrass meadows which are important for snapper. Spawning also takes place in surrounding bays outside of CS, though CS has been a nursery area since 1971. Loss of habitat could decrease the use of CS as a nursery area. Altered hydrological conditions from additional shipping channel may influence egg dispersal and survival. Any impacts to spawning or juvenile stages will influence adult population. Increased nutrients in the water column could increase the occurrence of toxic blooms that lead to fish kills. Overfishing may reduce population to unsustainable levels.	Use PIANC Working with Nature principles to create fish friendly habitat. Plan dredging to avoid snapper spawning and larval growth and design port to minimise vessel movement. Rehabilitate seagrass meadows now to avoid a lag in ecosystem functioning as some seagrass would likely be removed or impacted upon during port construction and operation. Engineer shipping channel to balance improved flushing with transport of eggs outside of CS.	2	3	M (6)	May still be some impact on fish using seagrass during periods of dredging and high vessel traffic, but fish are mobile and could avoid areas during these times. Shipping channel and any circulation changes may have unavoidable impacts for snapper eggs.
						Climate change	4	3	H (12)			4	3	H (12)	
						Other industrial and urban growth	3	3	M (9)			3	3	M (9)	
						Cumulative pressure	*4*	*4*	*H (16)*	*Pink snapper were restocked after 2015 fish kill incident. Eggs and larvae are sensitive to suspended sediments and spawning events are sensitive to environmental conditions, so a combination of these pressures in the future may cause a significant impact on the population in CS.*		*4*	*3*	*H (12)*	*Climate change an external driver. Unknown if second dredged channel between is definite.*

Ref #	Issue	Current risk C	L	R	DC	Future unmitigated risk Activity	C	L	R	Justification	Future harbour development mitigated risk Mitigation	C	L	R	Justification
Environmental value: Regionally significant spawning / nursery area- Whitebait															
8.4	Loss of favourable spawning area due to changes in environmental conditions	3	3	M (9)	L-M	Harbour development	3	3	M (9)	An increase in marine heatwaves would negatively impact spawning and lower catches resulted in the years following the 2011 marine heatwave. Altered hydrological conditions from additional channels may influence egg dispersal and survival. Eggs are transported via water movement, and increased flushing may transport eggs out of nursery areas where they would be less protected.	Engineer shipping channel to balance improved flushing with transport of eggs outside of CS.	2	3	M (6)	Shipping channel and any circulation changes may have unavoidable impacts for whitebait eggs.
						Climate change	4	4	H (16)			4	4	H (16)	
						Other industrial and urban growth	3	3	M (9)			3	3	M (9)	
						Cumulative pressure	*4*	*4*	*H (16)*	*Climate change impacts would likely be the greatest threat to whitebait in CS.*		*4*	*4*	*H (16)*	*Climate change is an external driver. Unknown if second channel is definite.*
Environmental value: Regionally significant spawning / nursery area- Southern garfish															
8.5	Decline in abundance and loss of nursery area due to environmental changes and loss of seagrass habitat	4	3	H (12)	M-H	Harbour development	3	3	M (9)	Loss of seagrass would reduce feeding opportunities and decrease survival of eggs as garfish feed on seagrass and attach eggs to seagrass blades in Cockburn Sound. Some seagrass will likely be destroyed in shipping channel and turbidity from dredging and ship traffic may affect important seagrass areas. An increase in marine heatwaves would negatively impact stocks as the 2011 marine heatwave had a negative impact. Industrial and urban growth may contribute to poor water quality which would impact seagrass.	Use PIANC Working with Nature principles to create fish friendly habitat and potential nursery areas. Rehabilitate seagrass meadows now to avoid a lag in ecosystem functioning as some seagrass would likely be removed or impacted upon during port construction and operation. Do not dredge during peak egg and nursery periods in case suspended sediments spread with unfavourable conditions. Design shipping channel and port to minimise vessel movement and reduce turbidity. Shipping channel may help to increase flushing times and improve water quality and seagrass growth in some parts of CS.	2	2	L (4)	Replacing lost seagrass habitat and restricting dredging activities to certain times would reduce impacts of port.
						Climate change	4	4	H (16)			4	4	H (16)	
						Other industrial and urban growth	3	3	M (9)			3	3	M (9)	
						Cumulative pressure	*4*	*4*	H (16)	*Stocks have been declining since 1990's and the fishery is vulnerable to collapse if it has a single year of poor recruitment.*		*4*	*4*	*H (16)*	*Climate change is an external driver. Shipping channel may help to increase flushing times and improve water quality and seagrass growth in some parts of CS- which would benefit the system overall. Unknown if second channel is definite- if so, it could help to flush the system and improve water quality and seagrass growth.*

Ref #	Issue	Current risk C	L	R	DC	Future unmitigated risk Activity	C	L	R	Justification	Future harbour development mitigated risk Mitigation	C	L	R	Justification
Environmental value: Shoalwater Islands Marine Park															
9	Degradation of marine park due to flow on effects of poor water quality and declining biodiversity, as well as erosion of shorelines	2	4	M (8)	M	Harbour development	3	3	M (9)	Due to close proximity, impacts on water quality and marine biota in Cockburn Sound would have flow on affects to the marine park. Port operations and other industrial and urban growth may contribute to poor water quality. Majority of park mixes with open coastal waters which would help water quality. Increased erosion of the shorelines is a concern for the park and beach renourishment already occurs. Inappropriately designed moorings in Safety Bay and Mangles Bay have caused localised damage to seagrass. Tropicalisation of the region will likely occur with increasing temperatures but not necessarily cause degradation.	Use PIANC Working with Nature principles to engineer ecological niche areas for valuable species that use both CS and marine park. Reduce impacts to water quality as much as possible.	2	2	L (4)	
						Climate change	3	4	H (12)			3	4	H (12)	
						Other industrial and urban growth	3	3	M (9)			3	3	M (9)	
						Cumulative pressure	*3*	*4*	*H (12)*	*The Park provides important habitat for little penguins, dolphins, sea lions, as well as occasional occurrences of southern right and humpback whales. Park has its own restrictions in place to help protect values.*		*3*	*4*	*H (12)*	*Climate change an external driver and control of erosion along coastline is not something Westport would be responsible for.*
Environmental value: Coastal processes															
10	Increased erosion and inundation of shorelines from rising sea levels, storms and changes to sediment transport	2	4	M (8)	M	Westport related development	3	3	M (9)	Increased erosion and inundation at localised points within Cockburn Sound with increasing sea levels and storms. Changes to hydrological conditions may change alongshore sediment transport and erode shorelines. Already documented from the construction of Causeway, groynes and rock walls. Hydrological conditions may change with additional shipping channels.	Use PIANC Working with Nature principles to engineer long lasting solutions for coastal erosion if shipping channel has a significant impact on sediment transport.	2	2	L (4)	Reducing sediment transport would help to reduce erosion.
						Climate change	3	4	H (12)			3	4	H (12)	
						Other industrial and urban growth	3	3	M (9)			3	3	M (9)	
						Cumulative pressure	*3*	*4*	*H (12)*	*Coastal erosion and inundation already affecting localised areas around CS.*		*3*	*4*	*H (12)*	*Climate change an external drivers.*

Table 4: Preliminary unmitigated and mitigated risk assessment for marine and estuarine social values in Kwinana.

Ref #	Issue	Current risk C	L	R	DC	Future unmitigated risk Activity	C	L	R	Justification	Future harbour development mitigated risk Mitigation	C	L	R	Justification
Social value: Heritage- Aboriginal															
1.1	Loss or degradation of important heritage sites with increased development	1	2	L (2)	H	Harbour development	2	2	L (4)	Valued sites occur around the coastlines of Cockburn Sound and on Garden Island, but not directly in port footprint. Cockburn Sound and waters to the north are part of the mythological 'Indian Ocean' aboriginal heritage site. However, degradation to these areas could occur from increased use and development. Sea level rise may impact on some coastal sites.	Avoid port construction on important aboriginal sites	2	2	L (4)	Indian Ocean mythological site may be perceived to be impacted upon, but the site covers a large area out to Rottnest Island.
						Climate change	3	3	M (9)			3	3	M (9)	
						Other industrial and urban growth	3	3	M (9)			3	3	M (9)	
						Cumulative pressure	*3*	*3*	*M (9)*	*Valued sites occur around the coastlines of Cockburn Sound and on Garden Island.*		*3*	*3*	*M (9)*	*Unknown whether other industrial and urban growth will impact on sites. Climate change an external driver.*
Social value: Heritage- Maritime/historic															
1.2	Loss or degradation of important historical sites with increased development	1	2	L (2)	H	Harbour development	2	3	M (6)	One shipwreck in proposed port footprint and degradation to other sites areas could occur from increased use and development in CS. Sea level rise and erosion may impact on some sites along coastline.	Engineer port structures around shipwrecks.	2	2	L (4)	Shipwreck location unaffected.
						Climate change	3	3	M (9)			3	3	M (9)	
						Other industrial and urban growth	2	2	L (4)			2	2	L (4)	
						Cumulative pressure	*3*	*3*	*M (9)*			*3*	*3*	*M (9)*	*Climate change an external driver.*
Social value: Public health- High quality source water for desalination															
2.1	Negative impact on drinking water supply due to declining water quality in Cockburn Sound	2	3	M (6)	M-H	Harbour development	4	3	H (12)	Potential decrease in water quality with increased use of CS. Expensive to treat/filter water or source water elsewhere if CS becomes unsuitable i.e. increased contamination, suspended sediments. Potentially more frequent maintenance (resulting in a loss of productivity and increase in cost) and potentially an increase in unplanned shutdowns (e.g. in response to elevated hydrocarbon concentration) to prevent damage. Could potentially cost the community more money for water. Other industrial and urban growth likely to influence groundwater flow into CS which would impact on source water.	Avoid dredging and high vessel use near intake pipe or move intake pipe to a more suitable location. Adopt engineering solutions that will reduce the frequency of maintenance and shutdowns.	2	3	M (6)	Still possible that a minor impact may occur if water quality issues spread.
						Climate change									
						Other industrial and urban growth	3	3	M (9)			3	3	M (9)	
						Cumulative pressure	4	3	H (12)	*Only one intake pipe in CS.*		3	3	*M (9)*	*Still potential impacts from other industrial and urban growth, however, if intake pipe moved further off the coast then the risk may lower.*

Ref #	Issue	Current risk C	L	R	DC	Future unmitigated risk Activity	C	L	R	Justification	Future harbour development mitigated risk Mitigation	C	L	R	Justification
Social value: Public health- Recreational water quality															
2.2	Increased safety concerns for primary and secondary contact with water due to decreased water quality	2	2	L (2)	M-H	Harbour development	4	2	M (8)	Many people swim or use CS for water sports or leisure. Some beaches have a current rating of 'fair' that may get worse with increased use of CS.	Time dredging operations with water circulation to avoid spread of sediments. Use a silt screen if conditions permit. Design port to minimise vessel movement i.e. less turning and manoeuvring which would limit disturbance to sediments. Monitor water quality regularly to detect any health concerns.	2	2	L (4)	Still may be temporary occurrences of reduced water quality that causes concern for contact with water, but likely not prolonged.
						Climate change									
						Other industrial and urban growth	2	2	L (4)			2	2	L (4)	
						Cumulative pressure	*4*	*2*	*M (8)*	*Perceptions of water quality would change with each person.*		*2*	*2*	L (4)	*Still may be temporary occurrences of reduced water quality that causes concern for contact with water, but likely not prolonged.*
Social value: Public health- Seafood quality															
2.3	Decrease in health of shellfish and fish with increased contamination in waters and sediments	2	3	M (6)	M-H	Harbour development	4	3	H (12)	Contamination may increase with port construction and operation. Quality assurance monitoring is not performed for wild shellfish or fish. Would reduce recreational and commercial fishing as well as aquaculture if contamination levels exceeded guidelines. Would impact on favourite past times and social gatherings. May cause death and wash up of marine life. Concerns over PFAS entering the water column and food chain.	Remove contaminated sediments associated with port operation. Dredge without overflow and discharge sediments safely. Design port to minimise vessel movement i.e. less turning and manoeuvring which would limit disturbance to sediments.	2	3	M (6)	Use of chemicals and paints on vessels is regulated by Australian and international standards
						Climate change									
						Other industrial and urban growth	4	3	H (12)			4	3	H (12)	
						Cumulative pressure	*4*	*3*	*H (12)*	*A lot of fishing occurs in CS and no widespread health issues have been reported or linked to seafood in CS.*		*4*	*3*	*H (12)*	*Westport is not responsible for mitigating against PFAS on Garden Island.*

Ref #	Issue	Current risk C	L	R	DC	Future unmitigated risk Activity	C	L	R	Justification	Future harbour development mitigated risk Mitigation	C	L	R	Justification
Social value: Social and community: Recreational fishing															
3.1	Decrease in recreational fishing due to restrictions around port area and the loss of popular fished species i.e. pink snapper, crabs with loss of habitat	4	3	H (12)	M-H	Harbour development	3	3	M (9)	Most boat based fishing is concentrated in the south of Cockburn Sound and northern waters, rather than the eastern margin where development may occur. Most shore based fishing is focused around jetties and to the north of Cockburn Sound. Some displacement in area of port development, but fishers could move to surrounding areas. Development could degrade current favoured habitats for fish and crabs, particularly seagrass beds. Climate change impacts may change fish patterns and distributions.	Use PIANC Working with Nature principles to engineer ecological niche areas for valuable species, as well as fisher friendly structures. Avoid dredging during spawning periods. Rehabilitate seagrass meadows now to avoid a lag in ecosystem functioning.	2	2	L (4)	PIANC principles may help to improve recreational fishing in CS.
						Climate change	4	3	H (12)			4	3	H (12)	
						Other industrial and urban growth	3	3	M (9)			3	3	M (9)	
						Cumulative pressure	*4*	*4*	*H (16)*	*Cockburn Sound is popular for fishing and even underwent the costly restocking of juvenile snapper after many were killed in 2015. A lot of time and money spent keeping the sound maintained for activities such as fishing. Blue swimmer crab fishing is still closed to allow stocks to recover.*		*4*	*3*	*H (12)*	*Climate change an external driver.*
Social value: Social and community: Recreational swimming															
3.2	Loss of popular swimming beaches with increased development i.e. Kwinana/ Challenger Beach	2	2	L (4)	H	Harbour development	3	3	M (9)	Depending on final port footprint, some popular swimming beaches may be removed. CS has other beaches for swimmers to utilise. Other industrial development may disturb swimming beaches. Sea level rise and erosion could impact access points for beaches that are used for swimming.	Create access to another stretch of beach in the vicinity of Kwinana Beach, or design port structures around beach so that it can still be used.	2	2	L (4)	Recreational swimming is retained as a value in CS and in vicinity of port.
						Climate change	2	3	M (6)			2	3	M (6)	
						Other industrial and urban growth	2	3	M (6)			2	3	M (6)	
						Cumulative pressure	*3*	*3*	*M (9)*	*Swimming currently considered safe in CS, and there are multiple beaches to access for the purposes of swimming.*		*2*	*3*	*M (6)*	*Climate change an external driver. Unknown impacts of other industrial and urban growth.*

Ref #	Issue	Current risk C	L	R	DC	Future unmitigated risk Activity	C	L	R	Justification	Future harbour development mitigated risk Mitigation	C	L	R	Justification
Social value: Social and community: Recreational water sports															
3.3	Decrease in water sports with increased development	1	2	L (3)	M	Harbour development	2	4	M (8)	Sports would likely only be displaced along the eastern margin of CS, and in shipping channels, and water sports are typically centred around the south of the sound and Woodman Point. May be restrictions on use put in place with increasing vessel traffic.	Designate new recreational areas specifically for water sports.	2	2	L (4)	Nearby bays can also be used for water sports, and value is still retained in CS.
						Climate change									
						Other industrial and urban growth	2	2	L (4)			2	2	L (4)	
						Cumulative pressure	*2*	*4*	*M (8)*	*Water sports popular in CS and surrounding bays.*		*2*	*2*	*L (4)*	*Nearby bays can also be used for water sports, and value is still retained in CS.*
Social value: Social and community: Recreational boating access															
3.4	Loss of boat ramps with increased development i.e. Challenger Beach boat ramp	1	2	L (3)	H	Harbour development	3	3	M (9)	Depending on final port footprint, access to eastern margin boat ramps such as Challenger Beach boat ramp may be lost. Recreational boat use expected to grow over time. Other boat ramps out of port footprint are more popular to use. Sea level rise and erosion may impact on some boat ramps.	If a boat ramp is removed, engineer access to a new boat ramp in a similar location that is long lasting under climate change.	2	2	L (4)	Replacing lost boat ramps with new ramps keeps the value present at a local and regional scale.
						Climate change	3	3	M (9)			3	3	M (9)	
						Other industrial and urban growth	2	2	L (4)			2	2	L (4)	
						Cumulative pressure	*3*	*3*	*M (9)*	*Erosion is likely to impact boat ramps before sea level rise does.*		*3*	*3*	*M (9)*	*Climate change an external driver.*
Social value: Social and community: Marina facilities															
3.5	Reduced use of marina facilities with increased development	1	2	L (2)	M-H	Harbour development	2	2	L (4)	Marina facilities not in port footprint, so should have limited impact, apart from increased vessel traffic in and around CS. Quality of marina may decline with increased use and development. Sea level rise and erosion may impact on some marine facilities.	No mitigation	2	2	L (4)	Marina facilities not in port footprint so should have limited impact.
						Climate change	3	3	M (9)			3	3	M (9)	
						Other industrial and urban growth	2	2	L (4)			2	2	L (4)	
						Cumulative pressure	*3*	*3*	M (9)	*Marinas likely to be upgraded over time rather than removed due to other further development. Climate change likely biggest threat if there is insufficient set back of coastal structures.*		*3*	*3*	M (9)	*Climate change an external driver.*

Ref #	Issue	Current risk C	L	R	DC	Future unmitigated risk Activity	C	L	R	Justification	Future harbour development mitigated risk Mitigation	C	L	R	Justification
Social value: Social and community: Educational and scientific values															
3.6	Reduced research and educational opportunities due to further development degrading the functioning ecosystem	1	2	L (2)	M	Harbour development	3	3	M (9)	Port footprint, and other development, could interrupt widespread/comprehensive research in CS and may impact on the collection of long time series data. Increased use and development in CS may cause educational operators to relocate to new sites due to a degraded and unhealthy ecosystem. Other industrial and urban growth could contribute to poor water quality and habitat degradation in CS. Climate change would not necessarily degrade or reduce opportunities.	Adopt PIANC Working with Nature principles maintain a functioning ecosystem. Grant permits to access certain regions of port if established study sites exist.	2	2	L (4)	PIANC principles may help to improve the functioning of the ecosystem not just maintain it.
						Climate change	2	2	L (4)			2	2	L (4)	
						Other industrial and urban growth	3	3	M (9)			3	3	M (9)	
						Cumulative pressure	*3*	*3*	*M (9)*	*Port development would be the biggest threat to this value.*		*3*	*3*	*M (9)*	*Unknown whether other industrial and urban growth will regulate heavily for impacts to CS.*
Social value: Social and community: Landscape and visual amenity															
3.7	Less visitation due to increased development negatively impacting on the landscape and visual amenity	2	3	M (6)	M-H	Harbour development	3	3	M (9)	Erosion will reduce visual amenity and access at popular beaches and coastlines- Palm Beach, Mangles Bay and Kwinana beach already undergone beach nourishment to manage shoreline erosion. Increased sightings of marine life kills due to decreased water quality from increased development. Lack of visitation due to obstruction of expansive views of the ocean horizon with large vessels and/or built structures, as well as sightings of temporary dredge turbid plumes. Some vessel use of the area already.	Manage dredging with water circulation to reduce spread of plumes. Use a silt curtain if allowable.	3	3	M (9)	Still may displace some users who think CS has become too industrialised.
						Climate change	3	3	M (9)			3	3	M (9)	
						Other industrial and urban growth	2	2	L (4)			2	2	L (4)	
						Cumulative pressure	*3*	*3*	*M (9)*	*Attractions of CS will vary per person. Port would be the biggest infrastructure project that would impact on visual amenity.*		*3*	*3*	*M (9)*	*Climate change an external driver. Unknown impacts of other industrial and urban growth.*
Social value: Business, industry and commercial: Tourism															
4.1	Loss of tourism due to restrictions around port area and the loss of marine life and habitat with increased development	2	2	L (4)	M-H	Harbour development	4	3	H (12)	Loss of marine life and habitat degradation due to increased development would reduce wildlife tourism i.e. any impacts to dolphins would significantly impact Rockingham Wild Encounters. Tourist activities would be displaced with port development along the eastern margin of CS and in shipping channels. The southern end of the sound most popular for tourist activities e.g. water sports hire, diving. Other industrial and urban growth could contribute to poor water quality and habitat degradation in CS, though likely to also attract more tourists.	Adopt PIANC Working with Nature principles to maintain a functioning ecosystem.	2	3	M (6)	Still restricted areas around port and visual amenity may also contribute to customer satisfaction.
						Climate change	2	2	L (4)			2	2	L (4)	
						Other industrial and urban growth	3	2	M (6)			3	2	M (6)	

Ref #	Issue	Current risk C	L	R	DC	Future unmitigated risk Activity	C	L	R	Justification	Future harbour development mitigated risk Mitigation	C	L	R	Justification
						Cumulative pressure	*4*	*3*	*H (12)*	*Tourism popular around Rockingham and southern CS. Direct and indirect effects of development on tourism.*		*3*	*3*	*M (9)*	*Unknown impacts of other industrial and urban growth.*
Social value: Business, industry and commercial: Commercial fisheries															
4.2	Decrease in commercial fishing due to an increase in rules and restrictions and lower catch rates from habitat loss and degradation with increased development	4	4	H (16)	M-H	Harbour development	4	3	H (12)	Increased rules and restrictions could lead to a further decrease in commercial fishing in CS. Further development could cause loss/degradation of habitat resulting in low catch rates. Climate change likely to impact distributions of fished species. Other industrial and urban growth could contribute to poor water quality and habitat degradation in CS.	Use PIANC Working with Nature principles to engineer ecological niche areas for valuable species, as well as fisher friendly structures. Avoid dredging during spawning periods. Rehabilitate seagrass meadows now to avoid a lag in ecosystem functioning.	2	3	M (6)	There would still be restrictions in place for fishing access around port region, but PIANC principles may increase the abundance of fished species.
						Climate change	4	3	H (12)			4	3	H (12)	
						Other industrial and urban growth	3	3	M (9)			3	3	M (9)	
						Cumulative pressure	*4*	*4*	*H (16)*	*Commercial fishing has already been impacted by development in Cockburn Sound and there has been a decline in licenses since the 1990s.*		*4*	*3*	*H (12)*	*Climate change an external driver. Unknown impacts of other industrial and urban growth.*
Social value: Business, industry and commercial: Aquaculture															
4.3	Loss of mussel aquaculture due to increased development and changing environmental conditions	4	3	H (12)	M-H	Harbour development	4	3	H (12)	Reduction of nutrients in CS due would reduce food available for mussel growth, and this may occur with the shipping channel increasing flushing rates. Increased vessel visitation would increase risk of introduced marine pests that could negatively impact mussel growth and sales. Availability of contaminants in the water column would increase and could cause health concerns in farmed mussels. Increase in water temperatures may negatively affect mussel growth as is thought to be a contributing cause of decline in the last 10 years. Other industrial and urban growth could contribute to poor water quality.	Use PIANC guidelines to create areas conducive to spat collection and mussel grow out. Implement additional monitoring measures to reduce incidence of marine pests. Remove contaminated sediments.	3	3	M (9)	Shipping channel still may impact flushing of nutrients.
						Climate change	4	3	H (12)			4	3	H (12)	
						Other industrial and urban growth	3	3	M (9)			3	3	M (9)	

Ref #	Issue	Current risk C	L	R	DC	Future unmitigated risk Activity	C	L	R	Justification	Future harbour development mitigated risk Mitigation	C	L	R	Justification
						Cumulative pressure	*4*	*4*	*H (16)*	*Mussel production has decreased and is attributed to decreased nutrient levels, warmer water, reduced recruitment and predation.*		*4*	*3*	*H (12)*	*Climate change an external driver. Unknown impacts of other industrial and urban growth.*
Social value: Business, industry and commercial: Suitable quality water for industrial use															
4.4	Reduced water quality due to increased development will impact industrial use	2	2	L (4)	M	Harbour development	2	2	L (4)	Potential decrease in water quality with increased use of CS. Expensive to treat/filter water or source water elsewhere if CS becomes unsuitable i.e. increased contamination, suspended sediments. Industrial water quality generally means a level of quality that allows it to be used as cool water and thus it is unlikely that water quality is reduced to such an extent it is no longer suitable for industrial use. Other industrial and urban growth likely to influence groundwater flow into CS which would impact on source water.	Avoid dredging and high vessel use near intake pipe or move intake pipes to more suitable locations.	2	2	L (4)	Still possible that a minor impact may occur if water quality issues spread.
						Climate change									
						Other industrial and urban growth	2	2	L (4)			2	2	L (4)	
						Cumulative pressure	*2*	*2*	L (4)	*Intake pipes would occur along eastern margin of CS.*		*2*	*2*	L (4)	*Still potential impacts from other industrial and urban growth, however, if intake pipe moved further off the coast then the risk may lower.*
Social value: Business, industry and commercial: Assimilation of wastewater															
4.5	Decreased water quality around outfall pipes due to wastewater operations	2	3	M (6)	L-M	Harbour development	3	3	M (9)	Contaminants and nutrients would increase with increased development. Port infrastructure and shipping channel may impact water circulation and wastewater assimilation close to the coast. A structure in this environment may reduce local flushing with consequences for assimilating effluent from existing wastewater outfalls.	Engineer port structures to prevent stagnate waters near coast. Move outfall pipes further offshore.	2	2	L (4)	Wastewater will be circulated and diluted.
						Climate change									
						Other industrial and urban growth	3	3	M (9)			3	3	M (9)	
						Cumulative pressure	*3*	*3*	*M (9)*	*Outfall pipes would likely increase with increased development but may be directed to SDOOL.*		*3*	*3*	*M (9)*	*Outfall pipes would likely increase with increased development but may be directed to SDOOL.*

Table 5: Preliminary unmitigated and mitigated risk assessment for marine and estuarine environmental values in Bunbury.

Ref #	Issue	Current risk C	L	R	DC	Future unmitigated risk Activity	C	L	R	Justification	Future harbour development mitigated risk Mitigation	C	L	R	Justification
Environmental value: Integral functioning ecosystem															
1	Decrease in ecosystem functioning with increased use and development in Koombana Bay	3	3	M (9)	L-M	Harbour development	3	3	M (9)	Port construction would not likely affect marine life in KB specifically as there is limited marine life currently present due to high turbidity. However marine life would migrate through KB to each the Inlet and Estuary. Already an operating port, but further expansion may impact on water and sediment quality and indirectly on the Inlet and Estuary. Climate change would change the functioning, but not necessarily cause a *decrease* if new species adapt to new conditions. As Bunbury becomes more populated, industrial and urban pressures on KB and surrounds would likely grow.	Use PIANC Working with Nature principles to engineer port structures and niche habitats, as well as keeping migration routes to and from the Inlet and Estuary relatively undisturbed.	2	2	L (4)	Niche habitats created need to be suitable for tropical species to inhabit *as well* in order to maintain a functioning, though different, ecosystem.
						Climate change	2	3	M (6)			2	3	M (6)	
						Other industrial and urban growth	3	3	M (9)			3	3	M (9)	
						Cumulative pressure	*3*	*4*	*H (12)*	*System has already undergone significant changes due to modifications to the coast- largely Leschenault Inlet and Estuary.*		*3*	*3*	*M (9)*	*Uncertainty around climate change impacts. Unsure of the management strategies that other industries would put in place to mitigate against a decrease in ecosystem functioning.*
Environmental value: Sheltered marine ecological community															
2	Alteration to the sheltered nature of Koombana Bay where dredge channels and built structures may impact on marine biota that depend on calmer waters	1	1	L (1)	M	Harbour development	3	3	M (9)	Development planned for inside of outer harbour and a dredge channel would be needed which may change circulation. Built structures may impact circulation on a localised scale, potentially causing stagnate waters or re-directing water flow. Any changes to or impacts of circulation would vary seasonally. Other industrial growth may influence localised flow if protruding from coast.	Engineer port structures to reduce stagnate waters.	2	2	L (4)	Still potential impact of shipping channel changing circulation but this may not necessarily be a bad thing for the health of KB.
						Climate change									
						Other industrial and urban growth	2	2	L (4)			2	2	L (4)	
						Cumulative pressure	*3*	*3*	*M (9)*	*Flushing times for Koombana Bay are estimated to be 4-6 days and for the inner harbour 40-90 days, so shipping channel may shorten flushing times.*		*2*	*2*	*L (4)*	*Low risk of altering the sheltered nature of KB.*

Ref #	Issue	Current risk C	L	R	DC	Future unmitigated risk Activity	C	L	R	Justification	Future harbour development mitigated risk Mitigation	C	L	R	Justification
Environmental value: Biological diversity															
3	Decrease in species diversity due to reduction of suitable habitat, invasive species and altered environmental conditions	2	2	L (4)	M	Harbour development	4	3	H (12)	Invasive species from increased vessel traffic could outcompete native species, and there are already invasive species in the area. In KB, most fish species are found in the shallows, which is where development would occur. Fish are mobile so they could move to other suitable areas if available. Temporal trends in abundance or diversity are not clear due to limited monitoring. Tropicalisation may not necessarily decrease biological diversity, as new species will be entering KB and some current species may have time to gradually adapt. Shipping channel would be likely to continually disturb benthos through prop wash, and if dredging occurs, benthic communities would be directly impacted.	Use PIANC working with nature principles to engineer ecological niche areas for valuable species. Implement additional monitoring measures to reduce incidence of marine pests. Engineer walls of built structures to be native species friendly in order to reduce establishment of invasive.	3	3	M (9)	Risk of invasive species is still an issue, but early detection may help to localise any negative effects to species diversity.
						Climate change	2	3	M (6)			2	3	M (6)	
						Other industrial and urban growth	2	2	L (4)			2	2	L (4)	
						Cumulative pressure	*4*	*3*	*H (12)*	*Invasive species could impact system wide functioning and cause declines or local extinctions of populations. Leschenault Inlet has relatively low diversity compared with the once connected Leschenault Estuary. Species diversity in KB is relatively low due to high turbidity and lack of benthic producers. Leschenault Estuary is thought to be globally significant in terms of the high richness of foraminifera species.*		*3*	*3*	*M (9)*	*Efforts to reduce invasive species would benefit the whole system. Would still have localised patches of habitat destroyed with any coastal development but may not necessarily cause a decline in biodiversity if other similar habitat is available.*

Ref #	Issue	Current risk C	L	R	DC	Future unmitigated risk Activity	C	L	R	Justification	Future harbour development mitigated risk Mitigation	C	L	R	Justification
Environmental value: High level of water quality															
4	Decrease in quality of water due to increased development and altered environmental conditions	3	4	H (12)	M-H	Harbour development	3	4	H (12)	Port development and operation could increase nutrients and contaminants in the water column from run-off and resuspension of sediments with high nutrient and contaminant loading. Decayed material collects in current dredge channel and is thought to be cause of increased nutrient levels in harbour waters. Dredging and continual propeller wash would increase turbidity, though KB is already a turbid environment. More vessels in KB also increases the risk of oil and fuel spills. Climate change will elevate temperatures inside KB, which could contribute to frequent toxic phytoplankton blooms as well as potential dead zones due to increases oxygen consumption. No phytoplankton blooms recorded in Koombana Bay since 1995 monitoring began. Climate change may also increase the incidence of flooding and increase acidification of the water. Other industrial and urban growth could increase the contamination of groundwater with excess nutrients and contaminants, which would then increase legacy issues for KB and Estuary.	Better management of groundwater, storm water and run off to reduce nutrients entering LI and KB. Additional dredge management options should be considered e.g. timing around high flushing periods or consideration of nepheloid layer in KB and outflow from Estuary during winter and spring. Dredge without overflow and discharge sediments safely. Design port to minimise vessel movement i.e. less turning and manoeuvring which would limit disturbance to sediments. Check maintenance records of vessels before port entry to reduce risk of oil spill and have first strike response kits in place to respond to level 2/3 oil spills as a minimum. Increased vigilance with management of fuel transfers. Upgrade waste water capture system or put in a second capture system to capture any remaining contaminants that may flow to Preston River and Vittoria Bay. Engineer structures to prevent coastal erosion if hydrology is changed from additional shipping channel.	2	3	M (6)	There would still be increased turbidity in the footprint of port from operations. Dredging plumes would still occur but sediments may not spread as far. If oil spills are responded to immediately, then impacts could remain localised. Use of chemicals and paints on vessels is regulated by Australian and international standards. Improved flushing of system from shipping channel may help to disperse turbid plumes generated from vessel movement.
						Climate change	4	3	H (12)			4	3	H (12)	
						Other industrial and urban growth	3	3	M (9)			3	3	M (9)	
						Cumulative pressure	*4*	*4*	*H (16)*	*Currently localised areas with poor water quality due to modifications to the coast and current operating port. The Estuary is considered to be under stress due to water quality and environmental change. Urban and industrial growth would increase groundwater contamination and nutrient loading, that would then enter into KB and the Estuary.*		*4*	*3*	*H (12)*	*If shipping channel improved flushing, then this would make improvements on other parts of the system. Industrial and urban growth will still continue to grow, putting more pressure on the system unless groundwater and any industrial outflows into KB can be heavily regulated. Climate change is an external driver.*

Ref #	Issue	Current risk C	L	R	DC	Future unmitigated risk Activity	C	L	R	Justification	Future harbour development mitigated risk Mitigation	C	L	R	Justification
Environmental value: High level of sediment quality															
5	Decrease in quality of sediments due to increased development	3	4	H (12)	M	Harbour development	3	3	M (9)	Likely increase in contamination of sediments with increased shipping and port operations. Bunbury would facilitate **mineral** exports, so load spills are possible and copper has been elevated in the inner harbour since copper concentrate exports started. Larger shipping channel may accumulate more decaying wrack and increase nutrient loading in the sediments There is a risk of exposing acid sulphate soils during development, and potential soils have been identified for the Leschenault Inlet and Estuary, but unknown for direct port footprint.	Remove contaminated sediments created from port operations. Larger shipping channel may improve flushing and reduce nutrient loads in sediments. Test for potential acid sulphate soils before developing port infrastructure.	2	2	L (4)	Use of chemicals and paints on vessels is regulated by Australian and international standards, so not a mitigation measure Westport can use. However, removal of contaminated sediments would help improve sediment quality.
						Climate change									
						Other industrial and urban growth	3	3	M (9)			3	3	M (9)	
						Cumulative pressure	*3*	*4*	*H (12)*	*Localised areas of contaminated sediments already in KB. Additional pressures would add to this.*		*3*	*3*	*M (9)*	*Some areas that have contaminated sediments are in proposed port footprint so could be removed during development which would help to improve health of system.*
Environmental value: Significant benthic communities and habitats- Seagrass															
6.1	Reduction in seagrass biomass and extent due to increased development and altered environmental conditions	2	3	M (6)	L-M	Harbour development	4	3	H (12)	Spread of suspended sediments from dredging and vessel movement may reach and impact on seagrass meadows outside of KB. Outflow of turbid plumes from the estuary can spread 10 km offshore during winter. Modelling of dredge suspended sediments from the inner harbour shows sediments entering Koombana Bay, Leschenault Inlet and Estuary and nearshore areas up to 8km north of The Cut; spread would be greater during winter than summer and concentrations would likely dissipate with increased distance from port. Increased incidence of marine heatwaves may cause decrease in seagrass biomass which occurred at Shark Bay. Some non-meadow forming patches of seagrass in KB which may be affected by development and increased nutrients in the system.	Manage dredging operations for tidal movements and water circulation. If conditions allow, use a silt screen during dredging. Additional dredge management options should be considered to protect benthic producers e.g. avoid winter when seagrass most vulnerable to low light. Rehabilitate new areas for seagrass colonisation now if predictions show a potential impact on meadows outside of KB. Design port to minimise vessel movement i.e. less turning and manoeuvring which would limit disturbance to sediments.	3	3	M (9)	Still a risk of dredge plume spreading but losses may be more localised. There would still be increased turbidity from vessel movement.
						Climate change	4	4	H (16)			4	4	H (16)	
						Other industrial and urban growth	2	2	L (4)			2	2	L (4)	
						Cumulative pressure	*4*	*4*	*H (16)*	*Even though meadows occur outside of KB, port development and operation still have the potential to impact. Climate change would likely have the most significant impact over time.*		*4*	*4*	*H (16)*	*Climate change impacts are external drivers.*

Ref #	Issue	Current risk C	L	R	DC	Future unmitigated risk Activity	C	L	R	Justification	Future harbour development mitigated risk Mitigation	C	L	R	Justification
Environmental value: Significant benthic communities and habitats- Mangroves															
6.2	Degradation of mangrove habitat due to increased development and changing environmental conditions	2	3	M (6)	M	Harbour development	4	2	M (8)	Further increases in salinity in Leschenault Inlet due to less storm water input may cease growth or degrade mangroves as it is believed to be the current cause of slow expansion since the excavation of The Cut and the blocking of Preston River delta. Conversely, warming of waters may see an increase in the occurrence of mangroves as far south as Bunbury. Development may cause degradation to mangrove habitat and reduce biodiversity as a whole in the Inlet. The mangrove area and mudflats have over 100+ species. Port footprint does not directly remove mangrove habitat but does sit adjacent to mangroves in the Inlet. Mangroves cope with turbidity well. Other development could occur around the Inlet that may impact upon mangroves. Mangroves so far appear to be coping with an operating port, however if it did have an impact, it would affect the population rather than a small localised patch because the mangroves in the Inlet are clustered together. Some patches of mangroves occur in the Estuary.	Use PIANC Working with Nature principles to ensure current mangrove habitat remains in place and additional room for expansion is allowed for.	2	2	Low 4)	As port occurs to close to other development that surrounds mangroves, then allowing room for expansion of mangroves would help to reduce the impact that other development may have as well.
						Climate change	3	3	M (9)			3	3	M (9)	
						Other industrial and urban growth	4	2	M (8)			2	2	Low 4)	
						Cumulative pressure	*4*	*3*	*H (12)*	*Mangroves in Leschenault Inlet are already surrounded by development and appear to be coping. However, they are occurring at their southern limit so any impacts are likely to be exacerbated.*		*3*	*3*	*M (9)*	*Climate change an external driver.*
Environmental value: Significant benthic communities and habitats- Other															
6.3 6.4 6.5 6.6 6.7	Degradation of other benthic communities due to increased development	2	2	L (4)	L	Harbour development	3	3	M (9)	Rocky reef on eastern margin of KB may be negatively impacted if further development occurred, however dominant biota is foliose and canopy algae which would be able to recover relatively quickly. A decline in primary productivity (e.g. microphytobenthos or turf algae) for soft sediments in KB may occur due to increased turbidity and sediment disturbance. Sponges may be negatively impacted if there is a reduction in water quality, including turbidity and sedimentation, which could spread to sponge gardens north of KB. A decrease in biodiversity of mud flats could occur due to degradation or removal of habitat. A decline of artificial reef habitat west of KB could occur due to spread of suspended sediments from dredging, however foundation artificial reef would still remain for marine life to re-establish. Increased vessel traffic may deter fishes from artificial reef though fish may return to artificial structure during periods of low vessel traffic or adjust their behaviours. Other development may have an impact on mudflats such as in Inlet.	Use PIANC Working with Nature principles to create niche habitat areas. Manage dredge and turbidity plumes and for tidal movements and water circulation to reduce risk of spreading to surrounding habitats.	2	2	L (4)	As port occurs to close to other development that surrounds benthic habitats, creating niche habitat areas may help to reduce the impact that other development may have as well.
						Climate change									
						Other industrial and urban growth	3	3	M (9)			2	3	M (6)	
						Cumulative pressure	*3*	*3*	*M (9)*	*Not enough information to assess climate change impacts on mentioned benthic communities though it is likely to play a role in future scenarios.*		*2*	*3*	*M (6)*	*Still potential impacts from other industrial and urban growth.*

Ref #	Issue	Current risk C	L	R	DC	Future unmitigated risk Activity	C	L	R	Justification	Future harbour development mitigated risk Mitigation	C	L	R	Justification
Environmental value: Listed and significant fauna- Fairy terns															
7.1	Decline in abundance and breeding success of fairy terns due to impacts on habitat and prey species	2	3	M (6)	L-M	*Harbour development*	*4*	*3*	*H (12)*	*Loss of shoreline habitat due to development and/or sea level rise. Preferred nesting spot is likely McKenna Pt within the current outer harbour and proposed port development lies adjacent to the area. Over time risk will increase with sea level rise. Lack of nesting sites would impact the population. Bioaccumulation of contaminants through the food chain could negatively affect survival and/or breeding success. TBT is being reduced, though there is potential for other contaminants to impact populations. Port operations my increase contaminants in the water and sediments. Other sites include Barr Island and Leschenault Peninsular and these sites are impacted by human disturbances e.g. 4WD, beach users and predators. Urban growth would increase risk of entanglement in fishing gear and rubbish.*	Use PIANC Working with Nature principles to incorporate protected bird friendly areas for current and future use. Develop a temporary or permanent nesting sanctuary at McKenna Point free of human disturbance and development. Areas of contaminated sediments could be removed and contamination of the water column heavily regulated to reduce bioaccumulation.	2	3	M (6)	Still don't know the impacts of bioaccumulation of contaminants, so if this doesn't cause death or reduced breeding success, then risk would be 'low'.
						Climate change	4	3	H (12)			4	3	H (12)	
						Other industrial and urban growth	3	3	M (9)			3	3	M (9)	
						Cumulative pressure	*4*	*4*	*H (16)*	*Feral predators also pose a risk to fairy tern abundance. Impacts to nesting sites would influence the overall population- i.e. mating opportunities.*		*4*	*3*	*H (12)*	*Sea level rise is still a major risk to nesting sites and is an external driver. Other nesting sites still exposed to human disturbance. However, having a protected nesting site at the already favoured McKenna may mean terns don't choose to nest at alternative sites as often.*

Ref #	Issue	Current risk C	L	R	DC	Future unmitigated risk Activity	C	L	R	Justification	Future harbour development mitigated risk Mitigation	C	L	R	Justification
Environmental value: Listed and significant fauna- Little penguins															
7.2	Decline in abundance and breeding success of little penguins due to a decline in foraging habitat and prey species, as well as increased collisions with recreational vessels	2	2	L (4)	M	Harbour development	4	4	H (16)	Penguin Island penguins have consistently been tracked down to coastal area adjacent to Bunbury from Kwinana region as KB is a core foraging area. No breeding colonies in Bunbury. Bioaccumulation of contaminants through the food chain could affect survival and/or breeding success. Increase in deaths from collisions with increasing recreational boat traffic is possible given it is a top cause of death. Warming sea temperatures would influence the distribution of prey. Penguins have been shown to utilise the area in years where there has been above average sea surface temperature. Urban growth would increase risk of entanglement in fishing gear and rubbish and increased collisions.	Use PIANC Working with Nature principles during port design. Areas of contaminated sediments could be removed during port development and when levels exceed guidelines in order to reduce bioaccumulation. Reduce recreational boat speeds in a large area around the port which would lessen the risk overall for penguins if they use those areas. Given that the port footprint would condense recreational vessel use into a smaller area, educational programs could be developed for boat users. Restrict vessel routes and speed limits. Conduct regular surveys of shoreline to look for dead penguins and perform necropsies to determine cause of death. Reduce removal of wrack and damage to seagrass meadows. Conduct boat cleaning above water line. Reduce underwater noise pollution.	3	3	M (9)	Still possibility of having some impacts on penguin populations due to port operations.
						Climate change	2	4	M (8)			2	4	M (8)	
						Other industrial and urban growth	2	3	M (6)			2	3	M (6)	
						Cumulative pressure	*4*	*4*	*H (16)*	*Risks are lower for penguins in KB as penguins are only temporarily visiting the region. If future colonies establish due to climate change then risks would increase.*		*3*	*3*	*M (9)*	*Climate change an external driver. Though Westport could help to reduce vessel speeds and educate boat users given that the port would indirectly contribute to high vessel density, rules would need to be enforced. Rising sea temperatures is an external driver.*

Ref #	Issue	Current risk C	L	R	DC	Future unmitigated risk Activity	C	L	R	Justification	Future harbour development mitigated risk Mitigation	C	L	R	Justification
Environmental value: Listed and significant fauna- Bottlenose dolphins															
7.3	Decline in resident and other populations due to a decline in foraging habitat, prey species and anthropogenic influences i.e. boat strikes, fishing entanglements and underwater noise	4	4	H (16)	M	Harbour development	4	3	H (12)	High quality of prey items that resident dolphins target may decline due to loss of habitat or contamination. Dolphins use KB and the Estuary foraging. Increase in underwater noise from development and construction could deter dolphins from their usual habitats and interrupt communications between dolphins. Dolphin abundances may decline and movement patterns altered for the Bunbury area under a changing climate. Increased tourism and feeding of dolphins could increase vessel strikes as well as increased risk of entanglement in fishing gear with increased recreational use of Koombana Bay.	Use PIANC Working with Nature principles to create niche areas for dolphins to forage and design structures of port that do not interrupt passage of dolphins to favoured areas. Avoid conducting noisy dredging operations and port maintenance (i.e. pile driving) during the breeding season when animals are socialising and calving. Engage Marine Mammal Observers to observe the occurrence of dolphins during the time development is occurring. Implement speed restrictions throughout most of Koombana Bay for all vessels.	2	3	M (6)	Creating niche areas would increase the occurrence of high quality prey.
						Climate change	4	3	H (12)			4	3	H (12)	
						Other industrial and urban growth	3	3	M (9)			3	3	M (9)	
						Cumulative pressure	*4*	*4*	*H (16)*	*The Bunbury population is currently forecast to decline. Accumulated pressures may cause dolphins to avoid KB and surrounds, more so than cause direct death to dolphins, and would impact the value being present in KB.*		*4*	*3*	*H (12)*	*Still issues with illegal feeding, entanglement in fishing gear and vessel strikes which would likely increase with urban growth. Climate change impacts on prey species is an external driver.*
Environmental value: Listed and significant fauna- migratory shorebirds and seabirds															
7.4	Decline in abundance and breeding success due to impacts on habitat and prey species	2	3	M (6)	L-M	Harbour development	4	3	H (12)	Sea level rise could inundate important shoreline habitat. Increased coastal development could remove important habitat. Bioaccumulation of contaminants through the food chain could negatively affect survival and/or breeding success. Loss, degradation, or complete removal of Preston River Delta could reduce the regional significance of the location for birds. Rising sea temperatures would influence distribution of prey. Urban growth would increase risk of entanglement in fishing gear and rubbish.	Use PIANC Working with Nature principles to create niche areas for birds to forage and incorporate coastal stretches for birds to nest and move up shore as sea level rises. Areas of contaminated sediments could be removed to reduce risk of bioaccumulation. **If port development intersects Preston River, then redirection of river back to Vittoria Bay would have less impact that truncation into the inner harbour.**	3	3	M (9)	Port operations may still cause some temporary or prolonged disturbance to birds using niche areas. Redirection of Preston River may still have lag effect.
						Climate change	4	3	H (12)			4	3	H (12)	
						Other industrial and urban growth	3	3	M (9)			3	3	M (9)	
						Cumulative pressure	*4*	*4*	*H (16)*	*Coastal development and human disturbance may impact on birds using coastal areas. Migratory birds frequent the same or similar locations year after year due to reliable conditions, so any impacts to known forging or nesting sites may have greater implications for migration.*		*4*	*3*	*H (12)*	*Climate change is an external driver and other coastal development and human disturbance may impact on birds using coastal areas.*

Ref #	Issue	Current risk C	L	R	DC	Future unmitigated risk Activity	C	L	R	Justification	Future harbour development mitigated risk Mitigation	C	L	R	Justification
Environmental value: Listed and significant fauna- Pouched lamprey															
7.5	Loss, degradation, or complete removal of Preston River Delta could reduce access to river and spawning opportunities in freshwater sources	2	3	M (6)	L	Harbour development	4	3	H (12)	**Development may alter the current state of the delta. Truncation of the river into the inner harbour instead of redirection into Vittoria Bay has been proposed. Redirection is also a possibility and this would also cause some disruption to the lampreys using the delta for access to Preston River, but may be more a 'medium' risk as lampreys would likely adjust to new conditions.**	If port development intersects Preston River, then redirection of river back to Vittoria Bay would have less impact that truncation into the inner harbour.	3	3	M (9)	Lampreys would still need to adjust to any modification of Preston River.
						Climate change									
						Other industrial and urban growth									
						Cumulative pressure	*4*	*3*	*H (12)*	*Priority 3 listed species under Wildlife Conservation Act of WA (not under imminent threat). Unknown what impacts climate change will have, so it is likely that the risk to the species will increase with more knowledge.*		*3*	*3*	*M (9)*	*Unknown what impacts climate change will have, so it is likely that the risk to the species will increase with more knowledge.*
Environmental value: Listed and significant fauna- Carter's Freshwater Mussel															
7.6	Further decline in abundance and occurrence of mussels due to reduced water quality (e.g. contamination) of the Preston River and environmental change	3	4	H (12)	L-M	Harbour development	3	2	M (6)	No mussels have been found in the Preston River in recent surveys. There is a risk that port expansion may impact on Preston River, though contamination of the river is already managed through a waste water capture system. Preston River may be at risk of becoming more saline under a drying climate, and mussels have a low tolerance of saline waters.	Upgrade waste water capture system or put in a second capture system to ensure high water quality in the Preston River.	2	2	L (4)	Limited impact of port operations on Preston River.
						Climate change	4	3	H (12)			4	3	H (12)	
						Other industrial and urban growth	3	2	M (6)			3	2	M (6)	
						Cumulative pressure	*4*	*3*	*H (12)*	*Threatened species under Wildlife Conservation Act of WA. Low tolerance of saline waters so likely that occurrence is limited in lower reaches of Preston River. Unknown what impacts climate change will have, so it is likely that the risk to the species will increase with more knowledge.*		*4*	*3*	*H (12)*	*Climate change an external driver.*

Ref #	Issue	Current risk C	L	R	DC	Future unmitigated risk Activity	C	L	R	Justification	Future harbour development mitigated risk Mitigation	C	L	R	Justification
Environmental value: Regionally significant spawning / nursery area- King George whiting															
8.1	Decline in abundance and loss of nursery area due to environmental changes and loss of habitat	2	2	L (2)	M	Harbour development	3	3	M (9)	Leschenault Inlet not directly in the footprint of the port, but there may be some degradation to Leschenault Inlet habitat, i.e. reduced water quality, which may negatively impact on an important nursery area. However, the Inlet is listed as a Priority 1 Priority Ecological Community for Western Australian due to the presence of relictual mangroves and therefor avoiding impacts to the Inlet from future development is strived for.	Use PIANC Working with Nature principles to create fish friendly habitat which could be used as nursery areas. Do not dredge during peak nursery use in case suspended sediments spread with unfavourable conditions.	2	3	M (6)	No guarantee that whiting will use created nursery areas if they have such a strong relationship with the Inlet.
						Climate change									
						Other industrial and urban growth	4	3	H (12)			4	3	H (12)	
						Cumulative pressure	*4*	*3*	*H (12)*	*Unknown what impacts climate change will have, so it is likely that the risk to the species will increase with more knowledge.*		*4*	*3*	*H (12)*	*Creating nursery areas would benefit the population overall and may provide an alternative if the Inlet is impacted by urban and industrial growth. Unknown what impacts climate change will have, so it is likely that the risk to the species will increase with more knowledge.*
Environmental value: Regionally significant spawning / nursery area- Whitebait															
8.2	Loss of favourable spawning area due to changes in environmental conditions	3	3	M (9)	L-M	Harbour development	4	3	H (12)	An increase in marine heatwaves would negatively impact spawning as reduced distribution and 2011 heatwave impacts suggest environmental limitations. There was reduced spawning success in winter of 2011 which resulted in low catches and catch rates. Rated as high risk to climate change. Added pressures of poor water quality from increased development may contribute to a decline.	Use PIANC Working with Nature principles to create fish friendly habitat. Do not dredge during peak spawning periods. Manage runoff to limit nutrients and contaminants entering the water.	2	3	M (6)	Still possible that stocks may be somewhat impacted due to increased use of KB.
						Climate change	4	4	H (16)			4	4	H (16)	
						Other industrial and urban growth	3	3	M (9)			3	3	M (9)	
						Cumulative pressure	*4*	*4*	*H (16)*	*Classified as unsustainable and inadequate. Climate change impacts would likely be the greatest threat to whitebait.*		*4*	*4*	*H (16)*	*Climate change is an external driver.*

Ref #	Issue	Current risk C	L	R	DC	Future unmitigated risk Activity	C	L	R	Justification	Future harbour development mitigated risk Mitigation	C	L	R	Justification
Environmental value: Regionally significant migratory pathway: Blue swimmer crab															
9.1	Decline in abundance and loss of nursery area due to environmental changes, reduced water quality and increased development	3	3	M (9)	L-M	Harbour development	3	3	M (9)	Environmental factors can influence abundances and is believed to be a cause of decline for stocks in Cockburn Sound. Reduced water quality can stress crabs making them more prone to infections such as shell disease, which was the cause of crab deaths in 2016. Reduced water quality may occur with increased use and development in KB. Increased urban and industrial growth would likely place more stress on water quality.	Use PIANC Working with Nature principles to create crab friendly habitat. Manage dredge and vessel generated turbidity to have least impact on surrounding habitats and spawning locations such as the Estuary.	2	3	M (6)	Port operations would still be occurring in areas that crabs use to migrate between KB, the Estuary and Inlet.
						Climate change	4	4	H (16)			4	4	H (16)	
						Other industrial and urban growth	3	3	M (9)			3	3	M (9)	
						Cumulative pressure	*4*	*4*	*H (16)*	*Climate change likely to be one of the biggest threats. Some concerns over declines in abundance in the Inlet.*		*4*	*4*	*H (16)*	*Climate change is an external driver and crabs are considered a 'high risk' to climate change (DPIRD).*
Environmental value: Leschenault Regional Park															
10	Degradation of park due effects of poor water quality and declining ecosystem function, as well as environmental change	3	4	H (12)	M	Harbour development	3	3	M (9)	Increase stress on the estuary will increase the occurrence of algal blooms and fish kills. Reduced water quality from port operations may impact the Estuary. Impacts due to storms and coastal erosion from climate change are recognised as needing management within the park. Storm events and erosion predicted to increase under a changing climate. Fertiliser use is one of the biggest contributors to high nutrient levels. Salinity expected to increase under a drying climate, though incidences of flooding which is predicted to increase may help to alleviate some of this.	Use PIANC Working with Nature principles to engineer ecological niche areas for valuable species that use both KB and the Estuary. Reduce impacts to water quality such as timing of dredging to reduce transport of sediments into the Estuary.	2	2	L (4)	
						Climate change	4	4	H (14)			4	4	H (14)	
						Other industrial and urban growth	3	4	H (12)			3	4	H (12)	
						Cumulative pressure	*4*	*4*	*H (14)*	*Estuary already showing signs of stress in the northern regions with algal bloom occurrences. Has adapted to being a wave dominated environment since The Cut was made. Salinity expected to increase under a drying climate.*		*4*	*4*	*H (14)*	*Fertiliser use is one of the biggest contributors to high nutrient levels. Climate change is an external driver.*

Ref #	Issue	Current risk C	L	R	DC	Future unmitigated risk Activity	C	L	R	Justification	Future harbour development mitigated risk Mitigation	C	L	R	Justification
Environmental value: Coastal processes															
11	Increased erosion and inundation of shorelines from rising sea levels, storms and changes to sediment transport	3	4	H (12)	L-M	Harbour development	1	2	L (2)	Koombana Beach and Yacht Club Groyne already face erosion issues. Risk of inundation to the Leschenault Inlet with rising sea levels and flooding. Stormwater pipes enter into the Inlet and could cause temporary flooding.		1	2	L (2)	
						Climate change	3	4	H (12)			3	4	H (12)	
						Other industrial and urban growth	1	2	L (2)			1	2	L (2)	
						Cumulative pressure	*3*	*4*	*H (12)*	*Bunbury listed as one of the most vulnerable locations to erosion in the south-west.*		*3*	*4*	*H (12)*	*Bunbury listed as one of the most vulnerable locations to erosion in the south-west.*

Table 6: Preliminary unmitigated and mitigated risk assessment for marine and estuarine social values in Bunbury.

Ref #	Issue	Current risk C	L	R	DC	Future unmitigated risk Activity	C	L	R	Justification	Future harbour development mitigated risk Mitigation	C	L	R	Justification
Social value: Heritage- Aboriginal															
1.1	Loss or degradation of important heritage sites with increased development	1	2	L (2)	H	Harbour development	3	4	H (12)	Leschenault Inlet and Koombana Bay are important contemporary areas for the Nyungar community. Leschenault Estuary, Koombana Bay and Preston River are all registered mythological sites. Alteration to Preston River would impact a mythological site, and current port footprint would directly cut across the river. Degradation to these areas could occur from increased use and development. Sea level rise could inundate some popular gathering areas.	Avoid port construction on important aboriginal sites or engineer built structures to incorporate sites and access to sites. Minimise modifications to Preston River.	2	4	M (8)	Still likely to be some impacts of port construction, particularly spatial extent.
						Climate change	3	4	H (12)			3	4	H (12)	
						Other industrial and urban growth	2	3	M (6)			2	3	M (6)	
						Cumulative pressure	*3*	*4*	H (12)	*Port development would be the biggest threat to this value due to the size and ongoing operations it would bring to the area.*		*3*	*4*	H (12)	*Unknown whether other industrial and urban growth will impact on sites. Climate change an external driver.*
Social value: Heritage- Maritime/historic															
1.2	Loss or degradation of important historical sites with increased development	1	2	L (2)	H	Harbour development	2	4	M (8)	One registered site occurs directly within port footprint and others occurring in immediate vicinity. Sea level rise could inundate some shore based sites.	Engineer port structures around shipwreck.	2	2	L (4)	Shipwreck location unaffected.
						Climate change	2	4	M (8)			2	4	M (8)	
						Other industrial and urban growth	2	2	L (4)			2	2	L (4)	
						Cumulative pressure	*2*	*4*	*M (8)*	*Quite a lot of registered sites occur right in KB and surrounds.*		*2*	*4*	*M (8)*	*Climate change an external driver.*

Ref #	Issue	Current risk C	L	R	DC	Future unmitigated risk Activity	C	L	R	Justification	Future harbour development mitigated risk Mitigation	C	L	R	Justification
Social value: Public health- Recreational water quality															
2.1	Increased safety concerns for primary and secondary contact with water due to decreased water quality	2	2	L (2)	M	Harbour development	4	2	M (8)	People use in Koombana Bay and Leschenault Inlet for water sports or leisure.	Time dredging operations with water circulation to avoid spread of sediments. Use a silt screen if conditions permit. Design port to minimise vessel movement i.e. less turning and manoeuvring which would limit disturbance to sediments. Monitor water quality regularly to detect any health concerns.	2	2	L (4)	Still may be temporary occurrences of reduced water quality that causes concern for contact with water, but likely not prolonged.
						Climate change									
						Other industrial and urban growth	2	2	L (4)			2	2	L (4)	
						Cumulative pressure	*4*	*2*	*M (8)*	*Perceptions of water quality would change with each person.*		*2*	*3*	*M (6)*	*Still may be temporary occurrences of reduced water quality that causes concern for contact with water, but likely not prolonged.*
Social value: Public health- Seafood quality															
2.2	Decrease in health of shellfish and fish with increased contamination in waters and sediments	3	3	M (9)	M	Harbour development	4	3	H (12)	Mussel tissue concentrations of copper, selenium and zinc have, at all sites, exceeded the food guideline values at some point in time and is a human consumption risk. Contamination may increase with port construction and operation. Quality assurance monitoring is not performed for wild shellfish or fish. Would reduce recreational and commercial fishing as well as aquaculture if contamination levels exceeded guidelines. Would impact on favourite past times and social gatherings. May cause death and wash up of marine life.	Remove contaminated sediments associated with port operation. Dredge without overflow and discharge sediments safely. Design port to minimise vessel movement i.e. less turning and manoeuvring which would limit disturbance to sediments.	2	3	M (6)	Use of chemicals and paints on vessels is regulated by Australian and international standards.
						Climate change									
						Other industrial and urban growth	3	3	M (9)			3	3	M (9)	
						Cumulative pressure	*4*	*3*	*H (12)*	*Food guidelines have been exceeded already for mussels under current use of KB.*		*3*	*3*	*M (9)*	*Industrial and urban growth could contribute to poor water quality over time.*

Ref #	Issue	Current risk C	L	R	DC	Future unmitigated risk Activity	C	L	R	Justification	Future harbour development mitigated risk Mitigation	C	L	R	Justification
Social value: Social and community: Recreational fishing															
3.1	Decrease in recreational fishing with increased development	3	3	M (9)	M	Harbour development	3	3	M (9)	Decrease of recreational fishing with port development due to restrictions. Some fishing would take place in Koombana Bay but is more popular in the Leschenault Estuary and the Inlet. Degradation of Leschenault Inlet could occur with port development. Concerns over reducing abundance of crabs in the Inlet. Rising sea temperatures likely to shift fish distributions. Industrial and urban growth could contribute to poor water quality and decline in fish abundances over time.	Use PIANC Working with Nature principles to engineer ecological niche areas for valuable species, as well as fisher friendly structures. Avoid dredging during spawning periods. Rehabilitate seagrass meadows now to avoid a lag in ecosystem functioning, if port is predicted to impact on coastal meadows.	2	2	L (4)	PIANC principles may help to improve recreational fishing in KB and surrounds.
						Climate change	4	3	H (12)			4	3	H (12)	
						Other industrial and urban growth	3	3	M (9)			3	3	M (9)	
						Cumulative pressure	*4*	*4*	*H (16)*	*Recreational fishing is a strong social value in Bunbury.*		*4*	*3*	*H (12)*	*Climate change an external driver. Industrial and urban growth could contribute to poor water quality over time.*
Social value: Social and community: Recreational swimming															
3.2	Degradation of swimming beaches due to increased development	2	2	L (4)	M	Harbour development	3	3	M (9)	Koombana Beach, Ski Beach, Jetty Baths are popular for swimming and are in the vicinity, but not directly in the port footprint. People would likely avoid swimming due to aesthetics of turbid water, or perceived low health and safety. Would be temporary. Other industrial development may disturb swimming beaches. Sea level rise and erosion could impact access points for beaches that are used for swimming.	Time dredging operations with water circulation to avoid spread of sediments. Use a silt screen if conditions permit. Design port to minimise vessel movement i.e. less turning and manoeuvring which would limit disturbance to sediments.	2	2	L (4)	Beaches are not directly removed so mitigating for good water quality is all that is needed.
						Climate change	2	3	M (6)			2	3	M (6)	
						Other industrial and urban growth	2	2	L (4)			2	2	L (4)	
						Cumulative pressure	*3*	*3*	M (9)	*Swimming currently considered safe in KB, and there are multiple beaches to access for the purposes of swimming.*		*2*	*3*	*M (6)*	*Climate change an external driver. Unknown impacts of other industrial and urban growth.*

Ref #	Issue	Current risk C	L	R	DC	Future unmitigated risk Activity	C	L	R	Justification	Future harbour development mitigated risk Mitigation	C	L	R	Justification
Social value: Social and community: Recreational water sports															
3.3	Decrease in water sports with increased development and environmental change	1	2	L (3)	L-M	Harbour development	2	2	L (4)	Leschenault Inlet most popular for recreational sports. Could still be used for sports despite turbidity or lower water quality. Footprint of port does not directly impact on Inlet. Water sports in KB would likely be restricted to certain areas. Several water sports clubs have leased land on the foreshore of the Inlet, which would be at risk from sea level rise due to insufficient set back.	Designate new recreational areas specifically for water sports if port development removes access to favoured areas.	1	2	L (2)	Port not likely to impact significantly, or at all, on water sports.
						Climate change	3	3	M (9)			3	3	M (9)	
						Other industrial and urban growth	2	2	L (4)			2	2	L (4)	
						Cumulative pressure	*3*	*3*	*M (9)*	*Water sports popular in CS and surrounding bays.*		*3*	*3*	*M (9)*	*Climate change an external driver.*
Social value: Social and community: Recreational boating access															
3.4	Flooding occurrences via storm water outfalls may impact on boat ramps in Leschenault Inlet	1	2	L (3)	M	Harbour development	1	2	L (2)	Port footprint does not remove current boat access. Temporary flooding in the Inlet will impact access and may be an increased risk long term with increased sea level.	No mitigation.	1	2	L (2)	
						Climate change	3	3	M (9)			3	3	M (9)	
						Other industrial and urban growth	2	2	L (4)			2	2	L (4)	
						Cumulative pressure	*3*	*3*	*M (9)*			*3*	*3*	*M (9)*	*Climate change an external driver.*
Social value: Social and community: Marina facilities															
3.5	Reduced use of marina facilities with increased development	1	2	L (2)	M	Harbour development	2	2	L (4)	Depends on structures built and shipping channel- current footprint indicates rock groynes will be built near the Casuarina harbour. Potential restrictions on Casuarina Boat Harbour entry and exit with increased port development. Quality of marina may decline with increased use and development. Sea level rise and erosion may impact on some marine facilities.	Ensure ease of access to marina with port development.	2	2	L (4)	Still may be impacts to perceived quality of marina- i.e. increased turbidity.
						Climate change	3	3	M (9)			3	3	M (9)	
						Other industrial and urban growth	2	2	L (4)			2	2	L (4)	
						Cumulative pressure	*3*	*3*	M (9)	*Marinas likely to be upgraded over time rather than removed due to other further development. Climate change likely biggest threat if there is insufficient set back of coastal structures.*		*3*	*3*	M (9)	*Climate change an external driver.*

Ref #	Issue	Current risk C	L	R	DC	Future unmitigated risk Activity	C	L	R	Justification	Future harbour development mitigated risk Mitigation	C	L	R	Justification
Social value: Social and community: Educational and scientific values															
3.6	Degradation of mangrove habitat would impact educational experiences and value for scientific purposes	1	2	L (2)	M	Harbour development	3	3	M (9)	Habitat may degrade over time with increased development if not managed sufficiently. Potential loss of birds and reduction in bird watching. Salinity in Inlet likely to increase under climate change which may cease growth of mangroves.	Adopt PIANC Working with Nature principles maintain a functioning mangrove ecosystem.	2	2	L (4)	PIANC principles may help to improve the functioning of the ecosystem not just maintain it.
						Climate change	2	3	M (6)			2	3	M (6)	
						Other industrial and urban growth	3	3	M (9)			3	3	M (9)	
						Cumulative pressure	*3*	*3*	*M (9)*	*Mangroves are completely surrounded by development.*		*3*	*3*	*M (9)*	*Climate change is an external driver. Surrounding future developments may have negative impacts.*
Social value: Social and community: Landscape and visual amenity															
3.7	Less visitation due to increased development negatively impacting on the landscape and visual amenity	2	2	L (4)	M	Harbour development	3	3	M (9)	Scenic boardwalk through mangrove habitat may lose scenic quality if habitat is degraded with increased development. Lack of visitation to Bunbury due to obstruction of expansive views of the ocean horizon with large vessels and/or building and structures, as well as sightings of dredge plumes. Increase in vessel traffic will occur if operations expand, and the shipping channel spreads right across Koombana Bay. Some vessels already operating in the bay. Erosion may reduce visual amenity and access at popular beaches and coastlines, such as Koombana Beach.	Manage dredging with water circulation to reduce spread of plumes. Use a silt curtain if allowable.	2	3	M (6)	Still may displace some users who think KB has become too industrialised.
						Climate change	3	3	M (9)			3	3	M (9)	
						Other industrial and urban growth	2	2	L (4)			2	2	L (4)	
						Cumulative pressure	*3*	*3*	*M (9)*	*Attractions of KB will vary per person. Port would be the biggest infrastructure project that would impact on visual amenity.*		*3*	*3*	*M (9)*	*Climate change an external driver. Unknown impacts of other industrial and urban growth.*

Ref #	Issue	Current risk C	L	R	DC	Future unmitigated risk Activity	C	L	R	Justification	Future harbour development mitigated risk Mitigation	C	L	R	Justification
Social value: Business, industry and commercial: Tourism															
4.1	Loss of tourism due to increased development, loss of marine life and environmental change	2	2	L (4)	M	Harbour development	4	3	H (12)	Reduced wildlife tourism due to loss of marine life and habitat degradation. Dolphin Discovery Centre would be significantly impacted if resident dolphin populations were displaced. Displacement of tourist activities with port development could occur, though a lot of tourist activities would occur in the Inlet. Increased erosion of Koombana Beach may leave a negative impression. Other industrial and urban growth could contribute to poor water quality and habitat degradation in KB and surrounds, though likely to also attract more tourists. Most recent tourism development strategy for Bunbury (2015-2019) includes developing a new marina that can facilitate cruise ships, dive boats and dolphin cruises.	Adopt PIANC Working with Nature principles to maintain a functioning ecosystem.	2	3	M (6)	Still restricted areas around port and visual amenity may also contribute to customer satisfaction.
						Climate change	2	2	L (4)			2	2	L (4)	
						Other industrial and urban growth	2	2	L (4)			2	2	L (4)	
						Cumulative pressure	*4*	*3*	*H (12)*	*Tourism is continually growing for Bunbury.*		*2*	*3*	M (6)	*Unknown impacts of other industrial and urban growth.*
Social value: Business, industry and commercial: Commercial fisheries															
4.2	Decrease in commercial fishing due to habitat loss and degradation with increased development, as well as environmental change	3	3	M (9)	M	Harbour development	3	3	M (9)	No commercial fishing allowed in the inner or outer harbour areas due to current port operations. If Leschenault Estuary or Inlet are affected by further development in the area, this may reduce fish stocks which use coastal areas during their life cycle. Climate change would influence the distributions of fished species.	Use PIANC Working with Nature principles to engineer ecological niche areas for valuable species, as well as fisher friendly structures. Design port so that migration pathways are not disturbed. Avoid dredging during spawning periods. Rehabilitate seagrass meadows now to avoid a lag in ecosystem functioning, if port is predicted to impact on coastal meadows.	2	2	L (4)	PIANC principles may increase the abundance of fished species.
						Climate change	4	3	H (12)			4	3	H (12)	
						Other industrial and urban growth	3	3	M (9)			3	3	M (9)	
						Cumulative pressure	*4*	*4*	*H (16)*	*Many different species are targeted in the Bunbury region, including species that rely on the Leschenault Estuary.*		*4*	*3*	*H (12)*	*Climate change an external driver. Unknown impacts of other industrial and urban growth.*

Appendix 5

Table 1: Responses to comments resulting from a review of this document by the Westport Environmental Work Stream. All corrections have been incorportated into the document.

Section	Specific	Comment	WAMSI response
Executive summary			
Purpose and approach	First paragraph	Some words deleted and added	Corrected
	First dot point	Reference? EWS Stage One Progress Report Nov 2018	Added
	Third and fourth dot points	Sentence restructure	Corrected
Important findings from the literature review	Fremantle Social: dot points 3 and 4	Added additional information for more context	Included
	Kwinana Social: dot points	Added additional data point: Tourism is important at Rockingham with diving and dolphin encounters being some popular options	Included
	Kwinana Social: dot points	Is the 'Indian Ocean' also relevant to Fremantle and Bunbury?	It is relevant for Fremantle and Kwinana and mentioned in the literature reviews. Not all findings were included in the Exec Sum, but will amend to include this site for Fremantle
	Bunbury Environmental dot points	Added: Leschenault estuary and Inlet are regionally significant nursery areas for blue swimmer crabs	Included
	Bunbury Social dot point 6	Reworded to say: Commercial fishing *for rock lobsters* occurs *on reefs around in and offshore* Koombana Bay with some restrictions in place for within the bay itself	Called DPIRD Bunbury office. Only recreational fishing for lobster occurs and done so outside of Koombana Bay (depending on where the boundary of KB is set), usually to the north. A low level of commercial fishing for baitfish (whiting and herring) occurs along the beaches within Koombana Bay at certain times of the year. Have changed to say: **Commercial fishing occurs outside of Koombana Bay, though some low level fishing for baitfish occurs at certain times of the year along the beaches of the Bay**
High risk values and preliminary mitigation measures	First paragraph	This would benefit from an introductory paragraph, rather than jump in to Freo. After paragraph, have a heading for each of Freo, Kwinana, Bunbury.	Included

Section	Specific	Comment	WAMSI response
	First paragraph	FPA questions the high risks to bottlenose dolphins and commercial fishing (mentioned for the Fremantle area of interest) and requests clarification	Not changed. DOLPHINS: Review by Delphine Chabanne mentions: Swan Canning Riverpark community is a sink within a source-sink dynamic system: the genetic flow is asymmetric with flow from Owen Anchorage – the source – to the Swan Canning Riverpark while very limited from the Swan Canning Riverpark to Owen Anchorage. **Connection through the inner harbour is critical for the survival of the dolphin community in the Swan Canning Riverpark**. Manuscript in prep and data also presented in Chabanne 2017 PhD thesis. In addition, to justify the high risk given for cumulative pressures on dolphins, Delphine suggested: 'accumulate pressures may cause dolphins to limit transitions / access between SCR and adjacent waters, more so than cause direct death to dolphins, and would impact the value being present in SCR'. COMMERCIAL FISHING: this risk rating was based on a medium level of data confidence, and the extent to which commercially fished species will be impacted by port expansion is somewhat unknown. Commercial fishing operators will be impacted if commercial fish using the inner harbour as a thoroughfare are negatively impacted by increased port activities.
	First paragraph	WHA suggests adding additional text (in red) "…which largely reflects the presence of a major working port, historical changes and relatively small area of footprint."	Added in historical changes, but not 'relatively small area of footprint' as this would require further justification and comparison to other ports. Combined with Matt's suggested inclusion, the sentence now reads: Fremantle was the area of interest with the lowest number of high risks scores, which largely reflects historical changes, its existing status as a major working port and a highly engineered environment.
	Exec Sum p2	General questioning of high risks identified for Fremantle.	Not changed. DOLPHINS: Review by Delphine Chabanne mentions: Swan Canning Riverpark community is a sink within a source-sink dynamic system: the genetic flow is asymmetric with flow from Owen Anchorage – the source – to the Swan Canning Riverpark while very limited from the Swan Canning Riverpark to Owen Anchorage. **Connection through the inner harbour is critical for the survival of the dolphin community in the Swan Canning Riverpark**. Manuscript in prep and data also presented in Chabanne 2017 PhD thesis. In addition, to justify the high risk given for cumulative pressures on dolphins, Delphine suggested: 'accumulate pressures may cause dolphins to limit transitions / access between SCR and adjacent waters, more so than cause direct death to dolphins, and would impact the value being present in SCR'. COMMERCIAL FISHING: this risk rating was based on a medium level of data confidence, and the extent to which commercially fished species will be impacted by port expansion is somewhat unknown. Commercial fishing operators will be impacted if commercial fish using the inner harbour as a thoroughfare are negatively impacted by increased port activities.
FRE	First bullet point under ***High risk values and preliminary mitigation measures***(page ii)	WHA suggests expanding PIANC to full organisation name	Not expanded: PIANC is expanded in the abbreviations table following the Exec. Summ.
FRE	Second bullet point under ***High risk values and preliminary mitigation measures****(page ii): "Implementing additional monitoring measures to reduce incidence of marine pests"*	FPA suggests to include a reference to the introduced marine pest surveillance program (Statewide Array Surveillance Program - SWASP) for context. The risk of introduced marine pests is mentioned throughout the report, but no information on how this risk is managed. The plan is in place since 2010 and monitoring reports are completed twice a year. Review/reconsider wording under bullet point. "Implementing additional monitoring measures to reduce incidence of marine pests"	Included. Have revised mitigation measure wording to: "**Ensure continuation of the State Wide Array Surveillance Program (SWASP) for introduced marine pests and regular reporting**" throughout. Have included reference to the SWASP in literature review Table 2

Section	Specific	Comment	WAMSI response
FRE	Third bullet point under ***High risk values and preliminary mitigation measures****(page ii): "Avoiding noisy operations during the breeding season and stop when dolphins are present in the vicinity of operations"*	FPA requests clarification on what is meant by 'noisy ops'. General port ops cannot stop due to the presence of dolphins.	Clarified: "Avoiding noisy **dredging** operations and **port maintenance (pile driving)** during the dolphin breeding season and stop-work when dolphins are present in the vicinity of these noisy operations"
FRE	Third bullet point under High risk values and preliminary mitigation measures(page ii): *Engineering fish friendly structures*	Addition of: Engineering fish friendly **shoreline** structures	The word 'shoreline' not included as it restricts the options. Engineering **fisher** friendly and accessible structures along the shoreline would benefit recreational fishing. Engineering **fish** friendly structures (to benefit fish and their habitats) could be done away from the shoreline.
FRE	Fifth bullet point under ***High risk values and preliminary mitigation measures****(page ii): "Avoiding dredging during peak spawning and migration periods through the Inner Harbour"*	FPA requests clarification on this point. In 2010, dredging was carried out over a 12 month period and no significant impact was observed on marine species.	There were no reports discovered that directly measured impacts on marine species, other than benthic habitats- i.e. seagrass and coral. This suggested mitigation measure would benefit from further expert consultation as suggestions made in this report are only preliminary.
FRE	Sixth bullet point under ***High risk values and preliminary mitigation measures****(page ii): "Establishing new seagrass meadows to help avoid a lag in ecosystem functioning"*	FPA request clarification and notes that establishing new seagrass meadows has been shown to be extremely difficult.	This suggested mitigation measure would benefit from further expert consultation as suggestions made in this report are only preliminary. A note on the difficulty in establishing seagrass meadows has now been included in the report: Establishing new seagrass meadows on shallow sandy banks offshore, adjacent the harbour and upstream of the Inner Harbour to help avoid a lag in ecosystem functioning. **Establishing new seagrass meadows is difficult so allowing an appropriate time frame for establishment needs to be considered**
FRE	Last bullet point	Not sure that this applies to Fremantle port? Or are we talking about seagrasses in the Swan River estuary to improve its functioning? Not clear which ecosystem is at risk here. I would have thought that the Swan River was most at risk from increased traffic and utilisation of Fremantle harbour.	Both the Swan River estuary and offshore of the Inner Harbour were considered. Now reads: **Establishing new seagrass meadows on shallow sandy banks offshore, adjacent the harbour and upstream of the Inner Harbour to help avoid a lag in ecosystem functioning. Establishing new seagrass meadows is difficult so allowing an appropriate time frame for establishment needs to be considered**
FRE		It incorrectly states that Fremantle had three high risk values when earlier reports listed zero.	Not sure if this comment is referring to earlier EWS reports, or this report. If it is referring to EWS reports, one purpose of this report was to refine the accuracy of the Westport Environmental Work Stream's initial assessment- and this is stated. It was expected that there would be differences in the assigned high risks between this report and EWS reports. If the statement is referring to this report, there were no instances where the number of high risks for Fremantle were reported as zero.
KWI	Text above KWI bullet points	WHA suggests that aquaculture is predominantly under threat by increased predation from fish and crabs and that - comparatively speaking - port development is a significantly lesser threat.	The impact of predation is noted in the literature review. There has been an incident relating to introduced pests (white sea squirts) in the past and the extent of the potential impact of nutrients on mussel growth due to the port cannot be ruled out.

Section	Specific	Comment	WAMSI response
KWI	Third bullet point in section on KWI *(page ii): "Implementing additional monitoring measures to reduce incidence of marine pests"*	FPA suggests to include a reference to the introduced marine pest surveillance program (Statewide Array Surveillance Program - SWASP) for context. - AS MENTIONED ABOVE	Included. Have revised mitigation measure wording to: "**Ensure continuation of the State Wide Array Surveillance Program (SWASP) for introduced marine pests and regular reporting**" throughout. Have included reference to the SWASP in literature review Table 3
KWI	Twelfth bullet point in section on KWI (page iii): *"Avoiding noisy operations during the breeding season when animals are socialising and calving, and Marine Mammal Observers could be engaged during development"*	FPA requests clarification on what is meant by 'noisy ops'.	Clarified: "Avoiding noisy **dredging** operations and **port maintenance (pile driving)** during the dolphin breeding season and stop-work when dolphins are present in the vicinity of these noisy operations"
KWI	First paragraph	Is impact on circulation/hydrodynamics a risk?	Potentially, but without concrete port designs to assess, this was given a medium unmitigated risk based on: No modifications to Garden Island Causeway, however new dredge channels may significantly impact on circulation in some parts of the Sound. Built structures may impact circulation on a localised scale, potentially causing stagnate waters or re-directing water flow. Any changes to or impacts of circulation would vary seasonally (under Sheltered marine embayment). This could be reviewed after the hydrological modelling takes place.
KWI		Has anyone thought of creating artificial seagrass meadows rather than growing new ones. The Fisheries Dept uses artificial seagrass "mops" to catch the Peurulus larvae of rock lobsters each year to determine the strength of recruitment to the fishery. Perhaps another area for research?	Included as a knowledge gap
KWI	2nd last bullet point	Inclusion of shoreline: Engineering fish/fisher friendly **shoreline** structures	The word 'shoreline' not included as it restricts the options. Engineering **fisher** friendly and accessible structures along the shoreline would benefit recreational fishing. Engineering **fish** friendly structures (to benefit fish and their habitats) could be done away from the shoreline.
KWI		It states in earlier reports Kwinana had 15 High Risk values (there were 19)	Uncertain whether this comment is referring to earlier EWS reports, or this report. If it is referring to EWS reports, one purpose of this report was to refine the accuracy of Westport EWS's initial assessment- and this is stated. It was expected that there would be differences in the assigned high risks between this report and EWS reports. If the statement is referring to this report, then a very small discrepancy was found between the executive summary and the risk tables, which is now fixed (15 changed to 14). It was also made clear that that high risks mentioned in the executive summary are harbour related high risks, not cumulative.
BUN	First paragraph	When the inner harbour and outer harbour channel were created in the late 1970,s early 80's , blasting of the basalt rock caused many house walls to crack and upset residents. Today the houses are closer, bigger and more expensive. Included extra wording: "residential housing close to the outer and inner harbour"	Not included. This would be a terrestrial consideration?
BUN	First paragraph	What if it was just an expansion of the existing inner harbour, rather than in to Koombana Bay?	Assessment in report based off Fig. 3 which does show a channel through Koombana Bay.

Section	Specific	Comment	WAMSI response
BUN	3rd bullet point	Replace "Mechanically removing basalt rather than using explosives" with "Adopting low impact dredging methods to excavate basalt" as mechanical removable may not be feasible.	Replaced
BUN	8th bullet point	Which wastewater capture system? Presumably that of the existing port? Do we mean run-off drainage system?	Yes, the wastewater capture system of the existing port- Clarified now in text
BUN	9th bullet point	Not sure that this applies to Bunbury or would work in Koombana Bay	Amended to say 'Rehabilitation of seagrass meadows **outside of** Koombana Bay' as seagrass meadows aren't currently occurring in Koombana Bay
BUN	10th bullet point	Incorporating protected bird friendly areas within the harbour boundaries- Again not sure that this is a useful mitigation for Bunbury given the large number of bird friendly habitats that already occur in the estuary and Inlet	The Outer Harbour (McKinnon Pt) is believed to be the main nesting site for fairy terns which is only protected from beach users and 4wds because of the restricted access. This colony should be protected if port expansions are to occur for Bunbury.
Information gaps	First bullet point under Information gaps (page iii): *Updated measurements...*	WHA suggests adding additional text (in red) "Updated measurements on groundwater nutrient concentrations, flux and contaminants."	Added
	Third bullet point under Information gaps (page iii): "*The impact of copper-based coatings or other TBT-replacement coatings for vessels on the marine environment*"	FPA notes that it "has good baseline data on copper levels at its sites in Cockburn Sound."	Acknowledged that this is good data to have if port activity increases
FRE	Only bullet point: *"Is the Inner Harbour habitat specifically utilised (i.e. foraging) by fish species migrating between the estuary and ocean?"*	FPA notes that Curtin University dolphin research may have looked at this question, further advice pending on whether this is a gap. FPA questions significance of gap.	Checked. There has been some BRUV and echosounder surveys done for fish in the Inner Harbour by Salgado-Kent et al. This report has not been released yet, but the conference abstract has been referenced. Has been removed as a gap.
KWI	7th bullet point "*Effects of PFAS on marine food webs*" (page iv)	WHA poses that along with PFAS old contaminants like Mercury are also important (found in penguins and terns). It would help what contaminants were in the wider food web.	Reworded to say: '**Effects of PFAS and other contaminants (i.e. mercury) on marine food webs**'
KWI		Inclusion of 'Experimentation into development of artificial niche foraging habitats for dolphins'	Included
KWI	3rd last bullet point	Why is PFAS only an issue in Kwinana?	PFAS didn't come through in the literature searches for the other two locations, but agree that this should be a general gap rather than specific to Kwinana
BUN	4th bullet point: Population and ecological studies on the giant cuttlefish that dolphins specialise in feeding on in Bunbury	Deleted the word specialise.	Change rejected- research specifically say 'specialisation'

Section	Specific	Comment	WAMSI response
BUN	2nd bullet point	Routine widespread monitoring of contaminants, refinement of trigger values and inclusion of reference sites - relevant for other two areas?	Yes, included for all three
Recommendations for next steps	Additional bullet point	WHA suggests to include development of ecological models - that allow scenario testing and that can be coupled with contemporary decision support models	Suggested added, but under gaps not recommendations for next steps
	2nd bullet point	Added in bold: Comprehensive risk analysis of environmental and social values based on more detailed harbour concepts and engagement with stakeholders and engineers **followed by preliminary EIA of preferred port infrastructure footprints and project descriptions**	Extra wording not included as not in WAMSI scope and can be followed up in further studies/reports.
	The outputs from this report were based on a rapid assessment of currently available literature and without knowledge on definite port footprints and specific engineering designs or project descriptions. This report is subject to, and must be read in conjunction with, the limitations, assumptions and qualifications contained throughout the report.	This is a very important statement and needs to be highlighted	Highlighted
Introduction			
1.1 Context	1.1.1 Fremantle	FPA notes that Inner Harbour was dredged to 14.7m in 2010	Corrected
	1.1.1 Fremantle	Deletion of 'as a result, sediments and benthic communities are continually disturbed in the region (SKM 2009c).'	Disagree and have left in
	1.1.1 Fremantle	An image of Freo would help here I think.	Agree. Does Westport have one we/they could add in?
1.2 Overview of current state of environment and key pressure points	1.2.1 Fremantle	FPA suggests to include a reference to the introduced marine pest surveillance program (Statewide Array Surveillance Program - SWASP) for context. - AS MENTIONED ABOVE	Added
	1.2.2 Kwinana - 1st paragraph	WHA notes that water quality issues (e.g. in southern section) and phytoplankton blooms in Cockburn Sound are not mentioned /discussed, but that these are significant and a critical water quality monitoring gap.	Water quality issues for the southern section of CS have been mentioned in the report, but a specific mention has now been added to this section.
	1.2.2 Kwinana - 1st paragraph	WHA notes that the outcomes of the snapper restocking project presumably are unknown and that - given current gaps (e.g. snapper holding capacity in the Sound) - it is unclear whether restocking in the future would have a positive effect.	Noted. Nothing added or changed.

Section	Specific	Comment	WAMSI response
	1.2.2 Kwinana - 2nd paragraph	WHA notes that surface water drainage may be a greater source of nutrient input into the Sound than groundwater input. WHA notes that contemporary groundwater studies are required to address this knowledge gap.	Amended knowledge gap to say: Updated measurements on **surface water drainage**, groundwater nutrient concentrations, flux and contaminants.
1.2 Overview of current state of environment and key pressure points		What are the "pressure points" mentioned on page 2?	The pressure points are listed in dot points underneath the mention of pressure points. The term "Pressure points" has been changed to "pressures" for clarity. These pressures are still the same dot points that are listed under the mention of "Pressures".
1.3 Purpose of this report	Table 1	WHA suggests that soft bottom environments should be a sub-category in Table 1	Not changed. The values in this table were what was assessed initially by EWS. The WAMSI assessment does include soft bottom sediments under 'Other' for significant benthic communities
Limitations		Option 5 (dredging new shipping channel) is not mentioned. Has this been eliminated or was it not considered for potential impacts?	Westport advised that this option was no longer for consideration
Layout of this report	Flow diagram	Nice figure. Where does section 3.5 and tables 27-29 fit in? Also the draft report does not follow this layout. It presents knowledge gaps and Recommendations for next steps at the end of the report. Which reads better as an overall conclusion to the report. So figure might need modification?	Amended schematic
Review of existing literature			
Table 2	2.3 Invasive species	FPA suggests to include a reference to the introduced marine pest surveillance program (Statewide Array Surveillance Program - SWASP) for context. - AS MENTIONED ABOVE	Done
	3. High level of water quality	FPA has conducted an annual marine quality monitoring program (MQMP) since 2001 and notes that copies of these reports are available upon request.	Noted. MQMP Reports were sought after to some extent but were not retrieved. Information from MQMP is presented in the literature review table but sourced from other reports that included the data. FPA have been contacted for these reports so they can be directly included.
	4. High level of sediment quality	FPA has conducted an annual marine quality monitoring program (MQMP) since 2001 and notes that copies of these reports are available upon request.	Noted. MQMP Reports were sought after to some extent but were not retrieved. Information from MQMP is presented in the literature review table but sourced from other reports that included the data. FPA have been contacted for these reports so they can be directly included.
	4.1 Contaminants	WHA notes that the info in this section may be out-of-date as some contaminant concentrations would have reduced since these studies were completed (e.g. TBT). New studies are required and these should investigate not just concentrations but also proportion of contaminants that are available to the environment.	Noted. The year of data collection has been added to the statements so that it is clear that more recent studies are lacking. However, if MQMP reports can be supplied by FPA and include contaminant data for sediments, then new studies may not be required.
Table 4	3.1 Fish assemblages	WHA notes that the species mentioned here (particularly *A. rueppellii*) have widespread, indo-pacific distributions and are relatively common around estuaries and coral reefs - in the case of *A rueppellii* from Darwin to Albany.	The word 'distinctive' was used in the literature, though it is now noted in the literature table that the statement was made in 1994. Changing climatic conditions may have caused the mentioned species to become more widespread since the study.

Section	Specific	Comment	WAMSI response
	4. High level of water quality	FPA has conducted an annual marine quality monitoring program (MQMP) since 2001 and notes that copies of these reports are available upon request.	Noted. MQMP Reports were sought after to some extent but were not retrieved. Information from MQMP is presented in the literature review table but sourced from other reports that included the data. FPA have been contacted for these reports so they can be directly included.
	4.3 Light attenuation/turbidity	WHA questions accuracy of statement that Cockburn Cement dredge plumes are generally intermittent and that water quality recovers by 75% within 6 hrs. WHA mentions that some work on this was done by Oceanica for Stage 2 CCL dredging approvals.	Statement came from Oceanica report 2011 on Cockburn Cement dredging. The statement reads: "There was an impact on water clarity and light conditions immediately after dredging at Parmelia and Success Banks; however, water quality within the plume recovered to 60-75 % of pre-dredge conditions after 5-6 hours". Text in literature review was changed from **up to 75%** to **60-75%** for better clarity.
	4.9 Groundwater	WHA questions whether groundwater is the major source of nutrient and contaminant inputs to the Sound. Considers that surface flows from urban areas and unmetered flows from the KIA are as important. Also noted there is no reference to a CSIRO report commissioned by the CSMC in 04/05 that describes the 12 major plumes in the Sound.	Amended knowledge gap to say: Updated measurements on **surface water drainage**, groundwater nutrient concentrations, flux and contaminants. The reference to the CSIRO report is in fact referenced under Trefry et al 2006. However, it is noted that mention of the thirteen priority plumes is of interest and this has now been included.
	4.10 Hydrology	This statement leaves the issue hanging. Perhaps we should present the findings of the recent WAMSI workshop Sept 2018??	Agree. Added: **A WAMSI workshop (2018) on the benefits and impacts of the Garden Island Causeway noted that the shallow sill (~5m) would restrict the physical mixing of water in the southern end of Cockburn Sound. There was disagreement over what extent removal of the Causeway, and increased exchange with the shelf, would have on improving water and sediment quality.** The report is referenced.
	4.10 Hydrology	Suggest replacing last sentence with something that notes that more recent studies have improved estimates of flushing? Feel that all studies are "old". (WP note that we would need to reference to more recent studies? But are there any or is it more of a vibe thing?)	Added: **A WAMSI workshop (2018) on the benefits and impacts of the Garden Island Causeway noted that the shallow sill (~5m) would restrict the physical mixing of water in the southern end of Cockburn Sound. There was disagreement over what extent removal of the Causeway, and increased exchange with the shelf, would have on improving water and sediment quality.** The report is referenced.
	5. High level of sediment quality	FPA has conducted an annual marine quality monitoring program (MQMP) since 2001 and notes that copies of these reports are available upon request.	Noted. MQMP Reports were sought after to some extent but were not retrieved. Information from MQMP is presented in the literature review table but sourced from other reports that included the data. FPA have been contacted for these reports so they can be directly included.
	5.1 Contaminants	Antifoulant, not antifoul.	Changed
	7.1 Fairy Tern	Boyd Wykes reference needs completing.	Corrected
	7.4 Australian Sea Lions	scientific name *Cinerea,* not *Cinereal*	Corrected
	8.3 Pink Snapper	2nd bullet point: spawning is mainly through the northern entrance, not only through.	Changed
	10 Coastal Processes	11th bullet: Sea level rise, not sea level rise.	Corrected
Table 5	1.1 Aboriginal	Is Point Peron not listed more broadly registered as a site? Rather than just artefacts and scatter?	It doesn't show up on the Aboriginal Heritage Inquiry System as Point Peron. There are smaller registered sites but this would fall under terrestrial
	4.3 Aquaculture	3rd bullet: 124-140 tonnes of mussels (not snapper)	Corrected

Section	Specific	Comment	WAMSI response
	4.4 Suitable water quality for industrial use	This comment ties in with recreational fishing too, water intake for industrial purposes, e.g. power plant cooling, also sucks in propagules of crabs and fish where they are sterilised (killed) from chlorine anti-scalant and antifouling processes with chlorine residue waters released out into CS afterwards. What effect this has on propagules and juvenile fish or the environment through intake or return water is completely unknown. Same for desal plant intake. Just what are their impacts - if none why no studies to show effect? Just what is the amount of waters used this way? Why doesn't Perth Desal plant move its intake away from the low protection zone? That was poor planning when the LPZ is for industrial purposes not producing potable water. Therefore it can be argued that consideration for the PDSP is minor.	The impact of industrial seawater intakes on larval and juvenile fish and other biota' is already listed as a knowledge gap for CS.
	4.5 Assimilation of groundwater	Is this contemporary info? My understanding is: -Western Power no nutrients, just TCRs from antiscaling waters -BP possibly through release of phenolics and some hydrocarbons but they have put in sophisticated waste water treatment so not sure about that anymore, but think they suck water out of Sound that is unscreened and not nice to propagules and juvenile fish in general - what impact? unknown -TiWest no? Does that company still exist? -Wesfarmers CSBP - no nutrients unless overflow emergency and that hasn't happened to its constructed wetlands and out to sea in a while? -Mintech - doesn't exist anymore, may only be mystery effluent from small tag along upstream industry? - improvements more to do with environmental regulation, rather than legislation.	This was flagged in the table as uncertain information.
Table 6	3.3 Plankton	Are forams considered plankton? Not micro-benthic calcareous forms? And aren't they extinct - i.e. fossils?	Yes, some species of forams are planktonic. Forams are still very much present in the water column and sediment. In this instance, the forams in the Leschenault Estuary were from sediments so this has been moved under 'Leschenault Regional Park'
	3.4 Invasive species	Why just Japan? Their harbours have some pretty nasty invasives but so does the rest of the world like ships from Europe, US and China? even Indonesia and Africa...Is this because of titanium trade or wheat exports from just this port? Also can include stats for all ports. 50 sp in Freo, 46 in Kwinana, 24 in Bunbury.	Leave as is. The mention of Japan specifically came from Bridgwood and McDonald 2014. Stats for Fremantle and Kwinana are included in their respective tables.
	4.4 Dissolved oxygen	remove the "reducing slightly" comment as is not well worded/confusing.	Removed
	6.1 Seagrass	is that depths of 9m or less? Also - is the inlet considered to have high tidal energy? Are more distant portions not calm enough?	No, 9m and deeper. Corrected
	7.4 Migratory shorebirds	Is migrator the correct word? Peel Harvey, not Peal.	Changed to migratory birds and Peel corrected
	7.5 Pouched Lamprey	Suggest saying [sic] This anadromous species moves....	Included
	9.1 Blue Swimmer Crab	Quote from Harrison out of place - just nore and reference. Also: re: LE as crucial habitat: Is this correct? female crabs usually go out to nearshore sea and spawn with the larvae recruited back into the estuary. If the females do this at Leschenault its completely different to what they do in the Peel-Harvey, CS and Swan estuaries?.....do you mean berried females congregate in the LE?	The mention of LE as a spawning ground was mentioned in a GHD report, however in a 2000 paper by Potter and De Lestang, females were spawning in Koombana Bay. Corrected.

Section	Specific	Comment	WAMSI response
		I'd just clarify that with the lady from Fisheries (Danielle?)	
Table 7	1.1 Aboriginal	Not protected? This is confusing, if not protected just registered don't put not protected in as that also applies to Swan and CS sections	This is the wording used in the Aboriginal Heritage Database, but agree it is confusing so have deleted 'not protected'
Section 2.3.2	Social Values	"some restrictions are in place for within Koombana Bay" - within OR for…	Within
Section 2.4	Metadata collection	In the Bunbury section of Table 8, there are dolphin sightings listed in the Bunbury section, but detailed as "Gage roads, Swan Canning, OA and CS. Not Bunbury.	Corrected
Section 3.1	P. 48	Incorrect reference to a Table 145.	Corrected
Table 15	6.2 Bottlenose Dolphins	Reference to KB should be in full (assume is Koombana Bay)	This statement was incorrectly placed in the Fremantle table. Has been corrected
	10 Coastal Processes	Deepening of Channel, not "Depending of"	Corrected
Table 17 & 18	3.1 Decrease in rec fishing due to restrictions around port area and the loss of popular fished species due to impacts to migration pathway	FPA presumably questions risk level and proposed management response (RE proposed dredging restrictions for avoiding spawning and migration periods). In 2010, dredging was carried out over a 12 month period and no significant impact was observed on marine species.	There were no reports discovered that directly measured impacts on marine species, other than benthic habitats- i.e. seagrass and coral. This suggested mitigation measure would benefit from further expert consultation as suggestions made in this report are only preliminary.
	3.6 Less visitation due to increased development negatively impacting on the landscape and visual amenity	FPA presumably questions proposed management response (RE proposed dredging restrictions for avoiding peak tourism periods).	This suggested mitigation measure would benefit from further expert consultation as suggestions made in this report are only preliminary.
	4.2 Decrease in commercial catches due to interruption to migration/recruitment of fishes through the entrance channel during dredging /expansion works	FPA presumably questions risk level and proposed management response (RE proposed dredging restrictions for avoiding spawning and migration periods). In 2010, dredging was carried out over a 12 month period and no significant impact was observed on marine species.	There were no reports discovered that directly measured impacts on commercial catches, only benthic habitats- i.e. seagrass and coral. This suggested mitigation measure would benefit from further expert consultation as suggestions made in this report are only preliminary.
Table 19	5 Sediment quality	"Decrease in quality of sediments due to increased development: "Somewhere in this Table mention of TBTs? If not sorry BUT most TBT would be in metabolised forms of MBT and maybe DBTs except some very local and not many hotspots near jetties in JB NH or SH where boat maintenance and painting happens. We don't have any recent survey beyond 2004-06 and only unpublished grey literature from Curtin Uni studies are more recent....We need a spatial and temporal study of CS to better estimate risk or not....!"	Not sure what the questions is. 'Establishment of environmental quality guidelines for the breakdown products if TBT (dibutyltin-DBT and monobutyltin- MBT)' is already listed as a knowledge gap.
	5 Sediment quality	The comment "Cockburn sound would facilitate cargo and container shipping rather than mineral exports…" This sentence does not reflect the existing and likely future bulk mineral trade through Kwinana Bulk Jetty and Terminal. Suggest delete.	Deleted
	6.1 - Reduction in seagrass, "Cumulative Pressure"	Is the seagrass extent increase significant enough to offset losses due to shoot density thinning? Worth adding a comment on shoot density?	No literature provides an answer to this question. Shoot density declines in CS have been mentioned in other sections of the report, but haven't added a clarification in this section as well.

Section	Specific	Comment	WAMSI response
	6.2-4 benthic communities "cumulative pressure"	Look at aerial and satellite photos over time, shows plumes already happen and yet dolphins and other biota still there but it is a pressure and issue	Uncertain if the comment is seeking clarification or change to benthic communities text or risk rating.
	7.4 Listed and significant fauna - Sea Lion	re: restricting proximity of vessels to haul out sites: "This is almost a static risk as it has always existed from too much boating and tourist visits to haul out sites but only becomes critical if no future sites identified or created and poor park mgt occurs...."	Agree, which is why the risks for climate change and other industrial and urban growth is medium as these would impact future haul-out site suitability.
Table 20	3. Decrease in species diversity due to reduction of suitable habitat, invasive species and altered environmental conditions	FPA suggests to include a reference to the introduced marine pest surveillance program (Statewide Array Surveillance Program - SWASP) for context. - AS MENTIONED ABOVE	Included
Assessment of marine values Section 3			
		Additional of options **KP0**2 and **KP0** 6 **(Westport Port Options and IMT Aspects March 2019)**	Not included as labelling to be kept consistent with proposed port maps initially provided. Check with Hans - is this part of the internal labelling protocols
	Kwinana	Reduced water quality was the only value rated "Extreme" and therefore likely to happen with potentially serious permanent impacts on the Sound. Was this taken into account for other values here reduced water quality would have an impact? Or was each value assessed independently?	Each value was assessed independently
		Exceptionally concerning to the MUA are instances where the literature cited in the report "increased confidence in the data" and caused the overall risk assessment after mitigation to be lowered. Due to time constraints, we were only able to look up a handful of these reports, and what we found does not give confidence to the report's conclusions. The information provided in these reports would increase the risk and severity of the impacts port development would have, not reduce the risks/impacts as claimed. See **attachment A** for examples where literature was cited in the report as reasons for reducing risk to the environment and the literature itself says differently.	The reports referenced in Attachment A by MUA are reports relating to dolphins, little penguins, pink snapper and garfish. These reports highlight the high risks facing these four values. These high risks, current issues and potential issues for the four values are all given in the literature review table for Kwinana i.e. mentions of Kwinana Shelf, noise pollution, vessel related deaths, inadequate fishing stocks etc. The risks facing these four values, as stated by the cited reports, are the exact reason why a 'High Risk' was assigned to each of the values in the risk assessment process in relation to harbour development, except garfish which were given a 'Medium Risk' for harbour development, but still a 'High Cumulative Risk'. The literature and risks assessment relating to little penguins and dolphins were also reviewed by subject matter experts who agreed with the risks assigned. These reports were never cited as the reason for reducing risks to these four values. There seems to be confusion with the mitigated measures reducing risks for these four values. These mitigation measures and associated risk scores are preliminary only. Again, it is clearly recommended that mitigation measures be assessed and validified in consultation with engineers and subject matter experts and that a comprehensive risk analysis be performed.
GENERAL			
		Inserted reference for EWS report: EWS Stage One Progress Report November 2018	Is this the correct reference to use throughout? Matt/Hans
	Request for introduction and conclusion	A key objective of the WAMSI report was “to refine the accuracy of the environmental and social values and confidence tables presented in the EWS Stage 1 Progress Report”. A comparison with the EWS report is presented in Section 3.5 and Tables	Done

Section	Specific	Comment	WAMSI response
		27-29 but there is no introduction or concluding section which makes Section 3.5 difficult to understand and interpret. In my opinion it would benefit from an introduction which explains the aim of the comparison, introduces Tables 27-29 and how to interpret them, presents the results as per sections 351,352 and 353, and finishes off with an overall concluding summary or synthesis perhaps in a new section 354? which relates back to the accuracy and confidence levels presented in the initial EWS assessment now being higher as a result of the literature review and the risk assessment presented in the WAMSI report?	
	Suggestion on ordering	Another objective of the WAMSI report was to identify opportunities for avoiding/mitigating adverse impacts and for improving environmental and social values at each port location. This has been addressed in preliminary detail in Section 3.2 and the second last column of tables 15-18 titled Harbour Development Mitigation and Risk. These tables should be read in conjunction with Section 4 which ideally should follow Table 18 as the conclusion to that section.	Section 4 moved up to follow on from section 3.4.
Executive Summary		The Executive Summary reads well and was useful to place the report contents into context but it would also benefit from an edit to clarify for the lay reader many of the dot points which in some cases are a bit cryptic in meaning.	Have amended section based on suggestions/comments
Mitigation strategies throughout		In the Kwinana section detailing mitigation strategies "adopt PIANC principals" is referenced in 31 separate values as a means to mitigate risks and lower their score. This generic statement is not good enough to warrant a reduction in risks to environmental values deemed important. We would expect specific actions to be mentioned for each of these instances as well as justification as to why those actions would lead the authors to reduce the associated environmental risks. Otherwise the risks cannot confidently be reduced	No changes. On several occasions throughout the report, as well as in the executive summary, it is highly stressed that the mitigation measures included in this report are very preliminary and should only be viewed as preliminary. It is stated very clearly that mitigation measures and reduced risks were done without consultation of engineers, final port footprints and subject matter experts (thought little penguins, dolphins and to some extent seagrass were reviewed by subject matter experts). It is also clearly recommended that mitigation measures be assessed and validified in consultation with engineers and subject matter experts and that a comprehensive risk analysis be performed.
Mitigation strategies throughout		Mitigation measures were determined in the absence of any conceptual engineering or design plans. Many of the measures used to mitigate risks for Kwinana rely on engineering/designed solutions. Do we know if such solutions exist? If they do exist would they reduce the risk to individual values as much as outlined in the report?	On several occasions throughout the report, as well as in the executive summary, it is highly stressed that the mitigation measures included in this report are very preliminary and should only be viewed as preliminary. It is stated very clearly that mitigation measures and reduced risks were done without consultation of engineers, final port footprints and subject matter experts (thought little penguins, dolphins and to some extent seagrass were reviewed by subject matter experts). It is also clearly recommended that mitigation measures be assessed and validified in consultation with engineers and subject matter experts and that a **comprehensive risk analysis be performed**.
Mitigation strategies throughout		Do any of the engineered "solutions" counter act each other? For example: it might be impossible to engineer port structures to reduce stagnant waters AND engineer port structures with niche habitats as suggested on table 19. I just picked those two at random, because they are next to each other. It would be useful to know if the mitigation "solutions" can actually work together. But without any designs available, how can there be confidence they even exist?	On several occasions throughout the report, as well as in the executive summary, it is highly stressed that the mitigation measures included in this report are very preliminary and should only be viewed as preliminary. It is stated very clearly that mitigation measures and reduced risks were done without consultation of engineers, final port footprints and subject matter experts (thought little penguins, dolphins and to some extent seagrass were reviewed by subject matter experts). It is also clearly recommended that mitigation measures be assessed and validified in consultation with engineers and subject matter experts and that a **comprehensive risk analysis be performed**. With respect to the example provided in table 19 the mitigation measure stated "engineer port structures **and** niche habitats". The engineered niche habitats don't have to be directly connected to the port structure.

Section	Specific	Comment	WAMSI response
		Many of the mitigation measures used to reduce the impacts of "future harbour development risk" for Kwinana involved engineering structures and design measures to achieve the outcomes. How can we know if such structures can be engineered, or designed in such a way to sufficiently reduce the risk to the identified values? Without knowing if infrastructure can be engineered/designed in such a manner, it seems premature to assume 1) that is possible to do so and 2) that the effect would be as dramatic as presented in this report	On several occasions throughout the report, as well as in the executive summary, it is highly stressed that the mitigation measures included in this report are very preliminary and should only be viewed as preliminary. It is stated very clearly that mitigation measures and reduced risks were done without consultation of engineers, final port footprints and subject matter experts (thought little penguins, dolphins and to some extent seagrass were reviewed by subject matter experts). It is also clearly recommended that mitigation measures be assessed and validified in consultation with engineers and subject matter experts and that a **comprehensive risk analysis be performed**.
		Zero mention of the hundreds of horses and owners who use the beach on a regular basis and the impact port development would have on them.	This was discussed before the report was written and it was agreed that this fell under the terrestrial scope of works.
		Initial consultation with traditional land owns by MUA indicate the risk and probability of development to impact sites is much greater than low as stated in the report	It is assumed the comment relates to Cockburn Sound. Once a detailed port footprint is produced, there would be a better understanding of whether Indigenous sites will be significantly impacted. This assessment was made based on data gathered from the Aboriginal Heritage Enquiry System and not through direct consultation with traditional land owners. It is also noted there are a number of important sites that would likely fall under a terrestrial or social scope of works. Consultation with TOs should be carried out and is included in the suggestion to "Development of a research framework to deal with the gaps identified in Section 5, which would include a better understanding of government, industry, Indigenous and community values " and "It is recognised that there are an abundance of stakeholders with interest and information on the three locations, and efforts should be made to engage with as many as possible throughout the Westport Project "
		We do not have confidence in the portrayal of the tables towards the end of this document as it appears they are heavily skewed toward lowering the potential impact port development would have in Kwinana	It is unclear which tables this comment refers to. It is unclear which specific parts of the document are skewed towards favouring Kwinana. Looking at the total high risks (unmitigated), Fremantle has a total of 15 cumulative high risks and 3 port related high risks; Kwinana a total of 20 cumulative high risks, one extreme risk, and 14 port related high risks; Bunbury has a total of 22 cumulative high risks and 12 port related high risks.

Section	Specific	Comment	WAMSI response
		Due to time constraints we were not able to complete a detailed analysis of every value cited, but the specific instances in the table at Attachment B would give any reader doubt about accepting the validity of this report's conclusions.	No conclusions were drawn from the report i.e. no recommendations were made on which location should be chosen to expand/build a port. This was not the purpose of the report. In relation to the points raised in Attachment B, these were taken from Appendix 2, which were the initial workings of the risk assessment tables presented within the report. MUA comments on 'How can habitat loss only be scored as “possible” when the justification for Kwinana says development is likely to cause the action to occur? I would say it is certain to cause habitat loss it’s just a question of where", when the focus was on a reduction of fish assemblages. There is likely to be loss of habitat if a port was built in CS, but the impact on fish assemblages in CS is assessed, not habitat loss/degradation. We refer readers to the full justifications given for assigning risks. MUA also states in Attachment B "If impacts are 'likely' at Fremantle with a degraded environment, the likelihood of impacts on a fragile environment like Cockburn sound should at least be equal- but probably rated even higher". CS was given a likelihood of 'possible', but this was in relation to having a 'major' consequence. That is, it is 'possible' that there will be a 'major' consequence for an 'integral functioning ecosystem' if a port was placed in CS (equalling a 'High Risk' score for this value) as opposed to Fremantle where it is 'likely' that there will be a 'minor' consequence for an 'integral functioning ecosystem' if the port was to be expanded in Freo (equalling a 'Medium Risk' score for this value). It is recommended that readers understand the likelihood x consequence process before reviewing the risk assessment table. In response to why Fremantle and Kwinana were given the same risk score in relation to demersal and benthic communities, we believe this is justified because there were particular locations identified where benthic fauna could be at risk for both locations. Fremantle is a working port already, but there is a possibility that further expansion could impact the benthic fauna remaining in Gage Roads. Thus the assessment erred on the side of caution and a medium risk was assigned independently of what could happen or was assessed for Kwinana.
Appendices			
Appendix 1	Table 1	MUA questions the choice to include the Director of Kwinana Industrial Council, Chris Oughton, as one of the key stakeholders consulted about the drafting of this report.	Chris Oughton was contacted by phone to ask if there were any reports not listed on the KIC website that could be made available. This was the only request. Mr Oughton was not asked to review any part of the report prior to it being sent to all of the EWS workstream for comment. A comment has been added to the table to clarify this fact.
Appendix 2	Table 3	Much of the supporting documentation says that a dredging campaign in Cockburn Sound would be 'short lived'. What is the definition of a short lived dredging campaign and can the reference for this be cited? The 2006 EPA report specifically mentioned "the long term duration and extent of any dredging campaign would have major short term and long term impacts on ecological values and also amenity across much of Cockburn Sound and possible beyond the Sound"	The term 'short lived' wasn't referring specifically to Cockburn Sound dredging, rather dredging in general and in a relative way. The use of 'short term' was meant to reflect that the dredging events likely to occur in the three areas of interest wouldn't be multi-year continues events. The use of the term 'short lived' has been removed from the appendix tables as it is agreed that the use of this term is unclear. It is also noted that 'short lived' dredging was not included in the justification for the more comprehensive risk assessments, as we do not know the timeframe of dredging, so this had no bearing on the risk scores generated. Appendix 2 represents some early thinking and processing and was included in the report for transparency and to show the logical progression of thinking. A mention of "Turbid plumes from dredging not long lasting" is mentioned for Bunbury in relation to seagrasses and, again, was a relative statement and based on flushing of the open coast line where the seagrass meadows occur. This statement has been removed to avoid confusion.