ENVIRONMENT PROTECTION AUTHORITY

A RISK ASSESSMENT OF THREATS TO WATER QUALITY IN GULF ST VINCENT

APRIL 2009
A risk assessment of threats to water quality in Gulf St Vincent
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April 2009

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GENERAL SUMMARY

Gulf St Vincent is a reverse estuary which has only limited exchange with the Southern Ocean. Throughout much of the region, extensive habitats comprising seagrasses and macroalgal dominated reef communities are prominent features of the environment. These systems support complex biological diversity with a high proportion of endemic species and a range of activities including recreational and commercial fisheries and a growing aquaculture industry. A range of pollution pressures present significant threats to the marine and coastal environment and their ability to support these values. This report reviews threats to water quality in order to identify and prioritise risks to inform management decisions.

Adelaide is a city of approximately 1.2 million people (Australian Bureau of Statistics 2007) that lies on the eastern coast of the Gulf St Vincent and there are numerous smaller towns around the surrounding coastline. The Gulf receives waste and stormwater discharges from Adelaide and surrounding coastal towns and has experienced significant environmental degradation over the last 50 years, particularly in nearshore areas along the Adelaide metropolitan coastline. The single most important threat to environmental values in this region is through the associated degradation of water quality and this is the principle focus of this report.

Water quality is a key requirement in aquatic environments and can have significantly more impact on ecosystems than all other pressures (e.g., predation, competition, etc). Good water quality will provide conditions conducive to support multi-layered, diverse and abundant ecosystems which foster environments where organisms thrive as well as presenting opportunities for aesthetic enjoyment and beneficial use by both urban and regional communities. For these reasons this risk assessment has focused on the threats to good water quality.

For the purpose of this risk assessment and for the ease of interpretation for managers and regional agencies, the Gulf has been separated into four sectors based on significant habitat type and pressures.

The northern region encompasses the area north from the Gawler River, and west to Port Julia (Figure 1). This region supports significant areas of intertidal mudflats, seagrass meadows, mangroves and tidal creeks.

The eastern sector encompasses the area between the Gawler River and Sellicks Beach extending approximately halfway across the Gulf (Figure 2). This region supports seagrass meadows with some dispersed rocky reef habitats. Generally wave energies are slightly higher than in the northern region and this region includes the city of Adelaide.

The western sector encompasses the region between Port Julia and Troubridge Point extending to the eastern sector boundary approximately in the middle of the Gulf (Figure 3). This region supports significant seagrass meadows and rocky reef habitats and is sheltered from waves due to the protection afforded by the Yorke Peninsula and the predominant south-westerly swell direction. The region is also subject to fewer anthropogenic pressures than the eastern region.

The southern sector is delineated between Point Morrison and Troubridge Point on the western side and from Penneshaw and Cape Jervis on the eastern side and encompasses the region between these boundaries north to Sellicks Beach and the boundary of the eastern and western regions (Figure 4). The southern region is subject to a variety of conditions but is dominated by rocky shores and reef habitats with areas of seagrass meadows. Wave energies are generally higher in the southern region than in other regions due to increased exposure to the south-westerly swells. There are areas with high current speeds through Backstairs Passage and also sheltered regions on the northern coast of Kangaroo Island.
Risk assessments generally focus on two aspects: likelihood and consequence. The likelihood is how often the incident is expected to (or has) occurred. The consequence is measured by the impact of that incident occurring. This risk assessment has used a ‘panel of experts’ approach on a well established framework for investigating the risks to water quality in Gulf St Vincent.

Environmental values in this region include both those that relate to beneficial use as well as those independent of human need. In broad terms environmental values for the Gulf include the commercial, cultural and aesthetic uses of the area but also extend to the preservation or conservation of biodiversity and ecosystem function.

The environmental value of **aquatic ecosystems** includes their ecological integrity and the associated native flora and fauna. Preserving these features involves protecting the ability of the water to support and maintain a balanced community of organisms comparable with that of a natural habitat (EPA 2003a). The value of ecosystem protection also aims to protect wild commercial and recreational fisheries as these resources rely on water quality and the protection of the ecosystems to maintain fisheries stocks (ANZECC 2000).

Waters that are classified as having an ecosystem protection value should have ambient water quality that meets Schedule 2 of the *Environment Protection (Water Quality) Policy 2003* (WQEPP) or the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC 2000) Tables 3.3.8 and 3.4.1 or better.

Water of a specific quality is needed for maintaining viable aquaculture operations, with regard to both organism health and the ability to market the end-product. This quality can be different to what is required for healthy ecosystems and as such waters that are used for aquaculture or shellfish harvesting (eg cockles and razorfish) have been classified for the protection of aquaculture (see ANZECC 2000 for details). Aquaculture production can be reduced when water contains contaminants that may impair development, growth or reproduction. Additionally the quality of the end-product can be reduced when low levels of a contaminant cause no obvious adverse ecological effects but gradually accumulate in the culture species to the point where it poses a potential health risk to human consumers or can taint flesh appearance or taste (ANZECC 2000).

Waters classified as having aquaculture values should have ambient water quality that meets Table 4.4.3 of the ANZECC Guidelines (2000) or Schedule 2 of the WQEPP.

All waters of the state are considered to have recreational and aesthetic values which includes primary and secondary contact and visual uses for the water. Primary contact covers activities that involve full body contact with the water such as swimming, surfing, diving and water skiing. Secondary contact involves partial body contact such as wading, paddling by children, boating and fishing where the probability of swallowing water is unlikely (EPA 2003).

A desktop sanitary inspection has been undertaken for each region within the risk assessment using the National Health & Medical Research Council (NHMRC) Guidelines (2005). Water with recreational values should comply with Table 5.13 in the NHMRC Guidelines for the sanitary inspection category applicable to that region.

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1 Values in the WQEPP and the ANZECC Guidelines were developed based on very limited data, which has resulted in values being disproportionally high. Recent studies have shown that these numbers need to be reduced in order to protect aquatic ecosystems and this process is expected to be undertaken when Natural Resource Management Boards develop site/region specific environmental values and water quality objectives following the process set out by the *National Water Quality Management Strategy* (2000).
The aesthetic value of water plays an important part in the public’s perception of recreational water environments. Decreased aesthetic values may be caused by obvious pollution, turbidity, scums or odours. This may result in people feeling repulsed by the waters which may have effects on local residents, and could impact on tourism (NHMRC 2005).

The results of this risk assessment are anticipated to aid managers and regional agencies in focusing attention and prioritising funding towards areas that are possibly at a higher risk. Additionally this document can aid in prioritising areas for future research, which could help to fill some of the data gaps within the risk assessment. Obviously there are many uncertainties with any risk assessment and this one is no different. In many cases risks have been generated on very limited site-specific information and based on the experience of the panel of experts consulted as a part of this risk assessment. Actual data has been used where possible and experts or researchers in the particular fields have been consulted in the majority of circumstances in order to get the best information that is available at the time of writing. As with all adaptive management processes this document is anticipated to evolve as more information is obtained from both local, Australian and international researchers, industry and the community.

**Risk ratings by region**

The results detailed below are a summary of the results of the risk assessment outlined in Appendix 1.

A total of 111 threats were assessed for the northern Gulf St Vincent region. Of these risks none were considered to be high and only five were considered to be moderate to maintain water quality for all environmental values. The moderate risks for the northern region were considered to be turbidity generated from urban runoff and nutrients from septic tanks and community wastewater management systems (CWMS) formerly known as sewage effluent disposal schemes (STEDS).

Of the 156 threats to water quality assessed for the eastern region, 5% of all risks were considered to be high. These threats to environmental values are the impact of nutrients and turbidity throughout the region. This risk is primarily from nutrients from the SA Water wastewater treatment plants (WWTPs) and turbidity from urban stormwater, ammonia from Penrice Soda Products and elevated temperature from the AGL Torrens Island Power Station.

There were 98 threats to water quality assessed in the western region, of these none were considered to be high. The moderate threats were impacts from nutrients from septic tanks and community waste management systems (CWMS), nutrients and trace metals from marinas and boat ramps and also the trace metal accumulation at wharves.

In the southern region 111 threats were assessed and of all of these only one was considered to be high. This was the discharge of agricultural runoff from Cygnet River with observed impacts seen from nutrients on seagrass throughout Nepean Bay.

**Risk ratings by environmental value**

**Ecosystem**

There were 177 threats to ecosystem values identified throughout Gulf St Vincent and 30% of these threats were considered to be a moderate or high risk to water quality. Generally the highest risks were related to nutrient and sediment discharges from WWTPs and Penrice Soda Products, urban runoff (in the east) and agricultural runoff (in the south). Nutrients and high turbidity have been shown to severely impact on nearshore seagrass and reef ecosystems. In the Port River nutrient elevated temperatures have a high risk to of threatening water quality in this system due to its contribution to eutrophication in the system as well as the significantly altered ecosystem in Angas Inlet. The Port River and Barker Inlet system has been identified as a vital
breeding and nursery area for fish stocks and impacts on this system could possibly be seen throughout Gulf St Vincent.

Agricultural runoff has been singled out in the southern region due to the well documented eutrophic state and associated seagrass loss throughout Nepean Bay and resultant impacts on primary productivity and fisheries production for the region.

**Aquaculture**

Some 95% of the threats to water quality for protecting aquaculture are considered to be low. Ammonia discharge from Penrice Soda products and the SA Water WWTP discharges (particularly Bolivar) which comprised 5% of the moderate or high risk were the worst. These discharges contribute to the eutrophic nature of the Port River Estuary where there are frequent blooms of the nuisance microalgae including the dinoflagellates *Alexandrium* spp. And *Gymnodinium* spp. Blooms of these species are known as red tides and these species contain toxins which can cause paralytic shellfish poisoning (PSP) in humans who consume contaminated shellfish. For this reason shellfish harvesting has been prohibited in the upper Port River for over 50 years.

**Recreation and Aesthetics**

There were no high risks relating to recreational or aesthetic values. However 10% of threats were considered to a moderate risk. These risks were the SA Water WWTPs (particularly Bolivar), Penrice Soda Products, the AGL Torrens Island Power Station and coastal dredging, all of which contribute to seagrass loss along the metropolitan coastline and/or the eutrophic nature of the Port Waterways. The seagrass loss causes sand instability and results in sand being held in suspension for extended periods during strong wind. The loss of seagrass also changes beach morphology often detracting from the appearance of the beaches. This degraded appearance of the beaches may be exacerbated by the cumulative impact of discharges of detrital seagrass into the nearshore zone from dredging events. The eutrophic condition in the Port River and Barker Inlet generates significant nuisance algae production in the form of *Ulva* spp. (sea lettuce). Apart from the ecological impact this sea lettuce accumulates where it can become dislodged and form large floating rafts of algae causing navigation hazards for small boats and detracts from the appearance of the waters. These rafts often become beached where they decay causing significant odour issues for surrounding residents.

**Table 1** Table of risk ratings for each region and environmental value as a percentage of total number of risks in that section (subscripts = n).

<table>
<thead>
<tr>
<th>Region</th>
<th>Parameter</th>
<th>n total</th>
<th>Low</th>
<th>Moderate</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Summary by region</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Northern</td>
<td></td>
<td>111</td>
<td>95%</td>
<td>5%</td>
<td>0</td>
</tr>
<tr>
<td>Eastern</td>
<td></td>
<td>156</td>
<td>69%</td>
<td>26%</td>
<td>5%</td>
</tr>
<tr>
<td>Western</td>
<td></td>
<td>98</td>
<td>93%</td>
<td>7%</td>
<td>0</td>
</tr>
<tr>
<td>Southern</td>
<td></td>
<td>111</td>
<td>87%</td>
<td>12%</td>
<td>1%</td>
</tr>
<tr>
<td><strong>Summary by value</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ecosystem</td>
<td></td>
<td>177</td>
<td>70%</td>
<td>27%</td>
<td>3%</td>
</tr>
<tr>
<td>Aquaculture</td>
<td></td>
<td>171</td>
<td>95%</td>
<td>3%</td>
<td>2%</td>
</tr>
<tr>
<td>Recreation &amp; Aesthetics</td>
<td></td>
<td>128</td>
<td>90%</td>
<td>10%</td>
<td>0</td>
</tr>
</tbody>
</table>
### Conclusions

This risk assessment has identified the major risks to water quality with potential to impact on environmental values of the protection of:

- ecosystems
- aquaculture
- recreational users of water
- aesthetic values of water.

It also acknowledges that there are many other risks to environmental values in Gulf St Vincent that have not been classified or prioritised using this risk matrix, some of these have been discussed within the document but are not water quality related (eg prawn trawling) and some have not been constructed so as to undertake an adequate assessment of risk to water quality (eg Port Stanvac desalination plant). It is envisaged that the risks classified within this document may change with time and with various management actions designed to lessen the risk. This document is intended to be updated regularly in order to re-evaluate risk in response to these changes.

While this risk assessment has been relatively comprehensive there are several areas that information or scientific data is limited and this has resulted in a risk that has been evaluated more on opinion than by weight of evidence. These areas have been flagged as needing further research in order to understand processes, particularly relating to environmental fate of chemicals in the marine environment. The areas where there is very little site-specific information and a need for further research are the discharge of pharmaceuticals, endocrine disrupting chemicals and personal care products from WWTPs.

The risks identified in this report have the potential to significantly impact on environmental values within Gulf St Vincent. These risks need to be managed in order to reduce any impacts that are occurring or could occur in order to protect the environmental values within Gulf St Vincent for all South Australians.
SUMMARY OF FINDINGS FROM THE GULF ST VINCENT RISK ASSESSMENT

Introduction

Gulf St Vincent is a reverse estuary which has only limited exchange with the Southern Ocean. Throughout much of the region extensive habitats comprising seagrasses and macroalgal dominated reef communities are prominent features of the environment. These systems support a range of activities including recreational and commercial fisheries and a growing aquaculture industry. A range of pollution pressures present significant threats to the marine and coastal environment and their ability to support these values. This report reviews these threats in order to identify and prioritise risks to inform management decisions.

Adelaide is a city of approximately 1.2 million people (Australian Bureau of Statistics 2007) and it lies on the coast of Gulf St Vincent. This gulf receives waste and storm water discharges from the city of Adelaide and has exhibited significant environmental degradation over the last 50 years. Studies have shown that over 5,200 ha of seagrass has been lost from the Adelaide metropolitan region and there has been significant seagrass loss throughout Nepean Bay on the north coast of Kangaroo Island. Over the last decade it has become apparent that the degradation has not been limited to seagrass but macroalgal reefs are also in decline in many areas. These degraded reefs are generally focused around the Adelaide metropolitan centre but there has also been some decline noted in a number of country areas such as Victor Harbor.

In order to protect the beneficial uses in the region (or environmental values) there is a need to assess what are the greatest risks to water quality within this region. Once there are community agreed environmental values for a region within Gulf St Vincent there may be a need to re-evaluate this risk assessment to reflect the importance placed on each value by the community and how threats impact on those values.

Environmental values

Environmental values are particular uses (or values) of the environment that are important for a healthy ecosystem or for public benefit, welfare, health or safety and which require protection from the effects of pollution (ANZECC 2000).

The National Water Quality Management Strategy (NWQMS) published by ANZECC and ARMCANZ (2000) outlines the process that states must undertake to designate ‘environmental values’ to a water body across regions in the state. This process involves consultation with stakeholders to determine the ‘uses’ or values of the water and as such the quality that needs to be maintained in order to use the water for this purpose. In freshwater systems these could be drinking water, irrigation as well as protecting ecosystems. The process of setting environmental values for a region is lengthy and is anticipated to be undertaken by the EPA in collaboration with Natural Resource Management (NRM) Boards in the near future. In the absence of agreed environmental values for a region the NWQMS recommends default values until agreed values can be assigned.

In South Australia the Environment Protection (Water Quality) Policy 2003 (WQEPP) specifies that a particular waterbody can have specific protected environmental values and water quality objectives which are of particular concern in that area and these can be outlined in the Policy. That area can then have specific water quality criteria in order to protect those specific environmental values or water quality objectives.

In the marine environment the default environmental values assigned to all waters in the WQEPP are:

- protection of aquatic ecosystems
• protection of recreational water quality and aesthetics
• protection of aquaculture species and human consumers of aquatic foods.

The environmental value, ‘protection of aquatic ecosystems’, aims to maintain water quality at a sufficient level of quality to ensure healthy populations of all species, including fish. It is anticipated that the maintenance of good water quality will maintain healthy fish stocks, however this environmental value does not consider the aim to protect the fishery as an extractable resource which is subject to overfishing.

While specific areas may not have (or plan to have) commercial aquaculture activities underway in that region the environmental value of protection of aquaculture includes maintaining water quality at a level where it would be unlikely that the collection and consumption of shellfish would cause illness to human consumers.

Risk assessments

Some form of risk assessment is used to make every management decision, including what needs to be managed, how much effort is required to achieve results and/or to avoid undesirable outcomes (Fletcher 2005). A risk assessment is the practice of determining the nature and likelihood of effects of on animals, plants, and the greater environment. It is hoped that this risk assessment will help organise information and contribute to informed decisions. It is a useful management tool that will:

• highlight the greatest risks, which is needed to support allocation decisions for limited resources
• allow for management agencies to ask ‘what if’ questions regarding the consequences of various potential management actions
• facilitate explicit identification of environmental values of concern
• identify critical knowledge gaps, thereby helping to prioritise future research.

(SETAC 1997)

This risk assessment used a workshop of experts in marine and environmental sciences including academics, managers, industry, researchers and technical staff to assess data (when available) and use collective experience to identify risks, assess likelihood and consequences for each potential threat to water quality within Gulf St Vincent.

Where available, data has been used to accompany and guide the risk assessment process. However it has been stated that the assessment of risk is probably of greatest importance in data poor situations (Fletcher 2005). In such situations, uncertainty is treated by using a conservative approach (in line with the precautionary principle) and in most cases an estimate of likelihood and consequence has been made. In some circumstances there has been too much uncertainty and these situations have been flagged for further research before any assessment can be made.

This risk assessment has been carried out assuming there are controls in place, ie if there are emergency safeguards in place to control any incident or pollution they are assumed to be in place, well maintained and working for the purposes of this risk assessment. To attempt a risk assessment using no controls at all would be pointless as this does not represent the real situation. The approach focused on:

• Likelihood—the probability of an impact that effects environmental values of a region occurring.
- Consequence—in this case, an environmental value compromised or environmental harm if an event occurs, which incorporates duration and scale.

This approach can only be used to calculate risk in a ‘semi-qualitative’ way. A quantitative risk assessment would be unachievable in most situations due to lack of data regarding the numerous complex discharges and impact situations.

The consequence rating in this risk matrix incorporates five levels starting with no measurable impact through to catastrophic, where the environmental value is compromised over a long time period (even permanently) and over a wide extent.

The risk rating is the position in the risk matrix (see Appendix 2) where the likelihood and the consequence are thought to lie based on the knowledge and experience of the person assessing it. The code in that position can then be used by management agencies to evaluate the level of risk from that specific event.

This risk assessment is not intended to be detailed to the point of characterising the catchment make up for every stormwater discharge in Gulf St Vincent or each aspect of every facility on a site. Instead, it is attempting to assess the risk on the aggregate inputs to Gulf St Vincent.

The risk assessment is based on agreed probabilities and likely impacts based on available information and knowledge. Some of the key aspects considered are explained below and Appendix 3 shows examples of how to look at risk assessment using this framework.

**Action of impact**

Harm may be caused to the environment at an immediate, fast or slow pace after an event has occurred.

The slower the action of an event the more scope for intervention and harm minimisation. This may reduce the final consequence or length until recovery.

**Toxicity**

The toxicity of a discharge will have great bearing on the level of consequence. This will take into consideration acute and chronic effects from toxicants, cumulative impacts and issues such as bioaccumulation and biomagnification.

**Pulse versus press discharge**

While the toxicity of the discharge will have a large bearing on the impact, the frequency of the discharge also needs to be considered. For example; if the same pollutant was discharged into the same habitat via a major event or as a result of numerous minor events, which is the greater risk to the environmental values?

Disturbances can generally be classified as either pulse or press discharges (Bender et al 1984; Glasby & Underwood 1995). Pulse discharges are generally short term and generally cause relatively immediate impacts on the receiving environment, however once the cause of the disturbance disappears, recovery will start and can be relatively quick (short term disturbance/short term impact). Press disturbances frequently result from continuous discharges and the impacts are generally long term (Glasby & Underwood 1995). Recovery is very slow (if at all) due to the sustained nature of the discharge and it is likely that the community composition will change to more pollution tolerant species (Koetsier 2002).

**Sensitivity of receiving environment**

While all receiving environments have the set environmental values as described above there are areas that are known to have organisms or habitats that are particularly sensitive (or even unique) or have follow-on effects of impacting food webs due to disturbances to fish spawning,
feeding, growth and reproduction, etc. These regions could be declared aquatic reserves or future marine protected areas (such as the Encounter Marine Park). If impacted, these areas may take longer to recover (if at all) or may result in a loss of a disproportionally high amount of the given environmental value. For example if a discharge impacts on a nearshore seagrass and mangrove habitat known to be a highly productive nursery area for fish and crustaceans which contributes to both the ecosystem and commercial and recreational fisheries then this may result in a higher consequence rating for that discharge.

**Duration**

The duration of impact will have a significant influence over the degree of harm and therefore the risk to the environmental value. If a receiving environment is particularly resilient then there is likely to be less risk of longer term damage. However if a region of *Posidonia* seagrass is completely denuded this region may take a lot longer to regrow and would therefore afford a higher risk.

**Complex mixtures**

The vast majority of toxicity data deals with single species and single toxicants. It is generally assumed that in a mixture the toxicity will be the summation of the individual toxicants (additive). There is evidence that mixtures of toxicants can result in higher toxicity to organisms than just the sum of the two toxicants. This effect is called synergism or potentiation (Walker et al 1996).

A detailed explanation of the key stressors in the marine environment is included in Appendix 1, section 3.

**Delineation of regions**

This risk assessment has divided the Gulf into four main regions. These regions are somewhat arbitrary but are based on the bathymetric conditions, wave energies and dominant habitats which characterise the regions. These conditions will alter the impact of particular stressors in each region.

**Northern region**

The northern region of the risk assessment encompasses the area north of the Gawler River to the top of the Gulf and west to a point just south of Port Julia (Figure 1). This area is approximately 60 km north–south and includes the small townships of Ardrossan, Port Wakefield, Price and Port Gawler. The main land uses in this area are grazing modified pastures and dryland cropping. Industries in the coastal region are predominantly limited to a large quarry at Ardrossan and saltfields at Price (EPA 2003b).

The Northern region receives between 300–400 mm of rain (Appendix 4), which is considerably lower than the other regions. The Wakefield and Light Rivers are the only drainage lines of significance in this region. These rivers frequently flow in the upper catchment however typically the flow dries up or flows underground which means surface water very rarely enters the marine environment [estimated at 1 in 5 years (DWLBC 2007; P Goonan pers comm)].

This region is considerably different to the other regions in the Gulf due to the lower wave energies in the northern region of Gulf St Vincent resulting in extended areas of sandy–muddy intertidal flats (Womersley & Thomas 1976). These flats are dominated by several well-defined plant communities including the seagrasses *Posidonia* and *Heterozostera* in the intertidal and subtidal regions. The grey mangrove *Avicennia marina* forms dense communities in the lower eulittoral into the supralittoral zones and samphire communities dominate in the supralittoral zones (Womersley & Thomas 1976).
Very little information exists about coastal and marine water quality north of the Gawler River, however there are only occasional riverine and no significant industrial discharges into these waters, so the water quality is expected to be relatively good. There is the potential for the northwards transport of nutrient rich water being transported from the Bolivar WWTP (in the eastern region) into the northern region. This water has the potential to impact on seagrasses, reef habitats and mangroves in the northern region.

**Eastern region**

The eastern region of this risk assessment covers an area reaching from the Gawler River in the north, south to Sellicks Beach (Figure 2). This area covers approximately 75 km north-south and encompasses the City of Adelaide and surrounding suburbs. The dominant land use is urban and in this risk assessment it has been considered that there is no agricultural land where runoff will be generated (see Appendix 1, sections 4.1 & 4.4). It is likely that there are some small flows from the Onkaparinga and Gawler Rivers however these regions in this risk assessment have been classed as urban. While this is not entirely accurate this was considered to be practical rather than breaking this risk assessment down into catchments. This may be a process that NRM Boards may undertake in the future. The region receives between 400–500 mm of rain in the coastal areas to between 600–800 mm in the Adelaide Hills (Appendix 4). The major industrial discharges in this region are the three coastal WWTPs at Bolivar, Glenelg and Christies Beach, Penrice Soda Products at Osborne and Pelican Point, Osborne Cogeneration and AGL Torrens Island power stations. There are numerous stormwater drains and the creeks that discharge stormwater into the marine environment including the Torrens, Patawalonga and Onkaparinga Creeks.

This region is generally a moderate energy coastline when compared to the other three study regions. The eastern region is dominated by gently sloping shallow sandy beaches, particularly in the north, while substrates are typically rocky, ranging from gently sloping dissected rock to almost horizontal rock platforms being common in the south of the region (Womersley & Thomas 1976). The main biotic communities within this region are the seagrass communities *Posidonia* and *Amphibolis*, usually in dense monospecific meadows and *Heterozostera* and *Halophila* species in scattered clumps, particularly in deeper water (for detailed analysis of seagrass communities see Shepherd & Sprigg 1976; Steffensen *et al* 1989; EPA 1998; Westphalen *et al* 2004). Where substrate exists, the species composition of reef communities are typically dependant on depth and water movement, however many inshore reefs are dominated by *Cystophora* spp., *Ecklonia radiata* and *Sargassum* species (for detailed analysis of reef communities see Shepherd & Sprigg 1976; Cheshire *et al* 1998; Cheshire & Westphalen 2000; Turner *et al* 2007).

This region has, at times, shown degraded water quality as a result of wastewater and stormwater inputs along the coast. This poor water quality has contributed to the significant impacts observed in the nearshore environment with over 5,200 ha of seagrass lost and significant macroalgal reef degradation along the metropolitan coast.

**Western region**

The western region of the risk assessment encompasses the Gulf St Vincent side of Yorke Peninsula south of Port Julia to Troubridge Point (Figure 3). This area is approximately 60 km north-south and includes the small townships of Port Vincent, Stansbury, Edithburg and Coobowie. The main land uses in this area are grazing modified pastures and dryland cropping (EPA 2003b). Industries in the coastal region are limited to the bulk grain wharves at Wool Bay, limestone quarries and agriculture. There are a number of commercial aquaculture ventures on the western side of Gulf St Vincent predominantly centred around oyster production. This region has also been experiencing growth in residential developments and marina developments over the last decade.
The region experiences annual rainfall of between 300–400 mm (Appendix 4) and there are no creeks or drainage lines of significance within Yorke Peninsula and therefore there is very little channelled surface runoff into the marine environment.

The Yorke Peninsula coast is generally low lying and changes from an exposed coast with strong wave action in the south (particularly south west) to one of very slight wave action dominated by sand and mud flats on the east (Laws 1973). Very little information exists about water quality in the western Gulf St Vincent, however regular algal and bacterial monitoring is undertaken by PIRSA South Australian Shellfish Quality Assurance Program (SASQAP) and data from their summary reports have been used in the assessment of risks to water quality. Turner et al (2007) have surveyed selected macroalgal reefs on the Yorke Peninsula and found that generally reefs were in good condition; however a number of reefs were rated either poor or at caution. Conclusions were that this is likely to be due to natural wave energies, topography and current flow, rather than poor water quality per se (Turner et al 2007).

Southern region

The southern region of the risk assessment encompasses the southern aspects of the Gulf including Backstairs Passage (Figure 4). This region is bordered on the southern side by Kangaroo Island and includes the regions south of Sellicks Beach on the Fleurieu Peninsula and south of Troubridge Point on Yorke Peninsula. This area is approximately 60 km north–south and includes the small townships of Kingscote, Penneshaw, Normanville and Cape Jervis. The main agricultural land uses in this area are grazing modified pastures and dryland cropping (EPA 2003b). Backstairs Passage is a key shipping route between Adelaide and the eastern seaboard and also between Adelaide and the West Coast. As a result there is significant vessel traffic through this region. This region experiences annual rainfall of between 500–600 mm (Appendix 4) and there are several creeks that discharge into the marine environment in the risk assessment region. The largest creek is the Cygnet River, which discharges into Western Cove within Nepean Bay on the north coast of Kangaroo Island. Other creeks that discharge into the southern region are the Myponga River and Deep Creek but it is likely that these only flow into the marine environment during large rainfall events.

The water environment and wave energies throughout the southern region vary greatly depending on aspect. The southern Fleurieu Peninsula is generally considered a high energy coast with distinctive steeply sloping rock cliffs or boulders with occasional sandy beaches between headlands (Womersely & Thomas 1976). The north coast of Kangaroo Island is relatively protected creating low wave energies and sandy beaches. The offshore habitats range from macroalgal dominated rocky reefs in the higher wave energy coasts commonly supporting dense canopies of Sargassum sp. and Ecklonia radiata communities (Shepherd & Sprigg 1976). Turner et al (2007) state that reefs on the Fleurieu Peninsula are in good condition, however reefs surveyed close to Victor Harbor (slightly outside the risk assessment region) were considered ‘at caution’.

Water quality in the southern region varies greatly depending on the surrounding catchment land use and creek condition. The Cygnet River is highly modified with a large agricultural catchment and water quality within the creek is generally classified as good to moderate (EPA 2006a) while the estuary and the marine receiving environment have been showing significant signs of aquatic ecosystem degradation (Gaylard 2005; Bryars 2003; Edyvane 1997). Recent surveys of the Myponga estuary have shown it to be very low in biodiversity (EPA unpublished); higher in the

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2 The reefs that were rated as poor were located on the western side of Yorke Peninsula and therefore are outside the boundaries of this risk assessment.
catchment water quality is classified as being generally moderate to poor (EPA 2006b). Very little information exists about water quality in marine waters outside of Nepean Bay in the southern region however available information suggests that the deep water and high current speeds results in effective flushing of the region with oceanic waters.

Summary of results

High risks

Wastewater treatment plants
In 2006 the three metropolitan WWTPs at Bolivar, Glenelg and Christies Beach cumulatively discharged almost 1,000 tonnes of nitrogen and over 400 tonnes of phosphorus into the nearshore marine environment (NPI 2007). These discharges also can contain occasional concentrations of trace metals, pesticides, pharmaceuticals and a range of other chemicals including potential endocrine disruptors.

Recent data indicates that between 1995−96 and 2002 there was still ongoing loss of 720 ha of seagrass from the Adelaide’s metropolitan coast (Cameron 2003), taking the total seagrass loss since observations began to in excess of 5,200 hectares. It is likely that in addition to degraded water quality, a significant proportion of this is due to increased fragmentation within beds, sediment instability and increased impacts of wave energies making seagrass beds more susceptible to erosion (Seddon 2001). Excessive nutrients have been shown to promote turf forming algae on macroalgal reefs in Southern Australia (Gorgula & Connell 2004). Once turfing algae are established they can out-compete canopy forming algae and potentially promote sedimentation of reefs (Worm 1999; Airoldi & Cinelli 1997; Kennelly 1987). It is highly likely that the discharge of nutrients from the coastal WWTPs is significantly contributing to the degradation of rocky reef habitats along Adelaide’s metropolitan coast (Turner et al 2007).

Seddon (2002) stated that the original causes of the seagrass loss in the metropolitan region are unlikely to be acting to the same degree as in the past. Appendix 8 shows that SA Water have reduced their nutrient loads from the Bolivar, Glenelg and Christies Beach WWTPs by 70%, 31% and 42% respectively. In addition the sewage sludge pipes at Glenelg and Port Adelaide were decommissioned in 1993 and there is some evidence of seagrass re-colonisation at the areas previously denuded. However the constant press nature of the discharge means that, while somewhat reduced from previous years, elevated nutrient concentrations are still likely to be causing a significant impact on seagrasses, macroalgal reefs and turbidity in the metropolitan coastal waters. It is likely that this pressure will continue until the quality of the water improves. The Bolivar WWTP discharge and also the discharge from the Port Adelaide WWTP (through nutrient release from sediments) are also contributing to the eutrophication of the Port River Estuary with large accumulations of macroalgae (particularly Ulva sp.), phytoplankton blooms and red tides (dinoflagellates).

The dominant species of seagrass in Adelaide’s nearshore environment are the Posidonia species. These species are widely considered to be very slow to recover from a disturbance whether it is natural or anthropogenic (Kirkman 1998) and seagrass have been shown to have significant value for ecosystem functions (providing habitat and nursery areas, improving water quality/clarity, arresting seabed erosion, etc), economic services (value of commercial and recreational fishing catch, cost of sand replenishment & wrack management, cost of restoration,
Figure 1  Northern Risk Assessment region
Figure 2  Eastern Risk Assessment region
Figure 3 Western Risk Assessment region
Figure 4  Southern Risk Assessment region
etc) and social values (enjoyment of using the beaches, odour from decaying wrack, education, etc) [McArthur & Boland 2006; Deans & Murray-Jones 2002].

Modelling as a part of the Port Waterways WQIP project by the EPA, has demonstrated that the Bolivar WWTP effluent plume is transported south into Barker Inlet and the Port River when there is a strong northerly wind (EPA 2008). The nutrients from this effluent contribute to the eutrophic state of the Port River Estuary and contribute to the blooms of the dinoflagellates *Alexandrium* spp. and *Gymnodinium* spp. The *Alexandrium* spp. blooms can be toxic to fish, either directly or through oxygen depletion in the waters. Toxins can bioaccumulate in shellfish, which if eaten by humans, can be potentially fatal, and has resulted in frequent prohibitions on collection of shellfish (Hallegraeff 1995).

This risk assessment has classified WWTP effluent a high risk to ecosystem, for aquaculture and shellfish harvesting within the eastern region.

Excessive micro and macroalgae can cause unsightly scums on the water surfaces, rafts of floating algae can become a navigational hazard, and the breakdown of such excessive amounts of algae can cause significant odour issues for nearby residents.

This risk has considered WWTP effluent to be a moderate risk to aesthetic and recreational values in the eastern region.

![Ulva in mangrove pneumatophores at St Kilda](Photo: Tony Lewis)
Urban stormwater in the eastern region of Gulf St Vincent

Stormwater enters the marine environment along Adelaide’s metropolitan coast and frequently discours the water in the nearshore environment approximately following the 5-m depth contour about 500 m offshore (Figure 7). This water will generally move parallel to the coast with only minimal mixing with deeper, clearer water resulting in the nearshore environment remaining discoloured for extended periods of time (up to 10 days) [Pattiaratchi & Jones 2005].

Stormwater from the Adelaide metropolitan region discharges high concentrations of suspended sediments, nutrients, and occasionally hydrocarbons, trace metals and pesticides (Wilkinson et al 2005). The high-risk rating results from the likely role of turbidity on the loss of seagrass and reef systems in the Adelaide metropolitan area (Westphalen et al 2005) and the long period of time for recovery of impacted seagrasses. Turbidity has also been shown to impact on shallow nearshore macroalgal reef habitats with reef condition surveys (Turner et al 2007; Cheshire & Westphalen 1999; Cheshire et al 1996) highlighting declining reef health along the northern section of the Adelaide metropolitan coastline (Brighton to North Haven) which is exposed to frequent stormwater runoff events, in which turbidity is a major pollutant. It is worthy to note that this decline cannot be wholly attributed to stormwater as there are several wastewater treatment plant and industrial discharges that could potentially impact on reefs in the northern metropolitan area (Tuner et al 2006; Cheshire & Westphalen 1999; Cheshire et al 1996).

This risk assessment has classified stormwater to be a high risk to ecosystem values in the eastern region.

In highly turbid environments shellfish can become smothered by high sedimentation and suspended particles can cause gill irritation of fish and tissue damage and make searching for prey harder (ANZECC 2000). In addition some aquaculture facilities require good light penetration through the water column in order for unimpeded microalgal production which feed the shellfish. Additionally trace metals, some hydrocarbons and pesticides can accumulate in filter feeding shellfish, which can impact on consumers as well as potential export markets. This risk is considered to be moderate for maintaining good water quality for aquaculture and shellfish harvesting.

Recreational values can be impacted by stormwater via a reduction in the visibility in the waters used as recreational areas. The eastern region has many large stormwater drains that discharge directly onto the beach or directly into the nearshore environment. This gives little opportunity for suspended solids to be filtered or settle out and results in turbid waters that can occasionally
A risk assessment of threats to water quality in Gulf St Vincent exceed the NHMRC Guidelines for safe bathing. Highly turbid waters can reduce visibility through the water column. Turbid water is a hazard for recreational activities such as swimming, making it hard to estimate the water depth or to see obstructions. There is also evidence that turbid waters also detracts from the enjoyment of water environments and therefore is likely to have a significant impact on aesthetic values as well as recreational values.

This risk assessment has classified stormwater to be a moderate risk to recreational and aesthetic values in the Eastern region.

![Turbidity plume at the Torrens outlet from a rainfall event on 25 October 2005 (Photo: S Bryars, SARDI Aquatic Sciences)](image)

**Figure 7** Turbidity plume at the Torrens outlet from a rainfall event on 25 October 2005 (Photo: S Bryars, SARDI Aquatic Sciences)

**Penrice Soda Products**
The Penrice Soda Products facility at Osborne discharges over 700 tonnes of nitrogen into the Port River every year. The vast majority of this nitrogen is in the form of ammonium (NH$_4^+$) and ammonia (NH$_3$), which is readily available to plants and algae. The excess of nitrogen in the Port waterways has led to macroalgal blooms of sea lettuce (*Ulva* sp.), seagrass loss and increases in turbidity. This discharge has also contributed to phytoplankton blooms within the shipping channel, including ‘red tides’ of the dinoflagellate *Alexandrium* spp. These blooms can be toxic to fish either directly or through oxygen depletion in the waters and toxins can bioaccumulate in shellfish, which if eaten by humans, can be potentially fatal. This risk has resulted in frequent closures to the collection of shellfish (Hallegraeff 1995) and permanent closure of the Port River south of North Arm.

The accumulation of macroalgae is unsightly and they can form large rafts that cause offensive odours when they decay (again releasing nutrients back into the waters). This alga, when in large amounts has also caused navigational hazards in North Arm and Barker Inlet.

The Port River has been inundated by nutrient discharges for a large part of the 20th century, so defining a definitive source of the obvious nutrient impact is difficult. Computer modelling as a part of the Port Waterways Water Quality Improvement Plan (WQIP) has shown that the current extent of the ammonia discharge from Penrice covers not only the immediate vicinity of the discharge but also well into North Arm, Barker Inlet and the upper reaches of the Port River (EPA 2008). In addition modelling for the Adelaide Coastal Waters Study (ACWS) has also shown that it is likely that the high total ammonia discharge from Penrice may be contributing to the seagrass loss along the metropolitan coast with its extent believed to reach as far south as Holdfast Shores (Bryars et al 2006b).
The discharge from Penrice Soda Products is considered to present a high risk to ecosystem values, aquaculture values in the eastern region.

Figure 8  Discharge from Penrice Soda Products in the Port River

Dredging
This risk assessment acknowledges that there are differences between large-scale dredging projects and smaller routine dredging (with a further separation between nearshore disposal and dewatered disposal in accordance with EPA Guidelines). In recent years there have been at least two large-scale dredging events that have caused significant turbidity in the surrounding waters for extended periods of time. The first was at O’Sullivans Beach in 1997 where a large ship was being used to dredge sediments for beach replenishment activities by the Coast Protection Board (Figure 9). The second was the Outer Harbor channel deepening project which resulted in significant turbidity plumes throughout Outer Harbour and Largs Bay throughout the summer of 2005–06.

The O’Sullivans Beach dredging caused widespread turbidity which caused significant sedimentation on Noarlunga and Horseshoe reefs. The combination of this event and high water temperatures due to a significant El’ Nino event caused a major recruitment failure of large brown algae such as *Ecklonia radiata* (Turner & Cheshire 2002). The effects of this recruitment failure (amongst other impacts) are still being seen on both Noarlunga and Horseshoe reefs over 10 years later (Turner *et al* 2007).

This evidence would suggest that dredging activities in the eastern region are a high risk to ecosystem values.

Small-scale dredging that disposes dredge spoil back into the nearshore environment has the potential to entrain fine particulates, detrital and coloured dissolved organic material into the nearshore environment. The ACWS has shown that this type of material in the nearshore environment is not well dispersed and can remain in the shallow waters for a long period of time. The cumulative impact of discoloured water from numerous dredging events along the metropolitan coast may be affecting nearshore water quality for ecosystem protection as well as recreational and aesthetic values.

Discoloured water can reduce the ability of swimmers to see through the water, increasing the risk of a swimmer being injured from failing to see obstructions in the water. Additionally
discoloured and turbid waters could make swimming less attractive and reduces the aesthetic value of our beaches.

**This risk assessment has considered dredging to be a moderate risk to recreational and aesthetic values in the eastern region.**

![Figure 9](image-url)

**Figure 9** Coast Protection Board dredging turbidity event at O’Sullivans Beach on 10 November 1997 (Photo: P Pfennig)

**Agricultural runoff**

The agricultural land in the southern region receives significantly more rainfall than the other risk assessment regions and therefore generates greater runoff from agricultural areas into streams into the marine environment. There are several streams that regularly flow into the marine environment from rural catchments in the southern region including Myponga, Yankallila and Cygnet Rivers. Monitoring of Cygnet River receiving environment in Nepean Bay has shown elevated levels of nutrients in Western Cove, with the flow from Cygnet River being identified as a likely source (Gaylard 2005). There is also anecdotal evidence that after periods of heavy rain, a large turbidity plume generated from the Cygnet River remains entrained in the water column reducing light penetration (S Gaylard pers observ).

Degraded water quality in parts of Nepean Bay has been identified as a probable cause of significant seagrass loss in the region and the receiving environment being considered eutrophic (Gaylard 2005; Bryars et al 2003; Edyvane 1997). Nepean Bay has been highlighted as an important nursery region for many species including both recreational and commercially valuable fish. Loss of these nursery areas could have an increased risk to fisheries in the whole southern region. An EPA snapshot of pesticides in sediments also detected a number of pesticides in the sediment of the Cygnet River estuary, indicating that occasional pulses of these chemicals could be reaching the marine environment.

**This risk assessment considered agricultural runoff to be a high risk to ecosystem values in the southern region.**
AGL Torrens Island Power Station

AGL Torrens Island has a peaking and load following generating role in the electricity market. Under the EPA’s environmental authorisation, cooling water is discharged from the AGL Torrens Island Power Station into Angas Inlet. The maximum thermal load is limited to a weekly average of 10.5°C above background temperature. Monitoring has shown that the power station complies with this criterion, and weekly averages are commonly 50%. Notwithstanding, there are demonstrated biological impacts in Angas Inlet, North Arm and Barker Inlet from the discharge of warm water. In addition the power station cooling water system is a conduit for the transport of nutrients and other ambient organic and inorganic materials between the Port River/North Arm and Angas Inlet. The elevated temperature in Angas inlet promotes algal production and exacerbates the eutrophic state of the environment.

This risk assessment considers that altered state is undesirable and that the risk to the receiving environment is that this altered state is maintained and that this is unlikely to change during the life of the plant.

In addition to the elevated temperature, the cooling water is treated with a biocide to manage the growth of biological organisms within the cooling water system. It is also likely that there are small amount of metals in the discharge due to corrosion of the pipes and the aging nature of the plant.

Therefore this risk assessment considered that the discharge from AGL Torrens Island Power Station is a high risk to ecosystem and aquaculture values in the eastern region.
Moderate risks

Commercial shipping and wharves

The eastern region is a key petroleum distribution point for the City of Adelaide. An Australian Maritime Safety Authority (AMSA) commissioned study investigating the risks from oil spills throughout Australia concluded that the greater risk of a large oil spill is a spill in a port rather than from a ship at sea (Jones et al 2000). The South Australian Marine Spill Contingency Action Plan (SAMSCAP) has designated Gulf St Vincent as a high-risk area.

Prior to Port Stanvac ceasing operations in 2003, in excess of 8.5 million tonnes of crude or refined products were shipped throughout the waters of South Australia annually in oil tankers (not all of this is in Gulf St Vincent). The Birkenhead petroleum storage facilities are located in close proximity to the Port River to facilitate petroleum product storage after it is unloaded from tankers. In 2005 there were 103 vessels that unloaded over 2 million tonnes of petroleum products at Port Adelaide, an increase from 75 vessels unloading 1.2 million tonnes in 2004 (Flinders Ports 2006).

Within Gulf St Vincent there have been two spills from the Port Stanvac Oil Refinery. One in 1982 when the Esso Gippsland caused a slick that impacted on beaches between Seaford and Aldinga. The second and more recent was also at Port Stanvac in 1999 where the refinery caused the spill of 230 tonnes of oil. However oil spill dispersant was used to break up the slick and consequently only 800 m of beach at Sellick’s Beach was affected (AMSA 2000).

Since the closure of Port Stanvac refinery there are more frequent vessels loading and unloading hydrocarbons in the Port River wharves. These loading facilities are generally adequate and are being upgraded to include vapour recovery to reduce significant odour issues for nearby residents. There are also well-maintained emergency safeguards in place due to the nature of the product being loaded.

This risk assessment considers the risk to ecosystem values to be moderate, but the risk to aquaculture and aesthetic values is considered low.

Commercial fishing

The southern region is home to a number of marine mammal species, including ecologically important seal and sea lion breeding and haul-out locations and penguin and seabird colonies. It also has significant commercial fishing effort in the region, which can impact on the habitats and
wildlife. Studies have shown that discarded fishing gear predominantly from the shark and rock lobster fisheries commonly impacts on seals and sea lions in those areas (Page et al 2004). The risk to ecosystem values in this region is considered to be moderate from commercial fishing rubbish. This risk rating would have been considered higher given the estimated seal and sea lion mortality rates from rubbish, but it is likely that the majority of the commercial shark and lobster fishing effort is outside the risk assessment area (where it is likely that risks would have been classified higher).

This region is also becoming more popular for beach tourism from an expanding local community and visitors from Adelaide. However currently the risk to aesthetic values in the southern region is considered to be low.

Recreational bathers
Following the NHMRC Guidelines for undertaking desktop and field assessments for risk characterisation the metropolitan coastal waters have been classified as being a low to moderate risk. The highest risk factor to recreational bathers in this region is from ‘bather shedding’. Studies have shown that bacteria can be released from bathers (known as bather shedding), either through accidental faecal release (AFR) or directly from the skin (Elmir et al 2007) and this can impact on recreational water quality (Papadakis et al 1997). EPA monitoring of Adelaide’s coastal waters and desktop sanitary inspections carried out for this risk assessment (see Appendix 1, section 2) have shown that there are times when microbial concentrations are elevated but there has been no rainfall in the days preceeding, and no other obvious sources other than high densities of swimmers in the water at the sampling site (EPA unpublished).

Bathers potentially may be at the most risk when dilution is low (dodge or very small tidal movement), low wind and there is very high bather densities. This could occur along Adelaide’s metropolitan coast during the summer months. However the salinity of seawater causes many pathogens to die off relatively quickly and thorough mixing of recreational waters leads to relatively safe waters for the majority of the time (NHMRC 2005; Corbin & Gaylard 2005).

This risk assessment indicates that recreational users of water are a moderate risk to recreational values in the eastern region. It is considered unlikely that there is significant recreational activity in aquaculture regions and therefore bathers are considered a low risk to aquaculture values in the eastern region.

Slipways
At the time of this risk assessment the fate of several slipways is uncertain. The Jenkins St boatyards in Port Adelaide are an icon in the Port and have been established at their current site for close to 100 years. A large proportion of these sites are subject to inundation in large high tides and as such are likely to be transferring trace metals to the marine environment. EPA monitoring has shown that the sediments close to many slipways are heavily contaminated with trace metals particularly copper and zinc, which are used in antifoulants (EPA 2000). The state government is currently undertaking a redevelopment of Port Adelaide waterfront precinct and has proposed to remove these facilities and build a best practice marine industry precinct at Snowdens Beach. Other slipways located in the Port River are North Haven, Outer Harbor and the Patawalonga Lake at Glenelg. At the time of writing, a number of the Jenkins St slipways are still in operation and as such have been assessed as a part of the risk ratings.

Antifoulant paints contain high concentrations of trace metals and are regularly removed from vessels while on a slipway. Additionally a number of slipways do not have adequate mechanisms to prevent pollutants from entering the marine environment.
Therefore this risk assessment considers the risk to ecosystem values from trace metals from slipways to be moderate. Currently there are no aquaculture facilities in close proximity to slipways that may be impacted by trace metals from slipways in this region and therefore the risk is considered low.

Quarries
The Rapid Bay quarry is located in very close proximity to the marine environment and is surrounded by very steep cliff faces. When the quarry was constructed the overburden was placed on the steep cliff face next to the water. This is relatively unstable and debris frequently fall into the sea. This discharge is likely to be contributing to the significant physical changes to the beaches in the region. In addition to the physical impacts large turbidity plumes can be seen in the nearshore environment during strong southerly winds extending northwards from Rapid Bay. Turbidity impacts may also be caused by surface water runoff across the site, which is also likely to reach the marine environment.

This risk assessment considers that turbidity from quarries in the southern region is a moderate risk to ecosystem values but a low risk to aquaculture and recreational values.

Acid sulfate soils
The CSIRO have undertaken a risk assessment of potential and actual acid sulfate soils across South Australia. This study has shown that the eastern region of this risk assessment has the only actual acid sulfate soils in the risk assessment region and have been rated by the CSIRO risk assessment as being 'very high'. This site, located in the Port Adelaide & Gillman region, has been shown to have a pH of 2.8–3.5 and elevated levels of metals in the water discharged to the adjacent marine environment (Thomas et al 2003). It is likely that this discharge is impacting on the Port River and Barker Inlet estuary. While the CSIRO risk assessment has classified this region as a very high risk in terms of potential for the formation of acid sulfate soils under disturbance, this risk assessment has classified it as a moderate risk for subsequent impacts on the environment. Although it is possible that the adjacent localised ecosystems, including fishery nursery areas, are being significantly impacted by these acid sulfate soils, it is considered that the actual and potential acid sulfate soils in the eastern region are a moderate risk to ecosystem values on a regional scale, based on the localised scale of impact.

Unclassified threats but significant risk to environmental values
Water quality has been shown to be a major influence in ecosystem condition and this risk assessment has focused on the threats to water quality. In carrying out this risk assessment it has been highlighted that there are a number of activities that are a significant risk to ecosystem values but have not been classified due to the water quality focus.

Prawn trawling
There are three main commercial fishing zones for the Western King Prawn in South Australia. These are Gulf St Vincent, Spencer Gulf and the West Coast. Trawlers use large funnel shaped nets to collect prawns into a smaller bag (codend) across the seabed.

There are 10 commercial licenses in the Gulf St Vincent prawn fishery and boats are permitted to use single, double and triple rigged nets to catch prawns. In the 2004–05 fishing year the total catch from the Gulf St Vincent fishery was 213 tonnes. This corresponded to catch per unit effort (CPUE) of 62.2 kg/hr, both of these statistics are significantly lower than peak figures indicating that the resource is at its lowest level for many years (Dixon et al 2006).
The physical disturbance of trawling these nets, particularly nets with tickler chains, can cause significant damage to the seafloor habitat and can effect biodiversity through impacts on bycatch species within fishing regions (Bridger 1970; Sainsbury 1988; Hall 1999).

Disturbance of the seafloor from trawling has not been formally considered for this risk assessment as it does not fit within the water quality focus of this document but it is considered to be a major issue in relation to the status of the Gulf St Vincent benthic environments (see work by Tanner, 2003 which contrasts current benthic habitats between recently trawled and untrawled locations in Spencer Gulf). It is possible that since trawling commenced in Gulf St Vincent many of the deeper water seagrasses have been wholly lost from these waters (AC Cheshire pers comm).

**Marine pests**

Marine pests can be introduced through a number of mechanisms:

- pests can be carried on the hull of a vessel if there are defects in the antifouling coating on the vessel
- pests can be carried by the vessel in ballast water and translocated when this ballast water is discharged
- pests can be carried in gear used for fishing and pests translocated when the gear is used at another location
- pests can even be accidentally (or deliberately) released into waters.

Each industry would have its own risk of translocating pests depending on a range of factors. For example commercial shipping would likely be a higher risk than commercial fishing in South Australia due to the shorter distances travelled.

Consequences on the marine environment of Gulf St Vincent from marine pests could be catastrophic with impacts possible on seagrass and reef habitats, commercial and recreational fisheries, industrial users of water and tourism. These impacts would be detrimental to all environmental values and result in the loss of millions of dollars to the state.

Marine pests are not an impact on water quality so have not been formally assessed in this risk assessment. However as stated in other sections, a specific risk assessment for *Caulerpa taxifolia* is being undertaken by PIRSA and SARDI Aquatic Sciences so the risk will not be assessed here.

**Desalination plants**

At the time of publication the South Australian Government proposed a reverse osmosis desalination plant at Port Stanvac in order to secure drinking water for the population of Adelaide. Initially a small-scale plant or ‘pilot plant’ was proposed, to investigate different water quality parameters and water treatment processes in order to understand how to design the full-scale plant (*The Australian* 21 January 2008). At the current stage of development it is not feasible to undertake this risk assessment process on either the pilot plant or the full-scale desalination plant, however there are a number of aspects that have significant potential to impact on water quality of Gulf St Vincent and the marine ecology of the surrounding region.

Reverse osmosis desalination plants use a membrane filter to remove the salt and other molecules from the feed water to produce water that is of a lower salinity than the feed water. In most cases the desired end-product is potable water. The waste product from this process is a brine solution that, due to the concentrating of the constituents of the water, has a very high salt load, typically in excess of 75‰ (seawater ~32.7‰). This concentrating effect will also increase the concentration of other constituents of the feed water that cannot pass through the
membrane. These can include a number of water treatment chemicals used in the process in order to maintain the integrity of the membrane and to prevent the build up of scale which reduces efficiency (referred to as antiscalants). The brine can also contain metals, pesticides and other pollutants that can be concentrated from very low concentrations in the feed water (Younos 2005). The brine solution is generally discharged into the marine environment where it may have deleterious impacts to the surrounding region if not well managed (Younos 2005).

The discharge of reverse osmosis desalination is hypersaline and therefore denser than water, causing it to sink in ambient seawater. Mixing and dilution/diffusion of the brine discharge is reliant on a number of hydrodynamic factors, principally local and far field bathymetry, tidal forces, local wind speed and direction which will dictate wind driven currents, wave height and speed, discharge rates and concentration and density driven mixing (Jenkins & Wasyl 2005). Modelling and other assessments of dilution need to take into consideration scenarios such as dodge tides with no wind and large tides with onshore winds (and other combinations) in order to understand possible normal and worst case scenarios.

There are a number of potential impacts from the brine discharge, including impacts from elevated salinity, temperature and altered dissolved oxygen of the water, and also the acute and chronic toxicity from the chemical additives and concentrated pollutants in the discharge (Younos 2005). These two impacts are not independent; the increased stress of maintaining the cells internal water balance (osmoregulation) can make the organism more susceptible to toxicity from the pollutants (Inman & Lockwood 1977). Higher salinities can also induce enzymes that increase toxicity (El-Alfy et al 1998; El-Alfy & Schlenck 2001).

The Hallett Cove reef (approximately 4.5 km from the proposed discharge site (T Kildea pers comm) has been sampled over the last 10 years through the Reef Health programs. This reef has consistently been considered to be in good condition, with relatively high cover of robust brown algae (such as Ecklonia radiata), low amount of bare substrate and relatively high amounts of diversity (Cheshire et al 1998; Cheshire & Westphalen 2000; Turner et al 2007).

Sessile organisms are more likely harmed than mobile organisms as it is likely that mobile organisms will move away from poorer quality water. While there has been some work investigating the impacts of lowered salinity on seagrasses (eg Westphalen et al 2005), little is known on the tolerance of elevated salinities on habitat forming species such as macroalgae and seagrass, particularly southern Australian species. Bay and Greenstein (1992) tested the effect of elevated salinities on the germination success of the giant kelp Macrocystis pyrifera and the marine amphipod Rhepoxynius abronius. This study found that there was no significant impact on the Macrocystis spores or the amphipods at 43‰ which was the highest salinity tested (Bay & Greenstein 1992).

There is some evidence that seagrasses can tolerate long-term higher salinities including environments in excess of 48‰ such as Port Augusta (Shepherd 1983; Ainslie et al 1994) and Shark Bay WA (Walker et al 1989). In these particular situations the ambient salinity has been slowly elevated and organisms have been capable of maintaining osmoregulation. Koch et al (2006) exposed a number of tropical seagrasses to slowly adjusted salinity changes which showed no adverse impact after 30 days at salinities up to 55–70‰. However when the salinities are suddenly increased the ability for seagrasses to osmoregulate is decreased and the salinity threshold is reached much earlier, eg 45‰ for Thalassia testudinum compared to its gradual increase threshold at 60‰ (Koch et al 2006). Walker & McComb (1989) have shown that the Shark Bay seedlings of Amphibolis antarctica (the dominant seagrass) have a maximum leaf production rate at 42‰, even when seedlings are collected from areas of higher salinity. This study also showed seedlings were impacted after five days at 65‰ (Walker & McComb 1989).

Seagrass and reef habitats are breeding and nursery areas for many commercial and recreationally captured fish and invertebrate species. For many marine species the eggs, larvae
and juveniles are generally most sensitive to acute and chronic toxicants, including salt (Buikema et al 1982; Calow 1993). There is laboratory based evidence that juvenile survival of Blue Swimmer Crabs can be significantly reduced when cultured at 45‰. Similarly growth rates have also been shown to be significantly reduced at ≥40‰ (Ramano & Zeng 2006). Inadequate mixing of high salinity discharges could impact on recruitment, breeding and survival. These activities are vital to seagrass and reef health, biological diversity and both commercial and recreational fishing stocks. This may jeopardise localised populations of protected species such as the sygnathids (seahorses and pipefish).

Many mobile organisms have the ability to avoid localised areas of poorer water quality or some toxicants (Sprague & Drury 1969). If organisms avoid an impacted region this could create movement of or barriers to migration routes, change in food sources, alterations to predator–prey relationships, spawning cues and aggregations, and will impact on community structure of the localised and adjacent ecosystems (Kroon 2005).

**Climate change**

The average temperature of the earth’s atmosphere and oceans rose by approximately 0.6°C over the last century and global ocean temperatures have also risen over the last 50 years. The vast majority of these increases have been caused by human activities (IPCC 2001).

The Intergovernmental Panel on Climate Change (IPCC) Scientific Basis Report (2001) states that there are widespread indications of the warming of global oceans at a rate of 0.7°C over the last century (IPCC 2001). This warming (and subsequent expansion) of the global oceans is expected to continue and have a wide variety of impacts. Higher water temperatures can lead to both direct and indirect impacts on biological systems, including changes in species distributions or ranges and abundances of some organisms, displacing others from their habitats and causing some to thrive (IPCC 2001), impacting on ontogenic timing of larvae and possibly impacting on growth and reproduction, particularly on species that are living close to their temperature threshold (Fine & Franklin 2007). In temperate areas organisms relying on colder waters could be displaced by more sub-tropical species, which could thrive in higher water temperatures, this impact can be seen (on a more dramatic scale) within Angas Inlet in the Port River, which receives water of higher temperature from the AGL Torrens Island Power Station (see section 4.5.1) where studies of the intertidal benthic environment receiving thermal effluent from the power station have shown the presence of several tropical species due to the altered water temperatures (Thomas et al 1986).

Increased water temperature is just one impact from climate change, additional impacts on all environmental values will occur and a number of potential impacts are listed as follows:

- **Increase in intense rainfall events will lead to fast flowing stormwater and riverine runoff carrying more sediment from increased erosion of stream banks and pollutant transport to the marine and coastal environments (IPCC 2001).**
- **Higher water temperatures will increase algal growth and exacerbate the impacts on nutrient enrichment leading to more and prolonged algal blooms.**
- **Likelihood of more invasive species establishing by increasing the range of subtropical species and potentially stressing endemic species.**
- **Increasing atmospheric carbon dioxide will slowly reduce the pH and carbonate ion concentrations in global oceans, particularly the Southern Ocean. If this trend continues (in a business as usual scenario) by the year 2050 the Southern Ocean will have an undersaturation of aragonite (a metastable form of calcium carbonate) which has been shown to experimentally cause a dissolution in some potentially sensitive marine organisms**
exoskeletons eg coralline algae, pteropods (a major zooplankton species in Antarctic waters and occasionally at higher latitudes), gorgonians and sea urchins (Orr et al 2005).

- Increase growth rates and algal productivity (in some regions) which may alter food webs and food availability.

- Sea level rise, estimated to be between 13–94 cm by 2100 (IPCC 2001) may cause the deeper extent of seagrass to retreat shorewards in order to maintain the same light intensity. If this retreat is not partnered with an expansion in shoreward seagrass cover (possibly due to increased erosion and increased sediment load from intense weather) the net result will be a decrease in seagrass coverage.

- Macroalgal reef species composition varies markedly based on many factors including depth and water movement (Shepherd & Sprigg 1976). A change in both sea level and an increase in intense weather events may significantly change the composition of macroagal reefs in Gulf St Vincent (and South Australia).

- Many macroalgal communities are dependant on a specific temperature range and an increase in water temperature will have an inhibitory effect on algal recruitment (Turner 2004).

- There are also temperature triggers for reproduction and larval development in many other organisms, which can be impacted by a change in water temperature, this may lead to changes in the abundance and distribution (ecology) of many species (Fine & Franklin 2007).

Due to the global nature of climate change and increasing water temperatures the impacts of these occurrences have been considered together as impacts of increased water temperature from climate change on Gulf St Vincent. However it should be noted that the summary for this risk assessment is extremely brief and there is very high uncertainty about the impacts of climate change on the marine ecosystems within Gulf St Vincent. A detailed assessment of the impacts of climate change is outside the scope of this report and has not been carried out for Gulf St Vincent.

**Conclusions**

This risk assessment has identified the major risks to water quality that have the potential to impact on environmental values of the protection of ecosystems, aquaculture, recreational users of water and the aesthetic values of water.

It also acknowledges that there are many other risks to environmental values in Gulf St Vincent that have not been classified or prioritised using this risk matrix, some of these have been discussed within the document but are not water quality related (eg prawn trawling) and some have been not been constructed so as to undertake an adequate assessment of risk to water quality (eg Port Stanvac desalination plant). It is envisaged that the risks classified within this document may change with time and with various management actions designed to lessen the risk. This document is intended to be updated regularly in order to re-evaluate risk in response to these changes.

While this risk assessment has been relatively comprehensive there are several areas that information or scientific data is limited and this has resulted in a risk that has been evaluated more on opinion than by weight of evidence. These areas have been flagged as needing further research in order to understand processes, particularly relating to environmental fate of chemicals in the marine environment. The areas that there is very little site-specific information and a need for further research are the discharge of pharmaceuticals, endocrine disrupting chemicals and personal care products from WWTPs.
The risks identified in this report have the potential to significantly impact on environmental values within Gulf St Vincent. These risks need to be managed in order to reduce any impacts that are occurring or could occur in order to protect the environmental values within Gulf St Vincent for all South Australians.
APPENDIX 1  DETAILED ASSESSMENT OF THREATS TO WATER QUALITY

1  Introduction

Gulf St Vincent is a reverse estuary, which has only limited exchange with the Southern Ocean. It supports extensive habitats of seagrass and macroalgal reef communities and maintains recreational and commercial fisheries and aquaculture. Adelaide is a city of approximately 1.2 million people (Australian Bureau of Statistics 2007) and it lies on the coast of Gulf St Vincent. This gulf receives waste and storm water discharges from Adelaide and has exhibited significant environmental degradation over the last 50 years. In order to protect the beneficial uses that is valued in the region, there is a need to assess the greatest risks to water quality within this region.

Some form of risk assessment is used to make every management decision, including what needs to be managed, how much effort is required to achieve results and/or to avoid undesirable outcomes (Fletcher 2005). A risk assessment is the practice of determining the nature and likelihood of effects of anthropogenic actions on animals, plants, and the greater environment. It is hoped that this risk assessment will help organise information and contribute to informed decisions. It is a useful management tool that will:

- highlight the greatest risks, which is needed to support allocation decisions for limited resources
- allow for management agencies to ask ‘what if’ questions regarding the consequences of various potential management actions
- facilitate explicit identification of environmental values of concern
- identify critical knowledge gaps, thereby helping to prioritise future research.

(SETAC 1997)

1.1  Overview of this risk assessment

Standards Australia outlines methods for undertaking ecological risk assessments (Standards Australia 2004) and while these were used as a basis for the assessment the methods have been modified to better achieve the goals for this particular risk assessment. This approach has been successful in other risk assessment processes such as the discharge of chemicals into the environment (USEPA 1992), fisheries management (Fletcher 2005), aquaculture (Sumner et al 2004), the introduction of marine pests (Hayes 1997) and genetically modified organisms (Hallerman et al 1999).

This risk assessment used a workshop of experts in marine and environmental sciences including academics, managers, industry, researchers and technical staff to assess data (when available) and use collective experience to identify risks, assess likelihood and consequences for each potential threat to water quality within Gulf St Vincent.

Where available, data has been used to accompany and guide the risk assessment process. However it has been stated that the assessment of risk is probably of greatest importance in data poor situations (Fletcher 2005). In these data-poor situations uncertainty has been treated by using a conservative approach (in line with the precautionary principle) and in most cases an estimate of likelihood and consequence has been made. In some circumstances where there is too much uncertainty, these situations are flagged for further research before any assessment can be made.
This risk assessment has been carried out assuming there are controls in place, ie if there are emergency safeguards in place to control any incident or pollution, they are assumed to be in place, well maintained and working for the purposes of this risk assessment. To attempt a risk assessment using no controls at all would be pointless as this does not represent the real-life situation.

Risk ratings in this risk assessment have been made on the current level of knowledge and understanding about the loads, fate and toxicities of the chemical discharges and the current ecological condition of the receiving environment. It is anticipated that an adaptive management approach will be used to review and refine the risk ratings based on increases in the level of understanding and whether the risk to the environmental values within Gulf St Vincent have increased or decreased.

1.2 Aspects to be considered when assessing the risk to water quality

This process will identify which risks to water quality within Gulf St Vincent are serious enough to require management actions. Risk is calculated by evaluating the consequence by the likelihood of the event occurring. The approach focuses on:

- Likelihood—also probability.
- Consequence—in this case, an environmental value compromised or environmental harm if an event occurs.

This approach can only be used to calculate risk in a ‘semi-qualitative’ way. A quantitative risk assessment would be unachievable in most situations due to lack of data regarding the numerous complex discharges and impact situations.

1.2.1 Likelihood

Theoretically, likelihood can be split into three categories: certain, uncertain and impossible. In many cases there are situations where risks are certain, as these are currently a fundamental consequence of the day-to-day operation of facilities necessary to maintain human society.

An example is the marine discharge from Bolivar wastewater treatment plants. In its risk matrix, ‘Likelihood’ has been split into six categories:

- once a day or more likely—this incorporates continuous discharges such as WWTPs
- once a week or more likely
- once a month or more often
- once a year or more often
- once every ten years or more often
- less often than once in every 10 years.

Where things occur regularly, or are ongoing, assessment of likelihood will be simple. When events are rarer, determining the probability of a risk may require an educated guess. This is the subjective nature of a risk assessment.

1.2.2 Consequence

The consequence rating in this risk matrix incorporates five levels starting with no measurable impact although a discharge or event has occurred, and ending with catastrophic where the environmental value is compromised over a long time period (even permanently) AND over a wide extent.
1.3 Definitions:

These definitions are aimed as a guide for the line of thinking that should be used to evaluate risk:

<table>
<thead>
<tr>
<th>Term</th>
<th>Descriptor</th>
<th>Indicative size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extent</td>
<td>Trivial</td>
<td>No measurable impact on environmental value</td>
</tr>
<tr>
<td></td>
<td>Minor</td>
<td>Very small proportion of region and minor impact on environmental value. Recovery is likely to be within days to weeks</td>
</tr>
<tr>
<td></td>
<td>Small</td>
<td>Likely to be a small area however this may change depending on conservation value of the region which could change the impacts on environmental value. Recovery is likely to be weeks to months</td>
</tr>
<tr>
<td></td>
<td>Moderate</td>
<td>Likely to be a measurable impact on environmental value over a small proportion of the region. Recovery is likely to be months to years.</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>Generally considered to be a significant impact on environmental value throughout a large proportion of the region. Recovery is likely to be years to decades.</td>
</tr>
<tr>
<td></td>
<td>Catastrophic</td>
<td>A severe impact on environmental values throughout the entire region. Recovery is unlikely within a generation.</td>
</tr>
</tbody>
</table>

All of the above indicative size categories can be subject to change based on the conservation status of the area being assessed. If the consequence of a discharge has been classified as a moderate risk but the discharge impacts on a sensitive area (e.g., sanctuary zone in a Marine Protected Area) then the consequence can be adjusted higher to reflect this conservation status.

The descriptions set out here are suggestive for extent and recovery only. They are not meant to be definitive criteria for the degree of degraded water quality. Assigning a level to the degradation in water quality will rely on many other factors such as how sensitive the receiving environment is, the speed of action, etc. (see below for detailed explanation).

*Trivial*

The discharge or incident results in no detectable harm or impact, or any impact is so small that it is not considered to impact in a substantive way on either ecosystem processes or aesthetic quality. Generally, this would apply to situations where the discharge is lower than the criteria in the WQEP.

*Example—The discharge of pesticides via regional community wastewater management systems (CWMS).*

*Minor consequence*

Potential for harm over a small scale where recovery would be complete and rapid. Some impacts may cause perturbations that are smaller than the typical scale of changes seen over seasonal or inter-annual cycles of natural variation. Also cases where discharges do not meet the WQEP but no harm is observed.

*Example—Temporary slight increase in turbidity as a result of dredging in a moderately impacted area.*
Small scale compromise of environmental values
This may be an event that temporarily exceeds water quality objectives for a designated environmental value. An impact may be seen over a limited extent but recovery is rapid and complete. No cumulative impacts and no clean up or remediation required.

Example—Urban runoff during winter rain events in non-metropolitan areas where levels of nutrients may exceed the WQEPP.

Moderate level compromise of environmental values
An event that exceeds water quality objectives for an environmental value where a measurable impact is observed temporarily over a wide extent OR over a small spatial extent for a longer period of time. Some organisms and habitats may be reduced in number or extent for a period of time. Some cumulative impacts may result in an overall reduction in status of environmental values.

Example—Small sewage spill (~1 ML) into marine waters with recreational values.

High level compromise of environmental values
An event where environmental values are compromised over a wide area OR over a moderate timescale. There may be significant losses of organisms and/or habitat but there is prospect for recovery of the system to yield a similar or equally productive and diverse community over a period of years.

Example—Dredging event where there is a prolonged significant increase in fine turbidity in a sensitive area.

Catastrophic compromise of environmental values
An event where environmental values are compromised over a wide scale AND for a greatly extended duration. Recovery within a generation is unlikely to result in a system that is as diverse or productive as the original. Wide-scale habitat and organism losses with the potential for whole ecosystems to be lost.

Example—large scale (thousands of hectares) loss of seagrass due to chronic impact of waste water disposal.

1.3.1 Understanding the consequence of an event
The following section looks at what issues need to be considered when evaluating the consequences of an event. This is a complex issue and is subjective given the semi-quantitative nature of this risk assessment.

Action of impact
Harm may be caused to the environment at an immediate, fast or slow pace after an event has occurred.

The slower the action of an event the more scope for intervention and harm minimisation. This may reduce the final consequence or length until recovery.

Toxicity
The toxicity of a discharge will have great bearing on the level of consequence. This will take into consideration acute and chronic effects from toxicants, cumulative impacts and issues such as bioaccumulation and biomagnification.
Pulse versus press discharge
While the toxicity of the discharge will have a large bearing on the impact, the frequency of the discharge also needs to be considered. For example; if the same pollutant was discharged into the same habitat via a major event versus numerous minor events, which is the greater risk to the environmental values?

Disturbances can generally be classified as either pulse or press discharges (Bender et al 1984; Glasby & Underwood 1995). Pulse discharges are generally short term and generally cause relatively immediate impacts on the receiving environment, however once the cause of the disturbance disappears, recovery will start and can be relatively quick (short term disturbance/short term impact). Press disturbances frequently result from continuous discharges and the impacts are generally long term (Glasby & Underwood 1995). Recovery is very slow (if at all) due to the sustained nature of the discharge and it is likely that the community composition will change to more pollution tolerant species (Koetsier 2002).

Sensitivity of receiving environment
While all receiving environments have the set environmental values as described above there are areas that are known to have organisms or habitats that are particularly sensitive (or even unique) or have follow-on effects of impacting food webs due to disturbances to fish spawning, feeding, growth and reproduction, etc. These regions could be declared aquatic reserves or future marine protected areas (such as the Encounter Marine Park). If impacted, these areas may take longer to recover (if at all) or may result in a loss of a disproportionally high amount of the given environmental value. For example if a discharge impacts on a nearshore seagrass and mangrove habitat known to be a highly productive nursery area for fish and crustaceans which contributes to both the ecosystem and commercial and recreational fisheries, then this may result in a higher consequence rating for that discharge.

Duration
The duration of impact will have a significant influence over the degree of harm and therefore the risk to the environmental value. If a receiving environment is particularly resilient then there is likely to be less risk of longer term damage. However if a region of Posidonia seagrass is completely denuded this region may take a lot longer to regrow and would therefore afford a higher risk.

Complex mixtures
The vast majority of toxicity data deals with single species and single toxicants. It is generally assumed that in a mixture the toxicity will be the summation of the individual toxicants (additive). There is evidence that mixtures of toxicants can result in higher toxicity to organisms than just the sum of the two toxicants. This effect is called synergism or potentiation (Walker et al 1996).

1.4 Risk Rating
The risk rating is the position in the risk matrix (see Appendix 2) where the likelihood and the consequence are based on the knowledge and experience of the person assessing it. The code in that position can then be used by management agencies to evaluate the level of risk from that specific event.

This risk assessment is not intended to be detailed to the point of characterising the catchment make-up for every stormwater discharge in Gulf St Vincent or each aspect of every facility on a site. This risk assessment is attempting to assess the risk on the aggregate inputs to Gulf St Vincent and is based on agreed probabilities and likely impacts gathered from available
information and knowledge, Appendix 3 shows examples of how to look at risk assessment using this framework.

2 Delineation of regions

2.1 Summary of some key marine habitats in Gulf St Vincent
This risk assessment has divided the Gulf into four main regions. These regions arbitrary but are based on the bathymetric conditions, wave energies and dominant habitats which characterise the regions. These conditions will alter the impact of particular stressors in that region and therefore should be separated from each other.

2.2 Northern Gulf St Vincent (Figure 1)
The northern region of the risk assessment encompasses the area north of the Gawler River to the top of the Gulf and west to a point just south of Port Julia. This area is approximately 60 km north–south and includes the small townships of Ardrossan, Port Wakefield, Price and Port Gawler. The main land uses in this area are grazing modified pastures and dryland cropping. Industries in the coastal region are predominantly limited to a large quarry at Ardrossan and saltfields at Price (EPA 2003b).

This region receives between 300–400 mm of rain (Appendix 3), which is considerably lower than the other regions. The Wakefield River is the only drainage line of significance in this region. This creek frequently flows in the upper catchment however this flow dries up or flows underground which means surface water very rarely enters the marine environment, estimated at one in 20 years (P Goonan pers comm).

This region is considerably different to the other regions in the Gulf due to the lower wave energies in the northern region of Gulf St Vincent resulting in extended areas of sandy–muddy intertidal flats (Womersley & Thomas 1976). These regions are dominated by several well-defined plant communities including the seagrasses *Posidonia* and *Heterozostera* in the intertidal and subtidal regions. The grey mangrove *Avicennia marina* forms dense communities in the lower eulittoral into the supralittoral zones and samphire communities dominate in the supralittoral zones (Womersley & Thomas 1976).

Very little information exists about water quality north of the Gawler River, however there are only occasional riverine or industrial discharges so the water quality is expected to be relatively good. However there is significant potential for poorer quality water to be transported from the eastern region into the northern region, particularly during strong southerly winds and northern current flows.

2.2.1 Environmental values within the region
In line with the National Water Quality Strategy and in the absence of specific values being set for a particular water body or section of coast, the WQEPP sets default protected values for all marine waters. The values adopted for the northern region in this risk assessment are:

**Protection of the aquatic ecosystem**
Significant seagrass habitats, and recreational and commercial fisheries throughout the northern region are in need of protection. The region is dominated by seagrass meadows, which are sensitive to reductions in light penetration through the water.

**Protection of aquaculture**
Water quality criteria for the region have been set not only for the culturing of fish but also for the protection of shellfish (ANZECC 2000. The major shellfish species that are or may be cultured
in this region include the Pacific Oyster, Blue Mussel and the Razorfish which are all filter feeding organisms. Filter feeders take in water and particulates including algae as food. This feeding strategy exposes the organisms to pollutants entrained in the water column and attached to particulates. The accumulation of such pollutants can result in impacts on shellfish consumers. This is particularly of concern for the accumulation of persistent pollutants such as trace metals and pesticides.

Currently aquaculture in the northern region is limited to oyster leases between Ardrossan and Black Point. However the environmental value of protection of aquaculture also encompasses the collection of shellfish within the region. The northern region has extensive razorfish beds, which are regularly harvested by recreational fishermen.

**Protection of recreation users and aesthetics**

Primary contact activities (swimming, snorkelling, surfing, diving, etc) are a key part of the South Australian lifestyle particularly during the summer months. A desktop sanitary inspection of the northern region has been undertaken and the risk of faecal contamination of recreational waters has been assessed as low. This is based on the fact that the entire northern region does not contain a sewage discharge to the marine or riverine environment. Human faecal wastes would be contained in septic tanks, which are pumped out via waste transport contractors. In the event that septic tanks are not well maintained or overflow, the potential for significant human faecal contamination in recreational areas would be limited due to the small populations at each town. The populations at each coastal township are quite low with less than 1,600 people (SA Tourism Commission 2007a) and therefore the risk of contamination from bather shedding or local shipping and boating would also be low. The northern region is farmed extensively and animal faecal wastes can cause contamination of waters however due to the low rainfall and dry nature of the region any wastes are unlikely to reach recreational areas, except in extreme events. This classification gives a set of trigger values for enterococci (as an indicator species) in recreational waters (Table 5.13; NHMRC 2005) and risks for this value are based on these guidelines.

All waters in the northern Gulf St Vincent region are considered to have aesthetic values, which impact on the way people look and feel about a water body. Algal scums, oils and wastes can detract from aesthetic values and reduce the participation and enjoyment gained from water. This can lead to reductions in tourism and subsequent local economies.

2.3 Eastern Gulf St Vincent (Figure 2)

The eastern region of this risk assessment covers an area reaching from the Gawler River in the north, south to Sellicks Beach. This area covers approximately 75 km north–south and encompasses the City of Adelaide and surrounding suburbs. The region receives between 400–500 mm of rain in the coastal areas to between 600–800 mm in the Adelaide Hills (Appendix 4).

This region is generally seen as being a moderate energy coastline when compared to other regions within Gulf St Vincent. The eastern region is dominated by gently sloping shallow sandy beaches, particularly in the north, while substrates are typically made up of regions of rocky substrates ranging from gently sloping dissected rock to almost horizontal rock platforms being common in the south of the region (Womersley & Thomas 1976). The main biotic communities within this region are the seagrass communities *Posidonia* and *Amphibolis* usually in dense monospecific meadows and *Heterozostera* and *Halophila* species in scattered clumps, particularly in deeper water (for detailed analysis of seagrass communities, see Shepherd & Sprigg 1976; Steffensen et al 1989; EPA 1998; Westphalen et al 2004). Where substrate exists, the species composition of reef communities are typically dependant on depth and water movement, however many inshore reefs are dominated by *Cystophora* spp., *Ecklonia radiata* and

There are 23 major and minor catchments in the eastern region, six of these are very small catchments which have little or no surface drainage (Wilkinson et al 2005). Wilkinson et al (2005) state that the land uses for these catchments is made up of urban/suburban/industry (36%), grazing and animal use (27%), horticulture/cropping (19%), low impact use (16%) and 2% is unmapped (Wilkinson et al 2005). This area also contains the most number of industrial discharges in Gulf St Vincent including three WWTPs at Bolivar, Glenelg and Christies Beach. There are nine large ‘riverine’ discharges that frequently drain into Gulf St Vincent and numerous small stormwater drains.

Water quality along Adelaide’s metropolitan coast has been shown to be generally lower than waters in non-urban areas with some conditional indicators being classified as poor (Gaylard 2004). The EPA undertook a survey of seagrass throughout Gulf St Vincent using Landsat TM satellite imagery. While this study was limited by low spatial resolution (30 m pixels) and to waters shallower than 12 m it showed that the loss of seagrass throughout the Gulf was limited to areas in relatively close proximity to the metropolitan coast of Adelaide and some area of seagrass loss near Bolivar (Cameron 1999). Declining water quality has been implicated in contributing to the loss of approximately 5,000ha seagrass from the Adelaide metropolitan area (Westphalen et al 2005; Cameron 2003; Seddon & Murray-Jones 2002) particularly in the nearshore regions between Largs Bay and Brighton (Westphalen et al 2005). Rocky reef systems have also demonstrated decline with reefs around the northern metropolitan areas generally being in poorer condition than reefs in areas outside of this risk assessment region (Turner et al 2007; Cheshire & Westphalen 2000).

In 2007 the Adelaide Coastal Waters Study (ACWS) concluded that the key issues impacting on the seagrasses along Adelaide’s metropolitan coastline are elevated nutrients causing growth of epiphytes, and sediment instability was preventing the re-colonisation of seagrass (Fox et al 2007). The ACWS has documented 14 recommendations and a Water Quality Improvement Plan (ACWQIP) is being developed to implement nutrient and sediment reduction strategies from the major sources.

2.3.1 Environmental values within the region

The values adopted for the Eastern region in this risk assessment are:

**Protection of the aquatic ecosystem**

As mentioned above there are significant seagrass and macroalgal reef habitats throughout the eastern region which are in need of protection. In addition there are large commercial and recreational fishing resources that rely on good water quality in order to be sustainable.

**Protection of aquaculture**

While there are no commercial aquaculture leases in the eastern region, the Port River and the intertidal regions northwards are well known for high abundances of Razorfish, which are consumed by fishermen. The ‘Section Bank’ within the Port River has been commercially fished for cockles (*Katelysia* spp.). Therefore the eastern region in this risk assessment has been assessed for aquaculture values.

**Protection of recreation users & aesthetics**

Primary contact activities (swimming, snorkelling, surfing, diving, etc) are a key part of the South Australian lifestyle particularly during the summer months. The Adelaide region (and therefore the Eastern Gulf St Vincent Risk Assessment region) has the highest concentration of
recreational beach users along Gulf St Vincent. The Department of Health have conducted a sanitary inspection of the Adelaide Coastal waters and have concluded that the waters are classified as ‘Low Risk’ (D Cunliffe pers comm). This assessment is based on the high level of treatment and disinfection of the sewage discharges into the marine and riverine environments and the significant dilution of the coastal waters. The relatively high bather numbers results in a risk of contamination of recreational waters from bather shedding, however due to the high water flows and regular tides this risk is considered low. The eastern region has limited areas of intensive pastures, which could contaminate waters after rainfall. However domestic animal faeces can often wash into waters in urban stormwater. The Department of Health has issued a statement recommending bathers avoid swimming in turbid waters after periods of heavy rainfall due to risks to bather safety. This classification gives a set of trigger values for enterococci (as an indicator species) in recreational waters (Table 5.13; NHMRC 2005), against which risks to water quality have been assessed.

All waters in the eastern Gulf St Vincent region have aesthetic values.

2.4 Western Gulf St Vincent (Figure 3)

The western region of the risk assessment encompasses the Gulf St Vincent side of Yorke Peninsula south of Port Julia to Troubridge Point. This area is approximately 60 km north–south and includes the small townships of Port Vincent, Stansbury, Edithburg and Coobowie. The main land uses in this area are grazing modified pastures and dryland cropping (EPA 2003b). Industries in the coastal region are limited to the bulk grain wharves at Wool Bay, limestone quarries and agriculture. This region has been experiencing growth in residential developments and marina developments over the last decade.

This region experiences annual rainfall of between 300–400 mm (Appendix 4) and there are no creeks or drainage lines of significance within Yorke Peninsula and therefore there is very little channelled surface runoff into the marine environment.

The coast of the Yorke Peninsula is generally low lying and changes from an exposed coast with strong wave action in the south (particularly south west) to one of very slight wave action dominated by sand and mud flats on the east (Laws 1973). Very little information exists about water quality in the western Gulf St Vincent, however regular algal and bacterial monitoring is undertaken by PIRSA South Australian Shellfish Quality Assurance Program (SASQAP) and data from their summary reports have been used in the assessment of risks to water quality.

Turner et al (2007) have surveyed selected macroalgal reefs on the Yorke Peninsula and found that generally reefs were in good condition however a number of reefs rated either poor or at caution, conclusions were that this is likely to be due to natural wave energies, topography and current flow, rather than poor water quality per se (Turner et al 2007).

2.4.1 Environmental values within the region

The values adopted for the western region in this risk assessment are:

Protection of the aquatic ecosystem

As mentioned above there are significant seagrass and macroalgal reef habitats throughout the eastern region which are in need of protection. In addition there are large commercial and recreational fishing resources that rely on good water quality in order to be sustainable.

Protection of aquaculture

Currently there is significant intertidal oyster aquaculture in the Western region and there are pilot leases for the use of sea-cage aquaculture for the production of Snapper and Kingfish offshore from Port Giles. There is also a subtidal shellfish lease near Port Julia. For these reasons
water quality must meet guideline values to ensure the growth and protection of cultured fish, molluscs and crustaceans.

**Protection of recreation users and aesthetics**

Primary contact activities (swimming, snorkelling, surfing, diving, etc) are a key part of the South Australian lifestyle particularly during the summer months. A desktop sanitary inspection of the western region has been undertaken and the risk has been concluded to be low. This is based on the fact that there are no sewage discharges to the marine or riverine environment across the entire western region. Human faecal wastes would be contained in septic tanks, which are pumped out by waste transport contractors and disposed of in accordance with an EPA licence or sewage is disposed of via CWMS schemes. In the event that septic tanks are not well maintained or overflow the potential for significant human faecal contamination in recreational areas would be limited due to the small populations at each town. The populations at each coastal township are quite low, less than 1,000 people (SA Tourism Commission 2007a) and therefore the risk of contamination from bather shedding or local shipping and boating would also be low. The Yorke Peninsula has significant areas of pastures and animal grazing which can wash faeces into local waterways, however there are very few drainage lines on the Yorke Peninsula and this waste is unlikely to reach recreational areas except in extreme events. This classification gives a set of trigger values for enterococci (as an indicator species) in recreational waters (Table 5.13; NHMRC 2005) for which risks to recreational values were assessed.

All waters in the western Gulf St Vincent region have aesthetic values.

### 2.5 Southern Gulf St Vincent (Figure 4)

The southern region of the risk assessment encompasses the southern aspects of the Gulf including Backstairs Passage. This region is bordered on the southern side by Kangaroo Island and includes the regions south of Sellicks Beach on the Fleurieu Peninsula and south of Troubridge Point on Yorke Peninsula. This area is approximately 60 km north–south and includes the small townships of Kingscote, Penneshaw, Normanville and Cape Jervis. The main agricultural land uses in this area are grazing modified pastures and dryland cropping (EPA 2003b).

This region experiences annual rainfall of between 500–600 mm (Appendix 4) and there are several creeks that discharge into the marine environment in the risk assessment region. The largest creek is the Cygnet River, which discharges into Western Cove within Nepean Bay on the north coast of Kangaroo Island. Other creeks that discharge into the southern region are the Myponga River and Deep Creek.

Industries in the coastal region are limited to commercial transport ferries at Cape Jervis and Penneshaw, the CWMS scheme at Kingscote, and a large quarry at Rapid Bay. The waters between the Fleurieu Peninsula and Kangaroo Island (Backstairs Passage) are frequently used for large commercial shipping lanes. There are significant areas of both intertidal and subtidal shellfish aquaculture throughout the north coast of Kangaroo Island. This region has been experiencing growth in residential developments and marina developments over the last decade.

The water environment and wave energies throughout the southern region vary greatly depending on aspect. The southern Fleurieu Peninsula is generally considered a high energy coast with distinctive steeply sloping rock cliffs or boulders with occasional sandy beaches between headlands (Womersley & Thomas 1976). The north coast of Kangaroo Island is relatively protected creating low wave energies and sandy beaches. The offshore habitats range from macroalgal dominated rocky reefs in the higher wave energy coasts commonly supporting dense canopies of *Sargassum* sp. and *Ecklonia radiata* communities (Shepherd & Sprigg 1976). Turner et al (2007) state that reefs on the Fleurieu Peninsula are in good condition, however reefs surveyed close to Victor Harbor (slightly outside the risk assessment regions) were considered ‘at
caution’. Increased wave energies may be confounding results but it was noted that increased runoff and nutrient and sediment loads from the Hindmarsh and Inman Rivers and fishing may be impacting on these particular reefs (Turner et al 2007). This may be highlighting the reliance of macroalgal condition on suitable water quality and potential for degradation as a result of anthropogenic influence.

Water quality in the southern region varies greatly depending on the surrounding catchment land use and creek condition. The Cygnet River is highly modified with a large agricultural catchment and water quality within the creek is generally classified as good to moderate (EPA 2006a) while the estuary and the marine receiving environment have been showing significant signs of aquatic ecosystem degradation (Gaylard 2005; Bryars 2003; Edyvane 1997). Recent surveys of the Myponga estuary have shown it to be very low in biodiversity (EPA unpublished). Higher in the catchment, water quality is classified as being generally moderate to poor (EPA 2006b). Very little information exists about water quality in marine waters outside of Nepean Bay in the southern region however available information suggests that the deep water and high current speeds results in effective flushing of the region with oceanic waters.

2.5.1 Environmental values within the region

The values adopted for the southern region in this risk assessment are:

Protection of the aquatic ecosystem

There are significant seagrass and macroalgal reef habitats throughout the eastern region which are in need of protection. In addition there are large commercial and recreational fishing resources that rely on good water quality in order to be sustainable.

Protection of aquaculture

Currently there is significant intertidal oyster and some subtidal shellfish aquaculture in the southern region predominantly throughout American River. For these reasons water quality must meet guideline values to ensure the growth and protection of cultured fish, molluscs and crustaceans.

Protection of recreation users and aesthetics

Primary contact activities (swimming, snorkelling, surfing, diving, etc) are a key part of the South Australian lifestyle particularly during the summer months. A desktop sanitary inspection of the southern region has been undertaken and the risk has been assessed as low. This is based on the fact that the entire southern region does not contain a sewage discharge to the marine or riverine environment. Human faecal wastes would be contained in septic tanks, which are pumped out via a waste transport truck and disposed of in accordance with an EPA licence. There is a CWMS scheme located at Kingscote on Kangaroo Island, which contains and treats human faecal waste. In the event that the CWMS scheme or the septic tanks are not well maintained or overflow, the small populations at each town and the short lifespan of many pathogens in sea-water means that the potential for significant human faecal contamination in recreational areas would be limited. This classification gives a set of trigger values for enterococci (as an indicator species) in recreational waters (Table 5.13; NHMRC 2005).

All waters in the southern Gulf St Vincent region have aesthetic values.

3 Impact of Pollutants

3.1 Turbidity

Turbid waters are caused by high levels of suspended and/or some dissolved materials in the water column. This suspended material can be made up of sediment re-suspended from the
bottom by wind and wave action, particles washed in from catchments via creek systems during rain events, and/or phytoplankton. Dissolved material (such as humics) in the water can change light penetration through the water column which will impact on turbidity and water clarity. Turbid waters result in a reduction of light penetrating through the water column and can cause sedimentation on seagrasses, reefs and other benthic habitats. Turbid waters have been highlighted as a possible factor in seagrass loss in the nearshore environment of Adelaide (Westphalen 2005) and also in other locations (Longstaff & Dennison 1999; Ruiz & Romero 2003). Sedimentation can result in smothering of seagrass (Shepherd et al 1989) or coating of leaves with silt reducing photosynthetic ability (Duarte et al 1997).

Elevated turbidity in the water column or sedimentation coating algal fronds can result in a reduction in photosynthetic ability of macroalgal species (Turner & Cheshire 2002). Macroalgal reefs can be adversely affected by sedimentation via competition with algal spores for space on a substrate, or result in the spore settling on sand, both of these mechanisms are likely to result in recruitment failure on a reef (Turner & Cheshire 2002). In extreme cases sedimentation can result in smothering of macroalgal species and result in a decrease in recruitment, growth and survival rates (Eriksson & Johansson 2005; Umar et al 1998). Turfing algae (small tuft like algae usually >5 mm high) are able to withstand large amounts of sediment deposition. Reefs affected by high sedimentation can change to a spatial dominance by turf forming algae, which can exclude canopy forming species (Gorgula & Connell 2004).

Turbid waters can also have adverse effects on higher organisms particularly fisheries where turbid waters can reduce feeding (Benfield & Minello 1995). Studies have shown that fish may avoid turbid areas (Boubee et al 1997; Bisson & Bilby 1982) and turbidity could potentially impact on visual spawning cues (Engström-Öst & Candolin 2006).

Turbidity is generally not thought of as a cumulative stressor. However recent evidence suggests that there are occasions where highly turbid waters can remain entrained in the water column for many days along the metropolitan coastline (up to 10) due to poor dispersion and constant re-suspension by persistent wind and wave action (D Ellis & S Bryars pers comm). This process has been suggested to be continuing the decrease in light penetration to sensitive components of the benthos such as seagrass, making the impact of turbidity potentially cumulative.

In terms of other environmental values highly turbid waters can result in a lack of visibility through the water column. This can be a hazard for recreational activities such as swimming where it may become hard to estimate the water depth or obstructions may become obscured, which can be potentially dangerous to swimmers. The National Academy of Sciences has shown that clear water fosters the enjoyment of water environments, where the clearer the water the more desirable the swimming area (National Academy of Sciences 1973 in NHMRC 2005).

The EPA uses a separate criterion to assess turbidity for the protection of ecosystem functions and waters being used for recreational purposes.

3.2 Nutrients

Nutrients can have deleterious impacts on the marine environment. This is particularly evident in waters that are oligotrophic (nutrient poor) such as South Australia. Research across southern Australia has shown that even a small increase in nutrient concentrations can cause a disproportionally large impact on marine benthic communities (Russell et al 2005; Gorgula & Connell 2004). Increased nitrogen and phosphorus have been linked to seagrass loss via the proliferation of macro and/or epiphytic algae and phytoplankton growth reducing light penetration, thereby starving the seagrass of light (Neverauskas 1987; Shepherd 1989, Burt et al 1995; Wear et al 1999; Westphalen et al 2005). Macroalgal reefs can be impacted by nutrients also through the proliferation of phytoplankton, which can reduce photosynthetic ability of the algae (Turner et al 2007). Nitrogen and phosphorus have also been shown to promote turf
forming algae (Gorgula & Connell 2004), which in turn inhibits the recruitment of large canopy forming algae such as *Ecklonia radiata* (Kennelly 1987) a key canopy forming species in South Australian waters (Turner *et al* 2007).

In some marine environments there may be nutrients that limit algal growth other than nitrogen or phosphorus. Carbon and iron can be limiting for algal growth and silica is often limiting for diatom growth in marine waters (Sundareshwar *et al* 2003).

An excess of nutrients can also lead to microalgal blooms. Some algae can be toxic to animals that ingest significant volumes (eg Blue-green Algae) and some have been shown to cause illness in humans who swim in contaminated waters (NHMRC 2005). Algae can be ingested by filter feeding shellfish and can lead to poisoning of the consumers of the shellfish (eg Paralytic shellfish poisoning from *Alexandrium minutum* (Hallegraeff *et al* 1988) and *Gymnodinium catenatum* (NIMPIS 2002). Other algal blooms can cause discoloration of the water and in some cases fish deaths through oxygen depletion in the water column (eg Port River red tides of *Gymnodinium* spp.). Large amounts of macroalgae, *Ulva* spp. in particular, can accumulate and form floating masses of material. This ‘wrack’ can settle on the pneumatophores of mangroves which starves the roots of oxygen and can smother seedlings. The wrack can also be a navigational hazard and often washes up on beaches where it decays causing significant odour issues to nearby residents (Coleman & Cook 2003). This process can be a cyclical problem by the release of ammonia from the decaying algae, which can cause further algal blooms. This can have a significant impact on both the ecological, recreational and aesthetic values of a waterway.

While nutrients are not considered to be conservative pollutants they can be considered cumulative. This is where lots of small additions can slowly build up to a point where nutrients are considered to be causing an impact. This has ramifications on how consequence is evaluated for a single discharge, particularly as a single discharge may not cause an impact when assessed alone but many discharges identical to the single discharge may cause an impact.

### 3.3 Trace metals

The impact of increased trace metals in the marine environment can take two forms; firstly acute and chronic toxicity of the metal to organisms, and secondly some metals can accumulate in organisms, plants and sediments.

Metals can impact on seagrass communities through both of the pathways described above. Copper and zinc, and to a lesser extent cadmium and lead, have been shown to cause a reduction in photosynthetic activity in seagrass (*Zostera capricorni*) at very low concentrations (Macinnis–Ng & Ralph 2002). Furthermore Bidwell *et al* (1998) have shown that trace metals (Cr⁶⁺, Cu and Zn) are acutely toxic to the zoospore reproductive lifestage of the canopy forming brown algae *Ecklonia radiata*, which may lead to reproductive failure. Low concentrations of metals have been shown to have acute and chronic impacts on a large number of marine organisms including fish, crustaceans, echinoderms, molluscs, annelids, nematodes, rotifers and algae. (See section 8.3.7.1 of ANZECC 2000 for complete review of toxicity of metals.)

The accumulation of metals in sediments can cause toxicity to benthic inhabitants and leave a lasting legacy of pollution. This legacy can continue causing impacts through re-suspension of metals by wind and wave action, shipping, or can be disturbed through anthropogenic means such as dredging, having costly disposal ramifications. Due to the very long half life of metals the contaminated site can exhibit toxicity for a long period of time (10s to 100s of years or more).

Some trace metals have been shown to exhibit endocrine disrupting impacts on marine organisms such as the impact of the organo-metal tributyltin (TBT); also arsenic, cadmium, lead and mercury. TBT has been extensively used as an antifoulant on large boats, particularly in the shipping industry. TBT causes imposex (females developing male characteristics) in bivalve
mussels at extremely low concentrations. Concentrations of as low as 1 ng/L have been shown to
cause imposex in the dogwhelk (*Nucella lapillus*) and have lead to reproductive failure and local
extinction (Walker *et al* 1997). Imposex has been recorded in some species of mussels in the Port
River (Nias *et al* 1993). The impacts of these metals are also discussed in the section on
endocrine disrupting chemicals (section 3.10). The risk assessment has considered this impact as
a part of the metals section under both the trace metals and endocrine disruption sections.

Filter feeding shellfish, long-lived fish, sharks and mammals can accumulate significant
concentrations of metals. This can cause impacts on the organisms and also on predatory
organisms. Concentration of metals in organisms that are regularly consumed by humans can
cause exposure to higher amounts of metals and result in an elevated health risk (FSANZ 2006).
An example of this was in Minimata Bay in Japan in the 1950s where paper factories on the
shores of Minimata Bay were releasing mercury into the bay. This mercury was being methylated
in the sediments of the Bay by bacteria into a more bioavailable form and concentrated in fish.
The local population relied heavily on fish for food and the resulting toxicity resulted in over 100
people dying and many more suffering severe disabilities (Kudo *et al* 1980).

### 3.4 Hydrocarbons

The small chain length (C6−C9) aromatic hydrocarbons are produced for their use as solvents in
adhesives, industrial cleaners, degreasers, paints and thinners. They have high volatility and
relatively low water solubility and are generally rapidly lost to atmosphere from a water body,
with short half-lives (ANZECC 2000). Biodegradation is also very rapid. The half-life of benzene
was 16 days in an aerobic river test (Vaishnav & Babeu 1987) but degradation is much faster in
systems contaminated by oil (HSDB 1996 in ANZECC 2000). Photo degradation is similarly rapid.

Polycyclic aromatic hydrocarbons (PAHs) are produced by incomplete combustion of organic
material both naturally (forest fires, volcanoes, etc) and through human uses such as combustion
(ANZECC 2000). PAHs can bioaccumulate in marine organisms and some particular PAHs have
been shown to be carcinogenic and increase the rate of chemically induced mutations (Walker
*et al* 1996). PAHs are generally highest in sediments, intermediate in biota and relative
concentrations are lowest in the water column. High molecular weight molecules are generally
bound to particulates in the sediment while the lower molecular weight molecules are lost
through volatilization and transport (ANZECC 2000).

The accumulation of PAHs by filter feeding bivalves could have an adverse impact on the health
of the organism but also the potential for harm to the consumer. However accumulation of PAH
residues in the environment and harvested foods (including shellfish) have not been addressed by
Australian & New Zealand Food Standards Authority (ANZFS) but have been classified as a
medium to low risk in other literature (NJCRP 2003).

The majority of impacts of hydrocarbons in the marine environment are from large oil spills from
transport accidents. The impacts of these spill events can range from minor to catastrophic
depending on the size of spill, and extent and sensitivity of the receiving environment. The main
route of toxicity in these cases is smothering of fauna with oil. The most infamous being the
1989 *Exxon Valdez* oil spill in Price William Sound, Alaska. This tanker spilled an estimated 42
million litres into a sensitive marine environment. The impact of this was immense with
devastating impacts on over 1,300 miles of coastline and a ‘passive use’ economic loss of
approximately USD 2.8 billion (EVOSTC 2006).

Hydrocarbons can also impact on the aesthetic value of water. Oily sheens detract from the
attractiveness of water and may result in the perception of pollution and people avoiding such
waters for recreational activities.
3.5 Micro-organisms
Recreational waters often contain a mixture of pathogenic micro-organisms such as Cryptosporidium and non-pathogenic micro-organisms such as *E. coli*, usually derived from faecal material. The origins of these micro-organisms may be from sewage effluents and overflows, industrial processes, livestock, domestic animals, farming activities, wildlife and recreational users of water themselves through bather shedding (NHMRC 2005).

Micro-organisms generally are not seen as a threat to marine ecosystems but are considered as a threat to recreational users of water. The most frequent adverse impact of exposure to faecally contaminated recreational waters is enteric illness, such as self-limiting gastroenteritis (WHO 2003). It is also possible for faecal or bather derived contamination to adversely impact on recreational users in the form of acute febrile respiratory illness, general respiratory illness and ear infections (WHO 2003). Severe adverse outcomes are also possible such as hepatitis, enteric fever and poliomyelitis, however these outcomes are usually limited to short-term visitors swimming in sewage polluted recreational waters after coming from regions of low endemic disease incidences (WHO 2003).

Pathogenic organisms, including bacteria, viruses, parasites and microalgae in marine waters can be taken up by filter feeding shellfish as they ‘strain’ the water, resulting in a concentrating of the pathogen. There have been many cases where people have become sick (with gastroenteritis) as a result of eating contaminated shellfish. In most of these cases it has been concluded that the cause was from eating raw or undercooked molluscs contaminated shortly prior to harvesting (ANZECC 2000).

3.6 Pesticides
Pesticides (including insecticides, herbicides and fungicides) have had an impact on the natural environments over the past 50 years. Similarly their economic value in increasing crop yields and their public health value in reducing mosquito borne disease are also well known.

Herbicides are the largest selling pesticide in Australia with 2001 sales in excess of $800 million with over 1,100 products. Insecticide sales were significantly lower at just over $350 million with just under 1,000 products, and fungicides selling just over 400 products for a value of approximately $115 million (APVMA 2002). There are two types of pesticides, those used in the home and garden, and others used in agriculture and commercial products. In South Australia over 90% of home owners use pesticides of some type and on average home owners are reported to use more pesticides per hectare than farmers. It is suggested that Adelaide Hills residents are applying pesticides at about five times the recommended rate, and misuse and overuse around the home is common (EPA 2005).

Pesticides act in many different ways. Pesticides typically are highly toxic and very small quantities can cause acute and chronic toxicity. Many of these chemicals can bioaccumulate and biomagnify in aquatic organisms. ‘Organochlorine’ style chemicals were used extensively in the 1950s and 60s until they were found to be biomagnifying through trophic levels and demonstrating impacts in the highest predators such as the fish-eating birds including (in North America) the Bald Eagle *Haliaetus leucocephalus* (see Carson 1962; Walker *et al* 1997). Due to their very long half-life and their accumulation in fat cells of organisms, high levels of these organochlorine chemicals can still be found in marine mammals such as seals and dolphins even though they have been banned for over 20 years (DDT banned in 1987) in Australia (Law *et al* 2003). Recently other types of pesticides have been replacing organochlorine pesticides, these chemicals include organophosphorus, carbamate, sulphonylurea, triazine and pyrethrin pesticides, many of these are relatively short lived in the environment but are still highly toxic to both target and some non-target species.
The EPA undertook a pesticide snapshot, which looked for pesticide residues in aquatic sediments throughout South Australia. This study found that the most common pesticide detected was DDE, which is a breakdown product of DDT. This was detected at 10% of the sites sampled (Appendix 7, from Jenkins in prep). In the marine and estuarine environment various pesticides were detected including the persistent organochlorines aldrin, chlordane, DDD, DDE and DDT (Jenkins in prep). It is not known whether these chemicals are still being used (illegally) or whether these loads are remnant signals from their historical use.

Herbicides (Atrazine & Diuron) have been shown to impact on the photosynthetic ability of seagrasses at very low concentrations in both laboratory and field experiments in other parts of Australia (Macinnes-Ng & Ralph 2003; Haynes et al 2000). Similarly macroalgae also demonstrate an inhibition of photosynthesis to very low levels of herbicides Bromosil, Diuron & Irgarol (Seery et al 2006). This demonstrates that there is a potential for harm to seagrasses and macroalgae from herbicides that are commonly used. These studies are primarily laboratory based and do not look at South Australia conditions.

Various studies have shown that some pesticides will bioaccumulate in marine organisms, particularly filter feeding molluscs (Andral et al 2004; Serrano et al 1995) and because of this mussels have widely been used as indicators of environmental pollution [eg US Mussel Watch program (O’Conner 1998)]. These residues can potentially impact on human consumers of seafood and standards for acceptable concentrations in edible flesh have been developed (FSANZ 2007) exceedences in these concentrations not only impact on consumers but also put valuable seafood markets in jeopardy.

Typically many pesticides quickly bind to particles (particularly organic matter) where they breakdown via chemical, photolytic and microbial degradation pathways. Many pesticides commonly used will readily break down in a matter of days to weeks depending on the chemistry of the particular chemical (for detailed reviews of toxicity and the environmental fate of pesticides see EXTOXNET <http://extoxnet.orst.edu/>).

In this risk assessment pesticides have been assessed as including insecticides, herbicides and fungicides and have all been classed together. It is accepted that each class of chemical acts on different target species but their entry into the environment and consequence have been assessed together.

3.7 Freshwater

Most marine organisms live within an optimal range of salinities. When salinity changes to above or below this range, an organism may become stressed and can succumb to predation, competition, disease or parasitism (ANZECC 2000 and references therein).

Westphalen et al (2005) experimentally tested the tolerances of the three dominant seagrass species (Amphibolis antarctica, Posidonia sinuosa and P angustifolia) from the Adelaide metropolitan coast. These experiments showed that A antarctica and P sinuosa were highly resilient to reductions in salinities over the short term. Over longer term experiments (weeks) A antarctica and to a lesser extent P sinuosa show signs of stress in the form of decreases in photosynthetic ability, then leaf decay and eventually death (Westphalen et al 2005). Therefore it was concluded that seagrass losses due to reduced salinity are only possible very close to freshwater sources where there would be long periods of lowered salinities. Additional experiments were carried out on seedlings of both species and Westphalen et al, (2005) found that 72 hours of exposure to low salinity water was enough to inhibit Amphibolis seedlings and enough to kill Posidonia seedlings. Therefore the conclusion was that recruitment of either seagrass species into areas subject to major salinity decline was highly unlikely (Westphalen et al 2005).
Data on the tolerance to low salinity water of other seagrass species dominant in other regions of Gulf St Vincent are limited. However Westphalen et al (2004) reviewed the current knowledge and found that the response of the majority of species is dependant on the longer term history of the individuals, and that responses varied greatly.

Currently there is very little known on the impacts of water at lower salinity on macroalgal reefs in southern Australia. However it is likely that the impacts of other constituents in any freshwater runoff (eg sediments & nutrients) would be likely to outweigh any effects seen from water at low salinities, but this is an area in need of further research.

3.8 Temperature

Increased temperature can have adverse impacts on marine organisms, particularly habitat forming assemblages such as seagrass and macroalgal reefs. Seagrasses loss has been linked to increased water temperatures beyond a typical species specific tolerance, species thought to be susceptible to temperature impacts are Zostera marina (Seddon et al 2000; Orth & Moore, 1986), Posidonia (Seddon et al 2000; Ainslie et al 1994) and Amphibolis antartica (Seddon et al 2000). Turner & Cheshire (2002) have noted that higher than normal water temperatures during an El Nino year may have contributed to the decline of Ecklonia radiata and Cystophora sp. on Noarlunga reef concomitant with a large sediment plume incident.

Studies of the intertidal benthic environment receiving thermal effluent have shown the presence of several tropical species due to the altered water temperatures (Thomas et al 1986). It is believed that the increased water temperature has supported the displacement of the native species and more temperature tolerant sub-tropical species (translocation was thought to be from recreational boats moored nearby) have colonised the immediate receiving waters (Thomas et al 1986).

In regions where nutrients are in excess, increased temperature also provides an environment conducive to algal production. While it would be hard to differentiate between the sources, temperature could be seen as a secondary contributor to the growth of algae.

Increasing water temperature is also looked at further in this document under the impacts of climate change (section 4.20).

3.9 Rubbish

In this risk assessment rubbish consists of the traditional items thought of as litter such as drink cartons, plastic bags but also incorporates green organic waste such as leaves and grass clippings.

Leaves from deciduous trees and other organic material enter the marine environment and will breakdown through microbial activity. This microbial action can cause oxygen depletion of waters from the increased respiration of the micro-organisms. Situations like this have contributed to significant fish kills including the Patawalonga Lake fish kill in January 2005. Estuaries and the wider marine environment are also impacted by the improper disposal of rubbish. Discarded fishing line has been implicated as the main cause of the death or maiming of over 100 seabirds just in the Port River and Barker Inlet each year (Westthorp 2006). Additionally discarded plastic bags have been widely been blamed for significant environmental harm. PlanetArk estimated that plastic bags are responsible for the death of over 100,000 birds, whales, turtles and seals every year (Zero Waste 2004).

Gross pollutant traps in the Patawalonga catchment intercept over 1,000 tonnes of rubbish from entering the Patawalonga system each year (DLWBC 2006) and this material is made up of approximately 60% by volume of organic material (TCWMB 2005).
Rubbish will also detract from the aesthetic value of water which may in turn have impacts on recreational users of the water.

### 3.10 Endocrine disrupting chemicals (EDCs)

Endocrine disrupting chemicals are a range of chemicals that can have very little structural similarity to each other apart from the impact that they can invoke. This impact is the disruption (either an increase or decrease) of the endocrine system that can cause an impact on an organism, its progeny or populations (Ying et al. 2004). Chemicals that can cause endocrine disruption can include pesticides (DDT, atrazine), some heavy metals (Cd, Pb, Hg) and organometals (TBT), persistent organic chemicals (PCBs, dioxins & furans), Alkyl phenols (nonylphenol), phytoestrogens, synthetic and natural hormones (β estradiol) [Ying et al. 2004; for a more comprehensive list of known and suspected EDCs please refer to Ying & Kookana 2002].

Animals can increase the levels of natural estrogens particularly in regions where there is intensive farming eg diaries (P Goonan pers comm).

Information on the impacts of EDCs in the marine environment is generally limited to overseas studies and these impacts have been demonstrated to include changes to estrogenic and androgenic activity in individuals as well as populations (Allen et al. 1999). Field studies have proved troublesome and the USEPA (1997) have formed the opinion that with few exceptions, a causal relationship between exposure to a suspected EDC or mixture of chemicals and an adverse effect from endocrine disruption in humans or populations of animals has yet to be established.

One area where there is significant body of research and a relatively conclusive outcome is the endocrine disrupting effects of tributyl tin (TBT). Studies have shown that in some cases extremely low concentrations have resulted in populations being significantly impacted including local extinction of sensitive species due to endocrine disruption, via imposex. A review of the risks from endocrine disrupting substances with a South Australian perspective published by the EPA is available at <www.epa.sa.gov.au/pdfs/risks_endocrine.pdf>.

In order to assess the risk from EDCs in Gulf St Vincent in this risk assessment an evaluation has been based on the most likely route of exposure to the marine environment which is the discharge of wastewater from WWTPs (Goonan 2008). This risk assessment has used population size, volume and location of wastewater discharged into the marine environment and the level of wastewater treatment as a basis for a relative estimation of discharge of these chemicals. Again this area is in need of significant research in order to quantify the loads of these chemicals in discharges and more importantly whether there are any impacts on adjacent populations.

### 3.11 Other chemicals

Obviously this category is poorly circumscribed; the risk assessment cannot cover all known chemicals as it would need to contain an analysis of tens of thousands of chemicals from a similar number of sources. However in order to be practical the ‘cryptic’ chemicals have been grouped together and an assessment of the risk has been conducted with several lengthy caveats. In considering risks from this category, chemicals that could not be easily fit into any other category were also considered to be ‘other chemicals’. These include persistent organic pollutants (POPs) such as polychlorinated biphenyls (PCBs), triclosan, pthalates, polyvinyl chlorides, etc. Many of the chemicals could be included into other broad categories such as EDCs (e.g. pthalates and some pharmaceuticals). There are also chemicals that are not covered in the above categories but possibly could still have a significant environmental impact and a risk should be generated based on the level of current understanding. If a chemical is assessed to have a significant risk obviously the first step would be developing an understanding on the chemical and its impact.
3.12 Physical

There are numerous pathways by which environmental values can be impacted within the marine environment that are not strictly related to water quality. Many of these pathways have not been formally considered as a part of this risk assessment, although have been highlighted as a moderate or high risk activity during the consultation and assessment process and therefore have been discussed but not formally assessed in this report.

3.12.1 Prawn trawling

There are three main commercial fishing zones for the Western King Prawn in South Australia. These are the Gulf St Vincent, Spencer Gulf and the West Coast. Prawn trawlers use large funnel shaped nets to collect prawns into a smaller bag (codend) as it is trawled across the seabed.

There are 10 commercial licenses in the Gulf St Vincent prawn fishery and boats are permitted to use single, double and triple rigged nets to catch prawns. In the 2004-05 fishing year the total catch from the Gulf St Vincent fishery was 213 tonnes. This corresponded to catch per unit effort (CPUE) of 62.2 kg/hr, both of these statistics are significantly lower than peak figures indicating that the resource is at its lowest level for many years (Dixon et al 2006).

The physical disturbance of trawling these nets, particularly nets with tickler chains, can cause significant damage to the seafloor habitat and can effect biodiversity through impacts on bycatch species within fishing regions (Bridger 1970; Sainsbury 1988; Hall 1999).

Disturbance of the seafloor from trawling has not been formally considered for this risk assessment as it does not fit with the water quality focus of this document but it is considered to be a major issue in relation to the status of the Gulf St Vincent benthic environments [see work by Tanner (2003) which contrasts current benthic habitats between recently trawled and untrawled locations in Spencer Gulf].

3.12.2 Dredging

Dredging is considered in this risk assessment for its potential to impact on water quality such as increasing turbidity and reducing dissolved oxygen in the water column. However the physical action of removing sediment (and any attached or entrained biota) has already been considered, particularly in the case of removing areas of seagrass.

3.12.3 Restriction of sand movement

The general net movement of sand along the Adelaide metropolitan coast is northwards where between approximately 40,000 and 70,000 cubic metres of sand is eroded and moved northwards between Brighton and Semaphore (DEH 2006). Large quantities of sand are locked up or removed from the beaches as a result of coastal development in areas that used to feed sand into the system such as sand dunes. Additionally the building of structures across beaches can block sand movement and cause sand to be trapped on the southern side. In extreme cases, this can result in smothering of intertidal or shallow subtidal seagrasses. The lack of sand moving northwards can cause erosion on the northward side of the structure often leaving a rocky beach, obviously having impacts on aesthetic values.

3.13 Marine pests

There are several established marine pests throughout many parts of Gulf St Vincent. Ports and marinas are often key locations for the establishment and translocation of marine pests due to the frequent arrival and departure of both commercial and recreational vessels. The Port of Adelaide has several known introduced marine pests established including Caulerpa taxifolia and Caulerpa racemosa, Sabella spallanzani, Carcinus maenas, Gymnodinium spp. and Alexandrium spp. Some of these species have expanded from Port Adelaide and now are established in
marinas and other inshore rocky regions in SA (including *Sabella spallanzanii* and the dinoflagellates described above).

The control of marine pests in South Australia is under the jurisdiction of Primary Industries of South Australia (PIRSA) and managed under the *Fisheries Act 1982*. A specific project to develop an economic and environmental risk assessment for *Caulerpa taxifolia* in South Australia is under development by PIRSA and SARDI Aquatic Sciences and is expected in 2009. However this project is not considering the high risk vectors but is on locations that may be conducive to the settlement and establishment of *Caulerpa taxifolia* (M Deveny (SARDI) pers comm).

This issue is not under the jurisdiction of the *Environment Protection Act 1993* (EP Act) nor generally considered to be a water quality issue. For these reasons this risk assessment has not looked at marine pest incursions, their transfer or environmental or economic impact on the marine environment in South Australia. However the EPA and all experts consulted agree that marine pests are a significant risk to the marine environment of South Australia.

### 4 Results

The results of this risk assessment are based on proceedings of a workshop of experts in various aspects of marine and environmental sciences, stakeholder groups and industries and further synthesis and editing during writing. A list of people who attended the workshop and a list of technical reviewers can be found in the acknowledgments section.

It should be noted that as with any risk assessment this was not a purely quantitative exercise and there is always a degree of subjectivity. While all effort has been made in this risk assessment to obtain data where available, many risks have been derived through using collective experience of many people.

This risk assessment is designed to follow the principles of adaptive management. The risks classified are based on current knowledge and many will change with an increase in understanding about marine biology and ecology, chemical fate and toxicities and even further knowledge about variables such as complex chemical constituents in some discharges and climate change. This risk assessment is expected to be reviewed at regular intervals and will be updated to reflect changes.

### Threats to water quality

#### 4.1 Urban stormwater

Stormwater is the surface water runoff from urbanised areas, in most cases stormwater is discharged into Gulf St Vincent through a myriad of drains across the Adelaide metropolitan area. The water quality from these drain systems depends highly on land use of the catchment. Highly urbanised catchments will have a higher proportion of impervious surfaces, allowing higher runoff. In catchments with more open or semi-agricultural land uses, water can infiltrate the soil and result in less runoff.

For this risk assessment the eastern region was considered urbanised to an extent where there were very little purely agricultural catchments. While this is not entirely accurate it was considered a better classification of risk than attempting to separate urban and agricultural catchments and sub-catchments. In all other regions there are both agricultural and urban runoff and each are classified separately.

Wilkinson *et al* (2004) estimates that in the Adelaide metropolitan region (Gawler to Sellicks Beach), approximately 100 GL/yr is discharged into the marine environment via the various drains and watercourses.
The typical analysis of urban stormwater shows that it can often contain heavy metals (zinc, copper, lead and cadmium), organic material, suspended sediment and hydrocarbons from a range of sources such as vehicles, nutrients from fertilisers and pesticides from domestic applications. Urban runoff can also contain high concentrations of bacteria from a range of sources such as birds, dogs, horses and livestock and can be highly coloured.

In most cases urban stormwater runoff into the marine environment is considered a pulse discharge. That is a short-term input of pollutants resulting in a short-term impact. There are various factors that will influence the severity of the input as well as the impact. The period between rainfall events is very important to the quality of water runoff. The longer the period between rainfall events the more time there is for pollutants to accumulate and these will likely be concentrated during the next rainfall event. Within South Australia there is typically more rainfall during winter than summer. This means that the period between rainfall events is shorter and the catchment takes less rain for infiltration to stop and runoff to start. Large storms occasionally occur during summer and can contribute significantly to pollutant loads into the Gulf due to the relatively large amount of time between rain events. This has been taken into consideration while assessing the consequence and a higher risk rating has been generated.

For this risk assessment a rainfall frequency of one rainfall event per month has been used as the probability of the event occurring. There is obviously more rainfall falling in South Australia than this but the risk assessment is based on a rainfall event big enough to generate pollutant loads that can impact on water quality. It is accepted that this is a generalisation but is considered a good approximate average of rainfall events throughout the year. There are likely to be seasonal differences between large summer and winter rainfall events and these were considered during the assessment however it was considered impractical to separate them in this document.

**Turbidity from urban stormwater**

**Discussion**

Turbidity is generated in urban stormwater through particulates dropped on the roads and stormwater system from cars and trucks and disturbed earth sites such as building developments and erosion from streams. It can cause significant reductions in light penetration in a receiving environment and impact on biological processes as outlined in section 3.1.

**Table 2 Turbidity from urban stormwater**

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>Moderate (C2)</td>
<td>Low (C0)</td>
<td>Low (D0)</td>
</tr>
<tr>
<td>Eastern</td>
<td>High (C4)</td>
<td>Moderate (C2)</td>
<td>Moderate (C2)</td>
</tr>
<tr>
<td>Western</td>
<td>Moderate (C2)</td>
<td>Low (C0)</td>
<td>Low (D0)</td>
</tr>
<tr>
<td>Southern</td>
<td>Low (C0)</td>
<td>Low (C0)</td>
<td>Low (D0)</td>
</tr>
</tbody>
</table>
Northern region
Population sizes in the northern region are quite low which reduces the amount of impervious surfaces and resultant runoff.

The northern region has been classified as a moderate risk to the aquatic ecosystem. This is primarily due to the role that turbidity plays in reducing light penetration to the large areas of seagrass throughout the northern region and the low wave energies and current speeds, which may retain any discoloured water in the nearshore environment. This risk assessment has found that the risk to recreational users is low due to the episodic nature of rainfall events in this region and their occurrence primarily in winter, which is not a peak recreational period.

Eastern region
Stormwater enters the marine environment along Adelaide’s metropolitan coast and frequently discolours the water in the nearshore environment approximately following the 5m depth contour about 500 m offshore (Figure 5). This water will move parallel to the coast with only minimal mixing with deeper, clearer water resulting in the nearshore environment remaining discoloured for extended periods of time (up to 10 days) [D Ellis/S Bryars pers comm].

The dominant species of seagrass in Adelaide’s nearshore environment is the *Posidonia* species. These species are widely considered to be very slow to recover from a disturbance whether it is natural or anthropogenic (Kirkman 1998) and seagrass have been shown to have significant value for ecosystem functions (providing habitat and nursery areas, improving water quality/clarity, arresting seabed erosion, etc), economic services (value of commercial and recreational fishing catch, cost of sand replenishment and wrack management, cost of restoration, etc) and social values (enjoyment of using the beaches, odour from decaying wrack, education, etc) [Deans & Murray-Jones 2002].

The high risk rating results from the likely role of turbidity on the loss of seagrass and reef systems in the Adelaide metropolitan area (Westphalen et al 2005) and the long period of time for recovery of impacted seagrasses. Turbidity has also been shown to impact on shallow nearshore macroalgal reef habitats with reef condition surveys (Turner et al 2006; Cheshire & Westphalen 1999; Cheshire et al 1996) highlighting declining reef health along the northern section of the Adelaide metropolitan coastline (Brighton to North Haven) which is exposed to frequent stormwater runoff events, in which turbidity is a major pollutant. It is worthy to note that this decline cannot be wholly attributed to stormwater as there are several WWTPs and industrial discharges that could potentially impact on reefs in the northern metropolitan area (Turner et al 2006; Cheshire & Westphalen 1999; Cheshire et al 1996).

In highly turbid environments shellfish can become smothered by high sedimentation and suspended particles can cause gill irritation of fish and tissue damage and make searching for prey harder (ANZECC 2000). In addition some aquaculture facilities require good light penetration through the water column in order for unimpeded microalgal production which feed the shellfish. While there is currently no sea-based aquaculture facilities within the eastern region, the risk is considered to be moderate for maintaining good water quality for aquaculture and shellfish harvesting.

Recreational values can be impacted by a reduction in the visibility in the waters used as recreational areas. The eastern region has many large stormwater drains that discharge directly onto the beach or into the nearshore environment. This gives little opportunity for suspended solids to be filtered or settle out and results in turbid waters that can occasionally exceed the NHMRC Guidelines for safe bathing. Highly turbid waters can result in a lack of visibility through the water column which can be a hazard for recreational activities such as swimming where it may become hard to estimate the water depth or obstructions, making it potentially dangerous.
to swimmers. There is also evidence that turbid waters also detracts from the enjoyment of water environments and therefore is likely to have a significant impact on aesthetic values as well as recreational values. This risk assessment has classified turbidity from urban stormwater to be a moderate risk to recreational and aesthetic values in the eastern region.

**Western region**
Population and town sizes in the northern region are quite low which reduces the amount of impervious surfaces and resultant runoff. Turbidity in urban runoff has been classified in this risk assessment as having a moderate risk to the ecosystem.

**Southern region**
Turbidity in urban runoff in the southern region has been classified in this risk assessment as having a moderate risk to the ecosystem. This is due to the small population and town sizes in the southern region, which reduces the amount of impervious surfaces and resultant runoff entering the marine environment.

**Nutrients from urban stormwater**

**Discussion**
Nutrients from urban runoff enter the marine environment during rainfall events. In Adelaide these typically occur during the winter months when the day lengths are shorter, ambient air and water temperatures are lower. Winter rainfall occurs when the environment is not optimal for algal growth and therefore there are likely to be fewer impacts from nutrients from stormwater during winter.

Summer storms however introduce nutrients into the marine environment when day lengths are significantly longer, ambient air and water temperatures are higher and tidal flushing is lower. This is an environment where algal growth is stimulated and impacts may be seen in localised areas.

**Table 3 Nutrients from urban stormwater**

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>Moderate (C2)</td>
<td>Low (C1)</td>
<td>Low (D0)</td>
</tr>
<tr>
<td>Eastern</td>
<td>Moderate (C3)</td>
<td>Low (C1)</td>
<td>Moderate (C3)</td>
</tr>
<tr>
<td>Western</td>
<td>Moderate (C2)</td>
<td>Low (C1)</td>
<td>Low (D0)</td>
</tr>
<tr>
<td>Southern</td>
<td>Low (C1)</td>
<td>Low (C1)</td>
<td>Low (D0)</td>
</tr>
</tbody>
</table>

**Northern region**
Population sizes in the northern region are quite low which reduces the amount of impervious surfaces and resultant runoff. The highly tidal nature of the northern region results in a mudflat receiving environment and the sensitive receivers such as seagrasses are a relatively long distance from stormwater discharge sites.

**Eastern region**
Compared to the other risk assessment regions the eastern region has a relatively large amount of stormwater runoff. This is due to the large amounts of impervious areas and the reduction in natural stormwater filtration such as natural wetlands and sand dunes.
As described in section 4.1, stormwater remains entrained in the nearshore water column of the eastern region for a long period of time after rainfall. There is significant evidence that seagrasses in the eastern region are being impacted by nutrients from industry (WWTPs and Penrice) and stormwater is very difficult. It is likely that nutrients in stormwater are impacting on seagrasses particularly in the nearshore region where they are stressed by low light levels due to increased turbidity (see above). However it is probable that the nutrient load from stormwater would be a lower risk than the load from industrial sources. Nutrients in urban stormwater is considered a moderate risk for adverse impacts on the nearshore seagrass and rocky reef habitats.

Risks to recreational and aesthetic values from nutrients in urban runoff are considered to be a moderate risk due to the role the nutrients play in seagrass loss and the resultant changes to sand stability and beach morphology which impact on recreational users, particularly during summer weather patterns.

**Western region**

Population sizes in the western region are quite low which reduces the amount of impervious surfaces and resultant runoff. Seagrass and rocky reef habitats are relatively close to the shore, which has the potential for impact from nearshore discharges. However at the current population sizes these impacts are considered to be a moderate risk.

**Southern region**

The southern risk assessment region is considered to be at low risk from the impacts of nutrients from stormwater. This is primarily due to the low population and town sizes and the higher energy coastlines which aids flushing.

**Trace metals from urban stormwater**

**Discussion**

Stormwater runoff frequently contains measurable concentrations of many trace metals, particularly copper, lead and zinc. The origins of these contaminants in urban runoff are predominantly from vehicles (wearing of parts and exhausts), leaking oils and petrol, and small industrial sources including air discharges that can deposit onto catchments (deposition directly onto water is considered under section 4.13 Atmospheric deposition). Section 3.3 describes the impact of trace metals in the marine environment. Trace metals in stormwater are bound to particles and therefore unlikely to be biologically available to most organisms. The metals will settle out with the particulates and over time may contaminate an area of land. This will adversely impact benthic organisms and has implications for any future use of the contaminated area.

Wilkinson *et al* (2004) describes the typical quality of stormwater from Adelaide’s stormwater network. This report shows metal concentrations in relation to number of ‘dry days prior to rainfall’. Predictably this report shows metal loads rising with increasing ‘dry days prior to rainfall’ for all metals except cadmium. Concentrations ranged from 98–198 µg/L Pb; 21–108 µg/L Cu; 386–1270 µg/L Zn with cadmium remaining at approximately 6 µg/L (Wilkinson *et al* 2005). These metals are toxic to marine organisms when bioavailable, and cadmium, lead and also mercury can accumulate in organisms, particularly bivalve mussels.
Table 4  Heavy metals from urban stormwater

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>Moderate (C1)</td>
<td>Low (C0)</td>
<td>na</td>
</tr>
<tr>
<td>Eastern</td>
<td>Moderate (C3)</td>
<td>Low (C0)</td>
<td>na</td>
</tr>
<tr>
<td>Western</td>
<td>Moderate (C2)</td>
<td>Low (C0)</td>
<td>na</td>
</tr>
<tr>
<td>Southern</td>
<td>Moderate (C1)</td>
<td>Low (C0)</td>
<td>na</td>
</tr>
</tbody>
</table>

**Northern region**
Population sizes in the northern region are quite low which reduces the amount of impervious surfaces, resultant runoff and toxicant loads. Therefore the risk of impacts on ecosystem values in the northern region are thought to be moderate.

**Eastern region**
Compared to the other risk assessment regions the eastern region has a relatively large amount of stormwater runoff. This is due to the large amounts of impervious areas and the reduction in natural stormwater filtration such as natural wetlands and sand dunes. The eastern region also has the highest amount of vehicles and the highest potential for pollutant loads from industries and spills entering the stormwater system.

Wilkinson *et al* (2005) indicates that the trace metal concentrations in stormwater (Cu, Pb and Zn) in the eastern region exceed by 1.5–4 times the ANZECC Guidelines for 95% protection of species over half of the time. However these concentrations have consistently fallen since the mid-1990s. These concentrations have been extracted from samples of stormwater and do not take into account significant dilution and mixing in the nearshore environment, it is unknown whether these pollutants are bioavailable and extend beyond the immediate discharge area. These concentrations would indicate that there is potential for adverse environmental impact from trace metals, therefore the risk assessment has given a moderate risk rating.

**Western region**
Population sizes in the western region are quite low which reduces the amount of impervious surfaces, resultant runoff and toxicant loads. Therefore the risk of impacts on ecosystem values in the western region are thought to be moderate.

The issue of accumulation of trace metals by bivalve aquaculture is a threat not only to the organisms but also to the viability of the local aquaculture industry and also the health of consumers. Currently there are no bivalve aquaculture facilities in close proximity to stormwater drains in the western region and the threat is considered to be low.

**Southern region**
Population sizes in the southern region are quite low which reduces the amount of impervious surfaces, resultant runoff and toxicant loads. Therefore the risk of impacts on ecosystem values in the southern region are thought to be moderate.

The issue of accumulation of trace metals by bivalve aquaculture is a threat not only to the organisms but also to the viability of the local aquaculture industry and also the health of consumers. Currently there are no bivalve aquaculture facilities in close proximity to stormwater drains in the western region and the threat is considered to be low.
Micro-organisms from urban stormwater

Discussion
Microbial contamination of stormwater occurs when rain washes faecal wastes from urbanised land or sewer pipe overflows into the stormwater system. This can reach beaches where swimmers may ingest contaminated water and become sick (see section 3.5). Aspects considered have been proximity of the recreational area to stormwater discharges and the potential for untreated faecal material to enter these waters.

Generally winter storms are of less risk to swimmers than large summer storms. This is due to the more frequent nature of winter storms and the less build-up time for contaminants in the stormwater system. Summer storms also occur during peak recreational use periods. The warmer weather means that more people will potentially be at the beach and could be exposed to any pathogens present.

Pathogenic organisms in urban stormwater can also contaminate shellfish immediately or shortly before harvesting which can result in significant health impacts to consumers. The PIRSA SASQAP undertakes regular monitoring of aquaculture zones and tests for potential pathogens. If detected the lease is closed and harvesting of shellfish is prohibited until there is no further evidence of pathogens. This action has an economic impact on the shellfish growers depending on the length of the closure.

Table 5 Micro-organisms from urban stormwater

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>na</td>
<td>Low (C0)</td>
<td>Low (C0)</td>
</tr>
<tr>
<td>Eastern</td>
<td>na</td>
<td>Low (C1)</td>
<td>Moderate (C2)</td>
</tr>
<tr>
<td>Western</td>
<td>na</td>
<td>Low (C0)</td>
<td>Low (C0)</td>
</tr>
<tr>
<td>Southern</td>
<td>na</td>
<td>Low (C0)</td>
<td>Low (C0)</td>
</tr>
</tbody>
</table>

Northern region
The northern region has smaller population sizes and less impervious surfaces, which means there will be less stormwater runoff. This risk assessment has considered that stormwater discharge to be a low risk to recreational values in the northern region.

Eastern region
The EPA carried out a study looking at the impact of rain on water quality at the beaches around the Barcoo Outlet and the Patawalonga Lake. This report had a particular emphasis on microbial contamination on recreational users, and showed that the beaches surrounding the Barcoo Outlet were classified as ‘poor’ for enterococci concentrations the day following rainfall. The study also showed a strong correlation between enterococci results and turbidity (Corbin & Gaylard 2005).

The sanitary inspection of the Adelaide region has classified the region as low risk (section 2.2.1) which means that the potential pathogenic sources are kept down due to effective treatment at WWTPs limiting potential for raw human faecal material entry into recreational waters. This risk assessment has classified the threat to recreational values from stormwater in the eastern region to be moderate.
Western region
The western region has smaller population sizes and less impervious surfaces, which means there will be less stormwater runoff than there would be in a largely populated area. This risk assessment has considered that stormwater discharge is considered to be a low risk to recreational values in the western region.

A review carried out in 2004 stated that there have been a number of closures of aquaculture zones in the western risk assessment region. These closures have been either on a precautionary basis or due to high levels of faecal coliforms in shellfish. SASQAP is confident that on all occasions regular monitoring detected the elevated levels and the lease was closed before any contaminated shellfish reached the market (Lee 2004). Due to the proximity of the aquaculture leases to the townships nearby it is unlikely that these closures were as a result of urban stormwater runoff.

Southern region
The southern region has smaller population sizes and less impervious surfaces, which means there will be less stormwater runoff than there would be in a largely populated area. This risk assessment has considered that microbiological pathogens in stormwater discharges are considered to be a low risk to recreational values in the southern region.

Lee (2004) stated that there have been a number of closures of aquaculture zones in the Nepean Bay aquaculture region (part of the southern risk assessment region). These closures have been either on a precautionary basis or due to high levels of faecal coliforms in shellfish. SASQAP is confident that on all occasions regular monitoring detected the elevated levels and the lease was closed before any contaminated shellfish reached the market (Lee 2004). Due to the proximity of the aquaculture leases to the townships nearby it is unlikely that these closures were as a result of urban stormwater runoff.

Hydrocarbons from urban stormwater
Discussion
Hydrocarbons are a likely constituent of urban runoff due to their presence in every form of transport (fuels, oils, lubricants, etc), and their use in industrial processes such as the manufacture of PVC, solvents, cleaning agents, resins and fibres (ANZECC 2000).

Table 6 Hydrocarbons from urban stormwater

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>Low (C1)</td>
<td>Low (C0)</td>
<td>Low (E0)</td>
</tr>
<tr>
<td>Eastern</td>
<td>Moderate (C2)</td>
<td>Low (C0)</td>
<td>Low (E1)</td>
</tr>
<tr>
<td>Western</td>
<td>Low (C1)</td>
<td>Low (C0)</td>
<td>Low (E0)</td>
</tr>
<tr>
<td>Southern</td>
<td>Low (C0)</td>
<td>Low (C0)</td>
<td>Low (E0)</td>
</tr>
</tbody>
</table>

Northern region
The amount of urban runoff in the northern region would be quite low compared to the regions with higher populations. The northern region is a key road transport route and while the populations are low the amount of traffic can be high depositing hydrocarbons onto the roads. There is potential for small chain molecules to spread widely across water and also for some degree of toxicity or coating/smothering of seagrass or nearshore reef systems. As stated in section 3.4 PAHs are a potential constituent of urban runoff. These chemicals have the potential
to accumulate in organisms and can be carcinogenic. Therefore this risk assessment has classified hydrocarbons in urban stormwater in the northern region to be a moderate risk.

**Eastern region**

The eastern region has the largest amount of vehicle traffic and stormwater runoff of the four risk assessment regions. This region has the highest potential for hydrocarbons to enter the stormwater system and impact on marine ecosystems, aquaculture, recreational and aesthetic values. As stated above the risks to the ecosystem are from both the small chain hydrocarbons and the potential for PAH toxicity and bioaccumulation. This risk assessment has classified this risk as being moderate for the protection of ecosystem values.

**Western region**

The amount of urban runoff in the western region would be quite low compared to the regions with higher populations. As stated in section 3.4, PAHs are a potential constituent of urban runoff. These chemicals have the potential to accumulate in organisms and can be carcinogenic. Therefore this risk assessment has classified hydrocarbons in urban stormwater in the southern region to be a moderate risk.

PAHs can accumulate in organisms and particularly shellfish. This creates a potential risk to aquaculture values. However aquaculture leases within the western region are expected to be sufficient distance from any stormwater discharges that contamination would be unlikely and is therefore rated as a low risk.

**Southern region**

The amount of urban runoff in the southern region would be very low compared to the regions with higher populations. As stated in section 3.4, PAHs are a potential constituent of urban runoff. These chemicals have the potential to accumulate in organisms and can be carcinogenic. Therefore this risk assessment has classified hydrocarbons in urban stormwater in the southern region to be a moderate risk.

PAHs can accumulate in organisms and particularly shellfish. This creates a potential risk to aquaculture values. However aquaculture leases within the southern region are expected to be sufficient distance from any stormwater discharges that contamination would be unlikely and is therefore rated as a low risk. However if volumes of stormwater significantly increase or aquaculture leases are established closer to large discharges then this risk may change.

**Freshwater from urban stormwater**

**Discussion**

The input of freshwater into Gulf St Vincent, particularly along the Adelaide metropolitan coast has changed substantially since European settlement through the diversion of the Torrens River away from a wetland system, so that it now discharges directly into coastal waters. In addition there are numerous stormwater drains that channel water to the marine environment.

There is limited information on the spatial and temporal extent of lower salinity waters within Gulf St Vincent from rainfall events. Obviously the extent and longevity of the decreased salinity will be highly dependant on the volume of runoff entering the marine environment. The EPA undertook a study of the impact of stormwater from the Barcoo Outlet on the Adelaide metropolitan coast (Corbin & Gaylard 2005). This report found a general trend that the first day after rain (>5 mm) the salinity was reduced up to 27% at locations close to the discharge (200 m) decreasing to approximately 10% salinity reduction 2.5 km from the discharge point. The amount of decrease varied with rainfall intensity, wind and tide conditions (Corbin & Gaylard 2005).

Section 3.7 details some of the impacts of reduced salinity water to the marine environment.
Table 7  Freshwater from urban stormwater

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>Low (C0)</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Eastern</td>
<td>Moderate (C2)</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Western</td>
<td>Low (C0)</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Southern</td>
<td>Low (C0)</td>
<td>na</td>
<td>na</td>
</tr>
</tbody>
</table>

**Northern region**
The northern region receives an average of 333 mm of rain each year (BOM 2006). In addition the towns within the northern region are relatively small. Therefore, the amount of urban runoff in the northern region would be quite low compared to the regions with higher rainfall and higher populations.

The risk to the ecosystem from freshwater in urban runoff is considered to be low.

**Eastern region**
The mean annual stormwater flow into the eastern risk assessment region over the last 10 years is 116.1 GL/annum (Wilkinson et al. 2005). In a large rainfall event the large stormwater drains such as the Barcoo Outlet can decrease the salinity for over 2.5 km for a period of over four days (Corbin & Gaylard 2005).

Westphalen et al. (2005) demonstrated that while adult seagrass would be unlikely to be adversely impacted by this short term decrease in salinity there may be impacts on the recruitment of new seedlings into areas with lowered salinity.

Therefore freshwater in urban runoff is considered to be a moderate risk to ecosystem values within the eastern region.

**Western region**
Similar to the northern region the western region receives lower rainfall and has less impervious surfaces than the eastern region. However there is considerable expansion of the townships in the western region with the potential for significantly increasing urban runoff into the marine environment. In addition the inshore edge of the marine habitats are closer to the low water mark, this may result in less dilution before the runoff reaches sensitive marine habitats.

For these reasons freshwater from urban runoff in the western region is considered a moderate risk to ecosystem values.

**Southern region**
The southern region receives more rainfall than the other three regions however has less impervious surfaces, which would reduce the amount of runoff entering the marine environment from urban areas.

This risk assessment considers that freshwater from urban runoff in the southern region is a low risk to ecosystem values.

**Pesticides from urban stormwater**

**Discussion:**
There is evidence that the overuse or misuse of pesticides in domestic applications can enter the stormwater system (EPA 2005). Pesticides have been detected in the sediment of urban watercourses and the discharge not only breach the WQEPP but can cause acute and chronic toxicity.

There is limited information on pesticides entering the marine environment. Considering that the majority of pesticides in urban runoff are likely to originate from domestic applications it has been assumed that the pesticide entry to the stormwater system is proportional to population sizes of the towns within the regions. Pesticide application from rural areas will be considered in the agricultural runoff section (section 4.4).

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>Low (C1)</td>
<td>Low (C0)</td>
<td>na</td>
</tr>
<tr>
<td>Eastern</td>
<td>Moderate (C2)</td>
<td>Low (C0)</td>
<td>na</td>
</tr>
<tr>
<td>Western</td>
<td>Low (C1)</td>
<td>Low (C0)</td>
<td>na</td>
</tr>
<tr>
<td>Southern</td>
<td>Low (C0)</td>
<td>Low (C0)</td>
<td>na</td>
</tr>
</tbody>
</table>

**Northern region**

The amount of urban runoff in the northern region would be quite low compared to the regions with higher populations. However there is always the risk of pesticide misuse. The low rainfall of the region may aid in reducing the amount of runoff entering the marine environment. There is very little information available on the domestic use of pesticides in the northern region and therefore there is significant uncertainty. Pesticides in urban runoff has been classified as a moderate risk in this risk assessment.

**Eastern region**

The eastern region has the largest population and therefore potentially the most domestic pesticide use of the three regions. In addition to this, the highly impervious catchments and constructed channel nature of the stormwater system, allows for the fast transport of stormwater to the marine environment. Wilkinson et al (2004) have demonstrated that detectable concentrations of a range of pesticides can be found in urban stormwater from the Adelaide region, particularly in the Torrens River and Brownhill Creek. The most common pesticide detected in the review by Wilkinson et al (2004) was Simazine, which is sold as a domestic herbicide under the names of Aquazine, Caliber, Sim Trol and others. This was detected in six out of 10 samples between 1996 and 1997 (Shultz et al 2000; Schultz & Thomas, 2000 in Wilkinson et al 2004). Wilkinson et al (2004) note that while the rate of detection was relatively high, Simazine is classified as practically non-toxic to aquatic organisms, however other authors have demonstrated that Simazine (and Paraquat) is toxic to marine microalgae at very low concentrations (Bonilla et al 1998).

There is significant uncertainty as to whether pesticides are impacting on ecosystem values in the eastern region. Therefore pesticides in the eastern region have been classified as a moderate risk to ecosystems and are flagged as in need for further research to determine loads and potential impacts on nearshore communities.

**Western region**
The western region, like the northern region, has a small population and lower rainfall than the other two regions. There are significant aquaculture leases within the western region however it is unlikely that they are located close enough to be impacted by a pesticide in stormwater. However again there is a paucity of information on the domestic use of pesticides on Yorke Peninsula and therefore there is significant uncertainty when considering the probability of pesticides entering the marine environment. Pesticides in urban runoff have been classified as a moderate risk to ecosystems in this risk assessment.

Pesticides in urban runoff from the western region were considered to be a low risk to aquaculture.

**Southern region**

There is no available data on pesticide use or pesticide entry into marine environment in the southern region. Therefore there is significant uncertainty in evaluating the probability of pesticides entering the stormwater system and the marine environment. However as described in previous sections the southern region has smaller populations sizes and less impervious surfaces, which means there will be less stormwater runoff than there would be in a largely populated area. In addition there are no aquaculture leases that are in close proximity to stormwater outlets in the southern region. Therefore pesticides in urban runoff from the southern region were considered to be a low risk to both the ecosystem and aquaculture.

**Rubbish from urban stormwater**

**Discussion**

Rubbish (gross pollutants) can enter stormwater from countless sources and quite often it is purposely thrown into the stormwater system in a case of ‘out of sight, out of mind’. Increasingly councils are installing gross pollutant traps to intercept rubbish from the stormwater system and remove it before it enters the marine environment.

A significant pollutant in stormwater is green waste, which consists of leaves from deciduous trees and grass clippings that fall on the road to be washed into the stormwater system. As discussed in section 3.10 this can reduce the dissolved oxygen in the water and cause fish kills.

There is very little information on the amount of rubbish entering the marine environment or that is being intercepted by gross pollutant traps in each region. Therefore this risk assessment has assumed that the amount of rubbish entering the stormwater system is proportional to the population sizes of the towns within the regions.

**Table 9 Rubbish from stormwater**

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>Low (C1)</td>
<td>na</td>
<td>Low (D0)</td>
</tr>
<tr>
<td>Eastern</td>
<td>Moderate (C2)</td>
<td>na</td>
<td>Moderate (C2)</td>
</tr>
<tr>
<td>Western</td>
<td>Low (C1)</td>
<td>na</td>
<td>Low (D0)</td>
</tr>
<tr>
<td>Southern</td>
<td>Low (C0)</td>
<td>na</td>
<td>Low (D0)</td>
</tr>
</tbody>
</table>
Northern region
The northern region has smaller populations than the eastern and western regions and so it is likely that there is relatively smaller amount of rubbish entering the stormwater system. Rubbish entering the marine environment from the stormwater system is classified as being a moderate risk to the ecosystem and a low risk to aesthetic values.

Eastern region
The eastern region has the largest population and the largest stormwater network which is likely to result in more rubbish entering the stormwater system. However the eastern region also has more gross pollutant traps than any other region in this risk assessment. These traps intercept rubbish before it reaches the marine environment. The eastern region also has more grassed area and more exotic trees, which can result in an increased amount of organic material entering the stormwater network. Therefore rubbish entering the marine environment from stormwater is considered to be a moderate risk to both the ecosystem and to the aesthetic value of water.

Western region
As stated previously the western region has smaller population sizes and lower rainfall than the eastern region. The towns are quite small resulting in less urban runoff however sensitive marine ecosystems are relatively close to the land. For these reasons rubbish entering the marine environment via urban stormwater was considered a moderate risk for ecosystems and a low risk for aesthetic values of the waters.

Southern region
The southern region has the smallest population of all the risk assessment regions and therefore is likely to be the lowest risk. Rubbish in urban stormwater is considered to be a low risk for both ecosystems and aesthetic values.

4.2 Wastewater treatment plant effluent
WWTPs receive raw sewage and use a range of filtration and biological treatment methods to break down and treat the sewage. SA Water also accepts trade waste from many industrial companies. The trade waste added to the wastewater stream is generally very spasmodic and can contain trace metals and other chemicals. A typical analysis of WWTP effluent reveals significant nutrient loads and also the presence of trace metals, potentially small amount of pesticides and other industrial and pharmaceutical chemicals.

There are three WWTPs that discharge directly into Gulf St Vincent in the eastern risk assessment region. Appendix 5 shows that the largest, in terms of loads discharged in the 2004–05 year, is the Bolivar WWTP, which discharges 440 tonnes of nitrogen (including 43 tonnes of ammonia) and 190 tonnes of phosphorus into Gulf St Vincent around the vicinity of Port Gawler (NPI 2006). The Glenelg WWTP discharges 330 tonnes of nitrogen (including 40 tonnes of ammonia) and 140 tonnes of phosphorus into the Gulf around Holdfast Bay (NPI 2006) and the Christies Beach WWTP discharges 190 tonnes of nitrogen (including 59 tonnes of ammonia) and 69 tonnes of phosphorus into the Gulf around Christies Beach (NPI 2006). All of these facilities are located in the eastern risk assessment region.

While the numbers quoted above are based on the 2004–05 year the facilities have shown a decrease in discharges (Appendix 7) particularly the Bolivar WWTP after the commissioning of the Department of Agriculture, Fisheries and Forestry plant in 2000.
The three WWTPs discharge effluent into Gulf St Vincent continuously and are considered press discharges. The impacts seen from these discharges such as the loss of *Posidonia* spp. seagrasses and degradation of macroalgal reefs are long term impacts and are not likely to recover until the discharge load is reduced.

There are no WWTPs in the other risk assessment regions that discharge directly into Gulf St Vincent. Sewage discharges into the marine environment from sources other than WWTPs will be covered under section 4.3 CWMS and septic tanks.

**Nutrients from WWTP effluent**

**Discussion**

Elevated nutrients in sewage discharges has been shown to promote epiphytic algal, phytoplankton and/or macroalgal growth, which can impact on seagrass by reducing light reaching seagrass (Neverauskas 1988). It is commonly accepted that over 5,200 ha of seagrass has been lost from the Adelaide metropolitan coastline since the 1940s (Seddon 2001). This cannot all be attributed to wastewater discharges, although in particular areas there is a strong causal link. As early as 1968, Shepherd (1971) recorded seagrass declines around the Patawalonga outlet and the Glenelg WWTP. In the northern metropolitan region losses of inshore seagrass between Barker Inlet and Gawler River followed the installation of the Bolivar WWTP in 1967 (Shepherd 1989). Similarly, the complete loss of 365 ha of seagrass and an impacted area of 1,900 ha was observed in 1984, six years after the installation and commissioning of the Port Adelaide sewage sludge pipeline in 1978 (Bryars & Neverauskas 2001). This loss has been attributed to the very high nutrient levels causing excessive epiphyte growth impacting on the seagrass (Neverauskas 1987). Eight years after the sludge outfall was decommissioned there has been a 33% recovery of seagrass to the previously denuded area (Bryars & Neverauskas 2001).

The impact of sewage effluent on macroalgal systems has been shown to change algal community richness and diversity, associated fauna and increase in nuisance algae (Brown 1990; Smith 1996). Furthermore the loss of seagrass can also have follow-on effects such as destabilising sediments, which may increase sediment loads onto reefs (Cheshire *et al* 1998; Turner & Cheshire 2002).

**Table 10** Nutrients from WWTP effluent

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Eastern</td>
<td>High (A4)</td>
<td>High (A3)</td>
<td>Moderate (A1)</td>
</tr>
<tr>
<td>Western</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Southern</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
</tbody>
</table>

**Eastern region**

Seddon (2002) stated that the original causes of the seagrass loss in the metropolitan region are unlikely to be acting to the same degree as in the past. Appendix 4 shows that SA Water have reduced their nutrient loads from the Bolivar, Glenelg and Christies Beach WWTPs by 70%, 31% and 42% respectively. In addition the sewage sludge pipes at Glenelg and Port Adelaide were decommissioned in 1993 and there is some evidence of seagrass recolonisation at the areas previously denuded.

Recent data indicates that between 1995−96 and 2002 there is still ongoing loss of 720 ha of seagrass from the Adelaide’s metropolitan coast (Cameron 2003). It is likely that a significant
A risk assessment of threats to water quality in Gulf St Vincent

For these reasons nutrients in WWTP effluent are considered a high risk to ecosystem values within the eastern region.

Modelling as a part of the Port Waterways WQIP project by the EPA, has demonstrated that the Bolivar WWTP effluent plume is transported south into Barker Inlet and the Port River when there is a strong northerly wind. The nutrients from this effluent contribute to the eutrophic state of the Port River Estuary and contribute to the blooms of the dinoflagellates Alexandrium spp. and Gymnodinium spp. These blooms can be toxic to fish, either directly or through oxygen depletion in the waters, and toxins can bioaccumulate in shellfish, which if eaten by humans, can be potentially fatal, and has resulted in frequent prohibitions on collection of shellfish (Hallegraeff 1995). For this reason the risk to water quality for aquaculture and shellfish harvesting in the eastern region is considered to be high.

Excessive micro and macroalgae can cause unsightly scums on the water surfaces, rafts of floating algae can become a navigational hazard, and the breakdown of such excessive amounts of algae can cause significant odour issues for nearby residents. Nutrients in WWTP effluent are seen as a high risk to recreation and aesthetic values in the eastern region.

**Trace metals from WWTP effluent**

**Discussion**

Trace metals are a constituent of WWTP effluent through normal WWTP operations and SA Water also accepts trade waste from industries in the metropolitan area. Due to the wide number of trade waste dischargers into the wastewater system and the potential (and high likelihood) of people pouring pollutants down the drain the volume of metals which enter the wastewater system are not well known, but are monitored regularly within the SA Water discharge system before being discharged into the marine environment. Section 3.3 describes the impact of metals in the marine environment.

**Table 11 Trace metals from WWTP effluent**

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Eastern</td>
<td>Moderate (A1)</td>
<td>Low (C1)</td>
<td>na</td>
</tr>
<tr>
<td>Western</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Southern</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
</tbody>
</table>

Eastern region
Bolivar and Glenelg WWTP discharge significant loads of boron, zinc, copper, nickel, chromium, lead, cadmium, and mercury into the marine environment (NPI 2008). All of these can be toxic to marine organisms to various extents depending on the chemical composition, species and environmental factors (section 3.3).

SA Water monitoring of metals in the final effluent shows that on occasions median concentrations at all three WWTPs exceed the water quality criteria in the WQEPP (>25 NTU) and ANZECC Guidelines for ecosystem protection (United Water 2006).

To date there have been no studies on the impact of trace metals specifically from WWTP outfalls in South Australia, however high flows from the WWTPs and good dispersion in the receiving environment have shown that concentrations in the receiving environment are generally below what would be expected for acute toxicity to marine organisms and the WQEPP criteria. There is the potential for bioaccumulation, particularly with lead and mercury as well as a spike of metals entering the sewage system through trade waste.

This risk assessment has concluded that trace metals in WWTP effluent is a moderate risk to ecosystem values in the eastern region.

**Turbidity from WWTP effluent**

**Discussion**

Turbidity from the effluent discharged from the three WWTPs has been considered only as direct turbidity, rather than turbidity from the increase in phytoplankton due to nutrient discharge. This aspect has been considered as a part of the nutrients in WWTP effluent section above.

Generally most seagrasses can store energy to varying extents, which allows them to be able to survive a short period of decreased light penetration, however this varies greatly between species (most likely related to rhizome longevity) [Walker et al 1999]. The discharge of turbidity from a constant effluent stream can result in decreased light penetration over a longer period of time which can result in seagrass loss at lower levels than what would be expected in short pulses (Walker & McComb 1992).

Section 3.1 outlines various impacts of increased turbidity on the marine environment.

**Table 12 Turbidity from WWTP effluent**

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>Na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Eastern</td>
<td>Moderate (A1)</td>
<td>na</td>
<td>Low (C1)</td>
</tr>
<tr>
<td>Western</td>
<td>Na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Southern</td>
<td>Na</td>
<td>na</td>
<td>na</td>
</tr>
</tbody>
</table>

**Eastern region**

Monitoring of the WWTP effluent and receiving environment shows that the turbidity from the three WWTPs is generally low, however there are occasional spikes of high turbidity, which may discolor the water for short periods of time (United Water 2006).

Turbidity in WWTP effluent is considered to present a moderate risk to ecosystem values. WWTP discharges occasionally exceed the WQEPP criteria for turbidity in recreational waters (>25 NTU). However it is unlikely that people would be swimming in close proximity to the WWTP.
effluent discharge locations. For these reasons turbidity in WWTP effluent is considered to be a low risk to recreation and aesthetic values.

**Freshwater from WWTP effluent**

**Discussion**

WWTP effluent is a constant discharge into the marine environment. This will almost permanently reduce the salinity in the receiving environment in close proximity to the outfall pipes.

The salinity of the three WWTP discharges along the Adelaide metropolitan coast are approximately 1 ppt (United Water 2006), where the typical salinity along the metropolitan coast of Gulf St Vincent is 35–36 ppt or approximately 55,000 µs/cm² (Gaylard 2004). Monitoring of the receiving environment has shown that the waters approximately 50 m north and south of the effluent pipes typically have salinities between 34 and 35 ppt (United Water 2006).

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Eastern</td>
<td>Low (A0)</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Western</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Southern</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
</tbody>
</table>

**Eastern region**

Westphalen *et al* (2005) reported that the dominant species of seagrass along the Adelaide metropolitan coast can survive a reduction in salinity (to 0 ppt) for up to four weeks. However the impact of a slight reduction in salinity as experienced in close proximity to WWTP effluent discharges was not tested. However, due to the very small difference in salinities, high dilution and the small extent of reduced salinity, the risk to ecosystem values from freshwater is low.

**Micro-organisms from WWTP effluent**

**Discussion**

The nature of sewage treatment with a marine discharge means that there is significant potential for human microbiological pathogens to enter the receiving environment. All three WWTPs in this risk assessment discharge wastewater that is tertiary treated where chlorine is dosed into the wastewater stream to kill any pathogens present.

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Eastern</td>
<td>na</td>
<td>Low (C1)</td>
<td>Low (C1)</td>
</tr>
<tr>
<td>Western</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Southern</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
</tbody>
</table>
A risk assessment of threats to water quality in Gulf St Vincent

Eastern region
Monitoring shows that the wastewater effluent exiting Bolivar, Glenelg and Christies Beach WWTPs has generally low levels of *E. coli* (used as an indicator for other pathogens) [United Utilities 2006]. Monitoring also indicates that there are occasional spikes of elevated bacteria in the effluent stream, which exceed recreational guidelines. However it is unlikely that people will be using waters in close proximity to WWTP effluent discharges as recreational areas. Therefore this risk assessment considers that micro-organisms in WWTP effluent a moderate risk to recreational values.

**Pesticides from WWTP effluent**

**Discussion**

Pesticides can enter WWTP effluent by people disposing of unused pesticides into the sewage system. This has the potential to cause impacts on the receiving environment from acute and chronic toxicity from the pesticide as described in section 3.6.

There is very little information regarding pesticide concentrations in South Australian WWTP effluent. Consequently there is significant uncertainty in estimating a probability for pesticide entry into the sewage system. For this reason a conservative approach has been adopted and pesticides discharge in WWTPs is flagged as an area in need of further research.

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Eastern</td>
<td>Moderate (C1)</td>
<td>Moderate (C1)</td>
<td>na</td>
</tr>
<tr>
<td>Western</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Southern</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
</tbody>
</table>

**Eastern region**

SA Water test for pesticides in their WWTP effluent at least once a year as a part of their EPA licence requirements. From the data available SA Water has detected a pesticide on two occasions from 1998 to 2005 (2000–03 data missing). The pesticide detected was Diazinon which is an organophosphorus pesticide commonly used in horticulture and broadacre cropping. It is rated as being slightly to highly toxic, particularly to insects and crustaceans (PAN 2006). The levels detected were below the limit recognised as toxic to most aquatic organisms however the issue was that the two detections were within two weeks of each other. This is a concern because currently SA Water only tests once a year and if the discharge of pesticides is sporadic then there is a high likelihood that pesticides could be missed.

While there have only been two pesticides detected in the recent data there is significant uncertainty in actual amounts discharged due to the nature of the sampling. Therefore this risk

---

3 SA Water currently monitor *E. coli* and since 2005 the National Health & Medical Research Council (NHMRC) has adopted the World Health Organization Guidelines for Safe Water Environments, which recommend using enterococci as an indicator of human pathogens in marine waters over *E. coli* (NHMRC 2005). However the previous NHMRC Guidelines incorporated a guideline for *E. coli* in recreational waters of 150 cells/100 ml (NHMRC 1996).
assessment has considered pesticides from WWTP effluent to be a moderate risk to ecosystem values.

**Endocrine disrupting chemicals (EDCs) from WWTP effluent**

**Discussion**

The discharge of wastewater from the three coastal WWTPs is considered to be the most likely source of EDCs into Gulf St Vincent. As stated in section 3.10 there are many different types of chemicals that have shown some degree of endocrine disruption response in the laboratory but translating this to a biological response in the environment has proved to be very difficult.

In the three coastal WWTPs, the effects of EDCs on the marine environment are currently unknown and is an area need of significant research. Due to limited literature about these chemicals from SA, Australia and around the world, this assessment was made using the precautionary approach. When new data become available, particularly for SA, this risk evaluation will be revised.

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Eastern</td>
<td>Moderate (A1)</td>
<td>Moderate (A1)</td>
<td>na</td>
</tr>
<tr>
<td>Western</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Southern</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
</tbody>
</table>

**Eastern region**

It is likely that many chemicals in the WWTP discharges would have EDC effects including non-ionic surfactants, bisphenol A, phthalates and a range of pharmaceuticals including 17α-ethinylestradiol (a common ingredient in contraceptives). The CSIRO have been conducting research into the fate, exposure and effects of effluent from various WWTPs in South Australia, however this project is primarily considering the effect of WWTP discharges on Australian riverine environments and investigating ways to monitor for EDCs and their impacts. The EPA has also published a report looking at risks from EDCs and results to date show that there is nothing remarkable about these discharges in terms of concentrations of EDC chemicals or effects in laboratory tests compared to similar studies overseas (Goonan 2008). The likely conclusion will be that, even in riverine environments, dilution appears to minimise the chance of adverse impacts to the environment (Goonan 2008). While relatively comparable, the discharges at Bolivar, Glenelg and Christies Beach are significantly different in character, volume and the receiving environments are significantly different to the studied riverine environments.

Further work including an evaluation of chemicals and research on biological effects in the field is required before there is confidence in any risk assessment made on the impact of these chemicals to Gulf St Vincent’s marine environment. However based on current evidence (where available) and using the precautionary principle this risk assessment has classified the risk as likely to be moderate but this area is flagged an in need of further research including field studies of EDC effects in the SA marine environment.
Other chemicals from WWTP effluent

Discussion
A category of ‘other chemicals’ is acknowledged as being very vague. This has been done to limit
the size of this risk assessment and for practicality. It is acknowledged that ‘other chemicals’
will have highly variable fate and toxicities to a range of different receptors and without
knowledge of what the chemicals that are discharged actually are, considering a probability or
consequence will be guessing at best. However it is also impractical to expect that SA Water will
analyse for every chemical in the effluent stream; it will only assess the potential for chemicals
to be introduced into the sewer system either through trade waste or otherwise. There are also
a number of chemicals that are common in WWTP discharges whose impacts are only starting to
become known. These chemicals can be common in everyday life such as triclosan which is an
antibacterial originally used in disinfectants and toothpaste and has been shown to be present in
WWTP discharges (Koplin et al 2002). Other chemicals commonly detected include
diethyltoluamide (DEET insect repellant), caffeine, tri(2-chloroethyl)phosphate (fire retardant),
and 4-nonylphenol (detergent breakdown product) (Koplin et al 2002) and ibuprofen (Thomas &
Foster 2004).

A number of ‘other chemicals’ may overlap with the endocrine disrupting chemicals category,
particularly a number of pharmaceutical chemicals.

It is an unfortunate fact that we know very little about the toxicity or environmental fate
of many chemicals that are regularly discharged into the marine environment. The risk presented
below is based primarily on opinion rather than scientific data. Significantly more research is
needed in order to have confidence that this risk has been addressed adequately.

Table 17 Other chemicals from WWTP effluent

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Eastern</td>
<td>Moderate (E3)</td>
<td>Moderate (E3)</td>
<td>na</td>
</tr>
<tr>
<td>Western</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Southern</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
</tbody>
</table>

Eastern region
It is currently unknown whether the chemicals outlined are being discharged into the marine
environment from the three large WWTPs in the eastern region however it is highly likely. It is
also unknown whether these chemicals are impacting on the biota in the receiving environment.
The chemicals are probably being discharged as a relatively constant stream into the sewer
network but their impact is largely unknown.

Two scenarios were envisaged when considering the risk from other chemicals discharged from
WWTPs. The first was the regular discharge of wastes from the WWTPs. This was considered to
be regular (possibly constant) and while data on this occurrence is virtually nonexistent, it is
unlikely that their discharge is having a widespread impact (based on intact biological
assemblages in the vicinity of WWTP effluent discharges). Nevertheless, it would be impossible
to tell whether there are chronic effects and it is possible that these would be indistinguishable
to impacts from chemicals such as metals and pesticides. The second scenario considered was
the potential for a sizable spike of a more toxic chemical through the effluent stream. This is
known to occur although infrequently (as with pesticide results) and again data is limited as
is information about impacts. This risk assessment has considered that this scenario is likely to result in a higher consequence and an impact is probably more likely, so the risk rating has been generated for this scenario. This risk was classified as being moderate to ecosystem and aquaculture values but is flagged as an area where a significant amount of research is needed to quantify risks with any confidence.

4.3 Community wastewater management systems

Community wastewater management systems (CWMS), formally known as Sewage effluent disposal schemes or STEDS, are built to service the effluent disposal needs of regional areas where the construction of a sewage system is not feasible (Appendix 6). They work by using a collection system, which consists of a network of pipes and pumping stations to transport effluent from septic tanks to a common treatment facility, which is usually owned and operated by the local council. There are several different methods for the treatment of the effluent, and the method selected for a particular CWMS will depend on a number of factors including the size of the available land, disposal method of treated effluent, economic factors, as well as proximity to an electricity supply.

As a minimum the collected effluent will pass through a secondary treatment process. These are usually of the biological type such as facultative lagoons or aerobic wastewater treatment systems. The options for disposal of effluent after secondary treatment are constrained by the South Australian Reclaimed Water Guidelines, Treated Effluent (EPA; DHS 1999). Commonly treated effluent is used for irrigation for agriculture, council sporting fields, common areas and woodlots.

CWMS currently service about 10% of all public wastewater services in South Australia or 130,000 people. Across South Australia over 18 million litres of effluent is treated each year. Of this more than 50% is reused through irrigation (LGA 2006).

There are many common problems with CWMS schemes and a contributing factor is that the average age of a scheme is 23 years old. This adds to maintenance requirements and costs. It has been found that management plans are generally not adequate, lagoons are not well maintained, pond liner integrity is frequently suspect and most maintenance is carried out on an as required (rather than preventative) basis.

Septic tanks are on-site sewage effluent treatment systems that use anaerobic bacteria to decompose and treat solids; liquids are allowed to infiltrate to the subsurface though a sand filter or leaching pond. Generally septic tanks need to be maintained to empty sludge from the holding tank. Poorly located, constructed or maintained septic tanks can leak or overflow. This can pollute ground or surface waters. The EPA and councils have the opinion that the majority of septic tanks are not well maintained (G Sorensen pers comm).

Significant concerns arise with coastal caravan parks and the potential for overloading of septic tanks at caravan parks during peak holiday periods, especially during Easter and Christmas holidays.

The northern region has one CWMS scheme that triggers an EPA licence (services more than 1,000 people). This is located at Ardrossan. However, there are several smaller systems that are in close proximity to the coastal region. These are located at Port Wakefield, Tiddy Widdy Beach Port Julia, Rogues Point and Black Point. All other effluent treatment is carried out via individual septic tank systems.

A large proportion of the eastern region’s effluent treatment is carried out by the three large WWTPs at Bolivar, Glenelg and Christies Beach (see section 5.1.2). However there are still many areas that are not linked into the wastewater system and must rely on septic tank systems.
The western region has several CWMS and these are located inland at Yorketown, also Sultana Point, Stansbury and Port Vincent. There is significant residential development underway close to the sea throughout Yorke Peninsula and therefore the potential for more systems to be put in place. Currently there are many small towns where effluent treatment is done via individual septic tank systems.

The southern region has three major CWMS schemes that are in close proximity to the coast, at Kingscote, Sellicks Beach, Maslins Beach, Second Valley and Wirrina.

Nutrients from CWMS and septic tanks

Discussion

Nutrients can enter the marine environment from CWMS and septic tanks located in close proximity to the coast or a watercourse that flows into the marine environment. This is commonly through leakage of the lagoons, overflows from pumping stations due to infiltration of stormwater or inadequate storage at pump stations (LGA 2002). Recent evidence states that on site soakage style treatment systems (septics) in densities higher than approximately 15 km² are most likely contaminating groundwater with nitrates and bacteria (Hoxley & Dudding 1994; Rural Water Corporation 1993; Whelan & Barrow 1984). In some cases the common practice was to discharge treated water to surface waters, or land disposal of sludge, however this practice is no longer considered appropriate.

Table 18  Nutrients from CWMS and septic tanks

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>Moderate (A1)</td>
<td>na</td>
<td>Low (D1)</td>
</tr>
<tr>
<td>Eastern</td>
<td>Moderate (A1)</td>
<td>na</td>
<td>Low (D1)</td>
</tr>
<tr>
<td>Western</td>
<td>Moderate (A1)</td>
<td>na</td>
<td>Low (D1)</td>
</tr>
<tr>
<td>Southern</td>
<td>Moderate (A1)</td>
<td>na</td>
<td>Low (D1)</td>
</tr>
</tbody>
</table>

Northern region

The northern region has several CWMS schemes and numerous shacks have septic tanks in close proximity to the marine environment. The land is generally flat and sandy so this is expected to provide good conditions for construction of systems and infiltration. There is some uncertainty about how well systems in this region are maintained.

Nutrients from CWMS and septic tanks in the northern region are considered to be a moderate risk to ecosystem values and a low risk to compromising aesthetic values.

Eastern region

The majority of the coastal residencies in the eastern region would be connected to the WWTPs although the rapidly growing areas to the north and the south of metropolitan Adelaide would not be serviced by this system and would rely on CWMS and septic tanks systems. The limited data available regarding septic tanks in this region indicates that they are not well maintained and a large percentage of tanks audited were found to be leaking (EPA unpublished).

In this risk assessment, nutrients from CWMS and septic tanks were considered a moderate risk to ecosystem values and a low risk to compromising aesthetic values.
Western region
The bulk of residential effluent from the western region is treated via the few small CWMS and septic tanks. Currently there is little known about the integrity of the septic tank systems in the Yorke Peninsula however it is likely to be similar to septic systems in other regions.

In this risk assessment, nutrients from CWMS and septic tanks were considered a moderate risk to ecosystem values and a low risk to compromising aesthetic values.

Southern region
The CWMS scheme at Kingscote had been highlighted as a potential source of pollution into Nepean Bay over the last few years (Gaylard 2005; Edyvane 1997). Recent work by the EPA and the Kingscote District Council have developed irrigation management plans which result in very little discharge of effluent to Nepean Bay. However, there is significant evidence that there is groundwater contamination which is likely to end up in Nepean Bay and possibly add to the eutrophic nature of the bay and impact on seagrass.

In this risk assessment, nutrients from CWMS and septic tank systems were considered a moderate risk to ecosystem values and a low risk to compromising aesthetic values.

Micro-organisms from CWMS and septic tanks

Discussion
The treatment of human sewage through septic and CWMS schemes does not normally involve a disinfection process. Therefore there is a risk of the presence of human pathogens. The discharge of human pathogens into surface or marine waters can in turn be accumulated by filter feeding shellfish (e.g., oysters) and recreational users of water.

PIRSA SASQAP test aquaculture shellfish and surrounding waters for bacteria to assess seafood safety. In the event that there are significant numbers of bacteria or toxic algal species detected PIRSA will close the lease until waters and fish are clean. This system has worked very well for many years and has resulted in very few incidents of people becoming ill after eating contaminated seafood.

Table 19 Micro-organisms in CWMS and septic tanks

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>na</td>
<td>Low (D1)</td>
<td>Low (D0)</td>
</tr>
<tr>
<td>Eastern</td>
<td>na</td>
<td>Low (D1)</td>
<td>Low (D0)</td>
</tr>
<tr>
<td>Western</td>
<td>na</td>
<td>Low (D1)</td>
<td>Low (D0)</td>
</tr>
<tr>
<td>Southern</td>
<td>na</td>
<td>Low (D1)</td>
<td>Low (D0)</td>
</tr>
</tbody>
</table>

Northern region
It is thought that any discharge or effluent from a CWMS or overflow from a septic tank into surface or marine waters would only occur during a period of heavy rain or during a major system failure. It is likely that any period of rain that generates runoff would be in winter and the prevalence of recreational users would be lower. Therefore the risk to recreational users is considered low.
Aquaculture in the northern region (Pine Point) has recorded elevated levels of bacteria around peak tourist season. However while the environmental value of protection of aquaculture could be potentially compromised, due to the vigilance of the SASQAP program (and the controlled nature of this risk) the risk of bacterial illness from contaminated aquaculture from the northern region is considered low.

Eastern region
Similar to the northern region, any CWMS or septic overflow would likely be due to a large rainfall event or a large system failure. It is likely that during large rainfall events the prevalence of recreational users would be lower. This risk assessment has considered microorganisms from CWMS and septic tanks to be a low risk to recreational users.

Western region
Aquaculture in the western region has recorded elevated levels of bacteria around peak tourist season and occasionally during winter. The reasons behind these events are largely unknown however an increase in tourists to the region and birds are possible sources (Lee 2004). While the environmental value of protection of aquaculture could be potentially compromised, due to the vigilance of the SASQAP program (and the controlled nature of this risk) the risk of bacterial illness from contaminated aquaculture from the northern region is considered low.

It is anticipated that any bacterial contamination of recreational waters from CWMS or septic tanks would eventuate through a large rainfall event. It is unlikely that this would coincide with a period of recreational use. However large summer storms are of concern as this coincides with peak tourism season and higher number of recreational users of waters. However this is still considered to be a low risk.

Southern region
The southern region has significant shellfish aquaculture in Nepean Bay, which is in close proximity to the Kingscote CWMS system. This system has previously been identified as potentially leaking or overflowing to the marine environment. The aquaculture leases within Western Cove have occasionally been closed due to elevated numbers of bacteria in shellfish (Lee 2004). It is unclear as to whether this is due to the CWMS systems discharging or due to flow from the Cygnet River (see section 4.4 Agricultural runoff).

While the environmental value of protection of aquaculture has been potentially compromised, due to the vigilance of the SASQAP program (and the controlled nature of this risk), the risk of bacterial illness from contaminated aquaculture from the southern region is considered low. This risk would be significantly higher without SASQAP intervention.

While the CWMS scheme is relatively close to the main recreational areas of the Kingscote township the risk to recreational users from the CWMS and septic tanks is considered to be low.

4.4 Agricultural runoff
Apart from the urbanised areas, land uses surrounding Gulf St Vincent are predominantly agricultural with very few areas of remanent native vegetation. Agricultural land surrounding Gulf St Vincent is commonly used for numerous types of dryland and irrigated crops, dryland and irrigated animal grazing, irrigated horticulture and some very small areas used for nature conservation.

Agricultural impacts are commonly derived from the application of fertilisers introducing excess nutrients into streams, which ultimately flow into the marine environment. Other impacts can be from excess pesticides and herbicides used to control insects and weeds and elevated micro-
organisms derived from grazing animals. An additional impact that is often overlooked is an increase in sediments from erosion of the land due to a lack of vegetation retaining soil.

Impacts in the marine environment from agricultural practices are highly dependant on flow from the drainage lines higher in the catchments. This flow is obviously highly dependant on rainfall. Therefore rainfall is a key influence on water quality in the marine receiving environment. The impact of ‘pulsed’ discharges such as agricultural runoff are often dependant on the time between pulses (time between rainfall) and the time of year. The time of year will heavily influence any pollutant load and the amount of runoff. The type of crops and soils in the catchment will influence the type of fertilisers and pesticides applied. This will obviously alter the impact in the marine environment from these discharges. Appendix 5 shows soil nutrient balances based on fertiliser application rates across Australia.

In line with section 4.1, agricultural runoff has not been assessed in the eastern region as this risk assessment has not attempted to delineate between urban and agricultural runoff in the eastern region. All runoff in the eastern region has been considered to have originated from urban catchments. It is acknowledged that this is not wholly accurate but is considered appropriate.

The northern region is considered to have some surface water runoff but admittedly this is likely to be spasmodic at best, see section 2.2 for more detail. The western region is also considered not to have any surface water runoff that may cause an environmental impact to the marine environment. As such risks from agricultural runoff in the western region have not been classified.

**Nutrients from agricultural runoff**

**Discussion**

The addition of nutrients into soils has been a key part of agriculture in SA since the turn of the 20th century. Fertiliser use has been ubiquitous since 1910 and use has been increasing over the last 15 years particularly the use of nitrogen fertilisers (NLWA 2001). Nitrogen based fertilisers are soluble in water, this means that if it rains before the nitrogen is utilised the nitrogen can leach into groundwater or into surface runoff. Phosphorus based fertilisers will readily attach to particles in the soil. When there is a rainfall event much of this phosphorus is lost through the erosion of soil into surface waters.

Past evidence shows an historical over-application of fertilizers in the Mount Lofty Ranges. Consequently, there is a legacy of nutrients within the soil where contemporary land owners apply little or no fertilisers yet significant amount of nutrients are still being exported from this land due to the historical loads (M Manou pers comm).

Export of pollutants from agricultural land occurs during heavy rainfall events. Typical export rates in the Gulf St Vincent catchment areas are between 0.5–1.0 kg/ha/yr for nitrogen and 0.03–0.1 kg/ha/yr for phosphorus (NLWA 2001). Current EPA monitoring and modeling indicates that the majority of pollutants from agricultural land are exported in one or two rainfall events throughout the year (M Manou pers comm).

Appendix 4 shows farmgate nutrient balances for nitrogen and phosphorus use across all farming and an indication of whether nutrient are actively being added or removed from the soils. This will have an impact on the amount of nutrients that may runoff during heavy rainfall events.
Table 20 Nutrients from agricultural runoff

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>Low (D1)</td>
<td>Low (D0)</td>
<td>Low (D0)</td>
</tr>
<tr>
<td>Eastern</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Western</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Southern</td>
<td>High (C4)</td>
<td>Low (D0)</td>
<td>Low (D0)</td>
</tr>
</tbody>
</table>

**Northern region**
The main creek drainage system in the northern risk assessment region is the Wakefield River. This creek has a catchment area of 1,913 km² however due to the low rainfall the estimated runoff is 68 mm/yr (NLWA 2001). The National Land and Water Resources Audit or NLWRA (2001) estimates that the amount of nitrogen delivered to the estuary is approximately 99 tonnes per year. However Favier et al (2000) suggests that the majority of stream flow downstream of Balaklava recharges groundwater and flow to the sea would only occur during significant rainfall events. This may highlight inadequacies in the estimation process of the NLWRA.

It is anticipated that there would be very little actual flow reaching the marine environment from any creek in the northern region, recent records show that the Wakefield River has only flowed past Port Wakefield for two weeks since 2002 (DWLBC 2007). This would suggest that the risk of nutrients compromising environmental values from agricultural runoff is low in the northern region.

Aquaculture values are not likely to be impacted and are considered to be a low risk. Similarly aesthetic values from the build up of algae are also considered to be low.

**Southern region**
The agricultural land in the southern region receives significantly more rainfall that the other risk assessment regions and therefore runoff into streams is far more likely. There are several streams that regularly flow into the marine environment. These are the Yankallila River and the Cygnet River, while the Myponga River rarely flows to the marine environment due to the SA Water reservoir. Monitoring of the Cygnet River receiving environment in Nepean Bay has shown elevated levels of nutrients in Western Cove, with the flow from the Cygnet River being identified as a likely source. This elevation in nutrients has been identified as a probable cause of significant seagrass loss in the region and the receiving environment being considered eutrophic (Gaylard 2005; Bryars 2003; Edyvane 1997). Nepean Bay has been highlighted as an important nursery region for many species including both recreational and commercially valuable fish. Loss of these nursery areas could have an increased risk to fisheries in the whole southern region.

This risk assessment considered nutrients from agricultural runoff to be a high risk to ecosystem values in the southern region.

**Turbidity from agricultural runoff**

**Discussion**
Erosion of agricultural land is a significant problem in Australia. Prior to European settlement the agricultural land in SA was vegetated with native trees and plants. Wide-scale erosion of agricultural land occurs when significant rainfall or winds dislodges loose soil that is
inadequately protected by vegetation. This soil is transported by local streams to the marine environment and can cause significant plumes of turbid water at the estuary and the receiving environment.

The majority of pollutants, including sediments, from agricultural land are exported in one or two rainfall events throughout the year. This is likely to introduce suspended sediment into the marine environment in large pulses.

The impact of highly turbid waters in the marine environment is outlined in section 3.1.

Table 21 Turbidity from agricultural runoff

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
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<td>na</td>
<td>Low (D0)</td>
</tr>
<tr>
<td>Eastern</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Western</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Southern</td>
<td>Moderate (C3)</td>
<td>na</td>
<td>Low (D0)</td>
</tr>
</tbody>
</table>

**Northern region**
The creeks in the northern region only flow into the sea very infrequently. Therefore any eroded soil is unlikely to reach the marine environment unless there is a significant rainfall event to connect the creek to the sea. However in the event that this does occur there is likely to be a significant build up of sediment, which may be transported to the coast. These events are likely to be short in duration and it is likely that the reduction in light penetration in the receiving waters would also be short in duration. This risk assessment considers turbidity from agricultural runoff a low risk to ecosystem and recreational values in the northern region.

**Southern region**
The southern region receives more rainfall than the other three regions and flow from creeks regularly reaches Gulf St Vincent. This flow carries sediment eroded from agricultural regions and can impact on sensitive habitats in the southern region. Nepean Bay has been shown to have very slow currents (Oceanique Perspectives 2000) and as such it is likely that large sediment particles will settle to the bottom very quickly, smaller particles may remain entrained longer however due to the low current speeds are less likely to impact on adjacent habitats. The risk to aquatic ecosystems from turbidity from agricultural runoff in the southern region is expected to the moderate. However the risk to recreational values are also considered to be low.

**Pesticides from agricultural runoff**

**Discussion**
Pesticides used in agriculture can enter the marine environment through runoff via a number of pathways. If pesticides are water soluble they can readily enter surface runoff, particularly if the pesticide in applied within a short time from rain. If the pesticide is not highly water soluble then the chemical will attach to a soil particle and this could enter runoff through erosion.

Alternatively if pesticides are applied from a plane or helicopter they can enter runoff if sprayed directly over a creek or be blown into a waterway if applied during adverse wind conditions.

Modern pesticides will generally breakdown relatively quickly in soil or water and most do not bioaccumulate in organisms. There are historical pesticides that can still be detected in sediments throughout the world even after decades of them being banned. Some will
In 2003 the EPA undertook a snapshot looking for pesticide residues in sediment and water across 157 sites in South Australia (Jenkins in prep). This study looked at both the modern pesticides and also historical pesticides that do not breakdown quickly. Appendix 6 shows locations where pesticides were sampled and locations where they were detected during an EPA Pesticide snapshot in 2003.

Generally this risk assessment is inadequate for properly evaluating risks from pesticides. A risk assessment detailing individual pesticides from various land uses is needed to adequately protect environmental values not only in the marine environment but in South Australian creeks and streams. In addition work is needed on the impact of pesticides that have a high risk of entering the marine environment and whether or not they could be a cause of seagrass and macroalgal reef habitat degradation or pose risks to aquaculture species. The CSIRO Land & Water have been developing a risk assessment system for pesticides in agricultural and urban areas and links to this program can be found at: <www.clw.csiro.au/research/biogeochemistry/assessment/projects/piri.html>.

### Table 22 Pesticides from agricultural runoff

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>Low (D0)</td>
<td>Low (D0)</td>
<td>na</td>
</tr>
<tr>
<td>Eastern</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Western</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Southern</td>
<td>Moderate (C2)</td>
<td>Low (D1)</td>
<td>na</td>
</tr>
</tbody>
</table>

### Northern region

The EPA pesticide snapshot detected both modern and historical pesticides in water (via passive samplers) and in sediment in the Wakefield River and Skilllogalee Creek, which drains into the Wakefield River. Relatively high concentrations of chlorosulfuron, metasulfuron and triasulfuron were detected at levels that would be considered toxic to aquatic plants and algae.

The creeks in the northern region rarely flow to the sea, and so the probability of the pesticides reaching the sea is wholly dependant on the recent pesticide applications in close proximity to the large rainfall event that may connect these creeks to the estuary and marine environment.

In addition there is little information of the impact of common pesticides on marine organisms in South Australia therefore the fate and toxicity of pesticides that may reach the marine environment is poorly understood.

The risk from pesticides from agricultural runoff is considered to be a low risk to ecosystem values in the marine environment in the northern region. This is also considered to be a low risk to aquaculture values in the northern region.

### Southern region

Jenkins (in prep) has shown that pesticides have been detected in estuarine sediments in the Cygnet Estuary, with aldrin, dieldrin, DDD and DDE being detected. This shows that it is highly likely that some pesticides may enter the marine environment in the southern region or at least have in the past. The risk to ecosystem values in the southern region is considered a moderate risk, the risk to aquaculture values is considered to be low.
Micro-organisms from agricultural runoff

Discussion

WHO (2003) state that the most likely pathogen group present in estuarine and coastal waters is human viruses that are found in sewage and human faeces. A ‘species barrier’ is assumed to exist where the density of pathogenic bacteria from animal excreta is less than in human excreta. This significantly lowers the risk of infection from recreational contact with waters contaminated by animal faecal material (NHMRC 2005). However there are still some micro-organisms that can be transmitted via this route such as Cryptosporidium parvum, Campylobacter spp. and E. coli 0157:H7 (NHMRC 2005).

Agricultural runoff in South Australia is likely to be high in bacteria excreted by animals particularly in areas used for grazing. The likelihood of this containing human excreta is probably low. Entry of human excreta or pathogens into streams and creeks from CWMS and septic tanks is covered in this risk assessment in section 4.3.

The impact of pathogens on recreational values and aquaculture is detailed in section 3.5.

Table 23  Micro-organisms from agricultural runoff

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>na</td>
<td>Low (D0)</td>
<td>Low (D0)</td>
</tr>
<tr>
<td>Eastern</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Western</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Southern</td>
<td>na</td>
<td>Low (D0)</td>
<td>Low (C1)</td>
</tr>
</tbody>
</table>

Northern region

While there are significant areas used for dryland grazing in close proximity to the coast, it is rare that agricultural discharges in the northern region reach the sea. In a rainfall event large enough to connect the creek to the estuary and the sea it is unlikely that the receiving environment will be used for recreation. However there is potential for large summer storms and also the potential for impacts on filter feeding shellfish aquaculture.

This risk assessment considers micro-organisms from agricultural runoff a low risk to recreational and aquaculture values in the northern region.

Southern regions:

There are significant areas of agricultural land in the southern region that are in close proximity to the coast or where the runoff may enter a stream, which regularly discharges into Gulf St Vincent. The southern region experiences more rainfall than other regions in this risk assessment and the streams are often connected to an estuary and the sea. Therefore the likelihood of agricultural runoff reaching the sea is higher than in other regions. As in section 4.3 the SASQAP will close the aquaculture leases from harvesting shellfish if they believe there is a high risk of microbial contamination. There have been occasions where this has occurred in the southern region (Lee 2004).

This risk assessment considers micro-organisms from agricultural runoff a low risk to recreational and aquaculture values.
4.5 Power generation stations

There are three large power stations that discharge water into the marine environment within Gulf St Vincent. These are:

- AGL Torrens Island Power Station, Port Adelaide
- Pelican Point Power Station, North Haven

The three facilities discharge cooling water to the marine environment. Due to the age of the AGL Torrens Island Power Station and demonstrated impacts from its marine discharge it has been classified separately from the newer power stations.

4.5.1 AGL Torrens Island Power Station

The AGL Torrens Island Power Station is the largest power station in South Australia. It is located on Torrens Island within the Port River Estuary. It has eight steam generators that produce energy from natural gas. The first unit of the first stage of the power station (120 MW of 480 MW) was operational in 1967 and the second stage (800 MW) was fully operational in 1980, making a total output 1,280 MW.

The power station uses marine water from intake pipes in the Port River to cool condensers within the power station. The cooling water is dosed with hypochlorite to disinfect the water to prevent micro- and macro-organisms from growing in the cooling water systems. The cooling water is then discharged into Angas Inlet. Due to the age of the station the effluent discharged is likely to contain some trace metals due to the corrosion of metals within the plant, however these are likely to be generally low in concentration. The major potential environmental impact of the AGL Torrens Island Power Station is the elevated temperature of its discharge.

The discharge from the power station is considered to be a press discharge due to the continuous nature of the discharge and the long-term impacts seen in the receiving environment. Populations considered to be native of the area are unlikely to return until the discharge temperature is similar to the background temperature of the region.

Temperature from AGL Torrens Island Power Station

Discussion

AGL Torrens Island Power Station’s EPA license allows a maximum thermal load corresponding to a weekly average of 10.5 °C above the background water temperature. Biological monitoring in the receiving intertidal environment from 1972 through until 1985 has shown that the fauna has been significantly changed due to the temperature and volume of the discharge from the power station (Thomas et al 1986). This monitoring has shown that several species of bivalve and worm species have been reduced or eliminated from areas near the outfalls. These species have been replaced by opportunistic tropical species of cirratulid worm (*Cirriformia punctata*). This species has subsequently been largely replaced by a more competitive tropical spionid worm (*Pseudopolydora* sp.) [Thomas et al 1986].

EPA modelling of the Port River Estuary as a part of the Port Waterways Water Quality Improvement Plan (WQIP) has shown the influence of warmed water on Angas Inlet, North Arm and Barker Inlet (Figure 6). This may also be contributing to the prolific nuisance algal growth throughout the waterway, which may be impacting on aesthetic values.

In addition, the intake pipes for AGL Torrens Island Power Station are located opposite the Penrice Soda Products effluent discharge. This effluent is very high in ammonia. EPA modelling has shown that the intake pipes from AGL Torrens Island draw ammonia rich water from the...
A risk assessment of threats to water quality in Gulf St Vincent receiving environment near Penrice and transport it through the cooling water discharge into Angas Inlet where it is likely to contribute to further nuisance growth of *Ulva* spp. in Angas Inlet, Barker Inlet and North Arm (P Christy pers comm).

Figure 12 Temperature plume from AGL Torrens Island Power Station (EPA 2008)
Table 24  Temperature from AGL Torrens Island Power Station

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Eastern</td>
<td>High (A3)</td>
<td>High (A3)</td>
<td>Moderate (A1)</td>
</tr>
<tr>
<td>Western</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Southern</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
</tbody>
</table>

**Eastern region**

Under their environmental authorisation with the EPA, the maximum thermal load corresponds to a weekly average of 10.5 °C above background temperature. Monitoring has shown that the power station does not exceed this criterion. However there have been demonstrated impacts in Angas Inlet, North Arm and Barker Inlet from the discharge of warm water from the power station. The Port River and Barker Inlet system is a key fish nursery area for many species of fish and invertebrates including commercial and recreational fished species, and impacts on this system are likely to affect fish and invertebrate stocks throughout the eastern region. The elevated temperature has altered the fauna of the receiving environment and it is also likely to be exacerbating the nutrient problem within the Port Waterways. this state is likely to be unchanged while the power station is discharging water at the current temperature.

This risk assessment considers that this altered state is undesirable but remains stable if allowed to continue. Therefore this risk assessment considers that the elevated temperature discharge from AGL Torrens Island Power Station is a high risk to ecosystem and aquaculture values in the eastern region but a moderate risk to aesthetic values.

**Trace metals from AGL Torrens Island Power Station**

**Discussion**

Galvanised metals and corrosion of pipes are likely to introduce small amounts of trace metals into the marine environment through either the cooling water system within the power station or from surface runoff across the site. NPI (2005) reports that very small amounts of arsenic, cadmium, copper, mercury and lead are discharged by AGL Torrens Island Power Station each year.

Table 25  Trace metals from AGL Torrens Island Power Station

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Eastern</td>
<td>Low (A0)</td>
<td>Low (A0)</td>
<td>na</td>
</tr>
<tr>
<td>Western</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Southern</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
</tbody>
</table>

**Eastern region**

AGL Torrens Island Power Station has reported to NPI that the power station discharges very small amounts of arsenic, copper, cadmium, lead and mercury from its station
drains. Given that the discharge is relatively constant, rather than pulses of metals, the likely trace metal concentrations from the discharge would be well below toxic levels.

This risk assessment considers the discharge of trace metals from AGL Torrens Island Power Station to be a low risk to ecosystem values in the eastern region.

**Hydrocarbons from AGL Torrens Island Power Station**

**Discussion**

There is an inherent risk in any large industrial facility that uses hydrocarbons within its processes or in its machinery that some could be spilled. The AGL Torrens Island Power Station is located on the shores of Torrens Island and in addition to the cooling water discharge, stormwater systems drain into the Port River.

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Eastern</td>
<td>Low (E1)</td>
<td>Low (E1)</td>
<td>Low (E1)</td>
</tr>
<tr>
<td>Western</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Southern</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
</tbody>
</table>

**Eastern region**

EPA auditing of power stations has shown that at the time of inspection all above-ground fuel and oil tanks were adequately bunded. This risk assessment has been undertaken with due consideration to the adequate operation of mitigation strategies and assuming that they are maintained and working. Therefore this risk assessment considers that the risk to ecosystem and aesthetic values from hydrocarbons from AGL Torrens Island Power Station is low.

**Other chemicals from AGL Torrens Island Power Station**

**Discussion**

Almost all facilities that use marine waters as a cooling medium will need to control marine growth in the cooling water system. AGL Torrens Island Power Station uses a constant dose of hypochlorite in the intake water to avoid growth of micro- and macro- organisms in the station. It is possible that there is some residual chlorine in the discharge stream that is discharged to the receiving waters, this chlorine is likely to reduce and possibly bind with organic material in the water to form chlorinated organic compounds (Rajamohan et al 2007). The specific make-up of these chemicals is unknown as is their impact.

Based on current operating practice, an equivalent of nine tonnes per year of sulfuric acid is produced by the regeneration of the condensate polishing plant and is discharged into the cooling water discharge stream to the marine environment.
Table 27 Other chemicals from AGL Torrens Island Power Station

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Eastern</td>
<td>Low (C1)</td>
<td>Low (C1)</td>
<td>na</td>
</tr>
<tr>
<td>Western</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Southern</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
</tbody>
</table>

Eastern region

It is possible that there are trace amounts of chlorine in the discharge stream, and for chlorinated organic chemicals to be formed in the discharge stream including trihalomethane and bromoform. These chemicals are likely to be long lived and can accumulate in sediments and in biota (Lawrence & Nicholson 1998). It is uncertain as to whether these chemicals are being produced as a by-product in the discharge and whether they are having an impact on the receiving environment.

This risk assessment considers that the risk to ecosystem and aquaculture values from other chemicals from AGL Torrens Island Power Station is likely to be low however more research is required in order to have higher confidence in this risk classification.

4.5.2 Other power stations

Pelican Point Power Station was built in 2000 and has been promoted as one of the most energy efficient power stations in the southern hemisphere (International Power 2007). It is located at Pelican Point near Outer Harbour at the top of the Port River. The power station uses marine water to cool its generators and discharges it back into the Port River. The receiving environment is located within a shipping channel with only a relatively short distance to open water.

The Origin Energy Osborne Cogeneration Power Plant is situated next to the Penrice Soda Products facility and was commissioned in 1998. In addition to the 180 MW of electricity generated, it also produces 410 tonnes an hour of steam for use by Penrice. Origin claims that this power station is over 50% more efficient compared to conventional power generation stations.

Temperature from other power stations

Discussion

Unlike the AGL Torrens Island Power Station the newer power stations are more efficient and the cooling water is not heated to the extent of the older facility. In addition to this their manufacture was after the inception of the EPA and relevant environmental legislation and the temperature discharge criteria applied to the new facilities were much stricter.
Table 28 Temperature from other power stations

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Eastern</td>
<td>Moderate (A1)</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Western</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Southern</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
</tbody>
</table>

**Eastern region**

Monitoring of both power stations shows that they are generally within two degrees of the background temperature. This change in receiving water temperature is likely to be having minimal effect on the receiving water fauna.

This risk assessment considers that the risk to ecosystem values from warmed effluent from other power stations within the eastern region presents a moderate risk.

**Turbidity from other power stations**

**Discussion**

There is a significant volume of water that flows through the cooling water systems. There is the potential for this water to become turbid through picking up suspended solids through the cooling water process or creating turbid plumes through scouring of the seabed at the discharge site.

Table 29 Turbidity from other power stations

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Eastern</td>
<td>Moderate (A1)</td>
<td>Moderate (A1)</td>
<td>na</td>
</tr>
<tr>
<td>Western</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Southern</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
</tbody>
</table>

**Eastern region**

There is the potential that the cooling water entering the Port River could generate turbid water plumes at the discharge site. Occasional turbid plumes have been observed at the discharge site from the Pelican Point Power Station (S Gaylard pers observations) and it is considered that while it is being discharged into a significantly modified system (shipping channel) it could be impacting on marine ecosystems in the region.

This risk assessment considers that the risk to ecosystem values from increased turbidity from other power stations within the eastern region to be a moderate risk to both the ecosystem values within the eastern region, the aquaculture values from the Section Bank cockle regions and to baitworm digging throughout the Port River.
**Other chemicals from other power stations**

**Discussion**

Like older power stations, newer facilities still have the requirement of removing marine growth from inside pipes and the cooling water system. Many facilities use hypochlorite to control growth within the systems and as stated in section 4.5.1 there can be residual chlorine in the discharge and possibly the generation of chlorinated organic chemicals. These chemicals have the potential to accumulate in sediment and biota.

In addition to biocides a large facility such as a power station may require other chemicals to be used in its running, cleaning and maintenance. While it is impractical to attempt to identify each constituent it is accepted that there is a risk associated with their use in the facility and a probability that they could enter the marine environment through the effluent or stormwater systems. Again this is an area in need of further research.

Table 30 Other chemicals from other power stations

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Eastern</td>
<td>Low (C1)</td>
<td>Low (C1)</td>
<td>na</td>
</tr>
<tr>
<td>Western</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Southern</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
</tbody>
</table>

**Eastern region**

The vagueness associated with the ‘other chemicals’ classification suggests that more monitoring and research is required before any risk assessment can accurately assess the probability and the likely impact of any of these chemicals in the marine environment. Based on the monitoring data that are available and information on chemicals so far identified this risk assessment considers that there is a low risk to the ecosystem values from other chemicals, however this is an area that is flagged for more research.

**4.6 Penrice Soda Products**

Penrice Soda Products produces soda ash, which is used in the production of glass, soaps and detergents, metals and mining. The industrial facility is located on the shore of the Port River at Osborne. The process used at Penrice is called the Solvay process which uses a brine solution, ammonia and limestone to produce sodium carbonate (soda ash). At the Osborne facility, Penrice use salt pans to partially evaporate seawater to get a brine solution that is transported to the facility. Some ammonia is recovered from the process but an effluent stream of approximately 40 ML/day is discharged into the Port River which is high in ammonia and contains some trace metals.

The discharge of total ammonia from Penrice is a press discharge (see section 1.4.1). This means that there is always a constant discharge of this nutrient, which can be toxic to some organisms, into the surrounding environment. This gives organisms in the receiving environment no respite from the impacts of this discharge and therefore it is likely that there will not be significant recovery until the discharge is reduced to a point below a threshold of impact on the receiving organisms.
The effluent discharge at Penrice was previously very high in suspended solids with a by-product of the Solvay process being calsilt (calcium chloride). Previously this was discharged into the Port River where it became a navigational hazard. As a part of its environmental improvement program (EIP), sedimentation ponds were installed at the facility and the calsilt settles out, and this has resulted in a 95% reduction in suspended solids in the effluent discharged into the Port River. Nevertheless, there is still a very large amount of ammonia discharged into the marine environment in the Port River.

As part of its EIP, Penrice has set ammonia reduction targets as a part of the Port Waterways WQIP which will be included in nutrient reduction strategies as a part of the ACWQIP. The aim is to improve the marine environment within the Port River, Barker Inlet and Adelaide coastal waters. For more details see <www.epa.sa.gov.au/water_port.html>.

**Total ammonia from Penrice Soda Products**

**Discussion**

The Solvay process uses ammonia, and while some percentage is recovered, 990 tonnes of total ammonia is discharged into the marine environment each year.

Total ammonia is made up of both ammonia (NH₃) and the ammonium ion (NH₄⁺). The ammonia portion of total ammonia is toxic to marine organisms (particularly fish) as it is neutrally charged and can cross the gill membranes and cause toxicity. The ammonium ion is positively charged and cannot cross the membrane and thus it is significantly less toxic. The percentage of each is dependent on temperature and salinity of the solution. In the receiving environment, the salinity is relatively constant and the temperature varies throughout the year. At these conditions, there is about 95% ammonium and 5% ammonia.

While significantly less toxic, the ammonium ion is readily available as a nutrient for plants and algae and can be a significant contributor to eutrophication. In addition, ammonium will oxidise to form nitrate, which is again readily available for uptake as a nutrient by plants and algae.

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Eastern</td>
<td>High (A4)</td>
<td>High (A3)</td>
<td>Moderate (A1)</td>
</tr>
<tr>
<td>Western</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Southern</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
</tbody>
</table>

**Eastern region**

The Port River has been inundated by nutrient discharges for most of the 20th century so defining a definitive source of the obvious nutrient impact is difficult. Computer modelling as a part of the Port Waterways WQIP has shown that the current extent of the ammonia discharge from Penrice covers not only the immediate vicinity of the discharge but also well into North Arm, Barker Inlet and the upper reaches of the Port River (P Christy pers comm). In addition, modelling for the ACWS has also shown that it is likely that the high total ammonia discharge from Penrice may be contributing to the seagrass loss along the metropolitan coast with its extent believed to reach as far south as Holdfast Shores (S Bryars pers comm).

Ammonia is readily available to plants and algae, and the excess of nitrogen in the Port waterways has led to macroalgal blooms of sea lettuce (<em>Ulva</em> sp.), seagrass loss and increases in...
turbidity. There are other contributors to the algal problem within the Port waterways including the thermal discharge from the AGL Torrens Island Power Station, nutrient discharges from the now closed Port Adelaide WWTP and the Bolivar WWTP.

The discharge of total ammonia by Penrice Soda Products is considered to present a high risk to ecosystem values in the eastern region.

The excess of nutrients has also contributed to phytoplankton blooms within the shipping channel, including ‘red tides’ of the dinoflagellate *Alexandrium* spp. These blooms can be toxic to fish either directly or through oxygen depletion in the waters and toxins can bioaccumulate in shellfish, which if eaten by humans, can be potentially fatal, and has resulted in frequent closures to the collection of shellfish (Hallegraeff 1995).

This risk assessment considers the ammonia discharge from Penrice is a high risk to aquaculture values in the eastern region.

The accumulation of macroalgae is unsightly and they can form large rafts that cause offensive odours when they decay (again releasing nutrients back into the waters). This algae, when in large amounts has also caused navigational hazards in North Arm and Barker Inlet.

The total ammonia discharge from Penrice is considered to be a moderate risk to aesthetic values in the eastern region.

**Other chemicals from Penrice Soda Products**

**Discussion**

National Pollutant Inventory (NPI) reporting shows that Penrice discharges 1.4 tonnes of cyanide and small amounts of phenol into the Port River. In addition, a large facility that uses marine water in its process will need to use descalants and biocides to clean marine growth from the inside of the pipes and throughout the system. These chemicals are toxic to marine life and if not managed properly can be discharged into the marine environment.

### Table 32 Other chemicals from Penrice Soda Products

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Eastern</td>
<td>Low (C1)</td>
<td>Low (C1)</td>
<td>na</td>
</tr>
<tr>
<td>Western</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Southern</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
</tbody>
</table>

**Eastern region**

Based on the monitoring data that are available and information on identified chemicals this risk assessment considers that there is a low risk to the ecosystem values from other chemicals.

**Hydrocarbons from Penrice Soda Products**

**Discussion**

There is an inherent risk in any large industrial facility that uses hydrocarbons within its processes or in its machinery that some could be spilt. Penrice Soda Products is located on the shores of the Port River, which is a sensitive marine environment. As the stormwater systems
drain into the river, there is a likelihood that a hydrocarbon spill may enter the river and impact on marine life.

Table 33 Hydrocarbons from Penrice Soda Products

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Eastern</td>
<td>Low (E2)</td>
<td>Low (E0)</td>
<td>Low (E0)</td>
</tr>
<tr>
<td>Western</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Southern</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
</tbody>
</table>

Eastern region
Recent EPA inspections of Penrice Soda Products have shown above-ground fuel and oil tanks are all adequately bunded and therefore present a low risk of spillage into the marine environment or stormwater systems.
This risk assessment considers the risk to ecosystem and aesthetic values to be low from hydrocarbons from Penrice Soda Products.

4.7 Commercial shipping
Commercial shipping is generally considered to be large cargo vessels that carry materials from one wharf to another. The distance travelled can vary from carrying limestone from Ardrossan to Port Adelaide to transporting grain from Port Adelaide to the Persian Gulf.
Commercial shipping vessels are vital to Australia, but they can be potential sources of pollution, not only from the cargo and fuel that they carry but also through black and grey water discharges, antifoulant residues leaching from the hulls, and the potential for translocation of an invasive marine pest through either ballast water discharges or biofouling on the hull.
Figure 13 shows the commercial shipping traffic routes within Gulf St Vincent.

Hydrocarbons from commercial shipping
Discussion
Carrying oil in ships has an inherent risk of a spill not only from carrying oil as cargo but also as fuel. There have been three major oil spills in South Australia with the largest being the Era tanker, which collided with the Turmoil tugboat at the Port Bonython jetty in the northern Spencer Gulf on 30 August 1992 and spilt an estimated 296 tonnes of heavy bunker oil into the northern Spencer Gulf (Wardrop et al 1996). The impact of this spill on the marine and nearshore environment included approximately 3.2 ha of extensively defoliated mangroves.
Other observations of impact were a reduction in mosquitoes at survey sites and a loss of sediment infauna (Wardrop et al 1996). The main cause of this impact was attributed to smothering by the heavy oils but no specific causal analysis was carried out.
Within Gulf St Vincent there have been two spills from the Port Stanvac Oil Refinery. One in 1982 when the Esso Gippsland caused a slick that impacted on beaches between Seaford and Aldinga. The second and more recent was also at Port Stanvac in 1999 where the refinery caused a spill of 230 tonnes. Oil spill dispersant was used to break up the slick and consequently only 800 m of beach at Sellicks Beach was affected (AMSA 2000).
An issue that has to be considered in the mitigation or containment of an oil spill is the use of oil spill dispersants. In some cases oil spill dispersants can be toxic to aquatic organisms and their use can cause environmental harm in their own right. Often it is the responsibility of the Environment Scientific Coordinator and the State Spill Commander to decide whether the harm from the oil spill would outweigh the harm from the dispersant. This decision is made on an individual spill basis (P Pfennig & F Peat pers comm.).

An AMSA commissioned study investigating the risks from oil spills throughout Australia concluded that the greater risk of a large oil spill is a spill in a port (Jones et al 2000). The South Australian Marine Spill Contingency Action Plan (SAMSCAP) has designated Gulf St Vincent a high risk area. Before Port Stanvac ceased operating in 2003, in excess of 8.5 million tonnes of crude or refined products were shipped throughout the waters of South Australia annually in oil tankers (not all of this is in Gulf St Vincent).

Commercial ships may also discharge significant amounts of bilge water whilst travelling within the Gulf. Bilge water can be found aboard every vessel, but its composition is usually unique. Because the bilge wells receive liquids from many parts of the ship, bilge water can contain water, oil, dispersants, detergents, solvents, chemicals, particles and more. MARPOL 73/78 requires ships to be fitted with certain pollution prevention equipment, including oil filtering equipment, oil content metres and oil/water interface detectors. Ships are required to filter oily bilge water to no more than 15 ppm prior to discharge into the receiving marine environment. If the oil content in the bilge water exceeds the limit, the discharge is automatically stopped and an alarm is sounded. Most reported incidents of oily bilge water discharge occur whilst the vessel is in port and involved in loading/unloading operations.

The impacts of hydrocarbons are outlined in section 3.4.

Table 34 Hydrocarbons from commercial shipping

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>Low (F2)</td>
<td>Low (F1)</td>
<td>Low (F1)</td>
</tr>
<tr>
<td>Eastern</td>
<td>Moderate (E4)</td>
<td>Low (E1)</td>
<td>Low (E2)</td>
</tr>
<tr>
<td>Western</td>
<td>Low (F2)</td>
<td>Low (E1)</td>
<td>Low (E2)</td>
</tr>
<tr>
<td>Southern</td>
<td>Moderate (E3)</td>
<td>Low (E1)</td>
<td>Low (E2)</td>
</tr>
</tbody>
</table>

Northern region

The northern region is not generally an oil tanker route, and there is very little shipping traffic throughout the region. As such this risk assessment considers the risk to ecosystem, aquaculture and aesthetic values to be low.

Eastern region

The eastern region is a key petroleum distribution point for the City of Adelaide. As stated above the main risk of an oil spill is considered to be at the port (both previous spills occurred at Port Stanvac). The Birkenhead petroleum storage facilities are located in close proximity to the Port River to facilitate petroleum product storage after it is unloaded from tankers. In 2005 there were 103 vessels that unloaded over 2 million tonnes of petroleum products at Port Adelaide, an increase from 75 vessels unloading 1.2 million tonnes in 2004 (Flinders Ports 2006). This risk assessment has only considered the risk from transporting hydrocarbons by commercial ships in this section. The transfer of product from the ships to the storage facilities is covered under
section 4.7—Wharves, and the risk of discharge to the marine environment from the fuel storage facilities is assessed under section 4.16—Fuel storage facilities at Birkenhead.

Considering that over the last 25 years there have been two significant oil spills in the eastern region and the amount of oil imported into Port Adelaide has increased, this risk assessment considers the risk to ecosystem values to be a moderate risk, however the risk to aesthetic values is considered low.

**Western region**

Similar to the northern region, the western region does not import petroleum products or is not a key shipping route. Therefore the primary risk is from a spill of oil used for fuel. This risk assessment considers the risk from hydrocarbons in the western region to be a low risk to ecosystem, aquaculture and aesthetic values.

**Southern region**

The southern region is a key petroleum tanker shipping route, particularly through Backstairs Passage and would carry a higher probability of a spill than the northern and western regions. This risk assessment has considered the risk to ecosystem values to be moderate. However the risk to aquaculture and aesthetic values is considered to be low.

**Trace metals from commercial shipping**

**Discussion**

Marine organisms will grow on most substrates available in the water. Vessels need protection from this marine growth in order to reduce fouling on the hull, which will cause hydraulic drag and increase fuel costs. An additional problem that can occur with marine growth on international ships is the translocation of invasive marine pests (see section 3.13). Antifoulant paints are used to coat the submerged hull of a vessel with a toxicant, which stops marine growth from attaching to the hull. The paint will slowly leach toxicant into the water to form a protective barrier around the hull. Alternatively the paint acts as a toxicant when a marine organism tries to attach to it. In most cases antifoulant toxicants enters the marine environment and are usually deposited into the sediment where they will remain indefinitely.

One of the most effective antifoulants, tributyltin (TBT), has been found to be one of the most toxic chemicals and impacts have been seen on marine organisms at extremely low levels. Impacts include the local extinction of sensitive organisms in regions adjacent to contaminated sediments and along open ocean shipping routes (Walker et al 1996). This chemical has been widely used throughout the world and a recent investigation led by the Australian Government has found wide contamination in Australian ports and harbours including South Australia (Mortimer 2004). In 2004 the Australian Pesticides and Veterinary Medicines Authority (APVMA) totally banned the use of TBT based antifoulants and trials have been ongoing with regard to a suitable replacement for large vessels.

These antifoulant paints are usually high in trace metals such as copper, zinc or some now include organic pesticides (or booster biocides) such as diuron and irgarol (Comber et al 2002). The booster biocides, in particular diuron, added to either cuprous oxide or cuprous thiocyanate have raised human health and environmental concerns. The United Kingdom has undertaken to control the use of diuron as an antifoulant on all vessels due to significant amounts being detected in water and sediment throughout estuarine and coastal sites. The US EPA is conducting a review of diuron but has yet to make final recommendations for usage. The APVMA is the registering authority for antifoulant paint and is also reviewing the use of diuron—no final recommendations relating to its use in antifoulant paint have been made.
There are no data available regarding trace metal contamination along shipping routes (contamination at wharves is considered in section 4.8) in SA leading to significant uncertainty about whether the volume of commercial shipping traffic would create an impact along shipping routes.

Table 35 Trace metals from commercial shipping

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>Low (B0)</td>
<td>Low (B0)</td>
<td>na</td>
</tr>
<tr>
<td>Eastern</td>
<td>Low (A0)</td>
<td>Low (B0)</td>
<td>na</td>
</tr>
<tr>
<td>Western</td>
<td>Low (B0)</td>
<td>Low (B0)</td>
<td>na</td>
</tr>
<tr>
<td>Southern</td>
<td>Low (A0)</td>
<td>Low (B0)</td>
<td>na</td>
</tr>
</tbody>
</table>

Northern region
There is no data available for trace metal loads along Gulf St Vincent shipping routes and significant uncertainty as to whether there is historical contamination from TBT or any impacts from other toxicants in current antifoulant paints.

Given the low vessel traffic in the northern region this risk assessment considers the risk to ecosystem and aquaculture values from trace metals to be low.

Eastern region
The eastern region encounters the most vessel traffic in Gulf St Vincent. It is likely this is still significantly below what may cause an impact on ecosystem values. There is significant uncertainty as to whether Gulf St Vincent has the vessel traffic to cause an impact, and with the banning of TBT whether the current antifoulants would cause an impact in shipping lanes. There may be some residual contamination in marinas or ports but this will be covered in sections 4.8 and 4.11.

This risk assessment considers the risk from trace metals to ecosystem values in the eastern region to the low.

Western region
Given the low vessel traffic in the western region this risk assessment considers the risk to ecosystem and aquaculture values from trace metals from commercial shipping to be low.

Southern region
Figure 12 shows that the southern region encounters significant vessel traffic through Backstairs Passage. However given the deep water and high current speeds in this region there is not expected to be any adverse impact on ecosystem or aquaculture environmental values in the southern region, therefore the risk has been considered to be low.
**Nutrients from commercial shipping**

**Discussion**

The discharge of sewage into the sea will be prohibited, except when the ship has in operation an approved sewage treatment plant, or is discharging comminuted (macerated) and disinfected sewage using an approved system at a distance of more than three nautical miles from the nearest land, or is discharging sewage which is not comminuted or disinfected at a distance of more than 12 nautical miles from the nearest land.

Whilst in port, ship masters are requested to contact the port authority who will make arrangements for a mobile waste contractor to pump-out sewage generated onboard. Most commercial vessels will discharge their greywater (water from galley, wash basins and showers) directly to marine waters. This will contain nutrient loads. Commercial passenger vessels produce the most substantial volumes of greywater and greatest nutrient loads and are being encouraged to install onboard wastewater treatment systems that can manage both black (sewage) and greywater but no current MARPOL standard exists.

Prior to entering Australian waters (outside of the Gulf), livestock vessels are required to be thoroughly cleansed. Australian Quarantine and Inspection Services (AQIS) regulates this activity. Once these vessels are loaded with livestock and leave port, vessel decks may be washed down to remove livestock excrement and sand. This generally occurs within the Gulf and will result in nutrient loads into the water.

The Kangaroo Island Ferries discharge untreated sewage from a holding tank in the middle of Backstairs Passage regularly which has the potential to increase not only nutrient loads but also microbial contamination.

<table>
<thead>
<tr>
<th>Table 36</th>
<th>Nutrients from commercial shipping</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Region</strong></td>
<td><strong>Ecosystem</strong></td>
</tr>
<tr>
<td>Northern</td>
<td>Low (B0)</td>
</tr>
<tr>
<td>Eastern</td>
<td>Low (A0)</td>
</tr>
<tr>
<td>Western</td>
<td>Low (B0)</td>
</tr>
<tr>
<td>Southern</td>
<td>Low (A0)</td>
</tr>
</tbody>
</table>

**Northern region**

There are relatively low numbers of ship passages in the northern region of Gulf St Vincent and therefore the risk is anticipated to be low for impacts on ecosystem, aquaculture and aesthetic values.

**Eastern region**

Nutrients can be discharged from vessels through greywater, treated or untreated blackwater and livestock wastes. While a significant amount of these nutrients will be discharged a long distance offshore the load of nutrients may still be contributing to eutrophication in the eastern region. Given the relatively high vessel traffic the discharge of nutrients from commercial shipping is considered to be a low risk to ecosystem aquaculture and aesthetic values in the eastern region.
Western region
Similar to the northern region the western region has relatively small amounts of commercial ships travelling through the region. It is anticipated that the discharge of nutrients would be in relatively low volumes and released in deep water away from land and aquaculture facilities. This risk assessment considers the discharge of nutrients from commercial shipping to be a low risk to ecosystem, aquaculture and aesthetic values in the western region.

Southern region
The southern region has a significant amount of commercial shipping travelling through the region. The southern region also incorporates a proposed marine park, which is aimed to protect representative marine biodiversity or organisms and habitats. However Backstairs Passage is a region with very fast currents and deep water, which is likely to disperse any nutrients discharged by vessel while traversing the region.

This risk assessment considers nutrients from commercial shipping is a low risk to ecosystem, aquaculture and aesthetic values in the southern region.

Rubbish from commercial shipping

Discussion
A daily input of more than 600,000 plastic containers into the oceans was attributed to shipping in 1982. In 1975 the US National Academy of Science estimated that 6.4 million tonnes of litter were jettisoned from ships at sea each year (Laist 1987). The longest running beach litter survey program has been undertaken at Robe. While not in the Gulf St Vincent risk assessment region, the survey allows comparisons about reductions across the state. The 2004 survey found 1,689 kg of debris, of which 1,326kg of this was preserved wood, possible origins of this wood are suggested to be wooden crates either dumped, lost overboard from fishing boats or offshore cargo vessels (Eglinton et al 2004). There was 272.2 kg of plastic which was a 38% increase since 2003 (Eglinton et al 2004). The disposal of rubbish, particularly plastics, has the potential to impact on iconic species such as whales, dolphins, seals and seabirds and impact on aesthetic values for beach tourism.

This risk assessment has considered that the amount of rubbish discharged from commercial ships is proportional to the amount of commercial shipping in the region.

Table 37 Rubbish from commercial shipping

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>Low (D0)</td>
<td>na</td>
<td>Low (D1)</td>
</tr>
<tr>
<td>Eastern</td>
<td>Low (C0)</td>
<td>na</td>
<td>Moderate (D2)</td>
</tr>
<tr>
<td>Western</td>
<td>Low (D0)</td>
<td>na</td>
<td>Low (D1)</td>
</tr>
<tr>
<td>Southern</td>
<td>Low (C1)</td>
<td>na</td>
<td>Moderate (D2)</td>
</tr>
</tbody>
</table>

Northern region
The northern region of Gulf St Vincent has only minimal shipping with the only commercial port in the region being Ardrossan. This risk assessment considers the risk from rubbish to ecosystem values and aesthetic values in the northern region is low.
Eastern region
The eastern and southern regions have significant commercial shipping and as such is likely to have a higher amount of rubbish disposed into these regions. Studies have shown that marine mammals often interact with rubbish which can result in mammal deaths, however the origin of the rubbish is thought to be from commercial fishing rather than shipping (Page 2004). The accumulation of rubbish on beaches can also impact on aesthetic values of people visiting beaches, this is particularly of concern given the eastern region has a higher proportion of beach tourists. This risk assessment has classified the risk to ecosystem values in the eastern region to be low however the risk to aesthetic values is considered to be moderate.

Western region
The amount of commercial shipping in the western region is relatively low and as such the risk from rubbish to ecosystem and aesthetic values is also believed to be low.

Southern region
Even with fewer ports, this region is used heavily as a shipping route and as such is exposed to a significant amount of shipping traffic. This region also has a higher proportion of large marine mammals and birds seen as icon species which if impacted upon could attract significant media and community attention. For these reasons rubbish from commercial shipping in the southern region is considered to be a low risk to ecosystem but as moderate risk to aesthetic values.

4.8 Wharves
There are several commercial shipping wharves throughout Gulf St Vincent. These are used to load and unload large ships that carry goods for import and export. Wharves in Gulf St Vincent vary greatly depending on the majority of cargo that they load and unload, and by their specialised nature. Each cargo also has its own environmental risk as does the facility itself, therefore it is accepted that each would have different environmental impacts. For the purposes of this risk assessment they have been grouped together.

The EPA carried out an audit of all wharves within South Australia and found that most facilities are in some need of upgrade to prevent substantial amounts of material being released into the air or waters. There was also a significant lack of emergency safeguards in place in the event of a spill and some needed improvement in clean-up practices.

A Code of Practice for Materials Handling on Wharves (2008) has been developed by the EPA to help manage risks from wharves across South Australia and it is expected to improve future design of facilities and improve management practices at wharves.

Nutrients from wharves
Discussion
Fertiliser, grain and livestock loading/unloading will contribute nutrient loads to waters adjacent to wharves. These loads are estimated to be anywhere from 1–10% of total cargo volume. Weather conditions and equipment breakdown are generally implicated as a cause for product loss and subsequent nutrient loads to the marine environment. These loads occur both through materials handling practices, vessel and wharf cleaning operations and from ineffective removal of spilt product onto the wharf apron—where it is likely to be washed via stormwater runoff into adjacent waters. Improvements to both wharf and materials handling practices are minimising these loads, especially in the eastern region of the Gulf with the redevelopment of some wharf infrastructure and purchase of world’s best practice handling equipment.
The state’s port authority has not invested in wastewater pump-out infrastructure on wharves and prefers to manage each commercial vessel entering port individually. Vessel masters are invited to request sewage pump-out facilities before entering port. The port authority will then make arrangements for the supply of a mobile wastewater contractor, the cost of which is then passed on to the vessel master or cargo owner. This process is thought to limit the potential for sewage discharges within the ports.

### Table 38 Nutrients from wharves

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>Low (C1)</td>
<td>Low (D0)</td>
<td>Low (E0)</td>
</tr>
<tr>
<td>Eastern</td>
<td>Moderate (B1)</td>
<td>Low (D0)</td>
<td>Low (E0)</td>
</tr>
<tr>
<td>Western</td>
<td>Low (C1)</td>
<td>Low (D0)</td>
<td>Low (E0)</td>
</tr>
<tr>
<td>Southern</td>
<td>Low (C0)</td>
<td>Low (D0)</td>
<td>Low (E0)</td>
</tr>
</tbody>
</table>

**Northern region**

Ardrossan wharf in the northern region loads grain where it is shipped to Adelaide and other ports. The loading facilities at this wharf is relatively basic where there is likely to be substantial fall through of product into the marine environment. The impact on the marine environment is likely to be small.

This risk assessment considers the wharf in the northern region is a low risk to ecosystem, aquaculture and aesthetic values.

**Eastern region**

There are several potential nutrient inputs from the wharves in the eastern region, which are all located at Port Adelaide. These wharves load grain and seeds, fertilisers, other agricultural commodities and livestock. The majority of these terminals are relatively old and in need of upgrade to bring them into line with best practices. Material often is released into the air and waters while being loaded and unloaded including faecal material and food from livestock transportation (J Ballantine pers comm).

It is accepted that the environmental impact from handling on a wharf will greatly depend on the material being handled, eg fertilisers will have a greater environmental impact than grain, but due to the scope of this risk assessment the wharves have been assessed individually but reported as a group.

This risk assessment considers that nutrients from wharves in the eastern region to be a moderate risk to ecosystem values and a low risk to aesthetic values.

**Western region**

The Port Giles wharf loads grains and seeds from the Yorke Peninsula. The facility is newer and more efficient compared to facilities in the Port River. In addition the impact from grains and seeds is likely to be more related to carbon, than nitrogen or phosphorus.

This risk assessment considers that nutrients from wharves in the western region to be a low risk to ecosystem, aquaculture and aesthetic values.
Figure 13 Shipping lanes throughout Gulf St Vincent
Southern region
The wharf facility at Kingscote is primarily a passenger ferry terminal, however there are occasional loadings of vessels and a grain barge which transports grain from Kingscote to Port Adelaide.

This risk assessment considers that nutrients from wharves in the southern region to be a low risk to ecosystem, aquaculture and aesthetic values.

Hydrocarbons from wharves

Discussion
Since the mothballing of the Port Stanvac Oil Refinery petroleum products are now shipped in via large tankers, which berth at wharves in the Port River to unload to the fuel storage facilities at Birkenhead. In 2005, over 1.3 million tonnes of petroleum products was imported through the Port River.

This risk assessment section is assessing the risk from the loading and unloading of fuel to and from ships to the wharves. The carrying of hydrocarbons by ship is assessed in section 4.7 Commercial shipping.

In addition to the loading and unloading of hydrocarbons, commercial ships may refuel whilst in port, this is often through pre-arrangement with the port authority before docking at the wharf. Mobile contractors are employed and generally carry emergency fuel spill response equipment. The port authority is also equipped with such equipment, particularly in the eastern region. As stated in section 4.7, an AMSA commissioned risk assessment concluded that ports were a greater risk of large oil spill than ships at sea (Jones et al 2000).

Table 39 Hydrocarbons from wharves

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>Low (E2)</td>
<td>Low (E2)</td>
<td>Low (E1)</td>
</tr>
<tr>
<td>Eastern</td>
<td>Moderate (D2)</td>
<td>Low (E2)</td>
<td>Low (E1)</td>
</tr>
<tr>
<td>Western</td>
<td>Low (E2)</td>
<td>Low (E2)</td>
<td>Low (E1)</td>
</tr>
<tr>
<td>Southern</td>
<td>Moderate (D2)</td>
<td>Low (E2)</td>
<td>Low (E1)</td>
</tr>
</tbody>
</table>

Northern region
Currently there are no hydrocarbon loading facilities located in the northern region of Gulf St Vincent. There may be infrequent refuelling of vessels while at Ardrossan wharf and it is likely that this operation would be carried out by contractors that are trained and carry fuel spill equipment to contain any spill.

This risk assessment considers that hydrocarbons from wharves is a low risk to ecosystem, aquaculture and aesthetic values in the northern region.

Eastern region
Since the closure of Port Stanvac Oil Refinery there are more frequent vessels loading and unloading hydrocarbons in the Port River wharves. These loading facilities are generally adequate and are being upgraded to include vapour recovery to reduce significant odour issues for nearby residents. There are also well maintained emergency safeguards in place due to the nature of the product being loaded.
This risk assessment considers the risk to ecosystem values to be moderate, but the risk to aquaculture and aesthetic values is considered low.

**Western region**

There are no hydrocarbon loading facilities in the western region, however it is likely that there are infrequent vessel refuelling while at the wharf. This is anticipated to be carried out by experienced contractors with adequate spill equipment in the event of a spill. This risk assessment considers hydrocarbons from wharves in the western region to be a low risk to ecosystem, aquaculture and aesthetic values.

**Southern region**

Based on the number of ship movements each day by the Kangaroo Island Ferries, the southern region is considered a higher risk than other regional areas without hydrocarbon loading facilities at the wharves. The refuelling of vessels is undertaken by contractors at the wharves. The receiving environment is a region with very high currents and is within the area of a proposed marine park to help protect its representative biodiversity of organisms and marine habitats (DEH 2005a).

This risk assessment considers hydrocarbons from wharves in the southern region is a moderate risk to ecosystem values and a low risk to aquaculture and aesthetic values.

**Trace metals from wharves**

**Discussion**

Section 4.7 outlines the potential impacts from antifoulants applied to commercial ships. The main risk from these trace metals is to the sediment in frequently used shipping areas. Wharves are the most frequently used shipping areas and monitoring has shown there is often trace metal contamination at wharves within South Australia (EPA unpublished data). Contaminated sediments can exhibit toxicity to benthic and demersal marine organisms and reduce biodiversity in the area.

The potential for contaminated sediments in this risk assessment has been considered by using available data from EPA licensee monitoring requirements for dredging at wharves and where data is unavailable the frequency of shipping traffic has been used to assume a relationship between traffic and loads.

**Table 40 Trace metals from wharves**

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>Moderate (B1)</td>
<td>Low (E0)</td>
<td>na</td>
</tr>
<tr>
<td>Eastern</td>
<td>Moderate (A1)</td>
<td>Low (E0)</td>
<td>na</td>
</tr>
<tr>
<td>Western</td>
<td>Moderate (B1)</td>
<td>Low (E0)</td>
<td>na</td>
</tr>
<tr>
<td>Southern</td>
<td>Moderate (A1)</td>
<td>Low (E0)</td>
<td>na</td>
</tr>
</tbody>
</table>

**Northern region**

Monitoring data has shown sediment sampled at the wharf in the northern region to exceed the ANZECC Sediment Quality Guidelines (ANZECC 2000) interim lower-trigger value for lead. While this shows that there is evidence of sediment contamination there is uncertainty as to whether this is having any impact in the localised area.
There is a relatively low amount of ship movements to and from Ardrossan and so this risk assessment has considered trace metals from wharves in the northern region to be a moderate risk to ecosystem but a low risk to aquaculture values.

**Eastern region**

EPA licensee monitoring data has shown that there is evidence of trace metal contamination at wharves in the eastern region. Sediment testing has shown in some cases to exceed the lower-trigger value for arsenic, copper, lead, mercury, TBT and zinc (EPA unpublished data).

These levels indicate that there is likely to be adverse impacts on sediment and benthic fauna in these regions, however the Guidelines stress that these levels are developed with limited data and significant uncertainty (ANZECC 2000).

Given the high volume of traffic relative to the rest of the state, frequent dredging of wharf areas removing potentially contaminated sediments and significant uncertainty in biological effects on benthic fauna, this risk assessment has considered trace metals at wharves to be a moderate risk to the eastern region.

**Western region**

There is no available information on the trace metal concentrations around the western region wharves. Given that there are less ship movements than the other regions it is anticipated that the sediment load of trace metals would be lower. Given the significant uncertainty, this risk assessment considers trace metals from wharves in the western region to be a moderate risk to ecosystem values and a low risk to aquaculture values.

**Southern region**

There is no available monitoring for sediment quality around wharves in the southern region however given the large vessel traffic and the permanent moorings of the two large passenger ferries the sediment trace metal load is anticipated to be higher than in other regional areas. Trace metals from wharves in the southern region is considered to be a moderate risk to ecosystem values and a low risk to aquaculture values.

**Turbidity from wharves**

**Discussion**

There can be frequent losses of material during the loading and unloading process on wharves. This material usually falls into the water where it can increase turbidity in the receiving environment.

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>Low (B0)</td>
<td>Low (E0)</td>
<td>Low (D0)</td>
</tr>
<tr>
<td>Eastern</td>
<td>Low (B0)</td>
<td>Low (E0)</td>
<td>Low (D0)</td>
</tr>
<tr>
<td>Western</td>
<td>Low (B0)</td>
<td>Low (E0)</td>
<td>Low (D0)</td>
</tr>
<tr>
<td>Southern</td>
<td>Low (B0)</td>
<td>Low (E0)</td>
<td>Low (D0)</td>
</tr>
</tbody>
</table>
Northern region
There is very little data on the frequency or extent of turbidity at wharves and this risk assessment has been considered primarily on the potential for turbidity to impact on the receiving environmental values.
This risk assessment has considered turbidity from wharves in the northern region to be a low risk to ecosystem, aquaculture and recreational values in the northern region.

Eastern region
There is very little quantitative data regarding increases in turbidity from loading and unloading of ships other than anecdotal evidence through EPA auditing and personal observations of workshop attendees. In addition, recent upgrades in security have made recreational activities around wharves, particularly in the eastern region difficult. Manoeuvring ships, particularly within the Port River causes significant turbidity in the immediate vicinity of the wharf, although this is generally short lived and likely to be of minimal impact.
Turbidity from wharves in the eastern region is considered to be a low risk to ecosystem and recreational values.

Western region
The Klein Point facility loads limestone for Adelaide Brighton Cement and it is in need of repair. There is likely fall through of product into the adjacent marine environment which may increase turbidity and also impact on the seabed. This risk assessment considers the risk to ecosystem, aquaculture and recreational values from turbidity from wharves to be low.

Southern region
The main risk from turbidity from the Kingscote, Penneshaw and Cape Jervois wharves is likely to be from re-suspension of sediment from prop wash while the boats are turning. This risk assessment considers the risk to ecosystem, aquaculture and recreational values from turbidity from wharves to be low.

Marine pests from wharves
Discussion
There is evidence that marine pests have been translocated from Port Adelaide to ports in Gulf St Vincent and other regional locations. It is believed that the dinoflagellates *Alexandrium spp.* and *Gymnodinium spp.* have been translocated from Port Adelaide to the sediments in regional ports of Thevenard, Port Lincoln, Kangaroo Island, Coffin Bay, Franklin Bay and Streaky Bay (J Cannon pers comm). It is unlikely that these species would cause red tides of similar scale to that in the Port River due to the greater level of mixing and lower nutrient status at these locations.

4.9 Recreational boating
The Boating Industry Association of South Australia (BIASA) estimates that there are over 50,000 registered boats in South Australia (BIASA 2004) and ranges from small aluminium boats to large ocean going yachts. Naturally each has different potential impacts to the marine environment but in this risk assessment they have been considered together. This risk assessment includes personal watercraft (jet skis) in its assessment of recreational boating.
Recreational boats are used for fishing, sailing, short- and long-term travel and cruising. Depending on the size of the vessel, the entire Gulf St Vincent is accessible to recreational boaters.
Nutrients from recreational boating

Discussion
There are several potential sources where nutrients could enter the marine environment from recreational boats. One is through direct discharge of organic material through fishing (discarded bait, burley, fish carcasses, etc) [Westthorp 2006], or through the discharge of sewage and greywater from boats without holding tanks.

Generally there is a concentration of recreational boats around popular fishing locations, these locations often coincide with reefs supporting significant fish stocks, such that the discharge of nutrients occurs in close proximity to a habitat that is sensitive to nutrient pollution.

The assessment of risk in this category is based on recreational boating density and the likelihood of nutrient discharge is assumed to be the same throughout the regions.

Table 42 Nutrients from recreational boating

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>Low (C0)</td>
<td>Low (E0)</td>
<td>Low (E0)</td>
</tr>
<tr>
<td>Eastern</td>
<td>Low (C1)</td>
<td>Low (E0)</td>
<td>Low (E0)</td>
</tr>
<tr>
<td>Western</td>
<td>Low (C0)</td>
<td>Low (E0)</td>
<td>Low (E0)</td>
</tr>
<tr>
<td>Southern</td>
<td>Low (C0)</td>
<td>Low (E0)</td>
<td>Low (E0)</td>
</tr>
</tbody>
</table>

Northern region
Recreational boating density is considered to be quite small in the northern region. For this reason the risk assessment considers the nutrient discharge from recreational boats to be a low risk to ecosystem and aquaculture values in the northern region.

Eastern region
The majority of recreational boaters in Gulf St Vincent would operate within the eastern risk assessment region. However it is anticipated that the nutrient discharge from a vessel would be small and may only be significant when there are high boat numbers in a small area over a particularly sensitive habitat. However there is very little information on this particular situation. This risk assessment considers the discharge of nutrients from recreational boats to be a low risk to ecosystem and aesthetic values in the Eastern region.

Western region
The western region is quite active for recreational boating however these numbers would still be considered low when compared to the eastern region. It is unlikely that there would be considerable aggregation of boats around small areas, however it is likely that these areas would be in better condition than similar areas in the eastern region. It is also unlikely that any aggregation would be in close proximity to aquaculture regions or in sufficient concentrations to promote unsightly algal blooms.

This risk assessment considers that nutrients from recreational boating is a low risk to ecosystem values, aquaculture and aesthetic values in the western region.
Southern region
Similar to the western region the southern region is unlikely to have large aggregations of boats over small areas, but these areas are likely to be in better condition than in the eastern region. These regions are also likely to be significant distances from aquaculture leases.

This risk assessment considers the risk to ecosystem, aquaculture and aesthetic values from nutrient discharge in the southern region is low.

*Micro-organisms from recreational boating*

**Discussion**
The majority of boats in South Australia would not have toilet facilities, or alternatively have a toilet facility which discharges directly to the marine environment, the potential for discharge of human faecal material is significant. Section 3.5 Micro-organisms describes the potential impact of coming into contact with human faecal material and the most frequent adverse impact is enteric illness, such as self-limiting gastroenteritis (NHMRC 2005). This may be of particular concern from boating in nearshore areas that are used as recreational swimming areas or in close proximity to shellfish aquaculture regions.

Risks in this section have been assessed by looking at recreational boating traffic, densities and destinations.

**Table 43 Micro-organisms from recreational boating**

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>na</td>
<td>Low (C0)</td>
<td>Low (C0)</td>
</tr>
<tr>
<td>Eastern</td>
<td>na</td>
<td>Low (C1)</td>
<td>Low (C1)</td>
</tr>
<tr>
<td>Western</td>
<td>na</td>
<td>Low (C1)</td>
<td>Low (C0)</td>
</tr>
<tr>
<td>Southern</td>
<td>na</td>
<td>Low (C1)</td>
<td>Low (C0)</td>
</tr>
</tbody>
</table>

**Northern region**
The discharge of micro-organisms into marine waters in the northern region has the potential to impact on both aquaculture leases and recreational areas. However the boating density is considered to be relatively low and the potential for contamination is likely to be small. Therefore this risk assessment considers the risk from micro-organisms from recreational boating is low for impacting on aquaculture and recreational values.

**Eastern region**
The eastern region has a considerably higher boat density than all other regions in this risk assessment and a large proportion of the nearshore environment is regularly used for recreation. This creates a higher consequence value in the region from recreational vessels in primary contact areas. However this potential is still considered to be low for impacting on recreational values.

**Western region**
The western region has considerably more aquaculture leases than the other risk assessment regions in Gulf St Vincent. Faecal contamination in these regions has the potential to close shellfish harvesting in this region. However water exchange along the Yorke Peninsula coast is relatively high and has the potential to dissipate any contamination quickly in most situations.
This risk assessment considers the risk from micro-organism discharge from recreations boating is a low risk to aquaculture and recreational values.

**Southern region**

Like the western region, the southern region in most cases has good water exchange and would dissipate any contamination quickly. However there are some regions that could be considered to be more susceptible, these are regions with high boating densities, low water exchange and with significant shellfish aquaculture, such as Nepean Bay and Pelican Lagoon on Kangaroo Island. This has increased the consequence in the risk assessment however over the whole southern region the risk rating is considered to be low for both aquaculture and recreational values.

**Trace metals from recreational boating**

**Discussion**

The discharge of heavy metals into the marine environment from recreational boats can be via a number of potential sources. Antifoulant residues from paint on hulls is a potential source, however its release from vessels within a marina is covered in section 4.10. This section assesses the risk from recreational boats outside of marinas and boat ramps. An alternative route for the entry of trace metals to the marine environment from recreational boats is through the illegal practice of beaching the vessel and either scraping old antifoulant paint off the boat or applying new antifoulants to the vessel while the tide is low and the vessel is out of the water. This practice was once considered acceptable and concrete blocks were often placed to aid in the placement of the vessel. However it is now contrary to the *Environment Protection Act 1993* (EP Act) and the WQEPP. Trace metals can also enter the water when a vessel with antifoulants runs aground and paint is scraped off and fall onto the sediment.

**Table 44 Trace metals from recreational boating**

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>Low (A0)</td>
<td>Low (A0)</td>
<td>na</td>
</tr>
<tr>
<td>Eastern</td>
<td>Low (A0)</td>
<td>Low (A0)</td>
<td>na</td>
</tr>
<tr>
<td>Western</td>
<td>Low (A0)</td>
<td>Low (A0)</td>
<td>na</td>
</tr>
<tr>
<td>Southern</td>
<td>Low (A0)</td>
<td>Low (A0)</td>
<td>na</td>
</tr>
</tbody>
</table>

**Northern region**

It is likely that the majority of recreational vessels in the northern region are trailered and would not have antifoulants applied to the hulls. However given that the northern region is quite isolated and there is a lack of slipways to perform maintenance of vessels there is a relatively higher chance that people could beaching vessels to perform maintenance. The likelihood of trace metal discharge is likely to be very small and therefore the risk is considered to be low to ecosystem and aquaculture values.

**Eastern region**

While the majority of recreational vessels would use the eastern risk assessment area, the quantities of trace metals discharged as a result of antifoulants is likely to be small, outside of marinas. However there is no information available on this.
This risk assessment has considered that trace metals from recreational vessels in the eastern region is a low risk to ecosystem values.

Western region
The western region also does not have a boating maintenance facility, which adds to the potential that people may perform maintenance on vessels in inappropriate locations. It is anticipated that there are only relatively small numbers of vessels that are antifouled and would require hard stands for this kind of maintenance. In addition the likelihood of trace metal contamination from recreational boats in close proximity to aquaculture is also considered to be small.

This risk assessment considers the risk from trace metals from recreational vessels in the western region to be low for ecosystem and aquaculture values.

Southern region
It is anticipated that due to the dominant wind and wave conditions in the southern region, there are higher numbers of recreational vessels that are antifouled than in the northern and western regions. However there is also a number of boating maintenance facilities in the southern region which can service these vessels.

Therefore this risk assessment considers the risk to ecosystem and aquaculture values from trace metals from recreational vessels is low.

Hydrocarbons from recreational vessels

Discussion
Recreational vessels use hydrocarbons for fuel and in the lubrication of motors. This refuelling process is usually undertaken either at a service station, in the case of trailered boats, or at a marine fuel depot, which is considered under section 4.11 Marinas and boat ramps.

Modern outboard motors discharge their exhausts below the water. The majority of hydrocarbons pass through the water in the gaseous phase and are released into the atmosphere. The remainder condense in the water or form a surface film on the water (UK CEED 2000). Studies have shown that while this process occurs the majority of hydrocarbons in the marine environment are centred around large stormwater and riverine systems that drain industrial and urban catchments rather than around heavily used boating areas (Bartlett 1990 in UK CEED 2000). This report suggested that residues from outboard motors were negligible compared to what is discharged from other sources (UK CEED 2000). These results were further supported by studies by both Butcher (1982) and the TNO Road Vehicles Research Institute (1991).

Conversely, the Californian Air Resources Board (1998) suggested that two-stroke engines can discharge as much as one third of their fuel mix unburnt into the water. This report concluded that there is significant potential for impact from such emissions. Clearly, such contradictory evidence emphasises the need for further research in this area, particularly in regions with high boating densities, high conservation status and low water exchange such as Barker Inlet. The Australian Government has just begun to undertake investigations relating to small engines in order to assess the need for any national action to be taken.

There is also a significant potential for a hydrocarbon spill into the marine environment from recreational vessels in the event of an accident. The likelihood of this is obviously much less than the discharge from outboard exhausts however there is potential for a more significant volume of hydrocarbons to enter the water.

The EPA Code of Practice for Vessel and Facility Management: Marine and Inland Waters (2008) requires all vessels generating oily bilge water to install and maintain oil filtration devices on
bilge pumps or place commercially manufactured oil absorption material in bilges (eg bilge socks).

Table 45 Hydrocarbons from recreational boating

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>Low (A0/D1)</td>
<td>Low (D1)</td>
<td>Low (D1)</td>
</tr>
<tr>
<td>Eastern</td>
<td>Low (A0/D1)</td>
<td>Low (D1)</td>
<td>Low (D1)</td>
</tr>
<tr>
<td>Western</td>
<td>Low (A0/D1)</td>
<td>Low (D1)</td>
<td>Low (D1)</td>
</tr>
<tr>
<td>Southern</td>
<td>Low (A0/D1)</td>
<td>Low (D1)</td>
<td>Low (D1)</td>
</tr>
</tbody>
</table>

Northern region
It is likely that the risk to the marine environment is negligible from outboard exhausts particularly in regions with relatively low boating densities but there is always a risk associated with the spillage of hydrocarbons in the event of an accident or similar. This risk assessment considered both situations of everyday discharge from exhausts and a spill and generated two risk ratings for impacts on ecosystem values. The everyday discharge from exhausts risk to the environment was considered to be low (A0) while the risk of a spill was also considered low but as a ‘D1’ reflecting increased consequence but lower likelihood. Overall this risk assessment considers the risk from hydrocarbons from recreational boating to be a low risk to ecosystem, aquaculture and aesthetic values in the northern region.

Eastern region
The risk to the eastern region is considered similar to the northern region however the need for further research is stressed for particularly sensitive areas with low water exchange and high boating density. Again two risk ratings were developed, one for exhaust discharges and the second in the case of spills.

This risk assessment considers the risk to ecosystem and aesthetic values from hydrocarbons from recreational boating to be a low risk.

Western region
Again there were two risk ratings developed for the discharge of hydrocarbons into the marine environment from recreational boating. One was for the everyday discharge of hydrocarbons from exhausts of outboard motors and the second was from accidental spills. Overall the risk to ecosystem, aquaculture and aesthetic values from hydrocarbons in the western region are considered to be low.

Southern region
Consistent with other regions there were two risk ratings developed for the discharge of hydrocarbons into the marine environment from recreational boating. Overall the risk to ecosystem, aquaculture and aesthetic values was considered to be low for the Southern region.

Rubbish from recreational boating

Discussion
International regulations state that the disposal of plastics into the marine environment is prohibited in all waters (MARPOL 73/78). It is also an offence to discharge plastics and animal carcasses into the marine environment under the WQEPP. Recreational boaters contribute
measurable quantities of rubbish into the marine environment as can be seen by discarded bait bags, plastics, fish and animal carcasses along beaches in Gulf St Vincent (Westthorp & North 2006).

The discharge of rubbish has the potential to impact, not only ecosystem processes, but also on iconic species such as whales, dolphins, seals and seabirds. Rubbish on beaches can impact on people’s aesthetic values by detracting from the appearance of the beaches.

Table 46 Rubbish from recreational boating

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>Low (C0)</td>
<td>na</td>
<td>Low (C0)</td>
</tr>
<tr>
<td>Eastern</td>
<td>Moderate (C2)</td>
<td>na</td>
<td>Moderate (C2)</td>
</tr>
<tr>
<td>Western</td>
<td>Low (C0)</td>
<td>na</td>
<td>Low (C1)</td>
</tr>
<tr>
<td>Southern</td>
<td>Low (C0)</td>
<td>na</td>
<td>Low (C1)</td>
</tr>
</tbody>
</table>

Northern region
The northern region has relatively low number of recreational boating compared to other regions in this risk assessment and as such would presumably have lower amounts of rubbish discharged. It also has less people using the beaches who could be impacted by unsightly rubbish discharged on beaches. This risk assessment regards the risk from rubbish from recreational boating to be a low risk to ecosystem and aesthetic values.

Eastern region
The eastern region has a relatively high amount of recreational boats. This region also has a high amount of beach tourists whose aesthetic values could be impact on by discharged rubbish on the beach. This risk assessment considers rubbish in the eastern region to be a moderate risk to aesthetic values but a low risk to ecosystem values.

Western region
The western region is very popular for recreational boating and as such there is significant potential for the discharge of rubbish into the marine environment. This region also has a significant influx of tourists in peak holiday seasons.

The discharge of rubbish in the western risk assessment region is considered to be a low risk to both ecosystem and aesthetic values.

Southern region
There are relatively fewer recreational boats in the southern region due to the more demanding weather and sea state encountered in the region. For this reason the amount of rubbish that is discharged is presumably less than in other regions with more recreational boats. This risk assessment considers the risk from rubbish from recreational boats in the southern region to be a low risk to both ecosystem and aesthetic values.

Marine pests from recreational boating
Recreational vessels are a potential source of marine pests in South Australia. Recreational vessels have been implicated in the spread of marine pests such as the black striped mussel into Darwin harbour in 1999. The incursion of the Black Striped Mussel (*Mytilopsis* sp.) into several marinas in Darwin harbour and the ensuing eradication effort resulted in the quarantine and
chemical treatment of chlorine and copper into the infected marinas at an estimated cost of $2 million (CSIRO 2004). The incursion and establishment of the related and ecologically similar Zebra Mussel in the Great Lakes of the United States resulted in wide ecological and economic impact. The economic impact has been estimated in excess of $600 million a year (CSIRO 2004).

Recreational vessels present a great risk for transporting two introduced marine pests into the Port River and Barker Inlet, Caulerpa taxifolia and C racemosa. These two algal species can be translocated by being caught in anchor systems and fishing gear particularly when fishermen travel from the Port River to a pest free region.

This risk assessment has highlighted that the incursion and establishment of marine pests is a significant risk to the ecology and economic status of Gulf St Vincent. PIRSA and SARDI Aquatic Sciences are currently developing a specific risk assessment for C taxifolia. This is expected to be delivered in 2009.

**Physical impacts from recreational boating**

**Discussion**

There can be many physical impacts from recreational vessels potentially the most significant is damage from anchors on the seabed, including seagrass and rocky reef habitats. There is significant evidence of chain swing moorings used for some boats, particularly in regional areas, causing damage to seagrass. This damage is done through the chain scouring the seagrass as the boat swings with the wind and tide. Scouring of seagrass by propellers (prop scars) has been shown to cause damage in many regions including Gulf St Vincent and can be further exacerbated by the expansion of scars through the development of blowouts. In addition many recreational boats anchor on rocky reef habitats for fishing or diving where anchors can become lodged in the structure of the reef. In many cases this causes significant damage to the reef.

While this action has the potential to cause environmental damage, the impacts are not caused by the discharge of a pollutant and therefore the WQEPP does not apply. For these reasons a risk rating has not been generated.

**4.10 Commercial fishing**

This category looks at the impacts of pollutants from commercial fishing. The majority of commercial fishing fleets in Gulf St Vincent are based at Port Adelaide but there are significant fishing areas throughout the Gulf. Fisheries include marine scalefish (up to 70 species but mainly on King George Whiting, Snapper, Garfish and Southern Calamari), Blue Swimmer Crab, Shark, Abalone and Western King Prawn.

This risk assessment is measuring the impact of discharge of pollutants from commercial fishing vessels on environmental values but is not assessing the risk to fishing stocks. The environmental value of ecosystem protection is considered to be sufficient to maintain fish health from pollutants in the water. Management of fishing effort and assessment of fish stocks are undertaken by PIRSA Fisheries and SARDI Aquatic Sciences.

There is a growing push to implement formal environmental management systems (EMS) in the commercial fishing industry. There are a number of companies that are now accredited including the Stehr Group’s Tuna Farm, the SA Marine Scale Fishery and the Coorong Fishery. The EMS is designed to ‘...to continually improve industry profitability, environmental performance and community relations through adoption of environmental management systems’ <www.seafood.net.au/ems/>.

It is hoped that with further implementation of EMS in the fishing industry the risk to impacts on water quality will reduce over time.
Nutrients from commercial fishing

Discussion

Nutrients can be discharged by commercial fishing vessels through the release of black and grey water, although it is anticipated that most commercial vessels will have sewage holding tanks or treatment systems installed with the introduction of the Code of Practice for Vessel & Facility Management for Marine and Inland Waters by the EPA. Other potential sources of nutrients include discarded bait, cleaning products, detergents and kitchen scraps. In this risk assessment nutrient discharge from commercial fishing vessels is assumed to be proportional to fishing effort in the region.

Table 47  Nutrients from commercial fishing

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>Low (A0)</td>
<td>Low (E0)</td>
<td>Low (E0)</td>
</tr>
<tr>
<td>Eastern</td>
<td>Low (A0)</td>
<td>Low (E0)</td>
<td>Low (E0)</td>
</tr>
<tr>
<td>Western</td>
<td>Low (A0)</td>
<td>Low (E0)</td>
<td>Low (E0)</td>
</tr>
<tr>
<td>Southern</td>
<td>Low (A0)</td>
<td>Low (E0)</td>
<td>Low (E0)</td>
</tr>
</tbody>
</table>

Northern region

There are several fisheries in the northern region for primarily crab, prawn and marine scalefish. The marine habitats in this area are relatively unimpacted and water energies are relatively slow which may result in more cumulative effects of nutrient discharge. However this risk assessment considers that the risk from nutrient discharges from commercial fishing vessels on ecosystem, aquaculture and aesthetic values is low.

Eastern region

The eastern region is home to the majority of the commercial fishing fleet in Gulf St Vincent. However this fleet is unlikely to discharge significant loads of nutrients into the nearshore region where it could impact on sensitive environments. It is likely that this discharge will be reduced with the implementation of the Code of Practice for Vessel and Facility Management for Marine and Inland Waters by the EPA. However currently it is likely that the risk from nutrients from commercial fishing vessels in the eastern region is low for ecosystem and aesthetic values.

Western region

The western region has low wave energies and relatively unimpacted marine habitats. However it is likely that any nutrients discharged from commercial fishing vessels would occur in relatively deep water and be very small quantities. Therefore the risk to ecosystem, aquaculture and aesthetic values are considered to be low.

Southern region

The southern region has numerous commercial fishing vessels based in the region. It is likely that any nutrients discharged into this region would occur in deep water where there are high wave energies. Therefore it is considered that nutrient discharges from commercial fishing vessels are a low risk to ecosystem, aquaculture and aesthetic values.
Trace metals from commercial fishing

Discussion
As outlined in section 4.7 trace metals can be discharged into the marine environment from vessels through the leaching of antifoulants or through the grounding of vessels so that the antifoulant is scraped from the hull onto the substrate. It is likely that the majority of commercial fishing vessel will be antifouled and the vessels based in marinas. Impacts from antifoulants within marinas are covered in section 4.11; there is still potential for antifoulants to be deposited in heavily used fishing areas, or travelling past aquaculture leases. This issue is of particular concern if boats are coated with TBT-based antifoulants. It is likely that these heavily used areas are in areas where the water is deep and well flushed so deposition is likely to be small.

Table 48 Trace metals from commercial fishing

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>Low (A0)</td>
<td>Low (A0)</td>
<td>na</td>
</tr>
<tr>
<td>Eastern</td>
<td>Low (A0)</td>
<td>Low (A0)</td>
<td>na</td>
</tr>
<tr>
<td>Western</td>
<td>Low (A0)</td>
<td>Low (A0)</td>
<td>na</td>
</tr>
<tr>
<td>Southern</td>
<td>Low (A0)</td>
<td>Low (A0)</td>
<td>na</td>
</tr>
</tbody>
</table>

Northern region
It is likely that any trace metal deposition in the northern region would be very small and therefore is considered to be a low risk to ecosystem values. The issue of vessels frequently travelling past aquaculture leases is not seen as a concern in the northern region due to very small amount of aquaculture in the northern region. Therefore the risk of trace metals impacting on aquaculture values in the northern region is low.

Eastern region
Although the majority of commercial fishing vessel are based within the eastern region, the amount of antifoulant residues likely to leach from commercial fishing vessel is considered to be low and water exchange in the fishing areas are likely to be high aiding in dispersion. Therefore the risk to ecosystem values in the eastern region is low.

Western region
The risk to ecosystem values in the western region is likely to be low from any antifoulants leached from commercial fishing vessels. There are numerous commercial fishing vessels that operate from bases in the western region and would frequently travel past shellfish aquaculture leases in the area. This is an area that needs further research although it is anticipated that the banning of TBT-based antifoulants would reduce the risk to shellfish leases from vessels travelling past leases. Therefore the risk to aquaculture values in the western region is likely to be low.

Southern region
It is likely that the risk to ecosystem values from trace metals from commercial fishing is low due to high current speeds, deep water and high wave energies aiding dispersion. As stated above there are numerous fishing vessels that would frequently travel past shellfish aquaculture leases and could leach trace metals into the waters where it may be taken up by shellfish,
particularly in areas where water exchange and current speeds are low, such as Pelican Lagoon and Nepean Bay. However data on this situation is not available and further research may be needed to add confidence in the risk rating. However the banning of TBT-based antifoulants is likely to greatly reduce this risk and therefore the risk rating is considered to be low.

**Hydrocarbons from commercial fishing**

**Discussion**

Sections 4.7 and 4.9 outline the risk from vessels carrying hydrocarbons such as fuel and cargo and their discharge from outboard motors. The majority of commercial fishing vessels use diesel-powered engines therefore exhaust discharges into the water are not an issue. It is also unlikely that commercial fishing vessels use codes of practice or environmental management systems such as ISO14000 or similar as in the commercial shipping industry (J Cannon pers comm). Commercial fishing vessels would generally carry more fuel than recreational vessels and there is the potential for accidents while at sea. Spillage during refuelling or at a marina is assessed under section 4.11 Marinas and boat ramps.

**Table 49 Hydrocarbons from commercial fishing**

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>Low (D1)</td>
<td>Low (D0)</td>
<td>Low (D0)</td>
</tr>
<tr>
<td>Eastern</td>
<td>Low (D1)</td>
<td>Low (D1)</td>
<td>Low (D0)</td>
</tr>
<tr>
<td>Western</td>
<td>Low (D1)</td>
<td>Low (D1)</td>
<td>Low (D0)</td>
</tr>
<tr>
<td>Southern</td>
<td>Low (D1)</td>
<td>Low (D1)</td>
<td>Low (D0)</td>
</tr>
</tbody>
</table>

**Northern region**

There is considered to be fewer commercial fishing fleets based in the northern region although there is significant amount of fishing within the region, and there is little aquaculture that may be impacted by any discharge. Therefore the risk considered from hydrocarbons from commercial fishing is expected to be low for the protection of ecosystem, aquaculture and aesthetic values.

**Eastern region**

The risk to ecosystem and aesthetic values from hydrocarbons from commercial fishing is expected to be low in the eastern region, however there is very little information relating to actual spills in the Adelaide region. This risk has been assessed as being similar to the likelihood from spills from recreational vessels but a lower risk than from commercial shipping, due to EMS in place on commercial shipping vessels (eg ISO 14000). Therefore the risk is assessed as being low to all environmental values.

**Western region**

While there is limited fishing fleets based in the western region the habitats in this area are relatively unimpacted and there is significant aquaculture that may be impacted by any spill. The risk from hydrocarbons from commercial fishing in the western region is considered to be low to ecosystem, aquaculture and aesthetic values.
Southern region
The risk to ecosystem and aesthetic values from hydrocarbons from commercial fishing is expected to be low in the southern region. It is expected that the high water flow and higher wave energies would aid in the dispersion of any spill in this region.

Micro-organisms from commercial fishing

Discussion
There is a risk from the discharge of black water into recreational and aquaculture regions where sensitive receivers could take up human pathogens.

The WQEPP states that it is an offence to discharge sewage into any waters in South Australia. In addition MARPOL regulations prohibit the release of sewage until at least three nautical miles away from land. Notwithstanding, many vessels currently do not have facilities to safely contain and hold sewage while at sea, and the discharge of black water is likely to occur in coastal regions.

Table 50 Micro-organisms from commercial fishing

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>na</td>
<td>Low (D0)</td>
<td>Low (E0)</td>
</tr>
<tr>
<td>Eastern</td>
<td>na</td>
<td>Low (D1)</td>
<td>Low (E0)</td>
</tr>
<tr>
<td>Western</td>
<td>na</td>
<td>Low (D1)</td>
<td>Low (E0)</td>
</tr>
<tr>
<td>Southern</td>
<td>na</td>
<td>Low (D1)</td>
<td>Low (E0)</td>
</tr>
</tbody>
</table>

Northern region
Although the northern region has fewer commercial fishing boats that are based within the region, there are significant fishing areas which are regularly fished. However it is unlikely that any discharge of black water in the northern region would occur in close proximity to aquaculture leases or recreational areas. Therefore the risk to aquaculture and recreational values from micro-organisms from commercial fishing is likely to be low.

Eastern region
There are significant fishing areas within the eastern risk assessment region. However the majority of these are significant distances from recreational areas. Therefore the risk to recreational values from micro-organisms discharged from commercial fishing in the eastern region is likely to be low.

Western region
The western region has significant shellfish aquaculture leases within the region. However PIRSA SASQAP testing has not shown evidence of bacterial contamination of waters or shellfish that could be attributed to passing vessels. In addition the fishing areas are not in close proximity to recreational regions. Therefore this risk assessment considers the risk to aquaculture and recreational values from micro-organisms from commercial fishing to be a low risk.

Southern region
The southern region is home to numerous commercial fishing vessels and the region is also extensively fished. This region has also some regions of shellfish aquaculture but these are likely
A risk assessment of threats to water quality in Gulf St Vincent

to be a significant distance from fishing areas or travel routes. It is also anticipated that the
higher water flow regime and increased wave energy would disperse any discharge before it
reaches any sensitive areas. This risk assessment considers the risk to recreation and aquaculture
values from micro-organisms from commercial fishing vessels to be a low risk.

Rubbish from commercial fishing
Beach debris surveys show that a significant proportion of marine debris is likely to have
originated from commercial or recreational fishing. Articles collected include buoys, floats,
rope, bait and burley baskets, nets and fishing line (Eglinton et al. 2006). This debris can
compromise ecosystem values by impacting on marine organisms, particularly iconic species such
as whales, dolphins, seabirds, seals and sea lions, and also compromise aesthetic values by
detracting from the attractiveness of beaches.

Discarding fishing nets and other material into the sea is a major problem linked with
commercial fishing. Derelict fishing gear impacts on marine organisms such as seals and sea
lions. Studies have shown that Australian Sea Lions are frequently entangled in monofilament
gillnet that most likely originated from shark fisheries. New Zealand Fur Seals are most
commonly entangled in loops of packing tape and trawl net fragments, suspected to have
originated from trawl and rock lobster fisheries (Page et al. 2004). The actual amount of rubbish
from commercial fishing is likely to be limited in Gulf St Vincent due to the lack of fishing effort
for shark and Southern Rock Lobster in the Gulf St Vincent risk assessment area. It is estimated
that based on recent studies, approximately 1,500 seals die from entanglement each year across
southern Australia (Page et al. 2004).

Table 51 Rubbish from commercial fishing

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>Low (C1)</td>
<td>na</td>
<td>Low (C0)</td>
</tr>
<tr>
<td>Eastern</td>
<td>Low (C1)</td>
<td>na</td>
<td>Low (C1)</td>
</tr>
<tr>
<td>Western</td>
<td>Low (C1)</td>
<td>na</td>
<td>Low (C1)</td>
</tr>
<tr>
<td>Southern</td>
<td>Moderate (C3)</td>
<td>na</td>
<td>Low (C1)</td>
</tr>
</tbody>
</table>

Northern region
The impact of rubbish on aesthetic values in the northern region is potentially less than in other
regions due to the isolation of the region and less people visiting beaches. The discharge of
rubbish from commercial fishing in the northern region is considered a low risk to ecosystem and
aesthetic values.

Eastern region
Beaches in the eastern region have significant aesthetic values for the population of Adelaide. In
addition impacts of rubbish on marine wildlife are much more conspicuous and can have an
increased perception of impact. The risk to ecosystem and aesthetic values from rubbish in the
eastern region is considered to be low.

Western region
The western region is becoming an ever popular destination for beach tourism and therefore
aesthetic values in this region are very important for the local economy. In addition there are
significant marine habitats and seabird populations that can be impacted by rubbish discharged
into the marine environment. However prevailing offshore currents are not conducive to deposition of material onto the western side of Gulf St Vincent. In addition fishing areas are a significant distance from local beaches. Therefore this risk assessment considers rubbish from commercial fishing to be a low risk to ecosystem and aesthetic values.

**Southern region**

The southern region is home to a number of marine mammal species, including ecologically important seal and sea lion breeding and haul-out locations, penguin and seabird colonies. It also has significant commercial fishing activity, which can impact on these habitats and wildlife. Therefore the risk to ecosystem values in this region is considered to be moderate. This risk rating would have been considered higher given the estimated pinniped mortality rates from rubbish, but it is likely that the majority of the commercial shark and lobster fishing effort is outside the risk assessment area. If the risk assessment included the south of Kangaroo Island then this risk would have been high, particularly given the threatened nature of the New Zealand Fur Seals.

This region is also becoming more popular for beach tourism from an expanding local community and visitors from Adelaide. The risk to aesthetic values in the southern region is considered to be low.

**Physical impacts from commercial fishing**

**Discussion**

There a number of physical impacts from commercial fishing, which are heavily dependant on the type of fishing undertaken. Probably the most significant physical impact is from prawn trawling. Historical data indicates that deep water seagrass communities (*Heterozostera spp.*.) were abundant throughout Gulf St Vincent, but more recent data suggests that these meadows have been largely lost, most likely as a result of historical prawn trawling activities (A Cheshire pers comm). Nowadays prawn trawling is restricted to areas that are deeper than 10 m and generally devoid of seagrass however there are still significant marine habitats that can be heavily impacted on from trawling (such as sponge communities) [Hall 1999; Tuck et al 1998]. It is likely that deep water seagrass species are not likely to return while trawling is ongoing. There is very little information on the impact of removing soft sediment communities from marine ecosystems; while this is likely to have a substantial impact on ecosystem values it is not considered a water quality issue and therefore the risks are not assessed in this risk assessment.

**Marine pests from commercial fishing**

**Discussion**

Marine pests can be introduced through a number of mechanisms; pests can be carried on the hull of a vessel if there are defects in the antifouling coating on the vessel; pests can be carried by the vessel in ballast water and translocated when this ballast water is discharged; pests can be carried in gear used for fishing and pests translocated when the gear is used at another location. These risks are considered to be lower than the risk from the introduction of marine pests from other industries such as commercial shipping due to the significantly shorter distances travelled by the fishing vessels in Gulf St Vincent and the locations that they work in are generally not likely to be currently infested with potentially invasive species.

However while the introduction of marine pests is less likely than other industries, the translocation of pests established in some areas of South Australia to or from Gulf St Vincent is not trivial. A specific risk assessment for *Caulerpa taxifolia* is being undertaken by PIRSA and SARDI Aquatic Sciences so the risk will not be assessed here.
4.11 Marinas and boat ramps

This risk assessment has considered marinas and boat ramps to be similar in potential impacts so they have been grouped together. There are over 50,000 registered boats in South Australia (BIASA 2004) and many of these boats are trailered, launched and retrieved at boat ramps around the state. A number of these boats too large to be trailered are moored at marinas.

Marinas are becoming common along the coast of Gulf St Vincent not only to provide easy access to the Gulf but also as a new way of developing waterfront land. This risk assessment is dealing with marinas and boat ramps as the facility to launch retrieve or store a boat and has not considered impacts from any associated housing development.

There are two phases of potential impact to the marine environment that were considered in this risk assessment. One was the construction of a marina or boat ramp as this is occurring more frequently in regional areas. The second is the day-to-day use and operation of the facility.

Potential impacts from these facilities include nutrient and microbiological input from grey and black water discharge from boats, trace metals from antifoulant residues accumulating in sediments, the physical impediment created to natural sand movement along the shoreline and associated potential for accumulation of beach wrack, the potential for an oil spill from refuelling or accident, and the introduction of invasive marine pests.

**Nutrients from marinas and boat ramps**

While many marinas have both on shore amenities and possibly sewage pump-out facilities, there is still a risk of black water being discharged into the water at marinas. In addition there are no regulations on the discharge of grey water (which often contains detergents) into the marine environment.

Marinas are often shallow basins that often do not have good exchange of water. This creates an optimum environment for algal growth, particularly in summer when water temperatures are warm and day lengths are long.

Marinas and boat ramps can also accumulate seagrass wrack where it decays and releases nutrients and carbon which can promote more algal blooms. The decay of algae and wrack can also impact on aesthetic values through the visual appearance of algal blooms and offensive odours.

**Table 52 Nutrients from marinas and boat ramps**

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>Low (B0)</td>
<td>Low (D0)</td>
<td>Low (D0)</td>
</tr>
<tr>
<td>Eastern</td>
<td>Moderate (A1)</td>
<td>Low (D0)</td>
<td>Low (A0)</td>
</tr>
<tr>
<td>Western</td>
<td>Moderate (A1)</td>
<td>Low (D0)</td>
<td>Low (A0)</td>
</tr>
<tr>
<td>Southern</td>
<td>Moderate (A1)</td>
<td>Low (D0)</td>
<td>Low (A0)</td>
</tr>
</tbody>
</table>

**Northern region**

Currently there are no major marinas in the northern region but there are numerous boat ramps. It is anticipated that the risk from these small boat ramps from nutrients to ecosystem values would be low.
Eastern region
There are several large marina developments in the eastern region and numerous large boat ramps that service the majority of boaters in Adelaide.

The EPA has brought in conditions on marina licences stating that no person is allowed to sleep overnight on a vessel that does not have a holding tank installed. This was introduced to try to combat the concentrated discharge of black water into the water at a marina. It is left to the marina to police this activity.

There is evidence of nutrient impacts within marinas in the eastern region, however it is difficult to differentiate the contribution of the marina particularly when there are often numerous stormwater drains that discharge into the marina basin and well-manicured domestic gardens that use fertilisers surrounding the marina. In addition there is uncertainty whether this nutrient impact extends outside a marina’s waters.

This risk assessment rates the risk from nutrients at marinas in the eastern region as a moderate risk to ecosystem values and a low risk to aesthetic values.

Western region
The boating community on Yorke Peninsula is relatively active and there are many boat ramps in the western region and one large marina at Port Vincent. It is anticipated that the risk from nutrients from these facilities to ecosystem values would be a moderate risk. Given the distance between aquaculture leases and the facilities in the western region the risk of impact from nutrients is considered to be low.

Southern region
There are several marinas and numerous boat ramps in the southern region. It is anticipated that the current speeds and wave energies would disperse any nutrients before an impact could be seen outside the marina itself. However due to the vessel traffic particularly in warmer months and holiday periods the risk from nutrients is believed to be moderate from nutrients impacting on ecosystem values. The risk to aquaculture and aesthetic values is considered to be low.

Trace metals from marinas and boat ramps

Discussion
Trace metals from antifoulants can accumulate in sediments (see sections 4.7 & 4.8), particularly in areas that boats stay for extended periods of time. In addition there is anecdotal evidence that in some regional areas, trace metals such as copper are used to kill algae that grow on the concrete boat launching ramp (making it slippery). While this is contrary to the WQEPP, there is significant potential for this to occur.

The EPA has conducted sediment and bioaccumulation experiments as a part of the Australian Government TBT Current Contamination Assessment at several locations in close proximity to marinas that berth both commercial fishing and recreational vessels. The tests showed that of the three sites monitored all three accumulated measurable levels of TBT or its metabolites (Mortimer 2004).

Trace metals can have ecological effects on benthic and sediment dwelling organisms. Given the very slow degradation rates of trace metals in these environments any additional input of metal could potentially increase the impact and these impacts can be cumulative, so even if the discharge itself is not toxic numerous small discharges can create an environment that is toxic.
While the risk from trace metal contamination of sediments is covered in this section the risk related to the impacts of moving the sediment through dredging has been considered in the dredging category in section 4.12.

### Table 53 Trace metals from marinas and boat ramps

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>Low (D0)</td>
<td>Low (D0)</td>
<td>na</td>
</tr>
<tr>
<td>Eastern</td>
<td>Moderate (A1)</td>
<td>Low (D0)</td>
<td>na</td>
</tr>
<tr>
<td>Western</td>
<td>Moderate (A1)</td>
<td>Low (D0)</td>
<td>na</td>
</tr>
<tr>
<td>Southern</td>
<td>Moderate (A1)</td>
<td>Low (D0)</td>
<td>na</td>
</tr>
</tbody>
</table>

### Northern region

The northern region does not have a major marina where boats with antifoulant paints spend significant amounts of time. However there is evidence or the potential for an antifoulant or trace metals used in killing algae to accumulates on the ramp. While this may cause a significant localised impact it is unlikely to impact on the whole region. Therefore it is likely that the risk to ecosystem and aquaculture values is likely to be low.

### Eastern region

The eastern region has numerous large marinas where antifouled boats remain for extended periods of time. Monitoring conducted by dredging contractors as a part of their EPA licence to dredge marinas has shown that many marinas are contaminated with levels of copper, mercury, nickel and tributyltin (TBT) that exceed the low and high trigger values for sediment quality.

The EPA has used oysters to show bioaccumulation of TBT at locations where contamination is likely (Mortimer 2004). Oysters were placed near the North Arm marina at Port Adelaide and after six weeks the oysters accumulated significant levels of TBT, copper, lead and zinc (Mortimer 2004; EPA unpublished). While biological effects were not specifically measured, literature reviews suggest that it is possible that the levels seen may be causing adverse impacts. This further supports findings of Nias et al (1993) who demonstrated that 100% of the female *Lepsiella vinosa* animals sampled from the Port River had symptoms of imposex.

This risk assessment considers the risk from trace metals from marinas in the eastern region to be moderate for impacts on ecosystem values.

### Western region

The western region has one large marina and numerous boat ramps where trace metals may accumulate or be applied. This risk assessment considers the risk to ecosystem values from trace metals to be a moderate risk.

While the risk assessment has considered the risk from the accumulation of trace metals at marinas with respect to aquaculture values it is doubtful that any trace metal accumulation will extend beyond the marine region to impact on aquaculture leases. This risk assessment considers trace metals from marinas to be a low risk to aquaculture values.

### Southern region

There are several large marinas that house large boats in the southern region where there is potential for trace metal accumulation not only in sediments but also in waters. There has been very little monitoring within these facilities. An assessment has been made in this case based on
the frequency of use and given the high amount of activity and large size of boats the risk is believed to be moderate to ecosystem values and low for aquaculture values.

**Micro-organisms from marinas and boat ramps**

A number of marinas have sewage pump out facilities and it is assumed that users know how to operate them. There is a potential for a spill of human derived faecal material into the water during the off loading of black water on boats. There is also the potential for people to discharge black water at a marina where there is no pump-out facility and the vessel does not have proper facilities. The discharge of black water into marinas has the potential to release high numbers of human-derived bacteria into the waters.

**Table 54 Micro-organisms from marinas and boat ramps**

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>na</td>
<td>Low (D0)</td>
<td>Low (D0)</td>
</tr>
<tr>
<td>Eastern</td>
<td>na</td>
<td>Low (D0)</td>
<td>Low (D0)</td>
</tr>
<tr>
<td>Western</td>
<td>na</td>
<td>Low (D1)</td>
<td>Low (D0)</td>
</tr>
<tr>
<td>Southern</td>
<td>na</td>
<td>Low (D0)</td>
<td>Low (D0)</td>
</tr>
</tbody>
</table>

**Northern region**

It is anticipated that the majority of boats in the northern region would be accessing boat ramps rather than a marina. Therefore the possibility of faecal material entering the water actually at the marina would not be likely, therefore the risk is considered to be low for recreational values.

**Eastern region**

The EPA has brought in regulations about people staying overnight in licensed marinas in order to reduce the chance of black water entering the marine environment. However this is left to the marina operator to police and enforce. Additionally the presence of people at boat ramps is likely to deter people from emptying black water in the vicinity of a boat ramp.

Therefore micro-organisms from marinas are expected to be a low risk to recreational values.

**Western region**

It is probable that there is a low likelihood of discharge of black water to the marine environment at marinas and this contaminated water impacting on the western region. Therefore this risk assessment considers the risk from micro-organisms from marinas and boat ramps as low. There is also likely to be a low risk to aquaculture values however this will entirely depend on the proximity of the marina to aquaculture leases and whether impacts could be cumulative from an associated housing development at a marina.

**Southern region**

The southern region has two large marinas but due to the relatively low numbers of permanent boats within these marinas the likelihood of black water discharge is anticipated to be low. There may be an increased likelihood at peak holiday periods. Overall the risk to the southern region is considered to be low to both recreation and aquaculture values.
**Hydrocarbons from marinas and boat ramps**

Many marinas and boat ramps have individual refuelling facilities. By design they must refuel over water, which creates a potential for release of hydrocarbons into the marine environment. Outboard motors release hydrocarbons into the marine environment (section 4.9) through their exhausts and in a concentrated area such as a marina or boat ramp hydrocarbons could accumulate with resultant impacts on environmental values.

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>na</td>
<td>Low (D0)</td>
<td>Low (D0)</td>
</tr>
<tr>
<td>Eastern</td>
<td>na</td>
<td>Low (D0)</td>
<td>Low (D0)</td>
</tr>
<tr>
<td>Western</td>
<td>na</td>
<td>Low (D1)</td>
<td>Low (D0)</td>
</tr>
<tr>
<td>Southern</td>
<td>na</td>
<td>Low (D0)</td>
<td>Low (D0)</td>
</tr>
</tbody>
</table>

**Northern region**

The boat ramps in the northern region currently do not have onsite refuelling facilities and as such the risk would be significantly lower than it would be for marinas or for facilities with refuelling. There is a certain risk associated with the day-to-day operation of the boat ramps such as the release of hydrocarbons from outboard motors, however this is considered to be trivial. This risk is low for ecosystem protection and also low for aesthetic values.

**Eastern region**

The eastern region has several facilities with on-water refuelling facilities, which increases the potential that hydrocarbons may enter the marine environment. The operating and maintenance of these facilities are variable and some may have the potential for either leakage from the storage tanks or spillage during refuelling. Within marinas there is also the risk that people will refuel large boats using jerry cans where there is a high likelihood of spillage to the marine environment.

An additional route of hydrocarbon entry into the marine environment is through an accident where fuel tanks are ruptured and hydrocarbons enter the water. Given the high numbers of boats within marinas and the preference towards floating pontoon style marina berths the likelihood of an accident is considerable.

As part of good operation, marinas have oil spill kits and staff training on mitigating a fuel spill or accident so the risk of any hydrocarbons spilt impacting on areas outside of the marina is likely to be low.

This risk assessment considers that the risk of hydrocarbons from marinas impacting on ecosystem values in the Eastern region is low. Similarly the risk to aesthetic values is also low.

**Western region**

The western region has one large marina to service boats too big to trailer. This facility has a refuelling facility and this system is relatively new. With spill mitigation equipment in place, any spill is unlikely to impact on ecosystem values outside of the marina. This risk assessment considers hydrocarbons from marinas to be a low risk in the western region for both ecosystem and aesthetic values.
Southern region
There are several marinas or boat ramps that have refuelling facilities in the southern region. These facilities are used frequently but again there are significant spill mitigation equipment on site.

This assessment considers the risk to ecosystem values in the southern region to be low. Similarly the risk to aesthetic values is also considered to be low in the southern region.

Marine pests from marinas and boat ramps
This issue is not under the jurisdiction of the EP Act and is not generally considered to be a water quality issue. The introduction, establishment and translocation of marine pests is considered to be a significant risk to the marine environment of South Australia particularly as marinas are often a first point of establishment. A project to develop specific ecological and economic risks for a high risk marine pests in South Australia is being assessed by PIRSA and SARDI Aquatic Sciences and is expected to be delivered in 2009.

Physical disturbance from marinas and boat ramps
In Gulf St Vincent the general movement of sand is northwards. Historically this movement was relatively unimpeded but construction of breakwaters, groynes, boat harbours and marinas in more recent times has hindered the natural movement of sand and regeneration of beaches from the extensive sand dune systems.

Sand will accumulate on the southern side of breakwaters constructed for boat harbours and marinas until it reaches a point where it can spill around the impediment. This often results in formation of a sand bar off the end of the breakwater, which can be a hazard to boating. This is well documented for the Patawalonga and its entrance, Holdfast Shores Marina, the West Beach boat harbour and the North Haven and Outer Harbour breakwaters. This sand accumulation causes beach degradation as the majority of the sand is eroded on the northern side and it can result in beach instability and the potential for storm damage to seafront homes. This problem is exacerbated by the construction of buildings on the sand dunes, which prevents the natural dynamic movement of sand between the beach and the sand dunes (DEH 2005c).

The Coast Protection Board is aiming to spend $56 million over the next 20 years as a part of Adelaide’s Living Beaches initiative. This program is aiming to replenish and maintain sand on metropolitan beaches (DEH 2005c).

While the physical disruption of a marina or boat ramp has significant impacts on the marine environment it is not a water quality issue and as such has not been classified using the risk matrix but the construction of marinas was seen to be a significant risk to the marine environment.

Similarly the construction of a marina or boat ramp can have significant impacts from turbidity in the surrounding environment. The amount of turbidity generated during construction is generally dependant on the method of excavation, the type of substrate being removed and any mitigation strategies used, eg silt curtains. The impact of this turbidity will be largely site specific but dependant on factors such as current speeds, wind and wave energies, and settlement rates. This risk assessment has classified turbidity during the construction of marinas and boat ramps as being under the dredging category and a risk rating has been generated in section 4.12.

4.12 Dredging
Dredging is the removal of sediment from the marine environment. This may be undertaken for many reasons including maintenance of the depth of water to enable vessels to berth at a wharf
or marina, construction of a deep water channel for vessel movement or construction of a marina such as the Port Adelaide marina at Snowdens Beach.

Dredging is regulated by the EPA and is licensed under the EP Act. Generally each dredging operation must carry out a marine monitoring plan, and if water quality criteria are exceeded then the dredging activity must cease until a remedy can be found.

There are many water quality issues associated with dredging that can potentially impact on environmental values. Increased turbidity can reduce light penetration to marine plants and algae. Many sediments are contaminated by trace metals, including TBT, organic pollutants such as PCBs and other hazardous substances. Removing this sediment can re-suspend these pollutants and cause impacts to organisms in the surrounding waters. The dredging of anoxic sediment can reduce the dissolved oxygen concentration in the surrounding waters, and alter the pH, which can make any metals in the sediment more bioavailable to marine organisms (see summary risk assessment on effects of dredging in the report by Cheshire et al 2001)4.

**Turbidity from dredging**

**Discussion**

Taking sediment from underwater has the potential to significantly increase the turbidity of the surrounding waters. This depends on the type of dredge that is used and the type of material that is being dredged. For example, sediment with a high amount of clay has the potential to create more turbidity than coarser substrates such as sand because it remains in suspension for a much longer time.

Generally the EPA requires all dredging to be carried out with a cutter suction dredge, which is seen as the current best practice in most situations. However there is still potential for turbidity in surrounding waters as a result of poorly managed dredging or by disposing of material into the nearshore environment, particularly detrital seagrass.

Dredging is usually undertaken either as a small maintenance dredging operation such as removal sand from an entrance to a marina, or can be a large-scale operation such as the Outer Harbor channel deepening project, which dredged the majority of the channel to allow ‘Panamax’ ships with a draft of 12 m to enter the port.

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Table 56 Turbidity from dredging

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>Low (E1)</td>
<td>na</td>
<td>Low (E1)</td>
</tr>
<tr>
<td>Eastern</td>
<td>High (D4)</td>
<td>na</td>
<td>Moderate (D3)</td>
</tr>
<tr>
<td>Western</td>
<td>Low (E1)</td>
<td>na</td>
<td>Low (E1)</td>
</tr>
<tr>
<td>Southern</td>
<td>Low (E1)</td>
<td>na</td>
<td>Low (E1)</td>
</tr>
</tbody>
</table>

**Northern region**
Currently there is a limited amount of dredging in the northern region. One of the reasons for this is that there are few structures that block the natural movement of accumulating sand. This accumulated sand needs to be dredged to maintain access to marinas, berths, etc. Occasionally the Ardrossan wharf and the Port Wakefield channel needs to be dredged. These operations are often small but sediments moved may be contaminated from activities on the wharf and loading ships. This risk assessment considers that the risk to ecosystem and recreational values from dredging in the northern region is low.

**Eastern region**
As outlined in section 4.11 Marinas and boat ramps, there are many structures that require dredging to stop the accumulation of sand from blocking access to these facilities. Several of these facilities now have sand pumping constantly operating to move sand around the blocking structure. In addition to regular maintenance dredging there are occasional large dredging events that have the potential to cause wide-scale impacts from turbidity.

The EPA's ambient monitoring of water quality along Adelaide's coastal waters shows a significant increase in turbidity in locations where there is regular dredging, although this cannot be wholly attributed to dredging activities. These locations are also subject to turbidity from stormwater drains and nutrient enrichment increasing phytoplankton levels, and can be impacted by sediment instability due to seagrass loss. Due to a considerable lack of water exchange with deeper waters the nearshore environment of the Adelaide metropolitan coast (Pattiaratchi & Jones 2005), there is significant potential for numerous small-scale turbidity events to cumulate and reduce light penetration in the nearshore environment, potentially impacting of ecosystem and recreational values.

In recent years there have been at least two large scale dredging events that have caused significant turbidity in the surrounding waters. The first was at O'Sullivans Beach in 1997 where a large ship was being used to dredge sediments for beach replenishment by the Coast Protection Board (Turner et al 2002). The second was the Outer Harbor channel deepening project which resulted in significant turbidity plumes throughout Outer Harbor and Largs Bay in the summer of 2005.

There are a number of small-scale dredges that discharge sand and detrital seagrass back into the nearshore waters along the metropolitan coast in the process of clearing boating facilities. These dredges are licensed by the EPA and have been operated by Transport SA in the past but more recently the Coast Protection Board. Given the hydrodynamic modelling results of the ACWS and the nature of much of the material being disposed (high coloured dissolved organic material and chopped seagrass) it is possible that this maybe impacting on nearshore water quality particularly the recreational and aesthetic values of recreational beaches.
While the risks from large-scale dredging events and the cumulative impact of numerous sites of nearshore disposal of organic material from smaller-scale dredging events present a significant risk to environmental values, there are many routine dredging operations that de-water the dredged material on land and discharge the relatively clear supernatant water of much lower risk to environmental values. However given that this risk assessment uses a precautionary approach the higher risk method has been used as the classification.

Using the evidence outlined above dredging in the eastern region is considered to be a high risk to ecosystem values and a moderate risk to recreational and aesthetic values.

**Western region**

The western region has a number of locations that are subject to occasional dredging to maintain depth for vessels. The marine habitats in the western region are considerably closer to shore compared to eastern region. However it is unclear whether the western region’s hydrodynamics are similar to that of the eastern region where nearshore water exchange is quite limited. This risk assessment considers the risk to ecosystem and recreational values in the western region to be low from dredging.

**Southern region**

The southern region is hydrodynamically quite different to other region is this risk assessment. A significant amount of the shoreline is made up of cliffs and rocks, which mean that sand movement will be very different to the other regions. Whether this impacts on how often the entrances to marinas and boat harbours need to be dredged is unknown at this stage but currently dredging is required at several locations. The waters in most areas in the southern region have higher current speeds and wave action than other regions and it is anticipated this will aid in dispersion of any turbidity arising from dredging. This risk assessment considers the risk from dredging in the southern region as low risk to ecosystem and recreational values.

**Trace metals from dredging**

Discussion

As outlined in sections 3.3 and 4.11 trace metals often accumulate in sediments which have been or are currently sources of contamination to the marine environment. Often these areas are around wharves, marinas and boat ramps and need to be dredged regularly in order to maintain a navigable depth for vessels to pass through.

The removal of this sediment through dredging has the potential to re-suspend trace metals in the water column and if poorly managed can impact on the surrounding organisms and habitats. This is often naturally mitigated by the highly buffered nature of seawater, which renders metals bound to particulates relatively non-bioavailable. However there is significant potential in some dredging operations that anoxic sediment can reduce the pH of the surrounding water converting the bound metals into a soluble form that can impact on marine organisms. The EPA requires an environmental monitoring plan for every dredging activity that it licenses. This monitoring is based around in situ monitoring of dissolved oxygen and pH, and requires contingencies in place if water quality drops to the extent that it may cause impacts.
Table 57  Trace metals from dredging

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>Low (E1)</td>
<td>Low (E0)</td>
<td>na</td>
</tr>
<tr>
<td>Eastern</td>
<td>Low (D1)</td>
<td>Low (E0)</td>
<td>na</td>
</tr>
<tr>
<td>Western</td>
<td>Low (E1)</td>
<td>Low (E0)</td>
<td>na</td>
</tr>
<tr>
<td>Southern</td>
<td>Low (E1)</td>
<td>Low (E0)</td>
<td>na</td>
</tr>
</tbody>
</table>

Northern region
The northern region has little potential for impacts from the dredging of trace metals due to few contaminated sediments in the region. The only potentially contaminated site that is likely to be dredged is the Ardrossan wharf. The risk of impacts from the contaminated sediment from this site is covered under section 4.8 however the risks from its removal is covered here. It is estimated that this site would be needed to be dredged approximately every 10 years (F Peat pers comm). From recent monitoring this sediment is well oxygenated and has a relatively low level of contamination (EPA unpublished data). This risk assessment considers the risk to ecosystem and aquaculture values from dredging in the northern region to be low.

Eastern region
The eastern region has the most potential for trace metal contaminated sediments to be disturbed from dredging and cause an impact on environmental values. This is due to the presence of more sites with contaminated sediments and an increased need for access due to more boats frequenting the region. However as stated above dredging proponents and contractors are required to undertake monitoring of both the sediment before it is dredged and water quality parameters during dredging to assure there is no mobilisation of trace metals which could impact on marine organisms. The risk of impacts on ecosystem values in the eastern region is considered low.

Western region
Currently it is likely that there are very few sites in the marine environment contaminated with trace metals in the western region. It is likely that any region needing to be dredged every 10 years will be undertaken by a licensed dredging contractor. Therefore this risk assessment considers the risk of impacts from trace metals dredged in the western region is likely to be low for both ecosystem and aquaculture values.

Southern region
It is possible that there are more sites that are potentially higher in trace metals that in other regions in the risk assessment. These areas would be sites that are frequented regularly by large ships either through antifoulant paints or loading/unloading of cargo (as outlined in sections 4.7 and 4.8) or sites where there has been dumping or accidental spillage. Sites that may meet these circumstances are the ferry terminals at Cape Jervis and Penneshaw, Wirrina Marina, and possibly the Kingscote wharf. It is likely that these sites would need to be dredged frequently in order for the large-sized ships to be able to navigate. However the risk for impacts on ecosystem and aquaculture values is still considered to be low.
Physical impacts from dredging

The very nature of the removal of sediment from the seabed will have a localised impact in the immediate area. The degree of impact will obviously depend on the volume of sediment to be removed and the habitat present. Environmental impacts will be much greater when seagrass is present or if there are sensitive habitats in close proximity as this may promote further loss of seagrass through creating a site for a blowout to expand. Additionally changing the sediment topography can change the hydrodynamics of the area, this can have profound impacts on many aspects of the marine and coastal environment including sand transport and movement, habitat colonisation, recruitment and water quality.

However while this is an issue that can cause significant environmental impacts, for the purpose of this risk assessment the physical action of dredging has not considered as a water quality issue and therefore the physical impacts from dredging have not been allocated a risk rating in this risk assessment.

Marine pests from dredging

There is potential for the transport, release and/or remobilisation of marine pests during dredging activities. This can occur by the picking up of sediment bound pests such as *Alexandrium spp.* or fragments of species such as *Caulerpa spp.* from the sediment and disposing the sediment at an offshore location where the pest can become established. There is also the potential for relocation through using the same dredge at several different locations and the pest is transferred from one site to the other within the machinery. However as stated previously in this risk assessment marine pests are not covered under the EP Act and are the focus of a separate risk assessment by SARDI Aquatic Sciences.

4.13 Atmospheric deposition

Atmospheric deposition is the process where pollutants are released into the atmosphere and fall out directly onto waters. This risk assessment has only considered deposition directly onto waters as deposition onto land will be assessed under either urban or agricultural runoff depending on the catchment where the pollutants are deposited.

Commonly pollutants are discharged into the atmosphere through industries with air discharges such as chimney stacks or fugitive emissions, particularly when the stacks are in close proximity to waters. Long range deposition can occur if the chimney stack is very high and the prevailing wind direction is towards water.

Current estimates of atmospheric deposition are based on surface area of water, prevailing wind conditions and volume of pollutants discharged. The most common pollutant is oxidised nitrogen, discharged from many industries and motor vehicles. Other pollutants can be particulates, trace metals and sulphur dioxide. There is significant uncertainty in the estimates of risk for atmospheric deposition due to a paucity of information on loads reaching Gulf St Vincent and its bioavailability within marine systems. Any estimate of risk in this risk assessment should therefore be treated with care.

Nutrients from atmospheric deposition

Nutrients can enter the marine environment from atmospheric deposition through the fall out of oxidised nitrogen from large industries such as power generation, glass and cement production, fuel combustion, motor vehicles and shipping. The NPI estimates that in 2004–05 approximately 78,000 tonnes of nitrogen oxides was discharged into South Australia each year. Of this the majority was from motor vehicles with 29,000 tonnes across the state (NPI 2005).

The impacts of excess nutrients in marine waters are outlined in section 3.2.
Table 58  Nutrients from atmospheric deposition

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>Low (A0)</td>
<td>Low (A0)</td>
<td>Low (A0)</td>
</tr>
<tr>
<td>Eastern</td>
<td>Moderate (A1)</td>
<td>Low (A0)</td>
<td>Low (A0)</td>
</tr>
<tr>
<td>Western</td>
<td>Low (A0)</td>
<td>Low (A0)</td>
<td>Low (A0)</td>
</tr>
<tr>
<td>Southern</td>
<td>Low (A0)</td>
<td>Low (A0)</td>
<td>Low (A0)</td>
</tr>
</tbody>
</table>

**Northern region**

The northern region has limited sources of atmospheric deposition of nutrients into its waters. Sources may be motor vehicles, particularly large numbers of trucks that travel through the northern region and also a small amount of commercial shipping. However it is unknown at this stage as to whether the large industrial discharges of nitrogen oxides into the air from the Adelaide metropolitan area could fall out in the waters of the northern region via the strong southerly winds which are frequent in the summer months. It is also not known whether the large industrial sources in the northern Spencer Gulf could fall out in the waters during strong northerly wind which are frequent in winter. While there is significant uncertainty in sources and also loads of nutrients that fall out directly onto the waters of the northern region their impacts on ecosystem values are estimated to be low, similarly for both aquaculture and aesthetic values.

**Eastern region**

The eastern region has the most potential for nutrients to enter the marine environment due to the large numbers of motor vehicles and trucks, and relatively high amounts of commercial shipping in the region. Large industries contribute significant loads of nitrogen oxides into the air such as Adelaide Brighton Cement and the AGL Torrens Island, Pelican Point and Osborne Cogeneration power stations. While there is significant uncertainty in loads actually deposited into the Gulf, all of these facilities are in close proximity to Gulf St Vincent and are likely to contribute significant loads of nitrogen to the marine environment. The EPA has generated estimates of the load of nitrogen into the Port River for the Port Waterways WQIP and this was estimated to be between 25–45 tonnes of nitrogen per year (Christy unpublished).

This risk assessment considers the risk of impacting on ecosystem values from nutrients from atmospheric deposition to be moderate. The risk to impacting on aquaculture and aesthetic values is likely to be low.

**Western region**

The western region has few sources of nutrients from atmospheric deposition with only motor vehicles, trucks and commercial shipping likely to be contributing to nutrient loads in the region. It is considered unlikely that nutrients discharged from large industries in Adelaide or even the northern Spencer Gulf would reach the waters in the western region (M Hartley pers comm).

Therefore the risk from nutrients in atmospheric deposition is considered to be low for the protection of ecosystem, aquaculture and aesthetic values.

**Southern region**

Like the western region the southern region has few sources of nutrients discharged into the air. Motor vehicles, trucks and commercial shipping are likely contributors in this region. Again it is
unlikely that significant loads of nutrients are exported via atmospheric deposition from the
Adelaide metropolitan region into the southern region.

Therefore the risk from nutrients in atmospheric deposition is considered to be low for the
protection of ecosystem, aquaculture and aesthetic values.

**Turbidity from atmospheric deposition**

Particulate matter (dust) can be discharged from industrial sources into the atmosphere where it
can be deposited into waters. It can also enter the atmosphere from windborne erosion of
agricultural areas and paved and unpaved roads. Windborne agricultural erosion can be
exacerbated by poor farming practices and excessive clearing of land.

Large bushfires may also increase the amount of material in the air, which has the potential to
be deposited over water.

**Table 59 Turbidity from atmospheric deposition**

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>Low (A0)</td>
<td>Low (D0)</td>
<td>Low (D0)</td>
</tr>
<tr>
<td>Eastern</td>
<td>Low (A0)</td>
<td>Low (D0)</td>
<td>Low (D0)</td>
</tr>
<tr>
<td>Western</td>
<td>Low (A0)</td>
<td>Low (D0)</td>
<td>Low (D0)</td>
</tr>
<tr>
<td>Southern</td>
<td>Low (A0)</td>
<td>Low (D0)</td>
<td>Low (D0)</td>
</tr>
</tbody>
</table>

**Northern region**

Turbidity from atmospheric deposition in the northern region is likely to be derived from motor
vehicles, domestic solid fuel burning and erosion from agricultural land and roads. Due to the
diffuse nature of these discharges estimates of loads and impacts are very difficult. This risk
assessment considers the risk from impacts from turbidity on ecosystem values in the northern
region from atmospheric deposition to be low. Similarly the risk to aquaculture and aesthetic
values is also likely to be low.

**Eastern region**

In addition to diffuse sources such as domestic solid fuel burning, motor vehicles and the
windborne erosion of agricultural areas, the eastern region is also potentially impacted by
industrial discharges of particulates. Large emissions of particulates in close proximity to water
include Penrice Soda Products at Osborne, Adelaide Brighton Cement at Birkenhead and the AGL
Torrens Island, Pelican Point and Osborne Cogeneration power stations along the Port River (NPI
2005).

This risk assessment considers that turbidity from atmospheric deposition in the eastern region is
a low risk to ecosystem, aquaculture and aesthetic values.

**Western region**

Sources of atmospheric deposition in the western region are likely to be similar to the northern
region, which are domestic solid fuel burning, motor vehicles, commercial shipping and
windborne erosion from agricultural and rural land and roads. However as stated previously data
from these activities is limited and there is significant uncertainty in the estimation of loads
deposited.
This risk assessment considers that turbidity from atmospheric deposition in the western region is a low risk to ecosystem, aquaculture and aesthetic values.

**Southern region**

Atmospheric deposition in the southern region is likely to be sourced from domestic solid fuel burning, motor vehicles and windborne erosion from agricultural and rural land and roads. As stated in sections 4.7 and 4.10 the southern region has significant commercial shipping fleets and is used frequently as a shipping route to the eastern states. This is likely to increase discharges in the region although it is likely that the impact on ecosystem values would remain low. Similarly impacts on aquaculture and aesthetic values are also likely to be low.

**Trace metals from atmospheric deposition**

Trace metals are discharged into the atmosphere from a range of sources, which includes motor vehicles, aircraft, paved and unpaved roads and numerous large industries. These trace metals will often adhere to particulates and it is likely that they would not be highly bioavailable in the marine environment. Trace metals can accumulate in sediment where they can bioaccumulate to impact on benthic organisms or in some cases can magnify through food chains to impact on larger vertebrates such as dolphins, sharks and long lived fish.

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>Low (A0)</td>
<td>Low (D0)</td>
<td>na</td>
</tr>
<tr>
<td>Eastern</td>
<td>Low (A0)</td>
<td>Low (D0)</td>
<td>na</td>
</tr>
<tr>
<td>Western</td>
<td>Low (A0)</td>
<td>Low (D0)</td>
<td>na</td>
</tr>
<tr>
<td>Southern</td>
<td>Low (A0)</td>
<td>Low (D0)</td>
<td>na</td>
</tr>
</tbody>
</table>

**Northern region**

The northern region has limited sources for the deposition of trace metals into Gulf St Vincent. Sources are likely to be motor vehicles including trucks, paved and unpaved roads and commercial shipping. While there is significant uncertainty in loads of trace metals deposited into Gulf St Vincent it is likely that the risk of trace metals impacting on ecosystem values is low. Similarly the risk of impacts on aquaculture values is also considered to be low.

**Eastern region**

The eastern region has numerous large industries that discharge trace metals into the air that could potentially fall out onto the surface of Gulf St Vincent, these include Adelaide Brighton Cement and AGL Torrens Island, Pelican Point and Osborne Cogeneration power stations. These discharges are in addition to the considerable amount of discharges from motor vehicles, paved and unpaved roads, commercial shipping, boating and aircraft in the eastern region.

The risk to ecosystem values from trace metals from atmospheric deposition in the eastern region is considered to be low. The risk to aquaculture is considered to be low.

**Western region**

The trace metal discharges into the atmosphere that could potentially impact on the western region include motor vehicles, paved and unpaved roads, commercial shipping and possibly aircraft.
While information on this issue is very limited it is estimated that the risk to ecosystem and aquaculture values is considered to be low.

**Southern region**

It is anticipated that the sources of trace metals to the atmosphere that could potentially result in deposition into marine waters in the southern region would be very similar to the western region. However it is likely that there would be an increase in the amount of metals discharged from commercial shipping due to the higher ship frequency in the southern region and its use as a main shipping route to the eastern states.

While quantifying the actual loads of trace metals deposited onto waters is extremely difficult in all of these cases it is anticipated that the risk to ecosystem and aquaculture values are low.

**Pesticides from atmospheric deposition**

Many common pesticides will attach to soil particles which, when taken by airborne erosion from agricultural regions, have the potential to transport pesticides into the marine environment. In most cases the pesticides will remain attached to the particles and settle out into the sediment, however under some circumstances they may become available to organisms.

There is considerable uncertainty about the loads of pesticides that may be transported into the marine environment and their bioavailability when in water. Evaluation of risk in this assessment is based on the amount of agricultural activity in the region and its proximity to the coast and sensitive habitats and an estimation on the frequency of large dust storms that may transport pesticides over marine environments. However there is significant uncertainty in all aspects of this category and therefore this is an area in significant need of further research and the risks assessed here are stated with very low levels of confidence.

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
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<tr>
<td>Northern</td>
<td>Low (D0)</td>
<td>Low (D0)</td>
<td>na</td>
</tr>
<tr>
<td>Eastern</td>
<td>Low (E0)</td>
<td>Low (E0)</td>
<td>na</td>
</tr>
<tr>
<td>Western</td>
<td>Low (D0)</td>
<td>Low (D0)</td>
<td>na</td>
</tr>
<tr>
<td>Southern</td>
<td>Low (D0)</td>
<td>Low (D0)</td>
<td>na</td>
</tr>
</tbody>
</table>

**Northern region**

The northern region has significant areas of agriculture and it is expected that pesticide use is undertaken frequently. This risk assessment has estimated that the frequency of major dust storm that could transport a pesticide to the marine environment is likely to occur at least once a year. However as stated above the fate and bioavailability of these pesticides transported via airborne erosion is largely unknown. This risk assessment considers the risk to ecosystem and aquaculture values from pesticides transported to the marine environment from atmospheric deposition is low. However this is stated with a very low level of confidence as there is very little available information on atmospheric deposition of pesticides, particularly in South Australia.

**Eastern region**

The likelihood that pesticides are transported to marine waters from the eastern region is considered to be very small. This is due to the small amount of agricultural land in the region.
and the low frequency of strong easterly winds that could transport particles over the marine environment.

Therefore this risk assessment considers the risk to ecosystem and aquaculture values from pesticides transported through atmospheric deposition to be low.

**Western region**

There is a considerable amount of agricultural land within the western region and it is anticipated that the use of pesticides is frequent. Therefore the likelihood that pesticides may be attached to particles that are deposited into the marine environment is considered possible. However as stated above the fate, bioavailability and potential impact of these pesticides is largely unknown and very difficult to assess.

This risk assessment considers the risk to ecosystem and aquaculture values from pesticides from atmospheric deposition to be low.

**Southern region**

The southern region contains significant amounts of agricultural land and pesticide use would be considered frequent in these areas. It is considered possible that pesticides may be transported to the marine environment by atmospheric deposition.

This risk assessment considers the risk to ecosystem and aquaculture values from pesticides from atmospheric deposition to be low.

**Other chemicals from atmospheric deposition**

The range of chemicals that are released into the atmosphere and can potentially be deposited into marine waters from industries is endless and attempting to assess each chemical is impractical. Additionally it is also accepted that using a category of ‘other chemicals’ is extremely vague and risks, frequencies and impacts will vary depending on each individual chemical.

Bushfires can result in burnt material entering the atmosphere and eventually being deposited into the marine environment. There is some evidence that persistent organic pollutants such as dioxins and dioxin-like compounds can be released into the atmosphere from large bushfires (Meyer et al 2004). However there is little information about a multitude of chemicals that could be released into the atmosphere and deposited into waters. Therefore any risk assessment process is limited to a best estimate, with significant uncertainty and a need for further research. This risk assessment has a very low level of confidence in the estimation of these risks due to the significant uncertainty in pathways, loads and potential impacts.

**Table 62 Other chemicals from atmospheric deposition**

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>Low (D0)</td>
<td>Low (D0)</td>
<td>na</td>
</tr>
<tr>
<td>Eastern</td>
<td>Low (A0)</td>
<td>Low (E0)</td>
<td>na</td>
</tr>
<tr>
<td>Western</td>
<td>Low (D0)</td>
<td>Low (D0)</td>
<td>na</td>
</tr>
<tr>
<td>Southern</td>
<td>Low (D0)</td>
<td>Low (D0)</td>
<td>na</td>
</tr>
</tbody>
</table>
Northern region
This risk assessment considers that the northern region has very few large industries that could discharge ‘other chemicals’ into the atmosphere that could be deposited into the marine environment. However it is possible that ‘other chemicals’ could be discharged from motor vehicles and commercial shipping. The fate, bioavailability and impact would be largely speculative. This risk assessment considers the risk from other chemicals to ecosystem and aquaculture values to be low.

Eastern region
In addition to large numbers of motor vehicles and commercial shipping the eastern region is likely to have numerous industries that discharge ‘other chemicals’ into the atmosphere which is likely to result in deposition into the marine environment. The fate, toxicity, bioavailability and impact these chemicals will have on the marine environment is highly variable and reliant on the nature of the individual compounds and even the toxicity of any mixtures. It is anticipated that other chemicals from atmospheric deposition pose a low risk to ecosystem and aquaculture values.

Western region
The western region is likely to have few discharges of ‘other chemicals’ into the atmosphere that could potentially be deposited into the marine environment and impact on ecosystem values. However motor vehicles and commercial shipping are possible sources in this region.

Inspite of uncertainty, this risk assessment has considered their risk of impacting on ecosystem and aquaculture values across the region to be low.

Southern region
It is likely that the southern region has very few potential sources of ‘other chemicals’ discharged into the atmosphere that could potentially deposit onto the marine environment. However motor vehicles and the high amount of commercial shipping traffic may be potential sources.

This risk assessment has considered that the risk to ecosystem and aquaculture values is likely to be low, however it should be stressed that there is significant uncertainty in these risk ratings as outlined above.

4.14 Boating maintenance slipways
From time to time there is a need to pull vessels out of the water to perform maintenance on the hull. This is normally undertaken at a slipway. A slipway is a facility that has a mechanism to pull a vessel out of the water to provide access to the underside of the boat including allowing maintenance to be performed on the underwater part of the vessel.

Due to the proximity of any slipway to the water environment, impacts can be potentially significant. Vessels are blasted with abrasives and re-painted, which can cause antifoulant and paint residues to enter the marine environment. There is also the potential for oil to leak or be spilt close to the water. Slipways have been used to maintain vessels for many years and this has resulted in many facilities being in poor repair or a poor design that allows water to flood the working area washing pollutants into then marine environment.

In regions where there are no adequate facilities for vessel maintenance there is significant potential for vessel owners to beach their vessels onto a sandy area and perform maintenance on the vessel below the high water mark. This will introduce pollutants into the marine
environment. However as this is not a risk associated with a slipway but with the vessel it has been assessed as a part of the risk assessment in sections 4.7–4.9.

**Trace metals from slipways**
As outlined in section 3.3, 4.7 and 4.9 large vessels are coated with an antifoulant paint. This forms a barrier between the vessel and colonising marine organisms. These antifoulants are generally effective for approximately 2–3 years when they will need to be replaced. This involves blasting or sanding the coating from the boat and painting a new coating on the vessel. An EPA audit of slipways in 2001 found that none of the facilities audited had mechanisms in place to prevent both solid and dissolved pollutants from entering the water. This audit also found that the working area of several facilities was underwater at large high tides, potentially transferring any material on the ground to the marine environment unless sites were regularly cleaned. Consequently there are significant areas of sediment surrounding slipways that have been contaminated with trace metals, possibly impacting on benthic ecosystems in close proximity.

Table 63 Trace metals from slipways

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Eastern</td>
<td>Moderate (B1)</td>
<td>Low (B0)</td>
<td>na</td>
</tr>
<tr>
<td>Western</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Southern</td>
<td>Low (D1)</td>
<td>Low (D0)</td>
<td>na</td>
</tr>
</tbody>
</table>

**Northern region**
Currently there are no slipways in the northern region.

**Eastern region**
At the time of this risk assessment the fate of several slipways is uncertain. The Jenkins St boatyards in Port Adelaide are an icon and have been established at their current site for close to 100 years. However a large proportion of these sites are subject to inundation in large high tides and are likely to be transferring trace metals to the marine environment. The state government is currently undertaking a redevelopment of Port Adelaide waterfront precinct, and has proposed to remove these facilities and build a best practice marine industry precinct at Snowdens Beach. Other slipways in the eastern region are located in the Port River at Snowdens Beach, North Haven, Outer Harbor and the Patawalonga Lake at Glenelg. At the time of writing a number of the Jenkins St slipways are still in operation and as such have been assessed as a part of the risk ratings.

Antifoulant paints contain high concentrations of trace metals and are regularly removed from vessels while on a slipway. Most slipways do not have adequate mechanisms to prevent pollutants from entering the marine environment. Therefore this risk assessment considers the risk to ecosystem values from trace metals from slipways to be moderate. Currently there are no aquaculture facilities in close proximity to slipways that may be impacted by trace metals from slipways in this region and therefore the risk is considered low.

**Western region**
There are currently no slipways in the western region.

**Southern region**
Currently there is one slipway facility at Kingscote. This facility does not have runoff interception drains and it is likely that contaminated runoff may enter the water if there is inadequate clean up of the site while it is being used. Currently there is no information regarding whether the sediment adjacent this slipway has elevated metal concentrations. This slipway is used less frequently than the slipways in the eastern region. Metals from this slipway are likely to be a low risk to the ecosystem and aquaculture values in the southern region.

**Hydrocarbons from slipways**

There is potential for leakage or spillage of hydrocarbons from operations undertaken at slipways. Due to the lack of containment facilities and sloping nature of slipways there is significant potential for any hydrocarbons discharged to enter the marine environment.

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Eastern</td>
<td>Low (C0)</td>
<td>Low (D0)</td>
<td>na</td>
</tr>
<tr>
<td>Western</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Southern</td>
<td>Low (D0)</td>
<td>Low (D0)</td>
<td>na</td>
</tr>
</tbody>
</table>

**Northern region**

Currently there are no slipways in the northern region.

**Eastern region**

As stated above there are very few slipways that have adequate pollution containment and treatment systems in place to stop potential pollutant from entering the marine environment. Any hydrocarbon spill at the slipway yards or from a vessel while in the slipway has the potential to enter the marine environment. This risk assessment considers the risk to impacts on ecosystem and aquaculture values in the eastern region to be low.

**Western region**

There are currently no slipways in the western region.

**Southern region**

It is likely that the risk of hydrocarbon spill at the Kingscote slipway is similar to slipways in the eastern region. The risk of impacts on ecosystem and aquaculture values in the southern region is low.

**4.15 Port Stanvac Oil Refinery**

The Port Stanvac Oil Refinery was operated by ExxonMobil and had a capacity of 100,000 barrels per day. In 2003 ExxonMobil decided to mothball the facility. Currently the facility remains intact but is not operating. There is a marine discharge pipe at Port Stanvac which releases effluent from the site into the marine environment approximately 100 m offshore. Currently this outfall pipe only discharges stormwater from the site. There is some evidence of hydrocarbon contamination of the groundwater beneath Port Stanvac and it is likely that the direction of groundwater flow is towards the marine environment (Coffey 2006). In addition to hydrocarbons, trace metals and nutrients have also been raised as potential pollutants from the site.
There are significant marine habitats in close proximity to the Port Stanvac refinery. Hallett Cove reef is located a short distance to the north of the marine discharge pipe but has been considered as being in good condition in both 1999 and 2005 (Cheshire & Westphalen 2000; Turner et al 2007).

Both water chemistry and biological assessments of the receiving environment are undertaken and current monitoring of the macroalgal reef areas close to the outfall show that they are in good condition (CCE 2007).

**Hydrocarbons from Port Stanvac Oil Refinery**

The impacts of hydrocarbons are outlined in section 3.4.

Table 65 Hydrocarbons from Port Stanvac Oil Refinery

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Eastern</td>
<td>Low (C1)</td>
<td>Low (E0)</td>
<td>na</td>
</tr>
<tr>
<td>Western</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Southern</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
</tbody>
</table>

**Eastern region**

While Port Stanvac Oil Refinery is not being operated there are no hydrocarbons in any of the storage tanks or pipes and therefore the risk would obviously be significantly lower. The facility has an oil water separator, which removed hydrocarbons from the stormwater before discharge through the outfall pipe into Gulf St Vincent.

Current water monitoring has shown that there are very few hydrocarbons discharged into the marine environment. However there is some evidence of hydrocarbon contamination of the groundwater and that this groundwater is travelling towards the marine environment (Coffey Environments 2006).

It is unclear whether the contamination has already discharged into the marine environment, is yet to reach the water or whether the degree of groundwater contamination is large enough to cause harm to the marine environment.

Therefore this risk assessment considers the risk from hydrocarbons from Port Stanvac to be a low risk to ecosystem and aquaculture values.

**Trace metals from Port Stanvac Oil Refinery**

Mobil monitoring of stormwater from the Stanvac site has shown some elevation of trace metals in the water discharged into the Gulf, particularly copper and selenium. The impact of trace metals on the marine environment is outlined in section 3.3.
Table 66  Trace metals from Port Stanvac Oil Refinery

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Eastern</td>
<td>Low (C0)</td>
<td>Low (C0)</td>
<td>na</td>
</tr>
<tr>
<td>Western</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Southern</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
</tbody>
</table>

**Eastern region**

Since its closure, the only trace metals discharged from Port Stanvac are via stormwater from the site. Monitoring of stormwater has shown slightly elevated levels of copper and selenium but the volume of runoff from the sites is estimated to be relatively small.

Therefore the risk to ecosystem and aquaculture values from trace metals is considered to be low.

**Nutrients from Port Stanvac Oil Refinery**

The discharge of nutrients in the surface runoff from the Port Stanvac site has the potential to impact on macroalgal reef systems surrounding the outfall site and impact on ecosystem values in the region. Excess nutrients can also impact on nearshore seagrass meadows and cause blooms of phytoplankton and macroalgae such as *Ulva*.

Table 67  Nutrients from Port Stanvac Oil Refinery

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Eastern</td>
<td>Low (D1)</td>
<td>Low (C0)</td>
<td>na</td>
</tr>
<tr>
<td>Western</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Southern</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
</tbody>
</table>

**Eastern region**

Monitoring by ExxonMobil has shown that the concentration of nutrients from the surface water runoff from Port Stanvac has decreased as has the volume of water discharged. This risk assessment considers the risk to ecosystem and aquaculture values to be low.

**Metals from Port Stanvac Oil Refinery**

The discharge of metals in the surface runoff has the potential to impact on macroalgal reef systems surrounding the outfall site and impact on ecosystem values in the region. An increase in metals in the waters surrounding Port Stanvac has the potential to be accumulated by filter feeding organisms.
Table 68  Metals from Port Stanvac Oil Refinery

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Eastern</td>
<td>Low (C0)</td>
<td>Low (C0)</td>
<td>na</td>
</tr>
<tr>
<td>Western</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Southern</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
</tbody>
</table>

**Eastern region**

Monitoring by ExxonMobil has shown that there are occasionally elevated concentrations of some metals from the surface water runoff from Port Stanvac. Elevated metals discharged into the marine environment have the potential to impact on both macroalgal and seagrass systems in the adjacent waters, however monitoring has shown that the concentrations discharged are generally not at a level that would cause environmental harm. This risk assessment considers the risk to ecosystem and aquaculture values to be low.

**Other chemicals from Port Stanvac Oil Refinery**

The use of the category of ‘other chemicals’ throughout this risk assessment has been followed with a caveat of caution. The impact of this category of chemicals will be entirely dependant on the actual compounds discharged and while it is conceded that this category is very vague it is considered impractical to try to identify and classify risks for every chemical.

Various chemicals are used in the Port Stanvac refinery and many of these could potentially be released to the environment. One of the most likely to be released is methyl ethyl ketone (MEK). This chemical is used as a solvent and in adhesives, varnishes and glues.

Table 69  Other chemicals from Port Stanvac Oil Refinery

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Eastern</td>
<td>Low (C0)</td>
<td>Low (C0)</td>
<td>na</td>
</tr>
<tr>
<td>Western</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Southern</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
</tbody>
</table>

**Eastern region**

‘Other chemicals’ have previously been detected in routine water sampling by Mobil however it is unclear whether levels of any of these chemicals are having an adverse impact on the marine environment. MEK is generally considered to be of low toxicity to aquatic animals (WHO 1993). Monitoring in 2007 suggests that very little MEK now enters the marine environment from Port Stanvac. ‘Other chemicals’ from the Port Stanvac refinery are considered to be a low risk to ecosystem and aquaculture values.

4.16  Fuel storage facilities at Birkenhead

There are four large fuel storage facilities at Birkenhead that receive fuel from ships on the Port River and fuel is stored in silos until it is distributed to service stations across Adelaide. These
facilities are located on the Port River where ships transfer fuel from vessels to the storage tanks. Risks of impacts from the fuel transfer from vessels to the storage facility has been assessed in section 4.8 Wharves.

**Hydrocarbons from the Birkenhead fuel storage facilities**

The fuel storage facilities at Birkenhead have the capacity to hold Adelaide's entire fuel distribution supply in large silo type tanks. These tanks are in a large bund, which in the event of a major spill are designed to retain spilt fuel.

**Table 70 Hydrocarbons from Birkenhead fuel storage facilities**

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Eastern</td>
<td>Low (E3)</td>
<td>Low (E3)</td>
<td>na</td>
</tr>
<tr>
<td>Western</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Southern</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
</tbody>
</table>

**Eastern region**

The fuel storage facilities are bunded and designed to retain any spilt hydrocarbons and prevent any discharge to the marine environment. In addition stormwater runoff is discharged via an oil water separator, which removes any oil on the surface of stormwater that passes through it. The Shell facility also has a reed bed, which is further designed to treat stormwater discharged from this site.

To date there has not been a fuel spill from these storage facilities where hydrocarbons have entered the marine environment. However there is always an element of risk. This risk assessment considers the risk of impacts from hydrocarbons on ecosystem and aquaculture values from the fuel storage facilities to be low.

**Trace metals from the Birkenhead fuels storage facilities**

Within any industrial facility trace metals are deposited onto the ground and can be discharged in stormwater runoff. In addition hydrocarbons contain some amount of trace metals and can be discharged to the marine environment.

**Table 71 Trace metals from Birkenhead fuel storage facilities**

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Eastern</td>
<td>Low (C1)</td>
<td>Low (C1)</td>
<td>na</td>
</tr>
<tr>
<td>Western</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Southern</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
</tbody>
</table>
Eastern region

Stormwater from these sites are designed to retain hydrocarbons and as such do not treat trace metals in the discharge. This could mean that the potential for some amount of trace metals might be discharged into the marine environment.

This risk assessment considers the risk to ecosystem and aquaculture values from trace metals to be low.

4.17 Saltfields

There are several locations around Gulf St Vincent that are used to evaporate seawater to harvest salt or brine for sale or to be used in various industrial processes such as the Penrice Soda Products Solvay process. The facilities used for this process comprise large areas of low lying land in close proximity to seawater (fields). Generally seawater is pumped in using the high tides to cover the fields with a shallow layer of water throughout an extended period of time. The water is passed through several stages where it is ‘shandied’ up to a specific gravity where the sodium chloride is dropped out. At this stage the water is used in industrial processes. The remaining concentrate or ‘bitterns’ is discharged back into the marine environment.

This discharge is generally high in salts and some trace metals and is released at a temperature higher than the ambient receiving environment.

**Bitterns discharge from saltfields**

Salts are concentrated in the bitterns discharge from saltfields and can impact on receiving water environments. The discharge does not contain significant amounts of sodium chloride but the discharge has a very high specific gravity and is denser than ambient water which may not readily diffuse with the surrounding waters. Monitoring by Cheetham Saltfields has shown that while trace elements are concentrated up in the process, metals in the bitterns water are generally below the ANZECC Guidelines for Fresh and Marine Water Quality (P Coleman pers comm).

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>Low (C1)</td>
<td>Low (C1)</td>
<td>na</td>
</tr>
<tr>
<td>Eastern</td>
<td>Low (C1)</td>
<td>Low (C1)</td>
<td>na</td>
</tr>
<tr>
<td>Western</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Southern</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
</tbody>
</table>

**Northern region**

The Cheetham Saltfields are located at Price within the northern region and covers approximately 15 km² of land near the foreshore south of Price. There are also saltwash plants at Price to clarify the salt products for sale. Generally bitterns are discharged into the intertidal mudflat and mangrove habitat at high tide. Monitoring has shown that the conductivity increases adjacent to the discharge point but rapidly returns to normal on the new tides. This risk assessment considers the risk from the bitterns discharge in the northern region is a low risk to ecosystem and aquaculture values.
Eastern region

There is a significant region of saltfields within the eastern region that are used to produce salt products and to feed a brine solution into the industrial process at Penrice Soda Products. These salt evaporation pans are approximately 40 km² and are located along the coastal region between Adelaide and Middle Beach.

The bitterns discharge into Barker Inlet via Dry Creek and North Arm Creek. These regions are considered sensitive marine habitats and there can be times of limited mixing. Marine monitoring at these sites shows that there is an increase in salinity in the creeks adjacent the bitterns discharge but this water rapidly returns to normal in times of good mixing (ie new tide). Studies have shown that this is similar to the increased salinity and resultant mixing as a result of water evaporating off natural saltmarshes into tidal creeks. This effect has been observed within the Little Para Creek (P Coleman pers comm).

Leinfelder (2000) found that in isolated pools that received bitterns discharges the high Mg:Ca ratio caused any mud crabs in that pool to become anaesthetised making them easy prey for seabirds. This was also found to occur in Dampier WA. However the study also demonstrated that there was no difference in macro-invertebrate populations between regions that received bitterns to control regions.

This risk assessment considers the risk to ecosystem and aquaculture values in the eastern region is low.

Western region

Currently there are no saltfields in the western region.

Southern region

Currently there are no saltfields in the southern region.

Temperature from saltfields discharge

Water at saltfields is evaporated from shallow basins to generate salt from the seawater. This results in an increase in water temperature which can impact on the marine organisms in the area. For more details on the potential impacts of increased temperature on the marine environment see section 3.8.

Table 73 Increased temperature of water from saltfields

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>Low (C0)</td>
<td>Low (C0)</td>
<td>na</td>
</tr>
<tr>
<td>Eastern</td>
<td>Low (C0)</td>
<td>Low (C0)</td>
<td>na</td>
</tr>
<tr>
<td>Western</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Southern</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
</tbody>
</table>

Northern region

The Cheetham Saltfields discharge water into the mangrove creek and intertidal region at Price. Currently there is limited information on the impact of increased temperature discharge in this region. The infrequent nature of the discharge (~once a month), the discharge at a high tide providing maximum water in the creek during the discharge and the subsequent outgoing tide provide for maximum potential mixing with fresh seawater.
This risk assessment considers the risk to ecosystem and aquaculture values from increased temperature to be low.

**Eastern region**

Due to the infrequent nature of the discharge (~once a month), the discharge at a high tide providing maximum water in the system during the discharge and the subsequent outgoing tide provide for maximum potential mixing with fresh seawater.

This risk assessment considers the discharge of increased temperature water from the saltfields in the eastern region to be a low risk to ecosystem and aquaculture values.

**Western region**

Currently there are no saltfields in the western region.

**Southern region**

Currently there are no saltfields in the southern region.

### 4.18 Recreational bathers

Although recreational bathers are one environmental value this risk assessment is looking to protect they can also be a source of pollution that can potentially impact on environmental values, particularly recreational values. ‘Bather shedding’ is the process where bacteria are released into the water directly from bathers, via accidental faecal release (AFR) or through the natural microbial fauna on the body (WHO 2003). The two main factors that influence the amount of bather shedding is the bather density and the degree of dilution (WHO 2003). Studies have shown that the concentration of bacteria (*Staphylococcus aureus*) in recreational waters correlated with bather density (NHMRC 2005). The likelihood of AFR is also greatly increased if there are no toilet facilities readily available at recreational beaches.

**Microbial contamination from recreational users**

Bather shedding can impact on recreational values and have the potential to contaminate aquaculture shellfishing waters if areas used for recreational activities in high densities are located in close proximity to aquaculture grounds.

**Table 74 Microbial contamination by recreational users**

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>na</td>
<td>Low (C0)</td>
<td>Low (C0)</td>
</tr>
<tr>
<td>Eastern</td>
<td>na</td>
<td>Low (C0)</td>
<td>Moderate (C2)</td>
</tr>
<tr>
<td>Western</td>
<td>na</td>
<td>Low (C0)</td>
<td>Low (C0)</td>
</tr>
<tr>
<td>Southern</td>
<td>na</td>
<td>Low (C0)</td>
<td>Low (C0)</td>
</tr>
</tbody>
</table>

**Northern region**

It is anticipated that the bather density in the northern region is likely to be low and the dilution rate is expected to be significant at recreational locations. It is also likely that there are no aquaculture shellfishing areas in close proximity to recreational areas. Therefore the risk to recreational and aquaculture values is considered low in the northern region.
Eastern region

EPA monitoring of Adelaide’s coastal waters and desktop sanitary inspections carried out for this risk assessment (see section 2) have shown that there are times when microbial concentrations are elevated. This only occurs when there has been no rainfall in the days preceding and no other obvious sources other than high densities of swimmers in the water at the sampling site (EPA unpublished). Other studies have shown that bacteria can be released from bathers (bather shedding) either through AFR or directly from the skin (Elmir et al. 2007) and can impact on recreational water quality (Papadakis et al. 1997).

Bathers may be at the most risk when dilution is low (dodge or very small tidal movement), low wind and high bather densities. This can occur along Adelaide’s metropolitan coast during the summer months. However the salinity of seawater causes high microbial die-off rates and thorough mixing of recreational waters leads to relatively safe waters for the majority of the time (NHMRC 2005; Corbin & Gaylard 2005).

This risk assessment to consider that recreational users of water are a moderate risk to recreational values in the eastern region. It is considered unlikely that there is significant recreational activity in aquaculture regions and therefore bathers are considered a low risk to aquaculture values in the eastern region.

Western region

The desktop sanitary inspection (section 2.4) highlighted that the population sizes within the western region are very small and dilution for the majority of the time would be considered good. Therefore it is anticipated that any bacterial contamination from recreational bathers would be considered very small and dispersed readily. This risk assessment considers that the risk to recreational values from bathers as low in the western region. It is also considered unlikely that there would be significant bather density in close proximity to aquaculture regions but the risk is likely to be low to aquaculture values.

Southern region

The southern region has very small populations and the waters are more exposed allowing for more dispersion. Therefore the numbers of recreational bathers is likely to be low and any bacterial contamination from these bathers would be dispersed readily. Therefore this risk assessment considers the risk to recreational and aquaculture values from recreational bathers is low in the southern region.

4.19 Quarries

There are two aspects to the impacts of quarries on water quality: first their construction and second their operation. There are three major quarries in close proximity to the coast that may impact on water quality. The first is at Ardrossan in the northern region, the second is at Rapid Bay in the southern region and finally the Klein Point Quarry south of Stansbury, which is in the western region.

The Ardrossan Quarry is the largest dolomite mining operation in Australia and was launched by BHP in 1950. The Rapid Bay Quarry was established in 1942 by BHP to supply limestone to steelworks at Whyalla, Newcastle and Port Kembla and was operational until 1988. Klein Point Quarry is used extensively by Adelaide Brighton Cement to supply limestone to the Birkenhead cement kilns. It was commissioned in 1925 and is still operational (Valentine 2006).

All these facilities are located less than one kilometre from the coast where there is the potential for runoff from the quarries to enter the marine environment.
Turbidity from quarries

Quarries are open-cut mines, which have the potential to cause increased sediment loads in any surface runoff that moves through the site. Due to the quarries’ close proximity to the coast there are few opportunities to mitigate this solids load before it enters the marine environment.

Table 75 Turbidity from quarries

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>Low (D1)</td>
<td>Low (D0)</td>
<td>Low (D0)</td>
</tr>
<tr>
<td>Eastern</td>
<td><strong>na</strong></td>
<td><strong>na</strong></td>
<td>Na</td>
</tr>
<tr>
<td>Western</td>
<td>Low (D1)</td>
<td>Low (D1)</td>
<td>Low (D1)</td>
</tr>
<tr>
<td>Southern</td>
<td>Moderate (D3)</td>
<td>Low (D1)</td>
<td>Moderate (D2)</td>
</tr>
</tbody>
</table>

**Northern region**
Currently there is no monitoring data for stormwater runoff from the Ardrossan Quarry. However it is likely that surface runoff flows towards the marine environment and there are few opportunities for sedimentation of runoff. In addition the receiving environment is predominantly seagrass, which are generally sensitive to reductions in light. This risk assessment considers turbidity from quarries in the northern region to be a low risk to ecosystem, aquaculture and recreational values.

**Eastern region**
Currently there are no quarries in close proximity to the coast in the eastern region.

**Western region**
The Klein Point Quarry is located in close proximity to the coast near Stansbury. Currently there is little information regarding stormwater drainage from the quarry and any impacts on the marine and coastal environment. However the receiving environment is dominated by seagrass in shallow regions of the coast and this habitat is likely to be sensitive to reductions in light. This risk assessment considers turbidity from quarries in the western region to be a low risk to ecosystem, aquaculture and recreational values.

**Southern region**
The Rapid Bay Quarry is located in very close proximity to the marine environment surrounded by very steep cliff faces. When the quarry was constructed the overburden was placed on the steep cliff face next to the water. This is relatively unstable and debris frequently falls into the sea. This discharge is likely to be contributing to the significant physical changes to the beaches in the region. In addition to the physical impacts large turbidity plumes can be seen in the nearshore environment during strong southerly winds extending northwards from Rapid Bay. Turbidity impacts may also be caused by surface water runoff across the site, which is likely to reach the marine environment.

This risk assessment considers that turbidity from quarries in the southern region is a moderate risk to ecosystem values but a low risk to aquaculture and recreational values.

4.20 Acid sulfate soils

Acid sulfate soils (ASS) is the common name given to naturally formed soils that are high in iron sulfides, principally iron pyrite or that contain the acidic products of the oxidation of sulfides.
When these soils or sediments are exposed to oxygen the sulfides oxidise and produce significant quantities of sulfuric acid. When left undisturbed acid sulfate soils are benign, however disturbing ASS can cause significant environmental impacts such as fish kills, increased prevelance of organism disease, decrease in habitat and biodiversity, and mobilisation of toxicants (NSMCASS 2000). In decreased pH conditions (such as when an acid sulfate soil is disturbed) any metals in the sediment may be converted from insoluble matrices into soluble forms which are readily bioavailable to organisms in the surrounding environment and may cause toxicity.

Generally adverse impacts of disturbed acid sulfate soils result from the mobilisation of toxicants, particularly aluminium in freshwaters due to the lack of buffering ions (DNR 2007).

The CSIRO and the South Australian Department of Environment and Heritage (DEH) have undertaken an extensive mapping and risk assessment of actual and potential acid sulfate soils in coastal regions of South Australia (Fitzpatrick et al 2003) and have generated digital mapping layers that classify regions according to their risk (available at <www.atlas.sa.gov.au>). Due to the comprehensive nature of the CSIRO/DEH study, this risk assessment will only touch on the risk from actual and potential acid sulfate soils. For more detail please refer to Fitzpatrick et al 2003.

**Impacts from acid sulfate soils**

The disruption of ASS can result in the formation of significant quantities of sulfuric acid being discharged into the marine environment. Decreased pH in quantities sufficient to exceed the natural buffering capacity of seawater can alter the physical properties of the water and have widespread impacts on the environment. These impacts include diseases, reduced hatching, survival and growth rates for a wide range of aquatic species, and smothering as a result of precipitation of iron and aluminium across benthic organisms and habitats (DNR 2007).

The release of sulfuric acid can also mobilise regions of metal contamination. The lower pH can increase the bioavailability of metals in marine waters and can result in acute and chronic toxicity (see section 3.3).

**Table 76  Decreased pH from disturbed acid sulfate soils**

<table>
<thead>
<tr>
<th>Region</th>
<th>Ecosystem</th>
<th>Aquaculture</th>
<th>Recreation &amp; Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>Low (E2)</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Eastern</td>
<td>Moderate (C2)</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Western</td>
<td>Low (E2)</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Southern</td>
<td>Low (E2)</td>
<td>na</td>
<td>na</td>
</tr>
</tbody>
</table>

**Northern region**

DEH mapping shows that the northern region has numerous locations where there are potential coastal acid sulfate soils which, if disturbed, could form and discharge sulfuric acid into the marine environment. Currently most of the northern regions are not disturbed and well mapped by DEH. The CSIRO risk assessment has classified individual areas within the northern region as being either a low or moderate risk, however this is based on the risk to the immediate area (using a triple bottom line approach) rather than the risk of impacts on the entire region as classified in this risk assessment. There is the potential for these soils to be disturbed, particularly during the current development boom in coastal areas and this risk assessment has classified acid sulfate soils as being a low risk to ecosystem values.
Eastern region

The eastern region has the only actual acid sulfate soils in South Australia and have been rated by the CSIRO risk assessment as being a very high risk. This site was located in the Port Adelaide and Gillman region and has been shown to have a pH of between 2.8–3.5 and elevated levels of metals in the water discharged to the adjacent marine environment (Thomas et al 2003).

While the CSIRO risk assessment has classified this region as a very high risk, this risk assessment has classified it as a moderate risk. This is due to the different classification approaches used by the risk assessments. The CSIRO has assessed the probability of actual acid sulfate soils occurring (CPB 200) while this risk assessment has assessed the probability that acid sulfate soils will have a significant impact on the risk assessment region.

It is probable that the ecosystems adjacent these acid sulfate soils, including fishery nursery areas, are being impacted by the very low pH and also potentially from the mobilising of metals. This may be impacting on sensitive nursery areas that are important for both commercial and recreational fisheries in the Gulf and the breeding of important species. This risk assessment has classified actual and potential acid sulfate soils in the eastern region as a moderate risk to ecosystem values.

Western region

The western region has not been extensively mapped however there are only a few regions that are classified by the CSIRO/DEH mapping. These locations are the Coobowie embayment and Sultana Point. Both of these regions are classified as low to moderate risks. This risk assessment classifies the risk to the Western region from actual or potential acid sulfate soils to be low.

Southern region

Actual or potential acid sulfate soils in the southern region are again only sparsely mapped but there are several areas that have been classified as a moderate risk by CSIRO and DEH. These are particularly centred around estuarine areas such as the Cygnet and Onkaparinga Rivers and their classifications in the CSIRO risk assessment inventory is low to moderate. In this risk assessment it is considered that actual and potential acid sulfate soils are a low risk to ecosystem values in the southern region.

4.21 Desalination plants

At the time of publication the South Australian Government is in the process of installing a reverse osmosis desalination plant at Port Stanvac in order to secure drinking water for the population of Adelaide. Initially a small-scale plant or ‘pilot plant’ is being built to look at different water quality parameters and water treatment processes in order to understand how to design the full-scale plant [The Australian 21 January 2008]. At the current stage of development it is not feasible to undertake this risk assessment process on either the pilot plant or the full-scale desalination plant. Nevertheless, there are a number of aspects that have significant potential to impact on water quality of Gulf St Vincent and the marine ecology of the surrounding region.

Desalination plants use a membrane filter to remove the salt and other molecules from the feed water to produce water of a lower salinity. In most cases the desired end product is potable water. The waste product from this process is a brine solution that, due to the concentrating of the constituents of the water, has a very high salt load, typically in excess of 75‰ (seawater ~32-7‰). This concentrating effect will also increase the concentration of other constituents of the feed water that cannot pass through the membrane. These can include a number of water treatment chemicals used in the process in order to maintain the integrity of the membrane and to prevent the build-up of scale which reduces efficiency (referred to as antiscalants). The brine
can also contain metals, pesticides and other pollutants that can be concentrated from very low concentrations in the feed water (Younos 2005). The brine solution is generally discharged into the marine environment where it may have deleterious impacts to the surrounding region if not well managed (Younos 2005).

The discharge of reverse osmosis desalination is hypersaline and therefore is more dense than water, making it sink in ambient seawater. Mixing and dilution/diffusion of the brine discharge is reliant on a number of hydrodynamic factors, principally local and far field bathymetry, tidal forces, local wind speed and direction which will dictate wind driven currents, wave height and speed and density driven mixing (Jenkins & Wasyl 2005). Modelling and other assessments of dilution need to take into consideration scenarios such as dodge tides with no wind and large tides with onshore winds (and other combinations) in order to understand possible normal and worst case scenarios.

There are a number of potential impacts from the brine discharge including impacts from the higher salinity, temperature and density of the water, and also the acute and chronic toxicity from the chemical additives and concentrated pollutants in the discharge (Younos 2005). These two impacts are not independent where the increased stress of maintaining the cells' internal water balance (osmoregulation) can make an organism more susceptible to toxicity from the pollutants (Inman & Lockwood 1977); higher salinities can also induce enzymes that increase toxicity (El-Alfy et al 1998; El-Alfy & Schlenck 2001).

The Hallett Cove reef, approximately 4.5 km from the proposed discharge site (T Kildea pers comm), has been sampled over the last 10 years through the Reef Health programs. The condition of this reef has consistently been considered to be good with relatively high cover of robust brown algae (such as Ecklonia radiata), very low amount of bare substrate and relatively high amounts of diversity (Cheshire et al 1998; Cheshire & Westphalen 2000; Turner et al 2007).

Sessile organisms are likely to be at greater potential for harm than mobile organisms as it is likely that mobile organisms will move away from poorer quality water. Little is known on the salinity tolerances of habitat forming species such as macroalgae and seagrass, particularly southern Australian species. Bay and Greenstein (1992) tested the effect of elevated salinities on the germination success of the giant kelp Macrocystis pyrifera and the marine amphipod Rhepoxynius abronius. This study found that there was no significant impact on the Macrocystis spores or the amphipods at 43‰ which was the highest salinity tested (Bay & Greenstein 1992).

There is some evidence that seagrasses can tolerate long-term higher salinities including environments in excess of 48‰ such as Port Augusta, SA (Shepherd 1983; Ainslie et al 1994) and Shark Bay WA (Walker et al 1989). In these particular situations the ambient salinity has been slowly elevated and organisms have been capable of maintaining osmoregulation. Koch et al (2006) exposed a number of tropical seagrasses to slowly adjusted salinity changes which showed no adverse impact after 30 days at salinities up to 55–70‰. However when the salinities are suddenly increased the ability for seagrasses to osmoregulate is decreased and the salinity threshold is reached much earlier, eg 45‰ for Thalassia testudinum compared to its gradual increase threshold at 60‰ (Koch et al 2006). While Amphibolis antarctica is the dominant seagrass in Shark Bay. Walker & McComb (1989) have shown that the Shark Bay seedlings have a maximum leaf production rate at 42‰ even when seedlings are collected from areas of higher salinity. This study also showed seedlings were impacted after five days at 65‰ (Walker & McComb 1989).

Seagrass and reef habitats are breeding and nursery areas for many commercial and recreationally captured fish and invertebrate species. There is laboratory based evidence that juvenile survival of Blue Swimmer Crabs (Portunus pelagicus) can be significantly reduced when cultured at 45‰; similarly growth rates have also been shown be significantly reduced at ≥40‰ (Ramano & Zeng 2006), and the post-hatch survival of cuttlefish (Sepia apama) has been shown
to be significantly impacted by salinities of higher than 45‰ (Dupavillion 2008). It is possible that if there is inadequate mixing of a high salinity discharges impacts on recruitment, breeding and survival may be seen. These activities are vital to seagrass and reef health, biological diversity and both commercial and recreational fishing stocks. This may jeopardise localised populations of protected species such as the sygnathids (seahorses and pipefish). Many mobile organisms have the ability to avoid localised areas of poorer water quality or some toxicants (Sprague & Drury 1969). If organisms avoid an impacted region this could create movement of, or barriers to migration routes, change in food sources, alterations to predator prey relationships, spawning cues and aggregations and will impact on community structure of the localised and adjacent ecosystems (Kroon 2005).
5 CLIMATE CHANGE

There are many likely or possible impacts from climate change on the marine environment. As with other aspects in this document it does not fit into the assessment model used in this risk assessment and therefore a risk has not been quantified. Some likely aspects are briefly discussed, although an in-depth risk assessment needs to be undertaken that specifically looks at all aspects of climate change and its impact on the marine environment.

Increased water temperature from climate change

The average temperature of the earth’s atmosphere and oceans rose by approximately 0.6°C over the last century and global ocean temperatures have also risen over the last 50 years, the vast majority of this caused by human activities (IPCC 2001).

The Intergovernmental Panel on Climate Change (IPCC) Scientific Basis Report (2001) states that there are widespread indications of the warming of global oceans at a rate of 0.7 °C over the last century (IPCC 2001). This warming (and subsequent expansion) of the global oceans is expected to continue and have a wide variety of impacts. Higher water temperatures can have both direct and indirect impacts on biological systems, including changes in species distributions or ranges and abundances of some organisms, displacing others from their habitats and causing some to thrive (IPCC 2001) and impacting on ontogenic timing of larvae, and may impact on growth and reproduction, particularly on species that are living close to their temperature threshold (Fine & Franklin 2007). In temperate areas organisms relying on colder waters could be displaced by more sub-tropical species, which could thrive in higher water temperatures. This impact can be seen (on a more dramatic scale) within Angas Inlet in the Port River, which receives water of higher temperature from the AGL Torrens Island Power Station (see section 4.5.1) where studies of the intertidal benthic environment receiving thermal effluent from the power station have shown the presence of several tropical species due to the altered water temperatures (Thomas et al 1986).

Increasing water temperatures can have impacts on fisheries through changes to spawning cues and areas, changes in productivity of breeding and feeding areas, growth rates, migration patterns, food availability and global water circulation currents (IPCC 2001). Similarly aquaculture may be impacted by more stress on organisms, changes to growth rates and the possibly of increased disease and algal blooms (IPCC 2001).

Higher water temperatures could result in increased erosion rates due not only to higher sea level but also due to a rise in intense weather events.

Due to the global nature of climate change and increasing water temperatures, the impacts of these occurrences have been considered together as impacts of increased water temperature from climate change on Gulf St Vincent. However it should be noted that the summary for this risk assessment is extremely brief and there is very high uncertainty regarding in the impacts of climate change on the marine ecosystems within Gulf St Vincent. A detailed assessment of the impacts of climate change has not been carried out for Gulf St Vincent and is outside the scope of this report.

5.1.1 Other impacts of climate change on water quality within Gulf St Vincent

Some of the impacts outlined here have significant linkages to other sections of this risk assessment, and as outlined in section 1 the risks generated in this risk assessment have been assessed under the current situation, ie future climate change will have an effect on many risks but these have not been assessed in previous sections. The impacts are:
• Increase in intense rainfall events leading to an increase in fast-flowing stormwater and riverine runoff carrying more sediment from increased erosion of stream banks and pollutant transport to the marine and coastal environments (IPCC 2001).

• Higher water temperatures with increase algal growth which can exacerbate the impacts on nutrient enrichment leading to more and prolonged algal blooms.

• Increase in likelihood of invasive species establishing by increasing the range of subtropical species and potentially stressing endemic species.

• Increase in atmospheric carbon dioxide slowly reducing the pH and carbonate ion concentrations in global oceans, particularly the Southern Ocean. If this trend continues (in a business as usual scenario) by the year 2050 the Southern Ocean will have an undersaturation of aragonite (a metastable form of calcium carbonate). Aragonite has been shown to experimentally cause a dissolution in some potentially sensitive marine organisms exoskeletons, eg coralline algae, pteropods (a major zooplankton species in Antarctic waters and occasionally at higher latitudes), gorgonians and sea urchins (Orr et al 2005).

• Increase in growth rates and algal productivity (in some regions), which may alter food webs and food availability.

• Sea level rise [(estimated to be between 13−94 cm by 2100 (IPCC 2001)] may cause the deeper extent of seagrass to retreat shorewards in order to maintain the same light intensity. If this retreat is not partnered with an expansion in shoreward seagrass cover (possibly due to increased erosion and increased sediment load from intense weather) the net result will be a decrease in seagrass coverage.

• Macroalgal reef species composition varying markedly based on many factors including depth and water movement (Shepherd & Sprigg 1976). A change in both sea level and an increase in intense weather events may significantly change the composition of macroalgal reefs in Gulf St Vincent (and South Australia).

• Increase in water temperature can have an inhibitory effect on algal recruitment (Turner 2004) as many macroalgal communities are dependant on a specific temperature range.

• Changes in the abundance and distribution (ecology) of many species (Fine & Franklin 2007) caused by temperature triggers affecting reproduction and larval development in many other organisms, which can be impacted by a change in water temperature.
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A risk assessment of threats to water quality in Gulf St Vincent


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A risk assessment of threats to water quality in Gulf St Vincent

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A risk assessment of threats to water quality in Gulf St Vincent


## APPENDIX 2  RISK MATRIX

<table>
<thead>
<tr>
<th>Catastrophic EVs compromised</th>
<th>A5</th>
<th>B5</th>
<th>C5</th>
<th>D5</th>
<th>E5</th>
<th>F5</th>
</tr>
</thead>
<tbody>
<tr>
<td>High level EVs compromised</td>
<td>A4</td>
<td>B4</td>
<td>C4</td>
<td>D4</td>
<td>E4</td>
<td>F4</td>
</tr>
<tr>
<td>Moderate EVs compromised</td>
<td>A3</td>
<td>B3</td>
<td>C3</td>
<td>D3</td>
<td>E3</td>
<td>F3</td>
</tr>
<tr>
<td>Small level EVs compromised</td>
<td>A2</td>
<td>B2</td>
<td>C2</td>
<td>D2</td>
<td>E2</td>
<td>F2</td>
</tr>
<tr>
<td>Minor consequence</td>
<td>A1</td>
<td>B1</td>
<td>C1</td>
<td>D1</td>
<td>E1</td>
<td>F1</td>
</tr>
<tr>
<td>Trivial</td>
<td>A0</td>
<td>B0</td>
<td>C0</td>
<td>D0</td>
<td>E0</td>
<td>F0</td>
</tr>
</tbody>
</table>

### Frequency
- **Daily or more often**
- **Weekly or more often**
- **Monthly or more often**
- **Yearly or more often**
- **Once in 10 years or more often**
- **Once in 100 years**

### Overall risk rating:
- **HIGH**
- **MODERATE**
- **LOW**
APPENDIX 3  EXAMPLES OF APPLYING RISK ASSESSMENT FRAMEWORK

Example 1:  Industrial discharge into Gulf St Vincent
Industry ‘X’ discharges 100 tonnes of ammonia each year into a tidal creek in Gulf St Vincent. The discharge is at the level where it would not be acutely toxic to marine invertebrates or fish but may be causing eutrophication and associated blooms of *Ulva* and microalgae. The discharge is continuous. The tidal creek maintains good flow in and out and has dense beds of *Zostera* seagrass.

Likelihood—Daily or more often (A).

Consequence—This discharge is likely to be compromising ecosystem values by not only exceeding the water quality objectives in the WQEPP but also by potentially lowering dissolved oxygen at night, reducing biodiversity, smothering seagrass and reducing light transmission through the water. The discharge may also be causing environmental harm in the form of increasing algal or aquatic plant growth. The area impacted is restricted to the tidal creek which is approximately 200-500 m². If the discharge was ceased immediately it is estimated that the creek would take less than five years to recover.

Consequence rating—between a moderate and high level compromise of ecosystem and aquaculture values.

Risk Rating—A3–A4, depending on additional site-specific factors.

Overall Risk—This activity is considered to be a High Risk to ecosystem and aquaculture values.

Example 2:  Potential for diesel tank spill
Council ‘Y’ has a large work area to service trucks and vehicles. The area drains into a large stormwater drain, which flows 200 m to the sea. The tank has a 5,000 L capacity, is 10 years old and is located above ground. There is no bunding around the tank.

The receiving environment is ecologically sensitive and there are significant oyster beds in close vicinity.

Likelihood—The likelihood of the tank rupturing and the spill reaching the marine environment is estimated to be one in 10 years (E).

Consequence—This discharge is likely to be compromising ecosystem values by not only exceeding the water quality objectives in the WQEPP but also by potentially causing acute and chronic toxicity to marine organisms and birds including oysters. The discharge would also be causing environmental harm through a reduction in native species (under section 12 of the WQEPP) and would also be likely to significantly impact on the aquaculture in the region. The area impacted would likely be over a wide extent (depending on the actual amount of diesel) and the clean-up and financial loss to the oyster farms would cost greater than $50,000.

Consequence rating—Serious compromise of ecosystem and aquaculture values.

Risk Rating—E4, depending on additional site-specific factors.

Overall Risk—This activity is considered to be a Moderate Risk to ecosystem and aquaculture values.

Example 3:  Stormwater discharge from an urbanised area
Town ‘Z’ has a population of 15,000 people and is located on the shores of an ecologically sensitive region. The ‘wet’ season is typically during winter with occasional heavy summer storms. As with all urbanised areas, cars deposit heavy metals and hydrocarbons onto the roads
between periods of rain. There is also occasional domestic pesticide and herbicide use, and numerous small industries such as car-repair shops, metal fabricators and commercial businesses in the catchment.

**Likelihood**—The likelihood of winter rain events would be monthly or more often (C). The likelihood of a large summer storm would be yearly or more often (D).

**Consequence**—This example will look at the impact of nutrients in urban runoff.

Winter storm: These discharges could typically be 5–10 mm of rain over the catchment with short periods of dry weather between rain events. These discharges may be compromising ecosystem values by possibly exceeding the water quality objectives in the WQEPP and also potentially causing environmental harm through cumulative impacts of eutrophication and algal growth. However winter has shorter day lengths, colder air and water temperatures, which are not optimal for algal growth. The area of impact may be limited to a small area.

**Consequence rating**—small compromise of ecosystem values.

Summer storm: This discharge could potentially be a one-in-one year rain event of approximately 30–50mm or rain during summer. The concentrations of pollutants are typically higher during summer storms due to the longer dry period between rain which allows more material to be deposited onto the catchment. The potential for an impact from nutrients resulting from a summer storm is greater due to the longer day length, warmer air and water temperatures which are more conducive for algal growth. The area of impact would probably be of moderate extent.

**Consequence rating**—Moderate compromise of ecosystem and aquaculture values.

**Risk Rating**—Winter rain: C2* (nutrients only).

Summer rain: D3* (nutrients only).

**Overall Risk**—This activity is considered to be a Moderate Risk to ecosystem and values.
APPENDIX 4  ANNUAL RAINFALL MAP OF SOUTH AUSTRALIA

(Bureau of Meteorology 2008)
APPENDIX 5  NUTRIENT BALANCES BASED ON FERTILISER APPLICATION RATES

Figure 3.12 Farm gate nitrogen balance (kg N/ha) for all land uses combined (averaged 1992 - 1996)

Figure 3.16 Farm gate phosphorus balance (kg P/ha) with all land used combined (averaged 1992 - 1996)

(National Land & Water Resources Audit 2001)
APPENDIX 6 COMMUNITY WASTEWATER MANAGEMENT SCHEMES

Licenced & Unlicensed Wastewater Treatment Plants
Gulf St Vincent

[Map showing licenced and unlicensed wastewater treatment plants in Gulf St Vincent]
APPENDIX 7  EPA PESTICIDE SURVEY SITES

(Jenkins in prep)
## APPENDIX 8  SA WATER WWTP NUTRIENT DISCHARGES

<table>
<thead>
<tr>
<th>Location</th>
<th>1999</th>
<th>2000</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bolivar</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Nitrogen</td>
<td>1,500</td>
<td>1,100</td>
<td>1,000</td>
<td>480</td>
<td>380</td>
<td>460</td>
<td>440</td>
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<td>470</td>
<td>68%</td>
</tr>
<tr>
<td>Ammonia</td>
<td>na</td>
<td>na</td>
<td>na</td>
<td>98</td>
<td>140</td>
<td>62</td>
<td>43</td>
<td>45</td>
<td>27</td>
<td>72%</td>
</tr>
<tr>
<td>Total Phosphorus</td>
<td>210</td>
<td>170</td>
<td>150</td>
<td>130</td>
<td>130</td>
<td>160</td>
<td>190</td>
<td>220</td>
<td>190</td>
<td>9%</td>
</tr>
<tr>
<td><strong>Glenelg</strong></td>
<td></td>
<td></td>
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<td>520</td>
<td>380</td>
<td>340</td>
<td>330</td>
<td>260</td>
<td>270</td>
<td>44%</td>
</tr>
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<td>140</td>
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</tr>
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<td>150</td>
<td>150</td>
<td>140</td>
<td>140</td>
<td>130</td>
<td>120</td>
<td>14%</td>
</tr>
<tr>
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</tr>
<tr>
<td>Total Nitrogen</td>
<td>330</td>
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<td>250</td>
<td>230</td>
<td>240</td>
<td>200</td>
<td>190</td>
<td>180</td>
<td>140</td>
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</tr>
<tr>
<td>Ammonia</td>
<td>na</td>
<td>na</td>
<td>na</td>
<td>170</td>
<td>200</td>
<td>120</td>
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</tr>
<tr>
<td>Total Phosphorus</td>
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<td>79</td>
<td>76</td>
<td>72</td>
<td>63</td>
<td>69</td>
<td>69</td>
<td>71</td>
<td>51</td>
<td>42%</td>
</tr>
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</table>

(NPI 2008)