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Griffin Energy Pty Ltd
Bluewater Power Station Expansion Proposal

Environmental Support Studies – Saline Discharge Pipeline and Marine Outfall Study

July 2008

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Prepared for

Griffin Energy Group Pty Ltd

Prepared by

Oceanica Consulting Pty Ltd

July 2008

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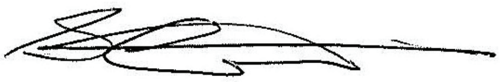

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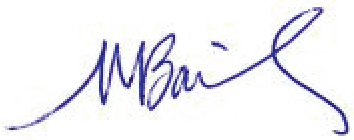

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Cover
Main image: Shoreline adjacent to proposed outlet location (S. Scott, Oceanica Consulting);
Minor images: Beach where existing Verve and MIC outfalls enter ocean (M. Bailey Oceanica Consulting); *Posidonia* seagrass in vicinity of proposed outfall (S. Shute Oceanica Consulting).

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Executive Summary

Griffin Energy is proposing to expand its Bluewaters Power Station located within the Coolangatta Industrial Estate, approximately 4 km from the eastern edge of Collie. Griffin Energy is proposing to expand the power station via the addition of another two 208 MW coal fired boilers or similar technology such as circulating fluidized beds (CFBs). This expansion will consist of Phase III and IV of the Bluewaters Power Station. Griffin Energy proposes to commence construction of the power station expansion in mid-2009.

Griffin Energy is also proposing to construct an outfall pipeline to the sea to discharge cooling water from Phases III and IV of its Bluewaters Power Station. The option of disposing of cooling water from all four Phases of Bluewaters (I, II, III and IV) through the same pipeline may also be considered.

The preferred route for the pipeline is in the same easement as Collie Power Station existing Saline Pipeline. The proposed outfall site at Buffalo Beach has two existing outfalls extending into the ocean; the MIC outfall and the CPS/Verve Outfall. The proposed location of the Griffin outfall is to the south of the existing outfalls to a depth of between -9 m and -10 m Chart Datum. It is proposed that the Griffin diffuser, designed for a peak discharge of 10 ML/d, will be inshore of the Verve diffuser, extending from 540 m to 650 m offshore. The average initial dilution for discharge to still water for this diffuser design is predicted to be 150:1.

The project is located just beyond the northern end of Geographe Bay at Buffalo Beach. The existing coast is open to the Indian Ocean and energetic, offshore the seabed consists of a sand veneer over limestone which outcrops as pavement and reef. Seagrass is present approximately 600 m offshore in the project area.

The following marine and coastal factors have been addressed within this document:

1. Construction
    a. Direct loss of benthic primary producer habitat due to pipeline footprint
    b. Short-term impacts on coastal processes
    c. Generation of turbidity during construction
    d. Impacts of construction noise on marine fauna
    e. Introduced marine species
    f. Closure of beach to recreational access during construction
    g. Dune rehabilitation
    h. Aboriginal heritage
2. Operations
    a. Water and sediment quality at the diffuser
    b. Impact of pipeline on coastal processes

Draft management plans have been prepared for the construction and operational stages of this proposal in order to address the factors listed above and are included in this document.

This document has been prepared as supporting documentation for the Public Environmental Review (PER) submission to the Environmental Protection Authority (EPA).

1. Introduction

1.1. This document

Griffin Energy Group Pty Ltd (Griffin Energy) contracted Oceanica Consulting Pty Ltd (Oceanica) to undertake specialist environmental support studies for the marine and coastal elements of their proposed saline discharge pipeline and marine outfall. This report is to be part of the supporting documentation for the Public Environmental Review (PER) submission to the Environmental Protection Authority (EPA).

1.2. The proposal

Griffin Energy is proposing to expand its Bluewaters Power Station located within the Coolangatta Industrial Estate, approximately 4 km from the eastern edge of Collie (Figure 1.1). The existing power station consists of two, 208 MW coal fired boilers (Phase I and II) currently under construction with Phase I due for commissioning in August 2008 and Phase II in August 2009. Griffin Energy is proposing to expand the power station via the addition of another two 208 MW coal fired boilers or similar technology such as circulating fluidized beds (CFBs). This expansion will consist of Phase III and IV of the Bluewaters Power Station.

Research by Griffin Energy has found that shortages in the supply of domestic gas in the south west of the State, for at least the next seven years, will require projects such as the Bluewaters Power Station to provide a reliable source of electricity while meeting the electricity growth requirements of Western Australia. Griffin Energy contends that in turn, this will provide significant economic and social benefits to the local, regional, State and National economies.

Griffin Energy proposes to commence construction of the power station expansion in mid-2009. Griffin Energy is also proposing to construct an outfall pipeline to the sea to discharge cooling water from Phases III and IV of its Bluewaters Power Station. The option of disposing of cooling water from all four Phases of Bluewaters (I, II, III and IV) through the same pipeline may also be considered.

There is an existing ocean outfall pipeline owned by Verve (formerly Western Power) which is utilised by the Verve owned Collie A Power Station 4 km to the east of the Bluewaters Power Station. Griffin Energy has negotiated with Verve to dispose of its cooling water from Phases I and II of Bluewaters to this pipeline, with flow capped at 0.7 ML/d. Griffin Energy does not have contractual arrangements in place with Verve for additional flow and it is unlikely that this pipeline will have the capacity to accommodate the full flow of cooling water from Phases III and IV of the Bluewaters Power Station.

The preferred route for the pipeline is in the same easement as Collie Power Station existing Saline Pipeline (Figure 1.2). The proposed outfall site at Buffalo Beach has two existing outfalls extending into the ocean; the MIC outfall and the CPS/Verve Outfall (refer to Figure 1.3). The MIC outfall extends approximately 300 m offshore to water depths of approximately -5 m Chart Datum (CD). The Verve outfall is approximately 800 m long, reaching water depths of approximately -10 m CD.

The proposed pipeline and diffuser design for the Griffin pipeline is discussed in detail in Section 2.

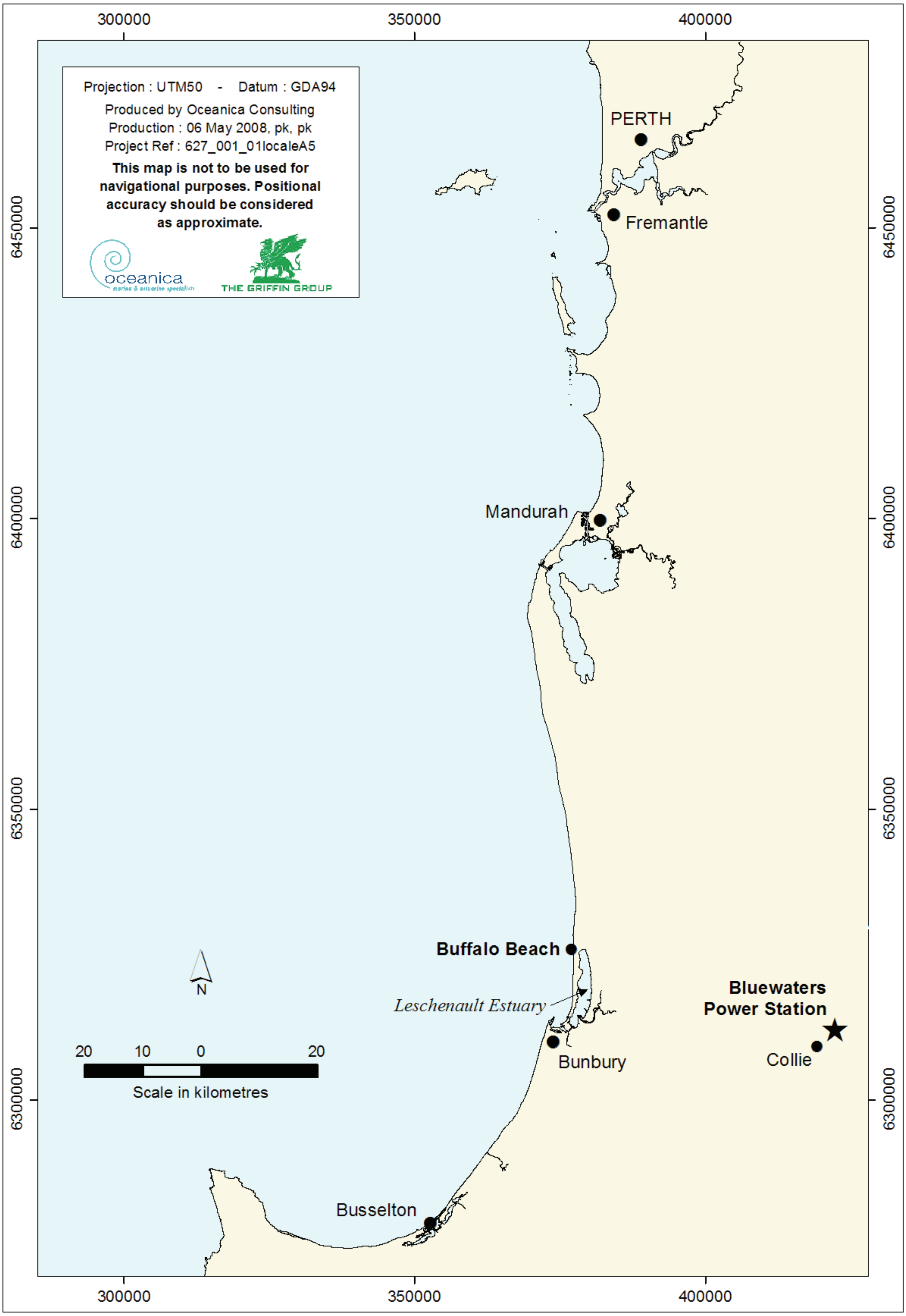


Figure 1.1 General location diagram

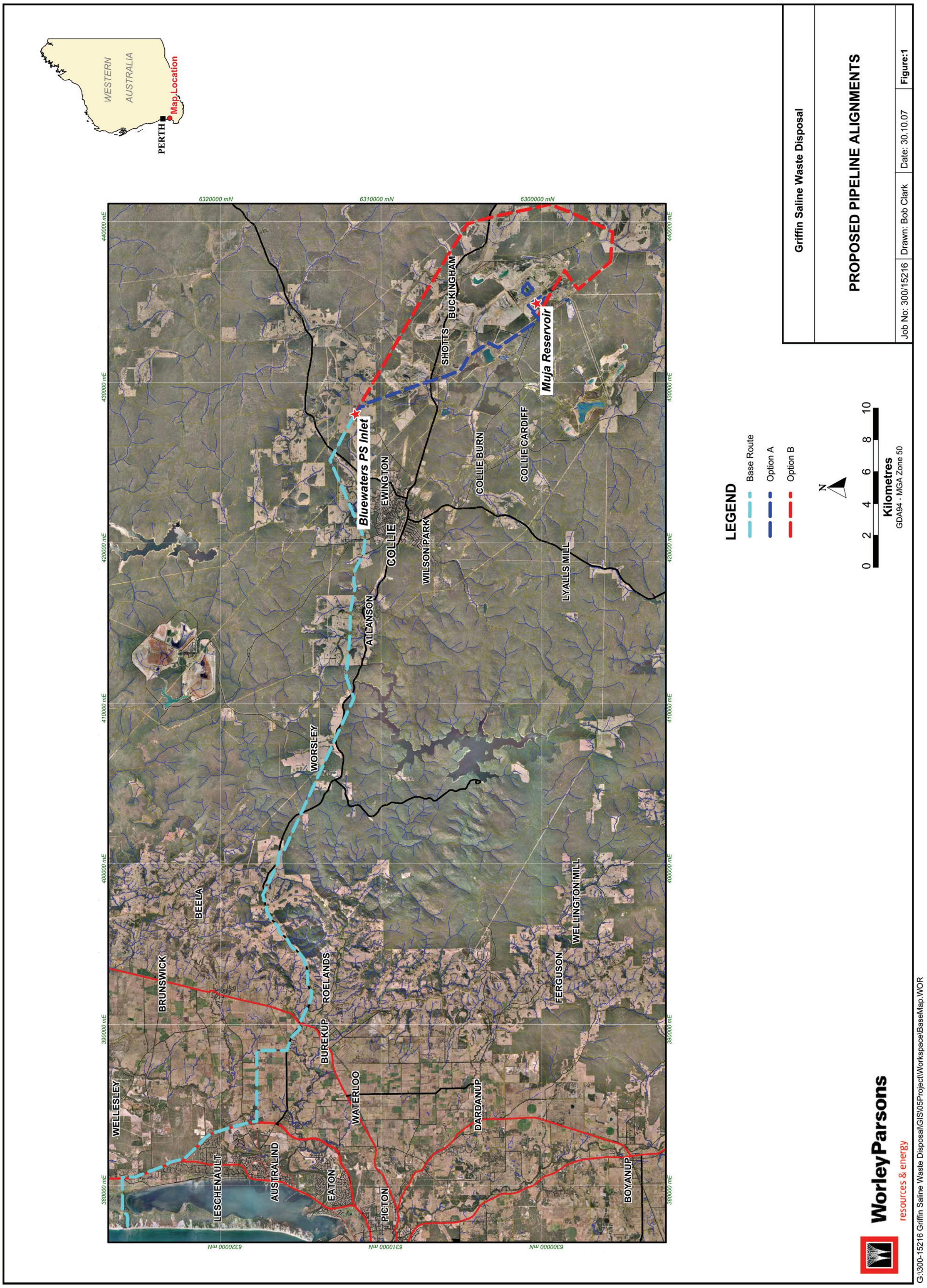
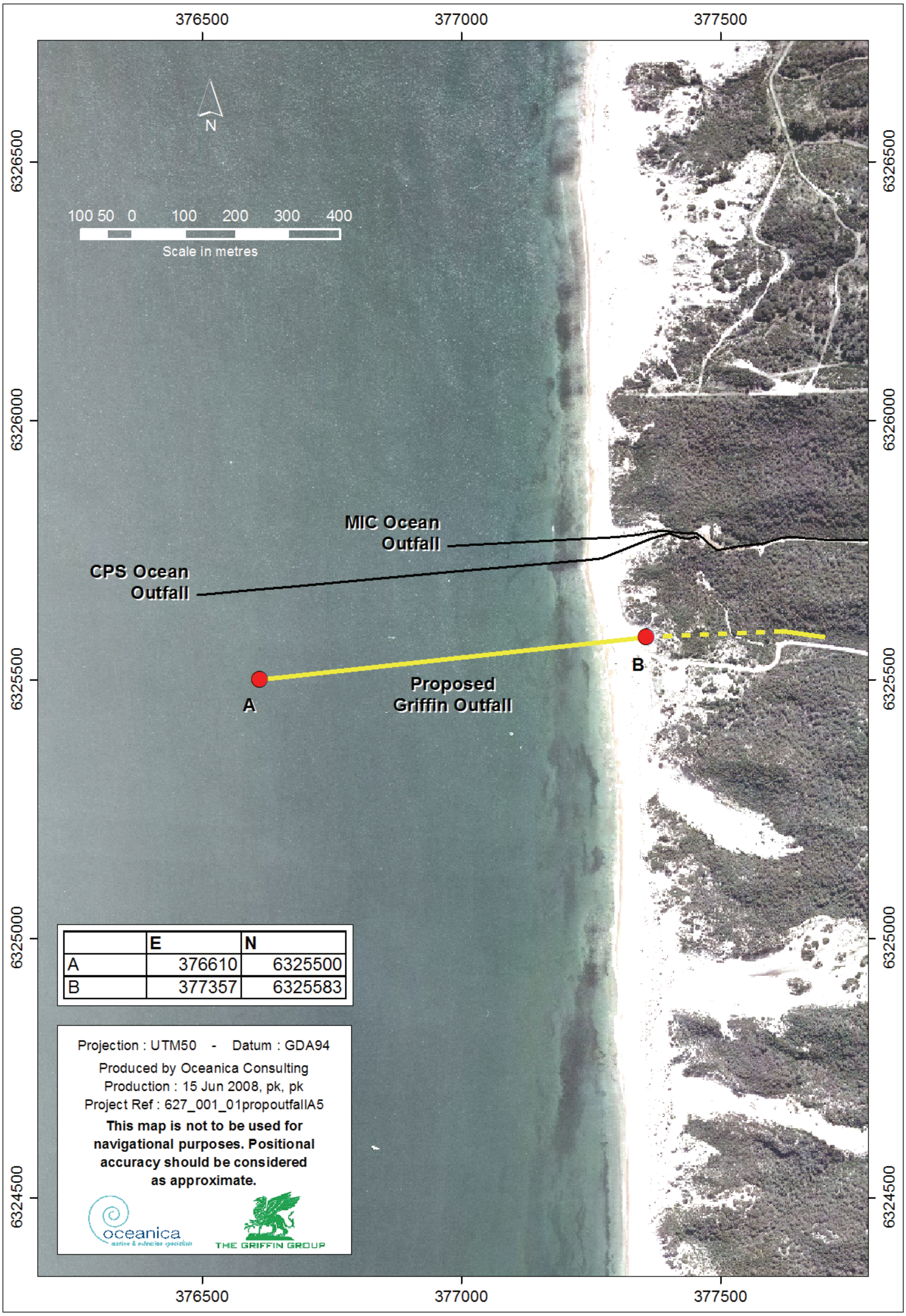


Figure 1.2 Preferred route for pipeline (Prepared by Worley Parsons)



	E	N
A	376610	6325500
B	377357	6325583

Figure 1.3 Location of proposed Griffin outfall and the existing CPS and MIC outfalls, point "A" denotes the offshore end of the diffuser, which is 110 m long.

2. Pipeline and diffuser design

Consulting Environmental Engineers (CEE) was commissioned to provide the pipeline and diffuser construction concept for the project, their detailed report is attached as Appendix A. The purpose of the report was to provide a concept design of the outfall as a basis for the environmental assessment of environmental impacts during construction and operations. CEE is highly experienced in ocean outfall design and was responsible for the design of the Verve Energy outfall and the Bunbury WWTP outfall and therefore the concept design is expected to be reasonably accurate.

The key considerations in the design of the outfall and diffuser were as follows:

1. The diffuser location was selected to avoid the loss of sensitive species or reef areas of significant ecological value, this location may need to be further refined as more detailed mapping is completed.
2. Initial dilution was maximised. The purpose of the diffuser is to mix the effluent with seawater so there is minimal risk of an adverse environmental impact from the discharge. A high dilution minimises the risk of toxic effects.
3. For buoyant effluent, it is normal practice for the ports to discharge horizontally to improve dilution.
4. The diffuser was designed so that it can be extended to handle higher flows or achieve a higher dilution if required at a later stage.
5. The diffuser was designed to achieve a satisfactory initial dilution over the full range of discharge rates.
6. The diffuser was located offshore from the zone of seasonal sand movement and the zone of breaking waves in regular storms.
7. The pipeline and diffuser materials must be highly corrosion resistant, with brackish water inside and seawater outside.
8. The diffuser has been sited to make best use of ambient currents and turbulence.

2.1. Alignment to beach

Several possible alignments for the new outfall were considered:

- North of the existing outfalls;
- Between the existing outfalls; or
- South of the existing outfalls.

The offshore bathymetry, seabed character and habitat were considered to be essentially the same for the three alignments.

On the land, there were several constraints:

- The need to minimise disturbance to coastal park;
- The need to minimise disturbance to foreshore dune;
- The need to minimise risk of damage to existing outfalls; and
- The benefit of focussing construction in dune blow out areas.

2.1.1. North Alignment

A north alignment would be either very close to the existing Kemerton outfall or require extensive excavation of a large dune or be well to the north of the Kemerton outfall, with all construction traffic travelling across the two outfalls. Neither of these alternatives was considered satisfactory and hence the north alignment was not favoured.

2.1.2. Central Alignment

The central alignment would use the existing dune blow out area in which the two existing outfalls are located. The two outfalls are very close together at the top of the dune and gradually separate with distance down the dune towards the ocean. All construction traffic would need to cross the Collie outfall. There would be a high risk of damaging an existing outfall when constructing a new outfall on the central alignment. Hence the central alignment was not favoured.

2.1.3. South Alignment

A south alignment would be closer to the beach access track and hence avoid the need for construction equipment to cross the existing outfalls. The south outfall would require either a new crossing over the top of the dune or drilling through the dune at a lower level. Inspection of topographic maps shows that there is a small blow out about 200 m south of the existing outfalls and this is considered an appropriate construction alignment with drilling through the dune to minimise disturbance to the top of the dune.

The south alignment has been adopted for the concept design. This assumes there are no heritage, flora or fauna constraints for the south alignment, which must be confirmed before proceeding. If such constraints are found, then it is most likely that the pipeline and outfall would be moved southwards.

2.2. Depth of burial across the beach

The outfall will need to be buried more than 2 m below the 'average' beach level to avoid being exposed during severe storms. An investigation of the depth of the active zone for the Bunbury Ocean Outlet found the same (2 m) depth of burial was required (Water Corporation 2000) while the adjacent CPS outlet was also buried approximately 2 m below the beach profile. Neither of these outfalls has since been exposed by wave action.

2.3. Offshore depth

As shown in Figure 2.1, the offshore depth increases quickly to 4 m at about 110 m from shore, to 6 m at 190 m, to 8 m at 330 m and to 10 m at 680 m from shore. The depth continues to increase gradually with further distance offshore. The outfall diffuser will be located in waters between 9 and 10 m deep at the lowest astronomical tide (Chart Datum).

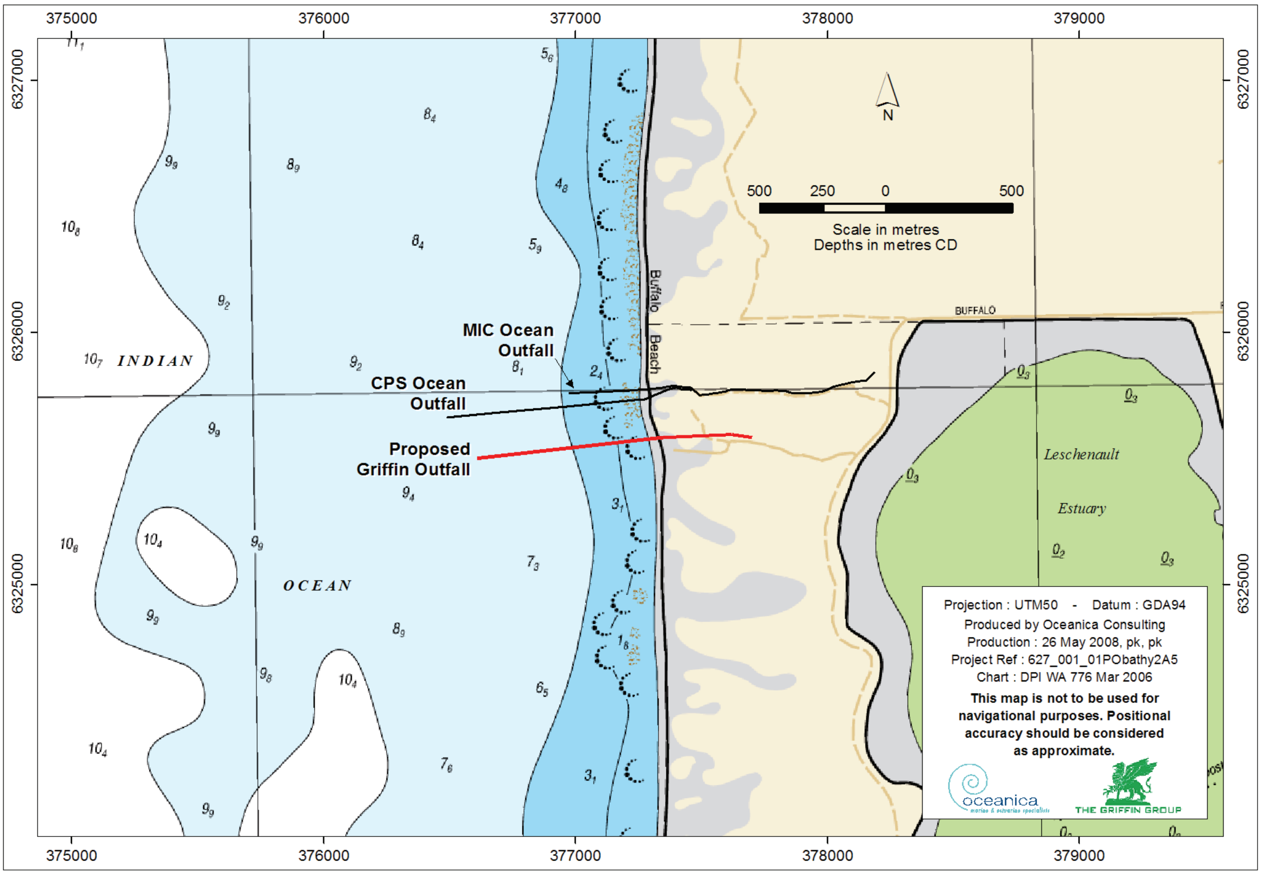


Figure 2.1 Proposed outfall overlying bathymetry

2.4. Seabed character

Inspection of the shore during the construction of the Collie outfall showed a thin layer of weak rock at about low tide level on the beach. Further offshore there is sand to a depth of about 7 m. Thereafter the seabed comprises a rough limestone pavement with pioneer invertebrates in the higher patches and sparse seagrass on less mobile sandy patches. There are occasional beds of deeper sand and seagrass growing in the sand.

No borehole logs are available from which to establish the local geology.

2.5. Diffuser design

To avoid overlapping discharges, the diffuser for the Griffin outfall can be placed either inshore or offshore of the Collie diffuser. For this report, it is proposed that the Griffin diffuser will be inshore, extending from 540 m to 650 m offshore (Figure 1.3).

A concept design for the diffuser for the proposed outfall was developed. The proposed diffuser for the peak discharge of 10 ML/d is as follows:

- Length of diffuser: 110 m
- Number of ports: 30
- Port spacing: 3 m

The average initial dilution for discharge to still water for this diffuser design was predicted to be 150:1.

For the concept design, it was considered most likely that the outfall would be constructed of HDPE. A nominal diameter of 450 mm with a wall thickness of 27 mm is considered to be the most likely sizing for the flows and purpose.

2.6. Construction approach

2.6.1. Drilling through dunes

The hole beneath the dunes would be drilled from the access track on the land side of the dunes. Standard drilling equipment would be used, and a HDPE pipe of the same diameter as the outfall pulled into the drill hole. The pipeline would be connected to the land pipes at the landward side of the dune and the de-aeration structure on the seaward side of the dune. All pipes would be buried and not visible.

Small pools lined with HDPE sheeting would be excavated at each end of the drill hole to capture any excess drilling mud (bentonite solution).

All disturbances will be rehabilitated on completion. There would also be an opportunity to stabilise the dune blow-out and revegetate it with local coastal plant species if the local authority and community were supportive.

2.6.2. Temporary construction track

The existing access track through the park would be used to install the land pipe to the dune. A small clearing would be necessary to allow drilling while maintaining access to the beach for other construction equipment.

The existing access track to the beach would be used for construction access and deliveries. A temporary access track would be constructed along the beach above the high tide line for a short distance using local limestone. The access track would extend from the existing access track to the offshore end of the borehole through the dune.

The limestone would be removed at the end of the construction phase and the beach reinstated to natural condition.

2.6.3. Temporary construction groyne

A temporary construction groyne would be constructed across the beach and out to the 3.5 m depth contour using local limestone. The same procedure was used successfully during the construction of the CPS outfall.

The top of the groyne would be about 1 m above high tide level and the end and sides would be armoured with limestone blocks. The groyne would be removed at the end of construction and the beach reinstated to natural condition.

The outfall to the 4 m depth contour would be installed by excavating a trench in the groyne and installing the pipeline in the trench using excavators. The long section of the outfall would be chosen so that it was buried at least 2 m below the beach on the shore and buried to the 4 m depth contour.

2.6.4. Construction period

The construction period is expected to be about 2 weeks to construct the temporary groyne, 3 weeks to install the pipe and 1 week to remove the groyne. For public safety access to this section of beach and dunes would be closed to public access during this period.

3. EPA factors for marine and coastal assessment

The following assessment factors have been developed on the basis of the work undertaken by the Water Corporation for the Alkimos WWTP Ocean Outlet (2006), the Bunbury WWTP Ocean Outlet (2001) and the Southern Seawater Desalination Plant (SSDP) at Binningup (current). The work is also informed by Oceanica's experience with the MIC and Verve Energy outlets; advice provided by the EPA Service Unit (EPSU) on similar projects in the region underway for the Water Corporation; and, attendance at Community Consultation Sessions for the SSDP. Although the marine and coastal factors have not been developed in consultation with the EPASU, they are based on a sound body of knowledge and are expected to be in accordance with the EPA's requirements.

3.1. Marine and coastal factors

The construction and operation of the project means that the following marine and coastal factors need to be addressed, the key factors are also nominated (i.e. where there is a real risk of environmental impact or threat to environmental values).

Construction

1. Direct loss of benthic primary producer habitat due to pipeline footprint (A key factor)
2. Short-term impacts on coastal processes (An applicable factor)
3. Generation of turbidity during construction (An applicable factor)
4. Impacts of construction noise on marine fauna (An applicable factor)
5. Introduced marine species (An applicable factor)
6. Closure of beach to recreational access during construction (An applicable factor)
7. Dune rehabilitation (An applicable factor)
8. Aboriginal heritage (An applicable factor)

Operations

1. Water and sediment quality at the diffuser (A key factor)
2. Impact of pipeline on coastal processes (An applicable factor)

The PER will need to include draft Environmental Management Plans (EMPs). This report contains draft Construction and Operation Saline Pipeline Marine EMPs which address the above key factors and residual management requirements for the applicable factors.

4. Existing marine environment

4.1. Overview

The project is located just beyond the northern end of Geographe Bay at Buffalo Beach (Figure 4.1). Geographe Bay is considered to extend from Cape Naturaliste in the west, to Bunbury in the north-east (DAL 2000). Cape Naturaliste provides some protection in this area from southerly and south-west swells, however, the coastline is relatively exposed to swells from the west and north-west (DAL 2000).

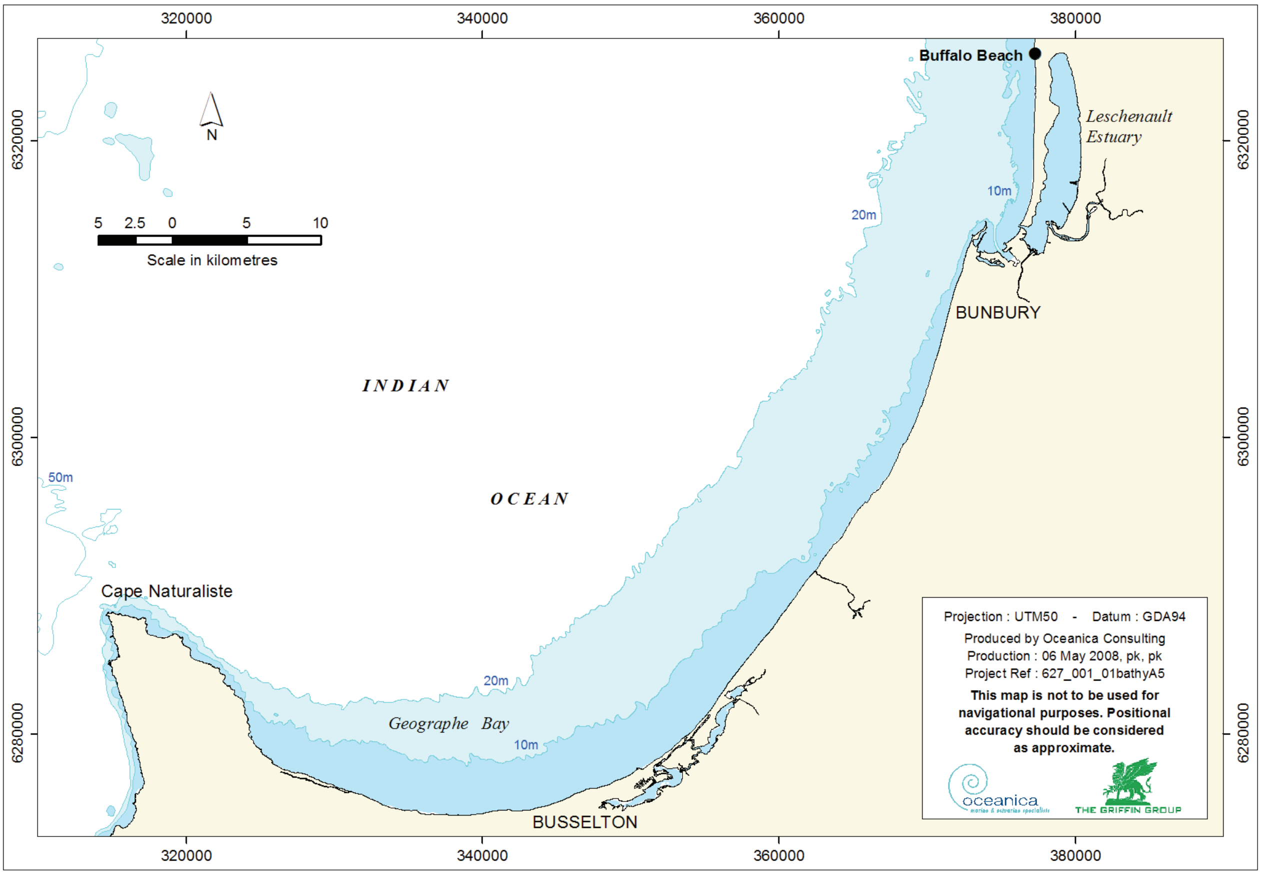


Figure 4.1 Geographe Bay

4.2. Meteorology

Wind is the dominant force generating nearshore water circulation in the region. Winds in the Bunbury region are determined largely by the locations of the sub-tropical high pressure ridge and the migratory low pressure systems (extra-tropical cyclones) which exist on the poleward side of the ridge (DAL 2000).

For the summer months, the subtropical ridge is usually located to the south of Australia. A predominantly easterly airflow is directed over the area. However, meso-scale breezes and the Western Australian heat trough, modify this airflow considerably (DAL 2000). Sea and land breezes are generated near coastal locations owing to the different thermal properties of land and water. Sea breezes of the lower west coast of Australia tend to be between south and west. They often begin mid-morning and last until mid-evening. The land breeze effect causes a reversal at night in which the winds blow offshore reinforcing the basically easterly flow (DAL 2000).

Occasionally in the late summer (March/April) decaying tropical cyclones may travel southward along the west coast. As they move southward they weaken and change their characteristics (DAL 2000). In the southern Indian Ocean they are almost always influenced by a nearby southern depression and cold frontal system. However winds associated with these systems can be of intensity similar to those of winter storms (DAL 2000).

As a result of these influences, in summer winds in the Bunbury/Kemerton region at nights and in the mornings are generally from between east and south at speeds of 2–7 ms^{-1}. In the afternoons and evenings winds are generally south-westerly at speeds of up to 15 ms^{-1} (DAL 2000).

For the winter months, extra-tropical cyclones occur on average about once every three to five days and pass from west to east just south of the Australian continent (DAL 2000). They are 500 to 1,000 km in diameter. As the low pressure system and its associated cold front (relatively sharp boundary between warm northerly air and cooler southerly air) move eastward the winds in the Bunbury region change from north-westerly through to south-westerly to southerly (DAL 2000). Mean north-westerly and westerly wind speeds in such systems are frequently of order 12 ms^{-1} but on occasions, perhaps once per winter month, they may reach up to 25 ms^{-1}. Winds from the south-west and south generally reach 10–15 ms^{-1} and rarely, perhaps once per season, reach 20 ms^{-1}. Winds exceed gale force for less than 5% of the time (DAL 2000). Between such extra-tropical cyclone events, winds are generally less than 8 ms^{-1} and for some 40% of the total time are less than 5 ms^{-1}.

The other periods—April/May and October/November—are transition periods between the summer and winter patterns when conditions are generally calmer and may reflect characteristics of both patterns (DAL 2000).

4.3. Oceanographic and coastal environment

4.3.1. Tides

Tidal ranges at Buffalo Beach will be almost identical to those at Bunbury Port which is 10 km south. Bunbury experiences a mixed predominantly diurnal micro tide with a Lowest Astronomical Tide (LAT) to Highest Astronomical Tide (HAT) range of 1.3 m (Table 4.1).

Table 4.1 Tidal elevations observed at Bunbury harbour

Tide	Elevation relative to chart datum (m)
Highest Astronomical Tide (HAT)	+1.2
Mean Higher High Water (MHHW)	+0.8
Mean Lower High Water (MLHW)	+0.5
Mean Sea Level (MSL)	+0.6
Mean Higher Low Water (MHLW)	+0.6
Mean Lower Low Water (MLLW)	+0.3
Lowest Astronomical Tide (LAT)	−0.1

4.3.2. Currents

Currents in the region are the result of a combination of forces including: wind stress, sea level fluctuations (tides, seiches, continental shelf waves and meteorological affects), short period sea and swell waves, density gradients and larger scale oceanic circulation features (mainly the Leeuwin Current) (DAL 2000).

Ocean currents

The Geographe Bay region is influenced offshore by the flows of two ocean currents: the Leeuwin Current and the Capes Current (Figure 4.2) (DAL 2000).

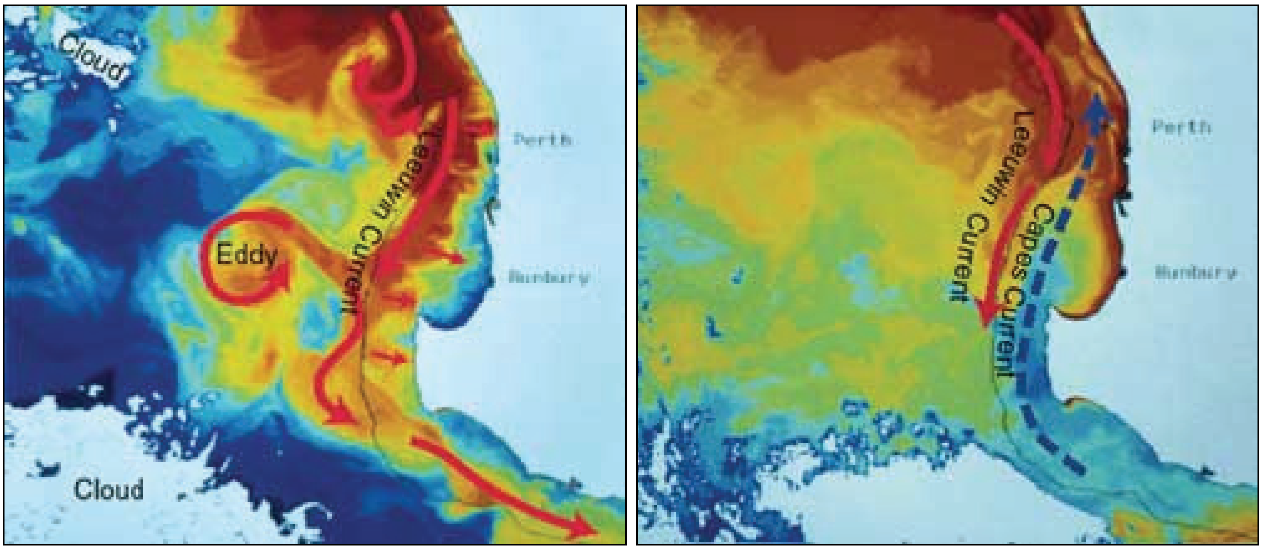


Figure 4.2 Influence of Leeuwin Current on Geographe Bay in winter (left) and summer (right). The Capes Current only affects the region in summer months (source: CSIRO)

The Leeuwin Current exerts a persistent influence on the circulation in the winter months mainly in the form of a residual drift towards the south (DAL 2000). The core of the Leeuwin Current is located over or just seaward of the shelf break, generally defined as the 200 m isobath, all year round. The landward boundary of the Leeuwin Current varies seasonally, closer to the shore during the autumn and winter months and retreating offshore to approximately the 50 m isobath during the spring and summer months (DAL 2000).

The Capes Current has been identified from satellite imagery and other data sources as a cool, seasonal inner shelf current which flows northwards opposite to the direction of the Leeuwin Current in the summer months when the seasonal southerly wind is at its maximum strength (DAL 2000). The unique feature of the Capes Current is that it has been shown that the source water of the cool Capes Current is augmented or fully supplied by upwelling between Capes Leeuwin and Naturaliste (DAL 2000).

The contribution of the ocean currents to the inshore water motion will be variable and it is likely to be less than 0.05 ms^{-1}.

Measured currents

Nearshore currents were measured off the Bunbury WWTP at the locations shown in Figure 4.3 and for the durations shown in Table 4.2 (DAL 2000).

Currents were predominantly parallel to the shore (longshore), constrained by the coastline and bathymetry. The residual drift was to the north in the summer and to the south in the winter (DAL 2000).

Table 4.2 Bunbury WWTP Outfall current measurement program

Meter type	Deployment dates	Height of meter above seabed (m)	Water Depth (m)	Latitude	Longitude
CM-04	5/3/99–30/7/99 13/1/00–5/3/00	2.0	6.0	33°23’00”S	115°36’07”E
CM-04	5/3/99–30/7/99 13/1/00–5/3/00	2.0	12.0	33°22’41”S	115°35’07”E
CM-04	5/3/99–30/7/99 13/1/00–5/3/00	7.5	12.0	33°22’41”S	115°35’07”E

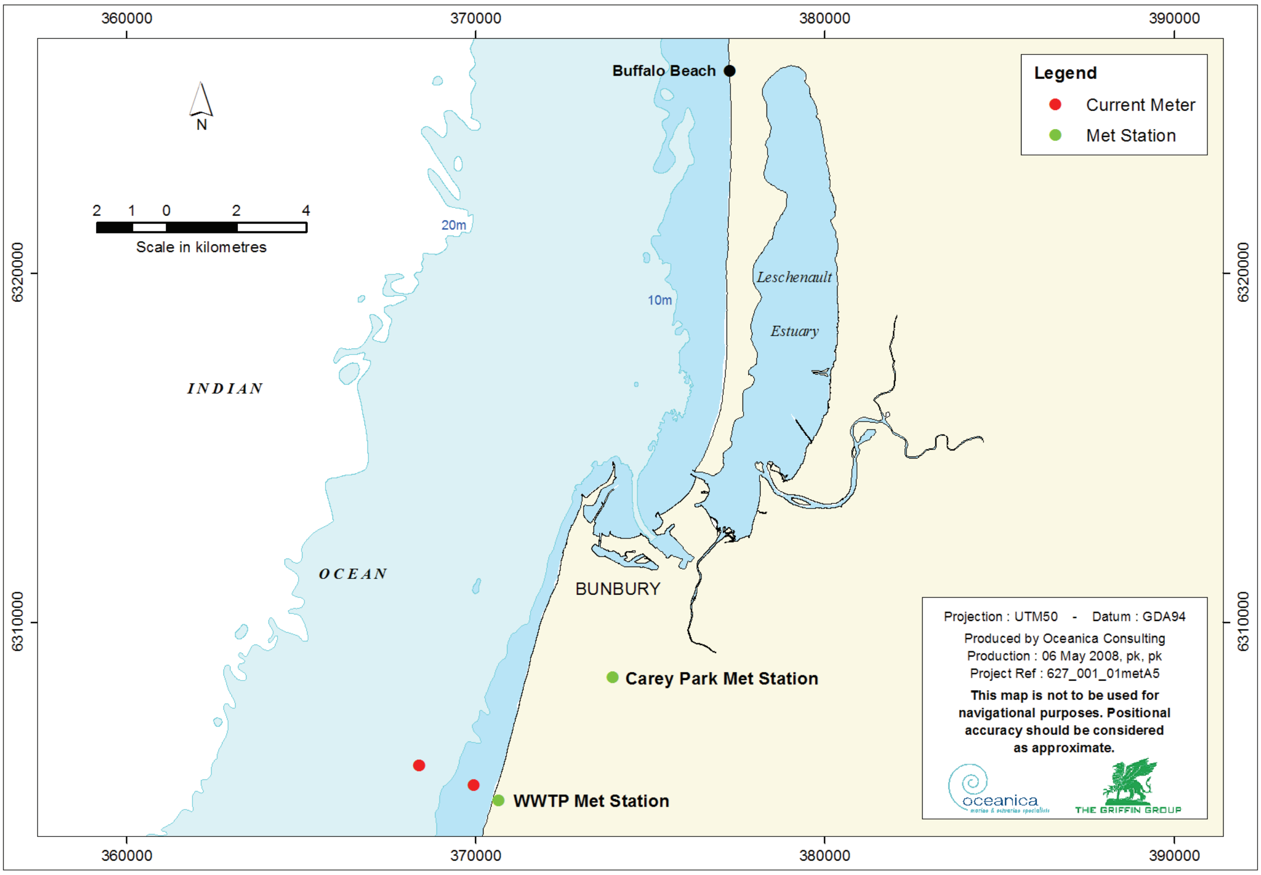


Figure 4.3 Location of existing infrastructure and measurement locations

4.3.3. Wave climate

Both wind waves (generated by the prevailing winds) and swell waves (distant from their place of generation) are experienced at the shoreline in the region (DAL 2000).

The predominant swells affecting the region are generated by low-pressure systems in the southern Indian Ocean (DAL 2000). These swells typically arrive from the south-west and are refracted and partly attenuated around Cape Naturaliste. North-westerly and westerly swells are also generated by cold fronts in the Indian Ocean and these swells often combine with wind waves to produce relatively high energy storm waves. Wave conditions were observed in 12.5 m of water offshore of Bunbury between April 1997 and May 1999 and the mean significant wave height ranged from 0.5 m during January to April to 1.1 m in August, with an annual mean of 0.8 m (DAL 2000). The mean spectral wave period ranged from 3.6 s in January to 6.4 s in July.

An analysis of the extreme wave conditions associated with extra-tropical storms and cyclonic storm events for Bunbury was conducted for DAL (2000) This analysis indicated extreme significant wave heights (in 10 m of water) of 3.9 m to 4.9 m for extra-tropical and cyclone storms, respectively. In late-summer, the wind field associated with dissipating tropical cyclones may generate high-energy north to north-westerly sea waves which may propagate directly to the shoreline adjacent to the Bunbury WWTP (DAL 2000). The wave climate at the proposed outfall site is expected to be similar.

4.3.4. Coastal processes

A rise in sea-levels during the early Holocene resulted in the delivery of a large supply of sand to this coast. In this region, this sand has resulted in the development of large parabolic dune sequences (termed the Quindalup Dunes). In the vicinity of Kemerton these parabolic dunes extend 500-800 m inland from the shoreline. The crests of these dunes typically have a height from 20 to 30 m. The majority of the parabolic dunes are vegetated and stable. However, dune "blow-outs" are also fairly common, with blow-outs extending 300-500 m inland in areas.

The beach is composed of an orange/brown medium to coarse grained carbonate sand. The beach is linear and aligned in a north–south direction. Beach cusps with a spacing of approximately 30 m and an amplitude of 5–15 m are typically observed along this beach. Recent (past 30 years) observations suggest that the coastline is stable in this area. The longshore sediment transport rate in the vicinity of Bunbury was estimated to be between 55,000 m^3 and 70,000 m^3 per year in a northerly direction (Department of Marine and Harbours, 1990) and similar rates are expected in this area, also with net northward transport.

The sediments in this area are consistent and generally comprise loose to medium dense sands overlying medium to very dense sands (possibly with some weakly cemented bands) to depths of approximately 10 m (DAL 2000). Figure 4.4 shows the potential beach crossing site for the proposed Griffin outfall.

Offshore the seabed consists of a sand veneer over limestone which outcrops as pavement and reef. The area has a relatively simple bathymetry with gentle offshore gradients. Offshore the seabed has a reasonably even slope with a gradient between 1:30 and 1:35 from the shore to a depth of 7 m (a distance of approximately 250 m offshore), the seafloor slope then reduces to 1:350 to 1:400 for the region further offshore, with a depth of 13 m generally occurring about 2–3 km offshore.

Figure 4.4 Potential site for Griffin pipeline (Oceanica 2008)

4.4. Water and sediment quality

4.4.1. Overview of regional water quality

Regional water quality data has previously been collated for Water Corporations proposed Southern Seawater Desalination Plant (Water Corporation 2008). Data included in this review was collected over 17 years in the area surrounding Griffin's proposed ocean outlet. The available data suggests that whilst slight density stratification has been observed (up to 0.1 kg/m^3), it is generally driven by a temperature gradient (i.e. through the solar warming of the surface waters) and limited to the winter months. Slight temperature gradients may only observed in winter, and not in summer as would logically be expected, as the wind stress from the strong sea breezes during summer may be sufficient to overcome the passive solar warming, resulting in mixing of the water column.

The available data contains no evidence of salinity stratification and shows that the waters in the region are generally warmer, saltier and of lower density during summer, and cooler, less saline, and of higher density during the winter months (Water Corporation 2008). Some salinity stratification may be experienced during heavy rainfall events and the subsequent increase in freshwater flows out of the Leschenault Inlet and the Harvey River Diversion Drain (see Figure 4.5).

The nutrient data indicates seasonal variation in nutrients and chlorophyll-a concentrations, with higher concentrations during the winter months and lower concentrations in summer. This may be associated with higher nutrient flow from land into the ocean during winter.

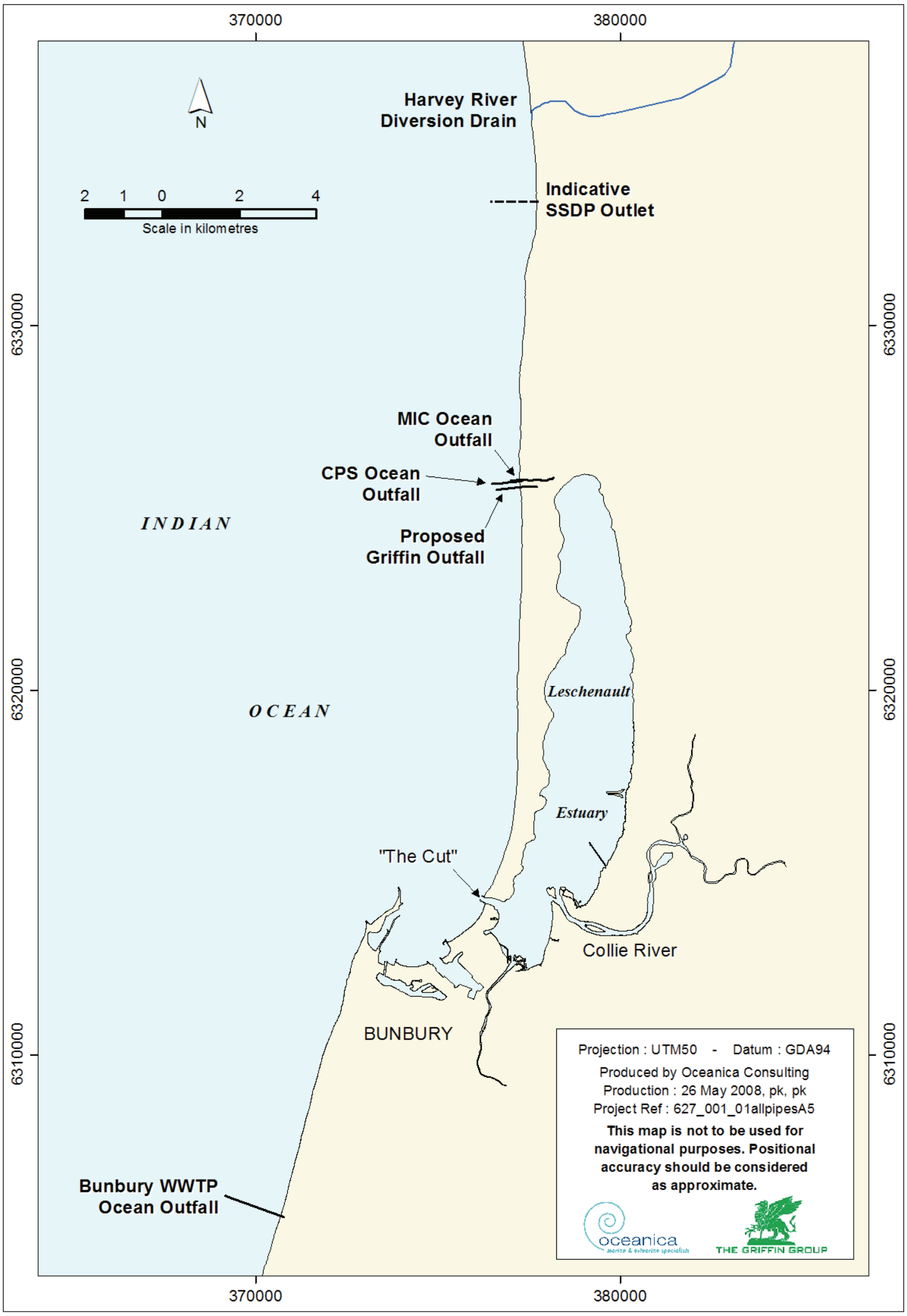


Figure 4.5 **General location figure showing Harvey Diversion Drain and the Leschenault Estuary**

4.4.2. Water column profiles for Griffin Energy location

Water column profiles were taken using a YSI6600 multi-parameter probe on 12 March 2008 at the sites shown in Figure 4.6. Co-ordinates of these sites are shown in Table 4.3.

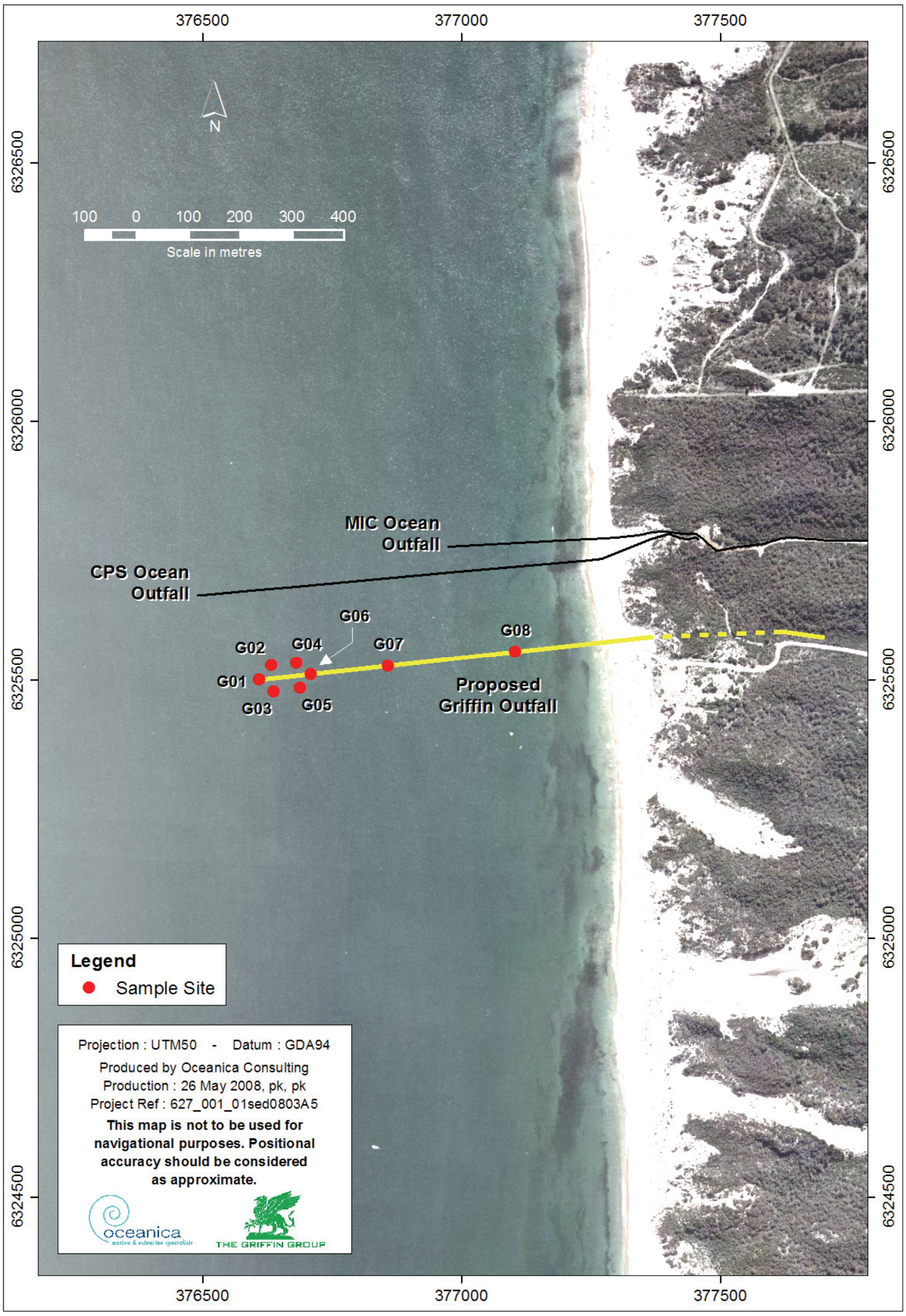


Figure 4.6 Water and sediment quality sampling sites

Table 4.3 Location of sampling sites (UTM50_GDA94)

Site	Easting	Northing
G01	376610	6325500
G02	376633	6325528
G03	376638	6325477
G04	376681	6325533
G05	376689	6325484
G06	376710	6325511
G07	376859	6325526
G08	377105	6325555

The pH was 8.2 at all sites and all depths and as a result has not been plotted. All of the other parameters are plotted in Figure 4.7.

The dissolved oxygen ranged from 85% to 97% at the different sites and depths. Generally the DO increased just below the surface and was fairly steady throughout the water column then decreased in the bottom metre.

Salinity was similar at all sites and depths ranging from 36.7 to 36.8 except for G04. At G04 the salinity increased from 36.3 at the surface to 36.7 at the bottom. It is not known why there is a difference in salinity at this site. Drogue measurements were taken on the same day and the currents were running to the north east so the lower salinity at G04 would not have been as a result of a plume from the Collie Power Station or Millennium Chemicals Ocean Outfalls.

Temperature was seen to gradually decrease with depth at all sites from approximately 24°C to 23.4°C. Temperatures can also be seen to gradually increase with increasing proximity to shore. Site G08 had a higher temperature than the other sites with an average of 24.2°C and no thermocline observed. This would be due to the greater mixing that occurred at this shallower site.

Turbidity can be seen to be relatively uniform around 2 NTU until 5m depth when the turbidity increased greatly to between 15 and 30 NTU on the bottom.

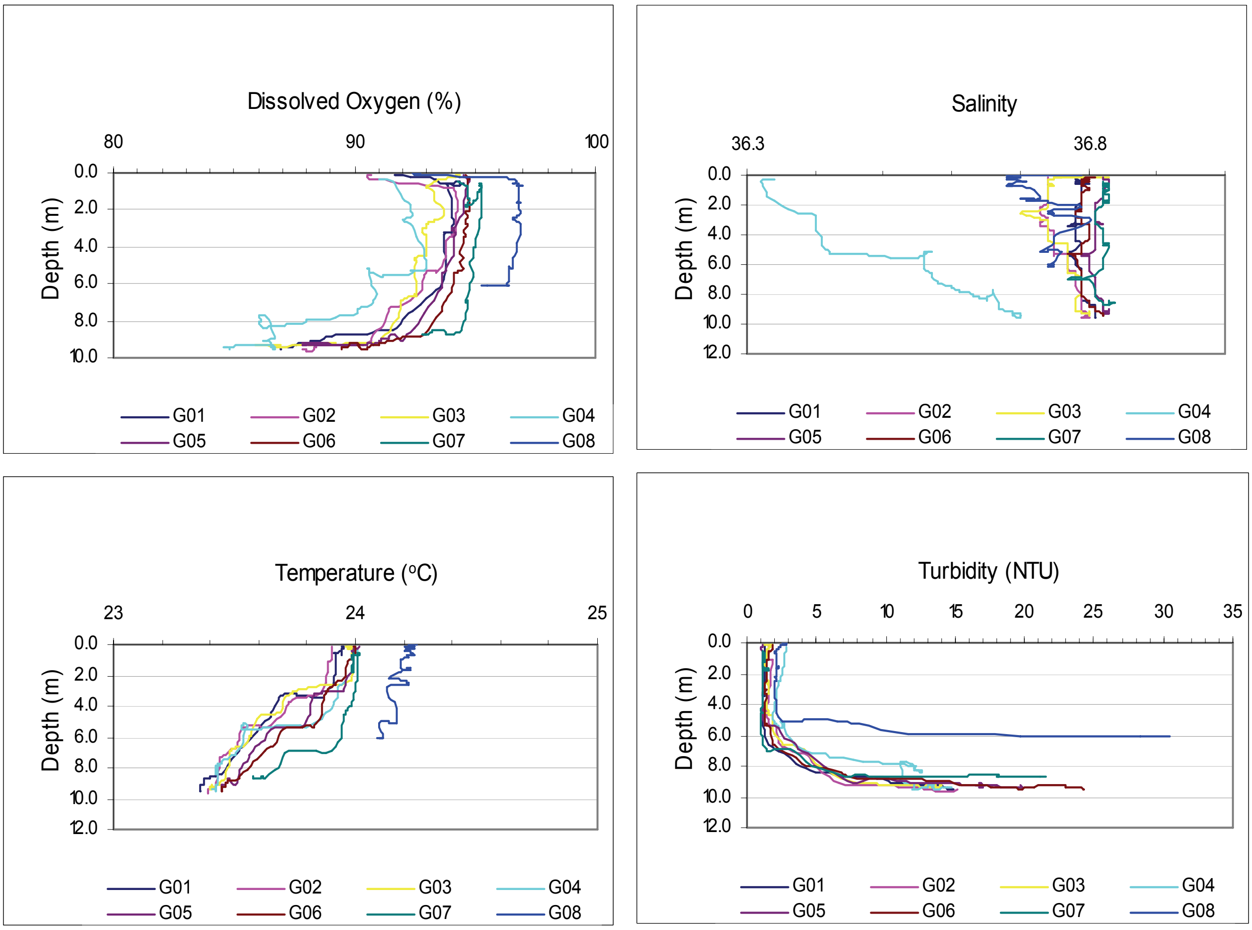


Figure 4.7 Water column profiles

4.4.3. Overview of regional sediment quality

Baseline sediment sampling was undertaken for the Bunbury Ocean Outlet which is not far from the proposed Griffin outfall see Figure 4.5 (Water Corporation 2000). The physical properties were variable and indicative of the variability in the habitat. Seagrasses in this area trap the finer particles and would contribute to higher organic content. Metals sampled for Water Corporation (2000) were below the ANZECC/ARMCANZ (2000) guidelines with the exception of arsenic.

4.4.4. Baseline sediment sampling for Griffin Energy

Sediment sampling was undertaken at the proposed Griffin Energy pipeline location on 12 March 2008 at the sites shown in Figure 4.6. Sediment samples were collected using a stainless steel Van Veen grab. Sediment samples were transferred into sample containers and kept on ice before being delivered to the Marine and Freshwater Research Laboratory (MAFRL) and the National Measurement Institute (NMI).

Metal concentrations

Sediment samples were analysed for the analytes listed in Table 4.4 by the MAFRL. Full reports are included in Appendix B.

All metal concentrations that are listed in the Interim Sediment Quality Guidelines were below the ISQG-low (from ANZECC/ARMCANZ 2000). These results provide us with a survey of background metal concentrations in the area surrounding Griffin's proposed outfall.

Table 4.4 Median metal concentrations (µg/g dry weight) in surficial sediments at sites around the proposed Griffin ocean outfall, 12 March 2008

Analyte	Al	As	Cd	Cr	Cu	Pb	Mn	Mg	Hg	Se	Ti	V	Zn
Reporting Limit	**20**	**1**	**0.06**	**0.2**	**0.2**	**0.1**	**0.05**	**2**	**0.01**	**2**	**0.1**	**0.1**	**0.1**
ISQG-Low		**20**	**1.5**	**80**	**65**	**50**			**0.15**				**200**
ISQG-High		**70**	**10**	**370**	**270**	**220**			**1**				**410**
G01	520	10	<0.06	9.4	<0.2	<1	28	2600	<0.01	<2	26	13	1.5
G02	460	10	<0.06	9.9	<0.2	<1	24	2800	<0.01	<2	22	12	1.4
G03	470	10	<0.06	10	<0.2	<1	31	2400	<0.01	<2	24	13	1.4
G04	530	12	<0.06	9.9	0.2	<1	30	2700	<0.01	<2	22	14	1.6
G05	540	10	<0.06	11	0.2	<1	34	2800	<0.01	<2	47	13	1.9
G06	540	9	<0.06	11	0.2	<1	71	7800	<0.01	<2	21	12	1.9
G07	500	10	<0.06	9.9	<0.2	<1	34	2600	<0.01	<2	55	13	1.5
G08	520	6	<0.06	9.2	<0.2	<1	27	2200	<0.01	<2	150	9.5	1.5

Organic matter and carbonate content

The sediment organic matter content ranged from 2.5 to 7.4% at the 8 sites (Table 4.5). Sites G03 and G05 had organic matter content around 2.5 and sites G01, G02, G04, G07 and G08 all had organic matter content between 4 and 5%. Site G06 had higher organic matter content than the other sites at 7.4%. The carbonate content was similar in all samples except for G06, 12%, with all other samples ranging from 1.1 to 3.3%.

Table 4.5 Organic matter and carbonate content of surficial sediment samples at sites around the proposed Griffin ocean outfall, 12 March 2008

Site	Percentage (%) Loss on Ignition at 550°C	Percentage (%) Loss on Ignition at 1,000°C
G01	4.2	2.2
G02	4.7	2.7
G03	2.7	3.3
G04	4.4	1.8
G05	2.5	2.6
G06	7.4	12
G07	4.0	1.1
G08	4.7	1.1

Particle size analysis

Sediments were analysed for particle size at the National Measurement Institute (NMI).

The surficial sediment particle size distributions at each site are presented in Table 4.6. The sediment particle size fractions were as follows:

- Clay <4 μm;
- Silt 4-63 μm;
- Very fine sand 63-125 μm;
- Fine sand 125-250 μm;
- Medium sand 250-500 μm;
- Coarse sand 500-1,000 μm;
- Very coarse sand 1,000-2,000 μm; and
- Gravel >2,000 μm.

Particle sizes were fairly similar at each site with the samples mostly consisting of coarse sand. There was very little fine material with no clay at any site and only one site consisting of any silt or very fine sand.

Table 4.6 Particle size distribution of surficial sediment samples at sites around the proposed Griffin pipeline.

Site	Percentage (%) by volume							
	Clay	Silt	Very fine sand	Fine sand	Medium sand	Coarse sand	Very coarse sand	Gravel
G01	0	0	0	1.0	5.4	81.3	12.2	0.1
G02	0	0	0	1.8	13.3	79.6	5.2	0.1
G03	0	0	0	0.9	8.5	80.4	10.1	0.1
G04	0	0	0	1.4	6.0	79.9	12.1	0.3
G05	0	0	0	1.3	16.2	78.8	3.6	0.1
G06	0	0	0	5.2	30.0	62.5	2.2	0.1
G07	0	0	0	1.0	12.0	78.5	7.9	0.6
G08	0	0.3	1.9	5.9	16.7	71.5	3.4	0.3

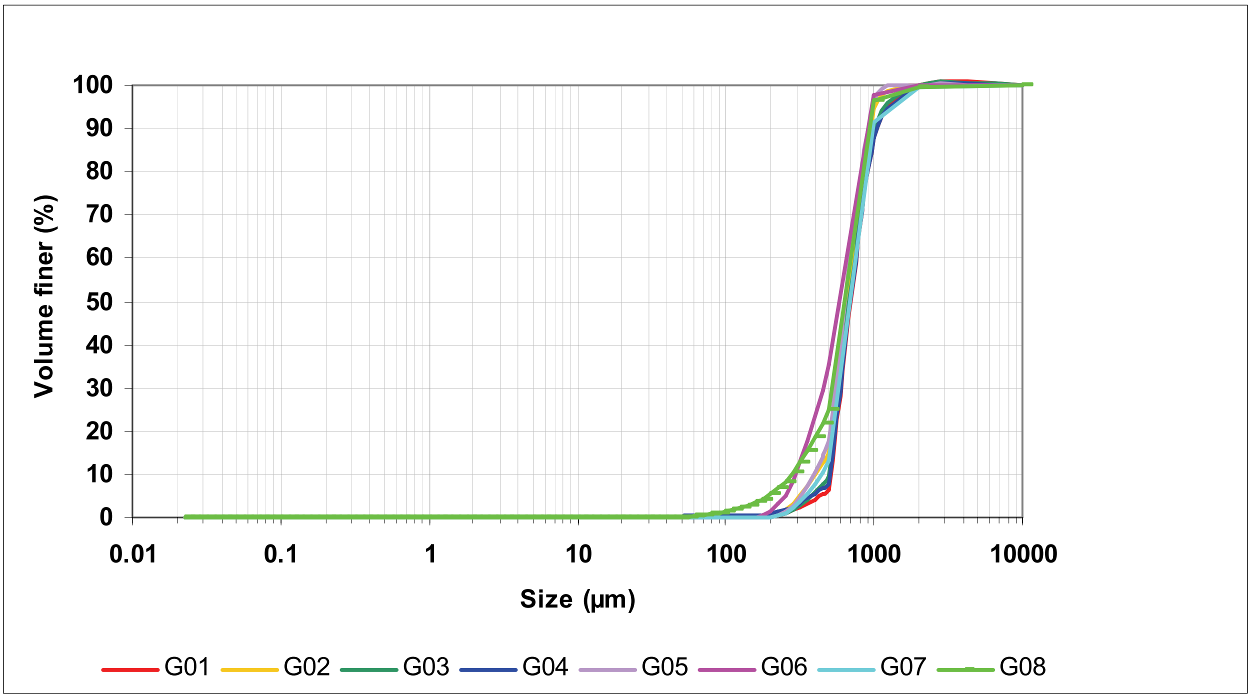


Figure 4.8 Particle-size distribution curves for the mean sediment characteristics from surficial samples at sites around the Kemerton ocean outfall, 28 March 2007

4.5. Benthic Habitat

4.5.1. Overview of regional benthic habitat

The proposed Griffin outlet is located approximately 8 km to the south of the proposed Southern Seawater Desalination Plant (SSDP). The marine benthic habitats in the vicinity of the proposed SSDP were characterised following a towed underwater video survey completed in December 2007 (UWA marine research group 2008). Habitats comprised of (i) no biota (i.e. free of obvious fauna in video footage), (ii) vegetation and sessile invertebrates, (iii) sessile invertebrates and (iv) vegetation.

The area mapped was described as highly disturbed (by natural wave energy), with large areas of reef pavement devoid of biota and where biota occurred they occupied a small proportion of the total reef surface (UWA marine research group 2008). Megaripples and sediment sheets were observed midshore suggesting that sediment was highly mobile (UWA marine research group 2008). The area had similar reef and seagrass communities to those reported to the north and south of the site although diversity and abundance of species in this region appeared to be poorer. The mosaic of seaweeds and benthic invertebrates was most developed on reefs 300-500m offshore with areas further inshore exhibiting an extensive pavement bare of invertebrates and seaweed which the authors suggested was due to the pavement being covered and scoured by shifting sands frequently (UWA marine research group 2008).

The seagrasses recorded in this study were *Posidonia angustifolia* and *Posidonia coriacea* with *Posidonia angustifolia* comprising 98.7% of all seagrass recorded (UWA marine research group 2008). The more extensive offshore meadows occurred on sand whereas closer inshore a mosaic of seagrass, seaweed and sessile benthic invertebrates occurred on relatively low relief reef and pavement (UWA marine research group 2008). No *Amphibolis* species were present although this genus often colonises areas along with *Posidonia angustifolia* after the colonisation of *Posidonia coriacea* which is an early successional species (UWA marine research group 2008). There were also no smaller, more delicate species (for example *Heterozostera* or *Halophila*) probably due to the high sediment movement in this area (UWA marine research group 2008). It is important to note that the quality of the imagery was low due to weather conditions prior to and during the survey.

There was no dense seagrass recorded in shallower water due to the high sediment movement in this area; seagrass was observed from 650m offshore however it was sparse and patchy (UWA marine research group 2008). The habitat mapping survey did not extend out to the offshore depth limit of the seagrass (*P. angustifolia* is known to occur to depths of 30m in Geographe Bay) and as such it is unknown how far from shore and to what water depth the seagrass extends in this area.

The specific types of macroalgae present were often not possible to discern due to the video quality, and as a result most of the macroalgae were described as undifferentiated (UWA marine research group 2008). The mosaic of seaweeds and benthic invertebrates was most developed on reefs 300-500m offshore with areas further inshore exhibiting an extensive pavement bare of invertebrates and seaweed which the authors suggested was due to the pavement being covered and scoured by shifting sands frequently (UWA marine research group 2008).

Previous habitat surveys undertaken by the Water Corporation (DAL 2000) showed that broad scale, benthic habitat from at least 10 km south and 15 km north of Bunbury and 3 km offshore is very similar, being a diverse assemblage of mixed seagrass, reef and sand.

4.5.2. Mapping of the proposed pipeline area

Aerial and satellite photography was used to distinguish benthic habitat types (vegetated versus unvegetated) using a supervised classification scheme by LandGate. The land area was masked and the marine area was divided into zones according to water depth and each depth zone was classified independently.

The classification of the aerial and satellite imagery (providing classification of the area into vegetated and unvegetated categories) was supplemented by groundtruth surveys undertaken within the mapping area by towed underwater video. The detailed groundtruth survey data was used to augment the spatial data from the aerial and satellite photography analysis and enabled definition of benthic habitat assemblages within the mapping area. Oceanica undertook a ground-truthing survey on 15 April 2008.

The classified imagery was then re-sampled, polygonised and imported into ArcGIS 9.1 for further analysis. Post-processing of the classified image was undertaken to derive the final habitat maps.

Mapping of habitat types within the vegetated areas classified from the aerial and satellite imagery was carried out by hand digitising within ArcGIS 9.1. Habitat types in areas not directly covered by towed video transects were inferred from examination of the aerial imagery, surrounding habitat types, particularly those recorded to the north and south in similar water depths, knowledge of the area gained during field work for other programs at Kemerton and Bunbury and bathymetric data. There are essentially four key habitat types in this region: sand, high relief reef low relief reef and seagrass. Seagrasses identified in the area were *Posidonia angustifolia* and *Posidonia coriacea*.

A short description and frame grabs of each habitat type is given in Table 4.7.

Table 4.7 Examples of habitat types identified in the area surrounding the proposed Griffin pipeline

Habitat type	Description	Screen capture from groundtruth video (April 2008)
Sand	Rippled sand	
Low Relief Reef	Low relief limestone reef with some algal and epiphytic cover	

Habitat type	Description	Screen capture from groundtruth video (April 2008)
High Relief Reef	High relief limestone reef with algae and encrusting invertebrates	
Seagrass	*Posidonia* beds	

As shown in Figure 4.9, the area surrounding the pipeline and diffuser was spatially heterogeneous with habitats of seagrass, sand and reef. Habitat mapping began within 50 m of the shore where a reef was observed. As the camera moved further from shore, sand and then reef were encountered. Generally the reef was low relief reef which consisted of limestone covered with a thin layer of sand and algae. The presence of algae was the factor that differentiated between sand and low relief reef. There was also a smaller section of high relief reef in the area surrounding the proposed Griffin Outfall. This limestone reef was raised from the ocean floor and appeared to support various invertebrate species as well as algae. Seagrass was generally not found within 600 m of the shore although there were some small patches. Seagrass meadows were observed to generally be sparse throughout the area.

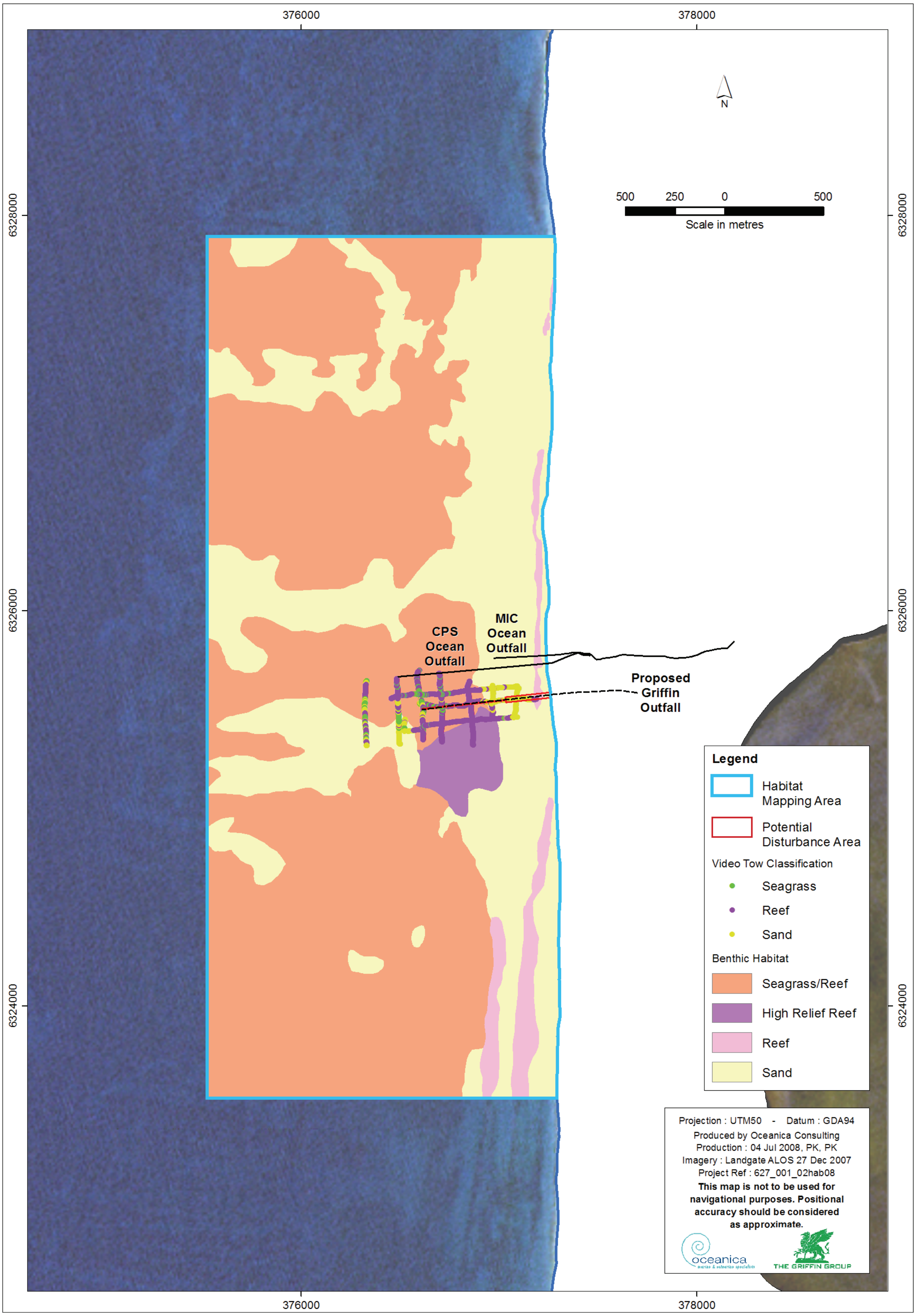


Figure 4.9 Habitat map

4.6. Marine Fauna

4.6.1. Marine mammals

Information on the occurrence, species diversity, abundance, distribution and movement of marine mammals is extremely limited in the project area (Burton 2008). Confirmed cetacean species at Binningup include dolphins and southern right whales.

The major impact to marine mammals during the construction stage is likely to be noise. As it is not anticipated that any blasting or pile driving will be required to take place this risk is lessened. Other impacts to marine mammals may be in relation to turbidity, boats in the water and the new objects placed on the seabed.

For large cetaceans there may be some displacement from the immediate area of the pipeline if the area is being used as a calving area or migratory column (Burton 2008). This would be unlikely to impact the recovery of the population (Burton 2008). The area may provide feeding opportunities for small cetaceans with the expected increase in fish life that is associated with the installation of marine pipelines (Burton 2008).

4.6.2. Fish

Maunsell (2008) carried out a literature review on fish in the area surrounding the proposed SSDP for the Water Corporation. Limited information is available on specific fish fauna assemblages in the area surrounding the SSDP (Maunsell 2008); however, information is available for the nearby Geographe Bay Region. Similar assemblages of fish species are found throughout most of the southwest of WA, with the Geographe Bay and Cape Leeuwin regions being dominated by warm temperate species (76%), several subtropical species (19%) and a few tropical species (5%) (Maunsell 2008). One survey that sampled fish species in the seagrass beds between Capel and Dunsborough found that 52% of all fish fauna caught were whiting species (Maunsell 2008). Although these fish community compositions do not include the area surrounding the proposed Griffin outfall, it is likely that similar assemblages occur throughout both regions.

Given the dominance of seagrass beds in this area (see Section 4.5.2), it can be assumed that the area would support a high abundance of fish fauna and other marine organisms. The area surrounding the proposed pipeline is unlikely to support unique communities of marine fauna as seagrass beds are well represented in the southwest.

4.7. Aboriginal Heritage (coastal)

A desktop assessment using the online Aboriginal Heritage Inquiry System was undertaken for the pipeline route. Aboriginal burial sites are commonly found in Holocene coastal dunes along the WA coast, and as such, a heritage survey will be undertaken prior to commencement of construction through the dune 200 m south of a known burial site (Site ID 15371) on Buffalo Road.

4.8. Social

The area is a known point for 4WD vehicles to access the beach for fishing. Griffin Power will determine current recreational uses at the site via consultation with relevant management agencies and user groups to assist with quantification of usage and the development of strategies to mitigate impacts.

5. Impact Assessment

5.1. Construction

5.1.1. Loss of benthic primary producer habitat

EPA (2004) presents a set of principles to be applied by proponents and the EPA when considering development proposals that may result in removal or destruction of, or damage to, marine benthic primary producer communities or the habitats which support them. Benthic primary producers (BPP) are predominately marine plants (e.g. seagrasses, mangroves, seaweeds and turf algae) but include invertebrates such as scleractinian corals, which acquire a significant proportion of their energy from symbiotic microalgae that live in coral polyps. These organisms grow attached to the seabed (i.e. subtidal and intertidal), sequester carbon from surrounding seawater or air and convert it to organic compounds through photosynthesis. Benthic primary producer communities are biological communities including the plants and animals within which the benthic primary producers predominate. Benthic primary producer habitats (BPPH) are both the BPP communities as well as the substrata that can/do support these communities.

It is recognised that not all benthos in the photic zone is BPPH (EPA 2004). Some of the area surrounding the proposed Griffin outfall may be an example of this as due to high wave action and sediment movement BPP have not become established.

The EPA recommends the delineation of a management unit of 50 km^2 (5000 ha) in which issues such as ecosystem integrity, cumulative impact and biodiversity are addressed (EPA 2004). To provide context, a 50 km^2 management unit, centred on the Griffin survey area (and proposed pipeline), is shown in Figure 5.1. This management unit extends approximately 8 km north and south of the proposed pipeline and 3 km west although the width does vary along the coast as the coastline is not straight.

Within this management unit the following calculations are required;

- All loss/damage to BPPH caused by human activities since European habitation of Western Australia;
- Current area of BPPH; and
- Loss/damage of BPPH likely to result from proposed works.

The BPPH guidance statement defines six categories of marine ecosystem protection and the cumulative loss thresholds for each. The area where the Griffin pipeline is proposed to be developed is characterised as a non-designated area or category D according to EPA (2004). EPA guidance for these areas is as follows:

- Limited damage/loss of BPPH and/or their associated BPP communities may be acceptable where proponents can demonstrate that there are no feasible alternatives to avoid damage/loss and/or where proposals are consistent with relevant management plans or a use of the management unit that is consistent with a State Government decision (Cumulative loss threshold = 5% loss of BPPH).
- The EPA expects proponents to design proposals to minimise damage/loss and to develop and commit to the implementation of a comprehensive environmental management plan that provides a context for the development in relation to the management unit and the wider area, with an objective of protecting and maintaining ecosystem integrity.
- The acceptability of any damage/loss in these areas will be a judgement of the EPA.

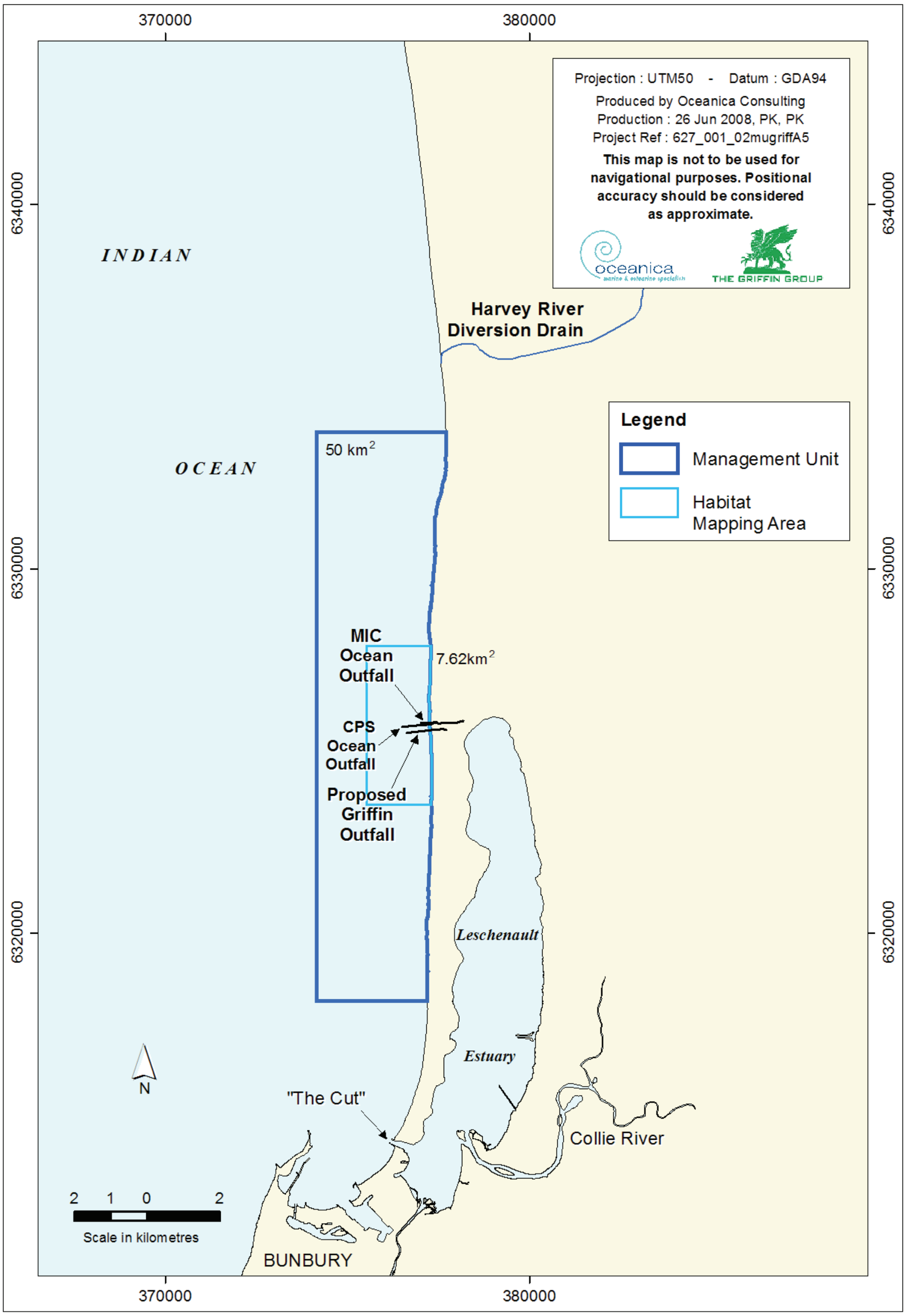


Figure 5.1 Management unit

5.1.2. Historic losses of BPPH

There are two outfalls within the management unit for the Griffin pipeline (see Figure 5.1). Millennium Inorganic Chemicals began discharging process water in 1988 and Verve Energy began discharging saline cooling water in 1999. Although the construction of these pipelines may have initially resulted in some loss of BPPH, there was no pre-impact assessment of loss that is consistent with GS29 and observations show that these pipelines have subsequently provided functional reef substrate for benthic primary producers. As a result, it is difficult to conclude that there has been a material historic loss of BPPH associated with these pipelines.

5.1.3. Extent of BPPH within mapped area

The habitat mapping area shown in Figure 4.9 and Figure 5.1 was selected on the basis of the extent of detailed groundtruthing and the quality of the imagery and classification in this region. A broader region could have been mapped but the lack of wider groundtruthing data coupled with the fact that the smaller area selected for mapping is sufficient to demonstrate that the EPA's objectives can be met means that, at this stage, broader mapping is unnecessary.

The coverage of BPPH types within the 7.6 km^2 mapped region is shown in Figure 4.9 and Table 5.1.

Table 5.1 Coverage of habitats within the mapped area (7.6 km^2)

Habitat/assemblage	Coverage (ha)	Coverage (%)
Sand	271	35
Reef	22	3
Seagrass/reef	455	60
High relief reef	15	2
TOTAL	763	100

Within the 7.6 km^2 mapping region, approximately 4.92 km^2 of habitat was found to be vegetated, representing 65% of the total area (Table 5.1). Extrapolation of the mapped area to the Management Unit suggests that vegetated habitats would represent around 65% (or 3250 ha) of the seabed area in the management unit (based on inspection of the image which suggest that coverage would be similar throughout). Previous habitat surveys undertaken by the Water Corporation (DAL 2000) showed that broad scale, benthic habitat from at least 10 km south and 15 km north of Bunbury and 3 km offshore is very similar, being a diverse assemblage of mixed seagrass, reef and sand.

5.1.4. Worst-case habitat loss footprint

The total length of pipeline from the shore to the end of the diffuser is likely to be 650 m. The potential disturbance corridor is based on a corridor 25 m wide from the shoreline to the 4 m depth contour where the groyne will be constructed (the pipeline will be buried in this same corridor). This was calculated assuming a 6 m wide trench in the centre of the groyne and 9.5 m either side. The pipeline will gradually emerge from the seabed beyond the 4 m depth contour and will be fully exposed at the 6 m contour. From the 6 m contour the pipeline will be supported by precast concrete blocks about 1.2 m by 1.2 m in area. After the 4 m depth contour (approximately 230 m from shore) the disturbance corridor has allowed for 1 m either side of the 450 mm pipeline to take into account trenching and then concrete blocks. This is a conservative estimate as most of the pipeline will be above the seabed. The disturbance footprint is a total of 0.72 hectares which consists of 0.61 ha to the 4 m depth contour and 0.11 ha from the 4 m contour to the end of the diffuser (Figure 5.2).

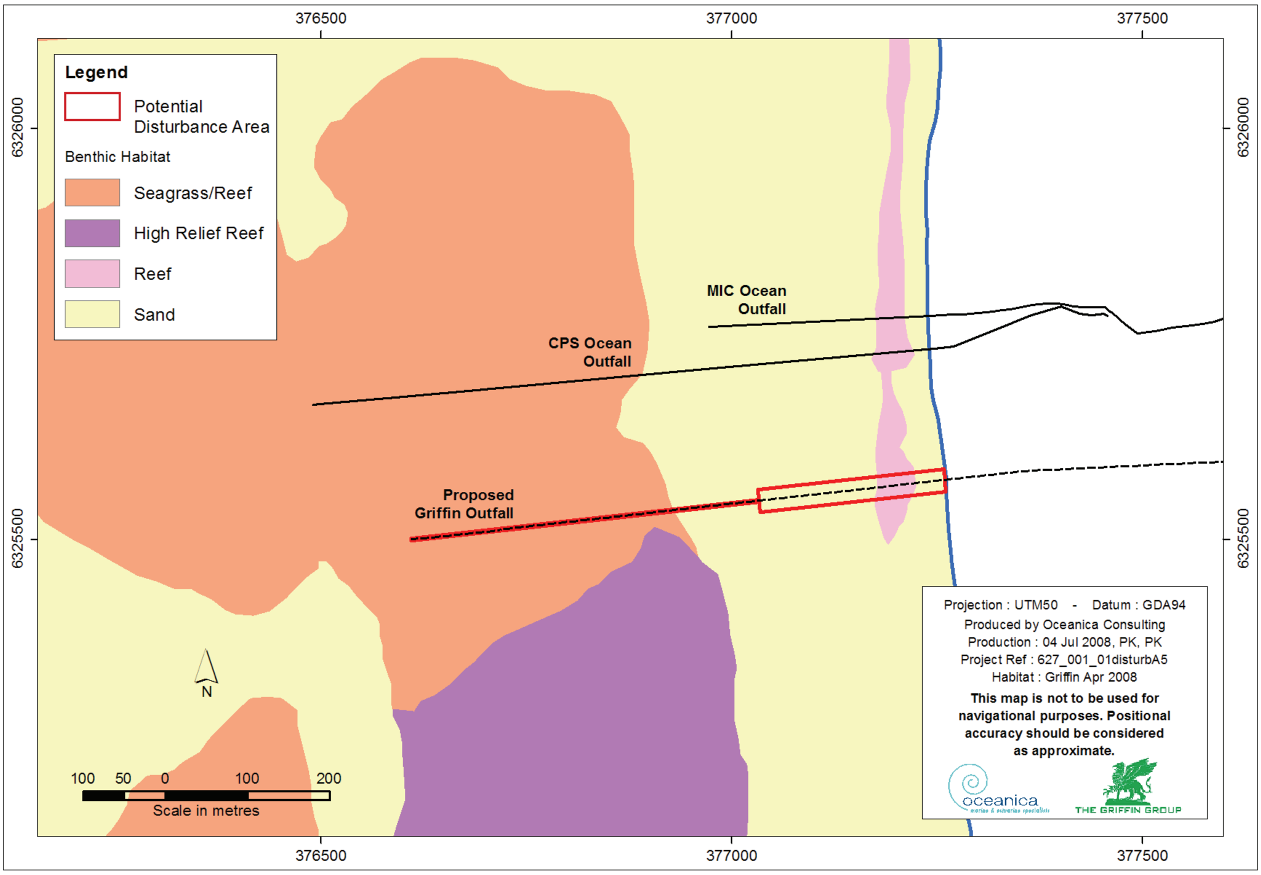


Figure 5.2 Potential disturbance footprint

5.1.5. Predicted potential habitat losses

Placement of the above predicted worst-case pipeline footprints over the mapped area allows for the maximum potential area of loss of each habitat type to be determined as shown in Table 5.2, also shown is an estimate of worst case management unit scale losses based on extrapolated values.

Table 5.2 Direct habitat loss estimates

Habitat/assemblage	Worst Case Loss		
	(ha)	(% of habitat within mapped area of management unit)	(estimated % of habitat within entire management unit based on extrapolated values)
Sand	0.512	0.189	0.029
Seagrass/reef	0.079	0.017	0.003
Reef	0.128	0.592	0.133
TOTAL	0.719	0.798	0.164

If no re-establishment occurs, it is estimated that up to 0.6% of vegetated habitats within the mapped area could be disturbed during construction of the pipeline. However, based on experience with other pipelines in the area, similar communities to those currently found within adjacent reef habitats will rapidly (<12 months) re-establish onto the pipe and disturbed reef surfaces.

It is shown that no more that 0.2% of any one habitat type (sand) will be lost within the mapped area. This in turn means that the cumulative losses of any one BPPH type in the management unit will fall well below the 5% loss threshold for high protection areas as set out in the guidance statement (EPA 2004). Therefore this proposal would meet the EPA's objective with regard to BPPH protection.

5.1.6. Coastal processes

The construction of the outfall pipeline will require in a temporary groyne to be built across the surf, the groyne will be in place for the order of 4-6 weeks. Given the short construction period, there is very limited risk of any significant interruption to long-shore transport posed by the groyne and any build-up of sand adjacent to the groyne will rapidly be redistributed on removal of the groyne.

There are no other potential impacts on coastal process during construction.

The beach will be complete reinstated on completion and graded to match the adjacent profile and all foreign material introduced will be removed.

5.1.7. Generation of turbidity during construction

The most likely material and size for the outfall pipeline will be an HDPE pipe of 450 mm diameter. The mostly likely construction approach will be for the pipeline to be drilled under the dunes then trenched across the beach and surf zone with the aid of a temporary groyne and would gradually emerge from the sandy seabed beyond the 4 m depth contour (refer Section 2.6). The pipe most likely will be supported on the seabed by pre-cast concrete blocks. Ultimately, the construction method and detailed design will be dependant on the contractor.

The only requirement for underwater excavation is in the surf zone and burial out to the 4 m depth contour. The volumes involved are very low (of the order of magnitude of 1,000's m^3) and all material will be used to fill in the location that it was removed from. There will be some dispersal of material during construction, however, as the following section shows, the potential impact on benthic habitat due to decreased light penetration from turbidity is low.

As is shown in the habitat map (Figure 4.9) no seagrass was observed on the pipeline route where excavation will be taking place. Some seagrass is located further offshore, where the pipeline will be supported by concrete blocks.

Timing of construction to reduce impact on seagrass

Until recently, the accepted approach to minimise risk of any turbidity-related impacts on seagrass was to carry out dredging between late autumn and early spring, when growth rates are lowest and food reserves (stored in seagrass rhizomes) at their highest (which help seagrass cope with the low light levels over this period). However, recent shading studies carried out over three months on *Amphibolis,* have found a greater impact when shading commenced in autumn than in spring (McMahon pers. comm.). As the morphology and growth characteristics of *Amphibolis* and *Posidonia* are quite different *Posidonia* may respond differently to turbidity. It is not believed that any studies have taken place to investigate differences in the impact of light reduction with season in *Posidonia*, nor can it be assumed that dredging would be best carried out between late autumn and early spring.

Construction is very unlikely to occur during winter months due to the difficulty and safety issues posed by storm conditions.

Previous studies on light tolerance in seagrasses

The seagrass species *Posidonia angustifolia* and *P. sinuosa* were described in 1979 and prior to this were known as narrow leaved forms of *Posidonia australis* (Cambridge & Kuo, 1979). The depth range of *P. angustifolia* is 2-35 m whereas *P. australis* and *P. sinuosa* occur from the low water mark to 15 m (Cambridge & Kuo, 1979): this indicates that *P. angustifolia* can survive at lower light levels than the other two species. Meadows of *P. sinuosa* and *P. angustifolia* are known to occur at depths from 2 m to 14 m in Geographe Bay, below 14m seagrasses become sparse and patchy in distribution (D.A. Lord and Associates, 1995). During the habitat mapping survey of the area surrounding the proposed Griffin outfall seagrasses observed were from the genus *Posidonia* but were not identified to species level.

Structurally large species such at *Posidonia* can survive for more than 140 days of shading (Collier 2006; Ralph et al. 2007). Westphalen *et al.* (2004) reported that *Posidonia angustifolia* has a relatively higher below ground component than *P sinuosa* or *P. australis*, although this is probably traded off against a slower rate of growth. The ability to store large quantities of carbon may be a benefit in terms of enabling the plant to tolerate extended periods of sub-optimal light but a high below ground biomass poses a substantial oxygen demand that cannot be fulfilled by dissolved oxygen in the water column (Westphalen *et al.*, 2004)). Thus, while the storage of carbohydrates assists seagrasses to tolerate low light levels to some degree, a severe and/or extended loss of photosynthetic capacity may result in profound root anoxia and even the localised production of poisonous sulphides which may adversely affect the growth or survival of sediment infauna (i.e. invertebrate fauna in the sediments) (Westphalen *et al.*, 2004). From the many studies that have taken place it is clear, however, that species with larger below-ground biomass, such as *Posidonia*, are better adapted to longer periods of sub-minimum light (Erftemeijer & Robin Lewis III, 2006).

The time taken to produce measurable responses (typically shoot loss) due to reduced light levels, is generally longer in *P. sinuosa* than most other seagrass species, with some shoots surviving over 12 months below minimum light requirements (Collier 2006). The minimum light requirement at depth limit for *P. sinuosa* is around 8% of sub-surface irradiance (Collier 2006, DEP 1996). In Cockburn Sound, *P. sinuosa* at a water depth of 7m (close to the depth limit of seagrass in Cockburn Sound)—when shaded to ~3% of sub-surface irradiance for just over 6 months continuously—exhibited a significant decrease in shoot density, but did survive (Collier 2006). Gordon et al (1994) found that *P. sinuosa* shoots survived 24 months with a light availability of 12% ambient.

Collier (2006) found that although shoots in the shade at 7m survived after receiving only 3 % of subsurface irradiance for just over 6 months, after 384 days of recovery (i.e. shading removed) the biomass in this treatment was still significantly lower than the control treatment. Thus although the seagrass may survive events of high shading the recovery time may be long.

The generation of turbidity during construction will at most pose a negligible risk to adjacent seagrass health for the following reasons:

- The shoreline excavation period is very short, with pipeline installation expected to take the order of 2-3 weeks.
- The entire construction period, from groyne construction to removal is expected to be complete within 2 months and construction will not be taking place 24 hours a day 7 days a week.
- The volume of material excavated underwater is likely to be relatively small (order of 5,000 - 10,000 m^3).
- The coast line is exposed to regular wind events which will act to rapidly disperse any turbidity.
- Field surveys and observations have shown that the local waters are often turbid inshore due to wave action.
- There are no seagrass meadows close to shore, where the excavation will occur.
- The fact that the coastline is high energy and observation of beach grain size, means that there is unlikely to be a significant fraction of fines in the material excavated.
- There should not be a substantial period of post-construction turbidity as any major event, such as the passage of a storm front will rapidly remove and disperse any fines and re-sort the material in the area.
- The local seagrass species are known to survive major shading events of substantially greater duration than the period of turbidity generation for this project.

Given the negligible level of risk of short duration turbidity affecting seagrass health, there is no need for the turbidity generation to be modelled. Similarly, there is limited benefit in any benthic health monitoring to be undertaken during construction.

5.1.8. Impacts of construction noise on marine fauna

As no percussive noise (e.g. blasting or pile driving) is anticipated to take place there is negligible risk that noise generated from construction will have any physiological impact on marine fauna. If blasting and pipe driving are required, a blasting management plan will be prepared and will address the issue of managing the impacts of underwater construction noise on marine fauna.

5.1.9. Introduced marine species

As marine construction is likely to take place with local plant over a short time period of 2-3 weeks and there will be no international vessels, the likelihood of introducing marine pests during construction is negligible. If international vessels are used for construction the construction management plan will be amended to provide details on preventing the introduction of marine species.

5.1.10. Closure of beach to recreational access during construction

The construction period will be up to 2 months, most likely over summer. The potential impacts to recreational activities in the area will be temporary and localised restriction of access by vessel and to beach due to the construction of marine facilities and temporary and localised restriction of access to land during installation of the pipeline.

Griffin Power will determine current recreational uses at the site and review potential impacts to existing recreational uses including access to the coast and other recreational areas. It will consult with relevant management agencies and user groups to assist with the evaluation of management strategies to mitigate impacts.

Construction activities which restrict beach access will be staged where practicable and/or alternative access will be provided. There will be ongoing management of vehicles in the local dune system on site.

5.1.11. Dune rehabilitation

A construction environmental management plan will be prepared in consultation with the DEC prior to the commencement of construction.

Following installation and burial of the pipeline the beach and dunes will be returned to their natural state. Griffin will implement a program of rehabilitation using species local to the dune that the pipeline passes through. As the pipeline is proposed to pass through the dune in the vicinity of a blow out, the rehabilitation program may result in a dune that is more stable than it is currently.

5.1.12. Aboriginal heritage

Although this site has been previously disturbed from the construction of the CPS and the MIC outfalls, it is acknowledged that Aboriginal burial sites are commonly found in Holocene coastal dunes along the WA coast, and as such, a heritage survey will be undertaken prior to commencement of construction through the dune.

The local Aboriginal population will be consulted prior to commencement of construction with regard to the potential disturbance to existing heritage sites and the significance of the dune. Action will be taken as required following this consultation.

Griffin power will avoid disturbance to identified heritage sites where practicable and ensure the Proposal is compliant with the *Aboriginal Heritage Act 1972* and the *Native Title Act 1993*.

5.2. Operations

5.2.1. Discharge modelling

Overview

The Griffin Energy outfall ultimate design is to discharge up to 10 ML/d, with a salinity of 3 ppt adjacent to the existing MIC and Verve Energy outfalls. As the discharge temperature is close to ambient and there are not anticipated to be significant levels of contaminants in the discharge water, the issues requiring investigation and the approach are as follows:

1. The salinity difference between the discharge water and ambient sea water: investigated using near-field modelling
2. The potential of the discharge to combine with or affect adjacent discharges: investigated using far-field modelling.

3. Concentrations of potential toxicants after initial dilution: investigated using near-field modelling.

To predict the likely mixing and extent of the brackish water discharge, Oceanica (on behalf of Griffin Energy) commissioned Asia Pacific Applied Science Associates (APASA) to undertake a detailed modelling study. To undertake this work, Griffin purchased the right to use a model previously set-up and validated for an adjacent Water Corporation investigation.

The full APASA modelling report is included as Appendix C. This report includes:

- the process of model validation against Water Corporation met-ocean data;
- the application of a US Environmental Protection Agency endorsed near-field model (UM3) to determine the initial dilution of the discharge based on the proposed diffuser configuration; and
- the BFHYDRO predictions of time-varying far-field salinity for summer and autumn conditions.

Initial dilution

The initial dilution or near-field modelling was undertaken for 10 ML/d of 3 ppt discharge into unstratified ambient sea water with salinity of 36 ppt (based on profile measurements collected in the region by Oceanica for Griffin and Water Corporation). The lowest 5th percentile of measured currents (0.008 m/s) was used as the ambient current as this was the worst case.

It was found that due to the high exit velocity (1.96 m/s through each port); the plume was initially driven by its own momentum horizontally from the outlet. As the plume velocity decreased (within 1 m of the port opening), the buoyancy of the plume caused it to rise rapidly towards the water surface, while continually entraining and mixing with the receiving water.

The APASA initial dilution model found that average dilution into a current of 0.008 m/s would be approximately 1:190 within 6 m from the diffuser pipe, while the CEE initial dilution modelling into still water reported an average initial dilution of 1:150 above the diffuser.

A 1:150 – 1:190 fold dilution of 3 ppt discharge in ambient waters of 36 ppt equates to a salinity of 35.8 ppt on completion of initial dilution, or a difference of 0.2 ppt from ambient. As shown by the following section, the EPA High Ecological Protection guideline for salinity is 0.8 ppt and so it is easily met (EPA 2005). Any toxicants of concern will also be diluted by the same amount.

Far-field modelling

In advice given by the EPASU to the Water Corporation for an adjacent project, the EPASU expressed a concern that the proximity of the cooling water discharges in this region may result in interference between discharges. The potential for this was investigated with a validated far-field model (Appendix C).

The model results for the far-field simulations showed that once the jet and buoyancy phase had ceased, transport and dilution of the saline plume was primarily influenced by the wind-driven surface currents. For the sample summer conditions (February 2000), the saline plume was predicted to advect to the north for the majority of the time. Simulations using the sample autumn conditions (April 2000) yielded a similar outcome. However, there were several instances of relatively long-term (days) current reversals that were attributed to changes in prevailing wind direction.

Unlike initial dilution modelling, the far-field modelling also incorporates the effects of 'build-up' in calm periods or current reversals when the plume is doubled back on itself so that salinities may further decrease in these times.

The 50th percentile (median) salinity contours were generated for the summer and autumn current conditions (Figure 5.3). The results indicated that the area and extent of the 50th percentile salinities were very similar for both the summer and autumn conditions.

As found with the initial dilution modelling, the fresher plume is highly diluted by the time it reaches the surface above the diffuser and the median salinity is within the EPA's high protection requirements (0.8 ppt; Table 7.1). The scale of any influence on median salinity beyond a maximum of 0.4 ppt is of the order of 50 m and it is suggested that for management purposes, a 50 m LEPA zone be applied to the diffuser.

The modelling shows that there will not be any impact on the ability of operators of adjacent diffusers to meet their environmental requirements as there will not be any effect on the median salinity in the vicinity of the outfalls. Examination of time series plots of plume trajectories suggests that on occasions, there could be times when parcels of slightly lower salinity (~0.4 ppt) water are advected to adjacent outfalls. Such events will be very rare and would not trigger a non-compliance.

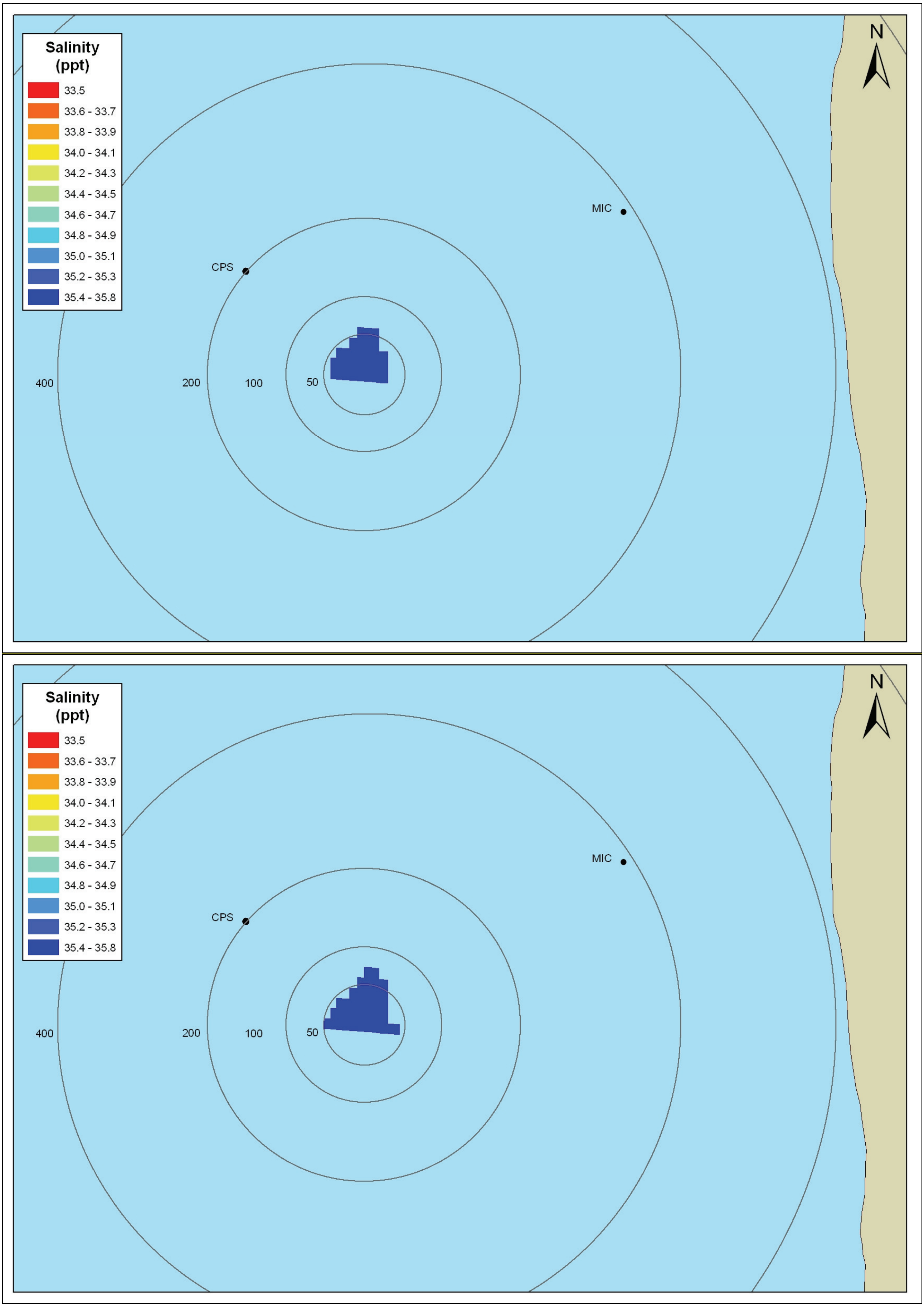


Figure 5.3 **Predicted 50th percentile salinity concentrations (for each grid cell), during February (top) and April (bottom) 2000 current conditions. Note the circular bands show the radii from centre of diffuser in meters.**

6. Draft Saline Pipeline Marine Environmental Management Plan: Construction

6.1. Project Description

For the project description please see Section 1.2.

6.2. This Document

This draft construction management plan has been prepared to be submitted with the PER for this proposal and is intended as a proponent commitment for this project. It will be finalised in consultation with the DEC when the construction method is confirmed.

This management plan was prepared according to the draft guidelines for preparing environmental management plans (DoE 2006).

6.3. Potential Impacts

Potential issues identified as requiring management during marine construction were;

- Disturbance of the beach and foredune;
- Disturbance of the dune blow-out area (vegetation and aboriginal heritage);
- Direct loss of habitat due to placement of the outlet pipe and any supports;
- Impacts on water quality (Aesthetics/visual amenity and risk of spills or contamination from marine plant); and
- Public safety.

Issues identified as not requiring management were:

- Smothering of marine flora and fauna with sediment from marine construction; and,
- Reduction of light to the seafloor due to suspended sediment from marine construction.

The above two issues were found not to require management for the following reasons:

- The shoreline excavation period is very short, with pipeline installation expected to take the order of 2-3 weeks.
- The entire construction period, from groyne construction to removal is expected to be complete within 2 months and construction will not be taking place 24 hours a day 7 days a week.
- The volume of material excavated underwater is likely to be relatively small (order of 5,000 - 10,000 m^3).
- The coast line is exposed to regular wind events which will act to rapidly disperse any turbidity.
- Field surveys and observations have shown that the local waters are often turbid inshore due to wave action.
- There are no seagrass meadows close to shore, where the excavation will occur.
- The fact that the coastline is high energy and observation of beach grain size, means that there is unlikely to be a significant fraction of fines in the material excavated.
- There should not be a substantial period of post-construction turbidity as any major event, such as the passage of a storm front will rapidly remove and disperse any fines and re-sort the material in the area.
- The local seagrass species are known to survive major shading events of substantially greater duration than the period of turbidity generation for this project.

6.4. Environmental Objectives

- To maintain the biodiversity within the geographical area and to ensure that any unavoidable impacts upon marine flora and fauna are minimised.
- To minimise adverse social impacts.

6.5. Performance Indicators/Criteria

Performance will be demonstrated by compliance with the monitoring listed in Section 6.7.

6.6. Implementation Strategy

Monitoring under this management plan shall be the responsibility of Griffin Energy. This work may be delegated to a nominated party to undertake the monitoring on behalf of Griffin. Prior to commencing, the party undertaking this monitoring shall provide a Job Safety Analysis (JSA) to the approval of Griffin.

6.7. Monitoring and Management

6.7.1. Disturbance of the beach and foredune

Table 6.1 Monitoring disturbance of the beach and foredune

IMPACT/ISSUES	GRIFFIN COMMITMENT	CONTROL	MONITORING	RESPONSIBILITY
• Excavation of the beach from the primary foredune to beyond the surf zone. • The pipeline will be buried from the rear of the foredune, across the beach and surf zone and emerge on the seabed at about 4 m below mean sea level (MSL). This will require excavation work and a temporary groyne to be constructed.	Rehabilitation of the beach after construction.	• Sand excavated above high water will be stockpiled and protected from wind erosion. • The beach will be accessed via the designated access road. • All temporary facilities will be completely removed from site on completion unless the material is required elsewhere on-site. • The cleanliness of the beach will be maintained during construction. Construction related debris and litter will be removed on a daily basis. • The trench across the beach above high water will be backfilled from the stockpile. • The beach profile will be restored to match the contours adjacent to the excavated region. • Prior to demobilisation, a final inspection for debris (including boulders, loose rock and litter) on the section of beach and surf zone impacted by construction activities should be undertaken and any such material removed. • Contact details for the construction supervisor will be prominent on site so that community members may report any issues immediately.	• Regular visual checks and photographs taken from fixed points of the temporary works, earthworks and stockpile during the construction period. • Regular visual checks to ensure that the beach is kept clean and waste disposal is appropriate. • Photographs will be taken from fixed points of the beach before and after construction to provide reference material and record of the condition of the beach. • Visual check that the final contours of the restored beach match the natural contours of the adjacent beach. • Visual check that the temporary works have been completely removed. • Visual check that the beach is free of debris (including rocks) and litter prior to project completion.	Griffin. Implementation by the Contractor.

6.7.2. Disturbance of the dune blow-out area (vegetation)

Table 6.2 Monitoring disturbance of the dune blow-out area (vegetation)

IMPACT/ISSUES	GRIFFIN COMMITMENT	CONTROL	MONITORING	RESPONSIBILITY
• Location of construction site in the dune blow-out area. • Excavation of degraded foredune. • Wind erosion of foredune and spoil during construction.	Minimisation of construction impacts on dune erosion. Stabilisation and revegetation of the foredune area and areas impacted by construction	• Following completion of excavation, stabilise banks to avoid erosion or slump of adjacent dunes. • On completion of works, the foredune excavation will be reinstated. This is to be effected by earthworks to re-establish the foredune barrier to a height and contouring equivalent to adjacent undisturbed sections of foredune. Physical breaches in the foredune barrier are to be closed to reduce the risk of new blowout formations and reduce access. • Short-term erosion protection by brushing with local species. The seaward face of the foredune is to be brushed with branches and vegetative material from a locally occurring species. Peppermint *Agonis flexuosa* would be a suitable species. Brushing is to adequately cover exposed sand faces. • The remaining foredune area is to be top dressed with locally sourced, weed free mulch and hydromulched with native seed. • Long-term erosion protection by revegetation with suitable local indigenous species. • Restrict unauthorised public access to dunes during period of contract. • Restrict traverse of dunes by workforce outside approved work area.	• Review the state of these stabilised faces during the construction period to determine if additional action is required. • Records of inspection and any corrective action taken (including photographic records). • A file will be maintained on site containing all records of environmental inspection, photographs, incidents and instruction sheets.	Revegetation by Griffin. Dune restoration, erosion protection and hydromulching by the contractor.

6.7.3. Disturbance of the dune blow-out area (aboriginal heritage)

Table 6.3 Monitoring disturbance of the dune blow-out area (aboriginal heritage)

IMPACT/ISSUES	GRIFFIN COMMITMENT	CONTROL	MONITORING	RESPONSIBILITY
• Dune systems in South Western, Western Australia are known to have been used for aboriginal burials. • The excavation works have the potential to impact on subsurface artefactual and/or skeletal material.	Heritage Survey and consultation with local Aboriginal groups Obtain advice from the Department of Indigenous Affairs on work practices		An Aboriginal Liaison Consultant will be involved in coordinating monitoring during earthworks.	Griffin. Plan to be implemented by the Contractor

6.7.4. Direct loss of habitat due to placement of the outlet pipe and any supports

Table 6.4 Monitoring direct loss of habitat due to placement of the outlet pipe and any supports

IMPACT/ISSUES	GRIFFIN COMMITMENT	CONTROL	MONITORING	RESPONSIBILITY
• The pipeline will be buried from the rear of the foredune, across the beach and surfzone and emerge on the seabed at about 4 m below mean sea level (MSL). This will require excavation work and a temporary groyne to be constructed. • The construction activity will impact a narrow strip of seabed extending offshore to a depth of about 10 m below MSL. • The work will result in unavoidable loss of 0.207 ha benthic primary producer habitat. • There may be a turbidity plume associated with the works. • Construction vessels will operate in the region.	Minimise impacts of marine construction on marine benthic primary producer habitats.	• The outlet alignment has been selected to minimise loss of benthic primary producer habitat. • Construction impacts will be limited to the minimum width possible to complete the installation of the outlet. • Seagrass was generally not found within 600 m of the shore and the local seagrass species are known to survive major shading events of substantially greater duration (months) than the period of turbidity generation for this project (2-3 weeks). • There are no habitats sensitive to turbidity or smothering within the immediate area (~600 m) of the excavation. The nearshore area is naturally energetic and turbidity due to resuspension of sediments by wave action is common. The key issue raised by turbidity is the aesthetic impact (refer below). • Turbidity impacts associated with the pipe installation will be small scale and of short duration (2-3 weeks). Impacts on marine flora and fauna from reduced light due to turbidity will be negligible over this timescale. • Blasting will not be required.	Underwater video footage of the pipeline route will be recorded before, immediately after and 12 months after construction to record the scale of impact of the pipeline construction and recovery. The results will be reported to DEC.	Griffin. To be implemented by the Contractor

6.7.5. Water Quality (aesthetics/visual amenity/spills)

Table 6.5 Monitoring water quality (aesthetics/visual amenity/spills)

IMPACT/ISSUES	GRIFFIN COMMITMENT	CONTROL	MONITORING	RESPONSIBILITY
There is likely to be a visible turbidity plume associated with the process of excavating across the beach. Construction plant on the beach and at sea will be fuelled with hydrocarbons.	Minimise impacts of marine construction on marine water quality. Ensure no hydrocarbon spills.	• Construction impacts will be limited to the minimum width and volumes possible to complete the installation of the outlet. • The nearshore area is naturally energetic and turbidity due to resuspension of sediments by wave action is common. • Turbidity impacts associated with the pipe installation will be small scale and of short duration (2-3 weeks). Silt curtains are not practicable in high energy environments such as this as the wave and long-shore current forces will rapidly destroy the function of the curtains. • There will be no fuel transfers on the beach or in the ocean. • Contact details for the construction supervisor will be prominent on site so that community members may report any issues immediately.	• Visual assessment will be carried out around midday when works are being undertaken as per the example field observation sheet in Table 6.6. • Site staff will maintain a complaints/community comments register. • Photography from fixed points during construction of temporary works. • Reporting of visual monitoring results and any community complaints/comments.	Griffin. Implementation by the Contractor.

Table 6.6 Example field observation sheet

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Date							
Time							
Weather Conditions (Swell, wind, cloud cover etc)							
Spatial Extent of Plume							
Direction of Plume							
Photographs taken of construction areas							
Photographs taken of turbid plume (if							

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
present)							
Visual check for waste undertaken and waste removed							
Other							

6.7.6. Public Safety

Table 6.7 Monitoring public safety

IMPACT/ISSUES	GRIFFIN COMMITMENT	CONTROL	MONITORING	RESPONSIBILITY
Construction will result in a short-term requirement for access to be restricted to dune blow-out area and beach in front of dune blow-out area. Marine plant may cause temporary navigation hazards. Awareness of personnel working on site of the environmental and safety issues and the procedures to be followed will be a key factor in reducing environmental impacts and safety risks. Behaviour on site may impact on safety and the environment.	Restriction of public access to the construction site (beach and dune blow-out area). Marine equipment to comply with Department of Planning and Infrastructure regulations. Public notification of any restrictions. Distribution of general information regarding construction activities.	• Public access to the site will be prohibited and managed by temporary fencing or other constraints as required. • The public will be informed of construction activities and timing of significant events through local media. A "Notice to Mariners" will be published by the contractor regarding the marine works. • An environmental and safety induction program will be prepared by the Contractor in consultation with Griffin prior to commencement of construction. • Contact details for the construction supervisor will be prominent on site so that community members may report any issues immediately. • Griffin's Occupational Safety and Health Procedures which include audit procedures will be enforced by the Contractor. • All incidents will be managed in accordance with Griffin's Incident Management Procedure.	• Observe and report all incidents of unauthorised access. • Personnel who have not been formally inducted will not be allowed to work on site. • Regular safety inspections and audits are a requirement of the Contract and will be undertaken • All incidents and resultant actions are recorded. • Site staff will maintain a complaints and community comments register. • Reporting of visual monitoring results and any community complaints or comments to the DEC within annual report.	Griffin. To be implemented by the Contractor.

6.8. Contingencies

Contingencies have been listed in the tables above.

6.9. Auditing

Details on the implementation of this plan throughout construction will be included in the annual report to be submitted to the DEC.

6.10. Review and Revision

This plan has been prepared for the construction phase of the project. A separate operations plan follows in Section 7. This plan will be updated after a Ministerial Statement is issued and prior to construction commencing on the project.

6.11. Reporting

Griffin Energy will report against the performance of this plan in an annual performance and compliance report to be submitted to the DEC.

6.12. Key Management Actions

Kay management actions from Section 6.7 are listed in Table 6.8.

Table 6.8 Construction EMP Key Management Actions

Key Management Action	Objectives/ Targets	DEC reporting/Evidence	Status
Monitor turbidity from the shore	To maintain visual amenity. Visual and photographic assessment to take place daily. Contact details for community complaints to be placed in a prominent position on site.	Annual report	
Minimise impact of marine construction on marine benthic primary producer habitats	Underwater video will be taken of the pipeline route prior to, immediately after and 12 months after the completion of construction.	Annual report	
Minimise disturbance to beach and foredune	Visual checks and photos to be taken during construction.	Annual report	
Establish marine exclusion area.	A temporary marine exclusion area will be established with marine warning buoys installed in the ocean in the area surrounding marine construction.	Annual report	
Establish a beach exclusion area.	A temporary beach exclusion area will be established to prevent public access to the construction area.	Annual report	
Remove exclusion zones	At completion of construction all infrastructure and materials for exclusion areas will be removed.	Annual report	
Restore beach profile	Beach profile will be restored following completion of construction to be consistent with surrounding beach.	Annual report	
Rehabilitate beach	Disturbed beach areas will be rehabilitated.	Annual report	
Consult with Department of Indigenous Affairs	To not impact on subsurface artefactual and/or skeletal material	Annual report	

7. Draft Saline Pipeline Marine Environmental Management Plan: Operations

7.1. Project Description

For the project description please see Section 1.2.

7.2. This Document

This draft operations management plan has been prepared to be submitted with the PER for this proposal and is intended as a proponent commitment for this project. The plan will be finalised in consultation with the DEC prior to the commencement of discharge.

This management plan was prepared according to the draft guidelines for preparing environmental management plans (DoE 2006).

7.3. Potential Impacts

Potential marine impacts identified as requiring management during operations were;

- Water quality
- Sediment quality

7.4. Environmental Objectives

The environmental objective is to maintain the ecological values of the surrounding environment.

7.5. Performance Indicators/Criteria

Criteria used to assess environmental performance during operations are listed in Section 7.7.2

Performance will be demonstrated by compliance with the key management actions listed in Section 7.13.

7.6. Implementation Strategy

Monitoring under this management plan shall be the responsibility of Griffin. This work may be delegated to a nominated party to undertake the monitoring on behalf of Griffin. Prior to commencing, the party undertaking this monitoring shall provide a Job Safety Analysis (JSA) to the approval of Griffin.

7.7. Environmental Quality Management Framework

Griffin Energy will report the results of their environmental monitoring programme against background data, relevant guidelines (e.g. the ANZECC/ARMCANZ (2000) Guidelines for Fresh and Marine Water Quality) and/or limits set in the Licence and/or Ministerial Statement to be issued by the Department of Environment and Conservation.

There are currently no Environmental Values (EVs)[1], Environmental Quality Objectives (EQOs)[2], Environmental Quality Guidelines (EQGs)[3] or Environmental Quality Standards (EQSs)[4] identified, or zones/boundaries of application established, for the coastal waters in the vicinity of the proposed Griffin Energy ocean outfall. Based on the precedents set for Perth's Coastal Waters it is generally accepted that, apart for areas specifically excluded, the waters in this region are classified as a High Ecological Protection Area (HEPA).

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[1] An Environmental Value has been defined as a particular value or use of the environment that is important for a healthy ecosystem or for public benefit, welfare, safety or health, and which requires protection from the effects of pollution, waste discharges and deposits.

[2] An Environmental Quality Objective is a specific management goal for a designated area of the environment.

[3] Environmental Quality Guidelines are quantitative, investigative triggers which signify a low risk of an environmental effect if they are met, and trigger further investigations if an exceedance occurs.

[4] Environmental Quality Standards are management triggers based on multiple lines of evidence, which if exceeded signify that the Environmental Quality Objective is not being met and that a management response is required.

It is acknowledged that in practice it will not be possible to protect all EVs everywhere if other uses of the environment which provide benefits to the community are to be accommodated (e.g. marinas, wastewater disposal) (Environmental Protection Authority 2000). Therefore it may be necessary to designate Environmental Quality Management Areas where some or all of the EVs will not be protected. The intent is that these areas where lower levels of protection have been set would be managed to ensure that there are no detectable effects outside of their boundaries (Environmental Protection Authority 2000).

The areas in the immediate vicinity of ocean outfalls are generally designated as Low Ecological Protection Areas (LEPAs). For these areas, the EQGs for water and sediment quality which have generally been considered applicable are the ANZECC/ARMCANZ (2000) 80% species protection guideline trigger values for toxicants identified as having the potential to adversely bioaccumulate or biomagnify (e.g. Government of Western Australia 2004, Environmental Protection Authority 2005). The areas where lower levels of protection have been designated are expected to be managed such that the criteria for the adjacent level of protection are met at the defined boundaries (Environmental Protection Authority 2000).

In this case, although the environmental risk posed by the decreased salinity is negligible, for management purposes it is recommended that a LEPA area be established immediately around the Griffin Energy outfall and that the HEPA criteria are applied at the LEPA boundary.

7.7.1. Proposed management zones

It is proposed that a Low Ecological Protection Area be established within 50 m of the diffuser structure, with High Ecological Protection criteria to be met at the boundary (Figure 7.1). There is no requirement for any social use restrictions or seafood harvesting restrictions. The scale of the LEPA is such that it is easily monitored and defined and yet is small relative to the open water.

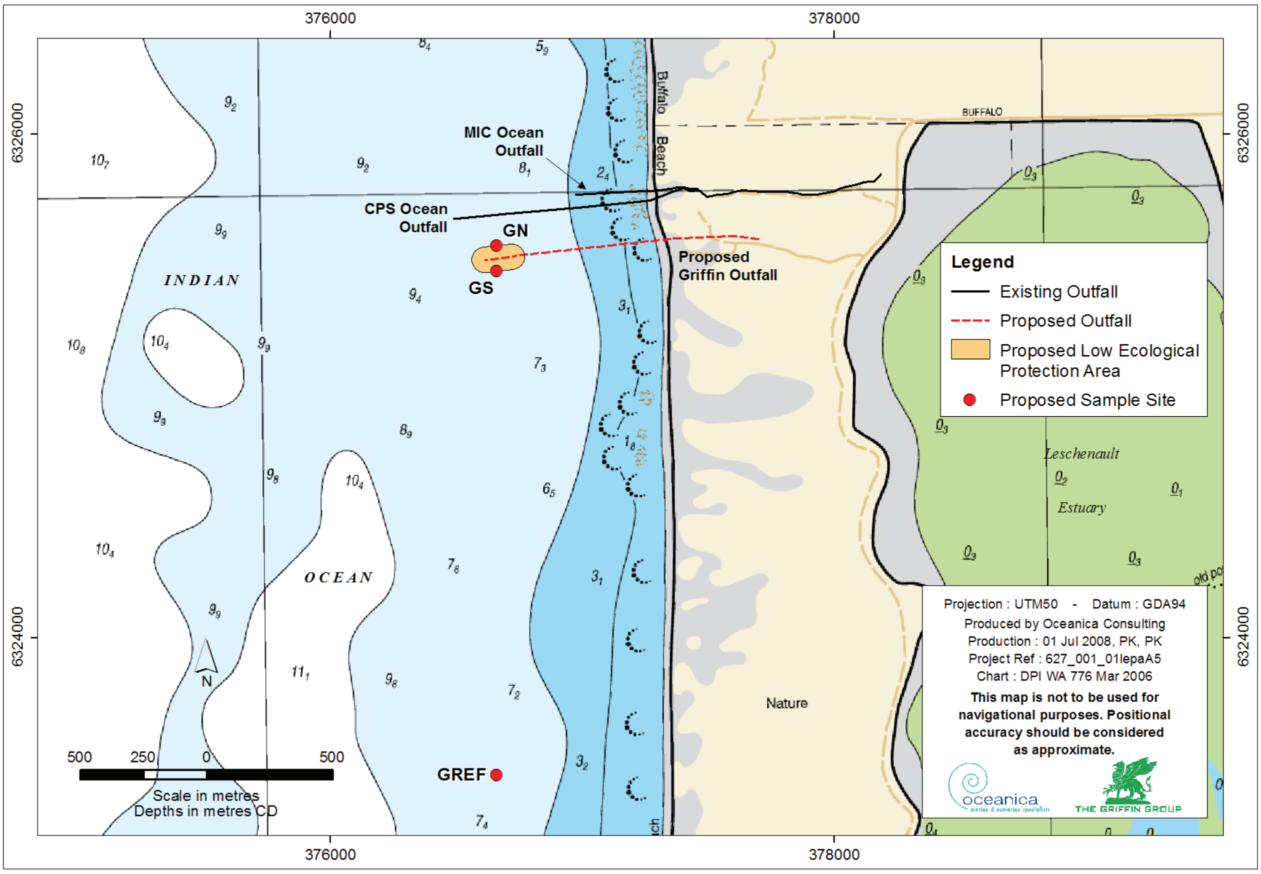

Figure 7.1 Proposed management zones and monitoring sites

7.7.2. Proposed Environmental Quality Guidelines and Standards

Physical and chemical

In the absence of any identified EQGs or EQSs, the State Environmental (Cockburn Sound) Policy (Government of Western Australia, 2005) will be used where applicable, these were developed within the framework of the ANZECC/ARMCANZ (2000) guidelines. It is important to note that the ANZECC/ARMCANZ (2000) guidelines emphasize that exceedances of trigger values should be regarded as an "early warning" mechanism. The guidelines do not demarcate a threshold for adverse environmental effects, rather they are intended as (conservative) values which, if exceeded, should "trigger" further investigation to assess whether a problem exists or not. The trigger values are not intended as a means of assessing "compliance".

The Environmental Quality Criteria Reference Document for Cockburn Sound (EPA 2005) sets EQGs for the high and moderate protection areas of Cockburn Sound. The EQG's for relevant parameters are shown in Table 7.1. The use of these guidelines requires measurements to be taken at both the potential impact sites and reference sites. The EQG for temperature and salinity were derived from reference sites in Cockburn Sound according to the recommended approach in ANZECC & ARMCANZ (2000) (i.e. 20^{th} and/or 80^{th} percentiles of reference distribution for high ecological protection and 5^{th} and/or 95^{th} percentile for moderate ecological protection).

Table 7.1 Environmental quality criteria for protecting the marine ecosystem from the effects of physical and chemical stressors

Environmental Quality Indicators	Environmental Quality Guidelines (High Protection)	Environmental Quality Guidelines (Moderate Protection)
Dissolved Oxygen	90%	80%
Temperature		
Summer	0.8	1.6
Autumn	1.9	3.1
Winter	0.5	1.5
Spring	1.2	3.0
Salinity	±0.8	±1.5
pH	±0.2	±0.2

Contaminants in sediments

The ANZECC/ARMCANZ (2000) recommended sediment guideline values are presented as low and high "interim sediment quality guideline" (ISQG) values[5]. ISQG values have not been developed for some metals (e.g. aluminium, manganese, titanium) because they are generally considered to have low toxicity in marine sediments or due to the lack of toxicity data (e.g. cobalt, vanadium). EPA (2005) contains environmental quality criteria for protecting the marine ecosystem from the effects of toxicants in sediments based on ANZECC/ARMCANZ (2000) and these can be seen in Table 7.2 below. The median sediment total contaminant concentration (analysed using a strong acid extraction) from a defined sampling area should not exceed the environmental quality guideline value for high, moderate and low ecological protection areas. The total contaminant concentration at individual sample sites should not exceed the environmental quality guideline re-sampling trigger.

Table 7.2 Guidelines for metal concentrations in sediment

Metal	ISQG-Low (Trigger Value) ($mgkg^{-1}$ dry wt)	ISQG-High (Re-sampling Trigger) ($mgkg^{-1}$ dry wt)
Antimony	2	25
Arsenic	20	70

[5] [5]The low and high descriptors correspond to the effects range-low and –medium as used in the NOAA listings (Long *et al.* 1995). These values are considered as 'trigger' values for all protection zones (i.e. low, medium and high) and as a 're-sampling trigger' respectively in the Environmental Protection Authority's *Environmental Quality Criteria Reference Document for Cockburn Sound (2003-2004)* (EPA 2005).

Metal	ISQG-Low (Trigger Value) (mgkg^{-1} dry wt)	ISQG-High (Re-sampling Trigger) (mgkg^{-1} dry wt)
Cadmium	1.5	10
Chromium	80	370
Copper	65	270
Lead	50	220
Mercury	0.15	1
Nickel	21	52
Silver	1	37
Zinc	200	410

Contaminants in mussels

The Environmental Quality Criteria Reference Document for Cockburn Sound (2003–2004) (Environmental Protection Authority 2005) recommends that *"The median tissue concentration of chemicals that can adversely bioaccumulate or biomagnify should not exceed the 80th-percentile of tissue concentrations from a suitable reference site"*. To assess the potential effects of bioaccumulating toxicants associated with the saline water discharge, the median tissue concentrations of cadmium and mercury (i.e. the bioaccumulating metals) in mussels deployed at sites located at the edge of the mixing zone, should be compared with the 80th-percentile of tissue concentrations of mussels deployed at the reference sites.

Standard 1.4.1 of the Australia New Zealand Food Standards Code (Commonwealth of Australia 2006) identifies 'Maximum Levels' for specified metal contaminants in nominated foods. A Maximum Level has been established "only where is serves an effective risk management function and only for those foods which provide a significant contribution to the total dietary exposure" (Commonwealth of Australia 2006). 'Generally Expected Levels' have also been introduced for certain metal contaminants in food, where the safety assessment indicates a low level of risk to the consumer and where adequate data were available—note that Generally Expected Levels are not legally enforceable. Table 7.3 lists the Maximum Levels and Generally Expected Levels for metal contaminants in molluscs.

Table 7.3 Australia New Zealand Food Standards Code Maximum Levels and Generally Expected Levels for metal contaminants in molluscs

Metal	Maximum Level (mg kg^{-1})	Generally Expected Level (mg kg^{-1}) (1)
Cadmium	2	-
Copper	-	30
Lead	2	-
Mercury	0.5 (2)	-
Selenium	-	1
Zinc	-	290 (3)

Note: 1. 90th-percentile.
2. Mean level of mercury in the prescribed number of samples units.
3. Generally Expected Level specifically refers to oysters.

Toxicants in water

The ANZECC/ARMCANZ (2000) guideline trigger levels for toxicants in marine waters to achieve various levels of ecosystem protection are shown in Table 7.4. Trigger values have been defined for four different levels of protection: 99%, 95%, 90% and 80%. The protection level signifies the (statistically inferred) percentage of species expected to be protected. Reliable national guidelines are presently unavailable for many contaminants (due to lack of toxicity data from which to derive guidelines), and for some of these contaminants ANZECC/ARMCANZ (2000) offers instead 'Low Reliability Values' (LRVs) that were derived using conservative assessment factors—with the caveat that LRVs not be used as default guidelines, but as indicative working levels until more data are available to derive a reliable guideline.

Table 7.4 ANZECC/ARMCANZ Guidelines for toxicants in marine waters

Parameter	ANZECC/ARMCANZ (2000) Guidelines (mgL^{-1}) Level of protection (% Species)				
	99%	95%	90%	80%	LRV [1]
Metallics					
Aluminium	ID [2]	ID	ID	ID	0.0005
Calcium	n.d. [3]	n.d.	n.d.	n.d.	n.d.
Cadmium	0.0007	0.0055	0.014	0.036	–
Chromium	0.0077 (Cr III) 0.00014 (Cr VI)	0.0274 (Cr III) 0.004 (Cr VI)	0.0486 (Cr III) 0.020 (Cr VI)	0.0906 (Cr III) 0.085 (Cr VI)	–
Copper	0.0003	0.0013	0.0033	0.008	–
Iron	ID	ID	ID	ID	0.3
Mercury	0.0001	0.0004	0.0007	0.0014	–
Magnesium	n.d.	n.d.	n.d.	n.d.	n.d.
Manganese	ID	ID	ID	ID	n.d.
Sodium	n.d.	n.d.	n.d.	n.d.	n.d.
Nickel	0.007	0.070	0.200	0.560	–
Lead	0.0022	0.0044	0.0066	0.012	–
Selenium	ID	ID	ID	ID	0.003 (Total Se)
Titanium	n.d.	n.d.	n.d.	n.d.	n.d.
Vanadium	0.050	0.100	0.160	0.280	–
Zinc	0.007	0.015	0.023	0.043	–
Non-metallics					
Chloride	n.d.	n.d.	n.d.	n.d.	n.d.
Nutrients					
Ammonium	0.500	0.910	1.200	1.700	-
Nitrate	ID	ID	ID	ID	0.7
Total Phosphorus	n.d.	n.d.	n.d.	n.d.	n.d.
Other					
Sulphate	n.d.	n.d.	n.d.	n.d.	n.d.
Calcium Carbonate, $CaCO_3$	n.d.	n.d.	n.d.	n.d.	n.d.
Bicarbonate, HCO_3	n.d.	n.d.	n.d.	n.d.	n.d.

Note: 1. LRV = Low reliability value.
2. ID = Insufficient data to derive a reliable national trigger value.
3. n.d. = Not defined in ANZECC/ARMCANZ (2000).

7.8. Monitoring

7.8.1. Sites

Annual water, sediment and mussel sampling will be carried out in the marine pipeline discharge area in summer (December to March) at sites shown in Figure 7.1. The reference site is located to the south of the diffuser as the flow is predominantly northerly in summer (see Section 4.3.2). A drogue will be deployed on each sampling occasion to check the direction of flow. The parameters that shall be analysed are listed in Table 7.5. The programme has also been designed to be consistent with the adjacent Verve Energy saline pipeline discharge monitoring programme, which discharges very a similar wastewater and flows.

7.8.2. Parameters and media

Sedentary, filter-feeding shellfish (such as mussels), are often used as biomonitors. Filter-feeding shellfish process large amounts of water from a fixed location, and tend to accumulate a wide range of toxicants in their tissues. Shellfish therefore provide an integrated measure of the bioavailable portion of toxicants in the water column over time at a particular site, and consequently toxicant levels in shellfish provide a good proxy for overall levels in the surrounding water column. For many toxicants, shellfish are also good indicators of toxicant transfer between the water column and the food web.

Concentrations of potential contaminants in sediments can provide a useful time-integrated measurement of the distribution and accumulation of contaminants from marine outlets. These measurements give an indication of the accumulation and/or toxicological effects of contaminants in/on benthic organisms in the vicinity of the proposed Griffin ocean outlet.

Water quality monitoring may indicate if the diffuser is operating as intended and if the discharge water is of sufficient quality.

Marine monitoring will be carried out as outlined in Table 7.5

Table 7.5 Marine monitoring programme

Type of sampling/ Monitoring site	Site(s)	Frequency	Parameter
Mussel sampling	GN, GS and GREF	Every 3 years	Arsenic, cadmium, chromium, copper, lead, mercury, vanadium and zinc
Sediment sampling	GN, GS and GREF	Annually	Arsenic, cadmium, chromium, copper, lead, mercury, vanadium and zinc
Water sampling	GN, GS, GREF and over diffuser	Annually	Salinity, pH, temperature, total dissolved solids, total suspended solids, dissolved oxygen, arsenic, cadmium, chromium, copper, lead, mercury, vanadium and zinc

7.8.3. Discharge quality monitoring

Testing will take place on the discharge water as outlined in Table 7.6. Trigger values will be developed in consultation with DEC and if parameters exceed the trigger values, saline water may not be discharged to the marine environment until such time as the water quality parameters return to values below the trigger values.

Table 7.6 Discharge water monitoring programme

Monitoring site	Frequency	Parameter
Saline water discharge point to pipeline	Continuous – to be reported as weekly averages and annual total volume discharged	Discharge volume, turbidity, total dissolved solids, dissolved oxygen
	Weekly	pH, temperature, total suspended solids
	Monthly	Total petroleum hydrocarbons, total nitrogen, total phosphorus
	Quarterly	Sodium, potassium, calcium, magnesium, iron, aluminium, selenium, titanium, manganese, chloride, sulphate, bicarbonate, silica, arsenic, cadmium, chromium, cobalt, copper, lead mercury, nickel, vanadium and zinc

7.8.4. Methods

Mussels

Mussels of uniform size will be obtained from commercially cultured stocks. The use of a consistent size of mussel reduces any influence of mussel size on bioaccumulation of toxicants.

At each monitoring site, replicate mussel lines will be deployed. Mussels will be suspended in mesh baskets 2-3 m below the surface on each of the mussel lines at each site.

Mussels will be deployed for an approximate six-week period with mussels and mesh baskets cleaned after three weeks to prevent the accumulation of algal growth which could smother and kill the mussels. After the six week deployment period, the mussels will be retrieved and the number of live mussels recorded. The live mussels will be placed into sterile bags and kept on ice while in transit to the analytical laboratory.

Mussels from the same batch deployed on the mussel lines will be stored frozen prior to analysis to provide an indication of the initial toxicant load of the mussels. These will be the 'control' mussels.

Samples will be kept frozen until analysis. For analysis, samples will be thawed, the shells shucked and the soft tissue homogenised, and the samples freeze-dried and ground. The mussels will be analysed for the parameters shown in Table 7.5.

Sediment

The sediment sampling method is as recommended by the Cockburn Sound Manual of Standard Operating Procedures (EPA 2005). A composite sediment sample shall be obtained from five sub-samples taken from the corner points and centre of a 1 m x 1 m quadrat using a 5 cm diameter corer. The top 2 cm of each core shall be scraped into a single container, placed on ice and then stored frozen prior to analysis. Three replicate composite sediment samples shall be obtained from each of the sites.

Sediment samples will be kept on ice and then kept frozen prior to analysis, which will be undertaken by analytical laboratories according to NATA-accredited methods. Sample analysis will report against the lowest practical analytical limits from a NATA commercial laboratory, and where possible analytical limits will achieve the ANZECC/ARMCANZ (2000) sediment quality guidelines. Where concentrations are reported as less than this limit, the limits of reporting will be used in the calculations. Samples will be analysed for the parameters shown in Table 7.5.

Water

A YSI multimeter will be used to measure temperature, pH, salinity and dissolved oxygen throughout the water column *in situ* at the compliance reporting sites. A Secchi disk will also be used at each site as a measure of vertical visibility. The YSI will also be used in the plume tracking survey, whereby readings of temperature and salinity will be taken initially above the diffuser, then in the direction of surface drift (see Plume tracking below) approximately 20 m, 50 m and 100 m 'downstream' of the diffuser.

Depth integrated water samples will be taken for total suspended solids, metals and total dissolved solids. Water samples and filter papers used for total suspended solids will be kept on ice for transport to the laboratory.

Discharge water

Saline water will be sampled from the discharge point to the marine pipeline.

Griffin will undertake continuous, weekly, monthly and quarterly measurement of the discharge volume as per Table 7.6.

The contaminants of concern will be identified (based on measured concentrations) and their concentrations compared against the criteria in Table 7.4 after calculation of average initial dilution with seawater, with ambient current set as 0 (worst case) and initial dilution calculated using velocities measured during drogue tracking.

The results will be reported annually.

Plume tracking

At the commencement of the water quality survey, a surface drogue will be deployed over the operational outfall diffuser. The location of the drogue will be recorded at intervals during the water quality survey using a GPS. Surface drogue tracking provides an accurate estimate of mean surface current for subsequent initial dilution modelling. In addition, YSI temperature and salinity profiles will be recorded in along the line of the drogue path as a way of measuring the 'maximum' impact of any plume.

7.9. Action in event of exceedance

In the event that contaminant concentrations (or loads) exceed the thresholds established in the final Licence, the following actions will be implemented:

- The data, QA/QC processes and application of the guidelines will be checked for accuracy.
- If there is no apparent reason for the exceedence (e.g. operational malfunction or introduction of new contaminant streams), additional sampling for the contaminant of concern will be undertaken as soon as practicable.
- If subsequent sampling demonstrates that exceedence is beyond doubt, the DEC will be informed of the exceedance, the cause of the exceedance, any impacts and the next action to be taken as soon as practicable.
- If the exceedance is the result of normal operations, the protocols set out in ANZECC/ARMCANZ (2000) will be followed, whereby the ecotoxicity of the effluent following initial dilution will be established and the results communicated to the DEC. If there is found to be unacceptable levels of toxicity, the proponent will need to modify the operations to ensure that the approved objectives are met.
- If the exceedance is the result of operational malfunction, the proponent will immediately engage with the DEC to present the extent of the problem and the solutions that will be implemented to ensure that the environment is protected form harm.

7.10. Auditing

Griffin Energy will report against the implementation of this plan in an annual performance and compliance report to be submitted to the DEC.

7.11. Review and Revision

Review and revision will be undertaken as required to incorporate the results of monitoring and/or further knowledge that may be obtained in the future on best practice environmental management for discharge of saline water into marine environments. If any significant changes to this management plan take place, the document will be resubmitted to the DEC.

7.12. Reporting

Griffin Energy will report against the performance of this plan in an annual performance and compliance report to be submitted to the DEC.

7.13. Key Management Actions

Key management actions are summarised in Table 7.7 below. For further detail refer to Section 7.8.

Table 7.7 Operations EMP Key Management Actions

Key Management Action	Objectives/Targets	DEC reporting/Evidence	Status
Monitor mussels	To ensure there are no adverse impacts on the marine environment. See Table 7.5 for further details on monitoring.	Annual report	
Monitor water quality in the marine pipeline discharge area	To ensure there are no adverse impacts on the marine environment. See Table 7.5 for further details on monitoring.	Annual report	
Monitor sediments	To ensure there are no adverse impacts on the marine environment. See Table 7.5 for further details on monitoring.	Annual report	
Monitor quality of discharge water	To ensure there are no adverse impacts on the marine environment. See Table 7.6 for further details on monitoring.	Annual report	

8. Acknowledgements

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This report was prepared by Sarah Scott and Mark Bailey (Oceanica) and reviewed by Mark Bailey (Oceanica), Nicole Zago and Harry Ventris (Strategen). Philip Kindleysides (Oceanica) provided GIS support and produced figures and Selby Walsh (Oceanica) formatted the report.

9. References

ANZECC/ARMCANZ, 2000, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality,* Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, National Water Quality Management Strategy No.4.

Burton C, 2008, *Preliminary advice and recommendations for the minimisation of potential impacts of the SSDP upon marine mammals near Binningup, WA*, Draft Memo 2, Western Whale Research February 2008.

Cambridge M.L. & Kuo J., 1979. Two new species of seagrasses from Australia, *Posidonia sinuosa* and *P.angustifolia* (Posidoniaceae). *Aquatic Botany*, Vol. 6, pp. 307-328.

Collier, C.J., 2006. *Characterising responses of the seagrass Posidonia sinuosa to changes in light availability*. Ph.D. thesis, Faculty of Computing, Health and Science. Perth, Edith Cowan University

Commonwealth of Australia. 2006, *Australia New Zealand Food Standards Code* (Incorporating Amendments up to and including Amendment 87), Canberra, ACT.

D.A. Lord and Associates, 1995. *Geographe Bay Study 1993-1995 Summary Report*, Prepared by D.A. Lord and Associates, in association with Centre for Water Research and Department of Botany, University of Western Australia for Water Authority of Western Australia (Southwest Region), June 1995.

DAL, 2000, *Bunbury Proposed Ocean Outlet for Treated Wastewater – Public Environmental Review Document*, Prepared for Water Corporation of Western Australia, Report number 98/088/4, October 2000.

Department of Environmental Protection, 1996, *Southern Metropolitan Coastal Waters Study (1991-1994) Final Report*, Report 17, Perth, Western Australia, November 1996.

Department of Environment, 2005, *Compliance Monitoring and Reporting – Guidelines for Proponents, Preparing Environmental Management Plans,* Department of Environment, Government of Western Australia, May 2006.

Department of Marine and Harbours, 1990. *City of Bunbury Back Beaches Coastal Management Plan*. Technical Report DMH P1/90, October 1990.

Environmental Protection Authority, 2000, *Perth's Coastal Waters Environmental Values and Objectives, The Position of the EPA – A Working Document*.

Environmental Protection Authority, 2004, *Benthic Primary Producer Habitat Protection for Western Australia's Marine Environment*, Guidance Statement No. 29, June 2004.

Environmental Protection Authority, 2005, *Environmental Quality Criteria Reference Document for Cockburn Sound (2003-2004),* A supporting document to the State Environmental (Cockburn Sound) Policy 2005, Environmental Protection Authority, Report No. 20, January 2005.

Environmental Protection Authority, 2005b, *Manual of Standard Operating Procedures - For Environmental Monitoring against the Cockburn Sound Environmental Quality Criteria (2003 - 2004) - A supporting document to the State Environmental (Cockburn Sound) Policy 2005*, Prepared by Environmental Protection Authority, Report no. 21, Perth, Western Australia, January 2005.

Erftemeijer P. L. A, & Robin Lewis III R.R., 2006. Environmental impacts of dredging on seagrasses: A review. *Marine Pollution Bulletin*, Vol. 52, pp. 1553-1572.

Gordon, DM, Grey, KA, Chase, SC & Simpson, CJ, 1994, Changes to the structure and productivity of a *Posidonia sinuosa* meadow during and after imposed shading, *Aquatic Botany*, vol. 47, pp. 265–275.

Government of Western Australia, 2004, *State Water Quality Management Strategy No. 6, Implementation Framework for Western Australia for the Australian and New Zealand Guidelines for Fresh and Marine Water Quality and Water Quality Monitoring and Reporting (Guidelines Nos. 4 & 7: National Water Quality Management Strategy).*

Government of Western Australia, 2005, *State Environmental (Cockburn Sound) Policy 2005*, Western Australia, State Environmental Policy Series 01, 30p, January 2005.

Maunsell, 2008, *Literature Review – Fish Larval Studies,* Prepared for Water Corporation, Document No. 60039425.

Ralph P.J., Durako M.J., Enríquez S., Collier C.J. & Doblin M.A., 2007, Impact of light limitation on seagrasses. *Journal of Experimental Marine Biology and Ecology*, vol. 350, pp 176-193

University of Western Australia Marine Research Group, 2008, *Characterising the Marine Benthic Habitats of the Proposed Southern Seawater Desalination Plant (SSDP) Site: Interpretation from Underwater Towed Video & Map Interpolation,* Report to KBR, 17 January 2008

Water Corporation, 2000, *Bunbury: Proposed ocean outlet for treated wastewater, Public Environmental Review Document*, Water Corporation Leederville, October 2000, Report Number 98/088/4.

Water Corporation, 2008, *Southern Seawater Desalination Project – Environmental Impact Assessment, Public Environmental Review*, Water Corporation Leederville.

Westphalen, G., Collings, G., Wear, R., Fernandes, M., Bryars, S. and Cheshire, A. 2004 *A review of seagrass loss on the Adelaide metropolitan coastline*. ACWS Technical Report No. 2 prepared for the Adelaide Coastal Waters Study Steering Committee. South Australian Research and Development Institute (Aquatic Sciences) Publication No. RD04/0073, Adelaide.

Appendix A

Griffin Outfall Construction Concepts; Consulting Environmental Engineers

Oceanica Consulting Ltd

Griffin Outfall

Construction Concepts

February 2008

Consulting Environmental Engineers

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14 February 2008

Mark Bailey
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Dear Mark,

Construction Concepts for Griffin Outfall

Consulting Environmental Engineers (CEE) is pleased to provide this report on construction concepts for the proposed Griffin brine discharge outfall. The purpose of the report is to provide a concept design of the outfall as a basis for the environmental assessment of environmental impacts during construction and operations.

1. Scope of Work

Oceanica Consulting Pty Ltd requested CEE to provide initial dilution predictions and outfall construction concepts for a potential future outfall to discharge brackish water from the proposed Griffin power plant.

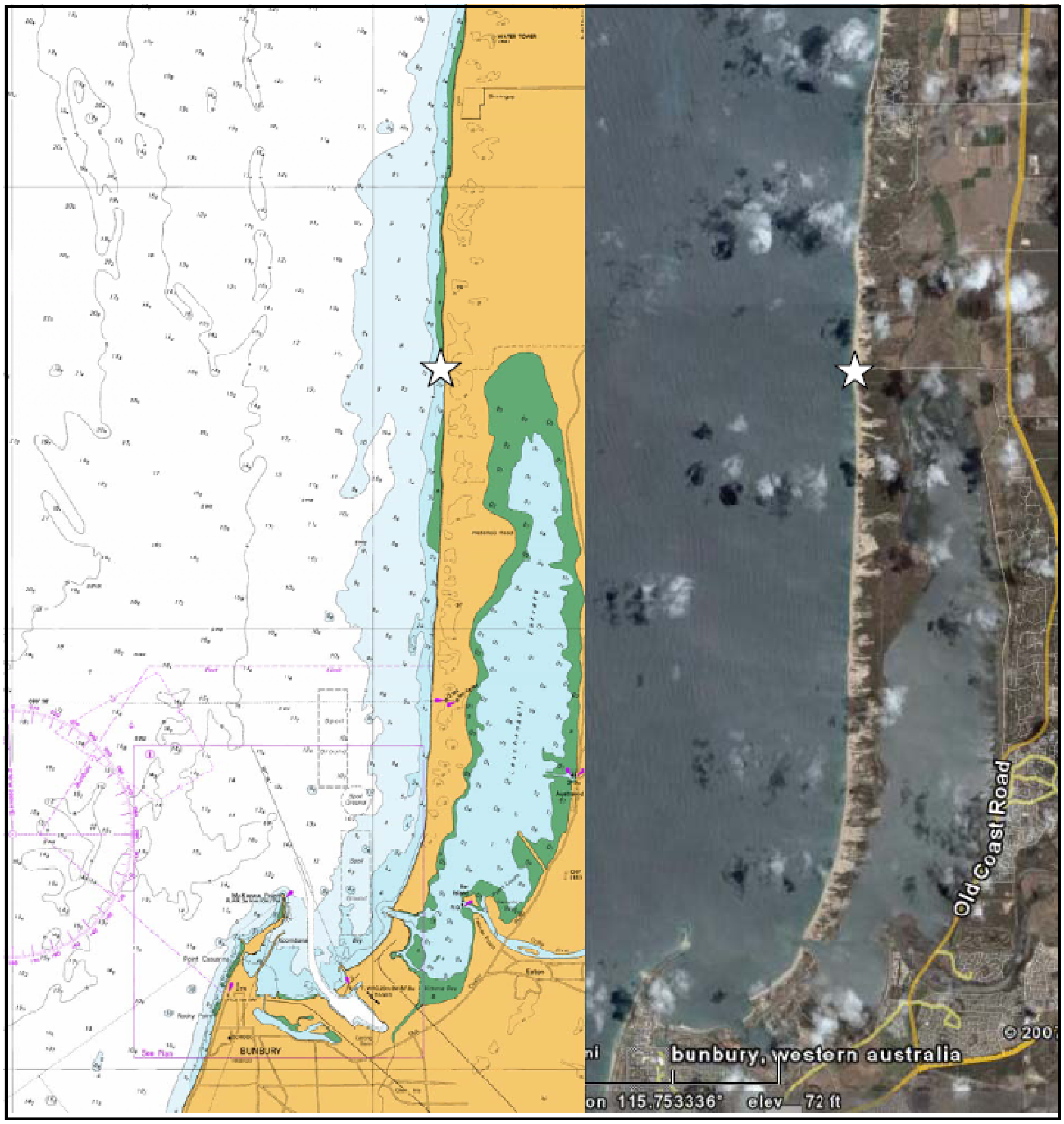
The outfall is to be located offshore from Kemerton, WA, adjacent to the existing outfalls serving the Kemerton industrial area (Kemerton outfall) and the Collie power station (Collie outfall). The location of the proposed outfall is shown in Figure 1.

As an initial stage of the project, it is necessary to develop a concept design of the outfall and associated diffuser to provide a basis for environmental assessment and planning applications. The scope of work for CEE was as follows:

- Assess pipe sizes and materials;
- Assess the likely outfall alignment and length, taking account of the influence of adjacent outfalls;
- Develop concept design for the outfall and diffuser; and
- Describe the likely construction procedure.

The concept design of the outfall and diffuser is an ultimate discharge of 10 ML/d, with a salinity of approximately 3,000 psu.

Figure 1. Location of Proposed Outfall Pipeline



Marine chart shown in left panel; aerial image shown in right panel
Star shows approximate location of proposed outfall
(Source: Oceanica Consulting)

2. Proposed Outfall Alignment

CEE was told that the pipeline from the Griffin power station to the coast would follow the easement for the Collie pipeline and thus approach the coast beside Buffalo Road.

Thus the new outfall would be in the same general area as the two existing outfalls. Figure 2 shows the offshore alignment of the two existing outfalls. Several possible alignments for the new outfall were considered:

- North of the two existing outfalls;
- Between the two existing outfalls; or
- South of the two existing outfalls.

Offshore, the bathymetry, seabed character and habitat are essentially the same for the three alignments. Thus the three alignments are equal in terms of offshore conditions.

On the land, there are several constraints:

- Minimise disturbance to coastal park;
- Minimise disturbance to foreshore dune;
- Minimise risk of damage to existing outfalls;
- Focus construction in dune blow out areas.

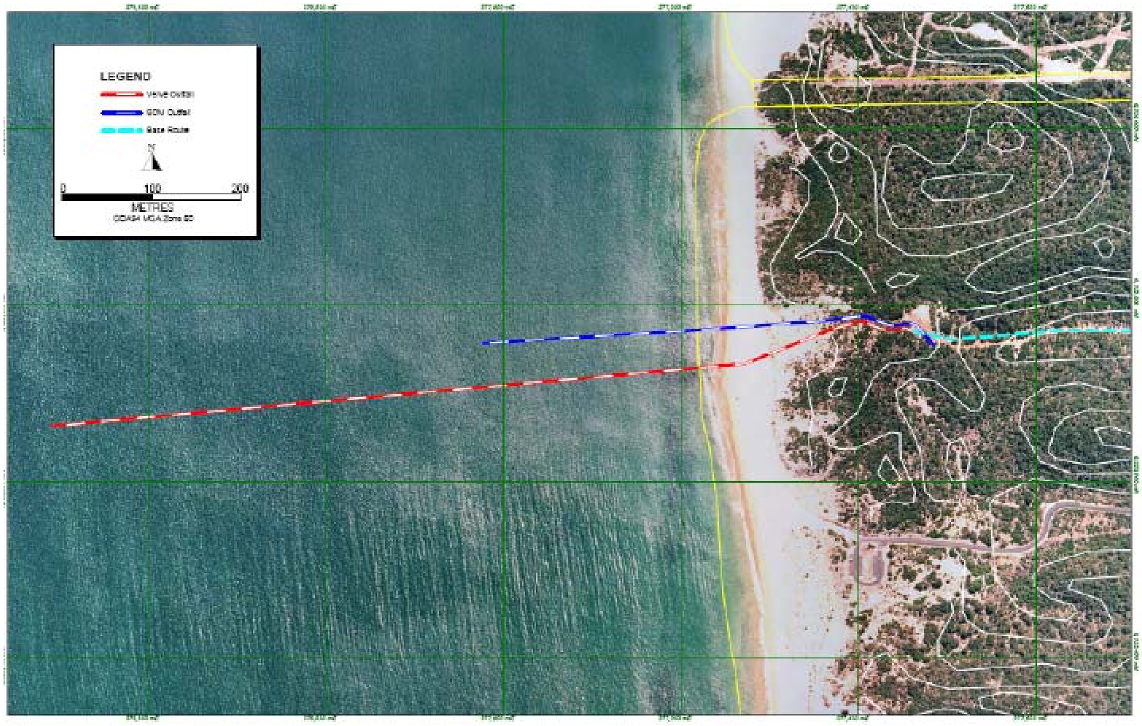
North Alignment
A north alignment would be either very close to the existing Kemerton outfall or require extensive excavation of a large dune or be well to the north of the Kemerton outfall, with all construction traffic travelling across the two outfalls. Neither of these alternatives is considered satisfactory and hence the north alignment is not favoured.

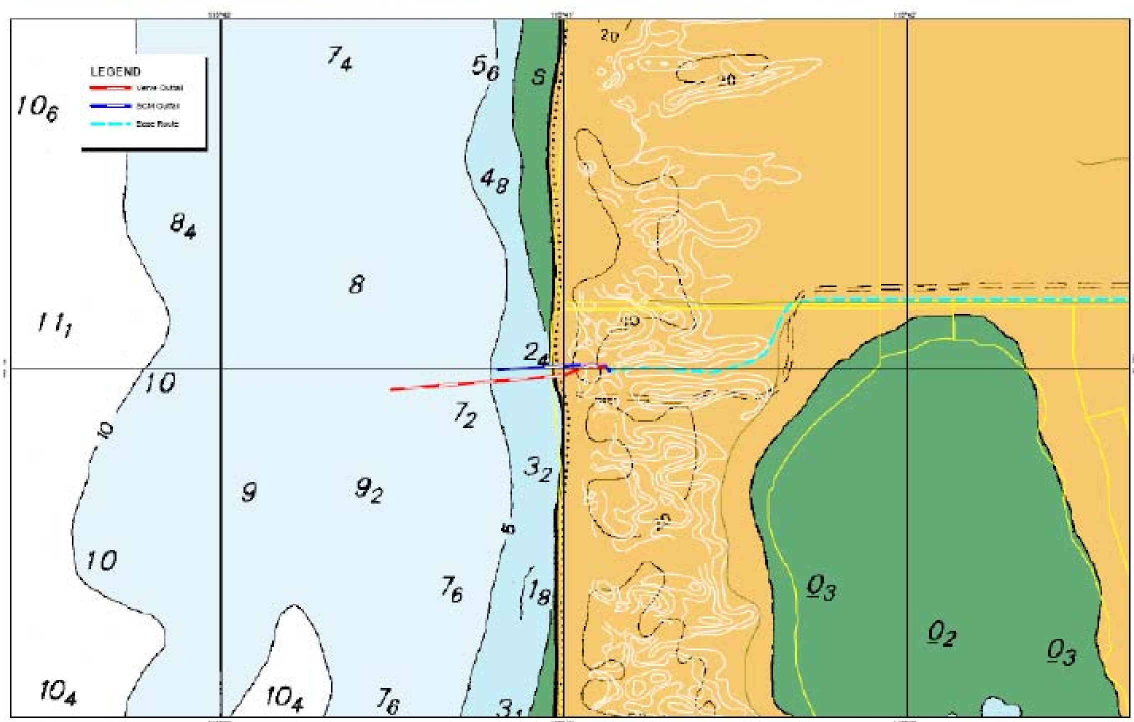
Central Alignment
The central alignment would use the existing dune blow out area in which the two existing outfalls are located. The two outfalls are very close together at the top of the dune and gradually separate with distance down the dune towards the ocean. All construction traffic would need to cross the Collie outfall. There would be a high risk of damaging an existing outfall when constructing a new outfall on the central alignment. Hence the central alignment is not favoured.

South Alignment
A south alignment would be closer to the beach access track and hence avoid the need for construction equipment to cross the existing outfalls. The south outfall would require either a new crossing over the top of the dune or drilling through the dune at a lower level. Inspection of topographic maps shows that there is a small blow out about 200 m south of the existing outfalls and this is considered an appropriate construction alignment with drilling through the dune to minimise disturbance to the top of the dune.

Conclusion
The south alignment is adopted for the concept design. This assumes there are no heritage, flora or fauna constraints for the south alignment, which must be confirmed before proceeding.

Figure 2 Alignment of Existing Kemerton and Collie Outfalls (Source: Oceanica Consulting)





3. Offshore Environmental Context

This section outlines the environment context based on available information.

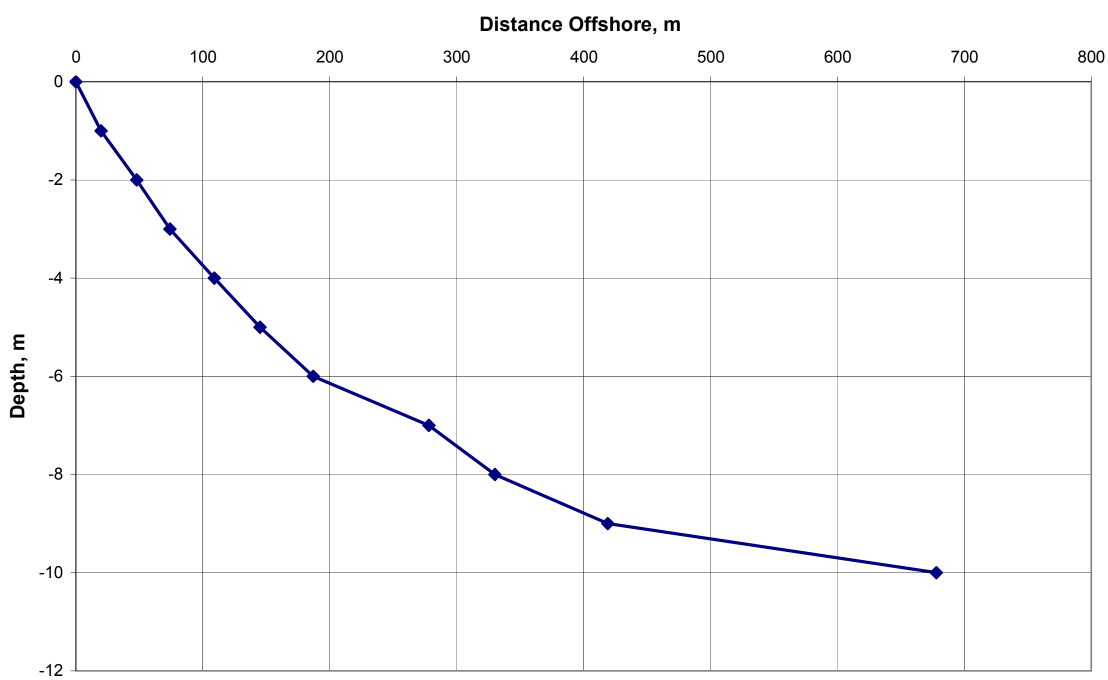
Coastal Foredune

On the proposed alignment, the top of the coastal foredune is at about 25 m above sea level and about 100 to 130 m inshore from the mean tide line. It would be feasible to drill horizontally through the dune at about 12 m above sea level from the bend in the access road behind the dunes.

Bathymetry

As shown in Figure 3, the offshore depth increases quickly to 4 m at about 110 m from shore, to 6 m at 190 m, to 8 m at 330 m and to 10 m at 680 m from shore. The depth continues to increase gradually with further distance offshore.

Figure 3. Bathymetry in Near Shore Area



Unlike the coastline north of Perth, at Binningup there are no offshore lines of reefs to protect the nearshore zone from weather and storm waves.

Seabed Character

Inspection of the shore during the construction of the Collie outfall showed a thin layer of weak rock at about low tide level on the beach.

Further offshore there is sand to a depth of about 7 m. Thereafter the seabed comprises a rough limestone pavement with pioneer invertebrates in the higher patches and sparse seagrass on less mobile sandy patches. There are occasional beds of deeper sand and seagrass growing in the sand.

Sub-surface Geology

No borehole logs are available from which to establish the local geology.

Sediment Movement

The net transport of sediment is to the north at about 20,000 m^3/year. There is substantially larger short-term longshore sediment transport north and south during storms.

Beach profiles show substantial local movement with the variation near the shore being typically 2 m over a year. These results show the outfall will need to be buried more than 2 m below the 'average' beach level to avoid being exposed during severe storms.

There is a regular seasonal change in the beach profile at the coast with accumulation of sand on the beach during the summer months and a sudden retreat in the winter storms. The vertical changes on the beach exceeded 1.5 m during the construction of the Collie outfall. The first autumn storm during the construction of the Bunbury outfall reduced the beach level by 1.8 m.

Tides

The tides at Bunbury are relatively small, with the spring tide range being only 0.6 m.

There are variations in the water level over several days along the Binningup-Bunbury coast of 0.1 to 0.3 m due to Shelf waves propagating southwards along the Continental Shelf.

Winter storms can cause sea level at the shore to rise by up to 1 m, due to the combination of inverse barometric pressure, wind set-up and wave set-up. Cyclone Alby caused a 1.2 m rise in sea level even though the cyclone was dissipating. These large variations in sea level will cause substantial erosion of the beach and foredune during winter.

Over the last 120 years there has been a steady rise in sea level which averaged about 1.2 mm/year. Climate scientists are currently predicting an increase in the rate of sea level rise, with the range being from 0.3 m to 1 m by 2100. It would be prudent to base the design on a rise in sea level of 1 m.

Currents

Information available on currents indicates that the tidal currents are weak – generally less than 0.05 m/s, and the wind is the main force producing local currents. Thus there are consistent currents to the north in summer (driven by the afternoon sea breeze) and bursts of currents to the south in winter storms.

There are regular periods with weak currents, and the diffuser should be designed to achieve a large initial dilution to minimise the environmental impacts of the discharge.

Wave Conditions

Table 1 shows the distribution of significant wave heights and periods for waves measured at Rottnest Island (in water depth of 48 m). It can be seen that over the year the median significant wave height is about 2.0 m and the median period is 8.8 sec.

During the summer sea breeze conditions, the significant wave height is mostly in the range of 1 to 2 m, with periods of 5 to 7 seconds.

Much larger waves occur during winter storms with several storms each year have a peak significant wave height of 4 to 6 m.

Table 1 Significant Wave Heights at Rottnest Island

	Spectral mean wave period T_8 (s)											
Significant Wave Height Hs (m) range	0-2	2-4	4-6	6-8	8-10	10-12	1 -14	14-16	16-18	>18	Total	% excee
0-1	-	0.0	1.1	2.4	1.8	0.4	0.0	0.0	-	-	5.7	97.5
1-2	-	0.0	5.5	17.0	14.7	6.2	0.5	0.0	0.0	-	44.0	91.8
2-3	-	-	0.8	11.3	11.4	7.5	1.3	0.1	0.0	-	32.4	47.8
3-4	-	-	-	1.9	5.2	2.7	0.6	0.0	-	-	10.6	15.4
4-5	-	-	-	0.3	2.1	0.7	0.2	0.0	-	-	3.3	4.8
5-6	-	-	-	-	0.8	0.3	0.0	-	-	-	1.2	1.5
6-7	-	-	-	-	0.1	0.1	0.0	-	-	-	0.2	0.3
7-8	-	-	-	-	0.0	0.0	0.0	-	-	-	0.1	0.1
8-9	-	-	-	-	-	0.0	-	-	-	-	0	0
9-10	-	-	-	-	-	-	-	-	-	-	0	0
Total	0.0	0.0	7.4	32.8	36.2	18.1	2.7	0.1	0	0		
% exc	97.3	97.3	97.3	89.9	57.1	20.9	2.8	0.1	0	0		

For the wide and relatively flat seabed offshore from Kemerton, the maximum wave height is approximately 1.5 times the significant wave height.

Seasonal Wave Climate

Wave patterns are not the same each year. Nonetheless, there are seasonal patterns in the wave climate which can be seen by examining records of recorded waves. The seasonal wave pattern at Bunbury is similar to that recorded at Rottnest Island which is 150 km to the north. Figure 4 depicts the significant wave height at Rottnest Island over the year 1995.

For the first four months of 1995, significant wave heights during storms were in the range of 3 to 3.5 m. Between storms, the significant wave height decreased and was mostly between 1 to 2 m. In 1995, there was a storm almost every two weeks until May, but the period January to April 1995 can be considered as relatively benign, in terms of storms and waves.

In May 1995, the weather pattern changed from summer to winter. The largest storm of the year arrived in May, with the significant wave height reaching a peak of 7.6 m. From May to August there were a series of large storms, with peak significant wave heights of 5 to 7 m, and smaller storms in between the larger storms.

In September 1995, the spring season commenced and the intensity of storms reduced so that peak wave heights were mostly 3 to 4 m, with an October storm having waves of 4.6 m. The peak wave height decreased as the summer season progressed.

Similar seasonal patterns are seen in other years. It can be seen that there is a no season without storms. However the storms in summer have smaller significant wave heights (3 to 4 m) that those on winter period (5 to 7 m). There is a gradual decrease in storm intensity and hence in peak wave height during spring.

Highest Expected Wave

Although waves are typically described in terms of the significant wave height, marine structures must be designed to withstand the maximum wave height. Figure 5 shows the maximum wave height are derived from two sources: (1) maximum wave height at Rottnest Island derived from wave records from 1994-2003; and (2) wave records for Bunbury (16 m water depth) from 1975-1981 (but no continuous data over this period).

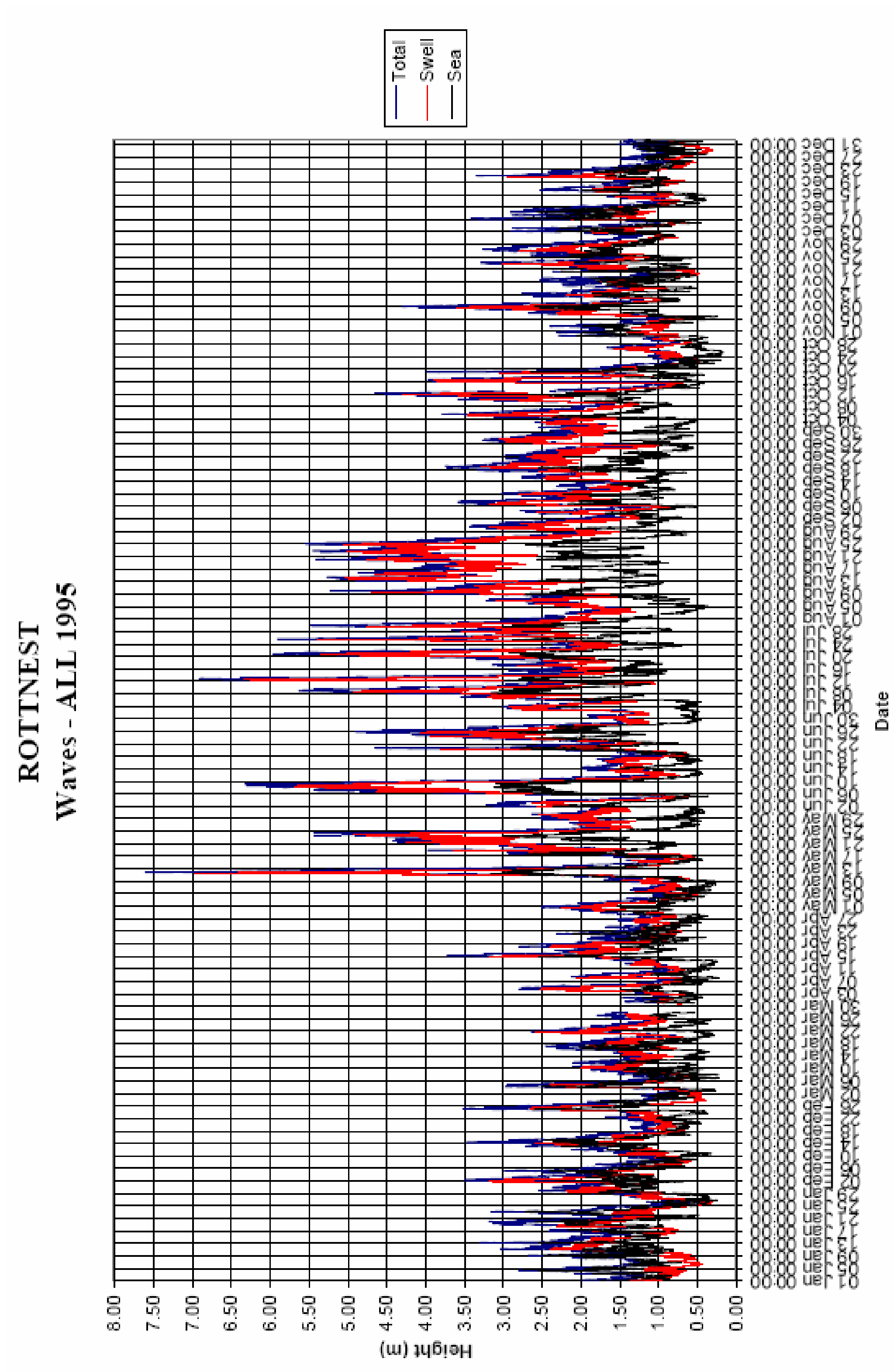
It can be seen in Figure 5 that the maximum wave heights at Bunbury are lower than at Rottnest Island. For a 3 year return interval, the maximum wave height is 10 m from the Bunbury data (depth-limited wave height), 13 m from the 3-year Rottnest data and 14 m from the 10 year Rottnest data.

Turbidity and Visibility

The offshore waters are generally clear over the summer period with good visibility for divers except after summer storms.

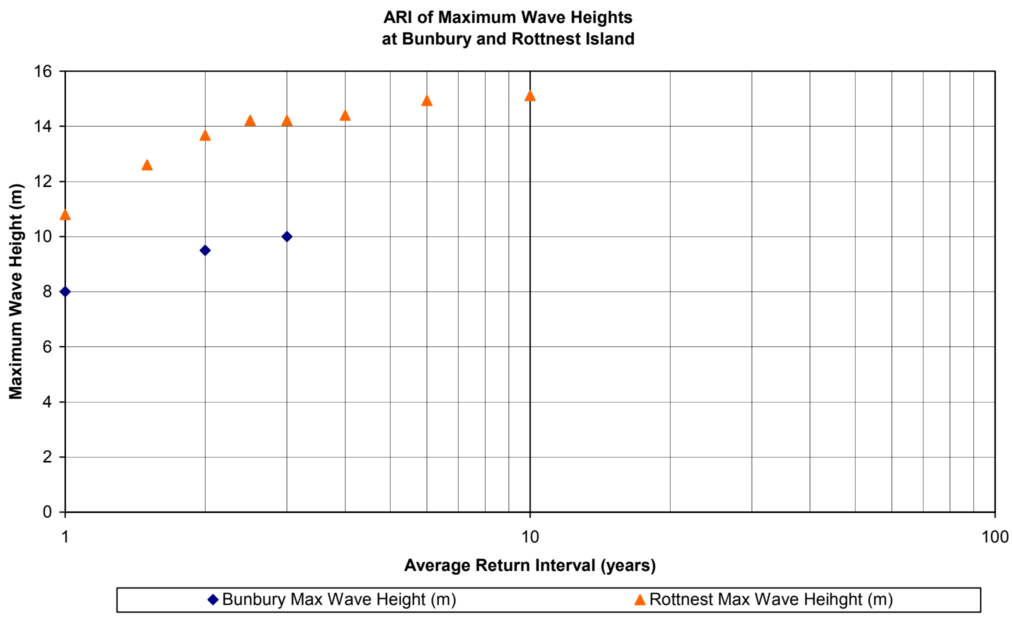
However visibility is generally poor over the whole winter period due to winter storms stirring up sediment and the break-up of wrack by ambient turbulence. Thus construction operations requiring divers need to be carried out in the September to March period.

Figure 4. Significant Wave Height at Rottnest Island in Year 1995



As the proposed outfall will be located in a water depth of about 9 to 10 m, it is apparent from this analysis that the structures should be designed for a breaking depth-limited wave.

Figure 5. Maximum Wave Heights at Rottnest Island and Bunbury



Breaking waves will be experienced for about 15 % of the year in waters 5 m deep and for about 1.5 % of the year in waters 10 m deep.

The larger waves will occur during winter storms and come from the north-west sector. Maximum bottom orbital velocities with the larger waves will be in the range of 0.5 m/s to 1.2 m/s. When combined with strong longshore currents generated by winds during storms, there will be substantial lateral loads on the proposed outfall.

Seasonal Constraints

In summary, the review of oceanographic factors shows that there is a strong seasonal variation in conditions in the Bunbury region. Summer is dominated by sea breezes, often with calm conditions in the early morning and waves of 1 to 2 m in the afternoon.

Each year in April (or a latest, May) winter storms commence and there are regular storms at intervals of 3 to 4 weeks for the next 4 months or so. During this period, there can be substantial erosion of the beach and fore dune.

Visibility for divers in the nearshore waters is good in summer but very poor in the winter months, and this is a substantial constraint on marine construction.

4. Concept Design of Outfall

4.1 Environmental Objective

The environmental objective for the diffuser is to discharge the wastewater to the ocean without any significant adverse effects on marine life, public health or the aesthetic appearance of the ocean.

The wastewater is brackish, with a salinity of about 3,000 psu. This is substantially less than the salinity of seawater (36,000 psu), and therefore the discharge will be buoyant.

4.2 Key Design Issues

Key issues in the design of the outfall and diffuser are as follows:

1. In locating the diffuser, great care must be taken to avoid the loss of sensitive species or reef areas of significant ecological value.
2. Aim for a high initial dilution. The purpose of the diffuser is to mix the effluent with seawater so there is minimal risk of an adverse environmental impact from the discharge. A high dilution minimises the risk of toxic effects.
3. For buoyant effluent, it is normal practice for the ports to discharge horizontally.
4. The diffuser should be designed so that it can be extended to handle higher flows or achieve a higher dilution if required at a later stage.
5. The diffuser should be designed to achieve a satisfactory initial dilution over the full range of discharge rates.
6. The diffuser should be located offshore from the zone of seasonal sand movement and the zone of breaking waves in regular storms.
7. The pipeline and diffuser materials need to be selected to resist corrosion with brackish water inside and seawater outside.
8. The diffuser should be sited to make best use of ambient currents and turbulence.

4.3 Adjacent Outfalls and Air Removal Structure

As noted discussed earlier, an alignment about 200 m to the south of the existing outfalls is proposed.

The top of the coastal foredune on the proposed alignment is at about 25 m above sea level. It would be feasible to drill horizontally through the dune at about 12 m above sea level from the access road behind the dunes.

The air removal structure for the new outfall would extend down the dune (buried in a trench) from an elevation of + 12 m AHD to -1 m AHD.

4.4 Diffuser Design

A concept design for the diffuser for the proposed outfall was developed. The proposed diffuser for the peak discharge of 10 ML/d is as follows:

- Length of diffuser = 110 m
- Number of ports = 30
- Port spacing = 3 m

The predicted average initial dilution is 150:1, as shown below.

CONSULTING ENVIRONMENTAL ENGINEERS

DIFFUSER CALCULATIONS - Proposed Griffin Outfall at 10 ML/d

```
DIFFUSER VARIABLES
Port Diameter  0.050 m
Port Spacing    3.00 m
Exit Velocity   1.59 m/s
Port Elevation   0.0 deg

INITIAL DENSITY DATA IN kg/cubic m
Discharge         1001.00
Adjacent Seawater 1025.00

HYDRODYNAMIC VARIABLES
Diffuser Depth       9.15 m
Froude Number       14.8
```

DEPTH m	WIDTH m	INITIAL DILUTION	VELOC m/s	TRANS m
9.15	0.1	1.5	1.24	0.06
9.06	0.4	4.7	0.41	0.66
8.73	0.6	8.3	0.31	1.17
8.25	0.8	12.5	0.28	1.54
7.70	0.9	17.4	0.27	1.81
7.13	1.1	23.0	0.26	2.02
6.54	1.3	29.2	0.26	2.19
5.95	1.4	36.1	0.25	2.32
5.35	1.6	43.6	0.24	2.44
4.75	1.8	51.6	0.23	2.54
4.14	1.9	60.2	0.23	2.62
3.54	2.1	69.4	0.22	2.70
2.93	2.3	79.0	0.22	2.77
2.33	2.4	89.2	0.21	2.83
1.72	2.6	99.9	0.21	2.89

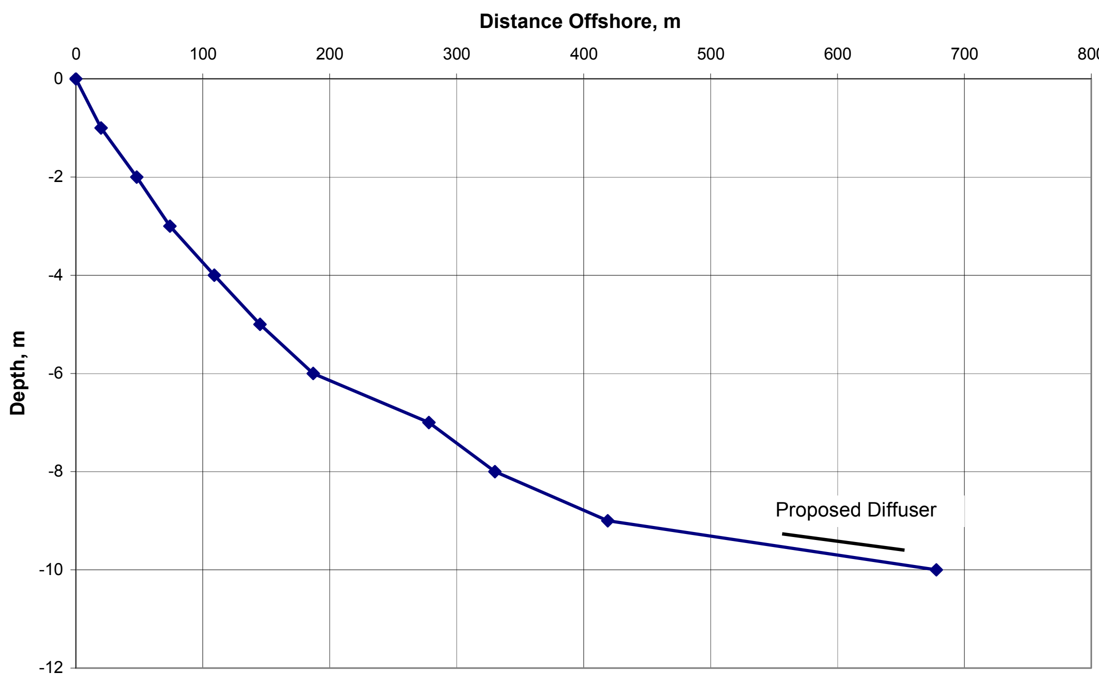
```
Surface has been reached
Plume stops at a depth of   1.3 m
And a DILUTION of   108 TO 1

AVERAGE DILUTION =  150 TO 1
```

4.5 Diffuser Location

Observation by divers shows that the limestone-seagrass habitat is very similar between the 9 m and 12 m depth contours. The Collie outfall has a 92 m long diffuser extending from 650 m to 742 m offshore (according to the distances shown in Figure 3).

To avoid overlapping discharges, the diffuser for the Griffin outfall can be placed either inshore or offshore of the Collie diffuser. For this report, it is proposed that the Griffin diffuser will be inshore, extending from 540 m to 650 m offshore (according to the distances shown in Figure 1). Figure 6 shows the location of the proposed diffuser on the bathymetric profile.

Figure 6. Proposed Diffuser Location for Concept Design



There would not be any changes to the construction concept or diffuser design if the outer location was chosen for the diffuser, and the outer location would produce slightly higher initial dilution because of the somewhat greater depth.

4.6 Pipeline Diameter

For the concept design, it is considered that the outfall should be constructed of HDPE. A nominal diameter of 450 mm (PN 10 for PE100) with a wall thickness of 27 mm is adopted for concept design. This would provide an internal diameter of 396 mm.

5. Construction Options

This section describes likely method of construction to provide a basis for the environmental assessment of the project. The proposed route is shown in Figure 7.

5.1 Drilling Through Dune

The hole beneath the dunes would be drilled from the access track on the land side of the dunes. Standard drilling equipment would be used, and a HDPE pipe of the same diameter as the outfall pulled into the drill hole. The pipeline would be connected to the land pipes at the landward side of the dune and the de-aeration structure on the seaward side of the dune. All pipes would be buried and not visible.

Small pools lined with HDPE sheeting would be excavated at each end of the drill hole to capture any excess drilling mud (bentonite solution).

5.2 Temporary Construction Track

The existing access track through the park would be used to install the land pipe to the dune. A small clearing would be necessary to allow drilling while maintaining access to the beach for other construction equipment.

The existing access track to the beach would be used for construction access and deliveries. A temporary access track would be constructed along the beach above the high tide line for a short distance using local limestone. The access track would extend from the existing access track to the offshore end of the borehole through the dune. The limestone would be removed at the end of the construction phase and the beach reinstated to natural condition.

Note that for public safety, the access track, car park and beach would be closed to public access during the construction period.

5.3 Temporary Construction Groyne

A temporary construction groyne would be constructed across the beach and to the 3.5 m depth contour using local limestone. The same procedure was used successfully during the construction of the Collie outfall.

The top of the groyne would be about 1 m above high tide level and the end and sides would be armoured with limestone blocks. The groyne would be removed at the end of the construction phase and the beach reinstated to natural condition.

The outfall to the 4 m depth contour would be installed by excavating a trench in the groyne and installing the pipeline in the trench using excavators. The long section of the outfall would be chosen so that it was buried at least 2 m below the beach on the shore and buried to the 4 m depth contour.

The pipe would gradually emerge from the sandy seabed beyond the 4 m depth contour and be fully exposed at the 6 m depth contour.

5.4 Supporting Concrete Blocks

Offshore from the 6 m depth contour the sandy seabed comprises a rough limestone pavement. The HDPE pipe must be supported above the limestone seabed so that it is not abraded during storm movement.

Concrete blocks will be pre-cast at a land site and installed on the seafloor at a spacing of about 6 m along the pipeline (the exact spacing will be determined in detailed design). The blocks will be about 1.2 m by 1.2 m in area and 1 m high, with a 450 mm deep slot for the pipe. The pipe will be secured in the slot by 316 SS plates bolted across the top of the blocks after the pipe is placed in the slots.

5.5 Fabrication and Installation of Outfall

The HDPE pipeline will be welded into strings about 150 m long at a launching site (probably in Bunbury Harbour) and towed by a workboat to the outfall site floating on the ocean surface. The pipe strings will be lowered into the slots in the blocks and secured in position by the SS plates. Successive pipe strings will be joined by bolted flanged joints.

5.6 Installation of Diffuser Ports

It is anticipated that the ports will not all be needed at the commencement of discharge. Thus the required number of ports will be drilled into the wall of the pipe using a special tool. Additional ports would be drilled as necessary when the peak discharge increases.

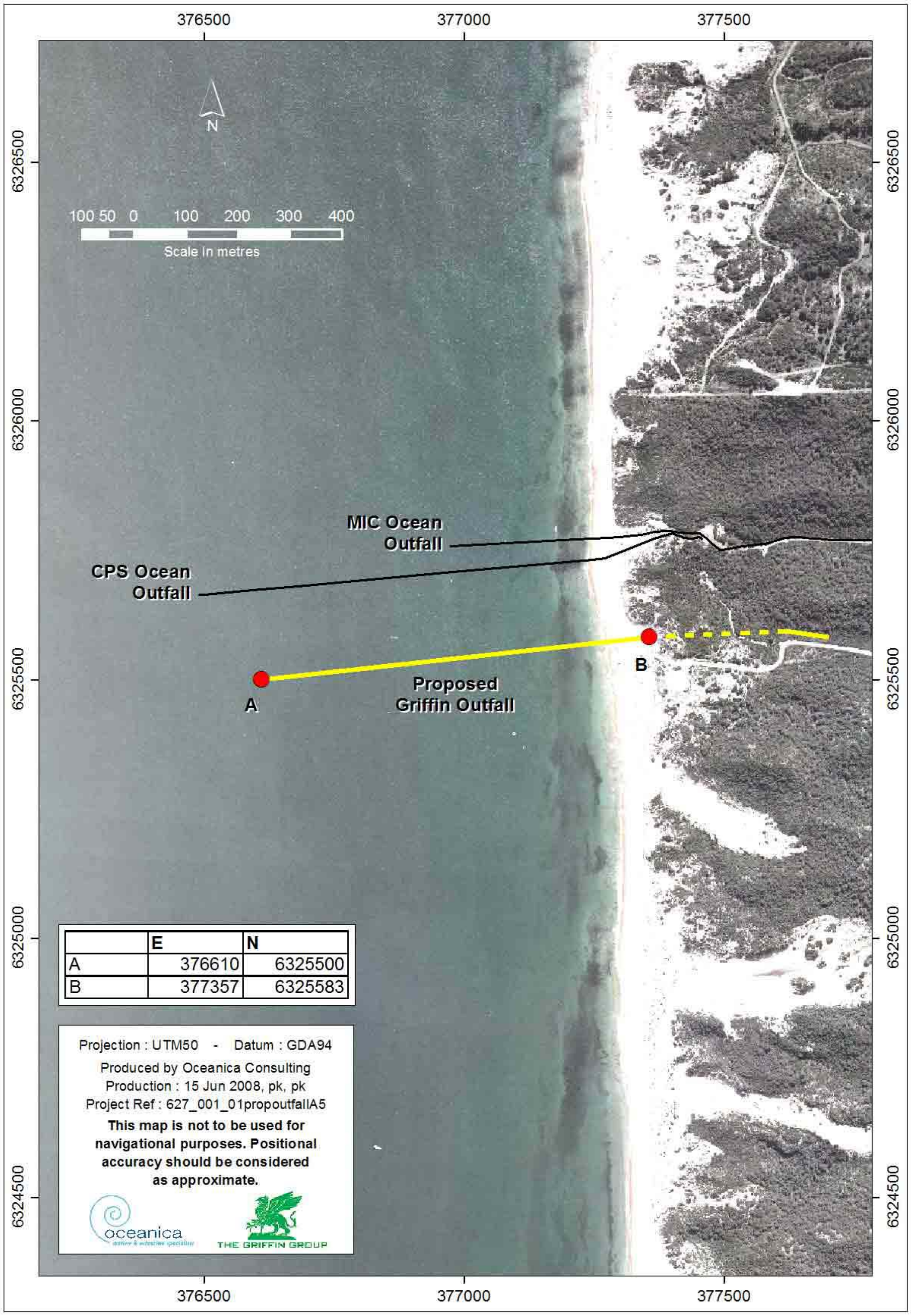
5.7 Installation of Air Removal Structure

While the offshore pipeline is being installed, the air removal structure would be installed between the end of the dune borehole pipe and the outfall pipeline. The air removal structure would comprise a buried HDPE pipe of about 1 m diameter, with an air removal manifold. The structure would be buried well below the sand and encased in concrete.

5.8 Reinstatement of Beach

After the outfall has been installed, tested and commissioned, the temporary groyne and beach access track would be removed. This can be done to the extent that the location of the new outfall is not visible and the beach is reinstated to the natural condition. The dune near the air removal structure would be planted with local indigenous plants to resist erosion.

Figure 7. Route and Offshore Alignment for Proposed Griffin Outfall



	E	N
A	376610	6325500
B	377357	6325583

Appendix B

Metal concentrations and organic content

Marine and Freshwater Research Laboratory
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SEDIMENT DATA

Contact: Sarah Scott
Customer: Oceanica
Address: 99 Broadway, Nedlands, WA 6009

Date of Issue: 06/05/2008
Date Received: 14/03/2008
Our Reference: OCA08-28
Your Reference: 627-001

METHOD		5400	5400	ICP002	ICP002	ICP002	ICP002	ICP002	ICP002
SAMPLE CODE	Sampling Date	% LOSS ON IGNITION AT 550°C	% LOSS ON IGNITION AT 1000°C	Total Ext Al mg/kg	Total Ext As mg/kg	Total Ext Cd mg/kg	Total Ext Cr mg/kg	Total Ext Cu mg/kg	Total Ext Mg mg/kg
Reporting Limit				<20	<1	<0.06	<0.2	<0.2	<2
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Signatory: [signature]
Date: 10/6/08

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Marine and Freshwater Research Laboratory
Environmental Science

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Customer: Oceanica
Address: 99 Broadway, Nedlands, WA 6009

Date of Issue: 06/05/2008
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METHOD		ICP002	ICP002	ICP002	ICP002	ICP002	ICP002	ICP007
SAMPLE CODE	Sampling Date	Total Ext Mn mg/kg	Total Ext Pb mg/kg	Total Ext Se mg/kg	Total Ext Ti mg/kg	Total Ext V mg/kg	Total Ext Zn mg/kg	Total Ext Hg mg/kg
Reporting Limit		<0.05	<1	<2	<0.1	<0.1	<0.5	<0.01
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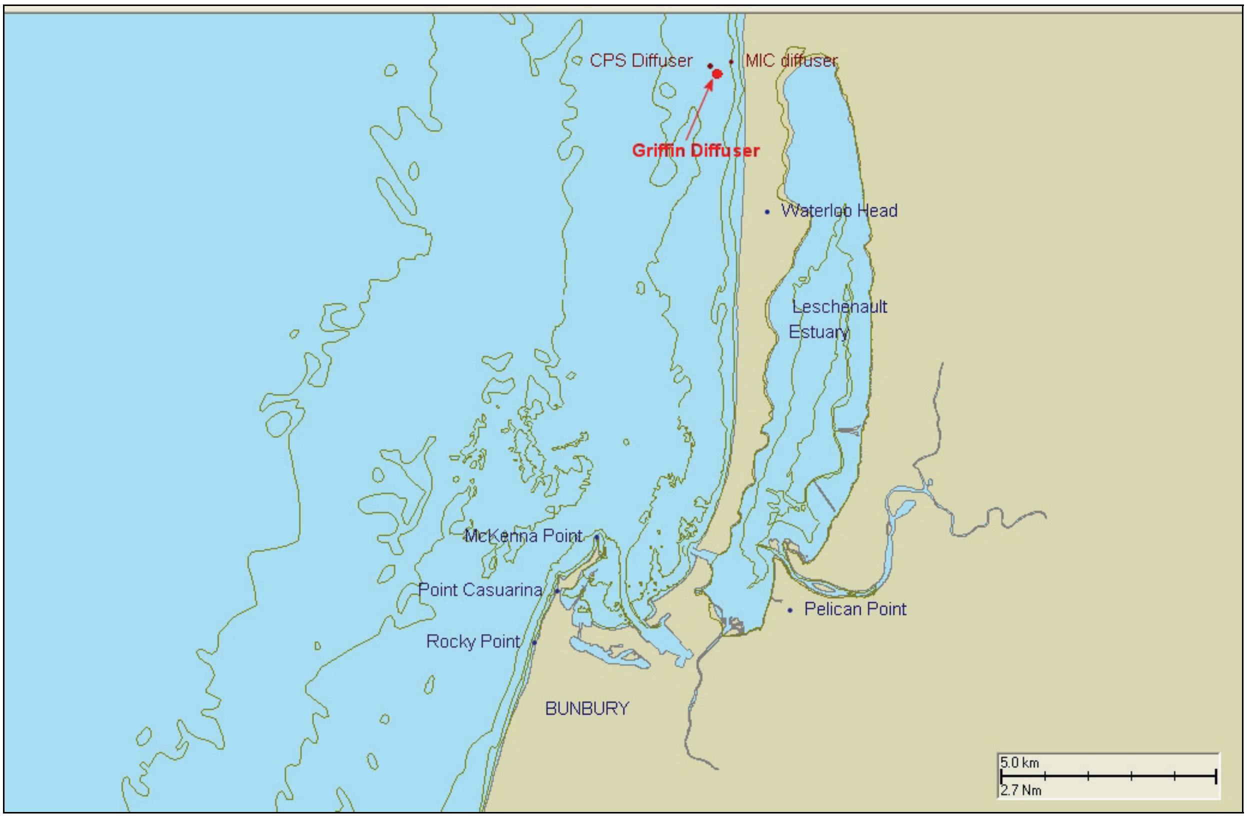
Appendix C

Modelling the Discharge of Brackish Water from the Proposed Griffin Power Plant Outfall; Asia Pacific ASA

MODELLING THE DISCHARGE OF BRACKISH WATER FROM THE PROPOSED GRIFFIN POWER PLANT OUTFALL



March 2008

Prepared for Oceanica Consulting Pty Ltd and Griffin Power Pty Ltd

Prepared by

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1 EXECUTIVE SUMMARY

Griffin Power (Griffin) is proposing to construct an outfall to discharge brackish water from the Griffin power plant, offshore from Kemerton, Western Australia. The Griffin outfall ultimate design is to discharge up to 10 ML/D, with a salinity of 3 ppt adjacent to two existing outfalls. To predict the likely mixing and extent of the brackish water discharge, Oceanica Consulting (on behalf of Griffin) commissioned a detailed modelling study.

To simulate the brackish water discharge from the Griffin outfall, the modelling study was carried out in two independent yet integrated stages. Firstly, a near-field discharge model (UM3) was used to determine the near-field mixing and dispersion of the less-saline water based on the proposed diffuser configuration. Secondly, the near-field mixing estimate was used as input into the circulation and salinity model, BFHYDRO, to predict the time-varying far-field salinity mixing for summer and autumn conditions.

The near-field simulation suggested that under a static weak current, due to the high exit velocity (1.96 m/s through each port), the plume was initially driven by its own momentum horizontally from the outlet. As the plume velocity decreased (less than 1 m from the orifice), the buoyancy of the plume caused it to rise rapidly towards the water surface, while continually entraining and mixing with the receiving water. This resulted in an initial dilution of approximately 1:190 within 6 m from the diffuser pipe.

The model results for the far-field simulations showed that once the jet and buoyancy phase had ceased, transport and dilution of the saline plume was mostly affected by the prevailing currents. Under the sample summer month (February 2000), the saline plume was predicted to advect to the north for the majority of the time. Simulations using the sample autumn month (April 2000) yielded a similar outcome. However, there were several instances of relatively long-term (days) current reversals that were attributed to changes in prevailing wind direction.

Using the far field modelling results, 50th percentile salinity contours (for each grid cell) were generated for the summer and autumn current conditions. The modelling results indicated that, the area and extent of the 50th percentile salinity were very similar for both the summer and autumn conditions and were confined to within a 100 m radius from the diffuser. Note estimates were calculated for salinities up to 35.8 ppt, greater than a 35.8 ppt were considered to be equivalent to ambient (36 ppt).

Finally, based on the summer and autumn conditions examined, there was no overlap with the MIC and CPS existing diffusers. The extent of the 50th percentile salinity plume was predicted to be approximately 169 m away from the MIC diffuser and 353 m from the CPS diffuser.

2 INTRODUCTION

Griffin Power (Griffin) is proposing to construct an outfall to discharge brackish water from the Griffin power plant, offshore from Kemerton, Western Australia. The Griffin outfall will be between two existing outfalls, Collie Power Station outfall (referred to as CPS diffuser) and the Millennium Inorganic Chemicals outfall (referred to as MIC outfall). Figure 1 shows the location of the proposed Griffin outfall and the existing outfalls. The Griffin outfall ultimate design is to discharge up to 10 ML/D, with a salinity of 3 ppt.

To quantify the mixing and dispersion of the Griffin brackish water discharge, Oceanica Consulting (Oceanic) on behalf of Griffin, commissioned Asia-Pacific ASA (APASA) to carry out a detailed modelling study. The primary objectives of the study were to:

1. Establish and validate a hydrodynamic model for the region;
2. Carry out initial dilution modelling to determine the initial plume behaviour based on the Griffin diffuser configuration;
3. Simulate the local circulation patterns and long-term (February – April 2000) far-field salinity mixing and dispersion, for the proposed Griffin outfall; and
4. Generate 50^{th} percentile salinity contours for the brackish water discharge under the influence of summer (February) and autumn (April) conditions.

The findings from the modelling study will be used to determine the likely dimensions of the proposed Griffin discharge.

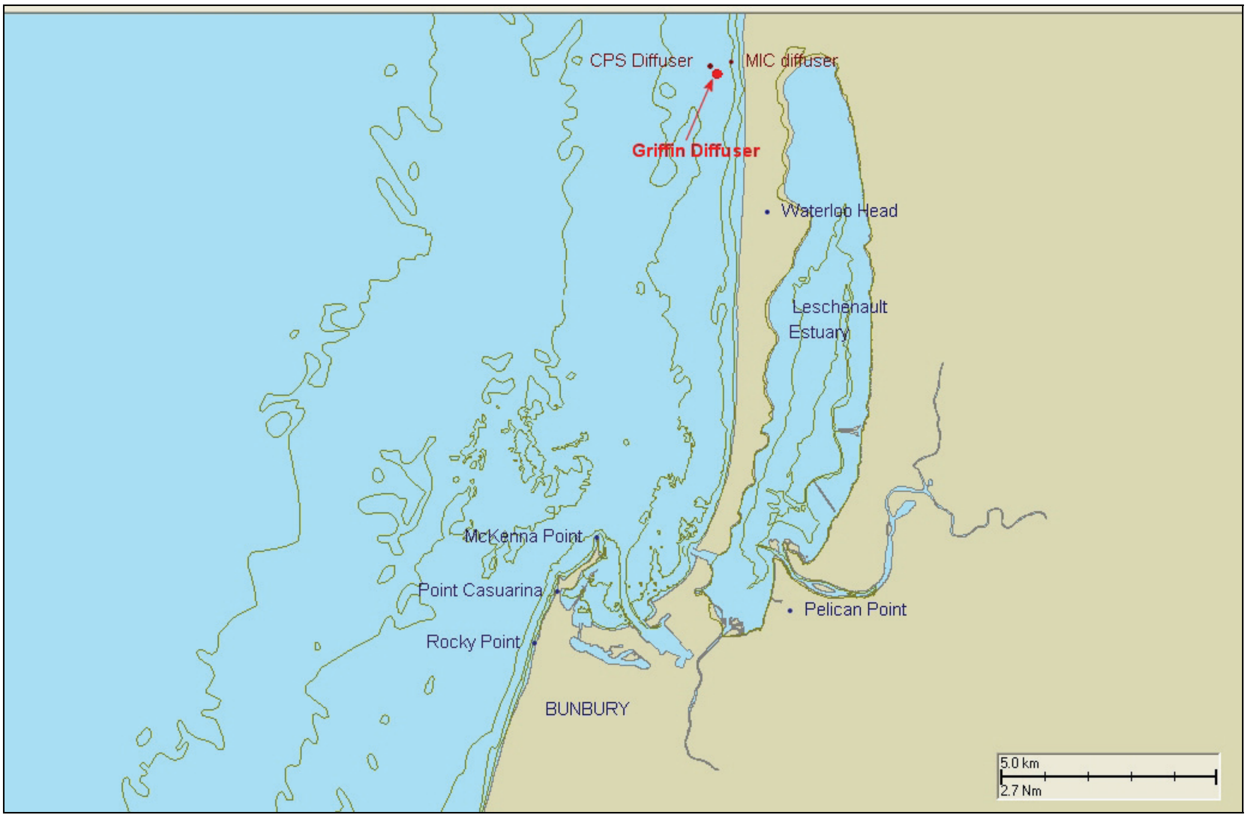


Figure 1: Map showing the location of the proposed Griffin diffuser outfall and existing CPS and MIC outfalls, approximately 10 km north of Bunbury.

3 METHODOLOGY

To simulate the brackish water discharge from the Griffin outfall, the modelling study was carried out in two integrated stages. Firstly, the near-field mixing and dispersion of the less-saline discharges was determined using the US EPA near-field model (UM3) based on the proposed diffuser configuration. Secondly, the near-field mixing estimate was used as input into the circulation model (BFHYDRO), to predict the far-field mixing and dispersion of the less-saline water. An overview of the environmental data, methodology and models are described in the following sections.

4 CIRCULATION AND SALINITY DISCHARGE MODEL – BFHYDRO

The circulation and salinity modelling was carried out using the three-dimensional model, BFHYDRO. BFHYDRO is used to generate tidal elevations, current velocities, salinity and temperature distributions for rivers, estuaries or coastal embayments. BFHYDRO has a long history of development (over 20 years) and application world-wide for simulation of hydrodynamic circulation in estuarine, coastal sea and continental shelf waters (e.g. Huang & Spaulding 1995, Peene *et al*. 1997, Mathison *et al*. 1989, Mendelsohn *et. al*. 1999, Yassuda *et.*

al. 1999, Kim & Swanson 2001, Ward & Spaulding 2001, Zigic *et al*. 2005b, Zigic, 2005a) and, thus, the model algorithms have been extensively peer-reviewed and developed over this time.

The three dimensional conservation of mass, momentum, salt and temperature equations are solved on a boundary-fitted curvilinear grid system that allows a freely variable grid-scale. This suits the model to situations where the waterway is constrained or adjoining to sinuous or complex shorelines. A sigma co-ordinate system is applied in the vertical to resolve bathymetric variations with a constant number of layers. Environmental forcing can include tidal constituents, salinity and temperature at ocean/estuarine boundaries; flux of water mass, temperature and salinity at river boundaries or any number of internal discharge points; wind shear, and density distributions.

BFHYDRO represents the mixing and dispersion of discharges that have different temperature and/or salinity to the receiving waters using baroclinic formulations. The salt and temperature transport equations are solved by a simple explicit technique, except for the vertical diffusion term, which is solved by an implicit scheme to ease time-step restrictions due to the small vertical scale-length. The advection term is solved using a modified higher-order upwind scheme (Smolarkiewicz, 1984; Smolarkiewicz and Grabowski, 1990). These schemes, commonly referred to as Multi-dimensional Positive Definite Advective Transport Algorithms (MPDATA) are effective in reducing artificial diffusion introduced by first-order upwind schemes.

The reader is referred to Muin & Spaulding (1996, 1997) and Swanson (1986) for detailed presentation of the governing equations and test cases of the BFHYDRO model.

4.1 Model Setup

The proposed Griffin outfall is to be located in the northern end of Geographe Bay. Geographe Bay is considered to extend from Cape Naturaliste in the west to Bunbury in the north-east. Cape Naturaliste and the southern coastline of Geographe Bay provides some protection from southerly and southwest winds at the outfall site. However, offshore waters are exposed to these winds, with potential effects on the regional circulation. The Bay waters are also directly exposed to winds from the west and northwest. To account for regional-scale effects, the hydrodynamic grid was set up over a domain that extended over the entire Geographe Bay and with a western boundary that extended 30 km seaward of Cape Naturaliste (see Figure 2).

Simulations were performed using an irregularly-spaced, boundary-conforming grid that consisted of 22,536 active computational water-cells. The size and shape of these grids were varied over the domain. A fine (<10m) grid resolution was defined adjacent to the Griffin outfall, to more accurately define the mixing and dilution of the discharge. A coarser grid cell resolution (between 250 m and 2000 m) was applied over the wider bay. This approach optimized model resolution around the release site while maintaining model efficiency and stability, important to allow sufficiently long simulations to be carried out. Particular attention was paid to ensure grid conformity to the coastline, which could have local impact on circulation and, in turn, transport of the saline plume.

The area has a relatively simple bathymetry with gentle offshore gradients. From the shore to a distance of approximately 250 m offshore, the seabed has a reasonably even slope to a depth of 7 m. A depth of 13 m is reached at about 2–3 km offshore.

Bathymetric data used to describe the shape of the seabed within the study area was compiled from a number of sources. Depths offshore from the 20 m contour line were described from the Geoscience Australia national bathymetric dataset, which has a nominal resolution of approximately 250 m over these areas. Depths in shallower waters were described from a combination of isobathy data (5 m depth contours) for the wider bay and detailed point data for Bunbury, which was supplied by the Department of Planning and Infrastructure and areas of the study region that were not resolved by the above datasets were digitized directly from the local admiralty chart. Spot depths were spatially interpolated to form a seamless interpretation of the bathymetry. Figure 3 shows the details of the bathymetric grid defining the hydrodynamic model domain.

Forcing by astronomical tides was defined at the open boundaries (represented by the blue cells along the grid, see Figure 2 of the model) and were calculated for real times using the latest Topex Poseidon global tidal set (TPX062; source: NOAA), which is a gridded set of tidal constituents derived from satellite altimetry. Tidal elevations at all open boundary cells were calculated at each time step in the model using the 5 largest tidal constituents for the area (O_1, K_1, N_2, M_2 and S_2). The model then calculated sea heights and resulting tidal currents for locations within the region by propagation of constant water mass over the three-dimensional shape of the region.

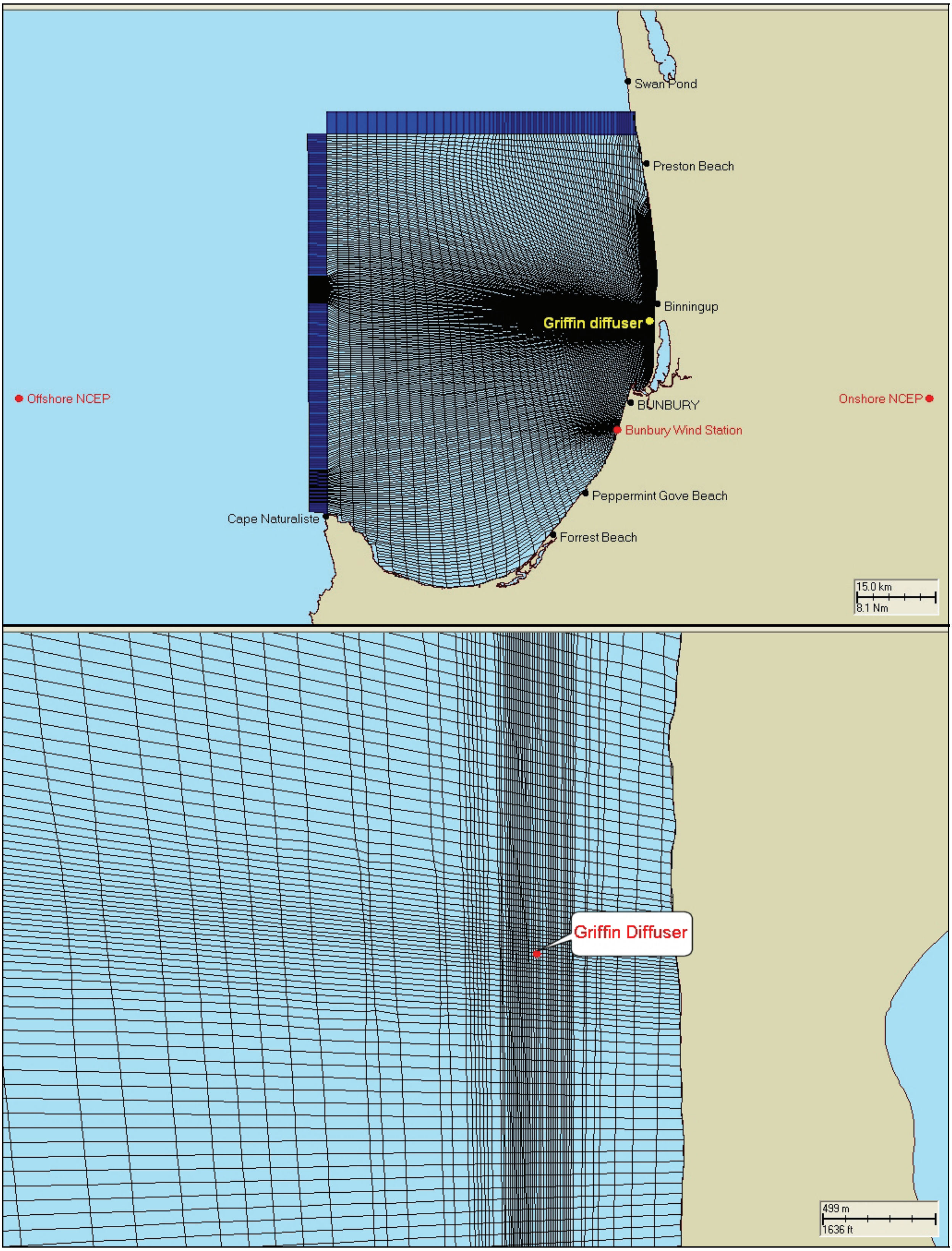


Figure 2: (a) Large scale view of the hydrodynamic grid covering Geographe Bay; and (b) Zoomed in-view of the fine grid resolution adjacent to the Griffin outfall. The top figure also shows the location of the Bunbury wind station and the historic NCEP wind nodes.

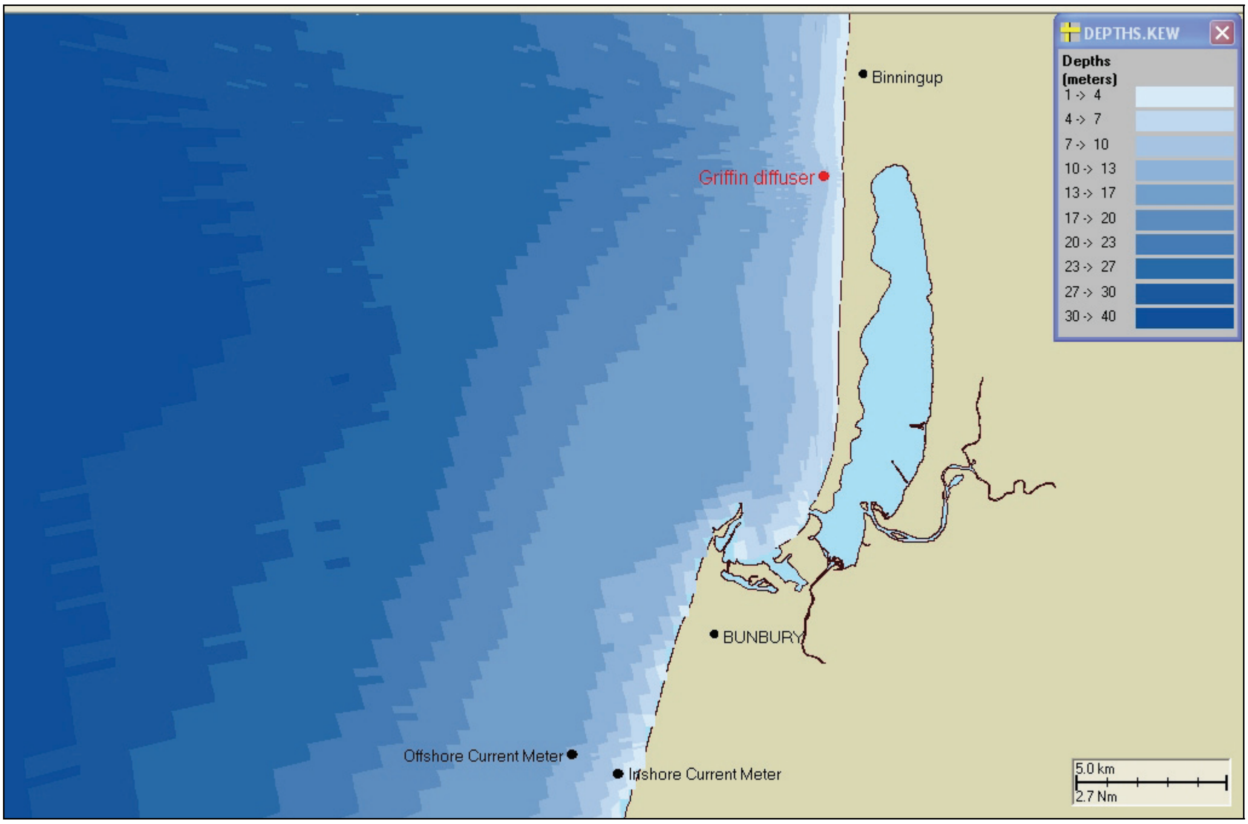


Figure 3: Details of the bathymetry adjacent to the Griffin outfall and the location of the current meter moorings.

4.2 Model Validation

To ensure the accuracy of the input data and settings, the model results were compared to February 2000 current records collected offshore and inshore of the Bunbury WWTP (Figure 3). Current measurements were collected at 2m and 8m above the seabed for the offshore site (mean depth: 12 m) and at 2m above the seabed for the inshore site (mean depth 6 m).

Due to relatively shallow, microtidal waters around the Bunbury and Kemerton locations, wind shear is the dominant force generating nearshore water circulation in the study region. Wind data collected at Bunbury WWTP (as hourly wind speed and direction), were used as input to BFHYDRO to describe wind shear over the model region. Figure 4 is a stick plot of the wind speeds and direction for February 2000. Note: contrary to atmospheric convention for defining wind speed and direction, the axes in Figure 4 indicate the direction the wind was blowing to: e.g. a stick plot pointing up the page from the centre designates winds to the north; while the length of the stick designates the wind speed.

Winds during February 2000 are predominantly towards the northern sector with a diurnal shift between northwest and northeast occurring frequently, indicating the influence of a sea-land breeze due to diurnal fluctuations in relative temperature of the land and the sea. During the nights and in the mornings, the winds are generally weaker (2 – 7 m/s) and fluctuate between heading west and north. In the afternoon, winds are generally towards the northeast or northwest direction (Oceanica 2006).

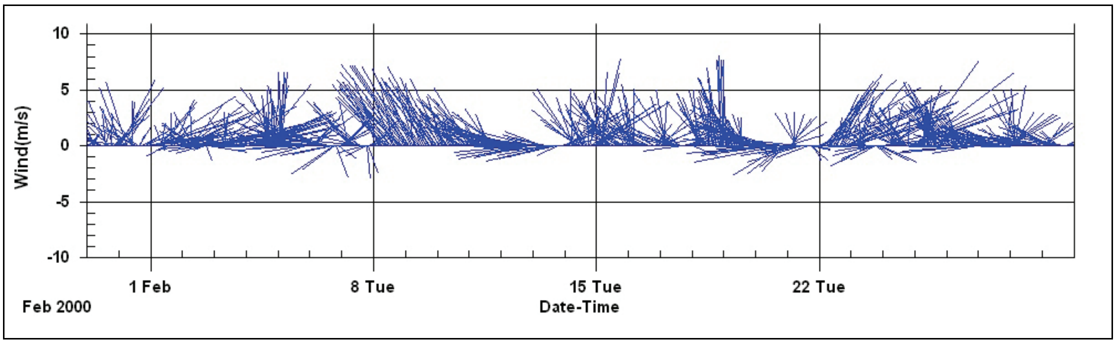


Figure 4: Stick plot showing the measured wind speed and directions between 1st – 29th February 2000 at Bunbury WWTP. Sticks point from the horizontal axis away from the source of the wind.

To scale the frictional drag between the seabed layer and the seabed, a spatially-uniform quadratic bottom roughness coefficient of 0.015, representative of a sandy seafloor, was applied. The sensitivity study showed that the currents and sea surface elevation were relatively insensitive to settings within 0.5 to 2 times that scale. The vertical eddy viscosity was used to control the amount of vertical shear present between the layers in the water column (Kowalik & Murty 1993). The value for vertical shear was between 10 cm^2/sec and 200 cm^2/sec, and the current speed and direction was sensitive to this parameter. Sensitivity testing was carried out using the data from the offshore current meters and it was found that a relatively high 100 cm^2/sec was the appropriate value.

The comparisons between the model predicted and measured current datasets, showed a good agreement throughout the duration of the simulation (Figures 5-7). The model had been capable of closely representing the combined effects of wind, tide and seabed drag in the study area. Analysis of the measured data indicates that circulation was predominately wind driven, evidenced by relatively small oscillations in the current speeds at the time-scale of the tide and relatively larger speeds generated at scales longer than the tide scale, due to the wind. The model predictions had matched this behaviour, showing the relatively large effect of the wind superimposed over smaller tidal variations. Both tidal-scale and large-scale fluctuations in currents were typically reproduced at a similar magnitude and timing.

The poorer fit generally occurred when the longitudinal current speeds were < 0.05 m/s, which might be induced by the intrusion of continental shelf waves and/or seiches due to unaccounted large scale oceanic currents (such as those associated with the Leeuwin Current) or spatial variations in the wind along the coastline. Despite this, stick plots comparing the combine currents from observations and predictions showed suitably accurate reproduction of the observed magnitude, direction and timing of current flows (Figure 8-10). Note each "stick" (also called a vector) on the stick plot contains three pieces of information: direction, time and magnitude (strength). Each arrow is pointing in the direction the current is flowing "to". For example a stick pointing up the page is pointing north. The time axis is located on the bottom of the figure. Finally, the length of the stick is the indicator the current speed. The longer the stick, the stronger the current speed. For more information please see (http://www.aims.gov.au/pages/facilities/oceanographic-buoys/reading-stick-plots.html).

To provide a quantitative assessment of model performance, the relative mean error (RME), and root mean square error (RMSE) were calculated between measured and predicted currents, following the recommendations of McCutcheon et al (1990). Table 1 shows the RME and root RMSE comparisons between observations and predictions at each location. Error estimates are below thresholds recommended for minimum fit in model calibration and validation by McCutcheon et al (1990), providing confidence that the model configuration is accurate for the assessment.

Table 1: Relative mean error (RME) and root mean square error (RMSE) comparisons between measured and predicted currents during February 2000.

Location	Component	HYDROMAP	
		RME (%)	RMSE (m/sec)
Offshore (8m ASB)	East - West (U)	25	0.028
	North – South (V)	13	0.036
Offshore (2m ASB)	East - West (U)	24	0.026
	North – South (V)	4	0.037
Inshore (2m ASB)	East - West (U)	-15	0.021
	North – South (V)	-1	0.026

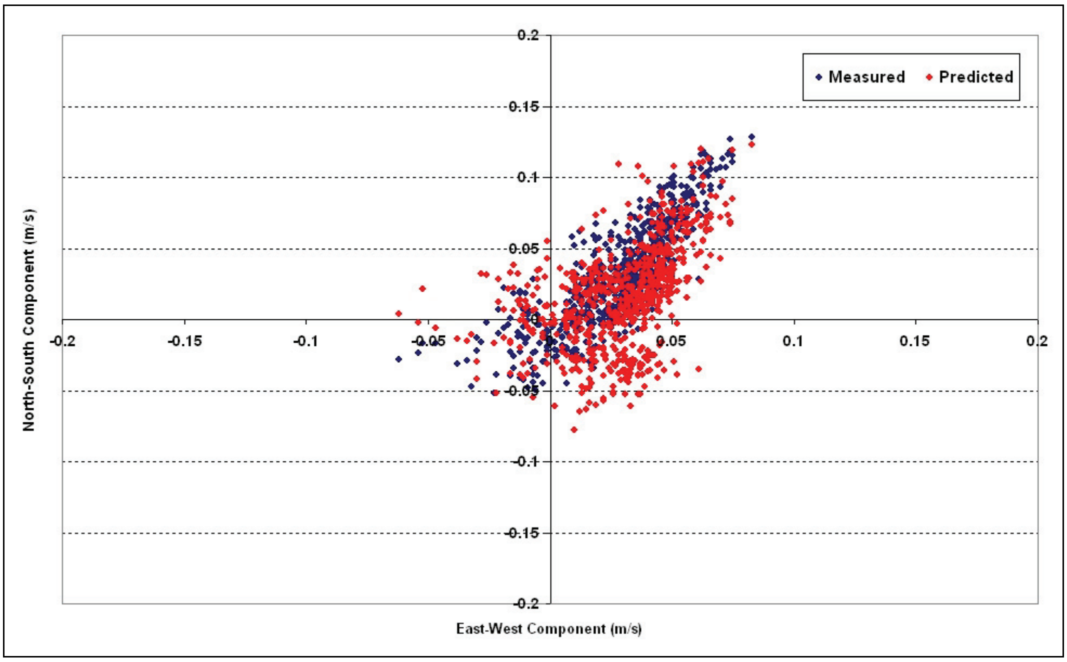


Figure 5: Scatter plot showing the comparison between the measured and predicted currents 8 m ASB over the offshore mooring.

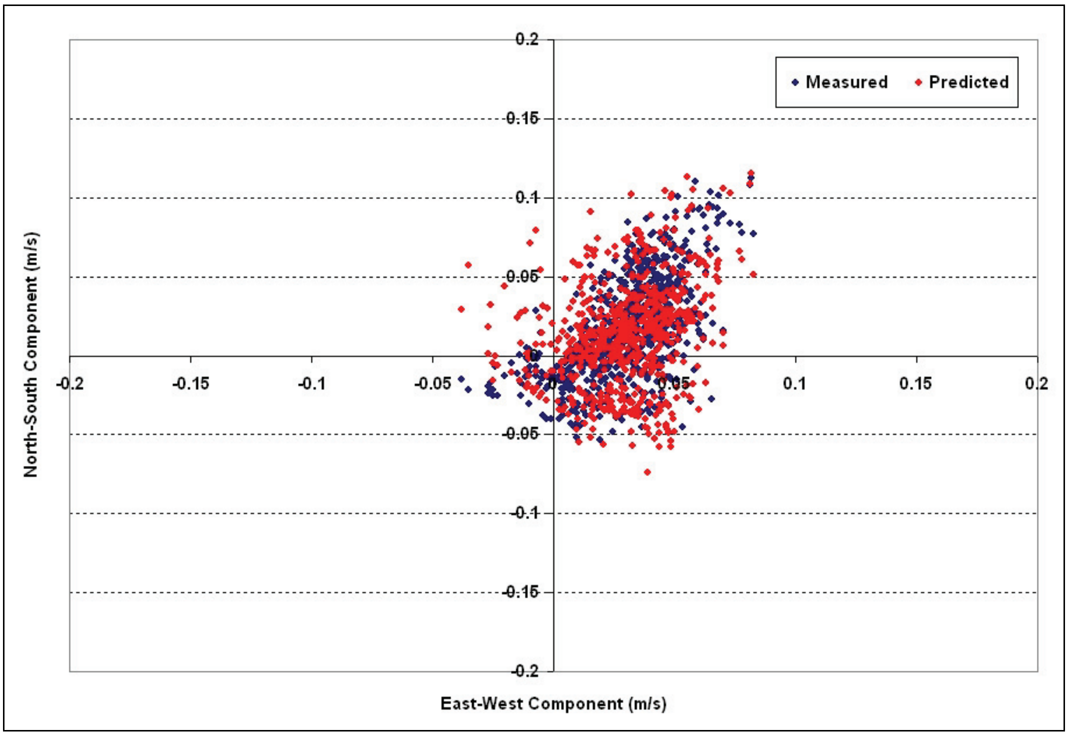


Figure 6: Scatter plot showing the comparison between the measured and predicted currents 8 m ASB over the offshore mooring.

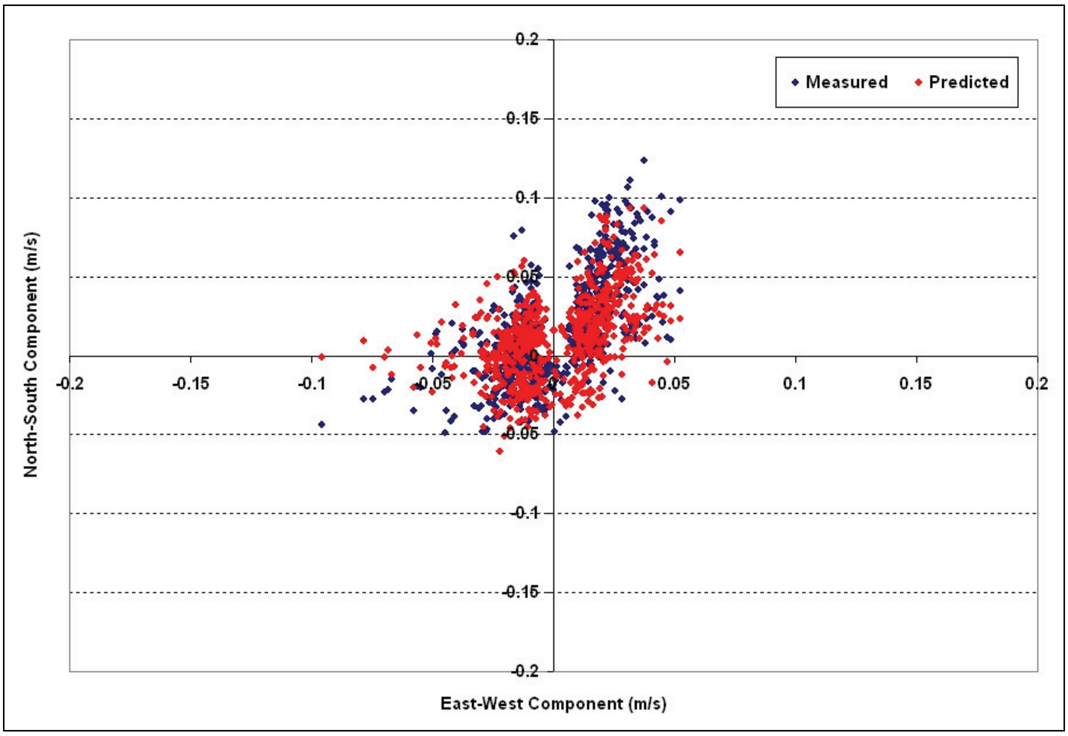


Figure 7: Time-series graphs showing the comparison between the measured and predicted currents 2 m ASB over the inshore mooring. Top panel shows the east-west component. Lower panel shows the north-south component.

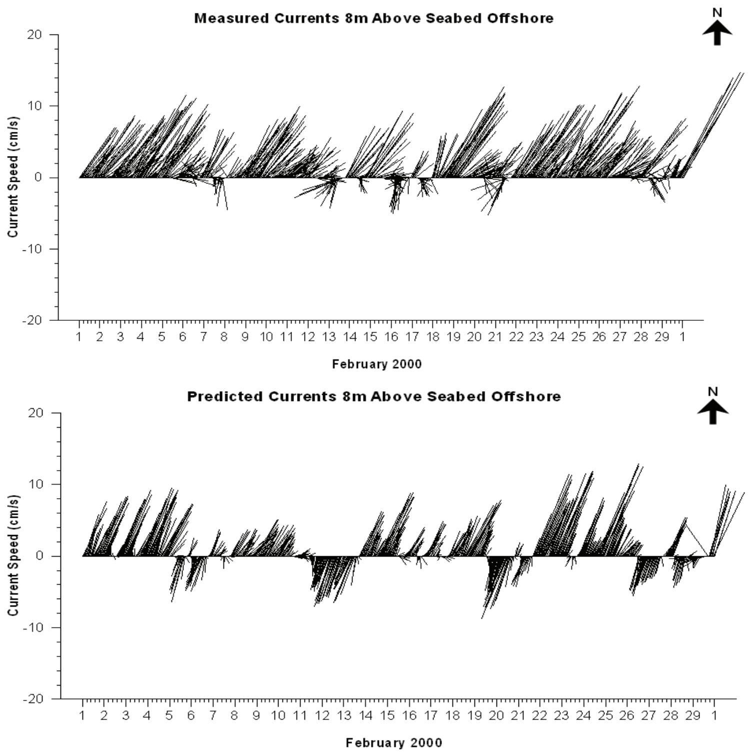


Figure 8: Stick plots comparing the speed and direction of measured and predicted currents 8m above the seabed at the offshore mooring (1st – 29th February 2000).

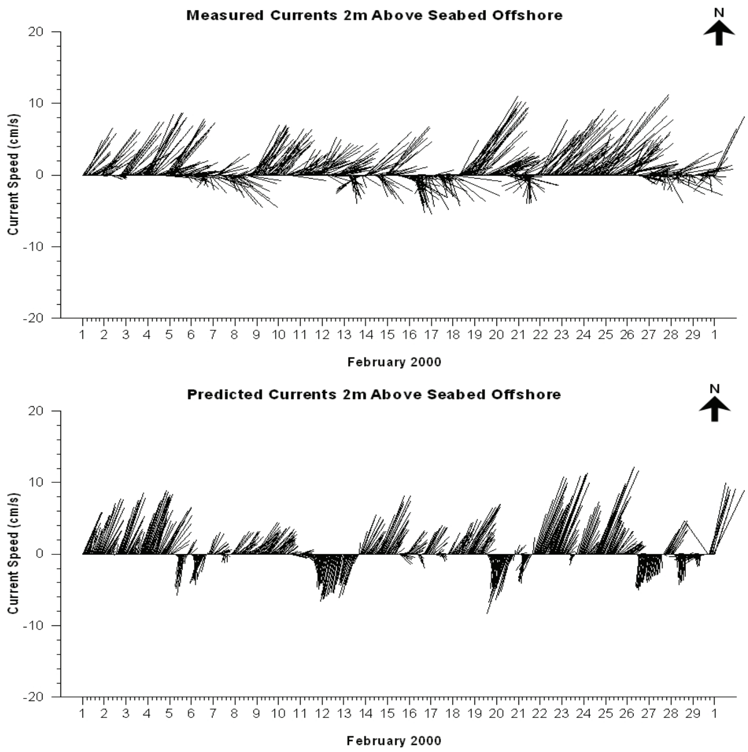


Figure 9: Stick plots comparing the speed and direction of measured and predicted currents 2m above the seabed at the offshore mooring (1st – 29th February 2000).

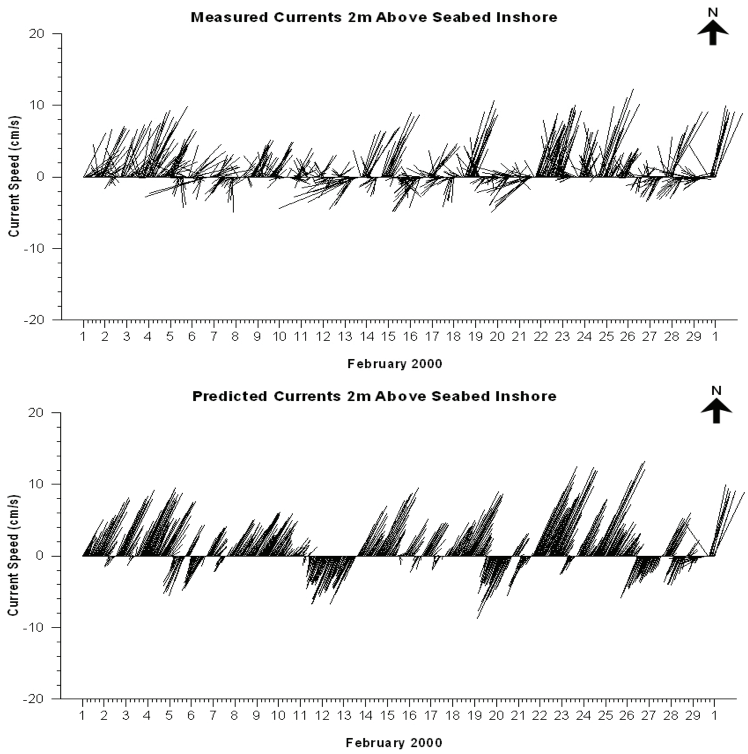


Figure 10: Stick plots comparing the speed and direction of measured and predicted currents 2m above the seabed at the inshore mooring (1st – 29th February 2000).

5 CURRENT DATA

Using the model settings validated above, the three-dimensional coastal circulation model was re-run for a 90-day period (February – April 2000) for the assessment. Figure 11 shows wind roses summarising the distribution of wind speeds and directions at Bunbury WWTP from February - April 2000. *Note that the convention for defining wind direction, that is, the wind direction **FROM**, is used to reference wind direction. Each branch of the rose represents the winds to that direction, with north to the top of the diagram. Eight directions are used. The branches are divided into segments of different thickness, which represent wind speed ranges for each direction. Speed intervals of 5 m/s are used in these wind roses. The width of each segment within a branch is proportional to the frequency of winds within the corresponding range of speeds for that direction.*

The data indicated that between the months of February to April the average and maximum wind speeds were 4.4 m/s and 15.4 m/s, respectively. The wind-roses highlight the predominance of winds from the east through to south-west. However, as April is the transitional period between the summer and winter patterns the wind rose also show variable winds from the Northern sector.

To examine the representativeness of the February – April 2000 Bunbury wind data, a 10 – year historic wind record (1995 – 2005) was retrieved for the nearby onshore and offshore NCEP wind stations (see Figure 2) of a numerical atmospheric model (the NCEP model reanalysis) provided by the NOAA_CIRES Climate Diagnostics Center in Boulder Colorado (http://www.cdc.noaa.gov). Figure 11b shows the February to April monthly wind roses for the two sites and in when comparing the Bunbury measured to the NCEP historic wind data, it is apparent that the wind directions and speeds compare well to the 10 year record and would be considered representative of the region and following years.

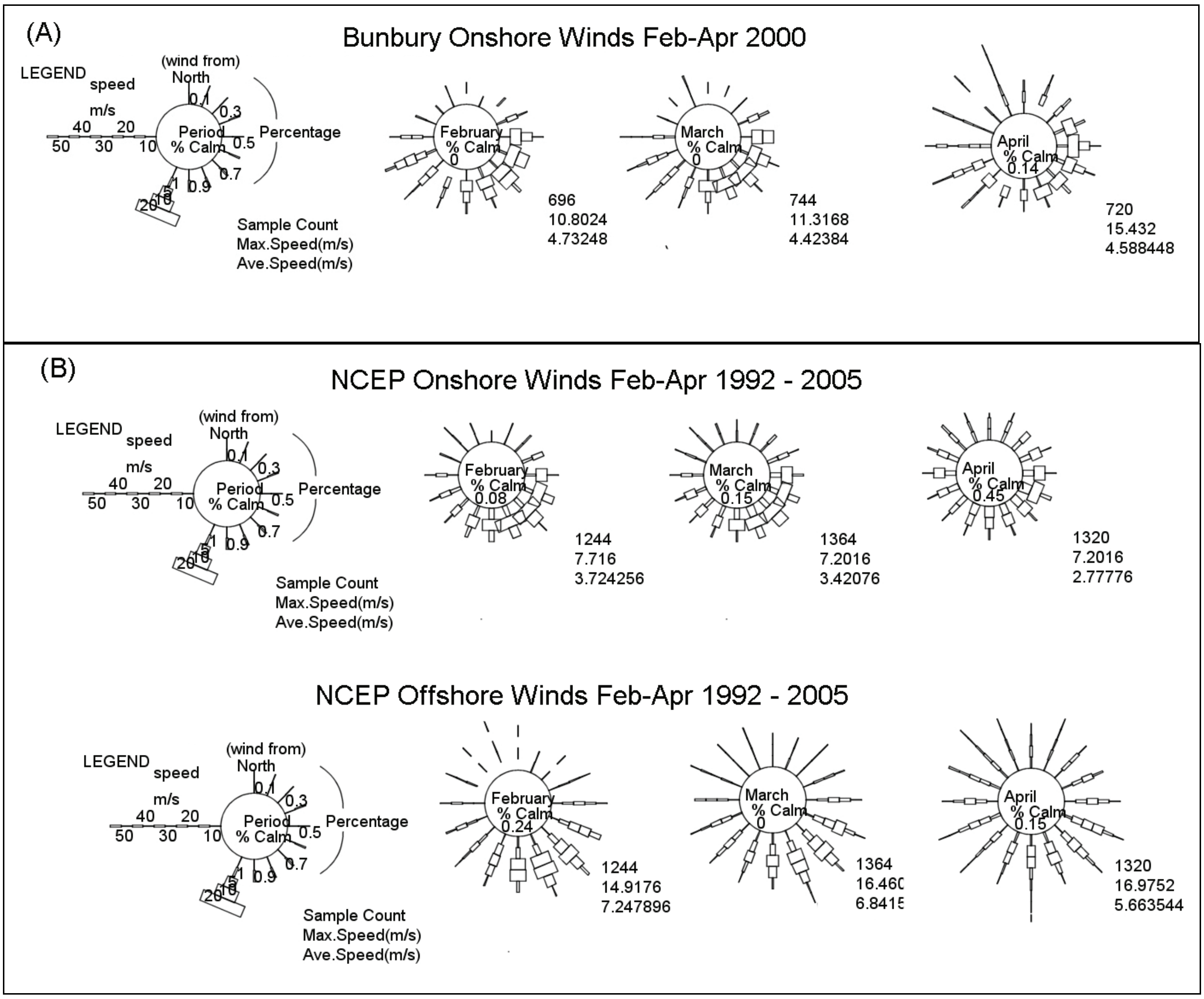


Figure 11: (a) February - April 2000 wind rose distributions of monthly wind speeds and directions at Bunbury WWTP; and (b) February – April historic (1995 – 2005) NCEP onshore and offshore winds. Sectors point toward the source of the wind.

Figure 12 shows the time-series plots of the predicted surface current speeds and directions at the Griffin outfall for February – April 2000. The predicted currents at the Griffin outfall during between February and April 2000 indicated to be almost exclusively northward, however, during March and April southward currents were more frequent, which would correlated with winds from the north. The 5th percentile, average and maximum predicted current speeds were 0.008 m/s, 0.037 m/s and 0.161 m/s, respectively.

Figure 13 shows examples of the predicted surface current patterns adjacent to the Griffin outfall site, during peak northward and southward flows selected from dataset. Note the density of the currents varies with the grid resolution with the highest grid resolution adjacent to the release site. Note, only every 3rd vector is shown to ensure clarity.

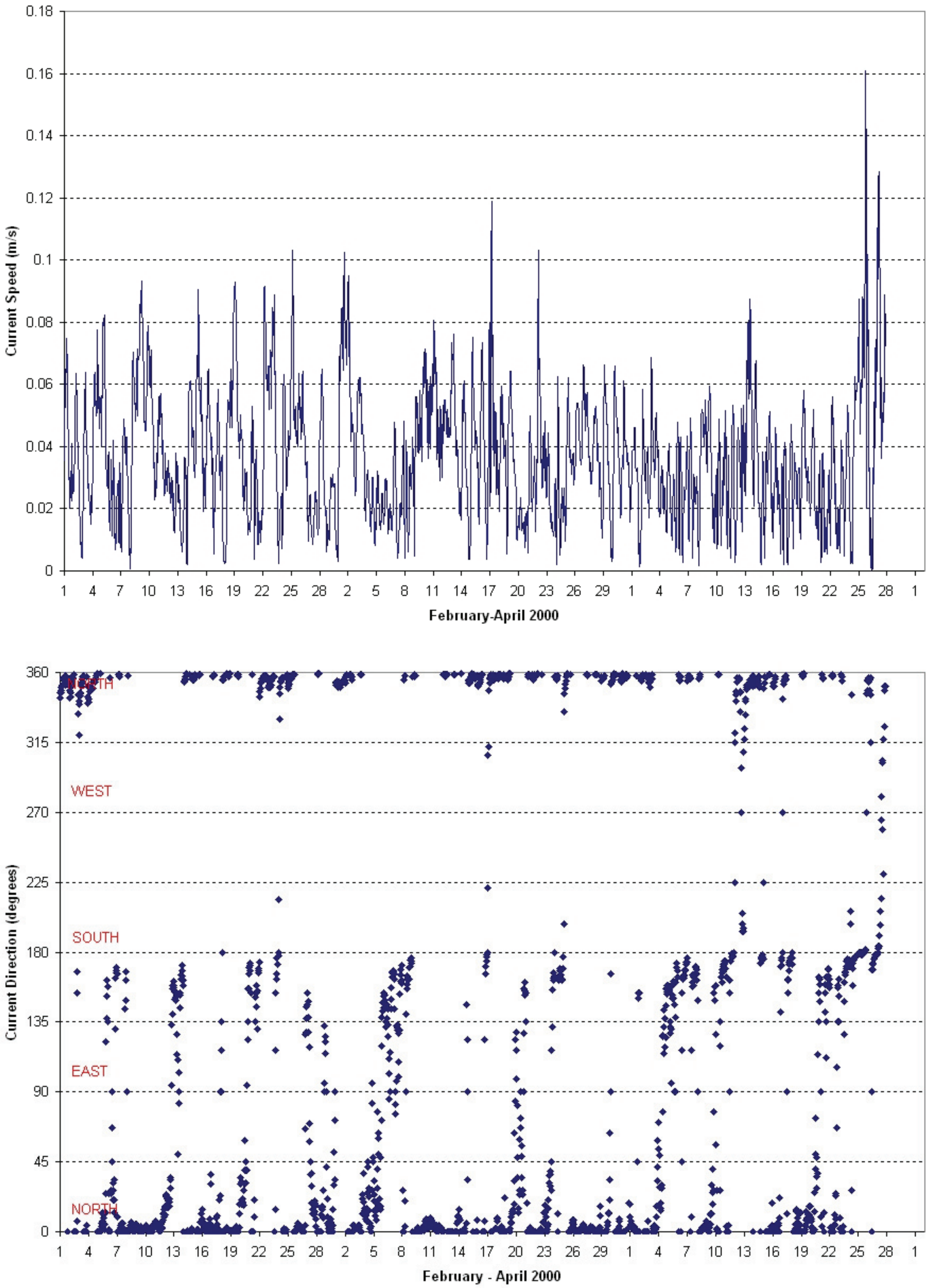


Figure 12: Time series graphs showing predicted current speed (top panel) and directions (bottom panel) at the proposed outfall site from February to April 2000.

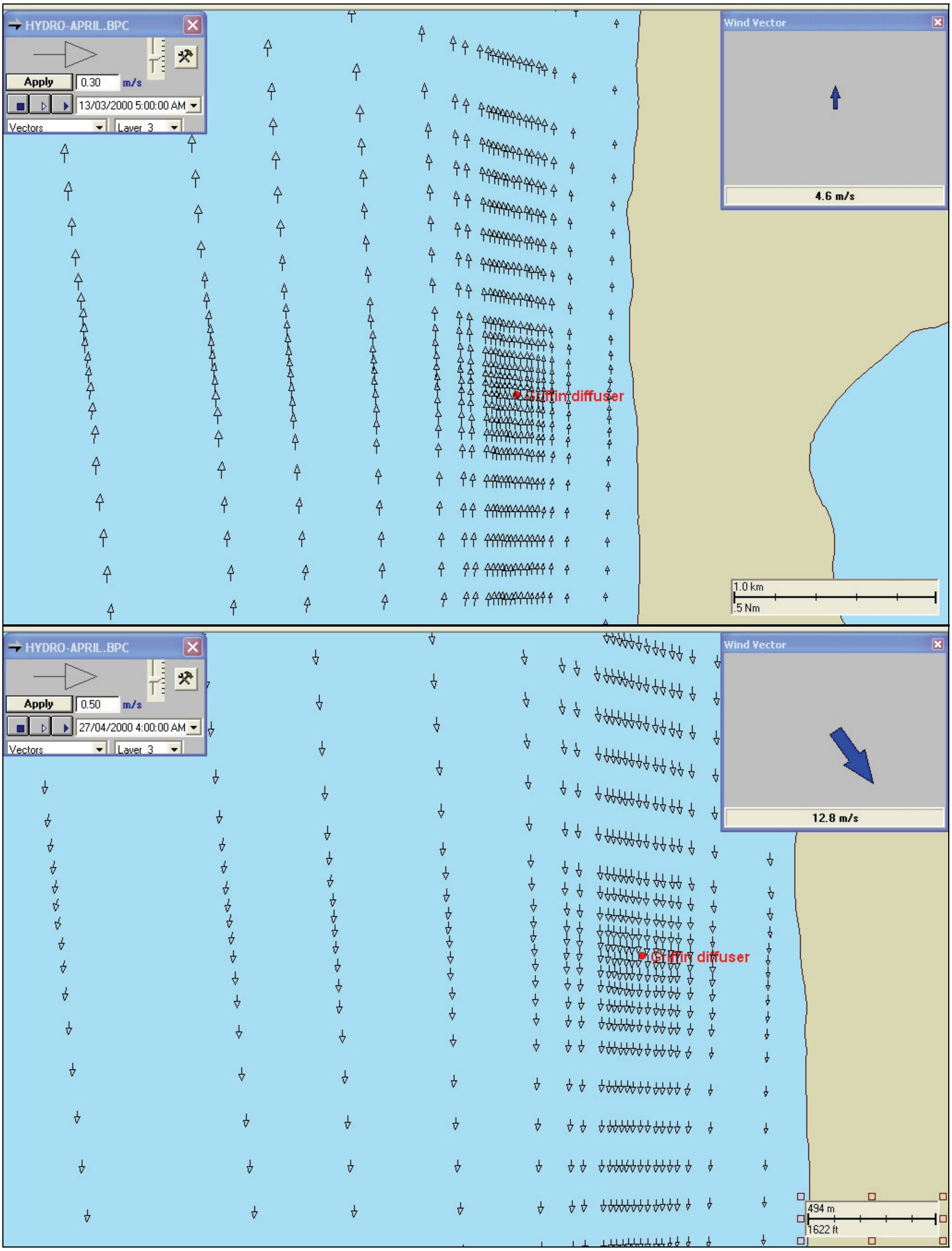


Figure 13: Examples of northward (top panel) and southward (bottom panel) predicted surface currents adjacent to the proposed Griffin outfall site. Note the density of the currents varies with the grid resolution. Current speed is indicated by the relative size of the arrows, with only every 3rd vector shown for clarity.

6 NEAR – FIELD DISPERSION MODELLING

The likely near-field mixing and dispersion of the Griffin outfall was predicted using the fully three-dimensional flow model, Updated Merge (UM3) model. UM3 is a three-dimensional plume model for simulating single and multi-port submerged discharges, available in the Environmental Protection Agency interface "Visual Plumes" (VP) (Frick *et al.*, 2000). The UM3 model was selected since it has been extensively tested for various discharges and found to predict the observed dilutions more accurately (Roberts and Tian, 2004) than other near field models (RSB and CORMIX).

In this Lagrangian model, the equations for conservation of mass, momentum, and energy are solved at each time step, giving the dilution along the plume trajectory. To determine the growth of each element, UM3 uses the shear (or Taylor) entrainment hypothesis and the projected-area-entrainment hypothesis. The flows begin as round buoyant jets issuing from one side of the diffuser and can merge to a plane buoyant jet (Carvalho *et al*. 2001). Model output consists of plume characteristics, including centerline dilution, rise-rate, width, centreline height and diameter of the plume. Dilution is reported as the "effective dilution", as the ratio of the initial concentration to the concentration of the plume at a given point, following Baumgartner *et al.* (1994). The model includes corrections for a reduction in surface area that is available for mixing that occurs with merging plumes, created by discharge through multiple adjacent ports.

Input data to the UM3 plume model includes specifications for the discharge: flow rate, salinity and temperature; specifications for the receiving water: current speed and direction, salinity and temperature; and the diffuser parameters: port diameter, number of ports, and port angle.

Summary of the proposed Griffin diffuser configuration, discharge characteristics and ambient water properties applied for the near-field modelling is shown in Table 2.

To predict the lowest initial dilution (i.e. the dilution resulting in the highest concentration adjacent to the diffuser) generated by the Griffin diffuser configuration, the 5^{th} percentile current speed (0.008 m/s) was applied in a northerly direction as input to the near-field model, following US EPA (2006). The simulation under low current speeds would cover the situation where buoyancy effects (acting upwards) are large compared to tidal advection (acting horizontally).

Table 2: Summary of the proposed Griffin diffuser configuration, discharge characteristics and ambient water properties applied in near-field modelling.

Diffuser Configuration	
Port diameter	0.05 m
Port orientation	Horizontal
Number of open ports	30
Port spacings	3 m
Depth of port below mean sea level (MSL)	9.15 m
Depth of port above seabed	0.5 m
Direction of ports	North
Discharge Characteristics	
Maximum flow rate	10 ML/day (10,000 m^3/day)
Exit velocity through each port hole	1.96 m/s
Salinity	3 ppt
Temperature	24 ^oC (average)
Ambient Waters	
Summer	
-Salinity	36 ppt
-Temperature	24 ^oC
Current speed	0.008 m/s (5th percentile)
Current direction	North (1 Degree)

The near-field simulation indicated that due to the high exit velocity (1.96 m/s through each port), the plume was initially driven by its own momentum horizontally from the outlet. As the plume velocity decreased (less than 1 m from the orifice), the buoyancy of the plume caused it to rise rapidly towards the water surface. Consequently, the velocity shear between the buoyant jet and their surroundings caused turbulence, which entrained the receiving water. This resulted in an initial dilution of approximately 1:190 within 6 m from the diffuser pipe.

Figure 14 shows the predicted plan view and cross section view of the predicted plume under a weak static current for the proposed discharge.

Please note that this initial modelling only serves to test the efficiency of the discharge configuration for the local settings and assumed a constant and relatively low current speed to estimate the minimum dilution. Output from this modelling became input for the “far-field” modelling, which simulated the saline discharge into a time-varying current field with the initial concentration set by the near-field modelling. The far-field modelling investigated the potential for concentrations to build during weak current events (i.e. weak winds) and then move off to expose more distant locations or for "double-dosing" due to the plume migrating back through the discharge zone. It also accounted for the plume being migrated further from the port under higher current speeds.

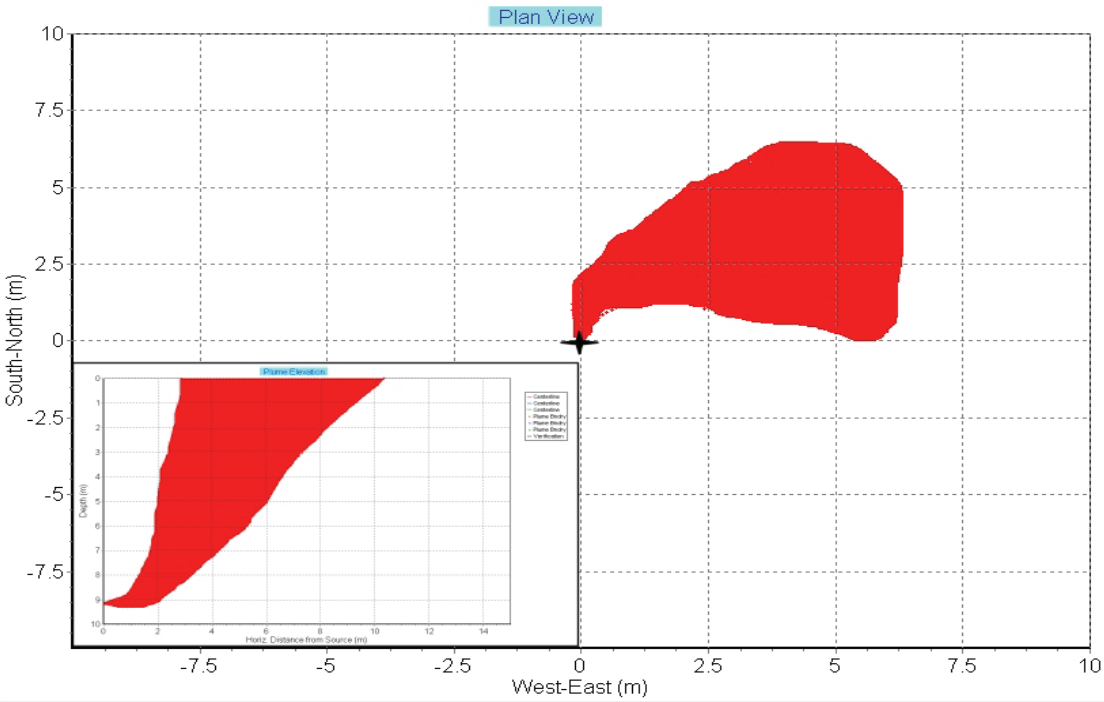


Figure 14: Predicted size and shape of the proposed plume from the Griffin outfall under a static weak summer current. The figure shows a plan view and the inset shows a cross-sectional view.

7 FAR-FIELD QUANTIFICATION OF SALINITY MIXING ZONES

The far-field salinity mixing and dispersion for the proposed discharge at the Griffin outfall was also predicted using BFHYDRO, which has been previously tested and validated for salinity and temperature intrusions (Muin, 1993; Spaulding et al., 1999).

Using the near-field modelling results as a guide, a spatially constant horizontal dispersion coefficient value of 0.1 m^2/s was used to account for the sub-grid scale turbulence and controlling the exchange of the discharge in the horizontal direction. A spatially constant, vertical dispersion value of 0.001 m^2/s (10 cm^2/s) was used to control the mixing in the vertical, based on typical values for well mixed water column (Okubo 1971). Also, the saline discharge was simulated as a uniform line across a number of grid cells, to ensure that the dynamics of the diffuser were well represented.

Far-field salinity simulations indicated that the discharge would form a surface-plume, whereby the near-surface currents would affect transport. Using the sample of summer conditions (February 2000), the salinity plume was predicted to drift northward most of the time, corresponding with the high frequency of northward currents. Figure 15 shows an example time-series of the predicted salinity for the Griffin discharge during summer conditions. Southward drift of the plume was predicted to occur at a higher frequency, and for longer durations (2-3 days) using the autumn conditions (April 2000). The generally slower currents in this period also tended to result in reduced dilution rates over the far-field. Figures 16 shows an example time-series for the discharge during autumn conditions. Note the each of the figures are shown up to 35.5 ppt, hence, greater than a 35.5 ppt were considered to be equivalent to ambient (36 ppt).

As each of the sample time series figures show, the lower than ambient salinity concentrations were patchy due to the variation in the current flows past the outfall and were generally predicted to be lowest during calm wind events. Dispersion of these lower salinity concentration patches tended to require stronger and persistent wind events to mix to within ambient levels. Further patchiness was predicted to occur when patches combined and when current reversals caused the plume to back up on itself and concentrate also known as “double dosing”.

Using the far field modelling results, 50th percentile salinity concentration contours (for each grid cell) were generated for the summer and autumn conditions (see Figure 17). The modelling results indicated that, the area and extent of the 50th percentile salinity contours were very similar for both the summer and autumn current conditions and were confined to within an 100 m radius from the diffuser (refer to Table 3).

The minimum 50th percentile salinity concentrations, area of exposure and maximum distance from the release were calculated for both seasons. As Table 3 indicates, the concentrations were producing only 0.4 ppt lower than ambient (36 ppt) for both seasons.

Finally, for both the summer and autumn conditions examined there was no overlap with the MIC and CPS existing diffusers. The extent of the 50th percentile salinity plume was predicted to be approximately 169 m away from the MIC diffuser and 353 m from the CPS diffuser.

Table 3: Minimum 50th percentile salinity, area of exposure and maximum distance (below 35.8 ppt) from the diffuser for summer and autumn conditions.

Season	Minimum 50th percentile salinity concentrations (ppt)	Area of exposure (m^2)	Maximum distance from the release site (m)
Summer	35.6	3577	80
Autumn	35.6	6901	92

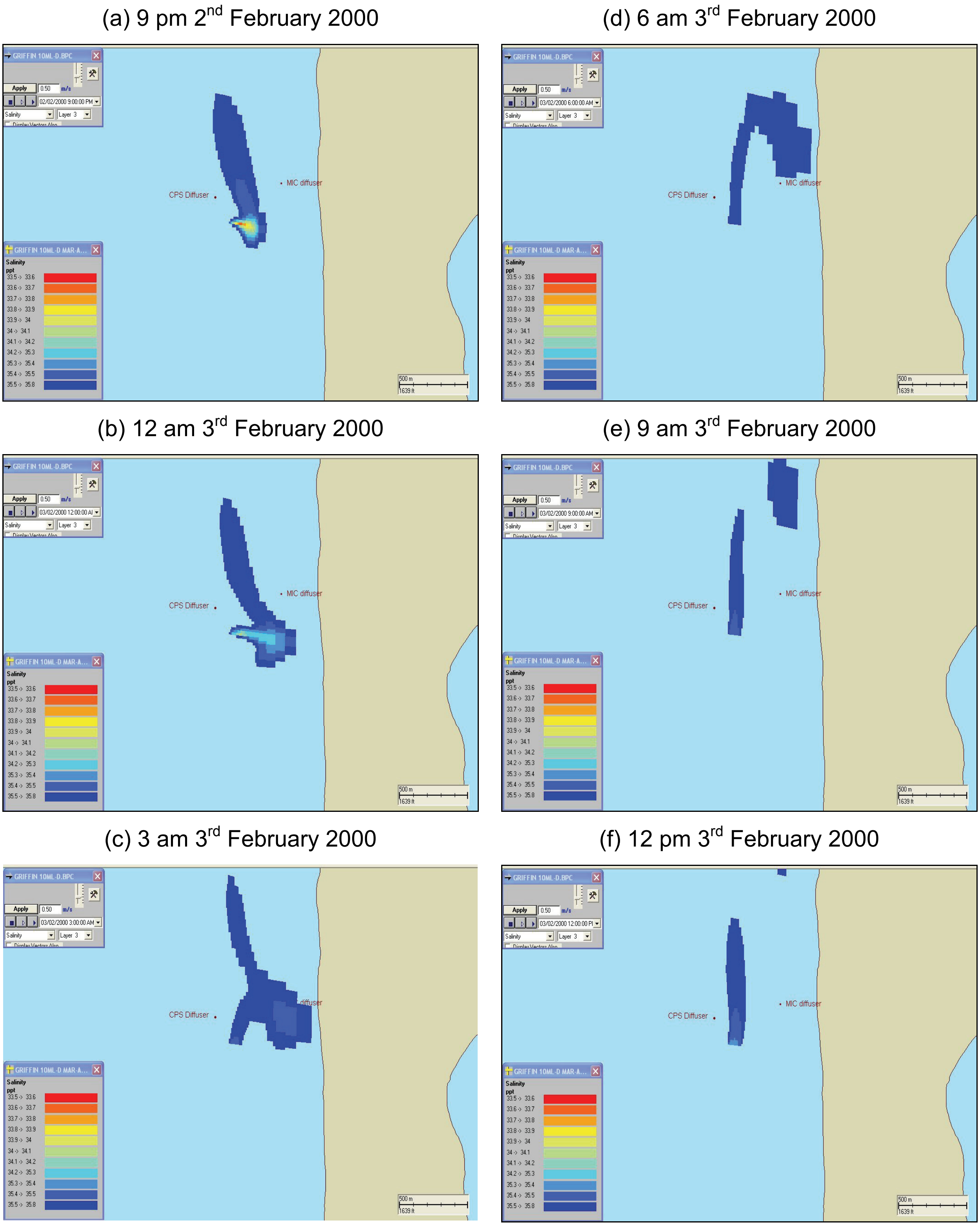
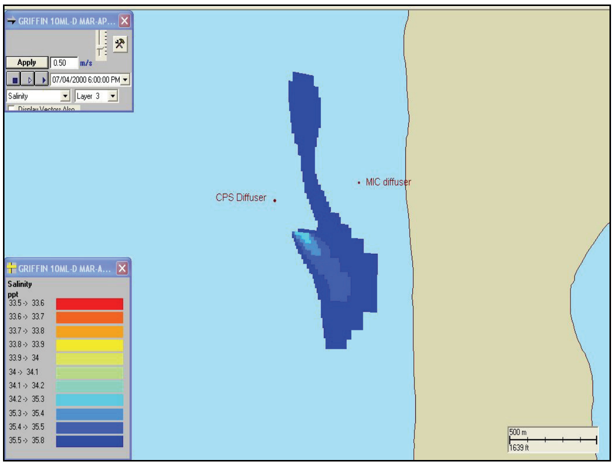
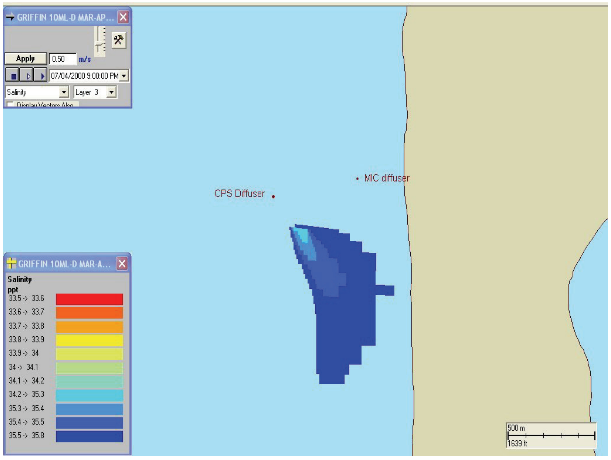


Figure 15: Example time series of the predicted salinity concentrations for the proposed 10 ML/day Griffin brackish water discharge under February 2000 current conditions.

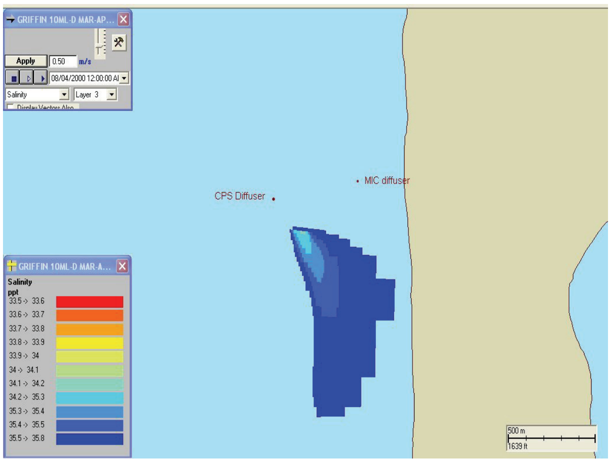
(a) 6 pm 7th April 2000



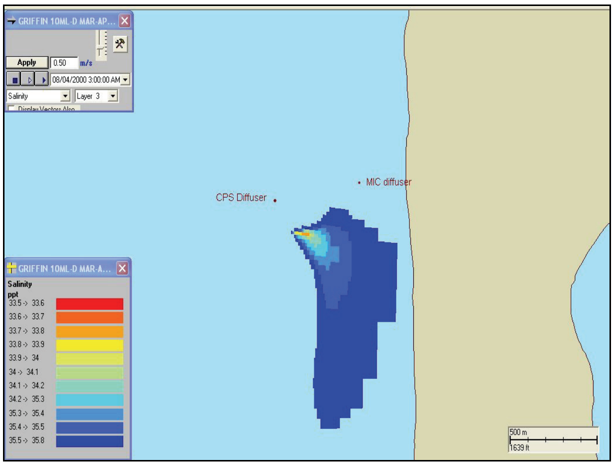
(b) 9 pm 16th April 2000



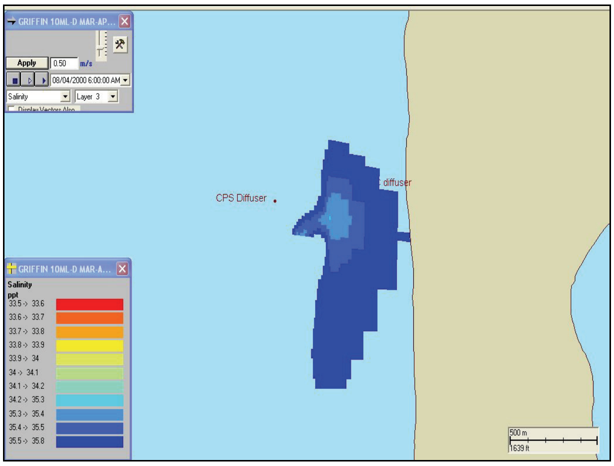
(c) 12 am 8th April 2000



(d) 3 am 8th April 2000



(e) 6 am 8th April 2000



(f) 9 am 8th April 2000

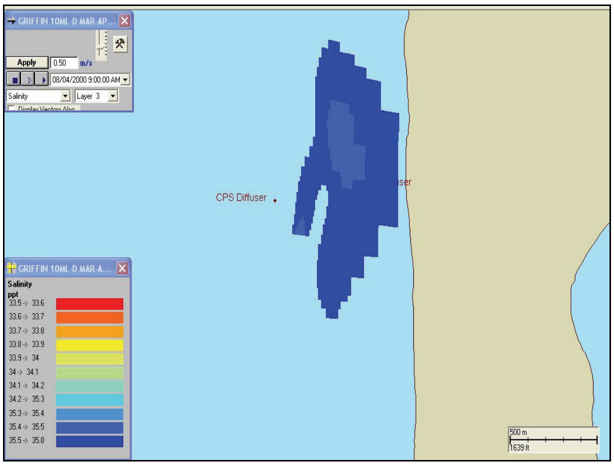


Figure 16: Example time series of the predicted salinity concentrations for the proposed 10 ML/day Griffin brackish water discharge under April 2000 current conditions.

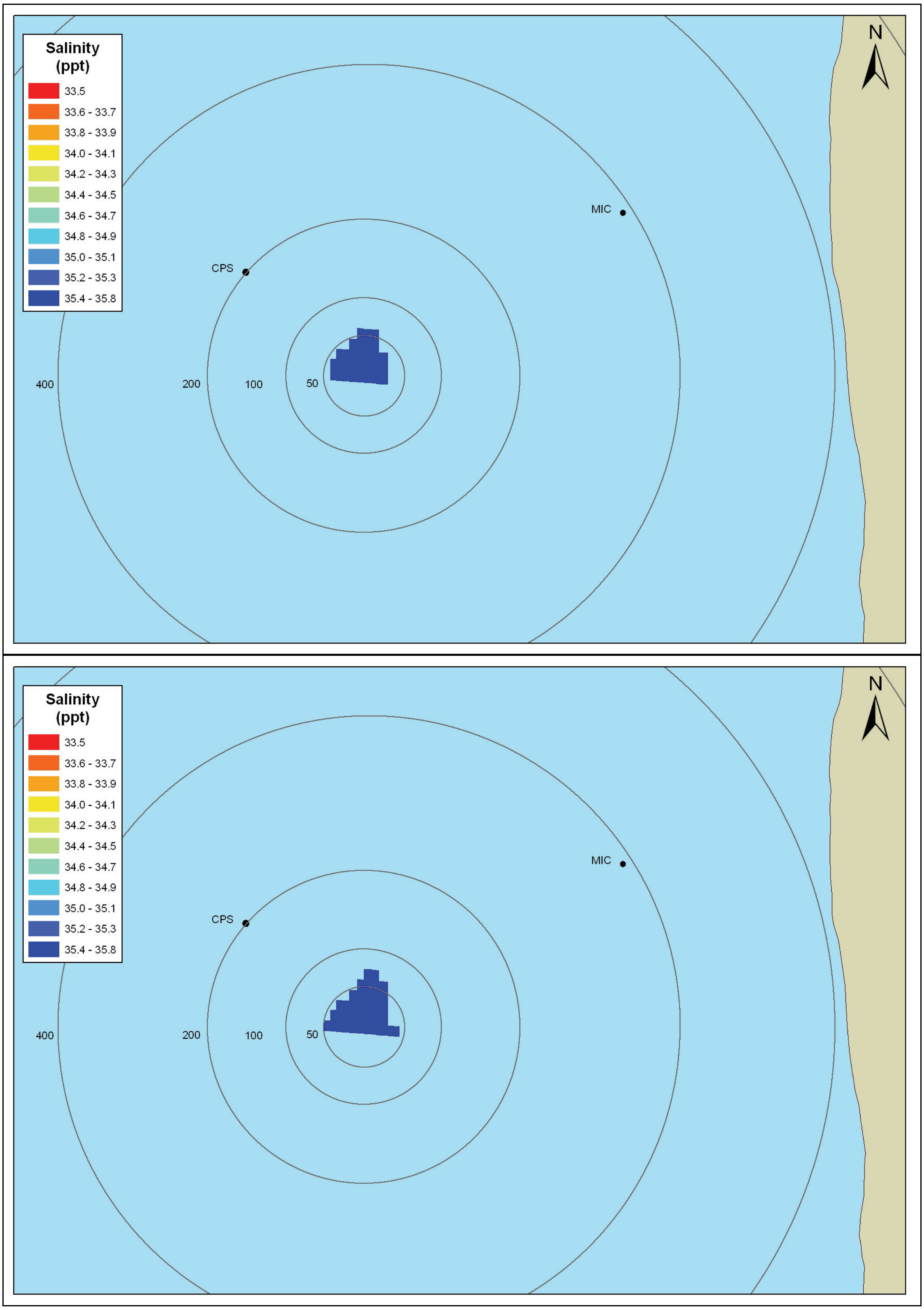


Figure 17: Predicted 50th percentile salinity concentrations (for each grid cell), during February (top) and April (bottom) 2000 current conditions. Note the circular bands show the radii from centre of diffuser in meters.

8 REFERENCES

Baumgartner, D., W. Frick., and P. Roberts., 1994. Dilution models for Effluent Discharges (3rd Ed.). EPA/600/R-94/086, U.S. Environment Protection Agency, Pacific Ecosystems Branch, Newport, Oregon.

Caldwell Connell Engineers., 1976. *Abstract of Report on Submarine Outfall Studies*. Report to Metropolitan Water, Sewerage and Drainage Board, Sydney, July 1976.

Caldwell Connell Engineers., 1980. *Analysis of oceanographic data and review of ocean outfall design concepts.* Metropolitan Water, Sewerage and Drainage Board, Sydney.

Davies-Colley, R.J., Bell, R.G. & Donnison, A.M., 1994. Sunlight inactivation of Enterococci and faecal coliforms in sewage effluent diluted in seawater, *Journal of Applied and Environmental Microbiology,* vol. 60, pp. 2049-2058.

Gameson, A.L.H. & Gould, D.J., 1985. *Investigation of sewage discharges to some British coastal waters. Chapter 8: Bacterial mortality. Part 2.* Water Research Centre Technical Report TR 222. Water Research Centre, Marlow, United Kingdom.

Huang, W. and M. L. Spaulding., 1995. A three dimensional numerical model of estuarine circulation and water quality induced by surface discharges. ASCE Journal of Hydraulic Engineering, 121:(4) April 1995, p. 300-311.

KBR., (2004). Ploom 3.2 hydrodynamic modelling of Perth's wastewater outlets". Technical report to DAL Science & Engineering Pty Ltd, May 2004PEN 185-DO-001.

kim, H.-S. and J. C. Swanson. 2001. Modelling of double flood currents in the Sakonnet River. Proceedings of the 7th Annual International Conference on Estuarine and Coastal Modeling (ECM 7), St. Pete Beach, Fl, November 5-7, 2001.

Kowalik, Z & Murty, T.S. 1993. Numerical modelling of Ocean Dynamics. World Scientific Publishing.

McCutcheon, S.C., Dongwei, Z, and Bird, S., (1990). "Model calibration, validation, and use, Chapter 5 in Technical Guidance Manual for Performing Waste Load Allocations." In: *Book III: Estuaries, Part 2: Application of estuarine waste load allocation models*. eds., Martin, J.J., Ambrose, R.B., and McCutcheon, S.C., US Environmental Protection Agency, Office of Water, March 1990.

Mathison, J-P., O. O. Jenssen, T. Utnes, J. C. Swanson and M. L. Spaulding, 1989. A Three Dimensional Boundary Fitted Coordinate Hydrodynamic Model, Part II: Testing and Application of the Model. Dt. hydrog, Z.42, 1989, p. 188-213.

Mendelsohn, D., S. Peene, E. Yassuda, S. Davie, 1999. A hydrodynamic model calibration study of the Savannah River Estuary with an examination of factors affecting salinity intrusion. Estuarine and Coastal Modeling 6 (ECM6), New Orleans, LA, 3-5 November 1999.

Muin, M. and M. L. Spaulding, 1997. A three dimensional boundary fitted coordinate hydrodynamic model, Journal of Hydraulic Engineering, Vol. 123, No. 1, January 1997, p. 2-12.

Okubo, 1971. Oceanic diffusion diagrams. Deep-Sea Research 8,789–802.

Roberts, P and X, Tian., 2004. New experimental techniques for validation of marine discharge models. Environmental Modelling and Software, 19, 691-699.

US EPA., 2006. Technical Evaluation: Physical Characteristics of Discharge US EPA document, 40 CFR 125.62 (a).

WHO., 1999. Health-based monitoring of recreational waters: the feasibility of a new approach (The 'Anapolis Protocol'). Outcome of an expert consultation, Annapolis, USA co-sponsored by USEPA.

Winiarsk, L. D and W. E. Frick., 1976. Cooling tower plume model. USEPA Ecological Research Series, EPA-600/3-76-100, USEPA, Corvallis, Oregon.

Sankaranarayanan., and M. C. Ward., 2006. Development and application of a three-dimesional orthogonal coordinate semi-implicit hydrodynamic model. Journal of Continental Shelf Research Vol. 26 pp

Spaulding, M., D. Mendelsohn and J.C. Swanson, 1999. WQMAP: An integrated three-dimensional hydrodynamic and water quality model system for estuarine and coastal applications. Marine Technology Society Journal, Volume 33, Number 3, Fall 1999, pp. 38-54.

Yassuda, E., S. Davie, D. Mendelsohn, T. Isaji, and S. Peene, 1999 Development of a waste load allocation model within Charleston Harbor estuary phase II: water quality. Estuary, Coastal and Shelf Science, Vol. 50, pp 1571 – 1594.

Zigic, S. 2005a. Methodology to calculate the time-varying flow through a hydraulic structure connecting two water bodies. PhD Dissertation. Griffith University Gold Coast Campus.

Zigic, S., King, B. and Lemckert, C. J. 2005b. Modelling the two-dimensional flow between an estuary and lake connected by a bi-directional hydraulic structure. Estuarine, Coastal and Shelf Science Vol. 63, pp 33 -41.

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