6.1 Introduction

This chapter addresses the impacts of the cooling water discharge from the proposed biomass Power Plant. The full technical report is included in **Appendix B**.

The assessment focused on the water quality and mixing zone requirements utilising a combination of near-field and far-field modelling. A number of scenarios were considered including the discharge of cooling water to the marine environment under typical and extreme conditions.

The purpose of the far-field modelling was to:

- develop three dimensional hydrodynamics of Twofold Bay;
- provide a characterisation of the depth average, alongshore currents for use in the near-field modelling; and
- provide a conservative estimate of the potential for accumulation of temperature in the vicinity of the discharge.

The purpose of the near-field modelling was to:

- determine the characteristics of the discharge plume as it disperses within the first few meters of the marine environment.

6.2 Existing Environment

6.2.1 Bathymetry and Topography

Presented in **Figure 6-1** are the bathymetry and topography contours for Twofold Bay. Twofold Bay is seen to reach depths in excess of 30 m (AHD). The study site is located on a peninsula with steep topography and at an elevation of over 10 m (AHD) overlooking the Bay.

6.2.2 Meteorology

Due to the absence of site-specific meteorology, the Air Pollution Model (TAPM) developed by the CSIRO was used to construct a year of hourly wind fields at a location over Twofold Bay (37.099 ºS, 155.899 ºE). A summary of wind speeds generated by TAPM for 2007 is presented in **Table 6-1**.

Table 6-1 Summary of Wind Speeds, 2007

Parameters	Unit	Min	1%	10%	50%	90%	99%	Max
Wind speed	m/s	0	1.2	1.8	2.7	3.9	5.7	11.7

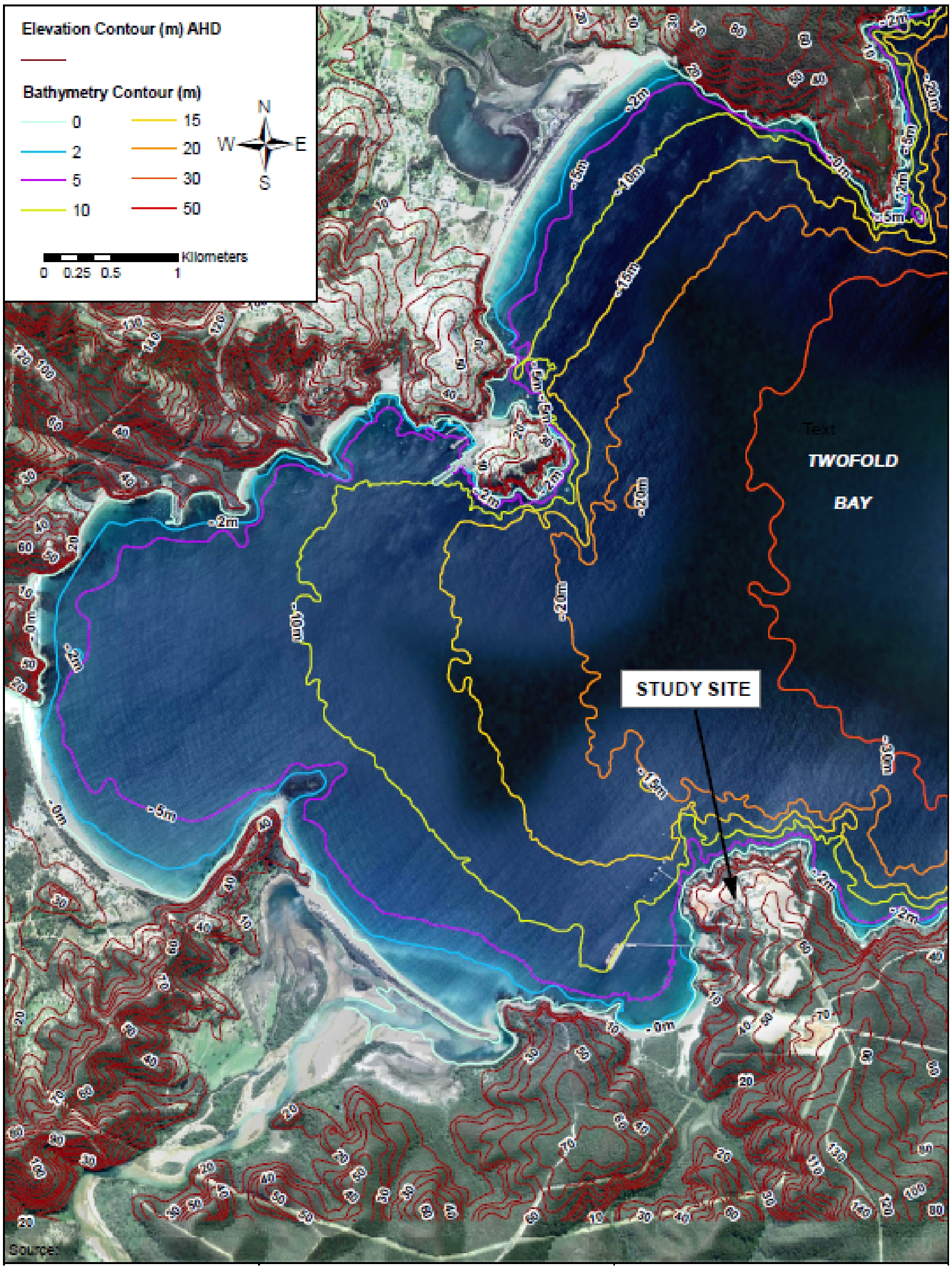

Figure 6-1 Topography and Bathymetry of Twofold Bay

6.2.3 Oceanography

Tides

Hourly tide records were obtained for the Eden tide gage for the period 17/09/1986 through 1/5/2009. Tide elevations for 2007 are presented in **Figure 6-2**. The data indicates a low frequency annual period for a small amplitude variation in water elevation, in the order of 0.25 m, peaking in January. Also evident is a spring neap tide cycle. The peak spring tide amplitude is approximately 1.75 m.

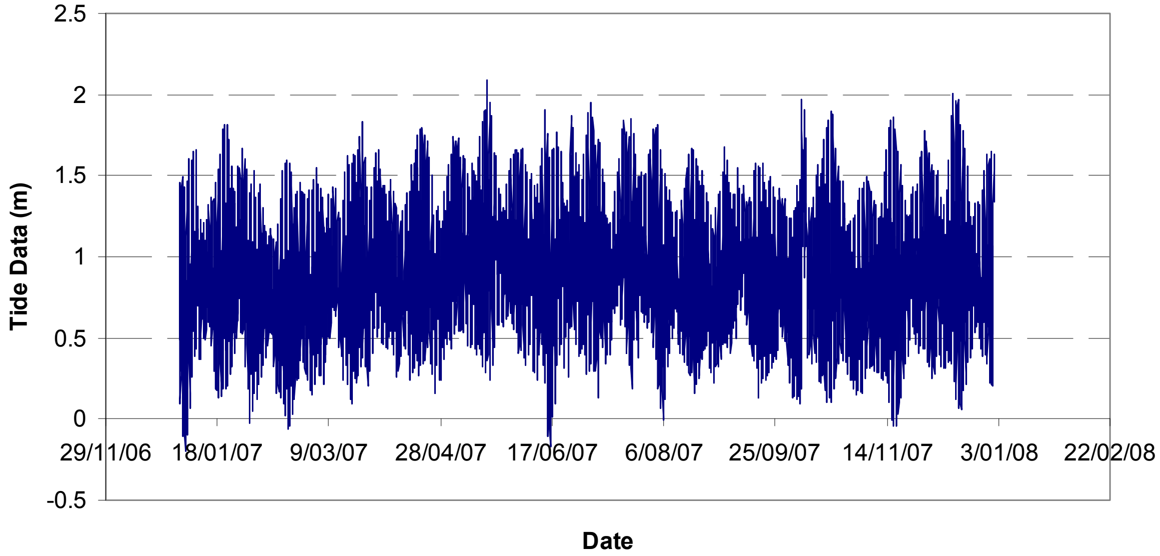

Figure 6-2 Tide Data from Eden Gauge, 2007

Currents

There was no current data available at the time of the assessment. Therefore, for the purposes of the characterisation of the ambient current environment, numerically simulated current information will be presented and has been developed using the methodology outlined in **Appendix B**.

Summarised in **Table 6-2** is the depth-averaged, alongshore current speeds extracted from the hydrodynamic modelling at the location of the diffuser outlet.

Table 6-2 Statistics for the Depth Averaged Alongshore Current Speeds

Parameters	Unit	Min	10%	25%	50%	75%	90%	Max
Current speed	m/s	0.027	0.105	0.118	0.130	0.144	0.158	0.229

6.2.4 Ambient Water Quality

To assess the effects of effluent from the diffuser discharge on the marine environment, it is necessary to consider the characteristics of the ambient environment likely to influence the dilution rate and plume behaviour.

The mean annual sea-surface temperature (17.5°C) reflects the influence of warmer waters brought into Bass Strait by the East Australian Current (EAC) (IMCRA 1998). The monthly average seawater temperature varies between 14.2°C and 20.2°C (DOM 2009) (**Table 6-3**).

The annual salinity range at Eden is 35.6 g/L to 35.7 g/L (DOM 2009), with an annual average salinity of 35.65 g/L (**Table 6-3**).

Table 6-3 Temperature and salinity monthly averages (DOM 2009)

	Jan	Feb	Mar	Apr	May	Jun
Temperature (°C)	19.6	20.1	20.2	20.1	18.3	16.4
Salinity (g/L)	35.7	35.7	35.7	35.7	35.7	35.7
	Jul	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Temperature (°C)	15.2	14.2	14.8	16.2	17.2	18
Salinity (g/L)	35.6	35.6	35.6	35.6	35.6	35.6

6.2.5 Water Quality Guidelines and the Trigger Value for Temperature

The Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000 establish the water quality standard necessary to support the identified environmental values. The guidelines provide instructions for translating the desired environmental values into water quality management criteria and also provide a framework for assessing the risks of each pollutant in the proposed discharge and how it affects each environmental value.

Environmental Values and Water Quality Objectives

Environmental values represent the characteristics or qualities of a waterway that support healthy ecosystems and the community's livelihoods and lifestyles. In ocean waters adjacent to the NSW coastline environment values are defined within the Marine Water Quality Objectives (MWQO) for NSW Ocean Waters (2005). The environmental values which apply to marine waters at the location of the proposed discharge are shown in **Table 6-4**.

Table 6-4 Environmental Values

Environmental value	Twofold Bay
Protection of high ecological value aquatic habitat	X
Protection of slightly to moderately disturbed aquatic habitat	✓
Protection of highly disturbed aquatic habitat	X
Suitability for human consumers of aquatic food	✓
Suitability for primary contact recreation (e.g. swimming)	✓
Suitability for secondary recreation (e.g. boating)	✓
Suitability for visual (no contact) recreation	✓
Protection of cultural and spiritual values	✓
Suitability for industrial use (including manufacturing plants, power generation)	✓
Suitability for aquaculture	✓
Suitability for drinking water supplies	X
Suitability for crop irrigation	X
Suitability for stock watering	X
Suitability for farm use	X

Table Notes:
✓: Bay is suitable for the environmental value.
X: Bay is not suitable for the environmental value.

Water quality criteria and guideline levels have been specified for each environmental value within the MWQO (2005). Together these represent the water quality objectives that must be maintained to achieve the specified environmental values.

Trigger Values for Temperature

The level of aquatic ecosystem protection for Twofold Bay is “slightly to moderately disturbed”. The key pollutant associated with the cooling water discharge is temperature. The water quality guidelines require that hot water discharges should not increase the temperature of the aquatic ecosystem above the 80th percentile temperature value obtained from the seasonal distribution of temperature data.

In relation to other studies of heated discharges to the marine environment, Department of Environment and Climate Change (DECC) has advised (NSW DECC reference number 282151A7:WOF13617:PW Attachment B) that:

Results of modelling scenarios should also be presented as differences between water temperatures with and without the thermal loading in order to illustrate the extent of the thermal disturbance above ANZECC (2000) trigger criteria. That is, the simulated 50th percentile temperatures must be compared with the 80th percentile natural ambient temperatures. This analysis can be undertaken for a summer period (e.g. 1st Jan to 28th Feb) and an equivalent winter period when ambient water temperatures are at a minimum.

Based on the monthly averaged temperature data presented in **Table 6-3**, the 80th percentile ambient temperature is 20.0ºC with a 50th percentile temperature of 17.6ºC. Interpreted in accordance with the comments of DECC, this suggests that the temperature differential (i.e. water temperature less the ambient temperature) should not exceed 2.4ºC. This temperature differential trigger value of 2.4ºC will be used to assess the extent of the mixing zone predicted by the near-field modelling.

6.3 Diffuser Characteristics

A concept design for the cooling water diffuser was prepared by URS (URS 2009). Information that is relevant to the assessment of the cooling water discharge is summarised in the following sections.

6.3.1 Geometry of the Diffuser

The Power Plant will use seawater cooling. Seawater will be pumped to the condenser via an above ground delivery pipeline, will pass once through the condenser, and will return via a return pipeline to the discharge point. The intake and outlet structures will be installed on the existing jetty. A schematic of the cooling system is shown in **Figure 6-3**.

The inlets will be positioned approximately 90 m from the shore where the average sea floor is at -9.2 m datum level. The outlet will be located approximately 190 m from the shore where the average sea floor is at -14 m. The outlet pipeline will end with a vertical section down to the sea floor with two 150 mm outlets at 2 m from sea bed and another two at 1 m from the sea bed. The orientation of the diffuser outlets will be parallel to the jetty and thus perpendicular to the coastline with one pair of outlets directed towards the shore, the other pair directed away from the shore. Thus the axis of the outlets has been taken as perpendicular to the alongshore currents. The diffuser geometry is summarised in **Table 6-5** and depicted in **Figure 6-4**.

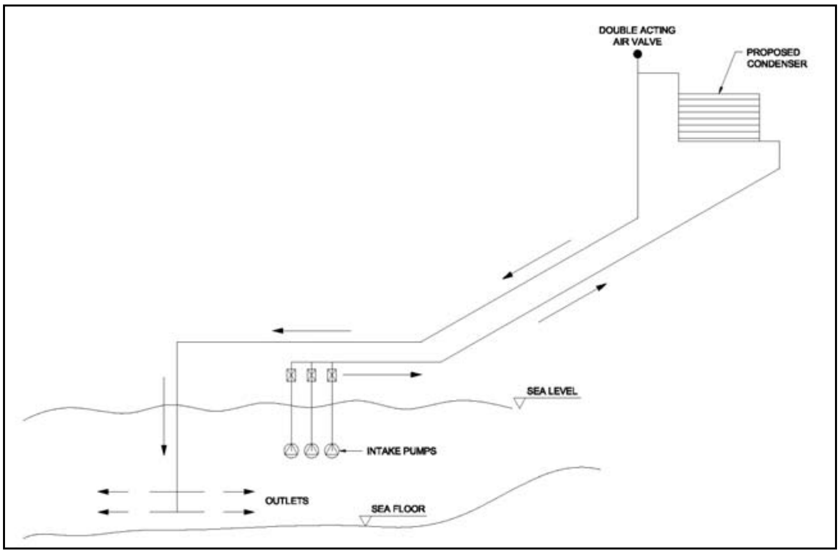

Figure 6-3 Schematic of cooling system (URS 2009)

Table 6-5 Diffuser Characteristics (URS 2009)

Parameters(1)	Units	Value
Length	m	190
Diameter	mm	400
Number of outlets	-	4
Port diameter	mm	150
Port orientation	Degrees above horizontal	0(1), 30
Port direction	Relative to the shore	Perpendicular
Port spacing	M	1
Port alignment	-	Alternating opposing orientation

Note (1): The concept design considered a 0 degree port orientation. Results of the near-field dispersion modelling suggested the use of a 30 degree port orientation to ensure that the plume does not impact the sea floor.

6.3.2 Effluent Characteristics

Consideration has been given to two cooling system design options denoted as Case 1 and Case 2, with cooling water discharge characteristics for each case summarised in **Table 6-6**. The Case 1 summer and winter scenarios involve a larger ambient to discharge temperature differential and a lower flow rate when compared with Case 2.

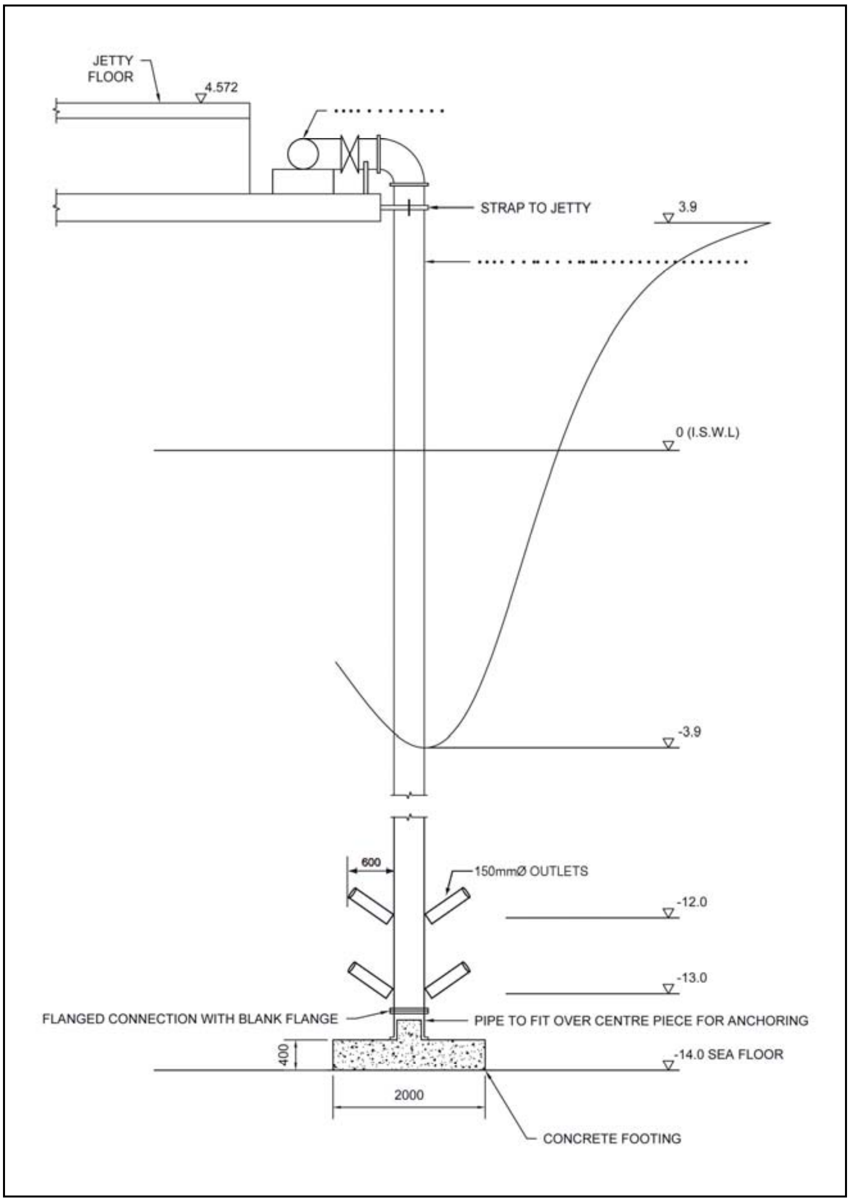

Figure 6-4 Diffuser Concept Design (Adapted from URS 2009)

Although the summer and winter temperature differential (i.e. discharge temperature minus the ambient temperature) is 21.1°C (case 1) or 19.1 °C (Case 2) during winter, and 10°C (Case 1) or 8°C (Case 2) during summer, the estimated heat load to the ambient environment (Q) which is proportional to the mass flow (m) and the temperature differential (ΔT), is constant throughout the year.

Table 6-6 Cooling Water Quality Characteristics

Scenario	Units	Case 1		Case 2	
		1A	1B	2A	2B
		Summer	Winter	Summer	Winter
Seawater temperature in	°C	23	13	23	13
Temperature rise	°C	10	21.1	8	19.1
Seawater temperature out	°C	33	34.1	31	32.1
Flow rate	litres/s	333	158	416	174

6.4 Far-Field Modelling

The model selected for the far-field modelling was the Environmental Fluid Dynamics Code (EFDC) which is supported and approved by the US Environmental Protection Agency (USEPA). The EFDC model solves the three-dimensional, vertically hydrostatic, free surface, turbulent averaged equations of motion for a variable density fluid.

6.4.1 Model Configuration

Details of the model configuration are provided in **Appendix B**. The EFDC model was configured using:

- five vertical levels;
- one year of tide data (01/01/07 through 31/12/07);
- one year of simulated meteorological data (01/01/07 through 31/12/07);
- constant heat loading of the ambient environment in the vicinity of the discharge; and
- constant ambient temperature and salinity. The monthly averaged temperature and salinity data presented in **Table 6-3** was not available at the time of the EFDC model set up and thus simulations were conducted using a fixed temperature and constant thermal loading throughout the year. This will not have a significant impact on the far-field modelling results.

6.4.2 Summary of Findings and Outcomes of the Far Field Modelling

The results of the far-field modelling suggest that:

- there is the potential for a background accumulation of temperature in the vicinity of the diffuser outlet of 0.25°C; and
- the hydrodynamic simulations provided a time series of depth averaged along-shore current velocities in the vicinity of the diffuser outlet that suggests the currents range in velocity from 0.03 m/s to 0.23 m/s.

Data were not available with which to characterise seasonal water column characteristics of temperature and salinity and thus a uniform water column (i.e. well mixed) has been assumed.

6.5 Near-Field Modelling

CORMIX modelling was used for the near-field assessment of the dispersion characteristics of the cooling water discharge.

6.5.1 Preliminary Assessment of Case 1 and Case 2 Design Options

In order to assess the two cooling system design options Case 1 and Case 2, four discharge scenarios were modelled with parameter values summarised in **Table 6-7**.

Table 6-7 Discharge Characteristics

Scenario	Units	Case 1		Case 2	
		1A	1B	2A	2B
		Summer	Winter	Summer	Winter
Seawater temperature in	°C	23	13	23	13
Temperature rise	°C	10	21.1	8	19.1
Seawater temperature out	°C	33	34.1	31	32.1
Flow rate	litres/s	333	158	416	174
Outlet angle wrt horizontal	degrees	30	30	30	30
Ambient current(1)	m/s	0.105	0.105	0.105	0.105
Salinity (ambient & discharge)(2)	ppt	35.65	35.65	35.65	35.65

Note (1): Based on the 10th percentile current velocity
(2): Based on the average value

6.5.2 Results of the Preliminary Assessment

Summarised in **Table 6-8** are the results of the near-field assessment for the four scenarios. Included in the table are the discharge temperature, the temperature differential, and the dilution at a downstream distance of 10 m from the diffuser as well as the temperature differential and dilution at 100 m. Results include an accumulation of 0.3°C based on the findings of the far-field modelling.

Table 6-8 Results of the Near-Field Assessment at 10 m and 100 m from the Outlet

Parameter	Units	Case 1		Case 2	
		Summer	Winter	Summer	Winter
		1A	1B	2A	2B
Ambient temperature	ºC	23.0	13.0	23.0	13.0
Discharge temperature	ºC	33.0	34.1	31.0	32.1
Temperature @ 10 m	ºC	23.6	13.8	23.6	13.8
Temperature differential @ 10 m	ºC	0.6	0.8	0.6	0.8
Temperature differential @ 100 m	ºC	0.5	0.5	0.5	0.5
Dilution @ 10 m		18.1	29.1	16.0	29.6
Dilution @ 100 m		22.2	50.6	18.1	49.2

For ease of comparison with the trigger value for temperature of 2.4ºC (discharge water to ambient water temperature differential), results for the summer and winter scenarios of Case 1 and Case 2 are presented in **Figure 6-5** as the temperature differential.

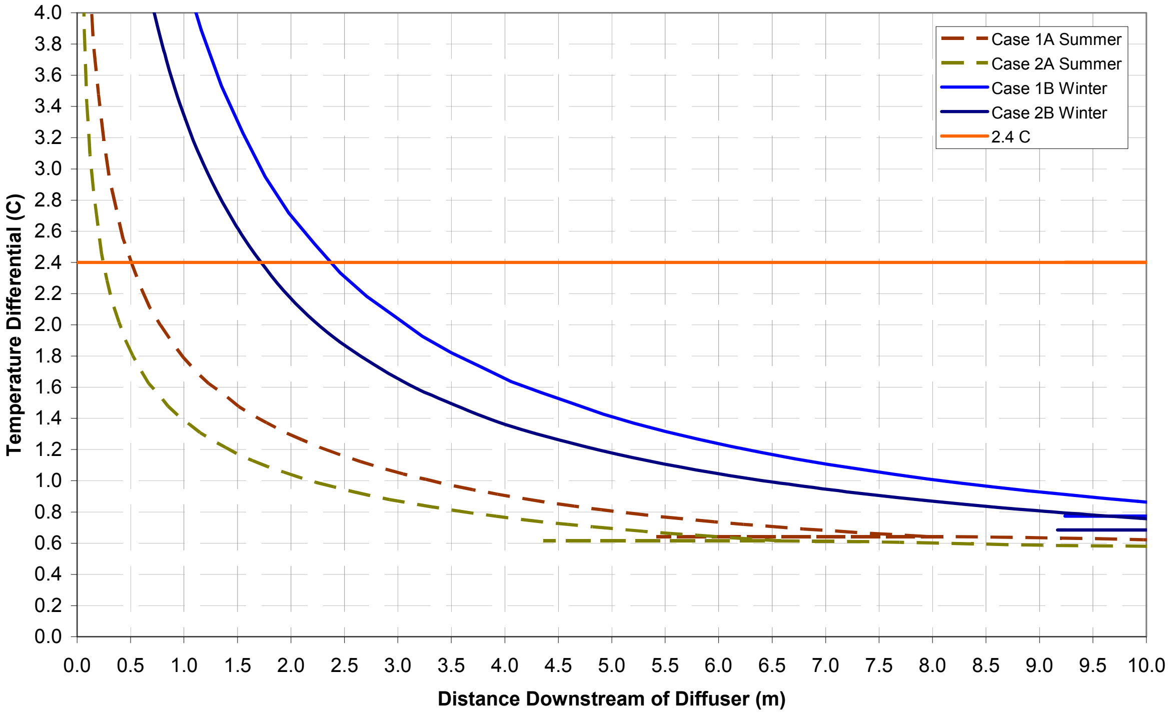

Figure 6-5 Temperature Differential for Case 1 and Case 2 as a Function of Distance Downstream of Diffuser

Results suggest that the centreline temperature differential between the discharge plume and the ambient environment will fall below the trigger value of 2.4ºC within 0.5 m (summer scenarios) and 2.5 m (winter scenarios) from the diffuser. Not surprisingly, winter scenarios (Case 1B and Case 2B) are associated with a larger zone of exceedance of the 2.4ºC trigger value.

Case 2 which has a smaller initial temperature differential and an increased flow rate compared with Case 1 has a slightly smaller area of exceedance for both the summer and winter scenarios.

It should be noted that the discontinuities in **Figure 6-5** (for example Case 2A) are the result of the use of multiple solution techniques by CORMIX where the selection of the theoretical model is based on the stage of plume development and its location within the marine environment. The discontinuities are associated with the discharge plume reaching the surface of the water column.

Based on communications with SEFE, it was concluded that the differences in the environmental outcomes between Case 1 and Case 2 did not warrant the large operational cost differential between these two design options. Case 1 will require lower flow rates than Case 2 and result in a significant reduction in pump running costs. Case 1 was therefore selected as the preferred option and was the focus of the detailed assessment.

6.5.3 Detailed Assessment of Diffuser Design Option Case 1

Based on the continuous nature of the proposed discharge, scenarios assessed focused on the worst, typical and extreme current and wind velocities within both a uniform and stratified ambient environment. Parameter values associated with each of the scenarios are summarised in **Table 6-9**.

In relation to the representativeness of the scenarios the following apply:

- calm conditions (current & wind) – scenario 1;
- typical conditions (current & wind) – scenario 8; and
- worst-case conditions (current & wind) – scenario 12.

Table 6-9 Modelled Scenarios for the Detailed Assessment

Scenario	Vertical Structure(0)	Current Speed (m/s)	Wind Speed (m/s)	Comments	
				Currents	Winds
1	U	0.027	0.0	Minimum	Minimum
2	U	0.027	2.7	Minimum	Median
3	U	0.027	14.7	Minimum	Maximum
4	U	0.105	0.0	10^{th} percentile	Minimum
5	U	0.105	2.7	10^{th} percentile	Median
6	U	0.105	14.7	10^{th} percentile	Maximum
7	U	0.130	0.0	Median	Minimum
8	U	0.130	2.7	Median	Median
9	U	0.130	14.7	Median	Maximum
10	U	0.229	0.0	Maximum	Minimum
11	U	0.229	2.7	Maximum	Median
12	U	0.229	14.7	Maximum	Maximum
13	S1	0.027	0.0	Minimum	Minimum

Note (0): U (Uniform ambient environment), S (stratified ambient environment)
(1): Stratified conditions are associated with periods for which both current velocities and wind speeds are minimal and a minimum of 3 °C temperature difference between the near surface and the bottom water.

6.5.4 Results of the Detailed Assessment

Presented in **Table 6-10** are the results of the detailed near-field assessment which includes a range of current velocities and wind speeds. A single stratified scenario (#13) has been considered which assumes a constant salinity profile with depth and a temperature differential between near surface and bottom temperatures of 3ºC. Results of the detailed assessment suggests that the trigger value for temperature of ΔT less than 2.4ºC will be achievable within 3.5 m of the diffuser outlet

Table 6-10 Results for the Discharge Scenarios

Case	Distance to ΔT = 2.4ºC	ΔT @ 10 m	Dilution @10 m	Dilution @ 100 m
Summer				
1	<0.5	0.45	24.25	28.25
2	<0.5	0.45	24.25	28.34
3	<0.5	0.45	24.25	34.52
4	<0.5	0.64	18.06	22.18
5	<1	0.62	18.67	22.20
6	<1	0.62	18.67	27.69
7	<1	0.60	19.52	24.06
8	<1	0.60	19.52	24.12
9	<1	0.60	19.52	28.15
10	<1	0.66	18.13	32.21
11	<1	0.66	18.13	32.21
12	<1	0.66	18.13	32.79
13	<0.5	0.49	22.69	27.17
Winter				
1	<1	1.31	17.7	26.5
2	<1	1.31	17.8	27.6
3	<1	0.92	30.9	70.4
4	<2.5	0.80	29.1	50.6
5	<2.5	0.86	28.7	50.6
6	<2.5	0.86	28.7	59.1
7	<3	0.92	27.0	55.0
8	<3	0.92	27.0	55.0
9	<3	0.92	27.0	60.5
10	<3.5	1.14	22.3	63.6
11	<3.5	1.14	22.3	63.6
12	<3.5	1.14	22.3	65.0
13	<1	1.37	16.9	25.9

Presented in **Figure 6-6** is the temperature differential as a function of downstream distance from the diffuser for Scenario 12 which represents worst-case conditions and is associated with a maximum current velocity of 0.229 m/s and maximum wind speed of 14.7 m/s.

The trigger value of 2.4°C has been included for ease of comparison. Results suggest that the trigger value is able to be satisfied outside a region approximately 3.2 m from the outlet of the diffuser.

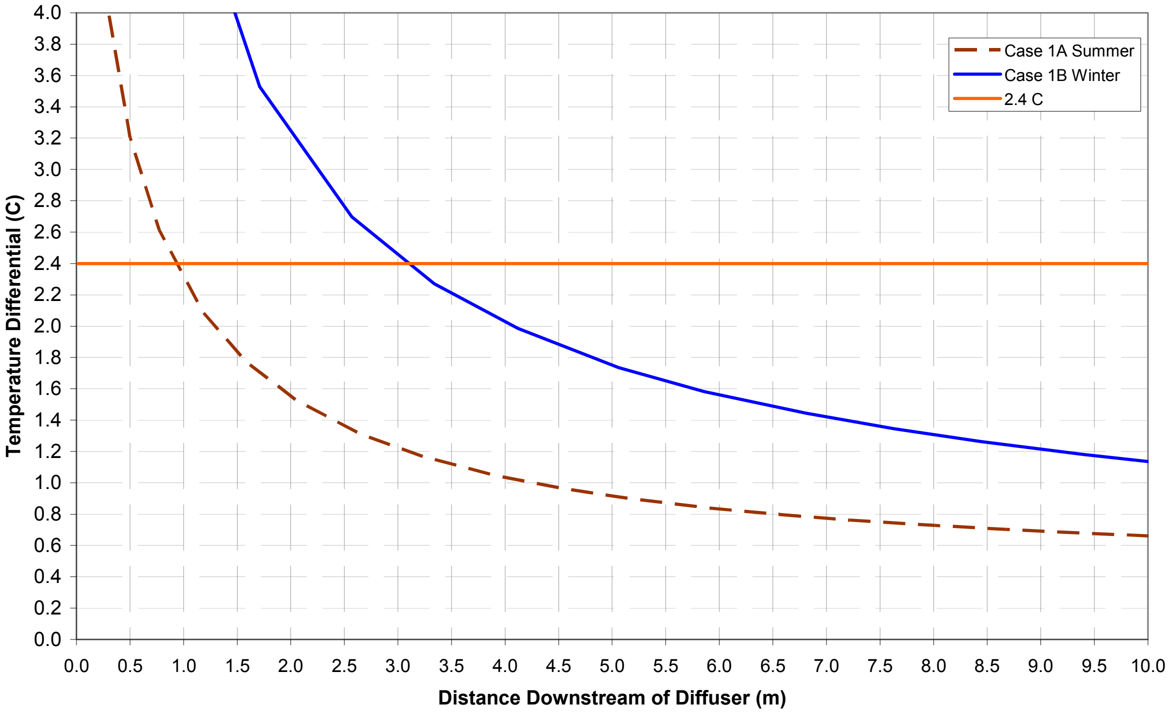

Figure 6-6 Scenario 12 Temperature Differential as a Function of Distance Downstream of Diffuser

6.6 Summary of Findings

The results of the near-field and far-field assessment of cooling water discharge demonstrate that:

- modification to the diffuser design can improve environmental outcomes;
- water quality objectives associated with trigger values for temperature can be achieved within 3.5 m from the outlet of the diffuser; and
- an accumulation of temperature in the vicinity of the diffuser outlet of 0.3ºC is considered to be a conservative estimate of the potential for localised elevation of background temperatures.

6.7 Mitigation Measures

Based on the above findings the following management measures are proposed:

- additional near-field modelling will be undertaken to further optimise the design of the diffuser during the detailed design phase of the project; and
- once the diffuser becomes operational, a model validation exercise will be undertaken with the objective of validating the findings of the near-field model predictions for dilution with distance from the diffuser. Such an exercise may involve (for example) a dye-release study during which a controlled concentration of a dye is released via the diffuser and the plume tracked throughout the water column using a fluorometer. Validation could occur during both summer and winter discharge conditions. Observations of the dilution rate with distance from the diffuser would then be compared with modelling results. The dye proposed would be approved by DECCW prior to use. In order to ensure that the model inputs accurately represent the conditions during the sampling period, data that will be collected at the time of the field study includes (but may not be limited to):
  - water column temperature and salinity profiles;
  - water column current velocities; and
  - meteorological conditions such as wind speed, wind direction and air temperature.

A summary of the mitigation measures applicable to the proposed works is provided **Table 6-11**.

Table 6-11 Mitigation Measures

Mitigation Measure	Project Stage		
	Pre construction	Construction	Operations
Additional near-field modelling will be undertaken to further optimise the design of the diffuser during the detailed design phase of the project.	✓		
Once the diffuser becomes operational, a model validation exercise will be undertaken with the objective of validating the findings of the near-field model predictions for dilution with distance from the diffuser.			✓