Southern Seawater Desalination Project

Overview of Water Quality -

Physical Parameters

March 2008

Project Number:

N-CWO1781

N-CWO1783

Document Number:

AQUA 626241

File JT1 2007 07426 Vol 1

Document History

Report	Version	Prepared by	Reviewed by
Southern Seawater Desalination Project: Overview of Water Quality – Physical Parameters.	Draft for internal review 200308	D. Luketina	F. Faskel
Southern Seawater Desalination Project: Overview of Water Quality – Physical Parameters.	Draft for EPASU review (prior to public release) 200308	D. Luketina	(no change)
Southern Seawater Desalination Project: Overview of Water Quality – Physical Parameters.	Final (includes GHD addendum data) 100408	D. Luketina	

Table of Contents

List of Figures

1 Introduction

This report provides a brief overview of the marine monitoring of physical parameters (temperature, salinity, dissolved oxygen and turbidity) collected for the Southern Seawater Desalination Project (SSDP). Each of these parameters is discussed separately followed by a brief discussion of sediment oxygen demand, stratification duration and dissolved oxygen lowering under stratified conditions.

An overview of the data collection programme is provided in Figure 1.1. The data presented in the following sections is a composite of the data collected from this programme.

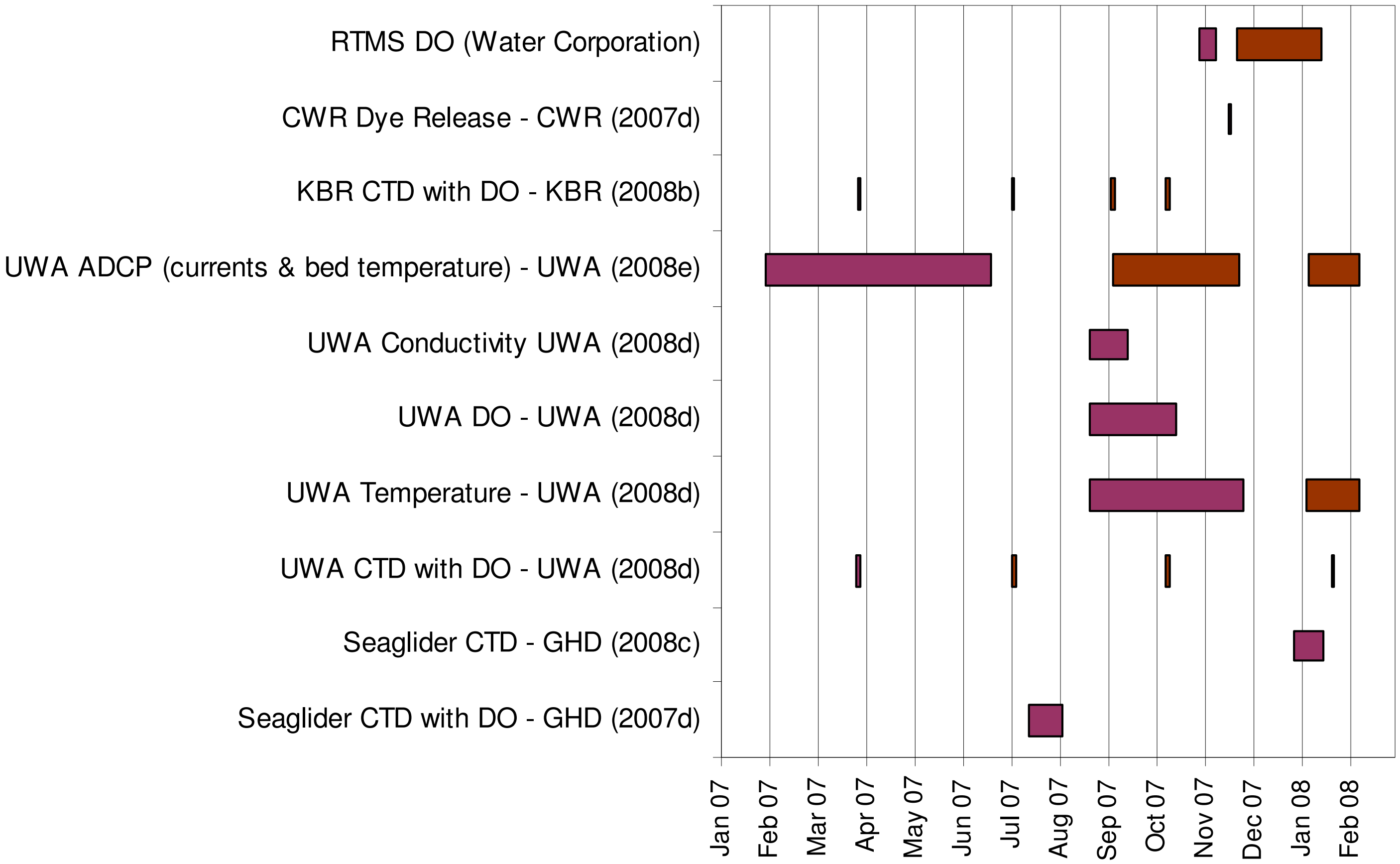

Figure 1.1 Overview of the monitoring of physical parameters

2 Seasonal Temperature Behaviour

Water column temperature data were gathered via CTD (Conductivity, Temperature, Depth) profilers (UWA 2008d and KBR 2008b), a Seaglider (GHD 2007d; 2008c) and thermistors at fixed heights (Real Time Monitoring System - RTMS and UWA 2008d). The RTMS was implemented by the Water Corporation and consists of sensors at fixed heights above the bed. The seaglider is an instrument that moves up and down through the water column as it moves forward. A compilation of the temperature data is shown Figure 2.1. Due to the large amount of data, only sub-sampled data is shown in Figure 2.1. The reports of UWA 2008d, KBR 2008b, GHD 2007d; 2008c and UWA 2008d should be viewed if more detail is required.

It can be seen that the temperature varies on a seasonal basis with a peak of around 24ºC in summer-autumn and a minimum of around 15ºC in winter-spring. Temperature fluctuations of up to 2ºC from this general seasonal behaviour can occur over periods of around 10 days of so. Analysis of temperature data (see UWA 2008d) shows that the site experiences well mixed conditions the majority of the time. A regular diurnal stratification-destratification cycle was observed where solar heating stratified the water column in temperature, which was then well-mixed by wind and over-night cooling.

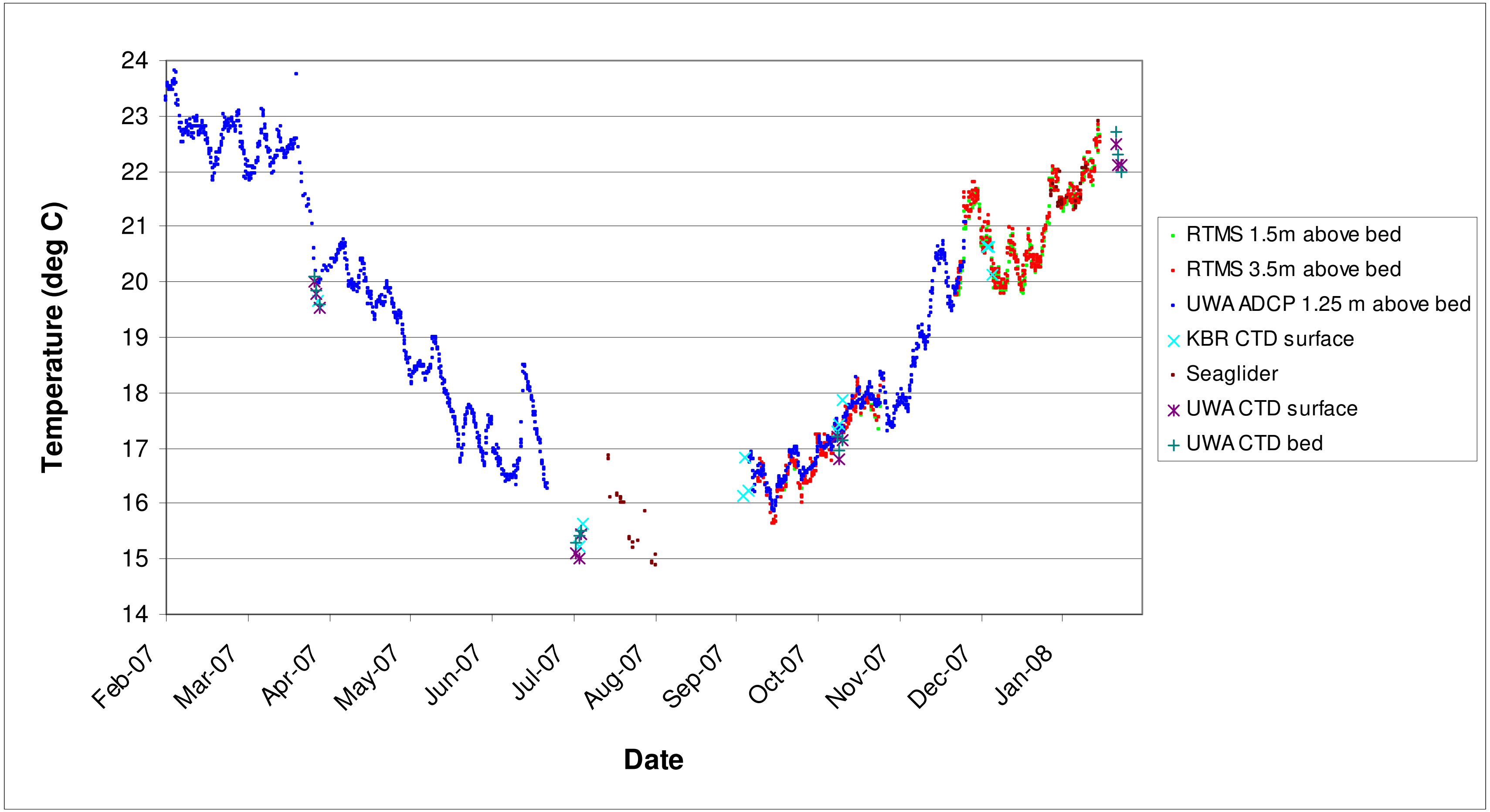

Figure 2.1 Temperature data collected at the Binningup site

3 Seasonal Salinity Behaviour

Salinity data were gathered via CTD profilers (UWA 2008d, KBR 2008b, Oceanica 2008a), a Seaglider (GHD 2007d; 2008c) and conductivity sensors at fixed heights (RTMS and UWA 2008d). A compilation of salinity data is shown in Figure 3.1. Due to the large amount of data, only sub-sampled data is shown in Figure 3.1. The reports of UWA 2008d, KBR 2008b, GHD 2007d; 2008c, and Oceanica 2008a should be viewed if more detail is required.

The salinity can be seen to generally vary on a seasonal basis with a peak of around 36.5 ppt in summer-autumn and a minimum of around 34.5 ppt in winter-spring. During rainfall events, freshwater outflow from the Harvey Diversion Drain mixing into Binningup marine waters can result in salinities as low as 30 ppt (see GHD 2007d for detailed plots).

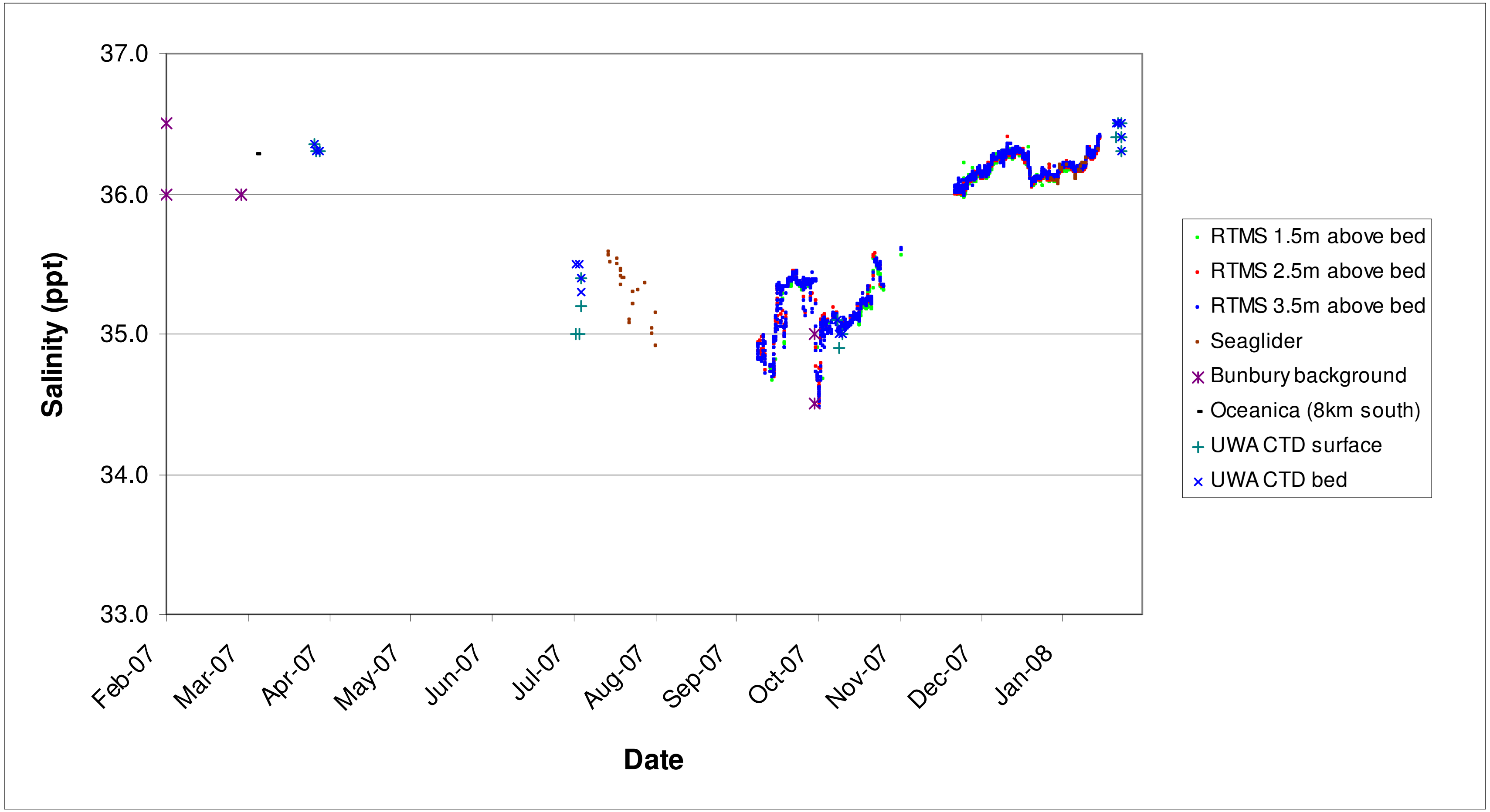

Figure 3.1 Salinity data collected at or near the Binningup site

4 Observed Dissolved Oxygen Levels

Dissolved oxygen data were gathered specifically for the SSDP for a period of over a year, utilising a combination of dissolved oxygen probes on a Seaglider (GHD 2007d), CTD profilers (UWA 2008d, KBR 2008b, Oceanica 2008a) and at fixed heights (RTMS and UWA 2008d). A compilation of 24 hour averaged (all data collected on the same day via a sensor were averaged to produce a single value for that sensor) dissolved oxygen data is shown in Figure 4.2. The reports of UWA 2008d, KBR 2008b, GHD 2007d and Oceanica 2008a should be viewed if more detail is required.

The dissolved oxygen data presented in Figure 4.2 is in units of mg/L. Dissolved oxygen data are also presented as % saturation in the reports of UWA 2008d, KBR 2008b, GHD 2007d. The relationship between dissolved oxygen in mg/L and % saturation for seawater is shown in Figure 4.1.

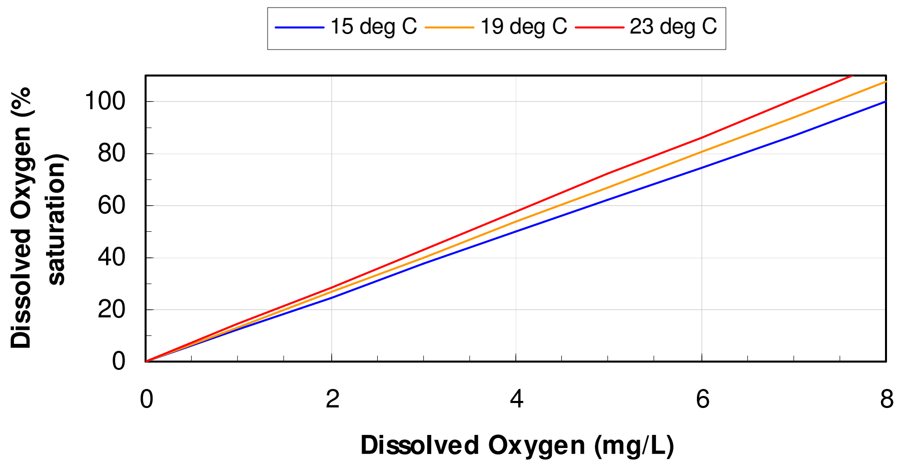

Figure 4.1 Relationship between dissolved oxygen in mg/L and % saturation

Dissolved oxygen concentrations based on a 24 hour average are generally between 6.5 and 8.5 mg/L with the lowest reading being 6.4 mg/L (i.e. above 80% saturation). There are only a few instances in isolated locations (i.e. dissolved oxygen was higher elsewhere) where the instantaneous dissolved oxygen reading dropped to around 5 mg/L (see UWA 2008d).

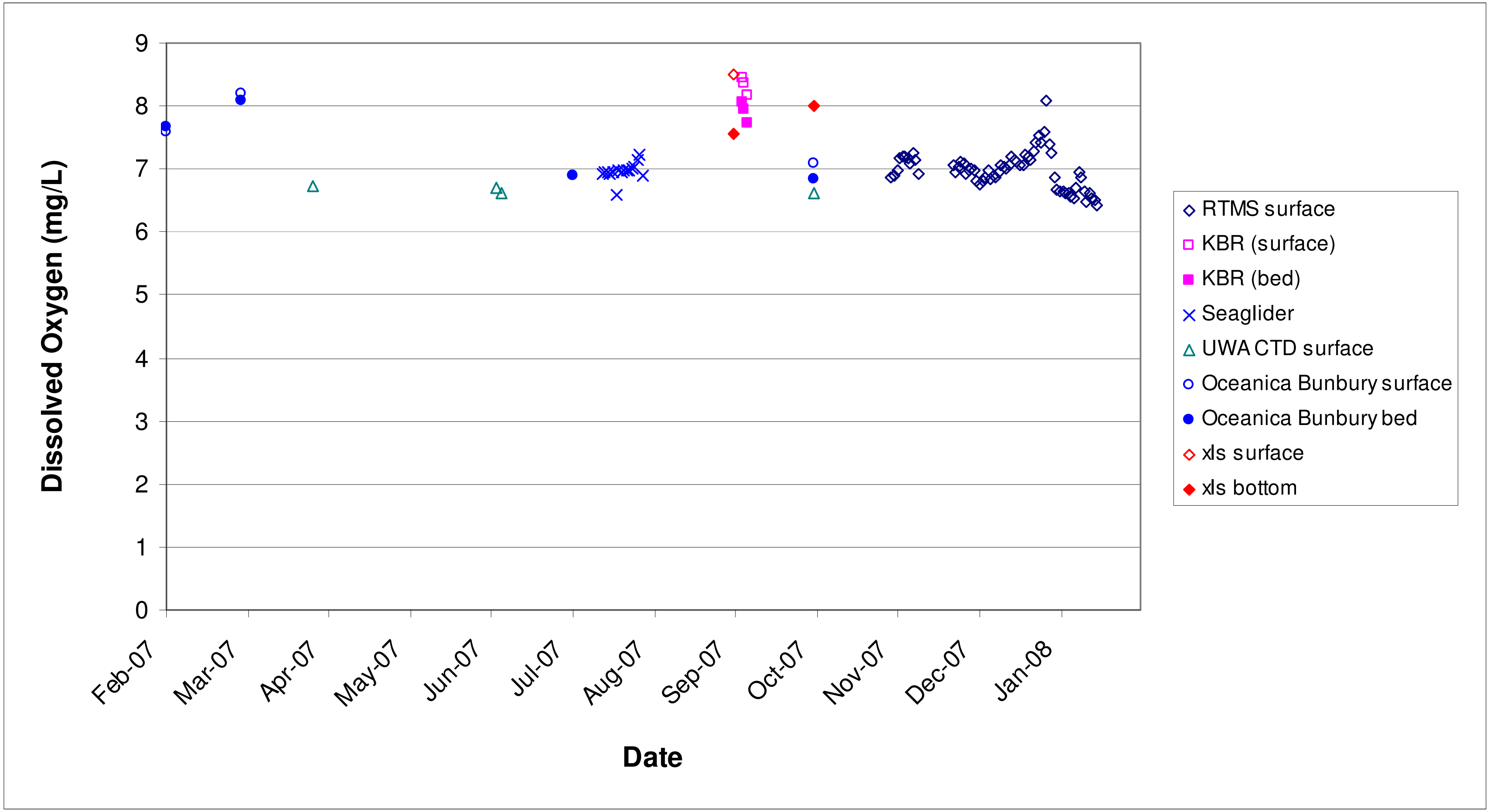

Figure 4.2 Dissolved oxygen data (mg/L) collected at or near the Binningup site as 24 hour averages

5 Observed Turbidity Levels

Turbidity data was collected by CTD profilers (KBR 2008b) and a Seaglider (GHD 2007d; 2008c). A compilation of this turbidity data is shown in Figure 5.1.The data from KBR 2008b was separated into surface (around 0.5 m below the surface) and bed (around 0.5 m above the bed) samples. The reports of KBR 2008b, GHD 2007d and GHD 2008c should be viewed if more detail is required.

Turbidity is typically in the range of 1 to 4 NTU at or near the water surface and 3 to 20 NTU near the bed.

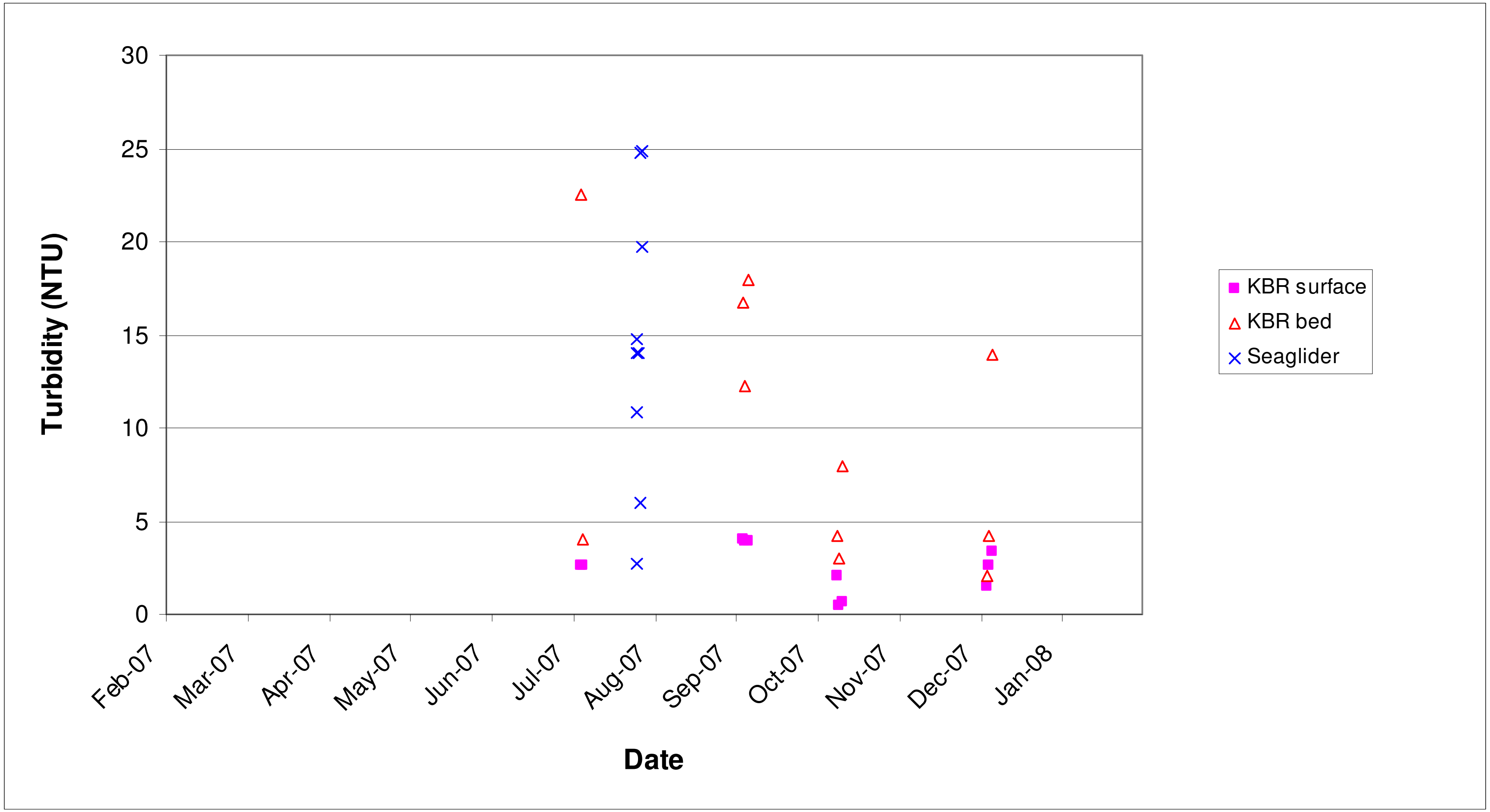

Figure 5.1 Turbidity data collected at the Binningup site

6 Sediment Oxygen Demand

The level of dissolved oxygen near the seabed in open shallow marine waters typically depends on the balance between supply of oxygen (mixed downwards from the atmosphere) and consumption of oxygen by microbial processes in the sediments (known as Sediment Oxygen Demand or SOD). Mixing, and hence the supply of oxygen, is lowest when there are light winds and/or density stratification.

Based upon laboratory tests (UWA 2008), the SOD of the bed sediments has been determined to be:

$$SOD\ (g/m^2/day) = k\ DO\ (mg/L)$$

where DO is the dissolved oxygen concentration and k = 0.058 for Binningup sediments. For Cockburn Sound sediments k = 0.02 (UWA 2005).

7 Duration of Stratification

Following rainfall events, freshwater flows from the Harvey Diversion Drain (around 2 km north of the diffuser) into the ocean. This results in a layer of lighter fresher water overlying more saline heavier water. The largest observed density stratification (i.e. the difference in density between the surface and bottom water) is due to the rainfall shown in Figure 7.1.

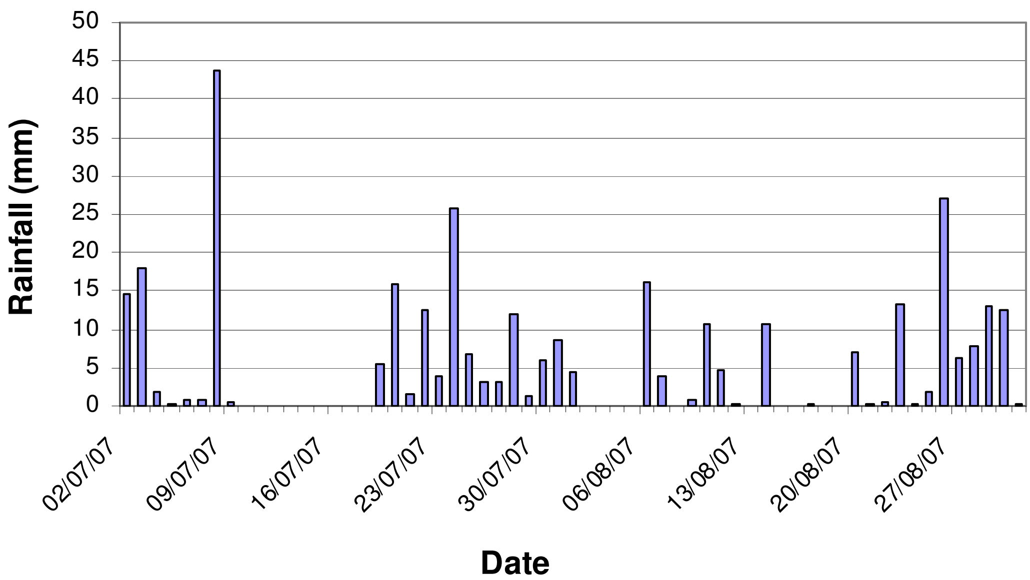

Figure 7.1 Rainfall in Bunbury in July and August 2007 (from Bureau of Meteorology)

The stratification, as shown in Figure 7.2 for 1 to 2 August 2007, was approximately 0.4 kg/m^3 - due mostly to a salinity stratification of around 0.6 ppt. Similar stratification was still present on 3 to 4 August 2007. However, dissolved oxygen levels, as measured by the Seaglider, remained above 8 mg/L (GHD, 2007) for the duration of the 14 July to 4 August 2007 Seaglider survey.

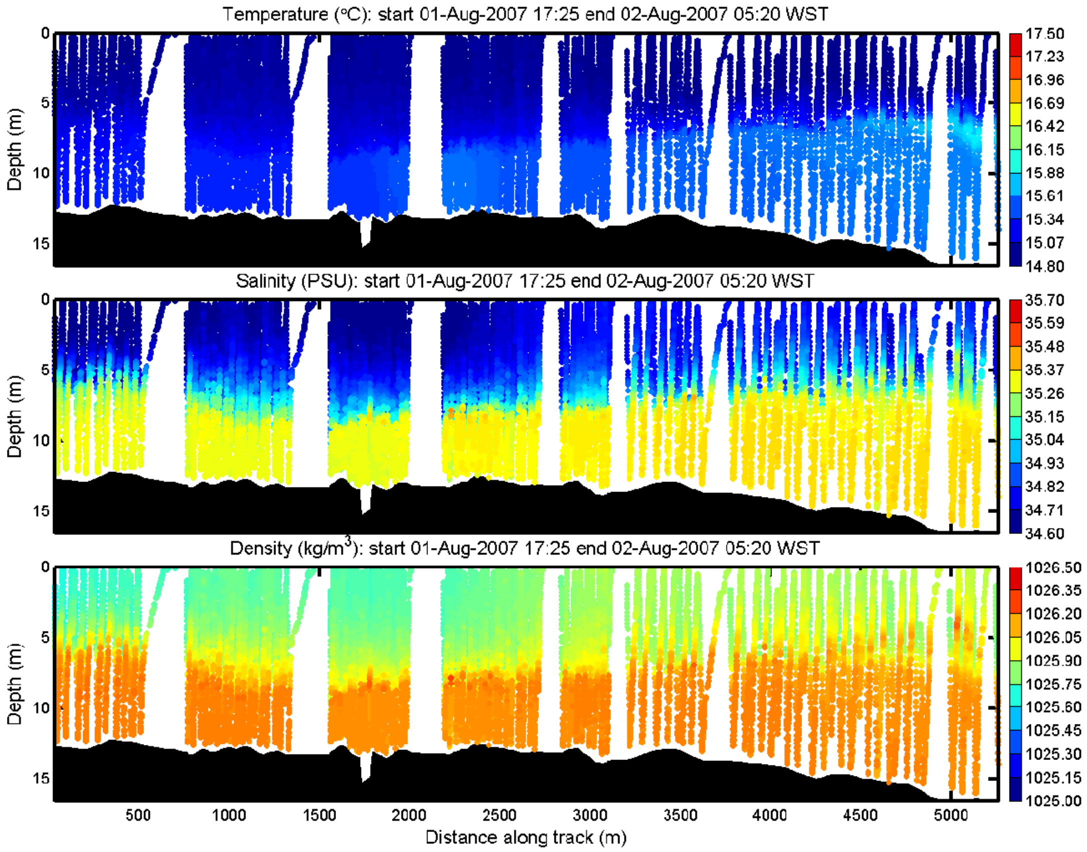

Figure 7.2 Temperature, Salinity and Density as measured using a Seaglider from 1 August to 2 August 2007 (extracted from Figure 17 GHD 2007).

Stratification also occurs due to heating where the surface waters warm more than the bottom waters. The maximum observed temperature difference from top to bottom was 1.8 ºC as shown in Figure 7.3.

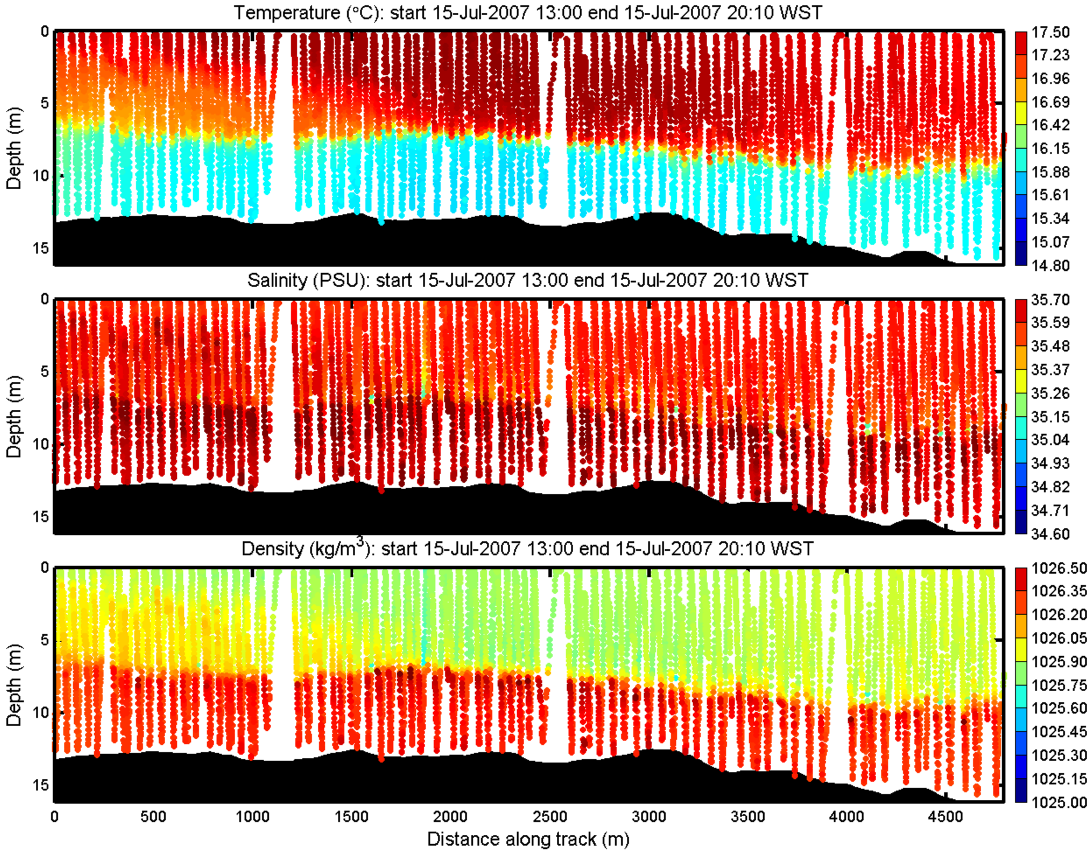

Figure 7.3 Temperature, Salinity and Density as measured using a Seaglider on 15 July 2007 (extracted from Figure 10 GHD 2007).

KBR (2008a) measured thermal stratification of around 1.8 ºC on 30 March and 11 October 2007 – however, the majority of this stratification occurred in the upper 2 m of the water column. A thermal stratification of 1.8 ºC corresponds to a density stratification of around 0.4 kg/m^{-3}. Hence the maximum density stratifications due to temperature and salinity are comparable (i.e. freshwater inflows and heating can cause around the same peak density stratifications).

The density stratification events observed to last longer than a day were:

- The event described above that lasted from 1 August until at least 4 August 2007.
- For 4 days from 31 August to 3 September 2007 when freshwater flowed out of the Harvey Diversion Drain (see Figures 40 and 43 of UWA 2008c). Dissolved oxygen at the bed dropped around 0.5 mg/L to 7.8 mg/L (see Figure 41 of UWA 2008c).
- A freshwater stratification event from prior to 4 July to at least 6 July 2007. There was no observable change in dissolved oxygen at the bed (see Figures 11 to 20 of UWA 2008c).
- An event commencing around 1 October 2007 and lasting for around 4 days during which the bed dissolved oxygen dropped around 0.7 mg/L.
- A few events lasting 2 days (see Figures 43 and 45 of UWA 2008c).

For the period from late August 2007 to February 2008, UWA 2008c concluded that there was no stratification for 75 to 80% of the time

Based upon the above, and the simple hydrological model presented in KBR (2008a), it appears that significant density stratification occurs due to freshwater inflows with stratification persisting up to around 4 days. This compares with stratification persisting for up to 11 days in Cockburn Sound (WRL 2005). The stratification that occurs at Binningup is strongest in shallow water and reduces with distance offshore due to the effects of heating and freshwater inflows being most prominent in shallow water. Figure 7.4 shows an example of warm salty water being produced near the shore during hot weather (heating increases evaporation which in turn increases salinity). The associated top to bottom density stratification was around 0.1 kg/m^{-3} (see UWA 2008d).

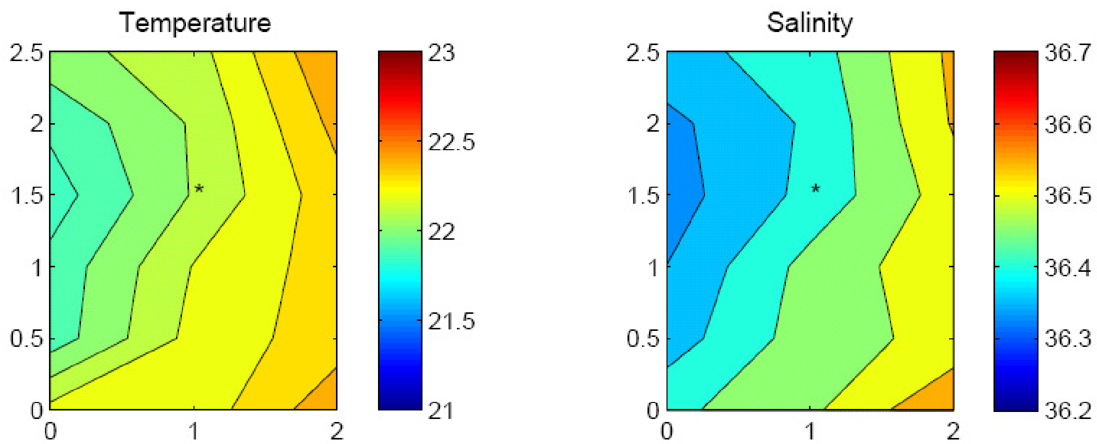

Figure 7.4 Plan view of Temperature (deg C) and Salinity (ppt) at the surface as measured on 23 January 2008 (from Figure A23 of UWA 2008d). Distances are in kilometres and the shoreline is 1 km from and parallel to the right hand edge of the plot.

8 Potential for Low Dissolved Oxygen Levels

The stratification durations from the preceding section can be used along with the SOD coefficients (i.e. k = 0.058 and 0.02 for Binningup and Cockburn Sound respectively) to predict the maximum dissolved oxygen (DO) lowering that could occur near the bed when a sufficiently density stratified layer prevents vertical transport of oxygen to the bed and there are no currents (to transport oxygen laterally). In such a conservative case, the reduction in dissolved oxygen ΔDO in the stratified layer adjacent to the bed can be estimated from:

$$\Delta DO = DO_{initial} (1 - \exp(-kt/h))$$

where $DO_{initial}$ (mg/L) is initial dissolved oxygen concentration, t (days) is time, and h (m) is the thickness of the stratified layer in contact with the bed. The results, assuming an initial DO level of 9 mg/L, are shown in Figure 8.1. Also shown in Figure 8.1 are the maximum observed decreases in dissolved oxygen for which a stratified layer thickness could be estimated from the Binningup data.

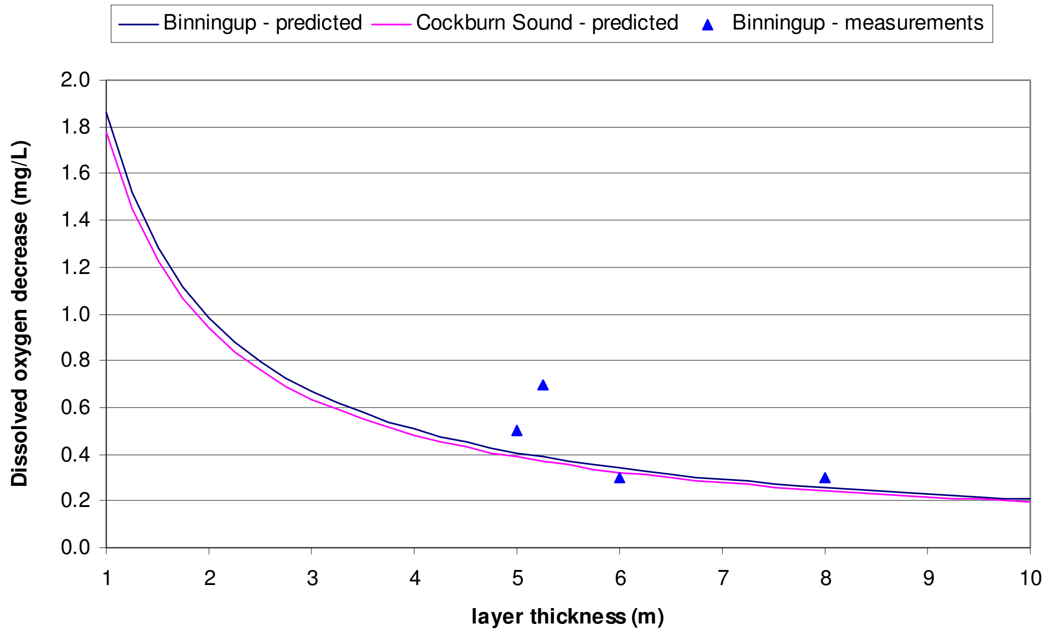

Figure 8.1 Predicted maximum possible decrease in dissolved oxygen levels during 4 and 11 day stratification events at Binningup and Cockburn Sound respectively as a function of the thickness of the stratified layer in contact with the seabed.

From this and the preceding discussion it can be concluded that, if there are no currents to transport oxygen rich water laterally, then natural decreases in dissolved oxygen levels in Binningup marine waters are unlikely to be greater than those in Cockburn Sound during long stratification.

However, the (24 hourly averaged) dissolved oxygen levels at Binningup did not drop below 6.4 mg/L and were always above 80% saturation. This compares to Cockburn Sound where the dissolved oxygen drops to around 60% saturation during the longer stratification events (see Water Corporation 2008b). This can be explained by:

- Greater connection with and flushing by oxygen rich ocean water at Binningup compared with the semi-enclosed embayment of Cockburn Sound; and
- The bathymetry at Binningup which progressively deepens offshore compared to the deep basin of Cockburn Sound (prolonged stratification events are more likely to occur in weakly flushed seabed depressions or embayments which can temporarily trap heavy salty water – see Figure 8.2).

As such, dissolved oxygen levels in Binningup marine waters do not drop as low as those in Cockburn Sound in response to stratification events.

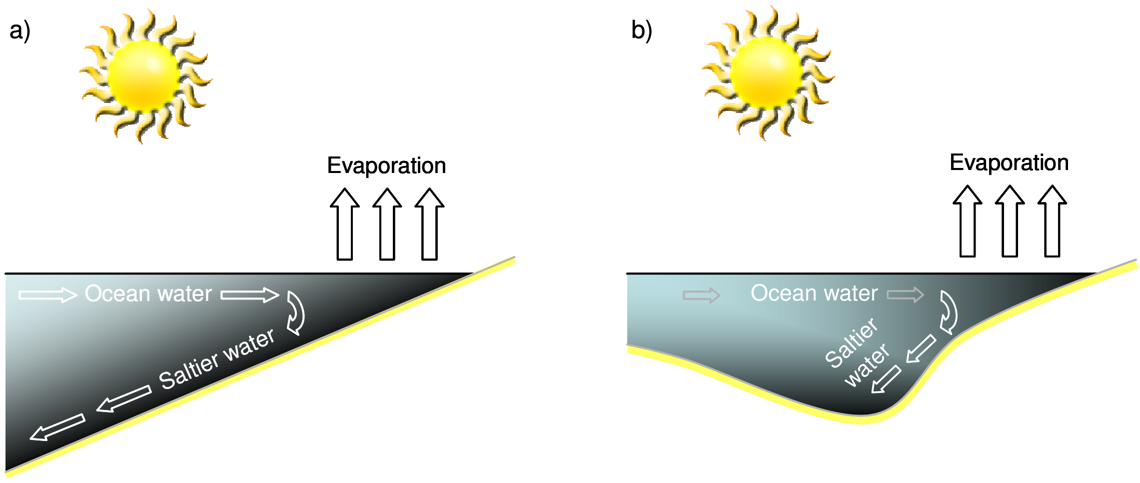

Figure 8.2 Evaporation (and desalination) remove freshwater from seawater resulting in saltier water being produced near the coast. This heavier saltier water a) readily moves offshore unless b) there are depressions which can temporarily trap the saltier water.

9 Conclusions

Temperature varies on a seasonal basis with a peak of around 24ºC in summer-autumn and a minimum of around 15ºC in winter-spring. Temperature fluctuations of up to 2ºC from this general seasonal behaviour can occur over periods of around 10 days of so.

The salinity varies on a seasonal basis with a peak of around 36.5 ppt in summer-autumn and a minimum of around 34.5 ppt in winter-spring. During rainfall events, freshwater outflow from the Harvey Diversion Drain mixing into Binningup marine waters can result in salinities as low as 30 ppt.

Dissolved oxygen concentrations based on a 24 hour average are generally between 7 and 9 mg/L with the lowest reading being 6.4 mg/L (i.e. above 80% saturation). There are only a few instances in isolated locations (i.e. dissolved oxygen was higher elsewhere) where the instantaneous dissolved oxygen reading dropped to around 5 mg/L.

Turbidity is typically in the range of 1 to 4 NTU at or near the water surface and 3 to 20 NTU near the bed.

Well mixed conditions occur for the majority of the time. A regular diurnal stratification-destratification cycle was observed for much of the year where solar heating stratified the water column in temperature, which was then well-mixed by wind and over-night cooling.

Significant density stratification occurs due to freshwater inflows or heating during hot weather with stratification persisting up to around 4 days. The stratification is strongest in shallow water and reduces with distance offshore. Dissolved oxygen levels in Binningup marine waters do not drop as low as those in Cockburn Sound in response to stratification events.

References

The following references are specified in the same way as those in the Southern Seawater Desalination Project Public Environmental Review document.

GHD 2007d Southern Seawater Desalination Plant – Marine Investigations. Report for Oceanography of Southern Seawater Desalination Plant: Seaglider Transects (July-August 2007).

GHD 2008c Southern Seawater Desalination Plant – Marine Investigations. Report for Oceanography of Southern Seawater Desalination Plant: Seaglider Transects (December 2007-January 2008).

KBR 2008a. Southern Seawater Desalination Plant – Marine Investigations. Oceanographic Modelling.

KBR 2008b. Southern Seawater Desalination Plant – Marine Investigations – Water Quality Monitoring Stage 1.

Oceanica 2008a. Southern Seawater Desalination Plant – Marine Investigations. Historical Water Quality Review.

UWA 2005. Sediment Oxygen Demand in the Deeper Basin of Cockburn Sound. Centre for Water Research.

UWA 2008c. Proposed Southern Seawater desalination Plant – Sediment Oxygen Demand. University of Western Australia, Nedlands.

UWA 2008d. Southern Seawater Desalination Plant: CTD Measurements. University of Western Australia, Nedlands.

Water Corporation 2008b. Perth Seawater Desalination Plant – Water Quality Management, Section 46, March 2008. Prepared by Water Corporation and 360 Environmental.

WRL 2005. Stratification and Dissolved Oxygen Issues in Cockburn Sound Pertaining to Discharge of Brine from Desalination. Water Research Laboratory Technical report 2005/03, University of New South Wales.