MARINE ENVIRONMENT 16

16.1 INTRODUCTION

BHP Billiton proposes to obtain sufficient freshwater for the mine expansion by desalinating seawater by reverse osmosis at Point Lowly in Upper Spencer Gulf (see Plate 16.1 and Sections 4.8 and 4.9). The fresh water would be pumped to Olympic Dam, and the return water, containing anti-scalant and increased concentrations of salt, would be returned to Spencer Gulf. Under an arrangement with the South Australian Government, the desalination plant may also supply water to the Upper Spencer Gulf and Eyre Peninsula regions, which currently use water from the River Murray.

Spencer Gulf is a marine embayment that extends 270 km inland from the Southern Ocean. It becomes progressively narrower, shallower and more saline as it extends beyond Point Lowly towards Port Augusta (see Figure 16.1). The unusual combination of relatively warm water, high salinity and sheltered conditions in the northern reaches of Upper Spencer Gulf has led to the presence of communities with tropical and subtropical affinities. The gulf supports a productive marine ecosystem and a diversity and abundance of marine organisms, including listed threatened species, species of particular conservation interest (such as the Australian Giant Cuttlefish), and species of commercial or recreational importance.

Other proposed coastal infrastructure would include a landing facility near Port Augusta to offload large fabricated components during construction (see Section 5.9.5), and upgraded port facilities at Outer Harbor and the Port of Darwin to receive mining and processing consumables and export product.

This chapter:

- describes the guiding principles in site selection and design of the desalination plant to ensure that the dilution and dispersion of the return water results in minimal effects on marine communities
- describes the hydrodynamic modelling and ecotoxicology studies that are used as the basis for the impact assessment
- assesses the impact of return water discharge, construction activities, operation of the landing facility and ports and increased shipping traffic on marine biodiversity, tourism amenity, fisheries and aquaculture
- presents measures to avoid, mitigate or manage impacts on marine communities.

In view of the high ecological importance of the Upper Spencer Gulf marine ecosystem, the impact assessment has adopted a precautionary approach by using conservative assumptions during the hydrodynamic modelling and ecotoxicology studies.

Plate 16.1 Point Lowly

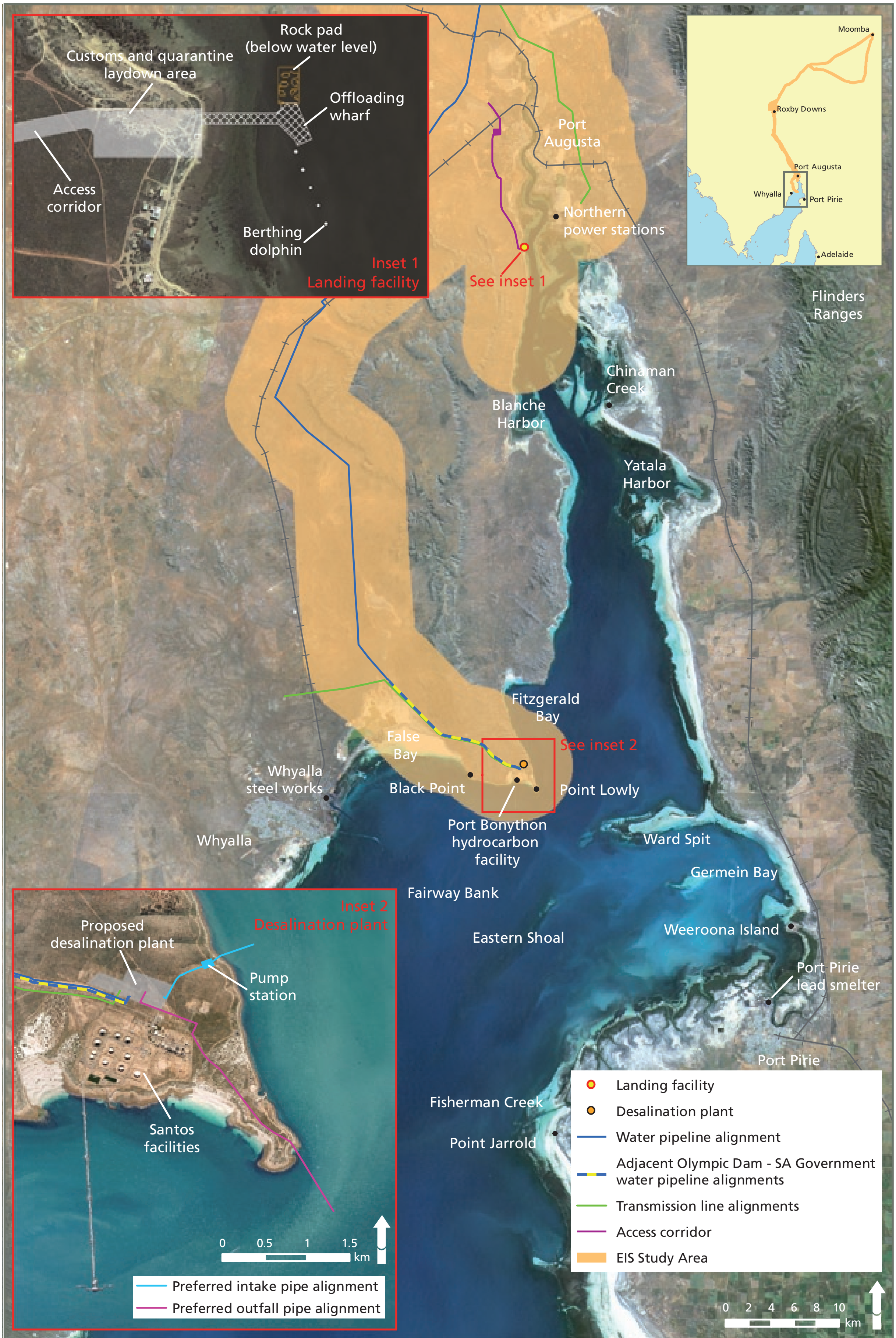

Figure 16.1 Upper Spencer Gulf location map

16.2 ASSESSMENT METHODS

16.2.1 LITERATURE SEARCH

The scientific literature was reviewed for information on the effects of discharges from desalination plants on marine communities, and the sensitivity of marine organisms to increases in salinity. A review was also undertaken of marine fauna, macroalgae, seagrasses and marine habitats recorded in the vicinity of Point Lowly, and more generally in Upper Spencer Gulf. The databases that were collated and reviewed and the major sources of information included:

- Department for Environment and Heritage Biological Database of South Australia (BDSA) extracted 1 August 2008
- Department of Environment, Water, Heritage and the Arts Protected Matters Search Tool (DEWHA 2008a)
- descriptions of the marine environment of Upper Spencer Gulf (e.g. SEA 1981; Shepherd 1983; Bryars 2003; Baker 2004)
- South Australian Research and Development Institute (SARDI) fisheries stock assessment reports.

The species recorded during the marine surveys (see Appendix O1) have been combined with the fish, invertebrate and plant species identified during the literature search to form a list of the marine species recorded or potentially occurring in Upper Spencer Gulf (see Appendix O2) with additional information being provided for listed species (see Appendix O3). Waterbirds are covered separately (see Appendix O4), and further information on Australian Giant Cuttlefish (*Sepia apama*) and other species of recreational or commercial importance is provided in Appendices O5 and O6 respectively.

16.2.2 MARINE SURVEYS

The aim of the marine surveys was to describe the marine communities in sufficient detail to enable potential impacts to be assessed. The surveys were not intended to provide a quantitative baseline against which to monitor potential construction and operational impacts. Seasonal surveys would be carried out during the two to three years prior to construction if the project is approved.

Desalination plant

Marine surveys were undertaken initially over an area extending from 2 km west of the Port Bonython jetty and 2 km south from the tip of Point Lowly. With a change to the preferred intake and outfall locations, the survey area was expanded 2 km north and 2 km east (see Figure 16.2). The initial surveys took place from 10–13 April and 15–16 May 2006, and the additional area was surveyed from 28–29 November 2006. A total of 37 uniformly spaced sites throughout the study area were surveyed at depths ranging from 5–29 m using scuba to assess the distribution and composition of benthic and jetty pile communities. At each of the 37 sites, benthic flora and fauna within 1 m of a 30 m transect placed on the seafloor were identified and video-recorded (see Plate 16.2). The communities of flora and fauna inhabiting the Port Bonython jetty piles near the end of the jetty were also surveyed. Sediment samples were collected at each site and analysed for grain size and a range of contaminants, including arsenic, iron, lead, zinc and hydrocarbons (see Appendix O7, Plate 16.3). Formal surveys of the intertidal habitats were not conducted because it was considered that previous surveys (SEA 1981) provided an adequate description of those habitats. Surveys specific to the Australian Giant Cuttlefish were conducted in June and July 2008 (during their spawning season), and are described in a report by Dr K Hall (see Appendix O5).

Landing facility

Surveys were also carried out at the site of the proposed landing facility during 3–5 August 2007. Surveys were performed along three 200–300 m long transects, located perpendicular to the shore and ranging in depth from about 2 m to 10 m. Benthic communities were surveyed along 30 m secondary transects at three locations along each of the main transects. Sediment samples were also taken at each site. A single transect covering the entire depth range was video-recorded.

In total, more than 100 person-hours were spent conducting marine surveys using scuba. Further details of the methods used during the marine survey are described in Appendix O1.

Plate 16.2 Videoing a transect during the marine survey

Plate 16.3 Collecting sediment for chemical analysis

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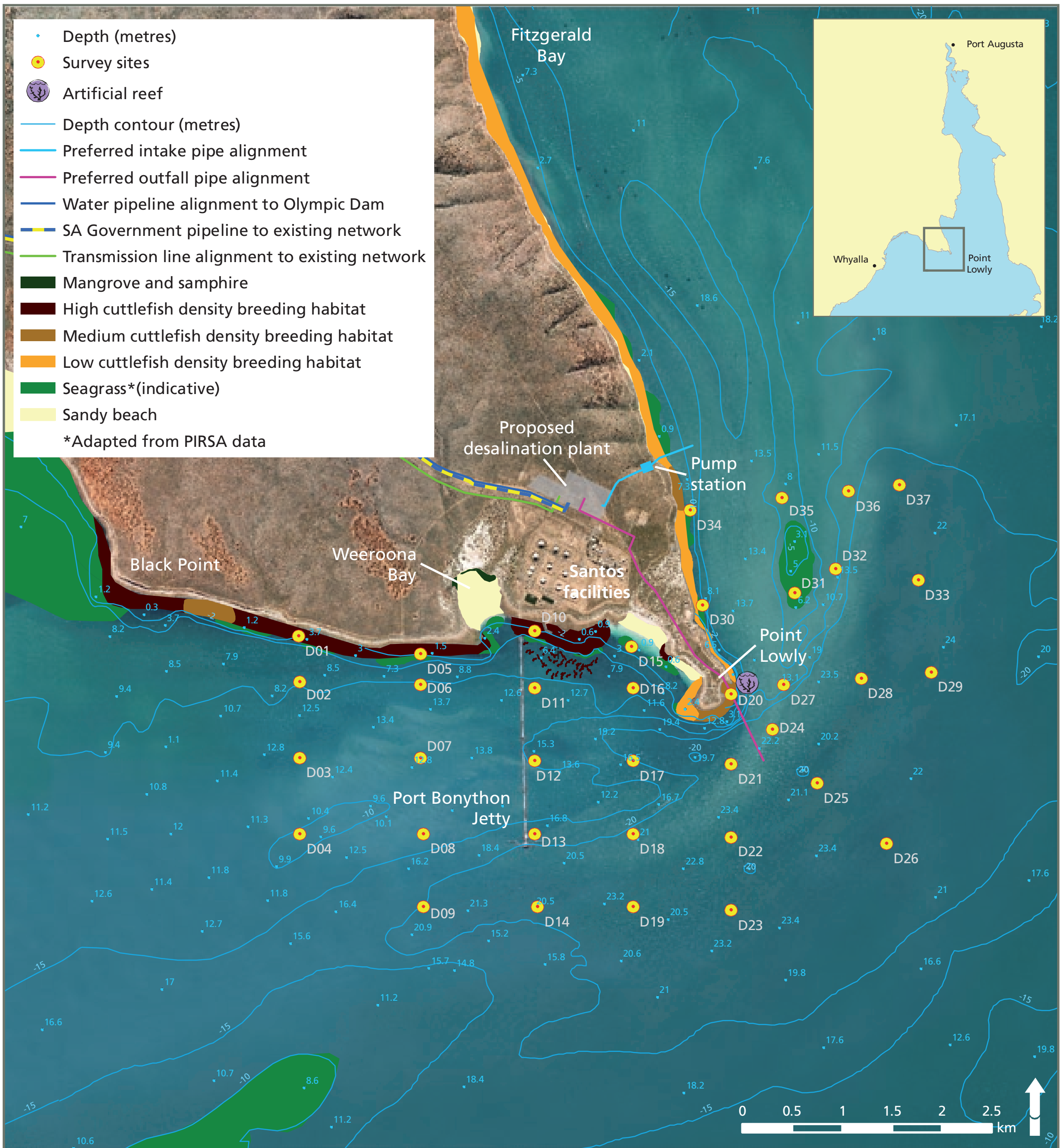

Figure 16.2 Marine benthic survey locations at Point Lowly

16.2.3 ECOTOXICOLOGY STUDIES

The tolerance of marine biota to salinity was reviewed and the results are summarised in Appendix O5 (Australian Giant Cuttlefish) and Appendix O8 (other species).

Laboratory-based whole effluent toxicity (WET) studies were used to determine the toxicity of the proposed return water for a range of species. Over the past decade, WET testing has become an important component of discharge assessment internationally and is included in the ANZECC/ARMCANZ (2000) Guidelines for Fresh and Marine Water Quality. During WET testing, a suite of bioassays is undertaken on species representing different trophic and taxonomic levels to produce a species protection trigger value (SPTV) for a specific discharge.

The WET tests were carried out in two phases. Geotechnical Services (GS), Ecotox Services Australasia (ESA) and the CSIRO Centre for Environmental Contaminants Research (CECR) conducted the first phase of tests in 2006. Hydrobiology Pty Ltd managed all of the 2006 tests except for the Australian Giant Cuttlefish test, which was developed and undertaken by Geotechnical Services. The second phase of tests, which aimed to supplement the 2006 tests, was conducted by Geotechnical Services in 2007 (with support from ESA for the Pacific Oyster test). The accurate measurement of salinity was critical to the correct interpretation of the ecotoxicology results, and was addressed by a further study (see Appendix O9). Methods used for the ecotoxicology tests are summarised below and described in detail in Appendix O10.

Simulated return water was produced by passing seawater sourced from Point Lowly through a portable reverse osmosis plant. The anti-scalant Nalco PermaTreat PC 1020T, which would probably be used in the desalination plant, was added to the seawater at a concentration of 3.6 mg/L prior to desalination. When the design of the plant has been finalised, the WET tests will be repeated to account for any change to the anti-scalant or use of other pre-treatment chemicals. The test solution contained approximately 78 g/L salt and 7.0 mg/L anti-scalant. Diluent was sourced from Point Lowly during late May when salinities are typically 41–43 g/L.

Acute, short-term sub-chronic and chronic WET tests were undertaken. The difference between these tests is mainly the duration of exposure to the toxicant. Acute WET tests generally expose the test organisms for two to three days, short-term sub-chronic (sub-lethal) WET tests expose the test organisms for the same duration but they expose sensitive life-stages, and chronic WET tests are usually conducted over weeks or months. For the purposes of deriving an SPTV, sub-chronic data can be treated as chronic estimates of toxicity.

The rationale for choosing test species was that they:

- represent at least four different taxonomic groups (as required by ANZECC/ARMCANZ 2000)
- are relevant to Upper Spencer Gulf
- have standard, established tests
- are regionally, socially or economically significant.

The tests had two main outcomes:

- they established the sensitivity of individual species to the return water
- they enabled the derivation of a threshold dilution species protection trigger value (SPTV) for the protection of species by combining the results for individual species using a computer program (Campbell et al. 2000), as recommended by the ANZECC/ARMCANZ (2000) Water Quality Guidelines.

The species used and the tests undertaken are summarised in Table 16.1. With the exception of the Australian Giant Cuttlefish *Sepia apama* and Blue Swimmer Crab *Portunus pelagicus*, previously developed and proven ecotoxicology tests were used. For the Australian Giant Cuttlefish, a test was developed in accordance with standard protocols (see 2006 report by Geotechnical Services, Appendix O10, for details) (see Plate 16.4). Australian Giant Cuttlefish eggs, Western King Prawns *Melicertus latisulcatus* and berried (egg laden) Blue Swimmer Crabs *Portunus pelagicus* were sourced from Upper Spencer Gulf and air freighted to Geotechnical Services' ecotoxicology laboratory in Perth. Other biota used in the tests were sourced from commercial hatcheries or from standard laboratory stock. Tests using Yellowtail Kingfish *Seriola lalandi* and Mulloway *Argyrosomus japonicus* eggs/larvae were sourced from hatcheries in South Australia and Western Australia.

16.2.4 RETURN WATER PLUME MODELLING

Model construction

The return water dispersion was modelled by the Centre for Water Research (CWR) and BMT WBM Pty Ltd. Existing information on the oceanography and meteorology of Upper Spencer Gulf was reviewed. Principal sources of oceanographic information were the reports of Nunes (1985), Nunes and Lennon (1986), and Nunes-Vaz and others (1990), which use three years of seasonal oceanographic data to provide a comprehensive understanding of the oceanography of Upper Spencer Gulf. Supplementary data were collected at Point Lowly during the preparation of the Draft EIS to inform and support the modelling (see Table 16.2 and model calibration report, Appendix O11).

These data sets were used to construct three hydrodynamic models (see Figure 16.3):

- A far field, or whole of Spencer Gulf, three-dimensional model, using the Estuary, Lake and Coastal Ocean Model (ELCOM). This model was set up with a 2 km grid (horizontal resolution) with a 2 m vertical resolution to determine salt balances and large-scale circulation patterns within the gulf as a whole. It was calibrated and validated using existing data sets, specifically those of Nunes and Lennon (1986) and Nunes-Vaz and others (1990). The potential accumulation of salt in Spencer Gulf was modelled until a steady state was reached. This model relates to oceanographic timescales of the order of months to years (and decades).
- A mid field model, again using ELCOM, which was nested within the far field model. The mid field model was set up with a 200 m grid with a vertical resolution of 2 m, to determine how the return water disperses within Upper Spencer Gulf. This model task relates to mixing and plume behaviour timescales of the order of hours to months.
- A near field model, using the CORMIX modelling program. The CORMIX model was used to determine how the return water plume behaves within the first 100 m of the diffuser and is principally targeted at assessing the performance of the diffuser design. This model relates to mixing and plume behaviour timescales of the order of minutes to hours.

Plate 16.4 Ecotoxicology studies of Australian Giant Cuttlefish eggs

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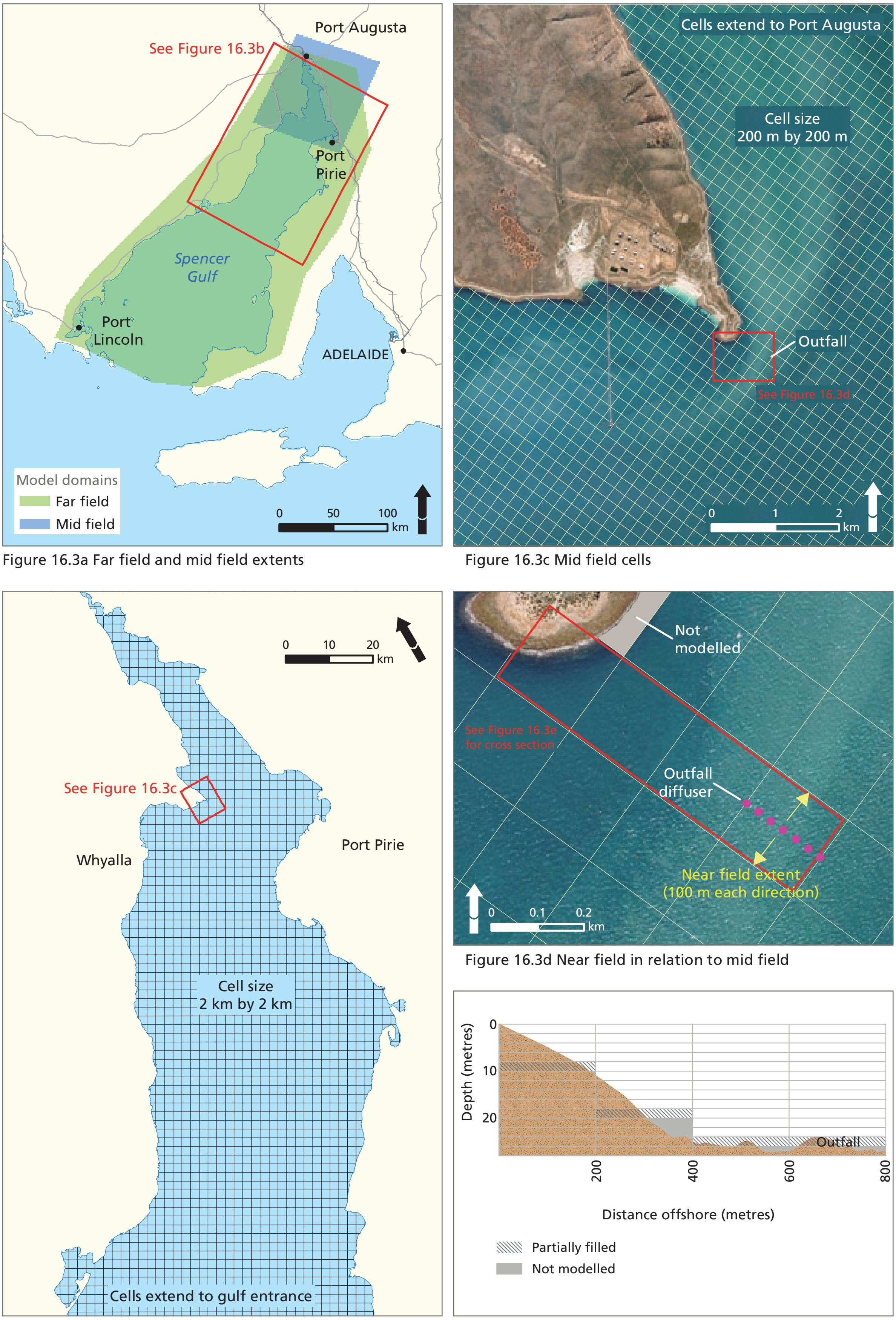

Figure 16.3a Far field and mid field extents

Figure 16.3c Mid field cells

Figure 16.3b Far field cells

Figure 16.3d Near field in relation to mid field

Figure 16.3e Cross-section of mid field cells

Figure 16.3 Near, mid and far field model domains

Table 16.1 Species and tests used during ecotoxicology studies

Species	Present in USG[1]	Test	Description	Laboratory	Year
Microalga *Nitzschia closterium*	Yes	72-hour growth rate inhibition test (chronic)	Widely distributed in Australian waters Widely used in WET testing in Australia and SE Asia	CECR[2], (New South Wales)	2006
Microalga *Isochrysis galbana*	Several unidentified *Isochrysis* species	72-hour growth rate inhibition test (chronic)	Species of the genus *Isochrysis* have been used in toxicity tests for over 15 years	GS[3]	2007
Macroalga Common Kelp *Ecklonia radiata*	No	72-hour germination success (chronic)	Widely distributed throughout SA waters but not found in USG	GS	2007
Macroalga Neptune's Necklace *Hormosira banksii*	Yes	72-hour germination success (chronic)	Widely distributed throughout SA waters Widely used for WET testing in Australia	ESA[4]	2006
Copepod *Gladioferens imparipes*	Unknown	28-day reproduction (chronic), 48-hour pulse exposure	Distribution includes south-western Australia Used in toxicity tests for over 15 years	GS	2007
Tiger Prawn *Penaeus monodon*	No	96-hour toxicity test of 15-day post-larvae (acute)	One of the most widely used tests to assess effluents in Australia	ESA	2006
Western King Prawn *Melicertus latisulcatus*	Yes	21 and 28-day growth tests on juvenile and adult prawns respectively (chronic)	Of significant commercial importance in USG Test developed for this study based on background laboratory work undertaken for aquaculture research	GS	2007
Blue Swimmer Crab *Portunus pelagicus*	Yes	7-day larval growth test (sub-chronic)	Of significant commercial importance in USG Test developed for this study	GS	2007
Pacific Oyster *Crassostrea gigas*	Aquaculture	48-hour larval development (sub-chronic)	Found in temperate waters throughout the world but introduced to South Australia for aquaculture Used in toxicity tests throughout the world for more than 25 years	ESA	2007
Sydney Rock Oyster *Saccostrea commercialis*	No	48-hour larval development test (sub-chronic)	Widely used for WET testing in Australia Pacific Oyster *Crassostrea gigas* that does occur in Spencer Gulf were not spawning during the 2006 testing period	ESA	2006
Sea urchin *Heliocidaris tuberculata*	No	72-hour fertilisation success test (sub-chronic)	Widely used in Australian toxicity assessment programs Sensitive to a range of heavy metals, ammonia and surfactants Distributed on rocky reefs from southern Queensland to central New South Wales	ESA	2006
Yellowtail Kingfish *Seriola lalandi*	Yes	96-hour imbalance test and mortality in 8–12 mm larvae (acute)	Important aquaculture species in Fitzgerald Bay	CECR, Adelaide	2006
Yellowtail Kingfish *Seriola lalandi*	Yes	7-day larval growth test (sub-chronic)	As above	GS	2007
Snapper *Pagrus auratus*	Yes	7-day larval growth test (sub-chronic)	Important commercial and recreational species distributed throughout Spencer Gulf	GS	2007

Table 16.1 Species and tests used during ecotoxicology studies (cont'd)

Species	Present in USG[1]	Test	Description	Laboratory	Year
Mulloway *Argyrosomus japonicus*	Yes	7-day larval growth test (sub-chronic)	Small recreational and commercial quantities caught in USG Juveniles favour estuarine environments	GS	2007
Australian Giant Cuttlefish *Sepia apama*	Yes	Developmental and hatching tests (chronic)	Very important breeding habitat at Point Lowly Tests developed for this study	GS	2006, 2007

[1] Upper Spencer Gulf.
[2] Centre for Environmental Contaminants Research, Commonwealth Scientific and Industrial Research Organisation.
[3] Geotechnical Services Pty Ltd.
[4] Ecotox Services Australia Pty Ltd.

Table 16.2 Oceanographic and meteorological data collected at Point Lowly

Data collected	Instrument used	Location	Time
Current profiles	Bottom mounted acoustic Doppler current profilers (ADCP)	Near the end of the jetty	30 days
Current profiles	Boat mounted ADCP	Seven transects in the vicinity of the jetty, up to 3.3 km long	1 ebb tide
Salinity and temperature	Bottom and surface mounted conductivity/ temperature/ density (CTD) probes	Mid-way along the jetty	1–2 years
Tide levels	Tidal water level gauge	Jetty and marina at Point Lowly	30 days
Wind speed and direction	Meteorological station (and Bureau of Meteorology data for Whyalla)	Jetty	30 days
Bathymetry	Echo sounder	Numerous transects	2–3 days

Model assumptions

The following assumptions were used in the hydrodynamic modelling:

- operational return water discharge rate would be at the peak rate of 370 ML/d (4.3 m^3/s)
- mean salt concentration of the return water would be 75 g/L
- temperature of the discharge would be 1 °C higher than the ambient seawater
- for the mid field model, only the bottom outfall cell is used for initial dilution of the return water (which is conservative because the effluent is discharged under pressure vertically into the water column and may rise up to 7 m above the seafloor) (see final modelling report, Appendix O11)
- return water would be discharged from 50 ports on a 200 m long diffuser located on the seabed, aligned perpendicular to the major current direction and in a depth of at least 20 m.

Model outputs

Thirteen sites were modelled within Upper Spencer Gulf to identify the preferred site for discharging return water. Section 16.5.4 discusses the sites investigated, the criteria used to determine acceptable sites and the findings of the modelling.

For the preferred discharge area near Point Lowly, more extensive modelling was done to assess impacts on adjacent sensitive communities and habitats. These findings are discussed in Section 16.4.3.

Further details of the modelling are provided in Appendix O11.

16.2.5 SILT PLUME MODELLING

Modelling of silt plumes during pipeline construction was undertaken by BMT WBM Pty Ltd using the Estuary, Lake and Coastal Ocean Model (ELCOM), coupled with the Computational Aquatic Ecosystem Dynamics Model (CAEDYM) for simulating sediment deposition and re-suspension processes.

The silt plume modelling objectives were to:

- predict silt deposition depths at cuttlefish habitats
- predict relative total suspended solids and turbidity increases at aquaculture facilities and seagrass habitats.

Sediment sampling along the pipeline alignments was undertaken in order to determine the likely materials to be encountered during construction.

The following key assumptions regarding construction methodology were used to derive sediment entrainment boundary conditions for the silt plume modelling:

- 50 m^3 of excavation per metre of pipeline
- excavation rate of 1,000 m^3 per day over 15 hours commencing 7 am (20 m of pipeline)
- excavation of natural material continues for five days during a 14-day tidal cycle to expose 100 m of trench
- within each 14-day tidal cycle excavation is timed to occur primarily during spring tides and pipe laying activities during dodge tides
- excavated spoil is dumped over the open sections of trench after installation of the pipe.

Further details of the modelling are provided in Appendix O12.

16.2.6 COASTAL PROCESS MODELLING

Modelling of coastal processes in Upper Spencer Gulf was undertaken by BMT WBM Pty Ltd. Effects of the landing facility on sediment transport and coastal dynamics were predicted using three models:

- the Estuary, Lake and Coastal Ocean Model (ELCOM) used to model return water dispersion in Spencer Gulf (see Section 16.2.4) was also applied to model tides and currents in Upper Spencer Gulf
- the Simulating Waves Nearshore (SWAN) model was used to predict the wave climate of Upper Spencer Gulf
- the TRANSPOR model was used to predict sand/sediment movement in the vicinity of the landing facility (see Appendix O13).

16.2.7 IMPACT AND RISK ASSESSMENT

The assessment of impacts and risks for the proposed expansion has been undertaken as two separate, but related processes (see Section 1.6.2 of Chapter 1, Introduction, and Figure 1.11).

Impacts and benefits are the consequences of a known event. They are described in this chapter and categorised as high, moderate, low or negligible, in accordance with the criteria presented in Table 1.3 (Chapter 1, Introduction).

A risk assessment describes and categorises the likelihood and consequence of unplanned events. These are presented in Chapter 26, Hazard and Risk.

16.3 EXISTING ENVIRONMENT

16.3.1 OVERVIEW

Spencer Gulf is a marine embayment that becomes more narrow and shallow as it extends towards Port Augusta. The warm to hot climate, low rainfall, minimal terrestrial run-off and high evaporation result in the northern reaches of the gulf being progressively more saline (see Figure 16.4). The hypersaline conditions (i.e. with a level of salinity much higher than that of seawater) within the northern reaches of the gulf are further elevated by the input of brine from saltpans in the Pirie–Torrens basin, which form an extension of the gulf into the arid north of South Australia (Bye and Harbison 1991). These factors result in the gulf behaving as an ‘inverse estuary’, where the more landward sections of the estuary are more saline.

The unusual combination of relatively warm water, high salinity and sheltered conditions in Upper Spencer Gulf has resulted in the presence of communities with tropical and subtropical affinities, and some species that are endemic to the area (Shepherd 1983). During summer in the northern reaches of the gulf, some species may be under salinity and temperature induced stress (Shepherd 1983). The environmental extremes of Upper Spencer Gulf are evident in its reduced biodiversity compared with southern sections of the gulf (Shepherd and Womersley 1970).

Upper Spencer Gulf supports a highly productive marine ecosystem that is defined by several major habitats, including tidal flats and mangrove woodlands, extensive seagrass meadows in the shallow subtidal zone, intermittent rocky reefs on the west coast and deep channels further off-shore (see Figure 16.5). These habitats support an abundance of marine organisms, some of which are commercially or recreationally important (see Section 16.3.8).

16.3.2 OCEANOGRAPHY

Circulation within Upper Spencer Gulf (particularly north of Point Lowly) is limited. The principal mechanisms for water exchange within the gulf are a combination of tidal, wind driven and thermohaline (density driven) currents (Harbison and Wiltshire 1993). It is estimated that 78% of the water north of Point Lowly is exchanged with water from below that point each year (see Section 16.6.4).

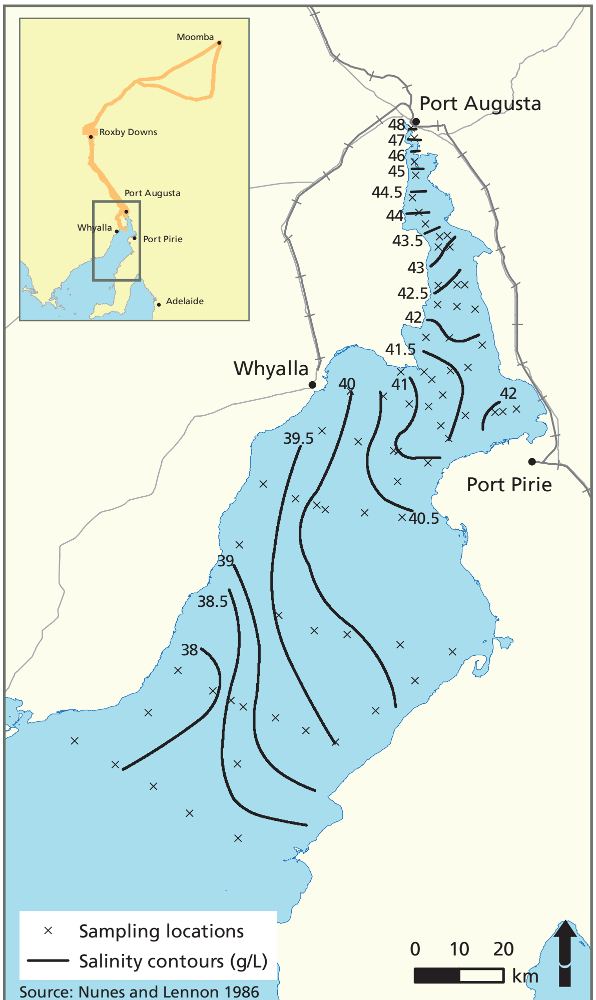

Figure 16.4 Example of salinity gradients within Spencer Gulf (early autumn)

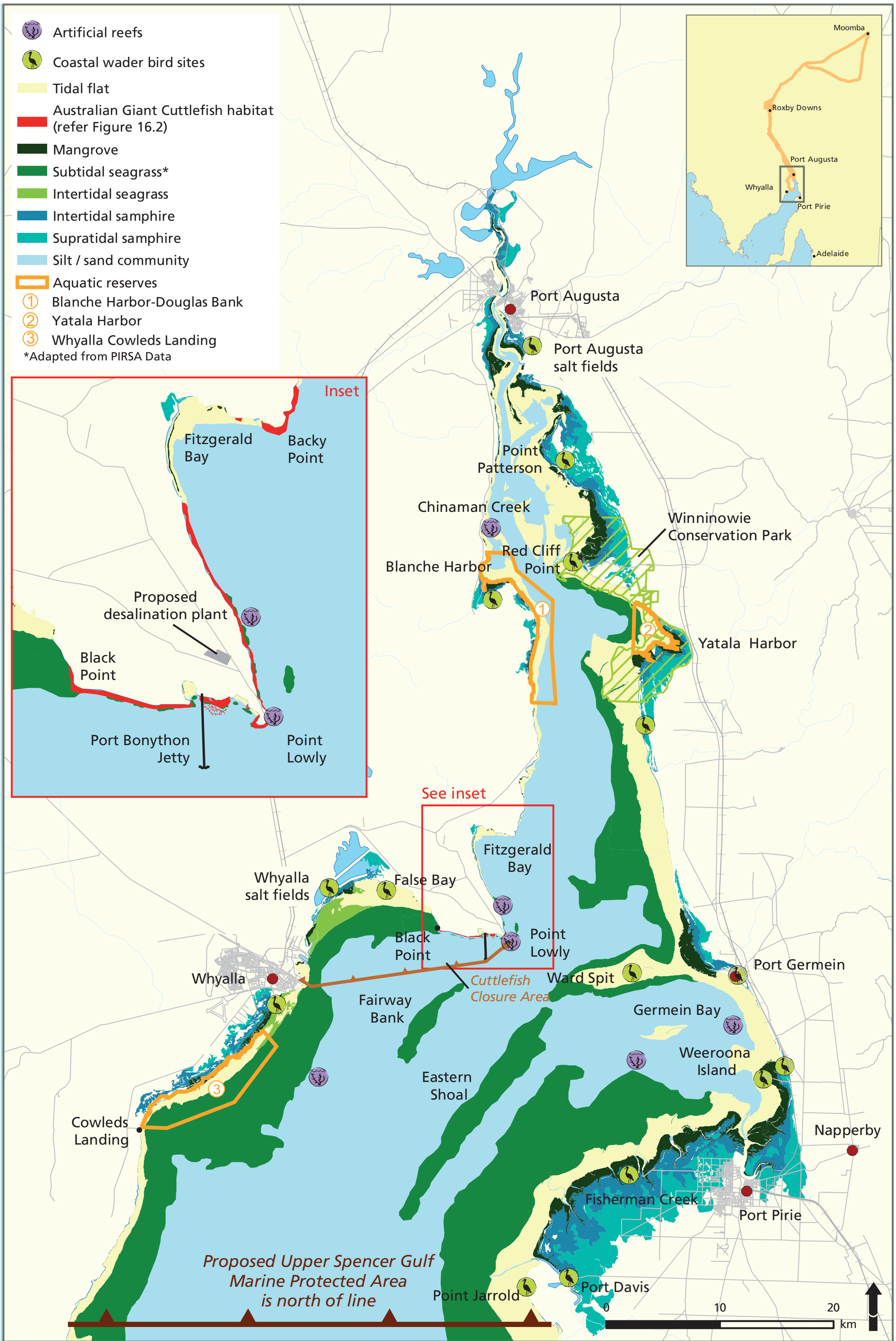

Figure 16.5 Principal marine habitat types and conservation areas in Upper Spencer Gulf

Upper Spencer Gulf is the only location in southern Australia where the shape and depth profiles of the gulf result in significantly greater than expected tides, with ranges of more than 4 m occurring at Port Augusta and 3 m at Point Lowly (compared with less than 2 m at the mouth of the gulf at Port Lincoln) (Noye 1984). Furthermore, the tidal patterns in Upper Spencer Gulf are uncommon; Spencer Gulf and Gulf St Vincent are two of the few coastal areas in the world where there are regular periods of minimal tidal movement. Tides are governed by the interaction of four main constituents (and many minor constituents) related to astronomical forcing, principally by the gravitational effects of the sun and the moon. Two of the main constituents are semi-diurnal (i.e. consecutive high tides are approximately 12 hours apart), and two are diurnal (i.e. consecutive high tides are approximately 24 hours apart). In South Australia, and a few other coastal locations in the world, the similar strength but slightly different period of the semi-diurnal constituents produces an approximately fortnightly cycle in which the semi-diurnal contributions add constructively during spring tides, then almost completely cancel one another during neap tides (known locally as 'dodge' tides), leaving (primarily) the diurnal contributions, producing only one tide per day (see Figure 16.6).

Extreme dodge tides occur every six months when both the semi-diurnal and diurnal constituents cancel one another simultaneously. In Upper Spencer Gulf, this phenomenon occurs in late May and November, and results in tidal ranges of less than 0.5 m (R Nunes-Vaz, consultant oceanographer, pers. comm., 5 May 2008). The combination of small tidal ranges and the longer duration of the diurnal tide during dodge tides results in limited water movement for periods of up to two days.

A narrowing of the gulf between Point Lowly and Ward Spit results in very strong currents in the vicinity of Point Lowly (see Figure 16.1) (an animation for this topic is available at <www.bhpbilliton.com/odxeis> and on the disc accompanying the Executive Summary). In the main channels off Point Lowly and near Fairway Bank, current velocities of 1 m/s are common (Baker 2004). Current velocities in the vicinity of Point Lowly can attain 2 m/s, and rarely fall below 0.05 m/s (see model calibration report, Appendix O11), except during dodge tides when limited water movement occurs. Tidal currents create a local clockwise eddy (circular movement of seawater) to the south of Point Lowly and other unusual circulation patterns near banks and shoals (SEA 1981).

The strong currents off Point Lowly result in relatively high turbidity levels in some areas, particularly the deep channels. Background turbidity levels have been measured off Point Lowly in the range 2–12 NTU during calm conditions, and up to 20 NTU during strong southerly winds when waves re-suspend sediment in the nearshore zone (see Appendix O12).

The annual salinity range at Point Lowly is 40–43 g/L, based on the most reliable historical measurements (see Appendix O9), with the peak in late autumn. The salinity of oceanic seawater is about 35–36 g/L. In addition to the annual variability of 3 g/L at Point Lowly, daily and depth related variability can also exceed 1 g/L (see Section 16.6.2). Annual temperature ranges at Point Lowly are 11 °C to 24 °C.

Variations in temperature and salinity result in the density of seawater ranging from approximately 1,029 kg/m^3 in summer to approximately 1,032 kg/m^3 in winter (Nunes and Lennon 1986; Baker 2004). Dissolved oxygen levels have been measured at 6–10 mg/L near Point Lowly (Johnson 1981; B Gillanders, University of Adelaide, pers. comm., 3 December 2008) and 7.4–8.8 mg/L, 5 km north of Point Lowly in Fitzgerald Bay (P Lauer, PIRSA Aquaculture, pers. comm., 26 May 2008).

There is a distinct north–south salinity and temperature gradient in Spencer Gulf (see Figure 16.4), with salinities at Port Augusta exceeding 48 g/L in summer. Higher levels are reached on shallow tidal flats. This gradient, in combination with the Earth's rotation and Coriolis effect, produces unique circulation patterns in the gulf. A large gulf-scale gyre is formed, whereby hypersaline water exits the gulf along the eastern shore and fresher ocean water enters on the western shore (Nunes and Lennon 1986).

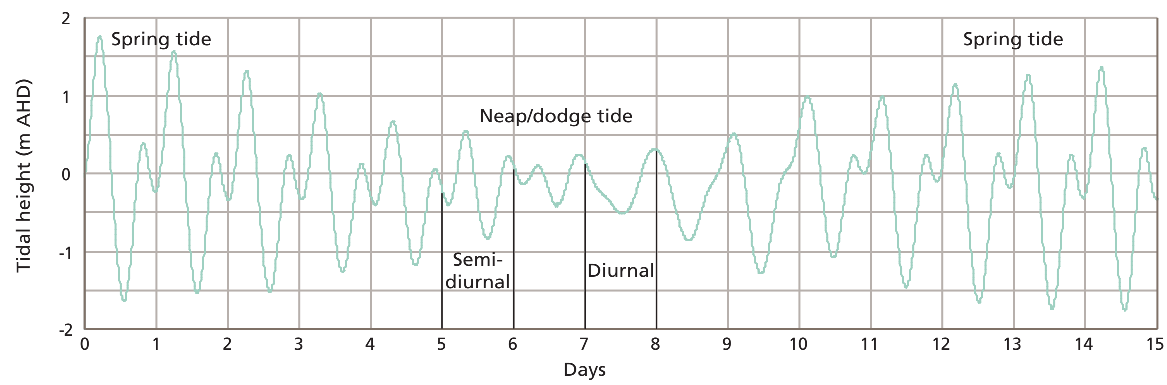

Figure 16.6 Dodge and spring tides

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In winter, thermohaline (density) currents created by the stratification of gulf waters result in the flow of 'slugs' of hypersaline seawater along the seafloor towards the mouth of the gulf (an animation for this topic is available at <www.bhpbilliton.com/odxeis> and on the disc accompanying the Executive Summary). This appears to be the principal means by which hypersaline seawater in the northern reaches of the gulf moves out of the gulf in winter. During summer, these density gradients reverse and the movement of salt from the gulf in this way is blocked (Lennon et al. 1987; Nunes-Vaz et al. 1990) (see Section 16.4.3, far field model reliability subsection, for illustration of seasonal influence on salinity gradients in Spencer Gulf).

Wind-driven currents have a relatively weaker influence on water exchange than tidal currents (Noye 1984; Nunes and Lennon 1986; Nunes-Vaz et al. 1990; Harris and O'Brien 1998).

16.3.3 EXISTING MARINE DISCHARGES

For more than 100 years, Upper Spencer Gulf has supported a number of heavy industries and urban centres that discharge effluent containing a variety of pollutants to the marine environment. The principal pollutant and effluent sources have been reviewed by Brown (2001), NOAA (2002), DEH (2003), EPA (2003a), Baker (2004), AMSA (2005) and the National Pollutant Inventory (DEWHA 2008b), and are summarised in Table 16.3. The marine sediment samples taken from 37 sites off Point Lowly as part of the Draft EIS marine surveys were analysed for particle size distribution and a variety of organic and inorganic contaminants. No samples returned contaminant levels above the Environment Australia (2002a) screening levels (see Appendix O7 for details).

16.3.4 MARINE HABITATS AND BIOTA

The literature search and marine surveys identified a total of 975 marine species that occur or are predicted to occur in Upper Spencer Gulf. These species and their conservation status are listed in Appendices O2 and O3. Species of conservation significance are discussed in Sections 16.3.6 to 16.3.8.

The marine habitats of Upper Spencer Gulf and Point Lowly are discussed in the following sections. Although the descriptions below include waterbird habitats, the impact assessment of the proposed expansion on waterbirds (including migratory birds) is provided in Chapter 15, Terrestrial Ecology.

Upper Spencer Gulf

The principal marine habitats are shown in Figure 16.5 and are defined by:

- the relatively sheltered eastern shore with beach ridges and wide inter-tidal flats, and tidal creeks that are frequently colonised by seagrass, mangrove and samphire communities (inter-tidal seagrass, samphire and mangrove habitats on Figure 16.5)
- the shallow subtidal zone (generally <10 m), which is colonised by extensive seagrass meadows (subtidal seagrass habitat on Figure 16.5)
- narrow deep channels (to 30 m depth) with fine silt, coarse sand and shell grit bottoms, that are dominated by benthic invertebrate communities (silt and sand bottom on Figure 16.5)
- the rocky intertidal zone and shallow reef communities (to 6 m depth) along the west coast that fall away steeply into deep water (reef on Figures 16.2 and 16.5).

Many of these habitats have been identified by Bryars (2003) as breeding and nursery habitat for a number of commercial fish and crustacean species. Some of the intertidal habitats are important to waterbirds. Each habitat supports a distinct assemblage of flora and fauna, including numerous species that have tropical affinities. Although such species have been described as 'relict' (Shepherd 1983; Baker 2004), implying that they are remnants from an earlier period of warmer climate, the relatively young age of Spencer Gulf (<8,000 years) suggests that they are immigrants, perhaps via the Leeuwin Current which originates in the Western Australian tropics and extends to Eyre Peninsula (Ridgway and Condie 2004).

Table 16.3 Existing marine discharges in Upper Spencer Gulf (see Figure 16.1 for locations)

Pollutants	Source(s)	Effects
Heavy metals	Port Pirie lead smelter, Whyalla steelworks, Playford and Northern power stations (Port Augusta)	Bio-accumulation in marine organisms and contamination of sediments
Ammonia/nutrients	Whyalla steelworks, Port Augusta, Port Pirie and Whyalla wastewater treatment plants, shack septic tanks, agricultural run-off, aquaculture discharges	Photosynthetic stress for seagrasses, algal blooms, elevated turbidity, smothering from elevated levels of epiphytes and from particulate matter, loss and decline of seagrass, elevated nutrient levels
Thermal effluent	Playford and Northern power stations (Port Augusta), Whyalla steelworks	Seagrass loss, elevated levels of nuisance algal growth
Dioxins, phenols	Whyalla steelworks	Bio-accumulation in marine organisms and contamination of sediments
Potential oil spills	Port Bonython hydrocarbon processing plant and port facility. Small spills also occur from everyday boating activities, disposal through stormwater drains and run-off from roads	Potential acute impacts on marine biota, particularly intertidal communities
Ballast water	Shipping ports at Port Pirie and Whyalla (ballast water is no longer discharged at Port Bonython)	Discharge of oily ballast water and potential introduction of exotic marine organisms

The supratidal zone of the sheltered, low energy sections of Upper Spencer Gulf is dominated by samphire communities of *Tecticornia* spp. up to 7 km wide. These communities often adjoin the Southern Mangrove *Avicennia marina* community, which occupies the intertidal mudflats and tidal creeks. The Southern Mangrove is usually a tropical species, but remnant communities remain along southern Australian coasts in sheltered locations. The mangrove and samphire communities of Upper Spencer Gulf are the most extensive in South Australia.

The mangrove, samphire and algal mat communities are an important component of the Upper Spencer Gulf ecosystem for several reasons. They form a decompositional environment that is biologically productive (Baker 2004). In particular, they provide feeding, nursery and possibly breeding habitat for a variety of fish and crustacean species, including a number of commercial species, such as the Western King Prawn *Melicertus latisulcatus*, King George Whiting *Sillaginodes punctatus* and Yellowfin Whiting *Sillago schomburgkii* (Jones 1979; King 1979; Bryars 2003). Similarly, the tidal flats and mangrove woodlands fringing the gulf provide nesting and feeding habitat for many species of waterbird (Baker 2004).

The shallow (<10 m) subtidal and lower intertidal regions of Upper Spencer Gulf are dominated by seagrass communities. The dominant species are Eelgrass *Heterozostera nigricaulis*, Garweed *Zostera mucronata* in the intertidal zone, and a succession of subtidal species, including the Tapeweeds *Posidonia australis* and *P. sinuosa*, Wireweed *Amphibolis antarctica*, and Paddleweed *Halophila ovalis* (Harbison and Wiltshire 1993). Extensive tapeweed meadows occur in shallow water in False Bay 5 km west of Point Lowly (see Plate 16.5).

The eastern side of the gulf provides the most suitable seagrass habitat, with the large area of relatively shallow water supporting dense seagrass communities. The western side of the gulf provides less suitable habitat, as the steeply shelving bottom generally limits seagrass distribution to a relatively narrow fringe above a depth of 10 m.

Seagrass communities are the primary source of productivity within the gulf's detritus-based food chain. As such, they support a diversity and abundance of fauna, including infauna (living in the sediment), epibenthic (living attached to the surface of the sediment), epifauna (living attached to other animal substrates such as molluscs) and free-swimming (nektonic) species. Seagrass communities in Spencer Gulf often support a high density of the Razorfish *Pinna bicolor* (see Plate 16.6). Several commercial fish species appear to depend on the shallow seagrass meadows for at least the juvenile stage of their life cycles (Bryars 2003; McDonald 2008). The most important of these are juvenile King George Whiting *Sillaginodes punctatus* and Garfish *Hyporhamphus melanochir*, which feed and shelter in the shallow seagrass habitat (Jones 1979; Connolly 1994a).

Rocky reef habitat is relatively scarce in Upper Spencer Gulf. Some of the near-shore rocky reefs along the west coast of Upper Spencer Gulf support a diverse and abundant community of flora and fauna (see Plate 16.7). Reefs are characterised by a calcareous rock substrate, often with a cover of macroalgae, shell beds and broken-rock bottom (Bryars 2003). The dominant canopy forming brown algae are *Cystophora polycystidea*, *Sargassum spinuligerum*, *Caulocystis* spp. and Corkweed *Scaberia agardhii* (dominant where the substrate changes from reef to sand at a depth of 5–6 m). The understorey consists of the brown lobed alga *Zonaria* sp. and the red algae *Gigartina brachiata*, *Asparagopsis taxiformis* and *Laurencia* spp. The filamentous brown epiphyte *Hincksia sordida* generally appears towards the end of summer, at times completely blanketing the reef, and

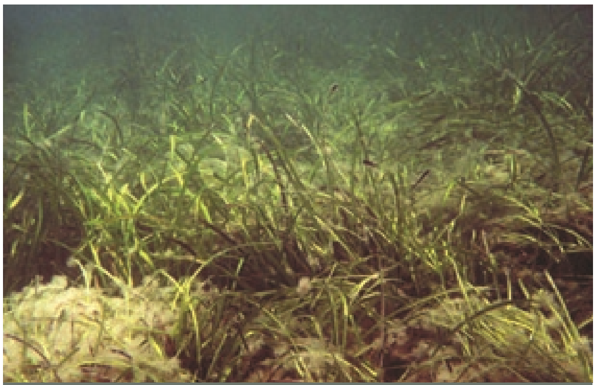

Plate 16.5 Seagrass meadow of *Posidonia australis* and *P. sinuosa* in False Bay

Plate 16.6 Razorfish *Pinna bicolor* off Point Lowly

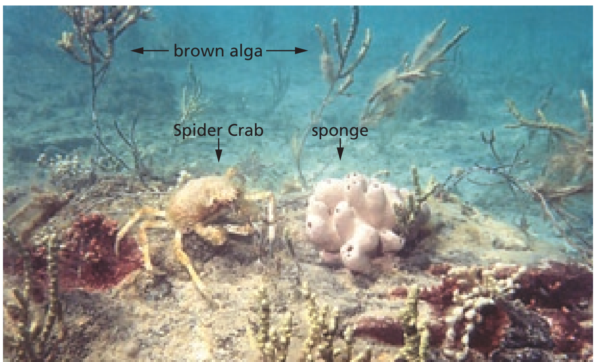

Plate 16.7 Spider Crab *Naxia* sp., sponge and brown alga *Scaberia agardhii* inhabiting shallow reef habitat

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Plate 16.8 Australian Giant Cuttlefish *Sepia apama*

Plate 16.9 Australian Giant Cuttlefish displaying mating behaviour at Point Lowly

Plate 16.10 Australian Giant Cuttlefish eggs attached to substrate at Point lowly

persisting while conditions remain calm. The reefs in the vicinity of Whyalla and Point Lowly are one of the few areas of suitable hard substrate where the Australian Giant Cuttlefish *Sepia apama* can attach their eggs (see Plates 16.8, 16.9 and 16.10).

Deepwater channels (up to 29 m deep) are the most extensive habitat in Upper Spencer Gulf. They extend beyond the maximum depth limit of the seagrass communities (about 10 m), where the silt, coarse sand and shell-grit substrate is generally bare. The strong currents that characterise this habitat result in the fauna being dominated by filter-feeding organisms such as the Razorfish (see Plates 16.11, 16.12 and 16.13). This habitat also supports detritivores, such as the Western King Prawn *Melicertus latisulcatus*, which is an important commercial species in Upper Spencer Gulf, with an annual harvest of 2,000 tonnes worth about $40 million per annum (Knight et al. 2005). Grazing molluscs inhabiting the deepwater habitat off Point Lowly include the Nudibranch *Doriopsilla carneola* (see Plate 16.14).

Introduced marine pests found in Upper Spencer Gulf include the European Fan Worm *Sabella spallanzanii*, the Pearl Oyster *Pinctada albina sugillata* and the Slime Featherduster Worm *Myxicola infundibulum* (see Appendix O2).

Point Lowly ecological survey

A non-seasonal survey of the various marine habitats and communities at Point Lowly was carried out in April, May and November 2006 (see Appendix O1 for details). The survey area extended 4.3 km west and 2 km north of Point Lowly and 2–3 km to sea (see Figure 16.2). Thirty-seven sites were surveyed at depths ranging from 5–29 m, to complement a previous study of the intertidal and shallow subtidal habitats (SEA 1981). Some additional dives were undertaken to clarify habitat boundaries near Point Lowly.

During the survey 167 taxa were identified, 117 of which were recorded on transects. The remainder was recorded through incidental observations during the surveys. The number of taxa identified on any particular transect ranged from eight at D28 to 28 at Site D35. In total, 9,639 animals and 275 linear metres of plant cover were recorded within the 1,100 m of transects surveyed.

Plate 16.11 Soft coral *Carijoa multiflora* growing on a Razorfish

Plate 16.12 Stalked ascidian *Pyura gibbosa gibbosa*

Plate 16.13 Sea Pen *Sarcoptilus grandis* off Point Lowly

Plate 16.14 Nudibranch *Doriopsilla carneola* off Point Lowly

Six distinct marine communities were identified in the vicinity of Point Lowly (see Figure 16.7 for a map and photos, and Appendix O1 for descriptions):

- a sandy intertidal community
- a rocky intertidal and subtidal reef community
- a sparse seagrass community
- a silt/sand community
- a sponge community
- a jetty pile community.

The distribution and extent of each of the marine communities at Point Lowly are influenced primarily by the substratum type, water depth and the amount of water movement. A schematic profile of the communities inhabiting the seafloor, from the reef habitat near the shore at Point Lowly to the deepwater channel habitat 750 m off-shore, is shown in Figure 16.8. More detailed schematic profiles of communities at representative survey sites (including the sponge and jetty pylon communities) are shown in Appendix O1.

Taxonomic diversity was similar across the three depth ranges sampled, but the diversity of plants and animals differed substantially according to depth (see Appendix O1). Plant diversity declined while animal diversity increased with increasing depth. Overall, the mean diversity of animals was almost twice that of plants.

Patterns of abundance were similar to those of diversity across the three depth ranges but were more pronounced. Average plant cover varied from 68% (depths <10 m) to 25% and 5% for sites at greater depth (11–20 m and 21–30 m, respectively). Conversely, the mean number of animals at deep sites (approximately 320 per m^2) was nearly three times greater than at shallow sites (approximately 120 per m^2).

Multivariate analysis was used to distinguish differences between biological assemblages at each of the survey sites (see Appendix O1). Clear differences in the assemblages at sites in different depth categories were evident. Shallow sites along the shoreline (<10 m deep) were the most distinct group and differed more from each other than sites between 11–20 m and 21–30 m. Communities at sites in intermediate depths were more similar to each other than those among both shallow and deep sites. The sponge community, found at Site D24 at 27 m depth (see Figure 16.2, and Plate 16.15) was quite distinct from other sites.

Plate 16.15 Sponge *Aplysina lendenfeldi* off Point Lowly

Landing facility ecological survey

A survey of the marine habitats and communities in the vicinity of the proposed landing facility south of Port Augusta was undertaken in August 2007. Twelve 30 m transects were surveyed.

In all, 62 taxa were identified from the surveys. Depths (adjusted for tide) ranged from intertidal (0 m) to 10 m. Sediment varied from sand to muddy substrate. Three distinct marine communities, primarily influenced by the substrate type and water depth, were identified (see Appendix O1 for details):

- an intertidal/upper subtidal community with adjacent mangroves
- a shallow, dense seagrass community
- a mid-depth (6–10 m), muddy sediment community.

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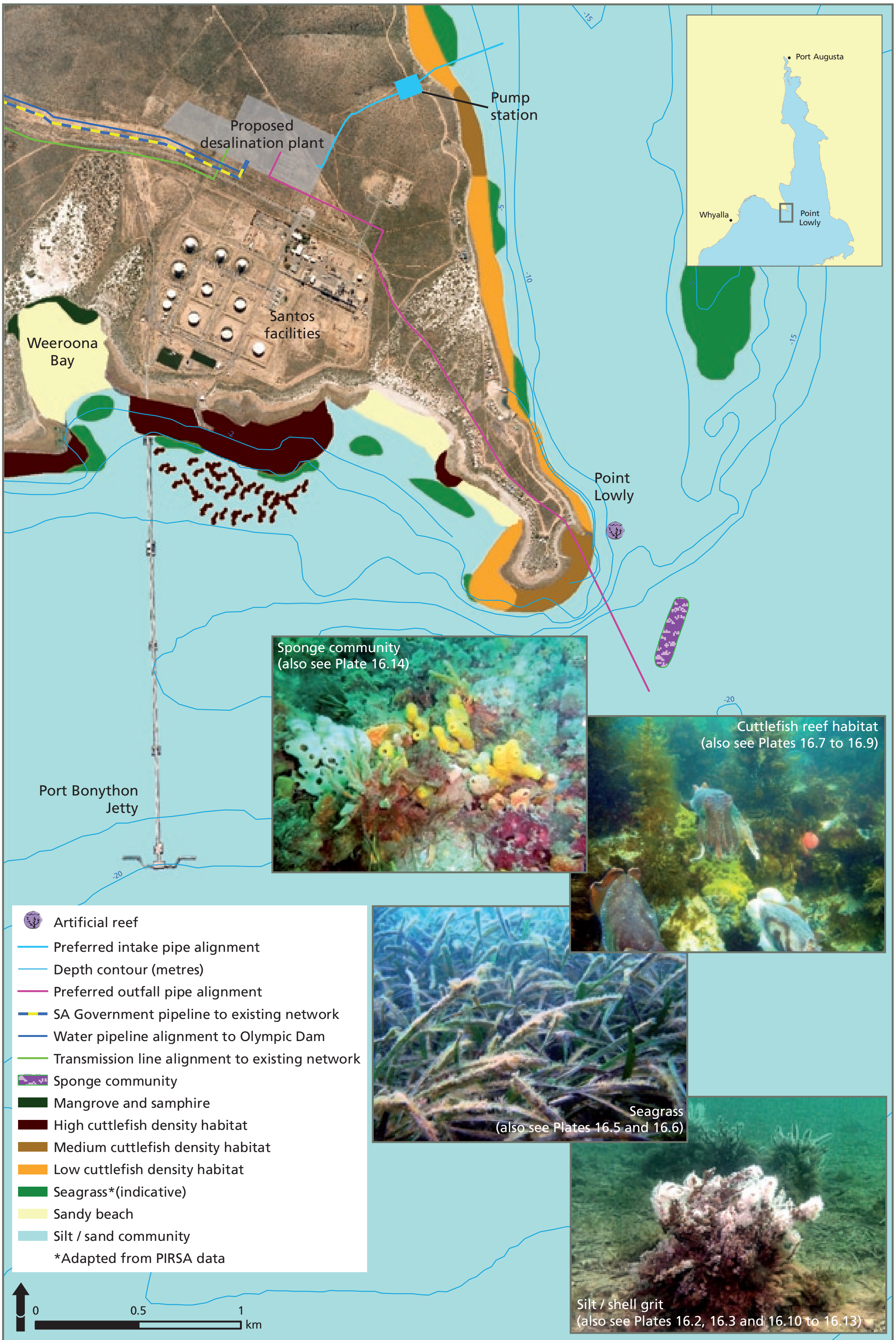

Figure 16.7 Subtidal habitats around Point Lowly

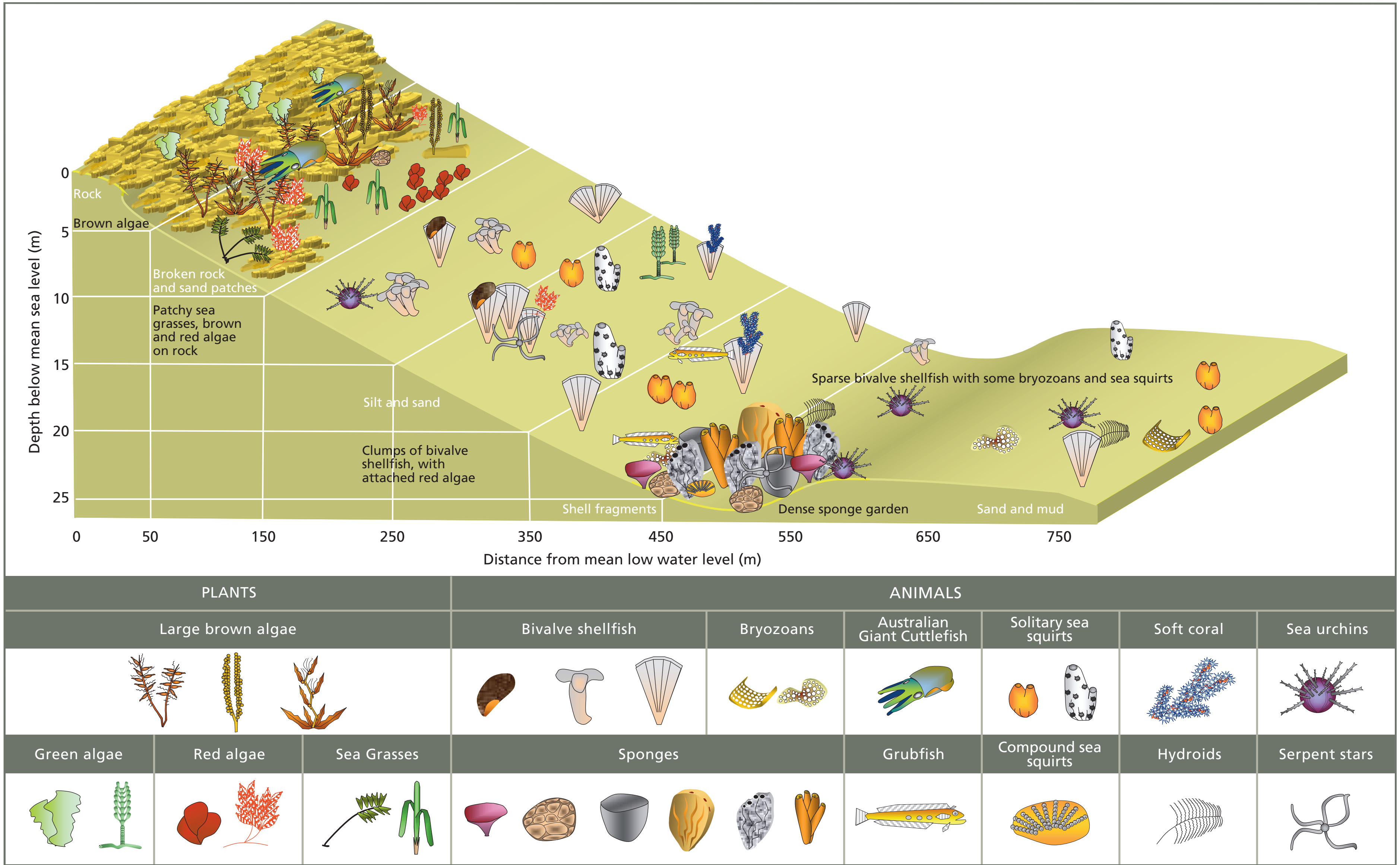

Figure 16.8 Schematic transects of biota at Point Lowly

16.3.5 LISTED MARINE SPECIES

Nationally threatened (endangered or vulnerable) marine species occurring or potentially occurring in Upper Spencer Gulf include the Southern Right Whale *Eubalaena australis*, Humpback Whale *Megaptera novaeangliae*, Australian Sea-lion *Neophoca cinerea*, Great White Shark *Carcharodon carcharias*, Loggerhead Turtle *Caretta caretta*, Green Turtle *Chelonia mydas,* Hawksbill Turtle *Eretmochelys imbricata* and Leatherback Turtle *Dermochelys coriacea* (see Table 16.4 and Appendices O2, O3).

Nationally listed marine species occurring or potentially occurring in Upper Spencer Gulf include two seal species, 24 species of Syngnathid (seahorses and pipefish) and eight whale and dolphin species. Of the 24 nationally listed Syngnathids, 16 species have been recorded in Upper Spencer Gulf (see Appendices O2, O3).

In addition to the nationally listed species above, state listed marine species occurring in Upper Spencer Gulf include the cetaceans Pygmy Right Whale *Caperea marginata*, Pygmy Sperm Whale *Kogia breviceps*, Dusky Dolphin *Lagenorhynchus obscurus* and Strap-toothed Whale *Mesoplodon layardii*, all of which are listed as rare (Appendices O2, O3). The seagrass *Zostera mucronata* is also listed as rare.

Potential impacts and proposed management strategies for threatened species are addressed in Section 16.6.5.

Table 16.4 Listed threatened marine species that may occur in the vicinity of Point Lowly

Species	Status	Description
Southern Right Whale *Eubalaena australis*	Endangered (Aus[1]), Vulnerable (SA[2])	Southern Right Whales are found throughout the southern hemisphere (Reilly et al. 2008a). Although numbers are small (approximately 7,000 animals total), substantial recovery is expected with continued protection (Reeves et al. 2003). Increasing numbers of the Southern Right Whale visit South Australian waters each winter to mate, calve and nurse their young. They are most common in coastal waters near Victor Harbor and the Great Australian Bight, and occasionally visit Upper Spencer Gulf. In 2001, divers from Whyalla Diving Service rescued a juvenile Southern Right Whale that had become entangled in crab nets in Fitzgerald Bay in Upper Spencer Gulf (T Bramley, Whyalla Diving Services, pers. comm., 4 August 2007). Southern Right Whales feed on krill in Antarctica.
Humpback Whale *Megaptera novaeangliae*	Vulnerable (Aus, SA)	Humpback Whales are found throughout the world and follow annual migration patterns. They usually feed during summer in arctic waters, and mate and calve during winter in warmer tropical waters. With the cessation of commercial whaling, Humpback Whale populations are recovering from near extinction to populations numbering thousands of animals (Clapham et al. 1999). They seem able to tolerate living close to a considerable variety and amount of human activities (Reilly et al. 2008b). During winter 2006, a number of Humpback Whales entered Upper Spencer Gulf and moved to within several kilometres south of Port Augusta (Australian Broadcasting Commission 2006). Humpback Whales feed on krill in Antarctica.
Australian Sea-lion *Neophoca cinerea*	Vulnerable (Aus, SA)	Australian Sea-lions are endemic to Australian waters and breed on at least 50 islands off the coast of Western and South Australia (Australian Museum 2003). Populations of the Australian Sea-lion were decimated during the 19th century, and their numbers remain relatively low. They are observed regularly during winter and spring in Upper Spencer Gulf where they feed on cephalopods and fish (Morelli and de Jong 1996, cited in Baker 2004).
Great White Shark *Carcharodon carcharias*	Vulnerable (Aus)	The Great White Shark is distributed throughout temperate and sub-tropical regions in the northern and southern hemispheres (Environment Australia 2002b). Population studies suggest that the abundance and average size of Great White Sharks have declined over the last 40 years (Fergusson et al. 2000). They are known to frequent marine fish farming operations. Great White Sharks are widely but sparsely distributed throughout southern Australia and have been recorded in Upper Spencer Gulf. Great White Sharks feed on cephalopods, fish, rays, other sharks, turtles, sea birds, sea-lions and seals (Environment Australia 2002b; CSIRO 2007).
Loggerhead Turtle *Caretta caretta*	Endangered (Aus, SA)	Turtles are in general widely distributed throughout the tropics and subtropics. They migrate from northerly parts of Australia, perhaps attracted to the relatively warm waters in the gulfs, but do not breed or reside in southern Australia. Turtles have been observed seasonally in Upper Spencer Gulf (Morelli and de Jong 1996; Robinson et al. 2000; DEH 2000 and 2003 cited in Baker 2004). Loggerhead Turtles are primarily benthic carnivores (DEWHA 2008c).
Green Turtle *Chelonia mydas*	Vulnerable (Aus, SA)	Green Turtles have been observed seasonally in Upper Spencer Gulf (see Loggerhead Turtle). They have a specialist sponge diet (DEWHA 2008d).
Hawksbill Turtle *Eretmochelys imbricata*	Vulnerable (Aus)	Hawksbill Turtles have been observed seasonally in Upper Spencer Gulf (see Loggerhead Turtle). They are herbivorous (DEWHA 2008e).
Leatherback Turtle *Dermochelys coriacea*	Vulnerable (Aus, SA)	Leatherback Turtles have been sighted in southern Spencer Gulf. They are carnivorous and feed mainly in the open ocean on jellyfish, squid and other soft-bodied invertebrates (DEWHA 2007, 2008f).

[1] Listed under the EPBC Act.
[2] Listed under the *South Australian National Parks and Wildlife Act 1972*.

16.3.6 AUSTRALIAN GIANT CUTTLEFISH

Although the Australian Giant Cuttlefish *Sepia apama* is not a threatened species, it is of particular conservation significance in Upper Spencer Gulf (see Appendix O5 for further details).

The rocky reef habitat near Whyalla and Point Lowly (see Figures 16.2, 16.7) attracts the only known mass aggregation of spawning cuttlefish in the world (R Hanlon, Marine Biological Laboratory, Woods Hole, North America, pers. comm., 6 June 2007). Between May and September each year, tens to hundreds of thousands of Australian Giant Cuttlefish migrate to the shallow rocky reefs between Whyalla and Point Lowly in Upper Spencer Gulf to breed. Point Lowly is one of the few locations in Upper Spencer Gulf where the reef habitat contains sufficient crevices and caves to receive large numbers of cuttlefish eggs. At the peak of the season, cuttlefish can reach densities of more than one cuttlefish per square metre near Black Point (Hall and Hanlon 2002). It attracts tourists, researchers and hundreds of recreational divers each year, and contributes to the local tourist industry. The spawning aggregation is recognised as one of the more significant and spectacular events in Australian marine waters by national and international marine biologists (R Hanlon, Marine Biological Laboratory, Woods Hole, North America, pers. comm., 6 June 2007).

The Point Lowly population is one of five genetically distinct populations existing in southern Australia, and has minimal interbreeding with the nearest population just north of Wallaroo. The Point Lowly and Wallaroo populations have some features of separate species such as genetic separation, separate but adjacent distributions and differences in morphology that may indicate ecological differentiation (B Gillanders, University of Adelaide and S Donnellan, South Australian Museum, pers. comm., 11 December 2007).

Knowledge of the biology of the Australian Giant Cuttlefish is largely limited to winter when they migrate inshore to spawn (Lu 1998). Males are known to weigh up to 6.2 kg and measure up to 52 cm along the mantle (Gales et al. 1993), making *Sepia apama* the largest species of cuttlefish in the world. Cuttlefish are carnivorous, opportunistic and voracious predators (Lee et al. 1998). They grow rapidly, but probably die after reproducing only once (termed semelparity), after perhaps one to two years. During the spawning period, males compete for females with elaborate visual displays involving complex behavioural interactions. Each female lays hundreds of eggs, which are attached to a rocky substrate under ledges or in caves, and hatch approximately four months later, with the latest in early November (Hall and Fowler 2003). Juveniles feed on small crustaceans prior to moving off-shore. Little is known about the subsequent life history of the juvenile cuttlefish until their return as adults in the following season to breed.

With the establishment of a commercial market in 1997, the spawning aggregation near Whyalla was targeted by fishers and the annual catch of *Sepia apama* increased from approximately four to 250 tonnes (Steer and Hall 2005). Over-exploitation quickly occurred and the population of cuttlefish near Whyalla declined severely in the ensuing years (T Bramley, Whyalla Diving Services, pers. comm., 6 June 2007). Australian Giant Cuttlefish are vulnerable to over-exploitation as they are short-lived and only reproduce once, resulting in no accumulation of spawning biomass from one generation to the next (Steer and Hall 2005). Recognising the threat to the cuttlefish aggregation, the South Australian Government imposed a seasonal closure in 1999, banning the collection of cuttlefish or related species from an area between the Point Lowly Lighthouse, the Port Bonython Jetty and the OneSteel jetty at Whyalla (see Figure 16.9). The seasonal closure was expanded to a year-round closure in 2004.

Following the introduction of the closures, the cuttlefish biomass in the Whyalla/Point Lowly region remained relatively stable between 1999 and 2001 at approximately 200 tonnes (Steer and Hall 2005). A survey in 2005 indicated that the biomass of cuttlefish had decreased by approximately 33% since the previous (2001) survey (Steer and Hall 2005), contrary to anecdotal evidence of increased abundance over the same time period (T Bramley, Whyalla Diving Services, pers. comm., 6 June 2007). Anecdotal observations from the 2006 and 2007 seasons suggest both increased abundance and return of larger animals (M Norman, Curator of Molluscs, Museum Victoria, pers. comm., 14 March 2008). A recent survey in 2008, however, recorded much lower numbers of cuttlefish in the aggregation area (less than half the abundances from 1999 to 2001) (see report by Dr K Hall, Appendix O5). Although the lower numbers in 2008 may partially reflect natural population variation in response to irregular environmental conditions (such as extended warmer water temperatures and excessive growth of *Hincksia* sp.), they may also indicate a real decline in the population since 2001. Annual surveys are required to enable more definite conclusions to be drawn on the status of the population.

16.3.7 OTHER SPECIES OF CONSERVATION SIGNIFICANCE

The subtropical marine conditions in Upper Spencer Gulf have resulted in regionally atypical marine communities that have tropical or subtropical, rather than temperate, affinities. As a result, Upper Spencer Gulf supports numerous species that are of conservation significance, but have no formal status at present. Recommendations have been made to protect a number of these species (Cheshire et al. 2000; Baker 2004). The most important of these are listed in Appendix O2, and include:

- ten species of plants, macroalgae, fish and invertebrates that have tropical or subtropical affinities, and disjunct or relict populations in Upper Spencer Gulf
- two species of invertebrates that are endemic to Upper Spencer Gulf, and a further four that are endemic to Spencer Gulf
- twelve species of fish and invertebrates that have limited distributions or are uncommon (Baker 2004).

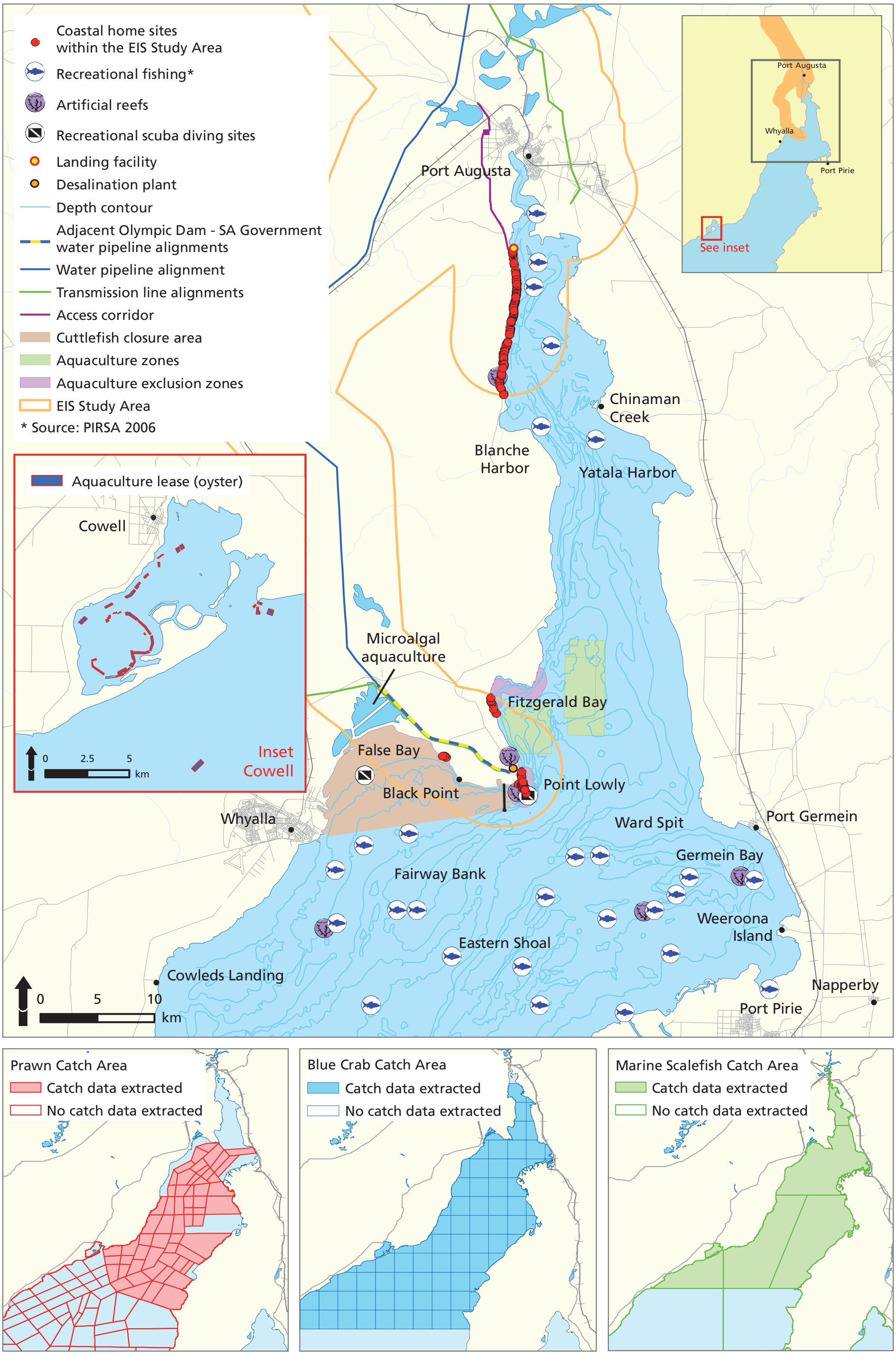

Figure 16.9 Principal fisheries and aquaculture in Upper Spencer Gulf

The sponge community off Point Lowly identified in Section 16.3.4 is also of regional conservation significance as it is one of the most diverse and dense communities of its kind in Upper Spencer Gulf (see Appendix O2 for the list of 13 sponges identified), and its extent is limited to only several hectares.

16.3.8 COMMERCIAL AND RECREATIONAL FISHERIES

Upper Spencer Gulf supports an important commercial and recreational fishing industry (see Table 16.5 and Figure 16.9). The zone between Whyalla and Port Pirie is particularly productive, with over 6,000 tonnes caught annually (Knight et al. 2005).

The principal species caught in Upper Spencer Gulf are the Australian Herring (or Tommy Ruff) *Arripis georgianus*, Australian Salmon *Arripis truttacea*, Blue Swimmer Crab *Portunus pelagicus*, Garfish *Hyporhamphus melanochir*, King George (or Spotted) Whiting *Sillaginodes punctatus*, Western King Prawn *Melicertus latisulcatus*, Snapper *Pagrus auratus*, Snook *Sphyraena novaehollandiae*, Southern Calamary *Sepioteuthis australis*, Yellow-eye Mullet *Aldrichetta forsteri* and Yellowfin Whiting *Sillago schomburgkii*. The Australian Sardine *Sardinops sagax* and four other Clupeoids are also caught in Spencer Gulf. Further descriptions of these species are provided in Appendix O6.

These species depend on the shallow seagrass and mangrove habitats for at least part of their life cycle (see Figure 16.5 for the location of these habitats). Most of them are caught within or near the seagrass meadows, which they use as feeding and refuge habitat. Two important species, the Western King Prawn and Snapper, are caught in the deepwater channels of Upper Spencer Gulf.

16.3.9 AQUACULTURE

Over the past 20 years, the aquaculture industry in South Australia has expanded rapidly and become a significant export industry. The sheltered, relatively clean waters of Spencer Gulf provide ideal conditions for aquaculture. Two important aquaculture species in Spencer Gulf are Yellowtail Kingfish *Seriola lalandi* (PIRSA 2003a) and the Pacific Oyster *Crassostrea gigas* (PIRSA 2003b).

Commercial culture of Yellowtail Kingfish commenced in South Australia in 1998 when a successful hatchery was established at Port Augusta. Since then, the industry has undergone rapid expansion, with commercial hatcheries located at Port Augusta and Arno Bay, and sea cage grow-out facilities established at Port Lincoln, Cowell, Arno Bay and Fitzgerald Bay (Hernen and Hutchinson 2003; PIRSA 2003a; DAFF 2004). The economic value of the Yellowtail Kingfish industry on Eyre Peninsula (grouped with abalone, mussel and other aquaculture excluding tuna or oysters) was reported to be about $26m in 2005–2006 (EconSearch 2007).

The Yellowtail Kingfish aquaculture farms in Fitzgerald Bay are located approximately 5 km north of Point Lowly (see Plate 16.16). Aquaculture in Fitzgerald Bay is governed by the Fitzgerald Bay Aquaculture Management Policy (PIRSA 2004b) that established a shellfish zone, two aquaculture exclusion zones and two finfish zones, of which the eastern zone provides for the long-term development of the finfish farming industry in the region (see Figure 16.9).

Leases for the culture of the Pacific Oyster have been established in Spencer Gulf off Port Broughton and Cowell, both located at least 50 km south of Point Lowly (see Figure 16.9). In 2005–2006, the economic value of the Pacific Oyster industry on Eyre Peninsula was $47m (35% of the value of the industry in South Australia) (EconSearch 2007).

Plate 16.16 Aquaculture leases in Fitzgerald Bay

Table 16.5 Commercial and recreational fisheries in Upper Spencer Gulf (USG) – summary of principal habitats, catch and percentage share of USG catch in South Australia

Species	Habitat[1]	Description/Comments	Average catch tpa (USG % in brackets)	
			Commercial[2]	Recreational[3]
Western King Prawn *Melicertus latisulcatus*	sb, m	Spencer Gulf supports one of the largest prawn fisheries in Australia. Trawling occurs within 1 km of Point Lowly. Most of Upper Spencer Gulf is regarded as a prawn nursery. Very high densities of prawn larvae occur between Whyalla and Germein Bay. High densities of juvenile prawns occur on tidal flats such as False Bay (Carrick 2003). There is no significant recreational fishery (Dixon et al. 2007).	1,439 (67%)	
Blue Swimmer Crab *Portunus pelagicus*	s, sb, tf, tc, m	The recreational catch in Spencer Gulf is relatively high. Adult crabs are reported to move into shallow inshore waters in Spencer Gulf to spawn (Smith 1982).	359 (60%)	213 (55%)
Snapper *Pagrus auratus*	r, s, sb	Upper Spencer Gulf accounts for the highest proportion of the commercial and recreational catch of Snapper in SA. At Point Lowly, Snapper are frequently caught in the deep channels close to shore. The main spawning grounds are reported to be the northern reaches of Spencer Gulf. Juveniles forage on bare, muddy tidal flats (Fowler et al. 2007).	242 (46%)	277 (66%)
Garfish *Hyporhamphus melanochir*	r, s, sb, tf, tc, m	Garfish are generally associated with shallow inshore regions of Spencer Gulf. They spawn in all areas of Spencer Gulf that support the seagrasses *Zostera* and *Posidonia*. Little is known about their nursery grounds.	139 (37%)	12 (8%)
Yellowfin Whiting *Sillago schomburgkii*	sb, tf, tc	Yellowfin Whiting are found throughout the inshore tidal sand/mud flats of Spencer Gulf. While adults are found throughout these waters, juveniles are confined to the central and more northern waters. They are not generally found in seagrasses, but do indirectly derive some food from them (K Jones, PIRSA, pers. comm., 9 September 2008).	126 (80%)	41 (56%)
Calamary *Sepioteuthis australis*	r, s, sb	Upper Spencer Gulf is one of the most productive calamary fishing regions in the state (Steer et al. 2005). Calamary generally breed in shallow water and attach their eggs to the leaves and stems of seagrass (SEA 1981).	78 (22%)	46 (12%)
Australian Herring (Tommy Ruff) *Arripis georgiana*	r, s, sb, tf, tc, m	Australian Herring are far-ranging migratory fish with a westward migration along southern Australia to the lower west coast of Western Australia prior to spawning. Recreationally, Spencer Gulf is the second most important area after Gulf St Vincent.	84 (43%)	43 (15%)
King George Whiting *Sillaginodes punctatus*	r, s, sb, m	The King George Whiting catch from Spencer Gulf fishery is the second largest after the Far West Coast, contributing 35% of the South Australian commercial catch. Only 12–15% of the catch, however, is from Upper Spencer Gulf (McGarvey et al. 2005).	51 (12–15%)	85 (18%)
Snook *Sphyraena noveaehollandiae*	sb	Snook are distributed across southern Australia. They are normally a by-catch of haul nets, but are also taken by commercial troll line fishers. The recreational fishery also targets Snook. Upper Spencer Gulf accounts for the highest proportion of the recreational catch of Snook in South Australia (Jones and Doonan 2005).	30 (31%)	26 (28%)
Australian Salmon *Arripis truttacea*	r, s, sb, tf, tc, m	Australian Salmon are far-ranging migratory fish that often inhabit the waters of Upper Spencer Gulf as juveniles. Juveniles typically inhabit shallow sand flats and *Posidonia* seagrass meadows (SEA 1981).	14 (6%)	26 (7%)
Yellow-eye Mullet *Aldrichetta forsteri*	r, sb, tf, tc, m	Yellow-eye Mullet are distributed across Southern Australia. The majority (70%) of the catch comes from the Lakes and Coorong fishery, with about half of the remainder coming from Spencer Gulf. Schools of Yellow-eye Mullet occur in brackish and inshore coastal waters and tidally inundated saltmarsh. Larger Yellow-eye Mullet show a preference for deeper habitats such as channels or 'gutters' on beaches, whereas juveniles remain in the shallow bank sections of estuaries and beaches (Higham et al. 2005).	19 (11%)	3 (7%)
Australian Giant Cuttlefish *Sepia apama*	r	See Section 16.3.6.	10 (70%)	

[1] Fisheries habitats are identified as seagrass meadow (s), unvegetated soft bottom (sb), tidal flat (tf), tidal creek (tc), mangrove forest (m) and reef (r), directly used during the lifecycle of each species (Bryars 2003).
[2] Sources for Commercial Fisheries catch included SARDI data request obtained 5 Sept 2006 and Knight et al. (2005, 2006) specifically for the fishery regions specified in Figure 16.9 between 2001–2002 and 2004–2005.
[3] Sources for recreational information included the National Recreational and Indigenous Fishing Survey 2000–2001 (Jones and Doonan 2005) and for Snapper, Fowler et al. (2007).

The microalga *Dunaliella salina* is cultured commercially in approximately 400 ha of hypersaline lakes between Whyalla and Point Lowly. Natural betacarotene and key dietary carotenoids, used in animal feeds and for human consumption, are extracted from the algae, which are harvested from up to one million litres of brine per hour (Cognis 2008). The industry had a value of $2.5m in 2005–2006 (O'Sullivan et al. 2008).

16.3.10 MARINE AND COASTAL PROTECTED AREAS

Under the *Fisheries Act 1982* (now the *Fisheries Act 2007*), three aquatic reserves have been declared in Upper Spencer Gulf. These are shown in Figure 16.5 and include:

- Yatala Harbor Aquatic Reserve
- Blanche Harbor – Douglas Bank Aquatic Reserve
- Whyalla – Cowleds Landing Aquatic Reserve.

The closest aquatic reserve to the proposed Point Lowly desalination plant is the Blanche Harbor–Douglas Bank Aquatic Reserve, which is about 20 km to the north.

A total of 1.6% of the marine habitat within Upper Spencer Gulf north of Point Lowly is protected. Sand, reef, benthic mud and seagrass habitats are poorly represented within the current marine protected areas (Baker 2004).

Three Conservation Parks or Reserves in Upper Spencer Gulf have been proclaimed under the South Australian *National Parks and Wildlife Act 1972*, and have important roles in protecting coastal habitats and species. These are:

- Winninowie Conservation Park (7,897 ha) – located about 23 km north of Point Lowly (see Figure 16.5)
- Munyaroo Conservation Park (12,392 ha) – located about 50 km south of Point Lowly
- Munyaroo Conservation Reserve (7,810 ha) (Baker 2004) – located about 55 km south of Point Lowly.

Four areas within Spencer Gulf have been identified by the South Australian Department for Environment and Heritage (DEH) (2003) as being of high conservation value. These are:

- Far Upper Spencer Gulf (listed threatened species/habitats, aesthetics, biodiversity and social values)
- Whyalla – Cowleds Landing (biodiversity, social and cultural values)
- Point Lowly (biodiversity and social values)
- Germein Bay – Port Davis – Fishermans Bay (biodiversity, rare and endangered species/habitats and social values).

DEH is currently developing a system of ecologically representative marine protected areas in South Australia (DEH 2008). Upper Spencer Gulf has been identified as one of the 19 representative areas across the State to be designated as a 'Marine Park'. The formal boundaries and rules governing the use of each Marine Park are yet to be declared under the *Marine Parks Act 2007*. However, it has been proposed that all of Upper Spencer Gulf north of Point Jarrod be included in a Marine Park (see Figure 16.5) (Baker 2004). Each Marine Park will be divided into zones, with controls applicable to each of those zones determining what activities and level of development may be permitted.

A Draft Marine Plan for Spencer Gulf developed within the Marine Planning framework by DEH was released for comment in 2006. The Draft Plan originally proposed the use of acceptable levels of impact and recovery times as part of the assessment approach (DEH 2006). However, the Draft Plan is currently under extensive review on the basis of feedback received. It is currently uncertain whether or not the same approach will be adopted in developing any subsequent marine plans, and therefore has not been considered further in the Draft EIS assessment.

16.3.11 OUTER HARBOR

Outer Harbor is, and would continue to be, an important shipping port for the Olympic Dam operation. The Port River is a highly industrialised and urbanised estuary, consisting of a network of tidal channels surrounded by mangrove *Avicennia marina* woodland and samphire *Tecticornia* spp. low shrubland. Despite being highly disturbed, the estuary remains ecologically valuable, and supports a diversity and abundance of marine life (Kinhill Stearns Pty Ltd 1985; PPK Consultants 1992; Connolly 1994b).

Fish and crustacean species of commercial and/or recreational importance frequent the estuary. Seventy species of fish are known to inhabit it (Ferguson 1986). In particular, Barker Inlet provides extensive nursery habitat for numerous species, including the Western King Prawn *Melicertus latisulcatus*, King George Whiting *Sillaginodes punctatus* and Yellowfin Whiting *Sillago schomburgkii* (Jones 1984; Jones et al. 1996).

The estuary also provides habitat for 30–50 resident Bottlenose Dolphins *Tursiops aduncus* and large populations of waterbirds, including the White Faced Heron *Ardea novaehollandiae*, Great Egret *Ardea alba* and Sacred Ibis *Threskiornis aethiopicus*. The Australian Sea-lion *Neophoca cinerea*, listed as Vulnerable under the EPBC Act, has also been recorded within the estuary (DEH 2007b).

The ecological importance of the estuary was formally recognised in 1973 with the proclamation of the Barker Inlet Aquatic Reserve, and the St Kilda–Chapman Creek Aquatic Reserve in 1980 (Jones 1984; Neverauskas and Edyvane 1993). The importance of the estuary as dolphin habitat was recognised in 2005 with the proclamation of the Adelaide Dolphin Sanctuary, which encompasses most of the estuary, including the section adjacent to the existing BHP Billiton port facilities (DEH 2007a) (see Figure 16.10).

Figure 16.10 Port Adelaide and associated vegetation types and reserves

Ongoing industrial and urban discharges have resulted in poor water quality in the estuary (EPA 1997). The high prevailing nutrient levels result in regular algal blooms and the proliferation of the Sea Lettuce *Ulva* spp. The introduction of exotic marine organisms to the estuary, mainly via the disposal of ballast water and on the hulls of ships, has been of considerable concern (DEH 2007b). These include the invasive seaweeds *Caulerpa taxifolia* (introduced by aquarium release) and *C. racemosa*, the European Fan Worm *Sabella spalanzanii*, the European Shore Crab *Carcinus maenas*, the New Zealand Greenlip Mussel *Perna canaliculus*, the ascidian *Ciona intestinalis*, the bryozoans *Zoobotryon verticillatum* and *Bugula flabellata* and the toxic Dinoflagellates *Gymnodinium* spp. and *Alexandrium* spp. (EPA 2003b; DEH 2007b).

Further and more recent degradation of the water quality resulted from a large dredging program, which deepened the shipping channel to an average depth of 14.2 m. Impacts were considered to be increased water turbidity leading to seagrass loss and the further spread of *Caulerpa racemosa* (Tanner 2004).

16.3.12 PORT OF DARWIN

Significant new infrastructure developments in and around Darwin has seen the relocation of the Port of Darwin from the capital city to East Arm (see Figure 16.11). East Arm handles bulk materials, containers, supply boats, fuel and acid tankers. The facility is located in Darwin Harbour about 4 km south-east of Darwin.

Darwin Harbour is a sheltered, naturally turbid embayment (Currey 1988) that supports about 3,000 invertebrate species (Russell and Hewitt 2000), about 440 fish species and rich communities of marine invertebrates and reptiles, including six species of sea turtle (DEWR 2006). The harbour is an important area for recreational fishing, with target species including Snappers/Emperors *Lutjanus* spp., Whiting *Sillago* spp., Tuskfish *Choerodon* spp., Barramundi *Lates calcarifer*, Trevallies *Carangidae* spp., Jewfish *Protonibia diacanthus* and Mud Crab *Scylla serrata* (Coleman 1998).

The harbour supports intertidal mudflats and the most extensive and diverse mangrove communities (20,000 ha and 36 species) in the Northern Territory (Brocklehurst and Edmeades 1996). The nearest mangrove communities to the proposed facilities lie immediately north of the existing rail line to East Arm (see Figure 16.11).

Nationally listed species (under the EPBC Act) potentially occurring within Darwin Harbour include the threatened Humpback Whale *Megaptera novaeangliae*, Whale Shark *Rhincodon typus*, two species of sawfish and the six marine turtle species. Migratory species including dolphins (three species) and Dugong *Dugong dugon* are regularly observed.

16.4 RETURN WATER CHARACTERISTICS, TOXICITY AND DISPERSION

To determine the potential impact of return water from the desalination plant on the marine environment, it is first necessary to consider:

- the physical and chemical characteristics of the return water
- the toxicity of the return water to local marine organisms
- the dispersion of the return water at scales ranging from within a hundred metres from the outfall to the whole of Spencer Gulf.

16.4.1 RETURN WATER CHARACTERISTICS

The desalination process

Desalination by reverse osmosis involves pumping filtered seawater through a series of polyamide membranes (see Chapter 5, Description of the Proposed Expansion, for details). Between 40–45% of the seawater passes through the membranes creating the product water, leaving most of the salt in the remaining 55–60% of the flow as 'concentrated seawater' or brine. The return water (a term used to describe the combination of concentrated seawater and anti-scalant that would be discharged into Upper Spencer Gulf) from the desalination plant would contain a maximum of 78 g/L salt[1] compared with about 41–43 g/L in ambient seawater in late autumn and 40–41 g/L in spring in the vicinity of Point Lowly. Typical flow rates and physical properties of return water are presented in Table 16.6. To provide context, an Olympic size swimming pool contains 2.5 ML.

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Table 16.6 Flow rate and physical/chemical characteristics of the intake and return water

Parameter	Seawater intake		Product water		Return water discharged	
Volume (ML/d)	Average	Maximum	Average	Maximum	Average	Maximum
	560	650	251	280	309	370
Salinity (g/L)	40–43		0.3		75–78	
Density (kg/m³)	1,028–1,032				1,056–1,058	
Temperature (°C)	Ambient				Ambient + 1	
pH	7.6–8.9				6.5–7	
Total suspended solids (mg/L)	5		0		2–10	
Dissolved oxygen (mg/L)	6–10				5.5–7	

[1] The major elements of 'salt' are sodium, chloride, magnesium, calcium, potassium, sulphate and bicarbonate ions, but there are many tens of trace elements (Turekian 1968; Drever 1982).

Figure 16.11 Key components of the proposed expansion – Port of Darwin, East Arm

Table 16.7 lists the chemicals routinely added to the intake seawater and their respective functions in the reverse osmosis process (see also Figure 16.12). All of the chemicals, with the exception of the anti-scalants, are commonly used in traditional domestic water treatment plants and discharged with treated waste water. It is noted that the list of chemicals is indicative and may change as a result of ongoing testing and design modifications.

Anti-scalants

The reverse osmosis process can precipitate salts which deposit as scale on the membranes and reduce their effectiveness. Scale is controlled by the addition of acid and/or organic, carboxylic-rich anti-scalant polymers. The anti-scalant used for the processing of the simulated effluent was Nalco PermaTreat PC 1020T, which is an organophosphonate compound. Although most of these compounds are described as being 'inherently biodegradable' (S Lattemann, University of Oldenburg, pers. comm., 26 March 2008), they can have relatively long residence times in coastal waters (Lattemann and Höpner 2008). Prior to this study, no ecotoxicity studies have been conducted on Nalco PermaTreat PC 1020T (Nalco 2006).

Anti-scalants generally have relatively low toxicity to fish and invertebrates, but can deprive algae of micro-nutrients (through the formation of metal complexes) rather than being directly

Table 16.7 Potential chemical additives used in the reverse osmosis desalination process

Main types of additives	Chemical	Dose (mg/L)	Frequency	Dosing point	Purpose	Disposal
Anti-scalant	Anti-scalant (organophos-phonate or other)	4	Continuous	Filtered seawater	Used to prevent scale accumulating on membranes	Sea
	Sulphuric acid (H_2SO_4)	15	Continuous	Raw seawater	Acid can also be used to minimise scale build up and for pH adjustment to improve reverse osmosis performance	Sea
Biocide	Chlorine (Cl_2 or hypochlorite salts ClO^-)	8 (indicative only)	Daily for one hour (indicative only)	Raw seawater	Control of biological growth in pipes	Chemically neutralised
	Sodium metabisulphite ($Na_2S_2O_5$)	24 (indicative only)	Daily for one hour (indicative only)	Filtered seawater	Removal of free chlorine from reverse osmosis feedwater	Chemically neutralised
Coagulants/ flocculants	Cationic polymer	0.2	Continuous	Raw seawater	Flocculation to remove suspended solids	Land (minor to sea)
	Ferric chloride ($FeCl_3$)	10	Continuous	Raw seawater	Coagulation to remove suspended solids	Land (minor to sea)

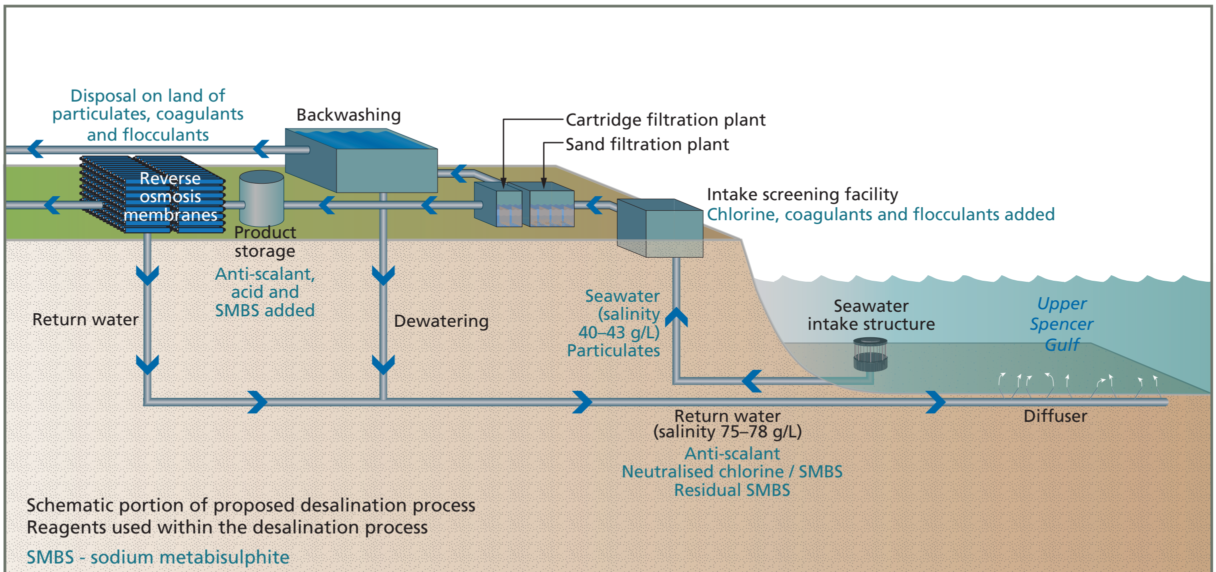

Figure 16.12 Chemicals in and out of the desalination plant

toxic (S Lattemann, University of Oldenburg, pers. comm., 26 March 2008).

The addition of acid lowers the return water pH to approximately 7 (compared with ambient seawater pH of 8). It is anticipated that ambient seawater would rapidly buffer the return water, resulting in a pH of above 7.6 being achieved near the outfall.

The ongoing development of anti-scalants that are even less toxic may result in new chemicals becoming available over the next few years. Newly developed anti-scalants may therefore ultimately be used in the desalination plant if they prove to be operationally more effective and/or environmentally more benign.

Biocide

Chlorine would be added to feedwater, possibly as a shock dose for about one hour each day, to minimise the growth of biota in pipes and other equipment. Neutralisation of chlorine using sodium metabisulphite would occur before feedwater entered the reverse osmosis unit because modern reverse osmosis membranes are sensitive to oxidising chemicals such as chlorine. However, some residual sodium metabisulphite, and possibly trace concentrations of halogenated organic by-products of chlorine (Lattemann and Höpner 2008) may be discharged to the sea.

Coagulants/flocculants

Particulates and colloidal material are removed from raw seawater by a filtration process before being treated by reverse osmosis. Coagulants (e.g. ferric chloride) and flocculants (cationic polymers) would be added to the seawater to assist the removal of suspended matter (i.e. silt and phytoplankton). Filter backwash would occur approximately daily, and result in the generation of a significant volume of backwash solids. Unless removed, ferric chloride can cause intense reddish discoloration of the discharge and receiving water (Lattemann and Höpner 2008). Backwash solids and associated coagulating and flocculating agents would be settled in ponds or filtered centrifugally prior to the residual liquid being discharged to sea. The solids would be dried in evaporation ponds and periodically removed for off-site land disposal at an appropriate licenced facility. Following the removal of most coagulants and flocculants, the residual liquid would be virtually benign.

Heavy metals

Seawater contains low concentrations of dissolved heavy metals that are concentrated approximately twice during the desalination process. Heavy metals may also result from the corrosion of metallic pipes/fittings within the desalination plant, and usually include traces of copper, iron, nickel, chromium and molybdenum.

Although many heavy metals are necessary for the maintenance of metabolic processes in all organisms, at higher concentrations they can adversely affect marine organisms.

At the prevailing pH in seawater, most metals within the intake water would be adsorbed onto particulates and removed by the pre-treatment process (media filtration and 5 μm cartridge filtration). Trace concentrations of metals arising from corrosion would be discharged in the return water. As with most metals, they would generally adsorb onto particulates, which would eventually be deposited into the sediments in the low energy sections of Upper Spencer Gulf (sediment sinks).

Dissolved oxygen

The dissolved oxygen saturation level (holding capacity) of the intake water would range from 7–8.5 mg/L due mainly to seasonal effects of salinity and temperature, but recorded levels at Point Lowly range from 6–10 mg/L (i.e. can be supersaturated).

Not much respiratory uptake of oxygen by fouling organisms growing in the intake pipes is expected to occur because the pipes would be regularly dosed with biocide (chlorine). The regular addition of sodium metabisulphite to remove the chlorine biocide would result in dissolved oxygen levels in the intake water being reduced to near zero for short periods.

The return water, however, would subsequently be thoroughly re-aerated as it passed over weirs into an outlet tank before being discharged (see Plate 16.17). The aerated water is expected to be saturated, although the increased salinity (and slightly increased temperature) of the return water would reduce its saturation level by about 1.5 mg/L.

Plate 16.17 Overflow weir to discharge outlet tank

Sterilisation of the intake water by filtration before reverse osmosis, and the high concentration of salt in the return water, would limit the potential for growth of fouling organisms in the outfall pipe.

It is concluded that the dissolved oxygen concentration of the return water would range from 5.5–7 mg/L.

Membrane cleaning waste

Every three to four months, the reverse osmosis membranes would be chemically cleaned *in situ* to remove deposits of mineral scale, biological growth or particulates.

The cleaning solutions may include acids, bases, detergents, biocides and complexing agents (which reduce salt build up on the membrane surface by binding with metallic ions to form a soluble complex). After use, the wastewater would be collected and directed to evaporation ponds adjacent to the desalination plant, where the water would evaporate and the solids would be collected and disposed of to a licenced landfill.

16.4.2 TOXICITY ASSESSMENT OF THE RETURN WATER

The toxicity of return water is influenced by increased salinity, chemical additives used in the desalination process (e.g. anti-scalant) and the concentration of toxicants that could be present in the intake water.

Background to salinity effects

Effects of increased salinity are a primary (but not the only) concern associated with the toxicity of return water. Elevated salt concentrations may adversely affect the behaviour, physiology and community structure of marine biota (WEC 2002) (see Appendices O5, O8).

Mobile species may avoid areas of increased salinity by emigrating to less saline waters. This may result in long-term changes to community structure in areas with persistently elevated salinity (Hendrix et al. 1981; California Coastal Commission 1993).

The physiological effects of elevated salinity relate principally to osmoregulation, which is the mechanism by which organisms maintain a relatively constant internal salinity. Osmoregulation requires considerable expenditure of energy, which may be at the expense of growth and development when salinity is high (Paulij et al. 1990; Sang and Fotedar 2004). Elevated salt levels may result in dehydration of cells, a decrease of turgor pressure and in extreme cases death of the organism (Einav et al. 2002). For many marine species, the eggs, larvae and juveniles are more sensitive to elevated salt levels than adults (Kinnetic Laboratories 2005).

The World Health Organisation (2007) suggests that a '10% increment above ambient ocean salinity is a conservative measure of aquatic life tolerance to increase in salinity'. It is noted that this value is a first approximation that should be refined using toxicity testing (S Lattemann, University of Oldenburg, pers. comm., 26 March 2008).

Average salinities in Upper Spencer Gulf range from 40 g/L at Point Lowly in late winter to more than 48 g/L at Port Augusta in summer. Many species that are distributed throughout Upper Spencer Gulf routinely tolerate salinity increases of at least 6 g/L or 14% above the ambient summer levels at Point Lowly. An extreme example is the juvenile Western King Prawn (*Melicertus latisulcatus*) which occurs in nursery habitat in the northern reaches of the Spencer Gulf, where salinity levels are reported to reach 55 g/L, i.e. 30% above the ambient summer levels at Point Lowly (Carrick 1982).

Similarly, healthy communities of the seagrasses *Posidonia* spp. and *Amphibolis antarctica* occur throughout Spencer Gulf, including the northern reaches of the gulf, indicating that they too can tolerate a wide salinity range (from 35 g/L to 48 g/L or about ±14% from ambient at Point Lowly). The American seagrass *Thalassia testudinum* is also reported to tolerate a wide salinity range (12% above ambient) (Tomasko et al. 2000). The Mediterranean seagrass *Posidonia oceanica* showed an increased mortality rate at salinities 10% above ambient and a reduced growth at 2.5% above ambient, despite occurring in other parts of the Mediterranean at 8% higher salinity (Fernández-Torquemada and Sánchez-Lizaso 2005).

Little is known about the degree to which wide salinity tolerances in seagrass can be explained by genetic divergence between populations of the same species. Although no genetic variation was found between populations of *Amphibolis antarctica* across a wide range of salinities in Western Australia (Waycott et al. 1996), there is some evidence for genetic divergence in *Posidonia oceanica* (Arnaud-Haond et al. 2007).

In parts of Upper Spencer Gulf, some species may be under salinity and temperature stress, and therefore more susceptible to additional stress (Shepherd 1983). In these cases, small increases in salinity may have adverse effects (Höpner and Lattemann 2002).

Summary of WET test results

Whole effluent toxicity (WET) testing was carried out on 15 species using return water produced at Point Lowly by a small reverse osmosis desalination unit. A test solution containing approximately 78 g/L salt and 7.0 mg/L of the anti-scalant Nalco PermaTreat PC 1020T was produced. Other chemicals listed in Table 16.7 would be included in the test solution for subsequent tests if they are relevant to the final design of the reverse osmosis plant.

Some of the tests undertaken with salinity-matched controls demonstrated that both salinity and anti-scalant could be contributing to a toxic effect. No clear conclusion could be drawn, however, about their overall relative impact across the range of salinities tested. Results from the salinity controls indicated that salinity was generally a major contributor to toxicity in the range 39–51 g/L. This was not necessarily the case, however, for some species in the range 40–43 g/L, which is most relevant to Point Lowly (see reports by Hydrobiology and Dr M Warne, Appendix O10).

The WET test results are presented in detail in Appendix O10. Traditionally, the no observable effect concentration (NOEC), defined as the highest concentration with no significant difference between the test data and the control, has been used to indicate the 'safe' dilution required to protect individual species. As the NOEC data can actually correspond to a 10–30% effect, and has other limitations (see report by Dr M Warne, Appendix O10), there is a transition towards using a concentration with a certain percentage effect when compared with the control, calculated using the results of all test concentrations. The lowest reliably measurable difference is a 10% effect concentration (EC_{10}), which is considered to be more precise than NOEC data (see Appendix O10). This was used to calculate the species protection trigger value (SPTV) for the Upper Spencer Gulf ecosystem.

The EC_{10} results are summarised in Table 16.8 and are presented as a percentage of return water (which reflects the overall toxic effect of the brine and additives) and a corresponding dilution factor (the reciprocal of the concentration percentage). The resultant salinity, which depends on the diluent and return water salinities, is also provided to place the results in context. These values may exaggerate the effects of salinity because they do not take into account limited acclimation of test species to the higher salinities, and toxicity arising from anti-scalant. The NOEC data are presented in reports by Hydrobiology and Geotechnical Services (see Appendix O10).

Species protection trigger values

The species protection trigger value (SPTV) is the safe dilution of desalination plant return water that protects the local marine ecosystem from a defined level of effect. The results of toxicity tests were analysed using BurrliOz software (Campbell et al. 2000) to derive a SPTV for a certain percentage of species, typically 95% of species for slightly to moderately disturbed ecosystems, and 99% of species for ecosystems of high conservation value. In the latter case, this means that in areas of the marine environment where the SPTV is achieved, or the dilution is greater, 99% of the species in that area would be protected.

The ANZECC/ARMCANZ (2000) water quality guidelines recommend that a minimum of five species representing four taxonomic groups be used to determine the SPTV. The guidelines further recommend that local species (adapted to the prevailing conditions), and chronic tests (i.e. long-term, typically sub-lethal) rather than acute tests (i.e. short-term, typically lethal) be used to achieve the most reliable SPTV.

For the Draft EIS, numerous chronic and acute toxicity tests were undertaken on 15 species, using test solutions of varying salinities and anti-scalant concentrations (including no anti-scalant) (see reports by Hydrobiology and Geotechnical Services, Appendix O10, for details). Dr Michael Warne (Senior Research Scientist for the Centre for Environmental Contaminants Research, CSIRO, and contributing author to the ANZECC/ARMCANZ 2000 Guidelines) reviewed all the toxicity data and drew the following conclusions (see Appendix O10 for Dr Warne's assessment report):

- The most appropriate dataset for determining the SPTV for the proposed Point Lowly desalination plant included sub-chronic tests of seven species from six taxonomic groups and a common diluent water of 41 g/L. This dataset resulted in a SPTV of 2.35% return water (equivalent to a safe dilution of 1 part return water to 43 parts seawater – represented as 1:43 and rounded by Dr Warne to 1:45).
- A second dataset, which increased the number of species tested from seven to ten, was also analysed and considered suitable. It resulted in a SPTV of 2.48% (or 1:41), a less conservative SPTV than the preferred dataset.
- An SPTV of 2.35% (or 1:45, rounded up from 1:43) is predicted to protect 99% of marine species in seawater of salinity 41 g/L from experiencing a sub-chronic effect of greater than 10%.
- The natural salinity at Point Lowly increases from 40 g/L to 43 g/L during autumn (as evaporation increases). The toxicity tests included a chronic test of the Australian Giant Cuttlefish using diluent water of 45 g/L, which resulted in an EC_{10} of 1.86% and a safe dilution of 1:55 (rounded up from 1:53.8) based on that value only. As well as being an extreme worst-case for the Australian Giant Cuttlefish, the inclusion of this test increased the reliability of the conclusions regarding the effects of return water discharge during the naturally higher salinity levels in autumn.
- The higher dilution (from the result gained using diluent water of 45 g/L) can be accommodated by increasing the percentage of species protected at 41 g/L from 99% to effectively 100%. This resulted in an SPTV of 1.23% concentration and corresponding dilution factor of 1:85 (rounded up from 1:81.3). This is equivalent to a salinity increase of 0.4 g/L, or 1% increase above background.
- Furthermore, for the SPTV of 1:85, the potential effects on Australian Giant Cuttlefish post-hatch survival would be reduced to less than 3%.
- It is also noted that the SPTV is derived from tests in which the test organism is constantly subjected to the elevated return water concentrations. In practice, tidal movements would be such that no organism would be subjected constantly to these elevated levels beyond the initial mixing zone. As such, the SPTV of 1:85 is very conservative.

16.4.3 MODELLING OF RETURN WATER DISPERSION

Dispersion of the return water off Point Lowly was modelled at three spatial scales: in the near field (within 100 m of the outfall), mid field (Upper Spencer Gulf) and far field (throughout Spencer Gulf). The three models make predictions about dispersion over minimum timeframes of minutes, hours and months respectively.

Detailed results for each model run are presented in the final modelling report (see Appendix O11). The following summary combines the results from each model (using the method discussed in Appendix O11) to account for the accumulated discharge over the preceding days and months.

Table 16.8 Results of whole effluent toxicity (WET) testing

Species	Test	Salinity of test solutions (g/L)		EC_{10}					Values used to calculate SPTV[1]	
		Diluent	Return water	% return water	Dilution[2]	Equivalent salinity (g/L)	Salinity increase (g/L)	% increase above ambient	Primary dataset	Secondary dataset
Microalga *Nitzschia closterium*	72-hour growth (chronic)	37	77	12.8	1:8	42.1	5.1	13.8	n.a.[3]	n.a.
Microalga *Isochrysis galbana*	72-hour growth rate inhibition test (chronic)	41.2[4]	78	84.4	1:2	72.3	31.1	75.4	84.4	84.4
Macroalga *Ecklonia radiata*	72-hour germination success (chronic)	41.2[4]	78	27.6	1:4	51.4	10.2	24.7	27.6	27.6
Macroalga *Hormosira banksii*	72-hour germination success (chronic)	36.3	78	16.5[5]	1:7	43.2	6.9	19.0	n.a.	16.5
Copepod *Gladioferens imparipes*	28-day reproduction (chronic), 48-hour pulse exposure	41.2[4]	78	10.9	1:10	45.2	4.0	9.7	n.a.	10.9
Western King Prawn *Melicertus latisulcatus*	28-day growth (chronic) – adult	41.2[4]	78	7.5[6]	1:14	44.0	2.8	6.7	7.5	7.5
Pacific Oyster *Crassostrea gigas*	48-hour larval development (sub-chronic)	41.2[4]	78	3.3	1:31	42.4	1.2	2.9	3.3	3.3
Australian Giant Cuttlefish *Sepia apama*	Post-hatch survival (chronic)	45	78	1.9[7]	1:55	45.6	0.6	1.4	n.a.	n.a.
Australian Giant Cuttlefish *Sepia apama*	Embryo development (chronic)	45	78	2.4	1:42	45.8	0.8	1.8	n.a.	n.a.
Australian Giant Cuttlefish *Sepia apama*	Embryo development (chronic)	41.2[4]	78	6.4	1:16	43.6	2.4	5.7	6.4	6.4
Yellowtail Kingfish *Seriola lalandi*	96-hour imbalance (acute)	40	84	12.5[5]	1:8	45.5	5.5	13.8	n.a.	n.a.
Yellowtail Kingfish *Seriola lalandi*	7-day larval growth (sub-chronic)	35.2	78	10.6[6]	1:10	39.7	4.5	12.9	n.a.	10.6
Snapper *Pagrus auratus*	7-day larval growth (sub-chronic)	41.2[4]	78	22.2	1:5	49.4	8.2	19.8	22.2	22.2
Mulloway *Argyrosomus japonicus*	7-day larval growth (sub-chronic)	41.2[4]	78	11.6	1:9	45.5	4.3	10.4	11.6	11.6

1 See following section and Dr Warne's report (Appendix O10) for explanation of primary and secondary datasets.
2 Dilutions are rounded up, percentages and salinities rounded to one decimal place.
3 n.a. = Not applicable.
4 Based on salinity measurement discussed in Appendix O9.
5 No Observable Effect Concentration (NOEC) used because EC_{10} was not calculated.
6 Adjusted following peer review (see Dr Warne's report, Appendix O10).
7 Most conservative EC_{10} used to verify SPTV.

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Although the modelling results are discussed in the context of the species protection trigger values, the detailed ecological impact assessment is presented in Section 16.6, Impact Assessment and Management.

Near field return water dispersion

Near field dispersion of the return water within 100 m of the outfall was modelled using the CORMIX program, which is supported by the United States Environmental Protection Agency (2008) and has been widely used elsewhere in the world for near field modelling studies. This model describes water dispersion in the minutes to hours after discharge from the diffuser.

The return water would be discharged under pressure towards the surface via a diffuser located on the seafloor in at least 20 m of water and orientated at right angles to the prevailing current direction. For the purpose of the hydrodynamic model, a 200 m long diffuser with 50 risers was used. After initially rising 2–7 m above the diffuser ports, the return water would be entrained by the prevailing currents and, being denser than the ambient seawater, would fall towards the seafloor. The currents, and to a lesser degree the wave action, would cause the return water to mix turbulently with the ambient seawater, which would result in the plume dispersing (see Figure 16.13).

The results of the near field dispersion modelling, extracted on the seafloor 100 m from the diffuser, are summarised in Table 16.9. These results have been derived over 40 days and include the predictions of the mid and far field models near the outfall. The mid field model assumes that, initially, all of the return water enters the bottom outfall cell only. The dilutions presented are therefore conservative because the discharge under pressure would disperse the return water into the lowest two or three cells.

The results show that at all times at 100 m from the outfall, dispersion of the return water would achieve the WHO (2007) guideline level of a 10% increment above ambient salinity, but the dispersion of the return water would not be sufficient to meet the SPTV of 1:85. The SPTV of 1:45 (protecting 99% of species) would be achieved 30% of the time (see Appendix O11.4 for details).

Mid field return water dispersion

The 3D ELCOM model was used to model dispersion of the return water in the mid field (i.e. Upper Spencer Gulf) at a horizontal resolution of 200 m x 200 m and a vertical resolution of 2 m. This model describes return water dispersion over periods of days to months, thus capturing neap-spring tidal cycles and oceanographical features such as the clockwise eddy that forms in the lee of Point Lowly on an ebb tide.

Model reliability

Developed by the Centre for Water Research (CWR) at the University of Western Australia, the ELCOM model has been successfully applied by a number of proponents to 50 systems world-wide, including the Adelaide coastline (Pattiaratchi et al. 2007), Venice Lagoon, Adriatic Sea, and the Caribbean Sea.

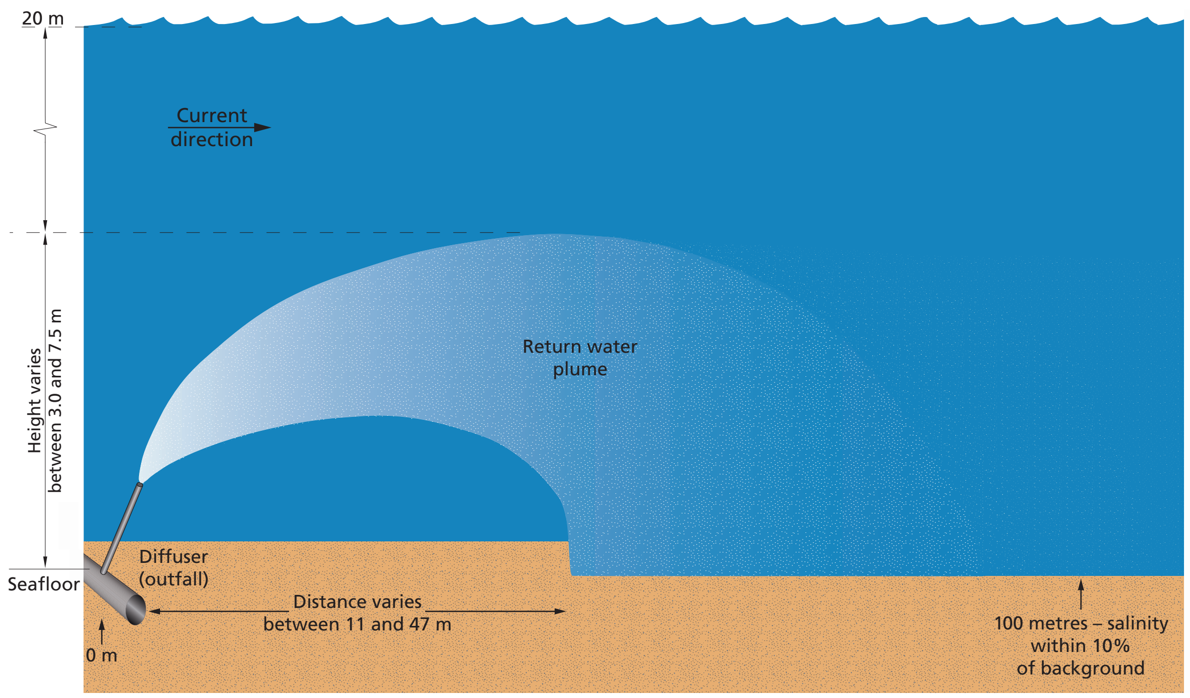

Figure 16.13 Profile of return water plume

Table 16.9 Return water dilution at 100 m from the outfall

Dilution percentile	Dilution at 100 m[1]	Increased salinity at 100 m (g/L)[2]	Increase above ambient (%)
0	1:8	3.7	8.9
1	1:10	3.1	7.5
5	1:12	2.7	6.4
10	1:14	2.3	5.5
25	1:21	1.5	3.7
50	1:35	0.9	2.2
75	1:47	0.7	1.6
90	1:54	0.6	1.4
95	1:56	0.6	1.4
99	1:59	0.6	1.3

[1] Dilution factors have been rounded down, salinities and percentage increases rounded to one decimal place.
[2] Based on return water concentration of 75 g/L and ambient seawater concentration of 42 g/L.

The ELCOM model was also used during environmental studies of the Cockburn Sound desalination plant in Western Australia, which began operating in October 2006. Recent performance monitoring in Cockburn Sound, comparing field sampling of salinity and rhodamine tracer dye dilutions with model results, confirmed that the salinity and extent of the plume were well predicted by the model (Okely et al. 2007a, 2007b). This modelling was undertaken by CWR which, in partnership with BMT WBM Pty Ltd, has produced the model for the proposed desalination plant at Point Lowly.

During the calibration of the ELCOM model within Upper Spencer Gulf, the mid field model accurately predicted and reproduced known oceanographic phenomena at Point Lowly (see model calibration report, Appendix O11), including:

- the clockwise eddy off Point Lowly during an ebbing tide with comparable speeds and directions
- current speeds and directions throughout the depth profile near the end of the Port Bonython jetty (where the outfall was originally planned).

The model, however, proved to be very conservative with its prediction of currents at Point Lowly. Using an acoustic Doppler current profiler (ADCP), average current speeds were recently recorded as being four times faster than the model predictions for slower currents, and one and a half times faster for faster currents (see model calibration report, Appendix O11).

Model runs

The model assumed the outfall to be at Site B3, 600 m south-east of Point Lowly (see Figure 16.14), which was selected as a worst case outfall within the area of acceptable return water dispersion (see Section 16.5.2). The discharge volume was set to the peak predicted flow of 370 ML/d, which is conservative compared with the average discharge volume of 309 ML/d. The model was run for a 40-day period simulating the tidal conditions recorded for summer 2001–2002, and at an eight-minute time step (i.e. model predictions recorded every eight minutes over a 40 day period). Mid summer was considered to be an indicative worst case, when high surface temperatures and thermally induced stratification can restrict mixing, dispersion and dilution. The model period included three dodge tides (see Figure 16.15). The modelled period (2001–2002) was chosen for the low tidal range during the dodge tides.
To ensure that true worst case conditions were simulated over this period, wind forcing was set to zero during one of the dodge tides, thus increasing surface temperatures (and thermal stratification) and removing the potential for wind induced mixing to occur.

Other extreme scenarios were also modelled. A strong south-easterly wind was simulated to determine the net effect of wind-driven currents on increased mixing and pushing the return water towards the cuttlefish habitat. The zero wind scenario resulted in lower dilutions (i.e. less dispersion) at the sensitive receivers than the strong south-easterly wind did (see final modelling report, Appendix O11), and therefore the zero wind scenario was used as the basis for the mid field modelling. Another scenario used a model boundary tidal amplitude that was modified very conservatively to cause less water movement than during an indicative extreme dodge period in May 2004. The results showed relatively minor changes to the dilutions achieved at sensitive receivers (see final modelling report, Appendix O11).

The outcomes from the mid field model are described in detail in the following sections as (see final modelling report, Appendix O11):

- graphs of salinity, both with and without the return water discharge, at representative sites around Point Lowly
- percentile dilutions of the return water at key sites off Point Lowly
- dilution contours showing a series of percentile dilutions within the vicinity of the outfall.

The ecotoxicology studies provide the context for interpreting return water dilutions. A dilution factor of 1:45 was identified as the species protection trigger value to protect 99% of marine

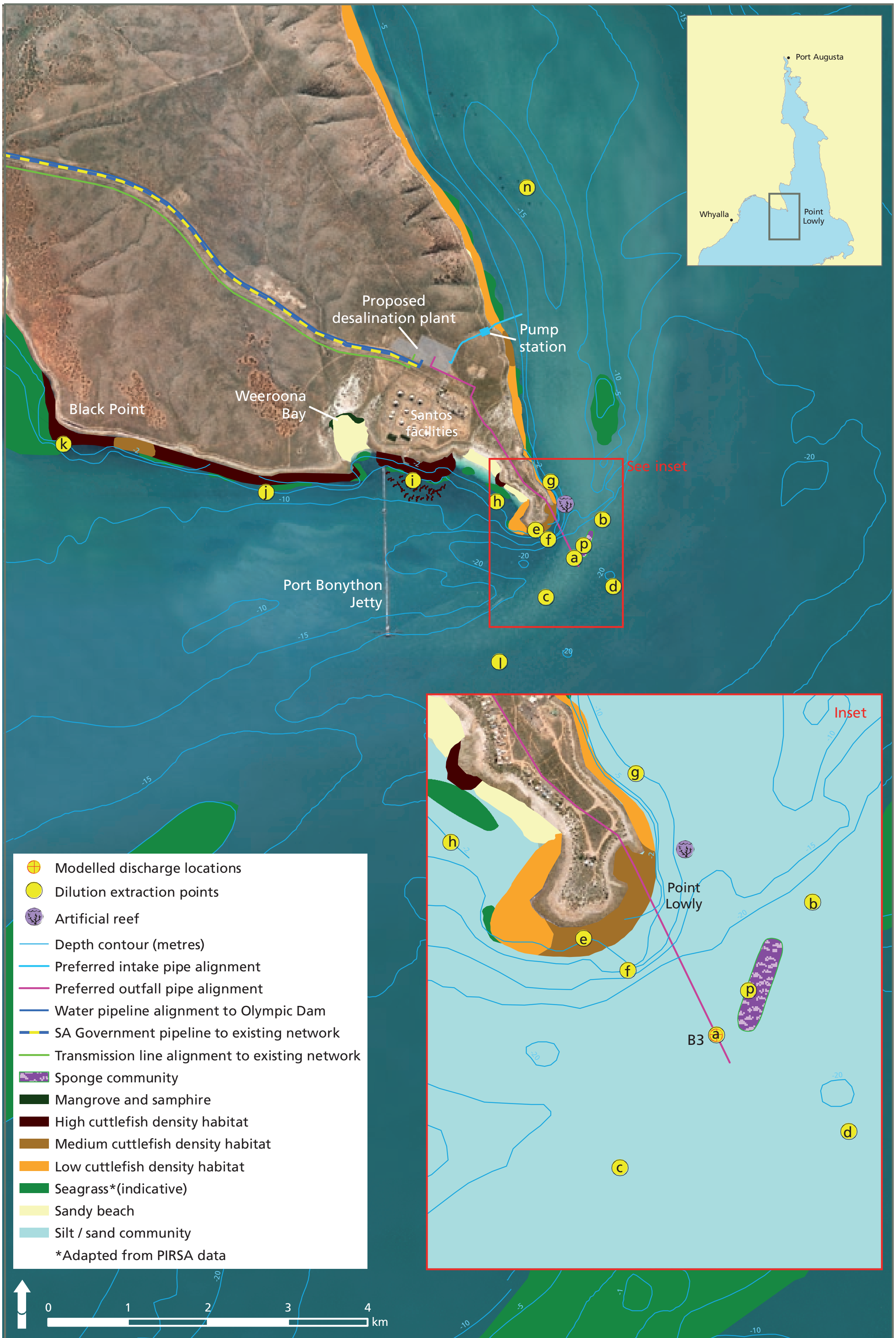

Figure 16.14 Mid field model extraction points

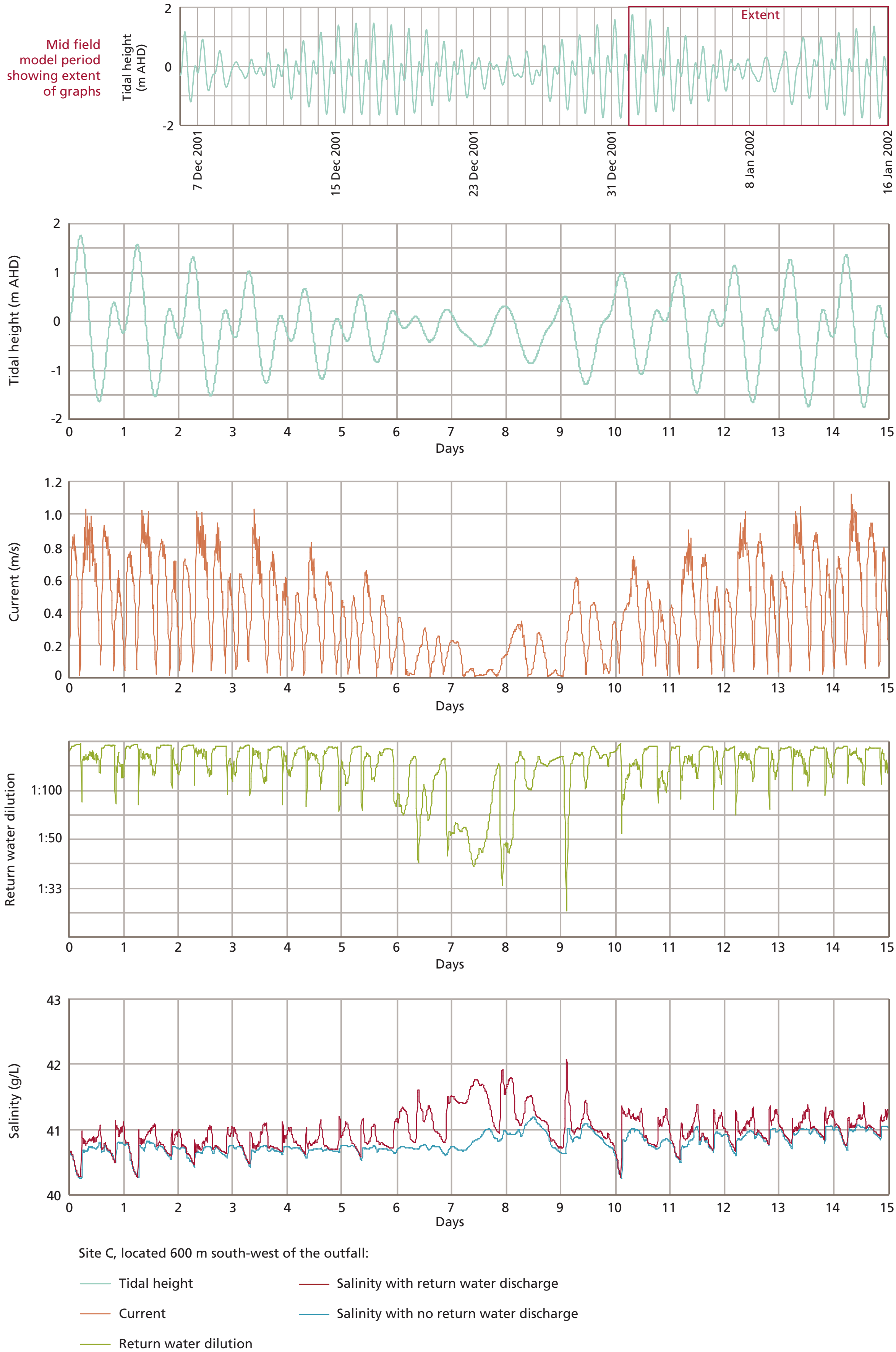

Figure 16.15 Correlation between tidal characteristics, currents, return water dilutions and salinities near the seafloor

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species that occur naturally in the waters off Point Lowly, at a background salinity of 41 g/L. A dilution factor of 1:85, adopted for the assessment in Section 16.6, increases the percentage of protected species to effectively 100%, or provides a buffer when background salinities are higher than 41 g/L.

Dilutions and salinities at representative sites off Point Lowly

Dilutions at each eight minute time step were extracted from the bottom cells of the model (i.e. adjacent to the seafloor) at sites 600 m to the north-east, south-east, south-west and north-west of the outfall (sites b–e on Figure 16.14), seven locations within the Australian Giant Cuttlefish breeding habitat (sites e–k), two locations within prawn trawling grounds (sites l and m), one location at the aquaculture cages in Fitzgerald Bay (site n) and one location within a deep water sponge community (site p). The findings (summarised in Table 16.10) were:

- the minimum dilution within cuttlefish habitat was 1:116 (salinity increase = 0.3 g/L) at site f, which is the cuttlefish site closest to the outfall; the minimum dilution at the remaining cuttlefish sites (e, g, h, I, j, k) was 1:184 (salinity increase = 0.2 g/L)
- the minimum dilution at the closest prawn site (l) was 1:38 (salinity increase = 0.9 g/L); dilutions were worse than 1:85 (salinity increase = 0.4 g/L) for 5% of the time, with the longest duration being 15 hours
- the minimum dilution at the aquaculture site in Fitzgerald Bay (site n) was 1:319 (salinity increase = 0.1 g/L)
- the minimum dilution within the sponge community (site p) was 1:17 (salinity increase = 1.9 g/L); dilutions were worse than 1:85 for 34% of the time, with the longest duration being 17 hours.

Dilutions were also extracted at several locations 600 m from the outfall (sites b, c, d), to assist interpretation of the return water dispersion and to give indicative results in the vicinity of the outfall (Table 16.10). A more complete description of the dilutions within 5 km of the outfall is given by the dilution contour plots.

Depth and current direction and speed have a significant effect on dilutions at key sites (see Figure 16.16a and Table 16.10). The extracted dilutions show that:

- the higher density of the return water compared with seawater resulted in it affecting deeper sites more than shallower sites (see Figure 16.16b, and dilutions at sites e and f compared with b, c and d, shown in Table 16.10)
- current speed has a strong influence on dispersion. When currents are strong (>50th percentile), there is rapid dispersion to far field background levels for all sites within the vicinity of the outfall (sites b, c, d, l) (see final modelling report, Appendix O11)
- when currents are moderate (between 5th and 50th percentile), sites aligned with the current (i.e. sites b, c and l, south-west and north-east from the outfall) recorded higher concentrations of return water than sites at the same depth but perpendicular to the current direction (e.g. site d)
- extremely low current speeds resulted in lower dilution of return water at all the deepwater sites near the outfall (i.e. sites a, b, c, d and l).

The lowest current speeds and poorest dispersion of the return water near the outfall occurred during (see Figure 16.15 for site c as a representative example):

- regular periods at the turn of tides (1–2 hours up to four times per day), particularly during changes from ebb to flood tides
- dodge tides (lasting for one day on this occasion).

Salinity at representative sites (predicted by the mid field model) was plotted as a time series over the 40-day period, with and without the desalination plant operating, to show the predicted change in salinity at key sites (see Figures 16.17a and b). For the sites near the outfall (i.e. sites a, b, c, d and l), there were periods with noticeable differences in salinity, which corresponded to the occurrence of low currents. For all other sites, the salinity increases were virtually indistinguishable from the background variability.

Dilution contours

Dilution contours are based on a specified percentile of dilutions over the entire modelled period for each point in the mid field domain (lowest cell). In other words, they show the maximum extent of the stated dilution factor rather than a snapshot of the plume at a particular time (an animation for this topic is available at <www.bhpbilliton.com/odxeis> and on the disc accompanying the Executive Summary).

For example, the 1:85 contour (10th percentile) includes all cells where the dilution is worse (i.e. lower) than 1:85 for more than 10% of the time. Outside the 1:85 contour (10th percentile), the dilution in all cells is worse than 1:85 for less than 10% of the time. Outside the 1:85 contour (0th percentile), the dilution in all cells is never worse than 1:85.

Dilution contours for the 40-day modelled period are presented as the 0th, 1st and 10th percentile of the SPTV of 1:85 (see Figure 16.18). The dilution contour for the 50th percentile never extends beyond the outfall cell (i.e. 200 m x 200 m) and is therefore too small to present. Dilution contours illustrating return water dispersion during spring, neap and intermediate (typical) tides (over two-day periods) are shown in the final modelling report (see Appendix O11).

Far field return water dispersion

The 3D ELCOM model was used to model dispersion of the return water in the far field (i.e. on a gulf-wide basis). This model captures oceanographic processes occurring over months and years, including the removal of salt from the system across the entrance to the Gulf and the formation of a gulf-wide gyre.

Table 16.10 Summary of return water dilutions and salinity increases at key locations near Point Lowly compared with species protection trigger values[1]

Receptor	Site (Figure 16.14)	Return water dilution		Return water concentration (%)		Salinity increase (g/L)[2]		Breaches of protection value (% of time steps)	Maximum duration of breach (hours)	Conclusion
		Protection value	Minimum	Protection value	Maximum	Protection value	Maximum			
Marine ecosystem	a	>1:85[3]	1:8[4]	<1.2	11.2	<0.4	3.7	100	Continuous	Continual effect
(outfall and three indicative sites)	b		1:37		2.4		0.9	7	7	Occasional effect
	c		1:27		3.4		1.2	10	20	Occasional effect
	d		1:35		2.6		0.9	4	10	Occasional effect
Australian Giant Cuttlefish	e	>1:55[5]	1:247	<1.9	0.4	<0.6	0.1	0	n.a.[6]	No effect
	f		1:116		0.9		0.3	0	n.a.	No effect
	g		1:211		0.5		0.2	0	n.a.	No effect
	h		1:230		0.4		0.1	0	n.a.	No effect
	i		1:184		0.5		0.2	0	n.a.	No effect
	j		1:184		0.5		0.2	0	n.a.	No effect
	k		1:393		0.3		0.1	0	n.a.	No effect
Prawns	l	>1:14[5]	1:37	<7.5	2.7	<2.6	0.9	0	n.a.	No effect
	m		1:152		0.7		0.2	0	n.a.	No effect
Kingfish	n	>1:10[5]	1:319	<10.6	0.3	<3.5	0.1	0	n.a.	No effect
Sponge community	p	>1:85[3]	1:17	<1.2	5.9	<0.4	1.9	30	16	Regular effect

[1] Dilutions rounded up for protection values, down for model predictions. Concentrations and salinities rounded to one decimal value.
[2] Based on return water salinity = 75 g/L; ambient salinity = 42 g/L.
[3] Species protection trigger value (see Section 16.4.2).
[4] Near field results (see Table 16.9).
[5] Lowest EC_{10} for individual species (see Table 16.8).
[6] n.a. = not applicable.

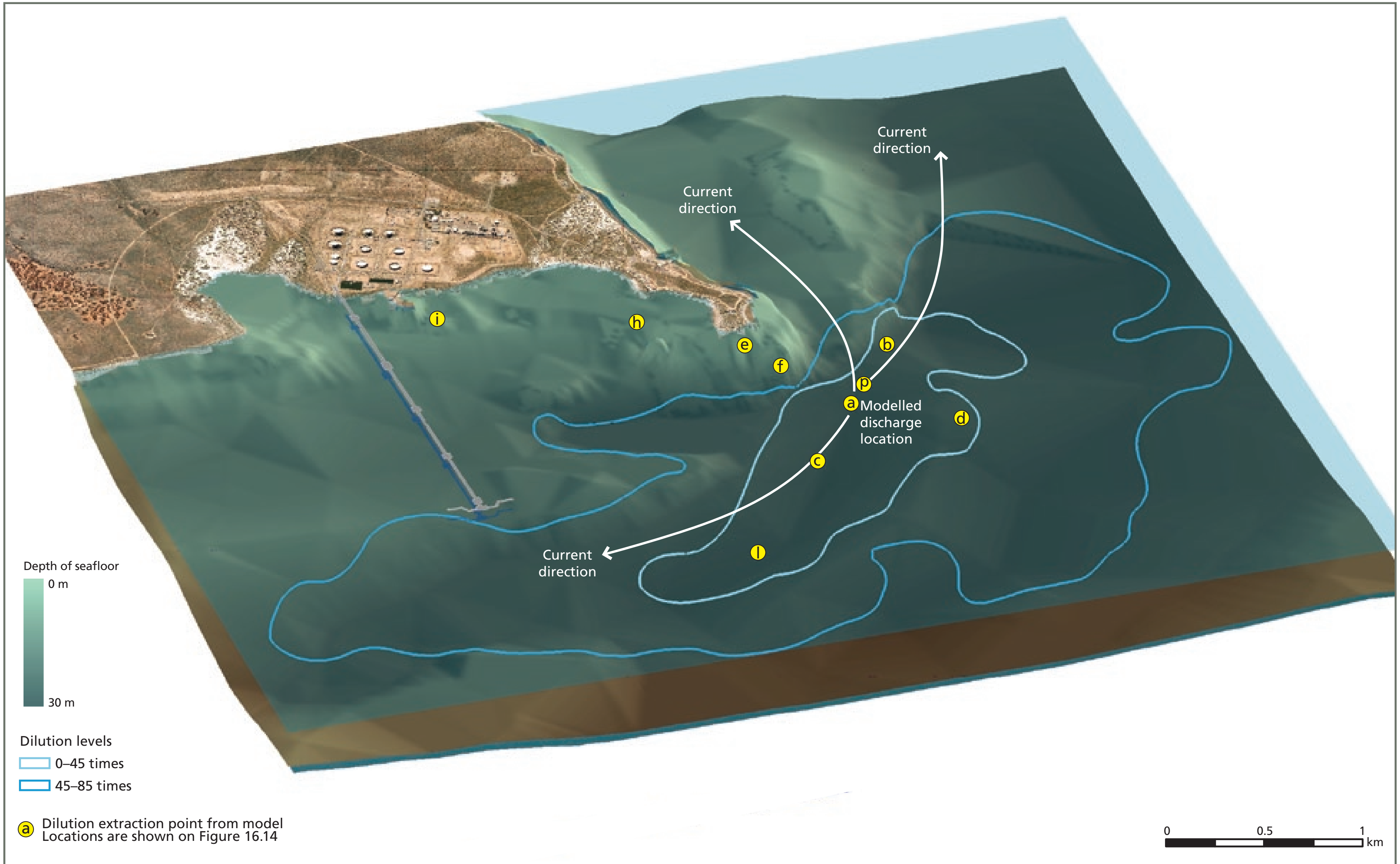

Figure 16.16a Maximum increases in salt concentration near seafloor at key sites over a 40 day model period

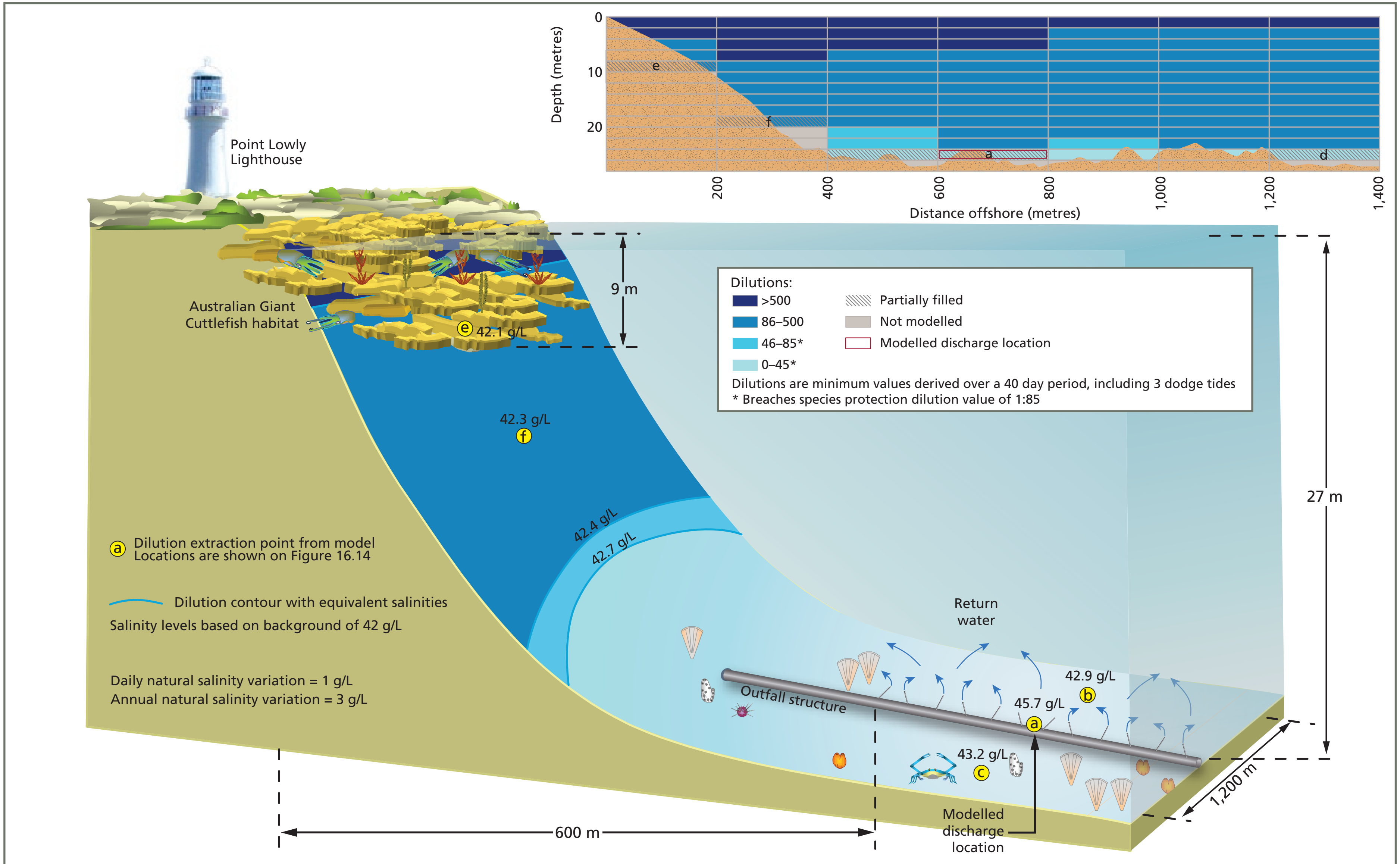

Figure 16.16b Conceptual locations of key sites showing maximum increases in salt concentration over a 40 day model period

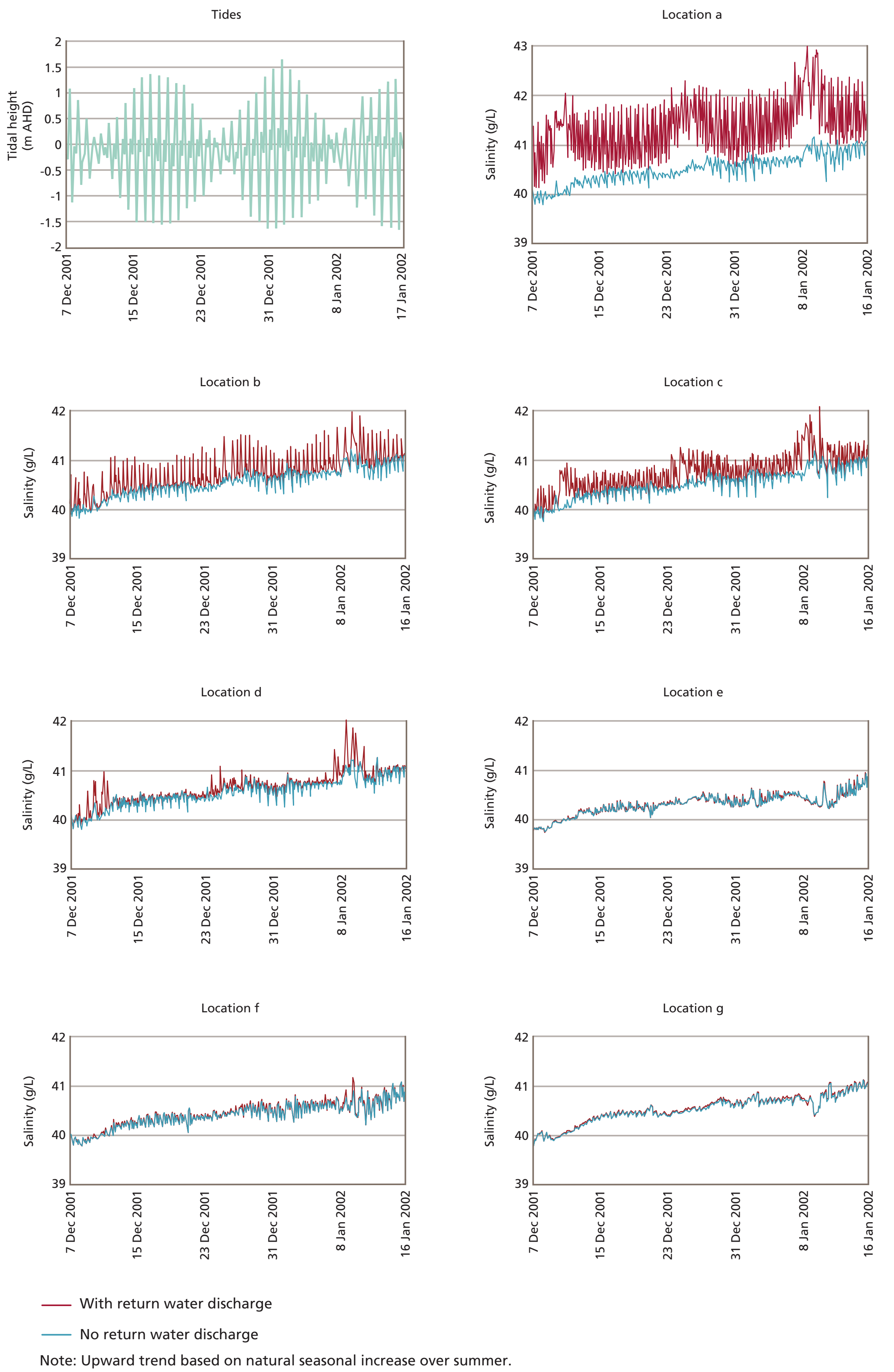

Figure 16.17a Predicted salinity levels near seafloor at key locations near Point Lowly during summer

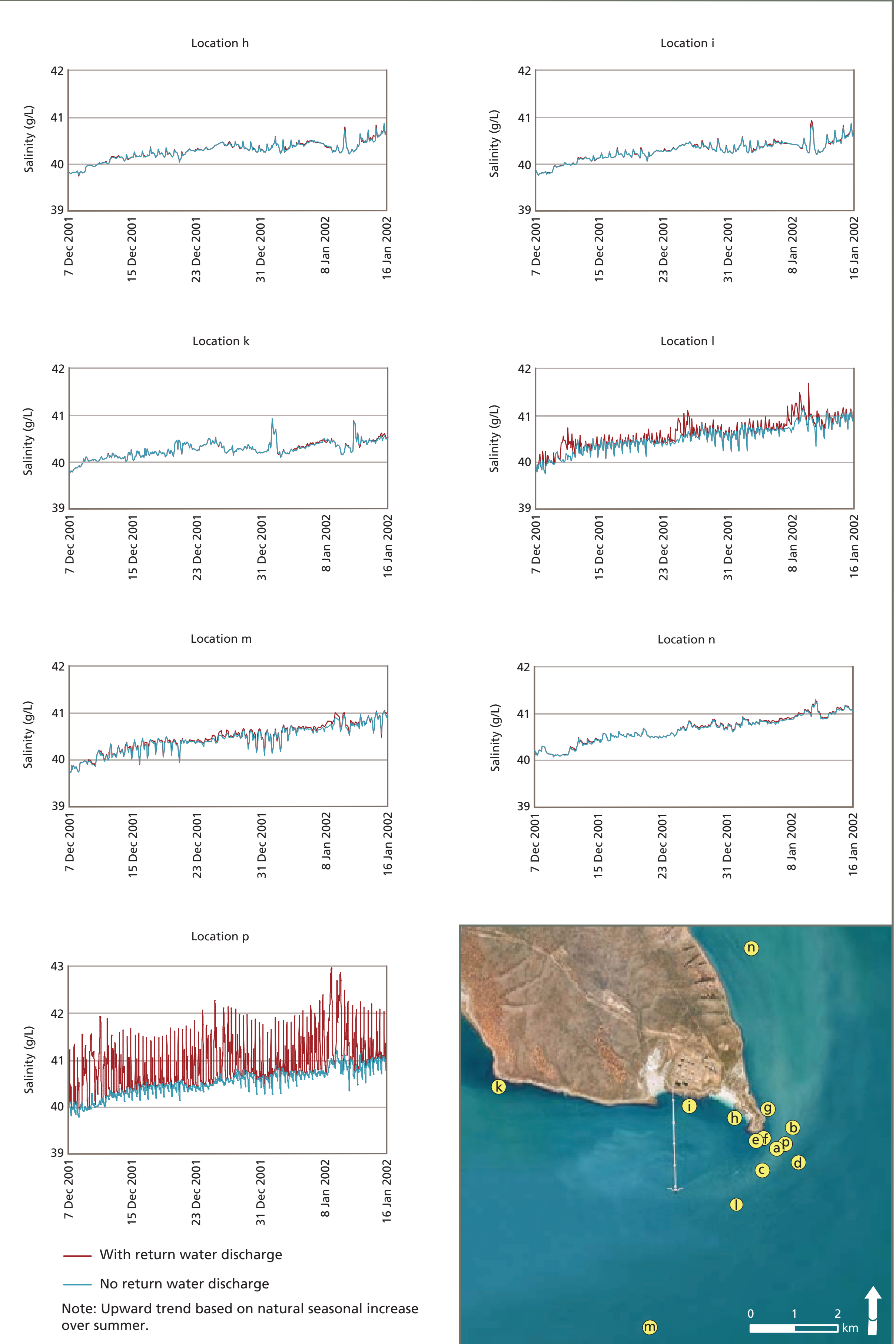

Figure 16.17b Predicted salinity levels near seafloor at key locations near Point Lowly during summer

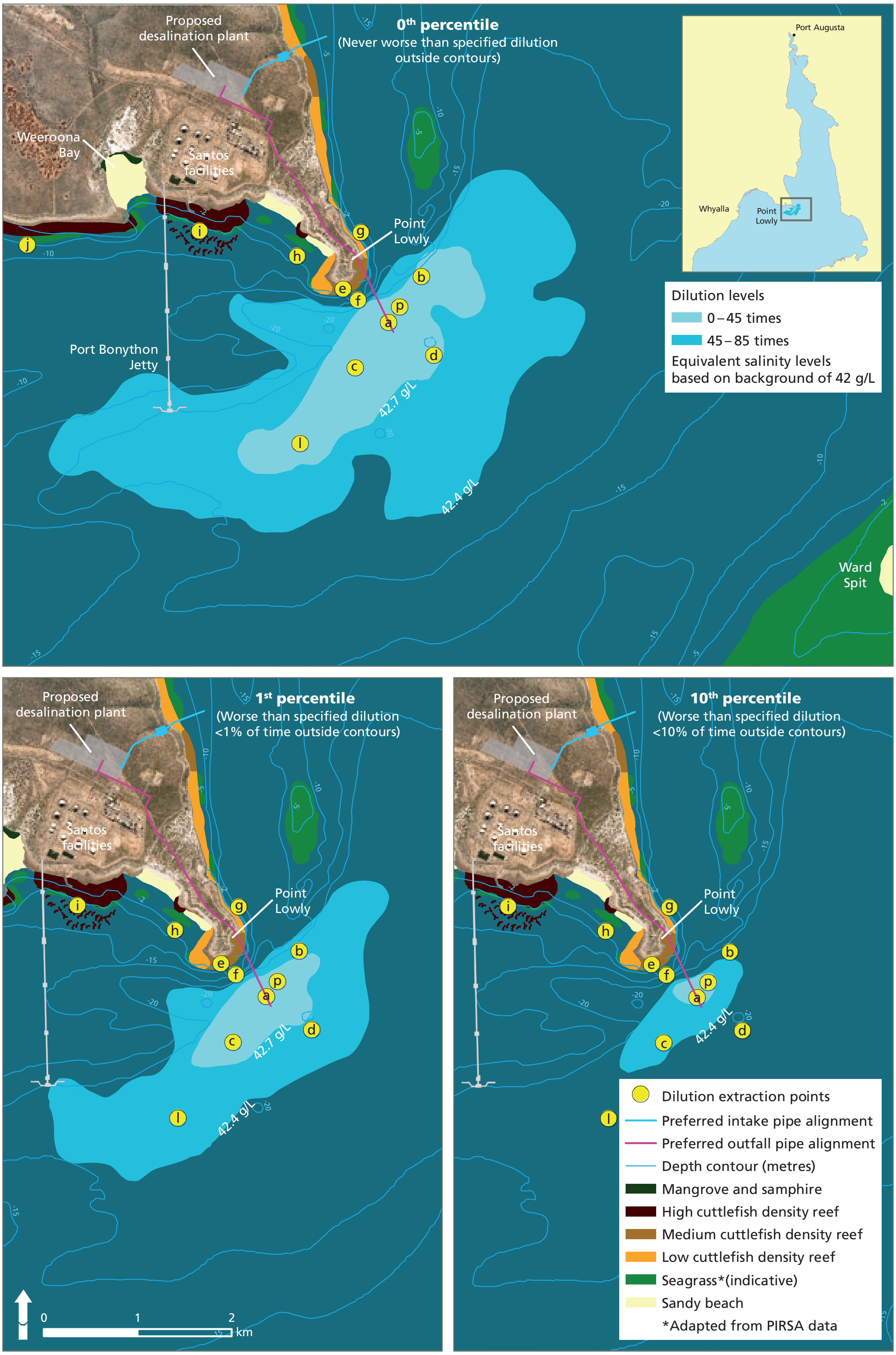

Figure 16.18 Dilution contours showing footprint near seafloor derived over a 40 day period

Model reliability

The ELCOM far field model predictions were validated against known oceanographic phenomena, including:

- tidal amplification in the northern reaches of Spencer Gulf
- the seasonal north-south salinity and temperature gradients throughout Spencer Gulf over a five-year period
- the gulf-scale clockwise circulation pattern in Spencer Gulf, with seasonal removal of salt along the seabed of the eastern shore (see Figure 16.19 and Section 16.3.2 for further detail).

In all cases the model was able to accurately reproduce these phenomena (see model calibration report, Appendix O11, for further details).

Potential salt increase

The model was run for a simulated period of five years to determine if the continuous discharge of return water from a desalination plant at Point Lowly would result in the build-up of salt in Upper Spencer Gulf (see final modelling report, Appendix O11, for details). The salinity at representative sites in Upper Spencer Gulf was plotted as a time series over five years (see Figure 16.20). The model reached quasi-steady state conditions relatively quickly, usually in less than a year (i.e. the detectable effect of adding salinity to the Gulf from the desalination plant reached equilibrium in less than a year). The long-term average increases in salinity at the representative sites are given in Table 16.11 and Figure 16.20. Predictions from the model (summarised in Table 16.11) included:

- the long-term increases in salinity at locations north of the gulf (near Port Augusta and Yatala Harbor) and south (near Cowell) were 0.03 g/L and 0.01 g/L, respectively
- the long-term average increase in salinity in False Bay was 0.07 g/L.

Salt and water balance

Additional modelling was carried out to determine flushing times and gulf-wide salt and water balances to provide context for the desalination plant impact assessment (see final modelling report, Appendix O11, for details).

Two methods were used to examine flushing times for Spencer Gulf (see Appendix O11 for a description of the methods). Both methods reproduced the east-west salinity gradient consistent with the gulf-scale clockwise circulation pattern and the ejection of 'older' more saline water along the east coast, giving confidence in the model outcomes, and showing that flushing times were longest for the most northern sections of the gulf. The most conservative result showed a flushing time of just under one year for the waters north of Yatala Harbor to be flushed with oceanic water, or three to four months to be flushed with water from south of Point Lowly (see Figure 16.21) (an animation for this topic is available at <www.bhpbilliton.com/odxeis> and on the disc accompanying the Executive Summary).

An annual salt and water balance was calculated for Spencer Gulf, and box model constructed, by considering net evaporation and current fluxes across the oceanic boundary (see Table 16.12 and Figure 16.22). Maintenance of the salt balance in Spencer Gulf requires the accumulated hypersaline water within the gulf to be exchanged with ocean water each winter via the gravity driven density current. The box model provides evidence that the far field model was able to accurately account for both the annual water balance (i.e. the net influx of seawater across the oceanic boundary to compensate for evaporative water losses), and the annual salt balance within the gulf.

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Table 16.11 Long-term average salinity increases at representative sites in Upper Spencer Gulf

Site[1] (see Figure 16.20 for locations)	Salinity increase (g/L)	Percentage increase (%)
Port Augusta (site 1)	0.03	0.06
Yatala Harbor (site 2)	0.03	0.07
False Bay (site 3)	0.07	0.17
Wallaroo–Cowell (site 4)	0.01	0.03

[1] Note: In Appendix O11, site 1 = 2–10; site 2 = 9–15; site 3 = 24–22; site 4 = 69–35.

Table 16.12 Spencer Gulf annual water and salt balance[1]

	Water (GL)	Salt (Gt)	Salinity (g/L)
Spencer Gulf content	460,000	17	37 (average)
Desalination/yr	–100	0	+0.01
Net evaporation/yr	–31,000[2]	0	+2.61
Summer inflow of oceanic water	+31,100 @ 35 g/L	+1	
Winter inflow of oceanic water	+500,000 @ 35 g/L	+17.5	-2.61
Winter outflow of hypersaline water (gravity flow)	-500,000 @ 37 g/L	-18.5	

[1] Note: negligible inputs/outputs include catchment run-off, groundwater inflows, salt extraction by Orica Ltd., and others.
[2] -36,000 GL evaporation, +5,000 GL rainfall.

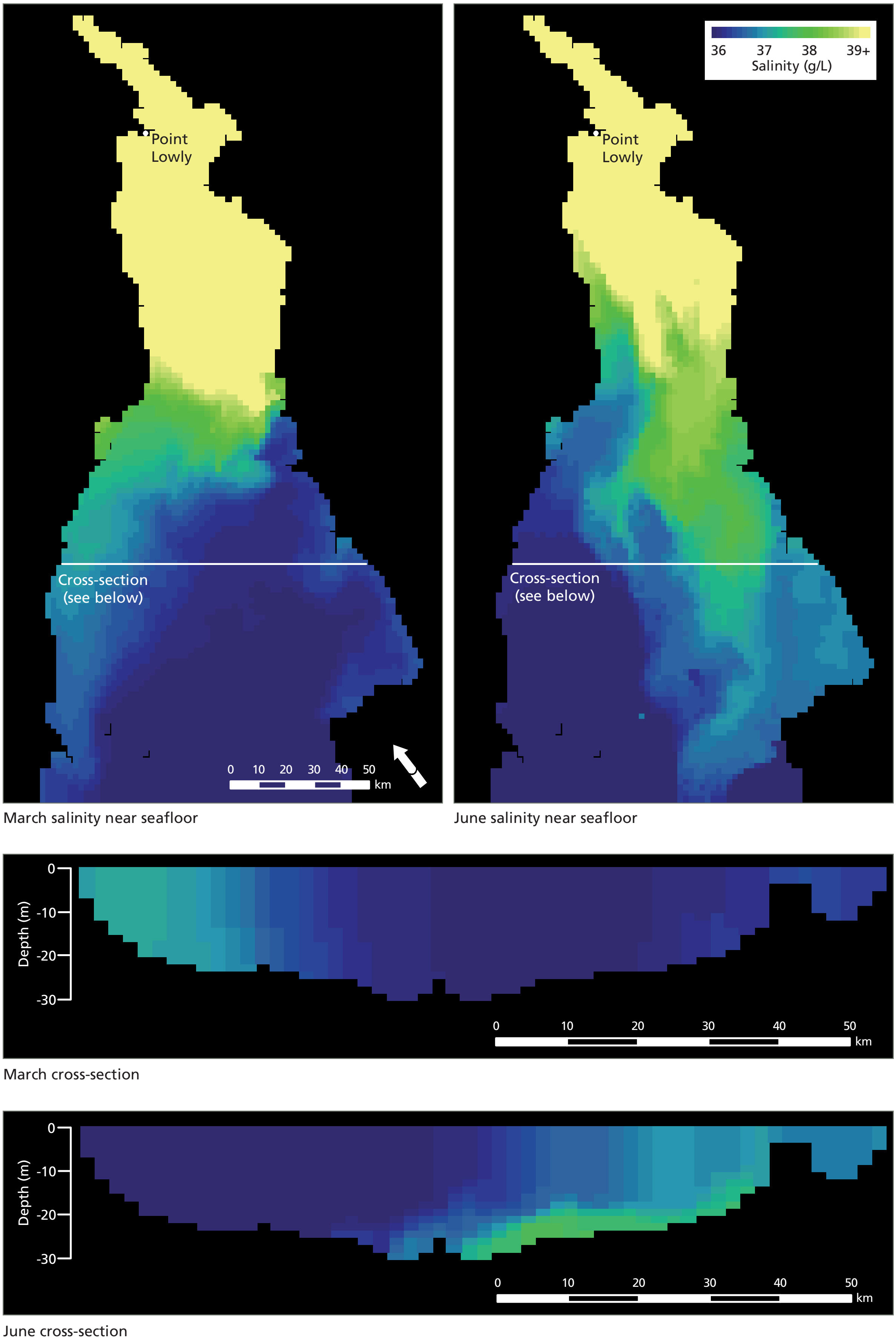


Figure 16.19 Salinity gradients in Upper Spencer Gulf showing seasonal salt movement

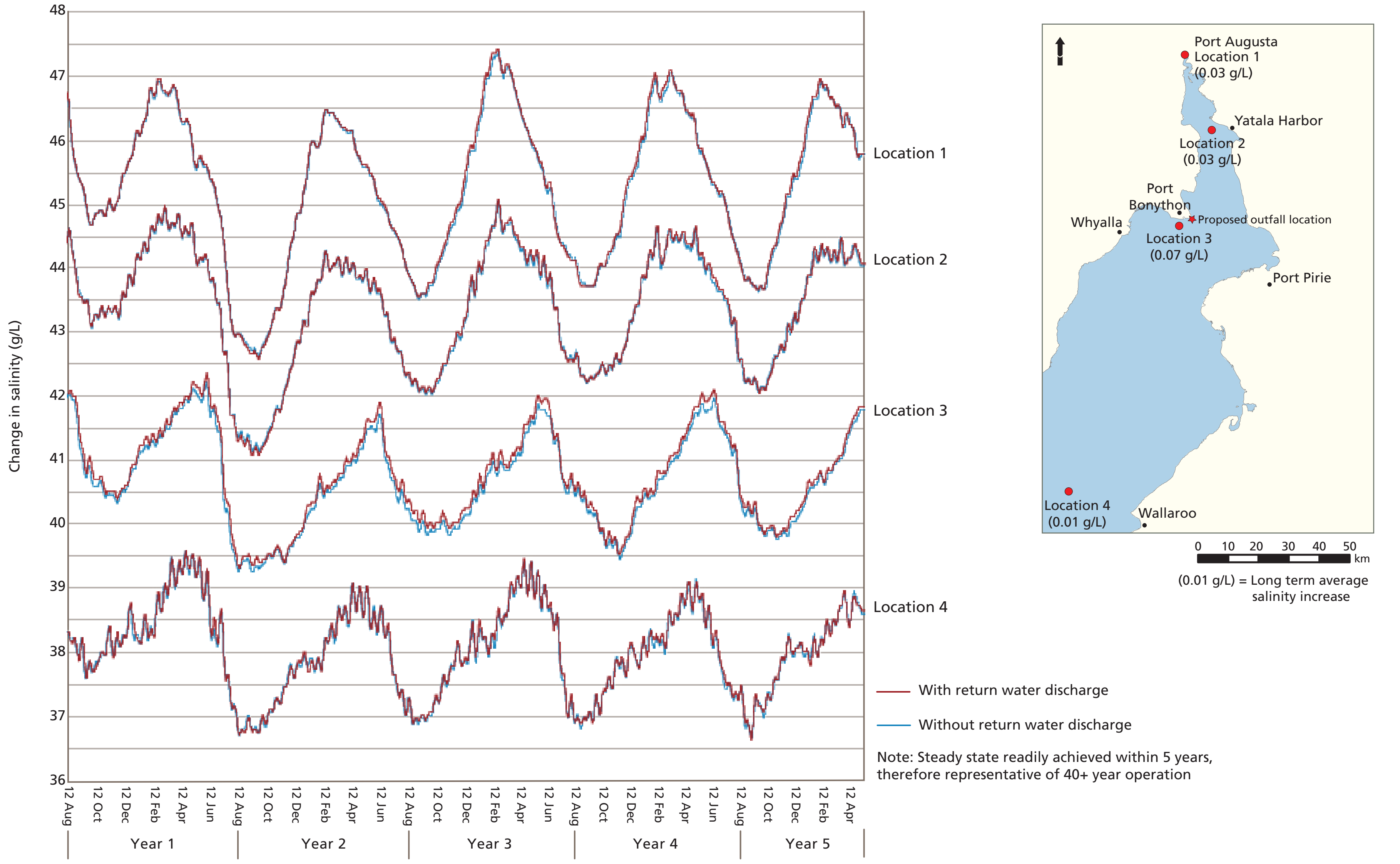


Figure 16.20 Predicted far field changes in salinity near seafloor with and without the Point Lowly outfall

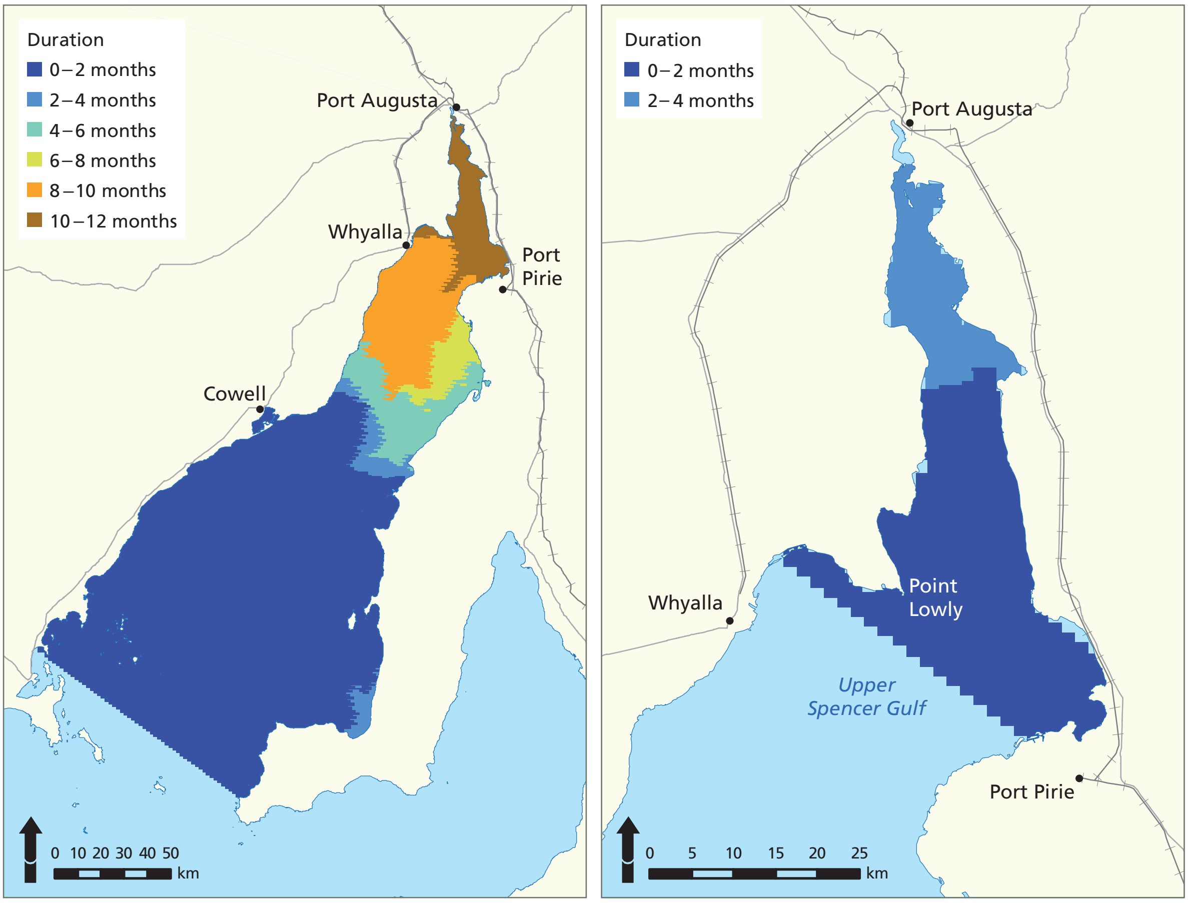


Figure 16.21 Spencer Gulf flushing durations

16.5 DESIGN MODIFICATIONS TO PROTECT ENVIRONMENTAL VALUES

16.5.1 ENVIRONMENTAL VALUES

The environmental values of Upper Spencer Gulf are described in detail in Section 16.3. The main values are:

- a large breeding aggregation of the Australian Giant Cuttlefish at Point Lowly that is of considerable scientific and recreational interest
- its extensive seagrass communities
- its marine biodiversity, which includes numerous rare or threatened species and a number of species with tropical affinities
- a number of aquaculture ventures, including Yellowtail Kingfish farms in Fitzgerald Bay
- a number of commercially and recreationally important fisheries
- its extensive breeding and nursery habitat for numerous commercially and recreationally important fish and crustacean species.

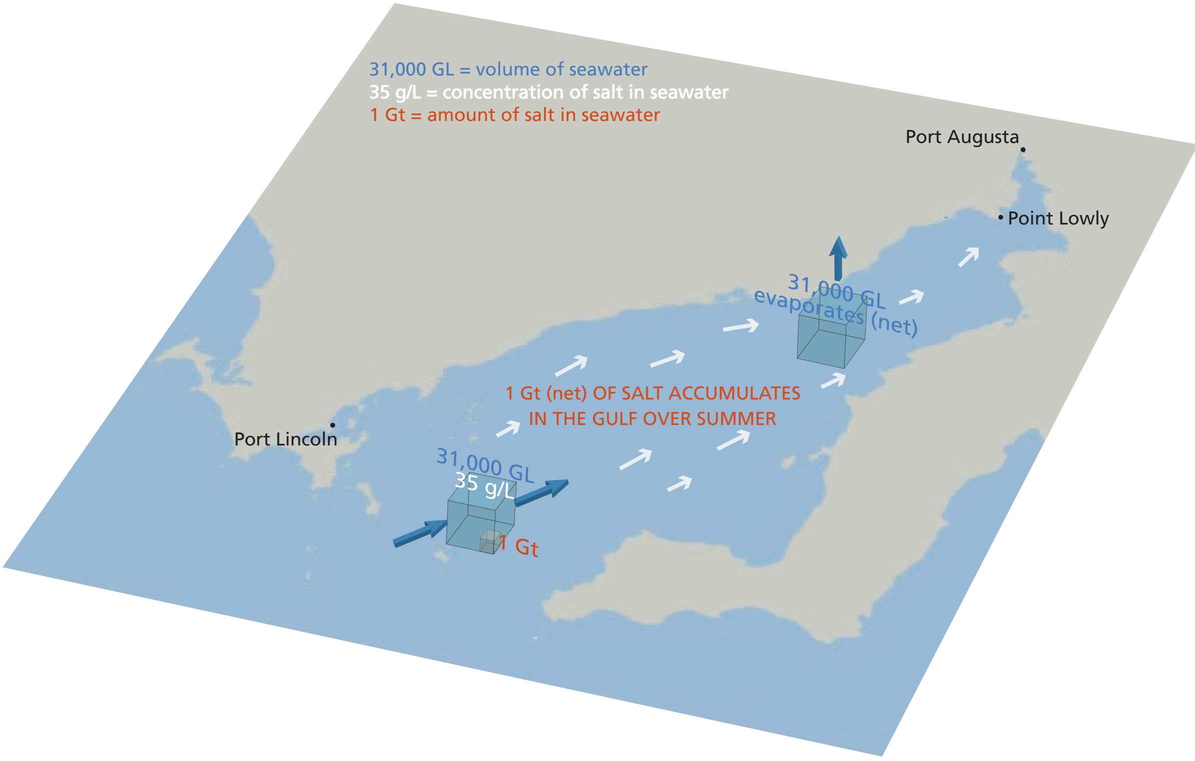
16.5.2 MAJOR ELEMENTS OF THE PROJECT DESIGN

Desalination plant location

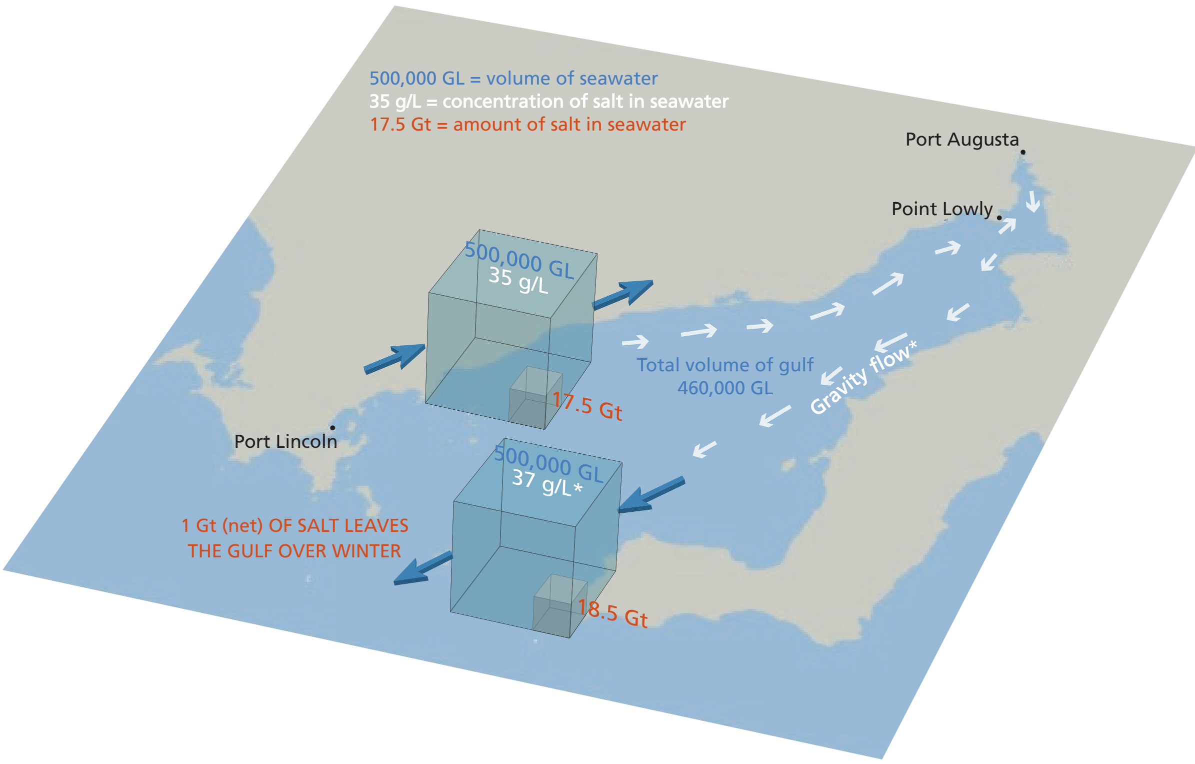
The following approach was adopted when assessing potential locations for the desalination plant to avoid or minimise impacts on environmental values. The principal environmental objectives were that:

- the return water is rapidly diluted and dispersed back to ambient salinity levels
- salt does not accumulate in embayments as a result of ongoing discharge of return water
- the discharge of return water has minimal effects on marine communities and does not affect sensitive receivers.

Sites at Whyalla, Port Augusta, Ceduna, south of Port Pirie and Point Lowly were considered for the location of the desalination plant (see Chapter 4, Project Alternatives). The criteria on which the decision was based included proximity to Olympic Dam, accessibility and constructability of the water supply pipeline, potential effects on sensitive receivers and likely rate of dispersion of the return water plume. The specific criteria used to assess potential impacts on sensitive receivers (i.e. marine communities) were:



SUMMER



WINTER

*Source: Lennon et al 1987

Figure 16.22 Summer / winter salt and water balance in Spencer Gulf

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a) increase in salinity was not to exceed 10% of background at 100 m from the outfall

b) 1:85 dilution contour (minimum or 0th percentile) was not to impinge on the cuttlefish breeding habitat

c) 1:85 dilution contour (minimum or 0th percentile) was not to impinge on seagrass communities

d) 1:85 dilution contour (minimum or 0th percentile) was not to exceed 6 km in diameter

e) far field increase in salinity was not to exceed 0.5% above background.

Figure 4.2 shows the broader assessment results, while Table 16.13 shows the results of the more detailed assessment against the above criteria for the potential sites at Port Augusta, Point Lowly and Whyalla. Point Lowly (with the strongest currents and deepest water in Upper Spencer Gulf) was considered to be the closest location to Olympic Dam with suitable conditions for the safe dispersion of the return water and was therefore chosen as the preferred general location for the desalination plant.

Sites J1 and J2 were not considered further because their location within the Port Bonython jetty exclusion zone was deemed to be problematic operationally (see Figure 16.23). Modelling of the return water dispersion at the remaining six sites off Point Lowly indicated that dispersion of the return water would be acceptable from an outfall located seaward of the line shown in Figure 16.23. Site B3 was selected as the outfall site for more detailed modelling (see Section 16.3.4) as it is the closest site to land and because it is the closest site to the cuttlefish habitat and therefore likely to provide worst-case ecological outcomes (see Figure 16.23).

Desalination plant design and operation

The following design and operating principles for the desalination plant would be adopted to avoid or minimise impacts on environmental values:

- the Australian Giant Cuttlefish breeding period would be avoided by constructing the intake and outfall pipes between 1 November and 1 May
- maximising initial dilution of the return water by discharging return water from a diffuser (nominally 200 m long with 50 ports), located on the seafloor at a depth of greater than 20 m, and aligned perpendicular to the major current direction
- the negative buoyancy of the return water would be overcome by discharging the return water under pressure from ports vertically into the water column. Valves would be used to maintain exit velocity during low flows of return water
- entrainment and impingement of biota would be minimised by designing the intake to achieve an average inflow rate of <0.2 m/s, which is one-third of the recommended safe intake flow (<0.6 m/s) to minimise effects on marine biota (TEL 2005) (see Section 16.6.10 for details)
- potential effects on marine communities would be alleviated by disposing of pre-filtration particulates and associated residual chemicals on land, and minimising the use and discharge of process chemicals.

Other elements

Impacts on coastal processes and seagrass communities at the site of the landing facility in Upper Spencer Gulf would be minimised by adopting an open pier, rather than a rock causeway design (see Section 16.6.12 for details).

Impacts on mangrove and other marine communities at the Port of Darwin would be avoided by locating infrastructure on existing cleared land or on Darwin Port Corporation reclaimed land (see Section 16.6.13 for details).

Table 16.13 Assessment of alternative desalination plant locations

Region	Outlet site[1]	Model run	Water depth at discharge point (m)	Criteria not met
Port Augusta	PA1	6, 20[2]	10	a, c, d, e
Point Lowly	J1	2[2]	15	
	J2	3, 8[2]	20	
	B2	4[2]	15	d
	B3	5, 9[2], 6, 7[3]	20	
	B4	11[2]	15	c
	B5	12[2]	20	
	B6	14[2]	20	
	B7	15, 16[2], 8[3]	20	
	B8	9[3]	20	
	B9	10[3]	20	
Whyalla	W1	10[2]	10	c, d
	W3	13[2]	15	d

[1] See Figure 16.23 for outlet site locations.
[2] As per model run numbers in the initial modelling report, Appendix O11.
[3] As per model run numbers in the final modelling report, Appendix O11.

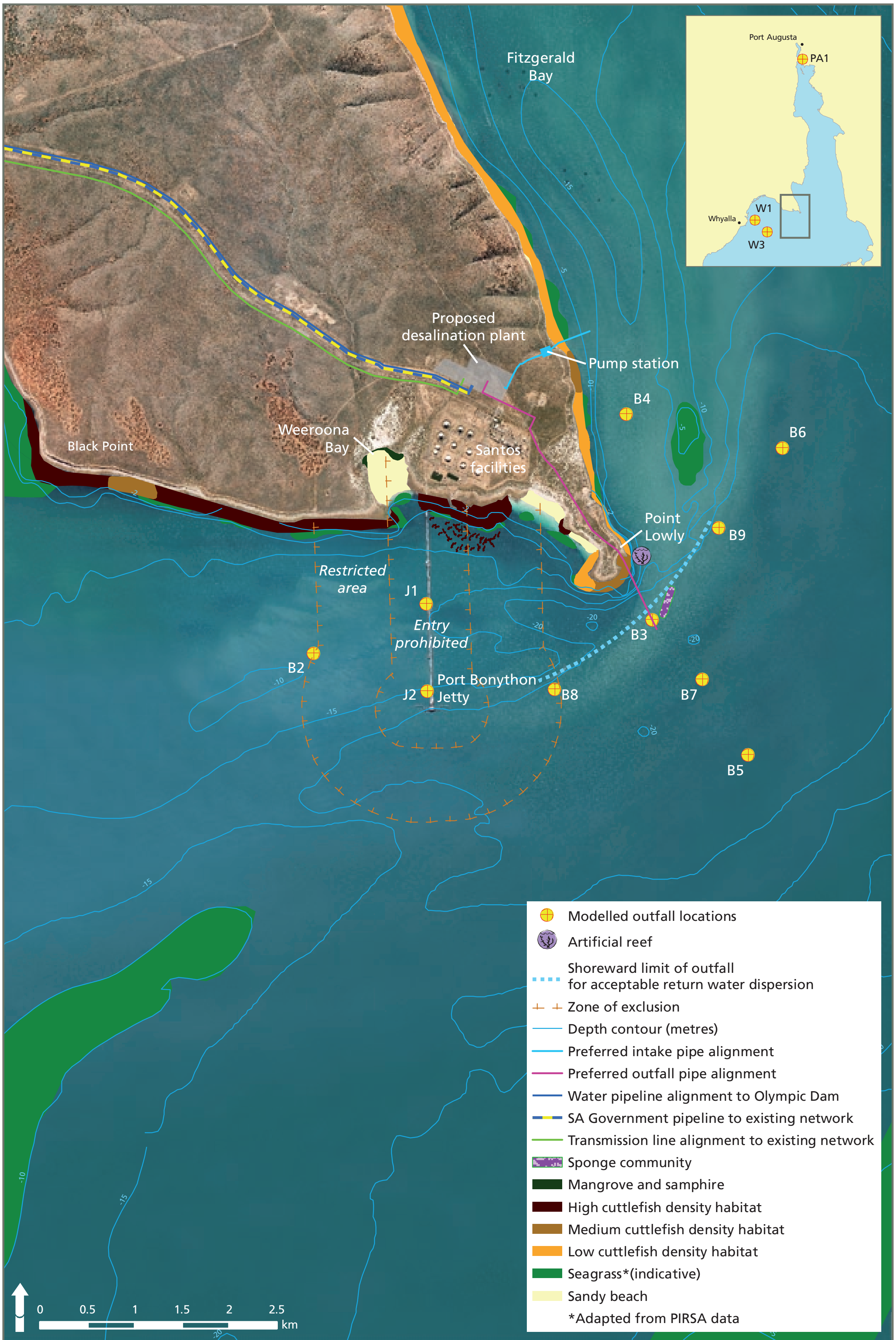

Figure 16.23 Modelled return water outfall locations

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16.6 IMPACT ASSESSMENT AND MANAGEMENT

16.6.1 ASSESSMENT APPROACH

The scope of the impact assessment of desalination plants was initially defined by reviewing the international literature (Al-Mutaz 1991; California Coastal Commission 1993; Höpner 1999; Einav et al. 2002; Höpner and Lattemann 2002; Danoun 2007; Dickie 2007; Lattemann and Höpner 2008) and Australian literature (WEC 2002; GHD Fichtner 2005; Gold Coast Desalination Alliance 2006; Department of Sustainability and Environment 2008). The most significant issues identified were the potential toxic effects of return water, turbidity and silt fall-out effects associated with construction activities, stratification and deoxygenation and impingement and entrainment of marine biota.

The effects of the desalination plant return water on the marine environment in Spencer Gulf were assessed using the following approaches:

- The scale of the return water discharge was placed into a local and regional perspective by:
  - comparing the volume of the return water discharges with the volume of water passing over the diffuser to indicate the potential for immediate dilution of the discharge
  - comparing the relative magnitude of freshwater removed from the gulf via evaporation, and from the desalination plant.
- The daily, seasonal and spatial variability in salinity at Point Lowly were presented to put into perspective the potential salinity increases caused by the discharge of return water.
- The discharges from the desalination plant were compared with existing water quality criteria defined by the Environment Protection (Water Quality) Policy of 2003 (EPA 2003a) to determine if discharges were likely to conform with the policy.
- The ecotoxicology and return water dispersion studies (described in Section 16.4) were used to assess the extent and severity of potential impacts on the marine environment. The ecotoxicology studies provide a specific water quality criterion (or SPTV) to protect local marine species from the impacts of return water. The hydrodynamic modelling studies provide quantitative information about the effect of the return water on salinity levels throughout Spencer Gulf.
- The results of the ecotoxicology and return water dispersion studies were used to define the zone around the outfall within which ecological effects may be detectable.
- Potential effects on the local ecosystem and significant species were assessed against the SPTV derived for the ecosystem, and the EC_{10} values derived for individual species.

Numerous conservative assumptions and measures were adopted in the dispersion modelling and ecotoxicology studies. The assessment outcomes are considered to be conservative because:

- peak discharge rates were used for hydrodynamic modelling (mean discharge is expected to be 16% lower)
- the mid field model assumes that return water in the outfall cell would disperse only in the bottom layer (rather than the bottom two to three layers)
- the modelled current speeds off Point Lowly (used to predict dispersion) were four times slower during low current speeds than those measured recently using a current meter
- the mid field model period combined extreme conditions of dodge tides and no wind
- the modelled outfall location at B3 is near the shoreward limit of acceptable dispersion and close to the sponge community (see Figure 16.23)
- the modelled extraction points for cuttlefish habitat off Point Lowly are worst case (e.g. site f in Figure 16.15 is deeper than, and seaward of, actual cuttlefish reef habitat)
- peak return water salinity of 78 g/L was used during ecotoxicity testing (the average is 75 g/L)
- the ecotoxicity tests involved continuous exposure to elevated salinity levels over several days or weeks. In reality, biota would be exposed to elevated salinity only intermittently with daily tide changes, and fortnightly for about a day
- test species obtained from oceanic water had limited acclimation to the ambient salinity at Point Lowly (which may have reduced effect concentrations and resulted in a higher SPTV dilution)
- the most conservative aspects of the ANZECC/ARMCANZ (2000) water quality guidelines were adopted (i.e. using lowest effect concentrations, using chronic rather than acute data, and assuming the site was pristine and therefore requiring protection of 99% rather than 95% of species. In addition, 10 rather than five species were used for calculation of the SPTV, and a more conservative SPTV was adopted to protect 100% of species and/or provide a margin of safety to account for slightly higher ambient salinities at Point Lowly.

16.6.2 POTENTIAL EFFECTS IN PERSPECTIVE

The discharge volume relative to receiving water volume

The scale of the discharge volume can be placed into perspective by comparing the volume of return water being discharged from the diffuser with the volume of seawater passing over the diffuser under various tidal flows.

The return water is discharged under pressure from the diffuser ports vertically into the water column. Comparing the volume of return water being discharged per second with the volume of seawater passing over the diffuser shows that significant immediate dilution of the return water is predicted to occur within 5 m of the diffuser (see Table 16.14 and Figure 16.24).

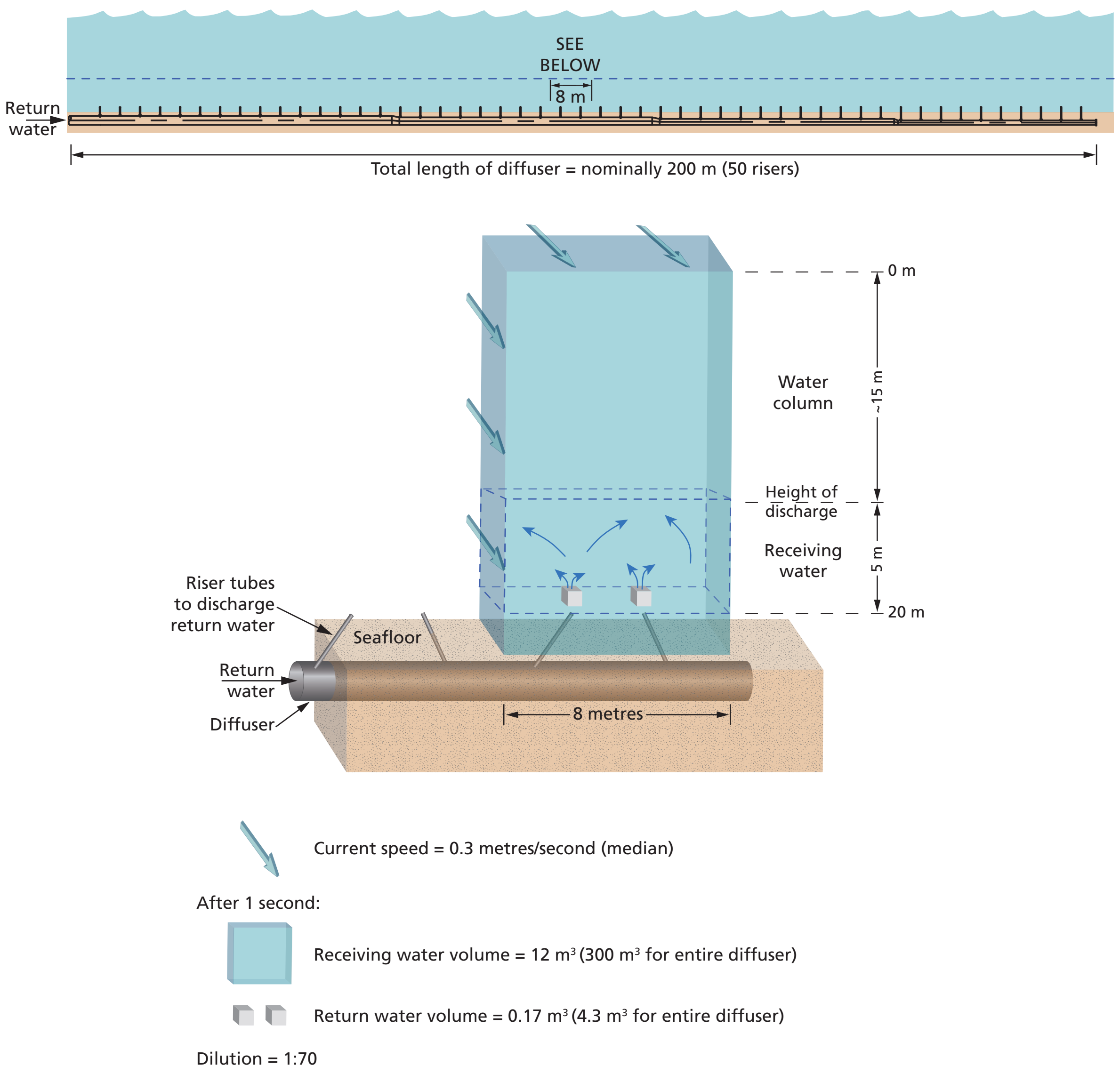

Figure 16.24 Relative volume of return water discharged per second compared to receiving water

Table 16.14 Dilution and resulting salinity (g/L) of the return water within 5 m of the diffuser, assuming perfect mixing

Current speed(m/s)	Current speed percentile (%)[1]	Return water flow rate (m^3/s)[2]	Receiving water flow rate (m^3/s)	Dilution[3]	Resulting salinity (g/L)[4]	Salinity above ambient (g/L)	Increase above ambient (%)
0.01 (extremely low)	1	4.3	10	1:2.3	51.9	9.9	23.6
0.05 (low)	10	4.3	50	1:11	44.6	2.6	6.2
0.3 (moderate)	50	4.3	300	1:70	42.5	0.5	1.1
0.8 (high)	90	4.3	800	1:186	42.2	0.2	0.4

[1] Approximate percentile based on the current speed frequencies shown in Table 16.9.
[2] Maximum discharge of 370 ML/d.
[3] Assumes return water discharged 5 m upwards from ports.
[4] Assumes return water average salinity is 75 g/L and ambient salinity is 42 g/L.

Table 16.14 shows that for 90% of the time (i.e. for current speeds higher than 0.05 m/s), the salinity increase within 5 m of the outfall would be less than 2.6 g/L or 6.2% above background (or would have already achieved a dilution factor of one part return water to 11 parts of ambient seawater).

The comparison is indicative only because it assumes perfect mixing within the water column above the diffuser and does not take into account the complex relationships between discharge rate and current velocities. It is noted, however, that for moderate currents with a plume height similar to the 5 m assumed here, it correlates relatively well with the near field CORMIX modelling results (see final modelling report, Appendix O11).

Effects of evaporation compared with desalination

The potential for long-term increases in salinity in Upper Spencer Gulf caused by the desalination plant can be placed in perspective by comparison with the effects of evaporation.

Extraction of freshwater from seawater by desalination and discharge of the return water to the sea is similar to natural evaporative processes, whereby fresh water is lost to the atmosphere through evaporation and the sea becomes slightly more saline as a result. To put the return water from the desalination plant into perspective, a comparison between water loss from Spencer Gulf through evaporation and desalination was undertaken using pan evaporation data provided by the Bureau of Meteorology (see Table 16.15). The comparison indicated that natural evaporation contributes more to the elevated salinity in Spencer Gulf than the desalination output by a factor of 318. In other words, return water discharge from a desalination plant 318 times the size of the one proposed for Point Lowly would generate the same salinity increase in Spencer Gulf as the natural salinity increase caused by evaporation.

Table 16.15 Comparison of water losses from Spencer Gulf via evaporation and desalination[1]

Water loss via evaporation (ML/d)	80,000
Average water loss via desalination (ML/d)	251
Number of desalination plants equivalent to evaporation	318

[1] A factor of 0.75 is used to convert pan evaporation to sea evaporation, evaporation rate = 4.8 mm/day, area = 22,000 km^2.

This result is consistent with the annual water balance developed using the far field model (i.e. 36,000 GL of evaporation compared with 100 GL for desalination, resulting in a factor of 360). The annual evaporation corresponds to approximately one fifteenth of the volume of the Gulf (see Figure 16.25).

Natural variability in salinity

The potential impact of return water discharge should be considered in the context of the natural daily, seasonal and spatial variation in salinity at Point Lowly. Salinity data collected by Nunes and Lennon (1986) and by water quality data loggers deployed off Point Lowly from June to August 2006 and since April 2007, as part of the Draft EIS studies,

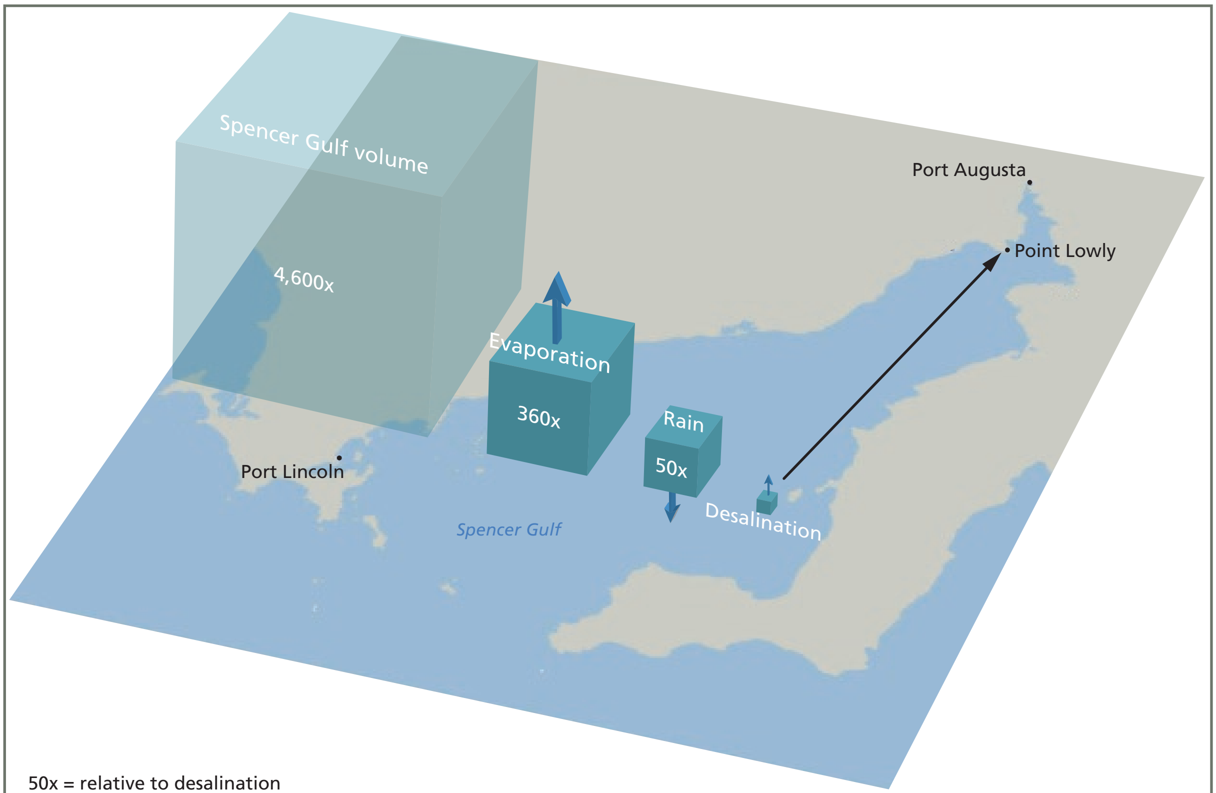

Figure 16.25 Effects of water removal via desalination compared with annual evaporation, rainfall and the volume of Spencer Gulf

have shown the following trends:

- seasonal salinity varies by 3 g/L or 7% (i.e. 40 to 43 g/L)
- daily salinity varies by as much as 1.3 g/L (or 3.1%)
- surface and bottom salinities (in 10 m of water) vary by as much as 1.4 g/L (or 3.3%)
- salinity between Point Lowly and Port Augusta in late summer varies by as much as 6 g/L (or 12%).

The data indicates that the natural salinity at Point Lowly varies substantially, daily and seasonally, and between surface and bottom waters (see Figure 16.26). The variation is caused by the mixing of more saline water from the northern reaches of the gulf with fresher oceanic water off Point Lowly (see Section 16.3.2 for details). The marine ecosystem at Point Lowly has adapted to the existing salinity regime, which is characterised by a relatively high degree of natural variability.

The mid field model predicts that the maximum salinity increase at sites b, c and d, 600 m from the outfall, and the nearest prawn site l, which is 2 km from the outfall (see Figure 16.15), would be approximately 1 g/L (see also Table 16.10). This is one-third of the annual variation at Point Lowly, one-sixth of the difference between Point Lowly and Port Augusta, and less than the natural daily variation and surface to bottom variation.

For 95% of the time, salinity increases at the sponge community (site p) would be similar to the above (compared with a worst case of approximately 2 g/L). The salinity increase at the nearest prawn site would reduce to less than 0.4 g/L, which is seven times less than the annual variation at Point Lowly, 12 times less than the Point Lowly/Port Augusta variation, and three times less than the natural daily variation and surface to bottom variation.

The salinity increase at sensitive receivers near the outfall would therefore be well within the range of natural variation at Point Lowly and Upper Spencer Gulf. The ecotoxicology results

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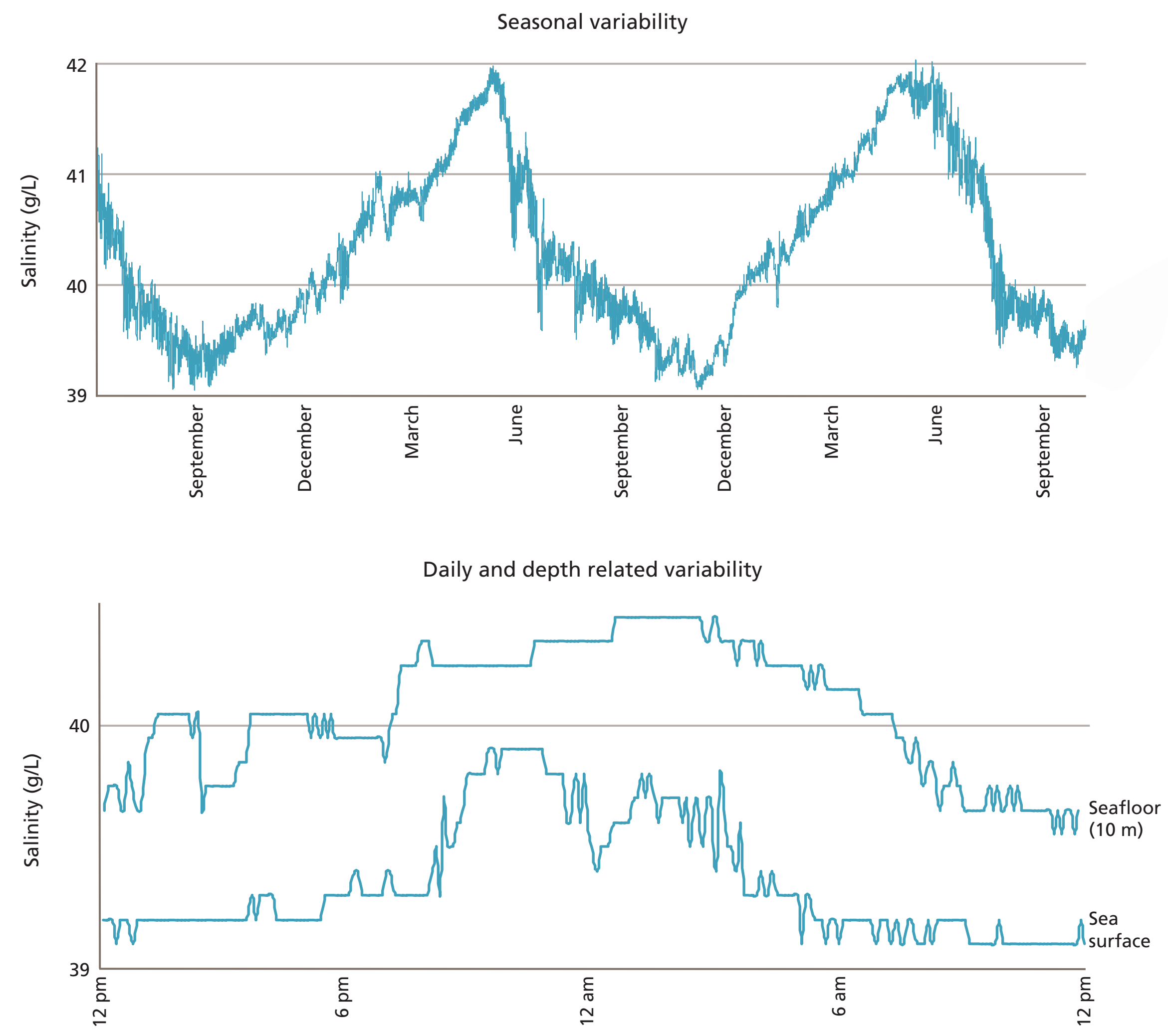


Figure 16.26 Natural variability of salinity at Point Lowly

and model predictions have been used to assess the impact of occasional cumulative extremes of natural variability and salinity increase arising from desalination (see Sections 16.6.5, 16.6.7, 16.6.8).

Ecological transition (ecotone)

The salinity and temperature gradients in Spencer Gulf create an ecotone, in which there is a transition in the composition of marine communities from south to north along the gulf. The communities at Point Lowly are about half way along the ecotone.

In summer, evaporation increases the salinity of gulf waters by an average of 0.5 g/L every 12 km from south to north. The predicted salinity increase of about 0.4 g/L for 95% of the time, at a prawn site 2 km from the outfall, would be equivalent to the existing natural salinity about 10 km north of Point Lowly (see Figure 16.27). Communities (including prawns) 2 km from the outfall are therefore likely to be exposed to salinities that existing communities experience 10 km north of Point Lowly.

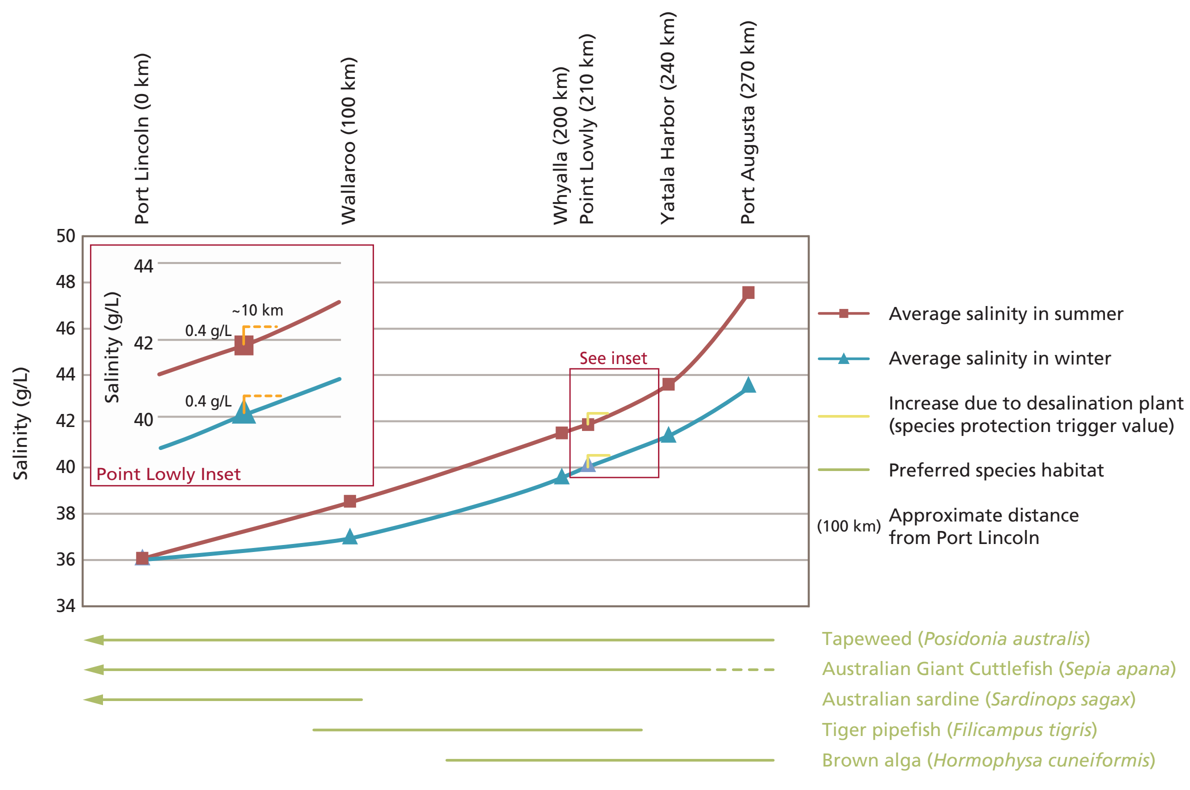
16.6.3 COMPARISON OF THE RETURN WATER DISCHARGE WITH WATER QUALITY STANDARDS

Comparison of the desalination plant discharge with water quality standards is relevant to the near field dispersion of the return water (i.e. within 100 m of the outfall).

Under the *Environment Protection Act 1993*, discharges from the desalination plant are required to conform to the water quality criteria defined by the Environment Protection (Water Quality) Policy 2003 (WQEPP) (EPA 2003a). The WQEPP provides default ambient water quality criteria, generally in the form of thresholds that should not be exceeded, or if already exceeded (e.g. through natural causes), that should not be further exceeded. The WQEPP is based on the water quality guidelines produced by the Australian and New Zealand Environment and Conservation Council and the Agriculture and Resource Management Council of Australia and New Zealand (ANZECC/ARMCANZ 2000), but have trigger values specific to South Australia.

Parameters relevant to an assessment against water quality standards include those in the intake water that are concentrated and discharged at about twice their original concentration, and those added to the discharge during the desalination process. Relevant parameters for which water quality standards exist include a variety of metals, inorganic and organic chemicals and micro-organisms. Preliminary comparisons with water quality criteria suggest that conformance is likely for most of these parameters. Further sampling is required to determine if conformance is likely for the others (see Appendix O14). Further assessments are under way as part of the BHP Billiton pilot desalination plant trials at Port Bonython.

The WQEPP does not specify criteria for salinity when discharging into marine waters. Advice is being sought from the South Australian Environment Protection Authority (SA EPA) in relation to a criterion for salinity. Based on other marine



Source of salinity data: Nunes 1985

Figure 16.27 Salinity increase in the context of the natural salinity gradient in Spencer Gulf discharges in South Australia and Australia, the SA EPA may grant an exemption from conformance with the water quality criterion within a mixing zone, at the edge of which the water quality criterion is to be met. The WQEPP specifies that the mixing zone should have a radius of no more than 100 m.

As noted previously, the World Health Organisation (WHO 2007) suggests that a '10% increment above ambient ocean salinity is a conservative measure of aquatic life tolerance to (an) increase in salinity'. The results of the modelling suggest that the desalination plant would meet this criterion, with the salinity falling to less than 10% above background at 100 m from the outfall, even for the worst case dispersion (see Section 16.4.3). For the purpose of the Draft EIS, a more conservative salinity increase (i.e. 1% above background) was used to determine ecological effects (see Section 16.6.5 for details).

The residual impact on water quality near the outfall at Point Lowly will be determined once appropriate guidelines and mixing zone size have been provided by the SA EPA.

16.6.4 POTENTIAL FOR SALT ACCUMULATION IN SPENCER GULF

Natural salinity levels in Spencer Gulf are stable despite high levels of evaporation (equivalent to 318 desalination plants annually), which implies that accumulated salt is effectively removed from the gulf (see Figure 16.4 and Table 16.15). The likely mechanism is the removal of salt from the gulf via clockwise circulation within the gulf and a hypersaline bottom current in winter (Nunes and Lennon 1986; Lennon et al. 1987; Nunes-Vaz et al. 1990).

The salt removal mechanism has proven to be insensitive to considerable variation in evaporation over the past 30 years. Despite an increasing trend in evaporation over the past decade (see Figure 16.28), there has been no substantial change to the salt balance in 2008 compared with 25 years ago (see report by Dr R Nunes-Vaz, Appendix O9).

The theoretical rate of water turnover across a boundary at Point Lowly required to maintain steady state salinity in Upper Spencer Gulf may be determined as follows. Average annual salinities at Point Lowly and Port Augusta are approximately 41 g/L and 46 g/L respectively (Nunes and Lennon 1986). Taking the midpoint of 43.5 g/L as the average salinity in Upper

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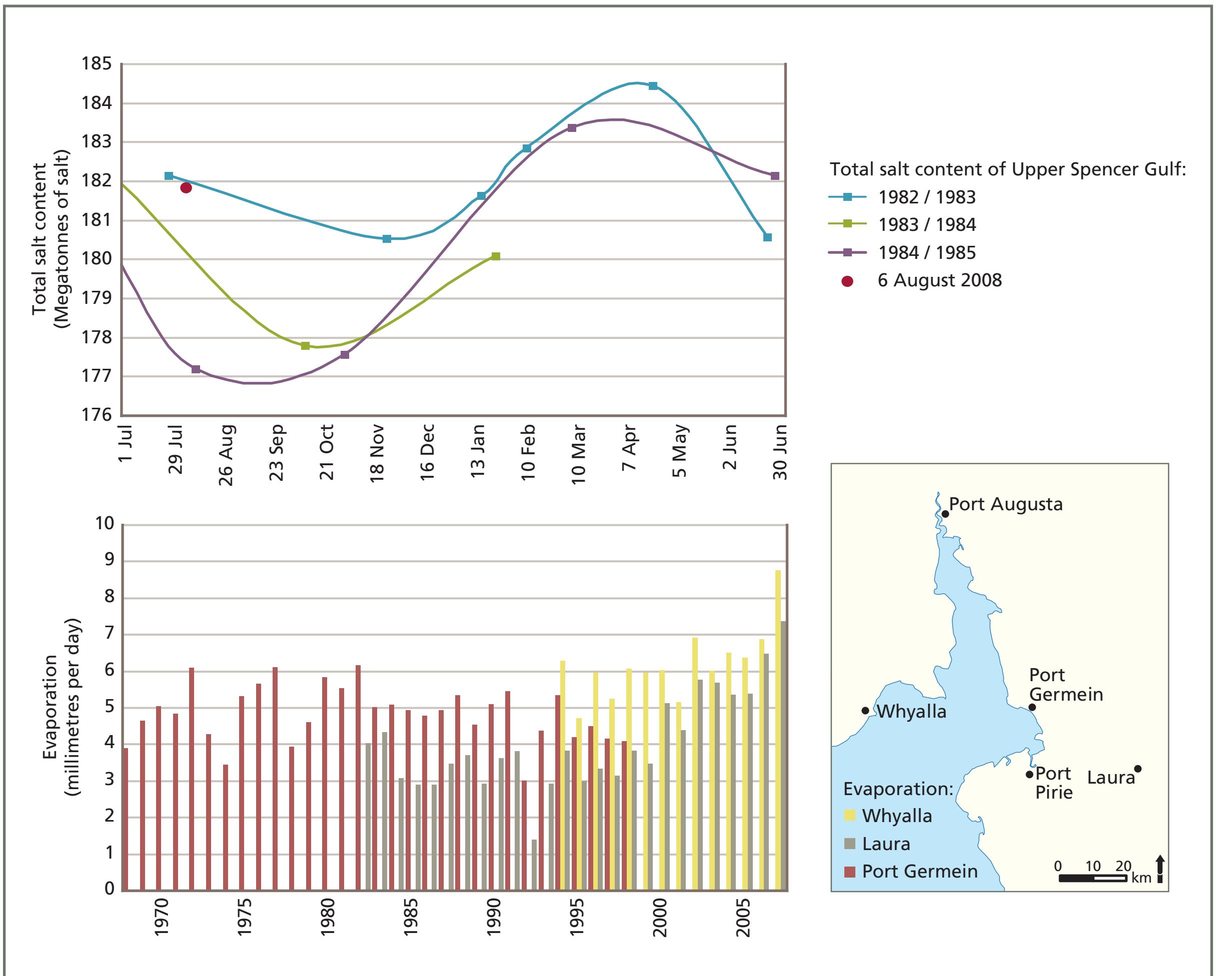

Figure 16.28 Climate change - salinity and evaporation in Upper Spencer Gulf

Spencer Gulf, and assuming evaporation of 2 m/yr and an average depth of 9 m, maintenance of steady state salinity requires approximately 78% of the seawater north of Point Lowly to be exchanged each year (or 63% each six months) with the less saline water south of Point Lowly. A lower average salinity in Upper Spencer Gulf than 43.5 g/L, which is likely because of the greater volume of water nearer to Point Lowly than Port Augusta, would result in a greater percentage of water being exchanged, hence the result of 78% is conservative.

The far field model results supported these findings (see Section 16.4.3), as it:

- confirmed the amount of evaporation relative to the proposed desalination plant
- reproduced the gulf-wide clockwise circulation pattern and hypersaline bottom current in winter
- predicted flushing times of one year for water in Upper Spencer Gulf to flush across the oceanic boundary (an animation for this topic is available at <www.bhpbilliton.com/odxeis> and on the disc accompanying the Executive Summary)
- predicted flushing times of a few months for water in Upper Spencer Gulf to flush across a boundary at Whyalla.

The far field model was run for five years to determine if salt levels could build up in Spencer Gulf as a result of continuous operation of the desalination plant. The model showed that steady state conditions were reached after one year and that the long-term average increase would be 0.07 g/L near Point Lowly, 0.03 g/L in Upper Spencer Gulf (see Figure 16.20). At the site near Wallaroo, towards the middle of the Gulf, the increase of 0.01 g/L is the same as that calculated for the salt balance (see Figure 16.20).

The predicted increases would be significantly less than the daily and surface to bottom variation measured at Point Lowly of 1.3 g/L, and seasonal variation of 43–48 g/L at Port Augusta and 38–39 g/L 160 km south of Port Augusta (Nunes and Lennon 1986) (see Figure 16.26). The predicted 0.07 g/L (0.17%) increase in salinity in Upper Spencer Gulf (based on the worst case at Point Lowly) is unlikely to have detectable ecological effects at the ecosystem scale (i.e. the whole of Upper Spencer Gulf).

To further test the sensitivity and possible limits of the salt removal mechanism, additional modelling was undertaken using climate change scenarios predicted for South Australia (Suppiah et al. 2006). The results are presented in Section 16.6.14.

The evidence shows that the ongoing discharge of return water to Spencer Gulf at Point Lowly would have a negligible residual impact upon the long-term salinity of gulf waters.

16.6.5 ZONE OF POTENTIAL ECOLOGICAL EFFECT

The zone around the outfall where ecological effects on the marine ecosystem may occur is defined by the species protection trigger value (SPTV) (generated from the ecotoxicity test) and the outcomes of the return water dispersion modelling.

The SPTV generated from the ecotoxicology tests suggests that a dilution of 1:45 would protect 99% of species occurring at Point Lowly, when the background salinity is 41 g/L or less. This level of protection (99%) is recommended by the ANZECC/ARMCANZ (2000) guidelines for ecosystems with high conservation value. An additional, more conservative SPTV dilution factor of 1:85 has also been determined, which not only protects 100% of species when the background salinity is 41 g/L or less, but also includes some toxicity data (for Australian Giant Cuttlefish) based on background salinity of 45 g/L.

The near field dispersion modelling shows that the maximum increase in salinity at 100 m from the outfall would be 3.7 g/L (approximately 9% above ambient), which is equivalent to a return water dilution of 1:8. The SPTV would be exceeded within 100 m of the outfall at all times. Effects on some species are therefore likely to occur within 100 m of the outfall.

The mid field modelling was used to define the area within which the SPTV would be breached (see Figures 16.16a and 16.18). The percentile plots illustrate how the extent of these dilution contours would vary (according to tidal conditions), as summarised in Table 16.16. For example, the extent of the 1:85 contour would be typically 2 km and a maximum of 3.9 km from the outfall during worst case conditions (no wind and dodge tide). The extent would be less than or equal to 1.1 km for 90% of the time when tides are stronger (an animation for this topic is available at <www.bhpbilliton.com/odxeis> and on the disc accompanying the Executive Summary).

Table 16.16 Maximum extent of dilution contours (distance from outfall)

Dilution percentile	Contour extent	
	1:45	1:85
0th (all of the time)	≤ 2.2 km	≤ 3.9 km
1st (99% of the time)	≤ 1.1 km	≤ 2.8 km
10th (90% of the time)	≤ 300 m	≤ 1.1 km

The residual impact on the marine ecosystem at Point Lowly has been categorised as: moderate within 100 m of the outfall (reflecting a long-term impact on a local receiver); low beyond 100 m of the outfall and within the 1:85 dilution contour, with a maximum extent 3.9 km along the direction of tidal flow south-west of, or 2.1 km north-east of, the outfall (reflecting a short-term impact on a local receiver); and negligible for higher dilutions (reflecting no detectable impact).

Before the desalination plant commenced operation, a monitoring program incorporating the following would be established:

- seasonal surveys describing the composition of benthic communities at permanent underwater monitoring sites
- a seawater program to provide comprehensive water quality data (including salinity and dissolved oxygen) for Point Lowly. Salinity/temperature meters and data loggers would be used to monitor salinity at critical sites

- a sediment sampling program at Point Lowly to provide comprehensive sediment quality information, including organic and inorganic pollutants and sediment oxygen demand.

During the first year of operation of the desalination plant, salinity and dissolved oxygen would be monitored intensively within 1–2 km of the outfall, under a variety of tide and wind conditions, to validate the hydrodynamic model predictions of dispersion and dilution of the return water. Rhodamine WT dye would be added to the return water on several occasions (including during dodge tide and no wind conditions) to provide a direct measure of return water dilution and dispersion within several kilometres of the outfall. If the model predictions were confirmed, the monitoring program would be reviewed and revised appropriately.

16.6.6 EFFECTS ON SIGNIFICANT SPECIES

The Australian Giant Cuttlefish, which is of particular conservation significance at Point Lowly, is discussed separately in Section 16.6.7.

Listed species

Forty-five species of listed marine flora and fauna were identified from relevant databases as potentially occurring in Upper Spencer Gulf. These include eight threatened species (see Table 16.4 and Appendix O3), and 37 species that are listed in non-threatened categories under the EPBC Act (i.e. migratory species, listed marine species and cetaceans) or South Australian legislation (i.e. rare, protected) (see Appendix O3 for details). The eight threatened species are the Southern Right Whale, Humpback Whale, Australian Sea-lion, Great White Shark, Green Turtle, Loggerhead Turtle, Leatherback Turtle and Hawksbill Turtle.

The potential risk to the 45 listed species was considered in terms of the following criteria:

- their occurrence in Upper Spencer Gulf
- their mobility
- the availability of suitable habitat in Upper Spencer Gulf
- the potential for return water from the desalination plant and construction activities to affect the habitat of these species
- the likely sensitivity of these species and their food resources to return water and construction impacts.

Sixteen of the 45 species have never been recorded in or near Upper Spencer Gulf. These include the threatened Loggerhead Turtle and Leatherback Turtle and the Robust Pipehorse.

Twelve of the species have been recorded in or near Upper Spencer Gulf but are highly mobile (see Appendix O3). These include the threatened Humpback Whale, Southern Right Whale, Australian Sea-lion, Great White Shark, Green Turtle and Hawksbill Turtle. These species have extensive suitable habitat in areas of Upper Spencer Gulf outside the area potentially affected by return water. With the proposed increased shipping movements in Spencer Gulf the likelihood of hitting these species remains low.

The remaining 17 sessile or less mobile species include the seagrass *Zostera mucronata* and 16 species of Syngnathid (seahorses and pipefish).

The nearest recorded communities of the seagrass *Zostera mucronata* occur at least 15 km from the proposed outfall (near Whyalla to the south and Yatala Harbor to the north), well beyond the zone where effects on water quality would be detectable. It is concluded therefore that Zostera mucronata communities would not be affected.

Syngnathids generally occur within relatively low energy seagrass environments, such as Fitzgerald Bay and False Bay, which are well beyond the zone where effects on water quality would be detectable. The return water dispersion modelling and ecotoxicology studies established that the return water would not affect seagrass communities.

The Tiger Pipefish (*Filicampus tigris*), however, is an exception. It inhabits sandy/muddy substrates adjacent to channels at depths ranging from approximately 2–30 m. Although common in north-eastern and north-western Australia, it has been recorded only in very low numbers in South Australia, in Upper Spencer Gulf (Baker 2008). Impacts on the Tiger Pipefish would be negligible, however, because the species protection trigger value would be exceeded only in a very small proportion of their habitat in Upper Spencer Gulf.

The impact on the 45 species of listed marine flora and fauna has been categorised as negligible.

The Department of Environment, Water, Heritage and the Arts (DEWHA) has developed administrative guidelines to assist proponents in identifying whether their project has the potential for significant impact on fauna and flora species listed within the EPBC Act (DEWHA 2006).

Nationally listed species potentially occurring within Upper Spencer Gulf include six threatened species and three listed migratory whales. All of these species (whales, turtles, the Australian Sea-lion and the Great White Shark) are highly mobile and have extensive habitat outside Upper Spencer Gulf. The proposed desalination plant and landing facility are not expected to fragment or decrease the size of populations, affect critical habitat, disrupt breeding cycles or introduce disease or pests that may adversely affect these species. It is concluded that the residual impact on each of these species would be insignificant (according to the DEWHA guidelines).

Other significant species

A number of species with tropical affinities are likely to be found in the vicinity of the desalination plant outfall (see Section 16.3.7) and may be affected by the return water discharge. These include the Sea Pen *Virgularia gustaviana*, and the Soft Coral *Carijoa multiflora*, which are commonly attached to Razorfish and to jetty piles. Impacts on these species may occur in the vicinity of the outfall, but would be of little ecological significance at the regional scale as they are widely distributed in Upper Spencer Gulf (see Appendix O2). Residual impacts on these species would be negligible.

A sponge community extending over approximately two hectares of the channel in the vicinity of the discharge point was identified during ecological surveys of the region (see Section 16.3.4). Impacts on this community have been categorised as moderate, reflecting a long-term impact on a common receiver. Further attention will be paid to minimising impacts on this community during the detailed design phase and when selecting the ultimate location of the outfall pipe.

16.6.7 EFFECTS ON AUSTRALIAN GIANT CUTTLEFISH

Background

Cephalopods typically have low tolerance to variations in salinity, temperature, dissolved oxygen and pH (Wells 1962; Holme 1974; Palmegiano and D'Apote 1983; D'Aniello et al. 1989; Paulij et al. 1990; Augustyn 1991; Vecchione 1991; Pörtner and Zielinski 1998; Domingues et al. 2001; Cinti et al. 2004; Sen 2005), and are unable to osmoregulate, which considerably affects their ability to tolerate elevated salinities.

The tolerable salinity range of developing cuttlefish embryos is likely to be narrower than that of adults, as the salinity inside cuttlefish eggs must be maintained at a higher level than surrounding waters (Vecchione 1991; Sen 2005). Osmotic stress is reported to result in developmental deformation (Paulij et al. 1990, see Appendix O8). These effects may relate to the diversion of energy from development and growth of the embryo to maintaining the osmotic gradient.

If increases in salinity or other variables cause stress to the adult cuttlefish, the complex breeding behaviour may be affected (Hall and Hanlon 2002). Avoiding the Point Lowly area and using alternative breeding sites may not be a viable option for adult cuttlefish as there is limited suitable reef habitat for breeding within Spencer Gulf.

Interaction with return water

Interaction of return water with the shallow cuttlefish habitat is expected to be minimal for the following reasons. After discharge of return water from the diffuser (at a depth of more than 20 m), the more dense return water plume would tend to fall to the seafloor and be entrained by tidal (rather than wind) currents, taking the plume away from Point Lowly (see Figures 16.17a and b). During periods of no current, the return water would flow under the influence of gravity away from the near-shore reef habitat towards the deeper sections of the gulf.

The results of the return water ecotoxicity tests and dispersion modelling confirm that the effects on Australian Giant Cuttlefish within the spawning habitat would be minimal. Ecotoxicology tests showed that the worst case dilution required to protect cuttlefish eggs, embryos and hatchlings from a sub-chronic effect (including growth) of greater than 10% was 1:55. Model results from the cuttlefish site nearest the outfall (see site f in Figures 16.14, 16.16a and b) indicated a dilution of at least 1:116 was always achieved, limiting the effect to less than 1% (i.e. doubling the EC_{10} dilution of 1:55 results in ten times less effect).

If the toxicity was due to anti-scalant alone, rather than salinity, the dilution to protect cuttlefish would be 1:55. Conversely, if the toxicity was due to salinity, as shown elsewhere (B Gillanders, University of Adelaide, pers. comm., 3 December 2008), the 1:55 dilution is likely to be conservative for the following reasons. This dilution was derived using diluent water of 45 g/L, which is more saline than the natural range at Point Lowly of 40–43 g/L. The salinity of 45.6 g/L equivalent to the EC_{10} could in fact be achieved with a dilution of less than 1:13, based on diluent of 43 g/L. This result was supported by further cuttlefish tests using diluent of salinity 41 g/L, which lies within the range of natural salinity for the cuttlefish breeding season. The result of these tests indicated that a dilution of 1:16 would protect cuttlefish.

The minimum dilution of 1:116 at the closest cuttlefish site is equivalent to a salinity increase of less than 0.3 g/L, or a maximum salinity of 42.3 (at the end of May, the start of the cuttlefish breeding season). Ten kilometres north of Point Lowly at Backy Point, where the density of cuttlefish is very high during the breeding season (see report by Dr K Hall, Appendix O5), the natural salinity reaches 43 g/L, which is significantly higher than the worst outcome within the cuttlefish habitat at Point Lowly.

It is concluded, therefore, that impacts on cuttlefish within the reef habitat at Point Lowly would be negligible (reflecting no detectable impact).

Programs would be established to:

- monitor Australian Giant Cuttlefish populations at Point Lowly before and after the desalination plant began to operate
- monitor salinity within the Point Lowly cuttlefish habitat before and after the desalination plant began to operate.

If the salinity model predictions were confirmed when the desalination plant was in operation, the monitoring program would be reviewed and revised as appropriate.

16.6.8 EFFECTS ON FISHERIES AND AQUACULTURE

The ecotoxicology studies have shown that a species protection trigger value (SPTV) dilution of approximately 1:85 is required to protect species in Upper Spencer Gulf (see Section 16.4.2). This dilution would be exceeded for up to 90% of the time up to 1.1 km from the outfall, and at all times within 100 m. As such, some commercial species that occur close to the outfall could be affected. During dodge tides the potential effects may occur up to 3.9 km from the outfall (see Section 16.6.5).

Although the SPTV for 100% of species is 1:85, the protection values for individual commercial species tested are significantly less (i.e. these species are less sensitive to increasing salinity levels). The ecotoxicology tests established that the protection value (expressed as return water dilution derived from the EC_{10} of the individual species – see Table 16.8) for a number of commercially important species are:

- Western King Prawn – 1:14
- Snapper – 1:5
- Yellowtail Kingfish – 1:10
- Pacific Oyster – 1:31.

The results of the hydrodynamic modelling have shown that for most species, predicted dilutions at 100 m from the outfall would only be worse than the 'safe' dilution during dodge tides or at the turn of each tide when water movement is minimal, and for Snapper, dilutions would always be better (at 100 m).

Snapper in particular would be attracted to the habitat provided by the intake and outfall infrastructure. Effects on Snapper are likely to be behavioural, with Snapper possibly avoiding the immediate vicinity of the outfall when plume dispersion is poor. The effect would be temporary, lasting no longer than the duration of the tide change (a few hours) or the fortnightly dodge tide (approximately one day).

The minimum dilutions predicted at the Kingfish farms in Fitzgerald Bay were 1:319, and therefore considerably better than the 'safe' dilutions required to protect Kingfish from chronic effects (i.e. 1:10). The ambient salinity in Fitzgerald Bay is between 40 g/L and 43 g/L. An acute test done on Kingfish fingerlings at a starting salinity of 40 g/L showed no mortality at 45.7 g/L.

The minimum dilution predicted for the prawn trawling sites off Point Lowly was 1:37 and therefore better than the 'safe' dilution to protect prawns (i.e. 1:14).

The oyster farms at Franklin Harbor would be affected only by a long-term average far field salinity increase of 0.01 g/L (see Table 16.11), which is considerably lower than the salinity increase of 1.2 g/L corresponding to the safe dilution of 1:31 (see Table 16.8).

The *Dunaliella salina* microalgal production in False Bay would not be affected, as the long-term average far field salinity increase of 0.07 g/L would be insignificant compared to the salinities of 100–300 g/L in which the algae are grown (Borowitzka et al. 1990; Ben-Amotz 2003). The return water would be highly diluted (approximately 1:500), which would result in no impact from anti-scalant or other chemicals.

Residual impact on Yellowtail Kingfish aquaculture in Fitzgerald Bay, macroalgal production in False Bay, Pacific Oyster farms in Franklin Harbor and Snapper near Point Lowly would be negligible at all times (i.e. no detectable impact). Residual impacts on Western King Prawns has been categorised as moderate within 100 m of the outfall (reflecting a long-term impact on a common receiver) and negligible elsewhere. Residual impact on species not individually tested (e.g. Blue Swimmer Crab) has been categorised as moderate with 100 m of the outfall, low within the 1:85 dilution contour, and negligible elsewhere. Accordingly, the residual impact on the associated commercial and/or recreational fisheries would be below detectable limits and is therefore categorised as negligible. Consequently, there would be no foreseeable impact on yields as a result of return water discharge.

16.6.9 Stratification and deoxygenation

Dissolved oxygen is critical to respiratory processes of aquatic fauna and sediment biogeochemical processes (Diaz and Rosenberg 1995).

The return water would be well oxygenated prior to discharge (see Section 16.4.1). Fouling of the outfall pipes and subsequent de-oxygenation has not proven to be a problem at other desalination plants, including the plant at Kwinana (Western Australia). During its first 12 months of operation, dissolved oxygen levels have consistently been 1–2 mg/L higher in the return water than the intake water (Water Corporation of Western Australia, unpublished data from first year of operation of Kwinana desalination plant, 2007–2008).

Prolonged periods of stratification, however, can lead to reduced mixing within the water column and draw down of dissolved oxygen in the water adjacent to the sediment to potentially low levels, affecting respiration of marine fauna.

Detailed studies of stratification and deoxygenation associated with the proposed desalination plant at Kwinana are relevant to the current assessment. With its weak currents and sheltered conditions, the adjacent waters of Cockburn Sound are relatively susceptible to stratification and deoxygenation. Hydrodynamic modelling studies of return water discharges from the Cockburn Sound desalination plant have shown that the effects of return water on stratification and dissolved oxygen levels within the deep channels of Cockburn Sound are likely to be relatively minor, and generally within the range of natural variation currently observed (Worley 2005; Van Senden and Miller 2005; Spigel et al. 2005; Yeates et al. 2006; Okely et al. 2006). Subsequent monitoring of the return water dispersion at Cockburn Sound has confirmed these findings (Okely et al. 2007a, 2007b). Although extreme natural conditions caused dissolved oxygen levels to drop below regulatory thresholds, there is convincing evidence from modelled and monitoring data to show that this could not be attributed to the desalination plant (Water Corporation and 360 Environmental 2008).

Spencer Gulf waters are naturally susceptible to stratification due to the north–south salinity and temperature gradients. The hypersaline bottom current that transports highly saline water out of the gulf during winter is an example of such stratification (Lennon et al. 1987). During neap tides, each fortnight, Spencer Gulf experiences stratification over wide areas, resulting in the formation of salinity 'slugs' that flow southwards along the eastern side of the gulf (Nunes-Vaz et al. 1990).

At Point Lowly, however, stratification is less likely to occur than in other parts of the Gulf as the regime of strong currents and frequent wind generated waves result in relatively good mixing of the water column. Although periods of low water movement occur regularly, periods of limited mixing last for at most two days (see final modelling report, Appendix O11).

The risk of significant deoxygenation occurring during fortnightly two-day periods of low water movement (when stratification may occur) is minimal because the sediment oxygen demand is too low. Assuming that the sediment oxygen demand off Point Lowly is 0.33–0.82 g/m^2/d (Lauer 2005), and the ambient dissolved oxygen level is 5.5 g/L (the lowest level in the return water), it would take 6–15 days to draw the dissolved oxygen level (in the bottom 2 m layer of water) down to a threshold of 3 mg/L below which ecological effects could occur (Diaz and Rosenberg 1995).

Within 100 m of the outfall, where stratification may last up to six days, deoxygenation would not occur as well oxygenated return water ejected through the diffuser would displace the ambient seawater 4–5 times each day.

Therefore the residual impact associated with stratification and possible deoxygenation of the lower section of the water column at Point Lowly is considered to be negligible, reflecting no detectable impact.

A monitoring program would be established before the desalination plant commenced operation. It would include comprehensive sampling of dissolved oxygen and sediment oxygen demand at critical sites at Point Lowly. During the first year of operation of the desalination plant, salinity and dissolved oxygen would be monitored intensively within 1–2 km of the outfall, under a variety of tide and wind conditions, to determine if the stratification and subsequent low dissolved oxygen occurs on the seafloor. If the predictions of negligible impact are confirmed, the monitoring program would be reviewed and revised as appropriate.

16.6.10 IMPINGEMENT AND ENTRAINMENT OF MARINE BIOTA

The intake of large volumes of seawater could adversely affect marine organisms if they are impinged (trapped) against the intake screens, or entrained (taken up) within the intake water.

Impingement

A number of established power stations have cooling water intakes and hence the potential to impinge marine organisms. The results of four studies on the effects of impingement associated with power stations in NSW suggest that rates of impingement of fish and crustaceans are small and affect relatively few species of economic importance (Ruello 1978; Henry and Virgona 1981; Scanes 1988; Scanes et al. 1993, cited in TEL 2005). It has been suggested that an intake velocity of <0.6 m/s would minimise the effects of impingement (TEL 2005). The inflow rate for the proposed intake structure is approximately 0.2 m/s, which is one-third of the recommended safe intake flow. The intake structure (see Figures 16.13 and 5.31) would be cleaned regularly by divers to ensure that fouling did not increase intake velocities. Virtually all mobile biota would be capable of swimming away from the proposed Point Lowly intake pipe.

The residual impact of the desalination plant through impingement would be negligible, reflecting no detectable impact.

Entrainment

Small biota, such as fish eggs, larvae, plankton and juveniles are more susceptible to entrainment by intake pipes, although adults may also be entrained.

A study for the proposed Sydney desalination plant (up to an estimated 1,000 ML/d intake compared with 650 ML/d at the proposed Point Lowly plant) suggested that although there may be some localised effects of entrainment on planktonic larvae, there would be little effect on a regional scale (TEL 2005). Furthermore, Ambrose and others (1996) found no evidence of even a local reduction in zooplankton abundance, despite up to 1,200 tonnes being entrained annually by a 10,500 ML/d cooling water system in a nuclear power station. Numerous power stations in Australia (including the Playford and Northern power stations at Port Augusta) have cooling water intake volumes typically two to three times that of the maximum 650 ML/d proposed for Point Lowly (see Table 16.17).

The potential scale of larval entrainment associated with the desalination plant intake pipe can be illustrated by comparing the annual volume of water taken into the proposed desalination plant (2.4 x 10^5 ML) with volumes of water in all of Spencer Gulf and Upper Spencer Gulf (i.e. the far field and mid field model domains, respectively) (see Figure 16.3 and Table 16.18). The comparison shows that on local and gulf-wide scales, the percentage of water entrained annually would be 2% and 0.04% respectively.

The ecological effects associated with the potential loss of larvae may also be put in perspective through comparison with the ongoing effects of commercial fishing. The Spencer Gulf prawn fishery is the most suitable fishery for comparison as considerable data on larval recruitment has been collected for this fishery (Carrick 2003; Dixon et al. 2007). The commercial prawn catch of Upper Spencer Gulf inevitably involves loss of larvae, and it has been demonstrated that there is a relationship between the number of spawning adults and subsequent recruitment levels to the fishery (PIRSA 2003c). Nevertheless, through an extensive research program and highly responsive fisheries management practices, the fishery has operated for decades at a sustainable level (PIRSA 2003c; Zacharin et al. 2008).

A simple series of calculations using conservative estimates has been undertaken to compare the loss of larvae in the entrained

Table 16.17 Cooling water intake rates for a number of power stations

Intake plant	Volume (ML/d)	Source/Notes
San Onfre nuclear power station (California, USA)	10,050	Ambrose and others (1996, cited in TEL 2005). 1,200 tonnes of larvae entrained annually (including larval fish)
Northern power station (Port Augusta)	1,863	Terry Manning, Flinders Power, pers. comm., 26 July 2007. A less recent source quoted 5,500 ML/d
Eraring power station (NSW)	1,814	<http://www.eraring-energy.com.au/docs/Eraring-power-station-fact-sheet.pdf>
Torrens Island power station (SA)	1,600	Rychard Oleszczyk, TXU Pty Ltd, pers. comm., 18 July 2007. May have been as high as 3,000 ML/d when plant was operating 24 hours/7 days
Munmorah power station (NSW)	1,382	<http://www.de.com.au/default.aspx?FolderID=193&ArticleID=265> Full capacity is 2,350 ML/d (Wayne Milner, Delta Electricity, pers. comm., 27 July 2007)
Playford power station (Port Augusta)	466	Terry Manning, Flinders Power, pers. comm., 26 July 2007

Table 16.18 Intake volume as a percentage of connected water volumes at different scales

Modelling domain	Locality	Volume of water (ML)	Percentage of water entrained annually
Far field	Entire Spencer Gulf	4.9 x 10^{8}	0.04
Mid field	Upper Spencer Gulf (to just south of Whyalla and Port Pirie)	9.5 x 10^{6}	2

Table 16.19 Calculations used to estimate the percentage of the commercial prawn catch equivalent to prawn larvae lost through entrainment

Step	Parameter	Source	Value
1	Density of prawn larvae	Carrick 2003 (derived from figure)	22 m^{-3}
2	Window of prawn larvae presence in gulf	Based on spawning window and larval survival time reported by Dixon et al. (2007)	7 months
3	Desalination plant intake rate	Table 16.6 (average intake)	560 ML/d
4	Total intake prawn larvae	Calculated from 1, 2, 3	2 x 10^{8}
5	Survival rate eggs to larvae	Variable – calculation parameter	10%
6	Number of eggs per prawn trawl shot	Dixon et al. 2007 (summed over all size classes for 2005)	7 x 10^{8}
7	Number of shots equivalent to larvae entrainment	Calculated from 4, 5, 6	37
8	Total catch equivalent to larval entrainment	Calculated from 7 and average catch per shot summed over all size classes for 2005 (Dixon et al. 2007)	4.5 tonnes
9	Total prawn catch	Total catch for 2005 (Dixon et al. 2007)	1,870 tonnes
10	Percentage of total catch equivalent to larval entrainment	Calculated from 8, 9	0.24%

water to the equivalent losses associated with the annual prawn catch. The key uncertainty is the proportion of fertilised eggs that survive to become larvae (see step 5 in Table 16.19). Assuming 10% of eggs survive, the comparison shows that prawn larval loss associated with entrainment into the desalination plant would be equivalent to the loss associated with 0.24% of the commercial prawn catch. Similarly, assuming 1% of eggs survive, the loss would equate to 2.4% of the loss associated with the commercial catch. In other words, the loss from the commercial prawn catch would be approximately 400 or 40 times greater than the proposed desalination plant (for 10% and 1% egg survival respectively).

Entrainment of Australian Giant Cuttlefish eggs would not occur as eggs are firmly anchored to rock substrate within crevices in the near-shore reef habitat at Point Lowly. Newly hatched cuttlefish would be more susceptible to entrainment, but would be capable of swimming away from the intake.

All three approaches used to assess the effects of entrainment on marine biota suggest that the residual impact of the desalination plant would be negligible, reflecting no detectable impact.

BHP Billiton has initiated further investigations into the potential effects of entrainment by commencing field studies to determine the seasonal diversity and abundance of fish and crustacean larvae off Point Lowly.

16.6.11 DESALINATION PLANT CONSTRUCTION

Although the construction method for the intake and outfall pipelines would not be determined until after detailed design and the appointment of a construction contractor, it would involve trenching at least through the intertidal zone and some, if not all, of the subtidal zone. In off-shore areas, the pipes may be laid on the seafloor. The most likely method of excavation is by clamshell bucket operated by a crane on a temporary jetty close to shore, and on a flat top barge secured by a temporary mooring system in off-shore areas. The trench would be excavated in sections, with spoil being used to cover completed sections of pipe. Potential impacts associated with construction operations include increased turbidity, silt deposition, and noise and vibration effects from excavating (and possibly blasting) the pipeline trenches.

Measures would be taken to minimise the impacts of construction on the breeding habitat and behaviour of the Australian Giant Cuttlefish. Construction works in the area of the cuttlefish breeding habitat would occur between 1 November and 1 May to avoid the cuttlefish breeding season from May until September and hatching that continues through to November. Suitable breeding habitat covers approximately 61 ha and extends 18 m off-shore near the intake and 75 m near the outfall (Hall and Fowler 2003). Assuming trenches of width 3.8 m and 4.6 m respectively would be required to install each pipe, then less than 400 m^2 (approximately 0.06%) of the cuttlefish breeding habitat would be directly affected by the construction activities in the area.

If the breeding habitat is disturbed during installation of the intake and outfall pipes, the reef would be reinstated over the pipe to maintain the habitat value of the area. It is likely that the reinstated reef over the pipelines would be used as breeding habitat, as the artificial rock breakwaters around Whyalla currently provide significant breeding habitat. Garden pavers have also been shown to be successfully used as breeding habitat (see Appendix O5). It is likely therefore that there would be no net loss of breeding habitat associated with the installation of the pipes. The creation of additional breeding habitat for cuttlefish adjacent to existing habitat with excess rock from the pipe trench would also be considered, in consultation with relevant stakeholders.

Approximately 2.5 ha of the seabed supporting patches of the seagrasses *Posidonia australis*, *P. sinuosa* and *Amphibolis antarctica* would be lost as a result of excavation of the pipeline trenches. The loss would be negligible in the context of the large area of similar seagrass communities in Upper Spencer Gulf.

Installing the intake and outfall pipes through rocky reef areas may require the use of underwater blasting to fracture the rock prior to excavation. The explosive charges would be placed in holes drilled 1.5–2 m into the seabed, which would dampen the concussive effect of the blasting by about 40% or more depending on the size of the charges used (see Appendix O12). The concussive effects would be further mitigated by using numerous small charges rather than fewer, large charges. Charge sizes would be the minimum required to effectively fracture the rock to limit the concussive energy lost into the water column (with a maximum charge size of 10 kg). Effects on marine fauna would be reduced to marginally detectable effects about 600 m from blast sites (see Appendix O12). Marine blasting would not occur during the cuttlefish breeding season, or if whales or dolphins were observed in the area. Prior to each blast, a 600 m exclusion zone would be established and monitored to minimise the risk of marine mammals or listed marine species entering the blast zone. Although some adverse effects on marine fauna would inevitably occur in the vicinity of the construction site (i.e. within 600 m), the effects would be of short duration and recovery would be rapid. A blasting management plan would be prepared to minimise the concussive effects of blasting and the potential for sediment mobilisation.

Noise and vibration associated with pipe laying is expected to arise mainly from the operation of the flat top barge. Increases in vessel-related noise would be slight in the context of the ongoing operation of barges and other vessels in the area, and the effect on marine communities would be negligible.

Sediment plumes and sediment deposition associated with installation of the intake and outfall pipes may potentially impact marine communities near the construction sites. Modelling of construction silt plumes (using ELCOM/CAEDYM) has shown that the sediment plume would be detectable (i.e. greater than 2 mg/L total suspended solids above ambient) 1 km from the construction activities for a cumulative total of about 24 hours per fortnight (i.e. 7% of the time); and detectable 2 km from the construction activities for a cumulative total of about 1 hour per fortnight (i.e. 0.3% of the time) (see Appendix O12). To place the effects in context, background total suspended solids (TSS) levels at Point Lowly range from about 2 to 20 mg/L, with levels of 4 mg/L occurring naturally during calm weather (assumes an approximate correlation of NTU to TSS of 1:1) (see Appendix O12). Within 1–2 km of construction activities, the sediment plume would only be detectable intermittently, and would typically persist for minutes 2 km from the construction sites, to hours or possibly days within 100 m. TSS levels would generally be higher during construction near the shore than in the deeper areas.

Modelling of sediment deposition from the construction plumes described above (using ELCOM/CAEDYM) indicates that sediment-plume deposition at detectable rates (i.e. greater than 10 mm over two weeks) would be restricted to within 200 m of the construction activities (see Appendix O12). Although wave re-suspension was not explicitly modelled, it is assumed that fine sediment deposited in the rocky near-shore habitats would be readily re-suspended and dispersed soon after deposition by wave and current action, particularly during storms.

Sediment plumes and deposition may affect marine communities in several ways. Increased turbidity and silt deposition can decrease the light available to seagrasses, which may affect their health in the vicinity of the construction sites. Effects on seagrass communities, however, would be relatively minor as the extent of seagrass communities near Point Lowly is limited (the nearest extensive areas occur 1.5 km north-east of Point Lowly in Fitzgerald Bay), the effects would be minor and recovery would be rapid upon completion of construction. Silt deposition may also affect some Australian Giant Cuttlefish habitat within 200 m of the construction sites. Although not prime habitat, the affected area would amount to about 6% of the breeding habitat at Point Lowly. Breeding of Australian Giant Cuttlefish, however, would not be affected as construction would occur outside their breeding season, and habitat quality would recover prior to the next breeding season with the rapid re-suspension and dispersal of silt by waves and tides.

The increased sediment load in the water column would have little effect on dissolved oxygen levels as the currents in the area are relatively strong.

Mobile vertebrate fauna would not be adversely affected by construction activities as they would avoid interaction with the silt plume and associated construction disturbance and return when construction was complete.

Spoil recovered from excavating the trench would be reused as cover material to reinstate the trench and help protect the intake and outfall pipelines. It is considered to be of suitable quality for reuse because sediment testing in the vicinity of Point Lowly showed no evidence of contamination (see Appendix O7).

A silt and sediment management plan would be prepared to minimise turbidity and silt deposition arising from installation of the intake and outfall pipes.

With implementation of the mitigation measures described above, the residual impacts on marine communities of constructing the intake and outfall pipes would be low, reflecting a short-term impact on a local receiver. Residual impacts on the Australian Giant Cuttlefish would be negligible.

16.6.12 LANDING FACILITY AND COASTAL PROCESSES

Installing a landing facility on the western side of Spencer Gulf, approximately 10 km south of Port Augusta, would require the construction of a piered jetty (20 m wide) extending approximately 200 m into Spencer Gulf, and a rock pad (80 m x 50 m) on the northern side of the jetty rising 4 m above the seafloor (see Figure 16.29).

There would be direct impacts (from seabed disturbance) and indirect impacts (from shading and increases in turbidity during construction) as a result of constructing the landing facility. This would require the removal of three mangroves and would affect less than 1 ha of the seagrass *Posidonia australis*, red algae, brown filamentous algae *Hincksia* spp., encrusting ascidians and the introduced Pearl Oyster *Pinctada albina sugillata*. Construction and operation of the landing facility in the deeper sections would result in impacts on the sand/silt benthic habitat, over an area of approximately 1 ha, which is dominated by the green filamentous turfing alga *Derbesia* sp., the Hammer Oyster *Malleus meridianus*, Pearl Oyster, and the stalked ascidian *Sycozoa pulchra* (see Appendix O1). In view of the extensive area of seagrass meadows and sand/silt benthic habitat in Upper Spencer Gulf, the residual impact of construction of the landing facility on these communities would be negligible.

Modelling of coastal processes for the proposed piered structure using ELCOM, SWAN and TRANSPOR has shown that (see Appendix O13):

- neither the jetty nor rock pad would have any significant impact on tidal flows and the nearshore wave field. The rock pad would cause slightly increased tidal velocities immediately above the pad
- the jetty would have no significant impact on sediment transport along the coast or shore alignment because there is little background movement of sediment in the nearshore region and the structure would be permeable
- individual piles and the toe of the rock pad may cause turbulence, which in turn could cause localised minor scouring of the seabed
- the jetty would have no significant impact on shoreline alignment due to its permeable nature and the insignificant hydrodynamic and wave impacts that are associated with this option.

A causeway structure for the landing facility was a design option investigated and so this structure was also modelled. Model results showed that there would be localised impacts on coastal processes within 1 km (see Appendix O13), including realignment of the shoreline north and south of the causeway (see Figure 16.29). On the basis of these results, the causeway option was rejected by BHP Billiton.

The models show that the residual impact of the proposed landing facility structure on coastal processes would be negligible.

Recession of the regional shoreline is more likely to occur due to an accelerating rise in the sea level associated with global warming. A shoreline recession of up to 20 m is expected over the next 100 years (see Appendix O13).

16.6.13 SHIPPING

Potential impacts associated with the increased shipping include the introduction of exotic species on the hulls of ships or from the discharge of ballast water, and increased turbidity resulting from the winnowing of sediments by ship movements in shallow water.

Figure 16.29 Local shoreline impacts due to piered and causeway structure options

Outer Harbor

The proposed expansion would require an additional 30 to 47 shipping movements per year at Outer Harbor (i.e. less than one per week); currently there are more than 1,100 commercial shipping movements per year (Flinders Ports 2007). The number of shipping movements would be determined by the size of the ship used, with either Panamax-class or Handymax-class being the likely options.

The principal materials that would arrive at the Outer Harbor facilities by ship would be sulphur and diesel. The activities associated with the arrival and unloading of sulphur and diesel would be similar to the current transfer activities for the existing Olympic Dam operation.

Existing berths and new facilities would be used (see Chapter 5, Description of the Proposed Expansion). No dredging would be required to accommodate either of the ship types proposed.

There would be no effects on the ecology of the estuary and the Adelaide Dolphin Sanctuary because:

- the slight increase in shipping traffic within the estuary (fewer than one per week compared with one every few weeks for the current Olympic Dam operation) would be unlikely to significantly increase the average turbidity of the water column, or result in additional siltation or smothering of benthic communities
- unloading of sulphur would occur within enclosed conveyors and storage prior to loading on rail wagons would be in a bunded compound. Consequently, spillage of product would not occur.

Residual impacts on the estuary associated with increased shipping operations would therefore be negligible.

Landing facility

BHP Billiton has undertaken extensive hydrographic surveys at the site of the proposed landing facility and in the approach channels. The surveys have revealed that there will be no need for dredging of the navigational channel in Upper Spencer Gulf to operate the landing facility. Some increased turbidity may be expected from winnowing of sediments by ship movements in relatively shallow waters, but the residual impact of the vessels using the landing facility would be negligible.

Port of Darwin

Earthworks for the preparation of buildings, rail embankment and stormwater management infrastructure may lead to soil erosion and the resulting sedimentation. However, first flush stormwater detention basins would be constructed as a first priority and measures would be taken to ensure that stormwater discharging from the site entered the existing stormwater detention ponds at East Arm (as per the Port of Darwin Draft Stormwater Management Plan).

The proposed expansion would require an increase in exported uranium oxide and export of approximately 1.6 Mtpa of the new concentrate product. It is anticipated that this would require approximately 24 to 27 Panamax-class shipping movements per year, which equates to an increase in the annual berth capacity at East Arm of approximately 18%.

Potential impacts associated with the storage and loading of uranium oxide and concentrate, and increased shipping operations, include fugitive dust, stormwater run-off, waste water and the potential introduction of exotic species on the hulls of ships or from the discharge of ballast water.

There would be no effects on the ecology of Darwin Harbour for the following reasons (see Appendix E4 for details):

- rail wagon wash down water from within the storage shed would be captured and recycled within the shed before ultimately returning to Olympic Dam by rail for disposal
- storage and loading of uranium oxide would occur within sealed drums, which would then be sealed within standard ISO (or equivalent) shipping containers
- loading of concentrate would occur within enclosed conveyors, and, consequently, loss of product via spillage would not occur
- the moisture content of the concentrate would be maintained at between 8% and 11% to ensure that dust generation does not occur during unloading and loading
- domestic waters and sewage would be treated via an on-site septic system, or via connection to the existing East Arm infrastructure.

Residual impacts on the marine environment of Darwin Harbour from construction operations and increased shipping operations would therefore be negligible.

Ballast water

BHP Billiton would assist the appointed ship owners to prepare a ballast water management plan that would be consistent with international, Australian and local (Flinders Ports and Darwin Ports Corporation) requirements. Potential impacts on the marine environment would be minimised through adoption of the national ballast water management requirements (AQIS 2008), developed to meet Australia's commitment to the International Convention for the Control and Management of Ships' Ballast Water and Sediments (DAFF 2008; IMO 2008).

As standard practice, ocean vessels would be required to discharge ballast water outside Australian waters. Nevertheless, the operation of barges in Upper Spencer Gulf would require the discharge and taking on of ballast water as part of unloading operations at the landing facility. Potential impacts on the marine environment would be minimised by establishing a system whereby ballast water would be discharged to on-shore tanks at the landing facility, rather than into Spencer Gulf. The same water would be used to re-ballast vessels.

16.6.14 EFFECTS OF CLIMATE CHANGE

Effects of climate change on the assessment outcomes can be inferred by examining the effects of average evaporation increases over the past 25 years on salt loads in Upper Spencer Gulf.

Over the past decade, there has been a marked increase in evaporation measured in Upper Spencer Gulf compared with that in the early 1980s (see Figure 16.28). A comparison of the salt content of Upper Spencer Gulf in August 2008 with that measured in 1982–1984 shows that the salt balance in Upper Spencer Gulf has not changed substantially (change is likely to be in the range 0–2%). Although the results are preliminary and further surveys are required to clarify how the August result fits into the annual cycle, they may be indicative of the salinity increases that can be expected from increased evaporation arising from climate change.

Climate change projections for South Australia have been expressed as temperature increases relative to the average from 1975 to 2004 (Suppiah et al. 2006). For areas within 200 km of the coast, the predicted increases are 0.2 to 1.6 °C by 2030, and 0.5 to 4.7 °C by 2070. These projections may decrease by about 25% and 48% respectively, under emissions reduction scenarios.

A far field model scenario of a 2 °C atmospheric temperature increase was run for five years to compare with a base case for the current climate.

The model predicted long-term average salinity increases of 0.01–0.04 g/L at the extraction points used for previous model runs (see Figure 16.21 and Table 16.20).

The results of the study of salt content and evaporation in Upper Spencer Gulf, and the modelled climate change scenario, suggest that potential salinity increases in Upper Spencer Gulf arising from the effects of climate change are not anticipated to exacerbate the impacts assessed in the Draft EIS.

16.7 FINDINGS AND CONCLUSIONS

Desalination plant location

Hydrodynamic modelling and water quality studies were undertaken for five desalination plant locations. Of these, only the Point Lowly sites met the acceptable criteria for return water dispersion and were selected as the preferred options, despite being further from Olympic Dam, and therefore more costly for the water supply pipeline.

Water quality standards

Although the South Australian Environment Protection (Water Quality) Policy 2003 sets out no specific water quality criteria for the discharge of salt to the marine environment, the WHO (2007) suggests that a '10% increment above ambient ocean salinity is a conservative measure of aquatic life tolerance to increase in salinity'. The results of the near field modelling predicted that the salinity of the return water would disperse to within less than 10% of background at 100 m from the outfall.

Accumulation of salt in Spencer Gulf

Modelling of the discharge of return water to Spencer Gulf using ELCOM established that:

- the entire gulf flushes over an annual cycle, with salt removal via the hypersaline bottom current along the eastern coast. This is consistent with previous field data collection programs
- the long-term average increase in salinity at locations in the north of the gulf (near Port Augusta and Yatala Harbor) was predicted to be 0.03 g/L, and to the south (near Cowell) were predicted to be 0.01 g/L
- the long-term increase in salinity in False Bay was a maximum of 0.07 g/L
- ecological effects associated with the long-term average percentage increases in salinity of 0.03 to 0.17% in Upper Spencer Gulf would be undetectable
- these changes would be small in the context of natural variability. For example:
    - the desalination plant would have to be 318 times bigger to match the annual salinity increase that natural evaporation brings to Spencer Gulf
    - the long-term average increase in salinity at Point Lowly would be significantly less than the natural daily or depth related variation in salinity (1 g/L) and seasonal variation (3 g/L).

Assessment of return water toxicity

Whole effluent toxicity (WET) testing of simulated return water was undertaken using 15 indicator species. The individual tests established that:

- the EC_{10} values (indicating a 10% sub-chronic effect) for the species most relevant to Point Lowly corresponded to a range of salinities from 0.6 to 31 g/L (or 1.4 to 75%) higher than the seawater in which they were tested

Table 16.20 Long-term average salinity increases under a likely climate change scenario[1]

Port Augusta (site 1)	Yatala Harbor (site 2)	False Bay (site 3)	Wallaroo–Cowell (site 4)
0.02 g/L	0.04 g/L	0.03 g/L	0.01 g/L

[1] See Figure 16.21 for locations. In Appendix O11, site 1 = 2–10; site 2 = 9–15; site 3 = 24–22; site 4 = 69–35.

- a species protection trigger value (SPTV), or a safe level of effluent dilution, was derived using chronic data for 10 species tested using diluent with salinity typical of Point Lowly (five species more than the ANZECC/ARMCANZ 2000 guidelines). An SPTV of 1:45 would protect 99% of species (consistent with the guidelines for pristine ecosystems) at 41 g/L. An SPTV of 1:85, however, was adopted to protect 100% of marine species at 41 g/L or provide a buffer for protection of species at higher salinities. The salinity increases corresponding to these two dilution factors would be 0.7 g/L and 0.4 g/L respectively.

Zone of potential ecological effects

The zone around the outfall where ecological effects on the marine ecosystem may occur is defined by the SPTV of 1:85 and the outcomes of the return water dispersion modelling.

Adopting the SPTV, the residual impact on the marine ecosystem at Point Lowly has been categorised as:

- moderate within 100 m of the outfall (reflecting a long-term impact on a local receiver)
- low beyond 100 m of the outfall and within the 1:85 dilution contour – with a maximum extent of 3.9 km along the direction of tidal flow to the south west or 2.1 km to the north east of the outfall (reflecting a short-term impact on a local receiver)
- negligible for higher dilutions (reflecting no detectable impact).

Salt concentrations at sensitive sites at Point Lowly

During a dodge tide, locations near Point Lowly would see a maximum increase in salinity of:

- 0.3 g/L within the Australian Giant Cuttlefish breeding sites, which is equivalent to a 0.7% salinity increase, or a return water dilution of 1:116
- 0.1 g/L at the aquaculture sites within Fitzgerald Bay (0.3% salinity increase, or dilution of 1:320)
- 0.9 g/L within the prawn trawling sites (2.1% salinity increase, or dilution of 1:37)
- 1.9 g/L within the sponge community (4.6% salinity increase, or dilution of 1:17).

These increases are substantially less than the seasonal variation at Point Lowly of 3 g/L and (with the exception of the sponge community) less than the daily and depth-related variability of 1 g/L.

Effects on marine biota

The hydrodynamic modelling and ecotoxicology studies indicate that:

- effects on Australian Giant Cuttlefish would be undetectable as the minimum dilution during the worst case tidal conditions (e.g. a dodge tide) within the cuttlefish habitat would be 1:116, limiting the sub-chronic toxic effect to less than 1% (i.e. negligible).
- effects on Yellowtail Kingfish in Fitzgerald Bay would not be measurable. The minimum dilution of the return water would be approximately 1:320 at the nearest fish rings, even during a dodge tide. This is more than 30 times greater than the individual protection level (EC_{10}) for kingfish (i.e. 1:10)
- minor effects on commercial species including the Western King Prawn may occur during dodge tides
- there is a theoretical possibility of minor reduction in relatively common relict species (such as the soft coral *Carijoa multiflora* and the sea pen *Virgularia mirabilis*) close to the outfall. This impact, if it were to occur at all in practice, would be of little ecological significance regionally
- effects on protected marine mammals are unlikely to occur as they are highly mobile and would avoid the localised area of slightly greater salinity.

Stratification and deoxygenation

Stratification and low dissolved oxygen are unlikely to be significant issues off Point Lowly because:

- the return water would be well oxygenated prior to discharge
- periods of reduced vertical mixing in the vicinity of Point Lowly are rare and relatively short due to generally good mixing by strong currents and wind generated waves
- the sediment oxygen demand is insufficient to reduce dissolved oxygen during periods of poor mixing to a level where ecological effects could occur.

Impingement and entrainment of marine biota

Impingement of marine biota by the desalination plant intake structure would be negligible (i.e. below detectable limits) because the proposed inflow rate is approximately 0.2 m/s, which is one-third of the safe intake flow recommended as the result of studies of cooling water intakes of power stations.

Entrainment of marine biota (particularly fish and crustacean larvae) into the desalination plant would have a negligible impact (i.e. below detectable limits) on the Spencer Gulf marine ecosystem because:

- the volume of water consumed annually by the desalination plant would comprise a small proportion of the water in the Gulf (0.04%)
- the commercial prawn catch of Upper Spencer Gulf inevitably involves loss of larvae but the fishery has nonetheless operated for decades at a sustainable yield. In this context, the effects of the desalination plant would be small: assuming that 10% of all eggs were to hatch, the loss of larvae would amount to a fraction of 1% of the corresponding loss to the normal prawn catch.

Construction operations

Construction silt plumes would be detectable (i.e. greater than 2 mg/L total suspended solids above ambient) 1 km from the construction activities for about 7% of the time, and 2 km from the construction activities for about 0.3% of the time.

Sediment deposition from the construction plumes would occur at detectable rates (i.e. greater than 10 mm over two weeks) within 200 m of the construction activities. Fine sediment deposited in the rocky near-shore habitats would be readily re-suspended and dispersed by wave and current action.

Effects on seagrass communities would be minor as the extent of seagrass near the construction sites is limited. Approximately 2.5 ha of sparse seagrass would be removed or adversely affected by construction activities. Temporary turbidity effects would occur, but the seagrass would recover quickly.

Effects on marine fauna from underwater blasting would be reduced to marginally detectable effects about 600 m from blast sites. Prior to each blast, a 600 m exclusion zone would be established and monitored to minimise the risk of marine mammals or listed marine species entering the blast zone.

Effects of construction activities on the Australian Giant Cuttlefish would be negligible because:

- construction on or near the reef would occur outside the cuttlefish breeding season
- only a small percentage of their breeding habitat would be affected by silt which is likely to disperse prior to the onset of cuttlefish breeding
- the trench through the reef would be reinstated with coarse rock (which may potentially lead to an increase in the area of suitable breeding habitat)
- wave action and tidal currents would quickly re-suspend and disperse the silt that accumulates within the reef habitat, resulting in rapid recovery of the habitat upon completion of construction.

Landing facility

Construction of the landing facility would lead to the loss of less than 1 ha of the seagrass *Posidonia australis*, associated epiphytic algae and Pearl Oysters in the shallow waters, and a similar area of sand/silt benthic habitat, dominated by the green filamentous turfing alga *Derbesia* sp. and Hammer and Pearl oysters, and the stalked ascidian *Sycozoa pulchra*, would also be disturbed in the deeper waters. Considering the extensive area of these habitats in Upper Spencer Gulf, the residual impact of construction of the landing facility on these communities would be negligible.

Installing a pier and associated rock pad on the western side of Spencer Gulf would have a negligible impact on the coastal processes in the area. Modelling demonstrated that:

- the pier would have an insignificant impact on accretion and erosion of the coast and sediment transport along the coast
- individual piles and the toe of the rock pad may cause turbulence and localised minor scouring of the seabed.

Shipping operations

Impacts on the ecology of the Port River estuary resulting from increased shipping and port operations at Outer Harbor would be negligible because:

- the very slight increase in shipping traffic (i.e. <1 per week) is unlikely to cause a significant increase in turbidity, siltation or smothering of benthic communities within the estuary
- ballast water would be managed according to recognised guidelines
- enclosed conveyors would prevent spills while unloading sulphur.

Impacts on the ecology of Darwin Harbour resulting from increased shipping and port operations would be negligible because:

- contaminated water from wagon wash-down would be captured and recycled
- a closed system would be adopted for the storage and handling procedures for concentrate to ensure no loss through spillage or dust
- ballast water would be managed according to recognised guidelines
- enclosed conveyors would prevent spills while loading concentrate into the ship hold.

Impacts on the ecology of Upper Spencer Gulf resulting from increased shipping and the operation of the landing facility would be negligible because:

- hydrographic surveys have revealed that there will be no need for dredging of the navigational channel
- increased turbidity from winnowing of sediments by ship movements is expected to be negligible
- the likelihood of hitting whales and other threatened or protected species remains low.

Climate change

The findings of climate change studies are that:

- a comparison of the salt content of Upper Spencer Gulf in August 2008 with the early 1980s suggested a salinity increase of at most 2%, and possibly no change, despite a marked increase in evaporation over the past decade
- a far field model scenario of a 2 °C atmospheric temperature increase, run for five years to compare with a base case for the current climate, predicted increases of less than 0.04 g/L (0.1%)
- potential salinity increases in Upper Spencer Gulf arising from the effects of climate change are not anticipated to exacerbate the impacts assessed in the Draft EIS.