WP 2160 PO

Summary of investigations into the impact of the Perth Seawater Desalination Plant discharge on Cockburn Sound

Final Report

P. Okely, J.P. Antenucci, P.S. Yeates, C.L. Marti and J. Imberger

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Centre for Water Research

The University of Western Australia, M023, 35 Stirling Hwy, Nedlands, Western Australia 6009

Phone 61 8 6488 2410 **Fax** 61 8 6488 3053 **Email** services@cwr.uwa.edu.au

Web http://www.cwr.uwa.edu.au

Executive Summary

This report summarises the results from two field experiments, an ongoing monitoring programme and an extensive modelling investigation all completed between August 2006 and April 2007 in Cockburn Sound. The general objective was to determine the dynamical behaviour of the saline effluent released by the Perth Seawater Desalination Plant. The duration of the investigation covers periods prior to the operation of the plant, through commissioning and into full operation.

The detailed objectives of these investigations were to:

a) Determine the impact of the desalination plant saline effluent on stratification in the Sound
b) Determine the impact of the desalination plant saline effluent on dissolved oxygen in the Sound

Details of the monitoring, modelling, and field experiments are contained in extensive, separate reports (Okely et al 2006, Okely et al 2007, Yeates et al 2006). The purpose of this report is to provide a detailed summary of this work.

Based on these investigations and ongoing monitoring it is observed that stratification in the Sound is highly episodic, not seasonal, and is driven by the combination of meteorological fluxes and boundary (tidal) inputs. Analysis of the oxygen budget demonstrated that the dominant process responsible for oxygen depletion in Cockburn Sound is oxygen consumption by the sediments, whereas the dominant sources of oxygen are atmospheric transfer at the air/water interface and advection through the northern opening. Dissolved oxygen measurements in the Sound were consistently above 70% saturation, indicating no low dissolved oxygen events that were likely to be harmful to marine life.

The hypothesis under which the desalination plant saline effluent might impact upon dissolved oxygen conditions in the Sound was that the duration of episodic stratification events must increase, due to the saline effluent discharge, to the point whereby oxygen consumption by the sediment would cause significant additional depletion compared with conditions prior to plant operation. Modelling investigations indicate that this hypothesis is not applicable and field measurements made during extremely calm weather conditions show that the salt plume from the plant does not reach the deeper parts of the Sound.

The dynamics of the saline effluent plume is the primary reason for this absence of cause-and-effect between the desalination saline effluent discharge and dissolved oxygen. The results from both the field work and the modelling showed that under calm conditions, the saline effluent from the plant leaves the diffuser vertically, forming a significantly diluted plume with an initial height of

approximately 4-5 metres above the bed in the vicinity of the diffuser. The negative buoyancy of the saline effluent causes the plume to plunge back to the sea floor where it spreads laterally following the depth contours of the Sound. The plume travels radially under gravity until it intersects the dredged shipping channels, where it is present as a semi-permanent feature (dependent on wind conditions) approximately 2-3 metres above the bed. Once in the shipping channels the plume moves both to the north and south under gravity. Measurements made during two experiments at the exit of Stirling Channel under very calm (worst-case) conditions indicate the plume was undetectable 45% of the time, and between 0 and 1.0m thick 33% of the time. In all cases the plume was undetectable approximately 500m from the exit of Stirling Channel. Thus, from an initial height of approximately 4-5m above the seabed in the vicinity of the diffuser, the lateral spreading and vertical mixing of the plume sees it completely mixed within 500m of the exit of Stirling Channel. There is therefore no possibility of a saline plume from the desalination plant saline effluent entering the deep waters of Cockburn Sound (> 10m) and sufficiently prolonging stratification such that dissolved oxygen is measurably affected.

The dilution in the near field (negatively buoyant vertical jet), the intermediate field (submerged underflow in the shipping channels) and the far field (dispersion as the effluent exits the Stirling Channel) lead to an overall dilution of the plant effluent of about 1:100,000 approximately within 500m from the shipping channel exits. Such highly diluted effluent does not enter the deeper basin of Cockburn Sound as a discrete plume.

In summary, based upon:

- State-of-the-art three-dimensional modelling simulating stratification and dissolved oxygen over seasonal timescales
- Two intensive field studies measuring high resolution salinity and temperature profiles at hundreds of locations with the desalination plant operating
- Approximately one hundred high resolution profiles of salinity and temperature collected during routine monitoring in 2007 with the desalination plant operating
- Continuous monitoring of dissolved oxygen in the deep basin at three stations
- Two dye release experiments (which provide direct measurement of the effluent mixing, dispersion and path of travel), one during calm summer conditions and one during calm autumn conditions

the effluent from the desalination plant is so highly diluted that it does not have a measurable impact on stratification or dissolved oxygen in the deep basin (> 10m) of Cockburn Sound.

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1 INTRODUCTION

Cockburn Sound is a coastal embayment south of Fremantle, Western Australia, which is bounded by the mainland to the east and Garden Island to the west. The Sound is about 16 km long and 8 km wide, with a maximum depth of 22 m, surface area of 80 km^2 and volume of approximately 1.2 x 10^9 m^3. The southern end of the Sound is partially closed by a solid rock-fill causeway that connects the mainland and Garden Island, with two openings to the sea approximately 300 and 600 m wide. The bathymetry of Cockburn Sound consists of a deep central basin around 20 m deep and 5 km wide that extends from 2 km north of Garden Island to Mangles Bay in the southern-most of region of the Sound (Figure 1). The northern entrance to the Sound is shallower than the main basin, ranging from 2 to 10 m deep east to west along the northern entrance and intersected midway by a narrow shipping channel of 15 m depth. The eastern section of Cockburn Sound is a 10 m deep shelf that extends 3 km into the Sound from the eastern shore. Several deeper shipping channels also intersect this shelf, servicing the port facilities that line the eastern shore. Cockburn Sound is the most intensely used marine embayment in Western Australia. Activities include industrial and naval shipping, waste disposal, fishing and recreation. The increase in industry in and around the Sound has led to increasing concerns about its ecological health.

The Water Corporation of Western Australia has recently constructed a seawater desalination plant along the eastern shore of Cockburn Sound that produces 45GL of potable water per year via reverse osmosis filtering. This process is approximately 45% efficient and therefore requires extraction of 100GL per year (3.2 m^3 s^{-1}) of water from the Sound, and the return of hypersaline discharge of 55GL per year (1.75 m^3 s^{-1}). This hypersaline discharge has a salinity of approximately 65 psu, and the salinity of the ambient receiving waters approximately 36 psu. The discharge enters the Sound via a diffuser that is designed to reduce the salinity to 1 psu above ambient concentrations within 50 metres of the diffuser. A series of studies were conducted to verify if the characteristics of the discharge conformed with the design criteria and to assess the likelihood of the saline discharge in prolonging the stratification periods in the Sound in such a way as to compromise the local biota, as indicated by dissolved oxygen levels.

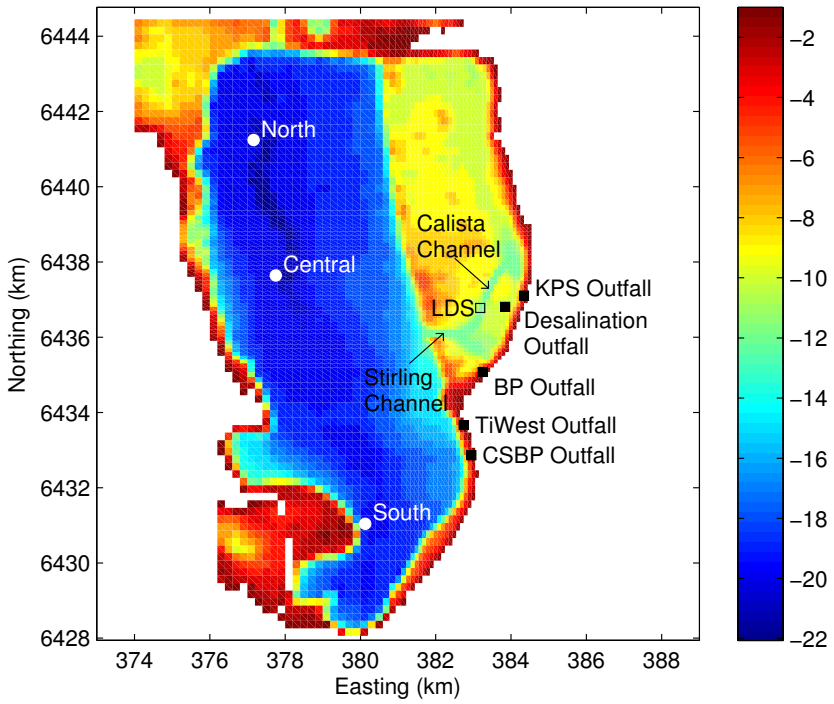

Figure 1. Cockburn Sound bathymetry (colour is depth in metres), showing significant industrial outfalls, monitoring locations and the LDS station. Note the shipping channels dredged in the shallow eastern bank, running initially East-West (Stirling Channel), and then North and North-East (Calista Channel). The exit of Stirling Channel is considered the point where the bathymetry drops rapidly to greater than 15 metres at the western end of Stirling Channel.

The three-dimensional Estuary, Lake and Coastal Ocean Model (ELCOM), developed at CWR, was used to model the hydrodynamics of the Cockburn Sound and the dynamical behaviour of the saline effluent. The model was first configured to compute the seasonal change in ambient salinity and temperature over one year using tidal forcing at the ocean boundaries and atmospheric forcing at the water surface. The model performance was assessed by comparing the simulation results with available field data (Yeates et al. 2006). A second simulation that included the desalination discharge was used to assess the predicted effect of the discharge plume on the salinity, temperature and density structure of the Sound. A grid resolution study was performed to design a plaid grid that best resolved the background physics and discharge plume dynamics while maintaining an affordable computation time. To assess the potential impact of the desalination discharge on dissolved oxygen conditions in the Sound, the Computation Aquatic Ecological Dynamics Model (CAEDYM), also developed at CWR, was coupled with the hydrodynamics driver ELCOM (Okely et al. 2006). CAEDYM was configured to simulate the major processes controlling

dissolved oxygen; transport from the ocean boundary, atmospheric transfer, sediment consumption, seagrass production and respiration, algal production and respiration, and nitrification. To complement the seasonal studies, detailed field experiments were conducted (Okely et al. 2007). The field work included the deployment of a Lake Diagnostic System (LDS), consisting of a meteorological station and thermistor chain over several months, and the opportunistic deployment of a high resolution profiling instrument to measure temperature, conductivity, pH, dissolved oxygen, and turbidity over several days in December 2006 and April 2007. During these experiments, Rhodamine WT dye was also added to the desalination plant discharge and tracked with a high resolution profiler to determine the dilution of the discharge over time and with distance from the diffuser. Numerical modelling was conducted in conjunction with the field experiments to further validate the model over short timescales.

The findings of these studies are summarised in this report, together with further analysis of routine monitoring data.

2 Seasonal Conditions Pre-Desalination

2.1 Stratification

In order to summarise the seasonal stratification conditions in the Sound, monitoring data and modelling results are presented for both temperature (Figure 2) and salinity (Figure 3) at the central station (Figure 1). The data shows a seasonal temperature range of 15 – 24°C, a seasonal salinity range of 35.3 – 37.2 psu, and no seasonal pattern of temperature or salinity stratification. The model reproduces these seasonal trends as well as the range of vertical stratification due to salinity and temperature. Field data and the model (see later sections in this report) clearly show that lowering of dissolved oxygen is due to episodic events (typically lasting a few days) with no seasonal behaviour of dissolved oxygen drawdown. For this reason, the key requirement for the models is to be able to simulate the vertical stratification and associated dissolved oxygen during stratification events.

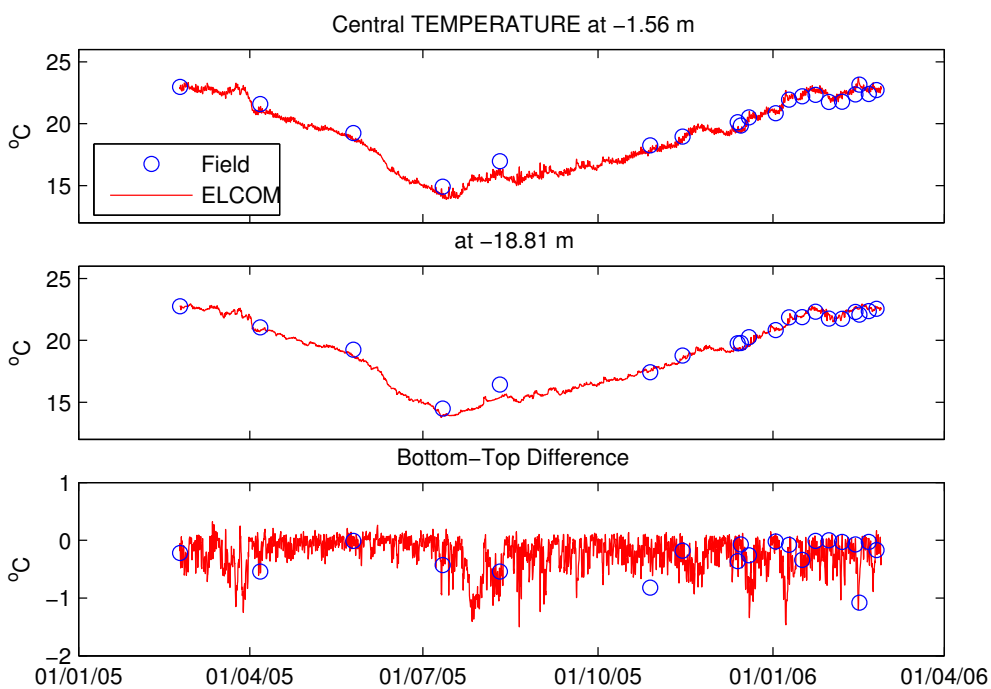

Figure 2. Comparison of monitoring data (circles) and model results (solid line) for the central station, for the surface (upper panel) and bottom temperature (middle panel). The lower panel shows the temperature difference

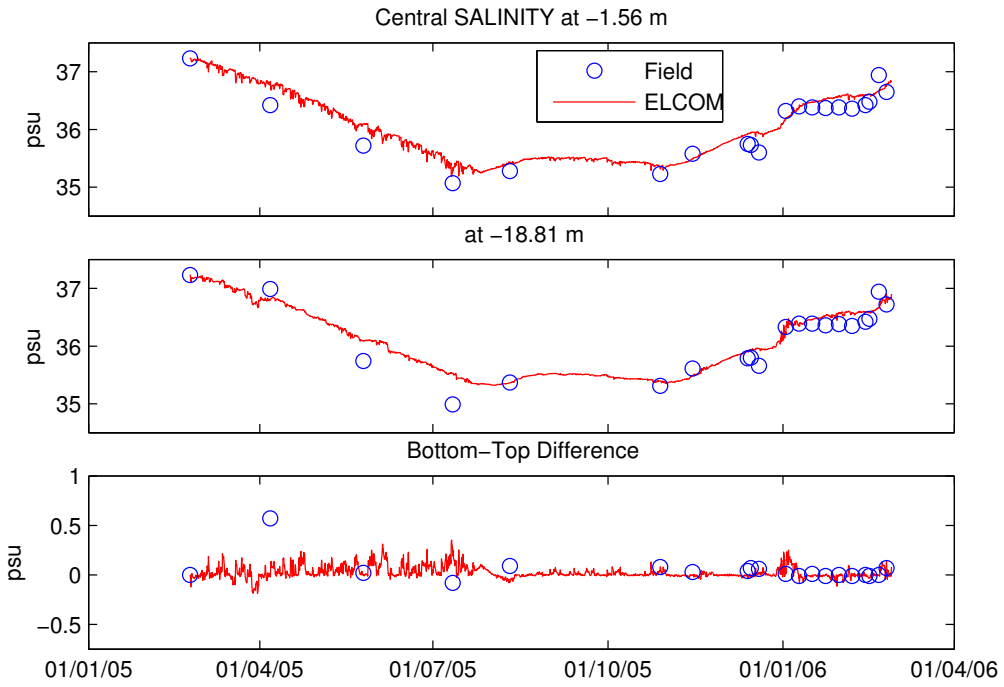

Figure 3. Comparison of monitoring data (circles) and model results (solid line) for the central station, for the surface (upper panel) and bottom salinity (middle panel). The lower panel shows the salinity difference

2.2 Dissolved Oxygen

Dissolved oxygen field measurements (Source – Cockburn Sound Management Council) and simulation results are presented to demonstrate the seasonal variability of dissolved oxygen in Cockburn Sound, the range of processes that affected oxygen drawdown, and the ability of the model to reproduce these processes. Data from autumn 2006 (Figure 4) shows an oxygen drawdown event at the central station occurring in early March, with bottom dissolved oxygen decreasing from approximately 70% to 65% This event is suddenly halted by a mixing event around March 10, shown by the rapid increase in bottom dissolved oxygen. The mixing event is predicted by the simulation, showing the return to uniform top and bottom saturation conditions. The ability of the model to predict this dissolved oxygen event demonstrates that the model is a suitable tool to examine the hypothesised cause-effect relationship that enhanced stratification leads to lower dissolved oxygen levels, and that periodic mixing events return oxygen conditions to near-saturation. Summer conditions (Figure 5) show higher saturation levels (typically greater than 80%) for the whole period, which were also replicated by the simulation.

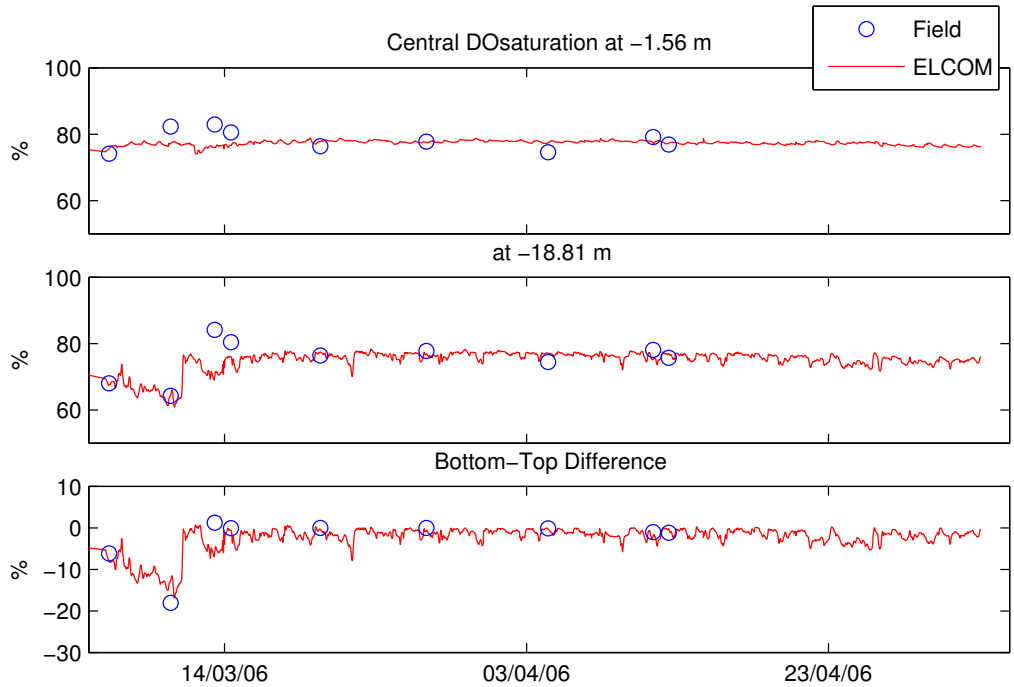

Figure 4. Comparison of field measurements of dissolved oxygen saturation (open circles) with simulated dissolved oxygen saturation for the central station during autumn. Top panel shows surface measurements, middle panel shows bottom measurements, and the lower panel shows the top-bottom difference.

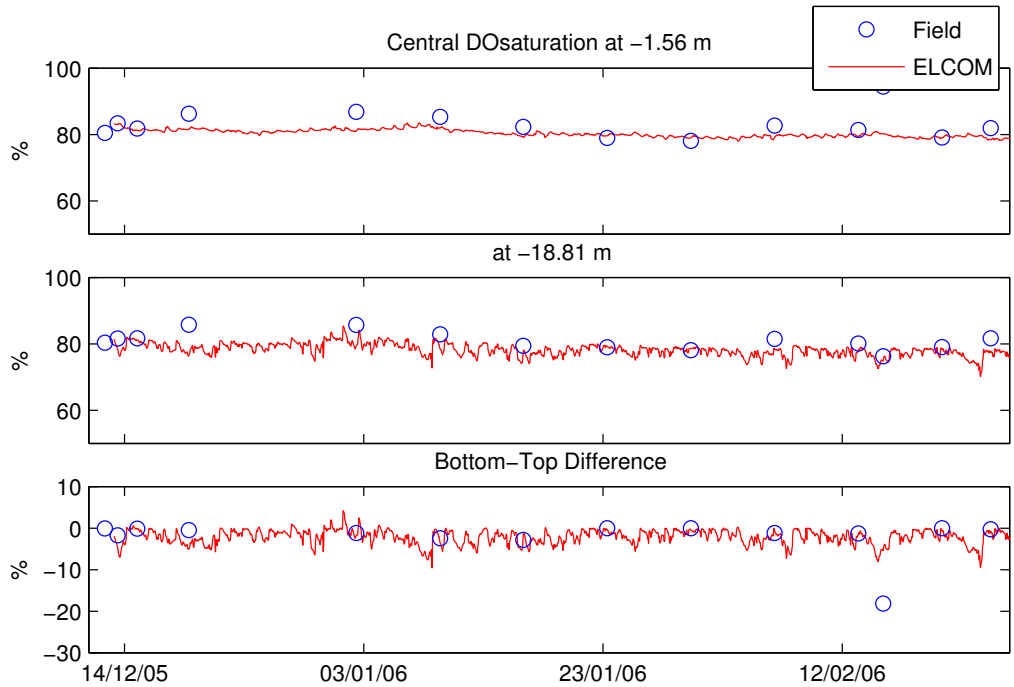

Figure 5. Comparison of field measurements of dissolved oxygen saturation (open circles) with simulated dissolved oxygen saturation for the central station during summer. Top panel shows surface measurements, middle panel shows bottom measurements, and the lower panel shows the top-bottom difference.

3 Seasonal Forecast with Desalination

3.1 Stratification

Seasonal forecasts of the impact of the desalination plant saline effluent show no impact of the plant on the stratification in the deep waters of the Sound in an average sense (Figure 6). These results agree with the findings of the two field experiments, that showed the plume moves both north and south along the shipping channels on the eastern bank of the Sound, with the plume becoming more dilute as it moved in both directions (see Figure 16, Figure 17 in subsequent section). The highest salinities are expected to be found north of the diffuser. Analysis of stratification episodes both with and without the desalination plant saline effluent also demonstrated that the saline effluent discharge increases the background stratification slightly, but it does not extend the duration of stratification episodes, therefore there is no measurable affect on dissolved oxygen levels (see following section) (Figure 7 - Figure 10).

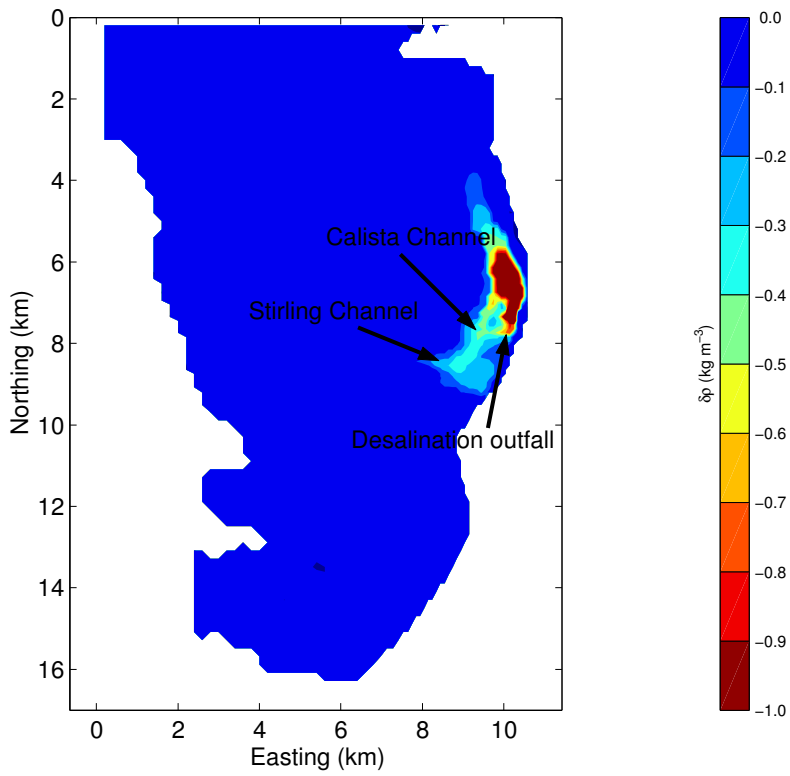

Figure 6. Annual average simulated top-to-bottom density difference due to the desalination plant effluent, showing the containment of the saline effluent to the shipping channels on the shallow eastern bank of Cockburn Sound, with the plume present both to the north and south of the diffuser.

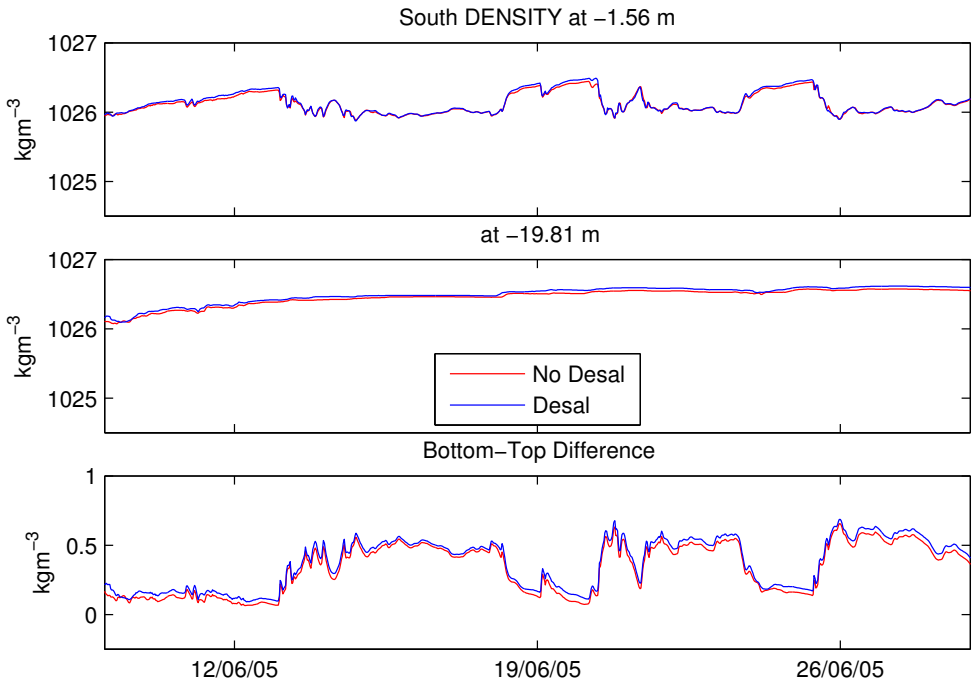

Figure 7. Surface density (upper panel), bottom density (middle panel) and density difference (lower panel) for the base case (red) and case with desalination (blue) for a brief period in 2005 at the southern station.

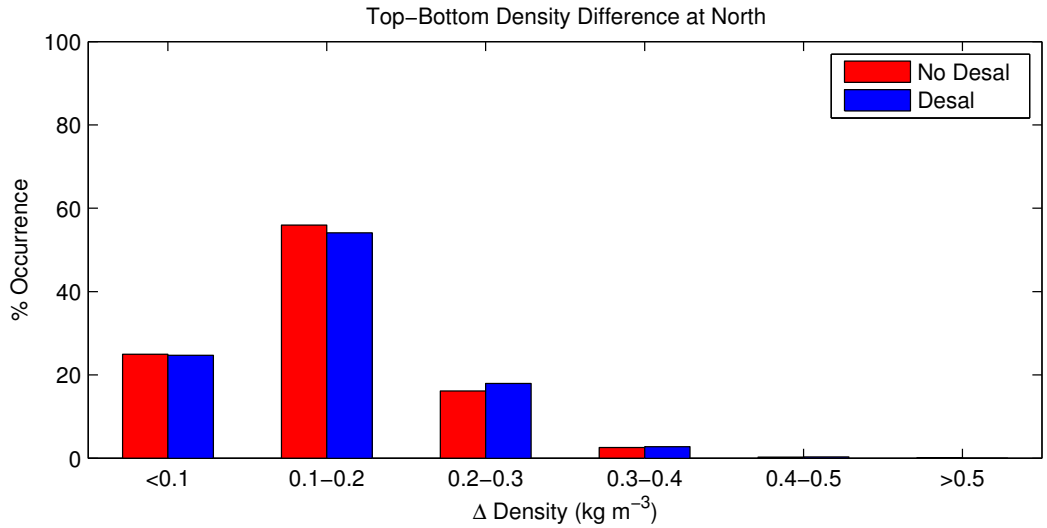

Figure 8. Percentage occurrence of top-bottom simulated density difference at the north station with and without the desalination plant.

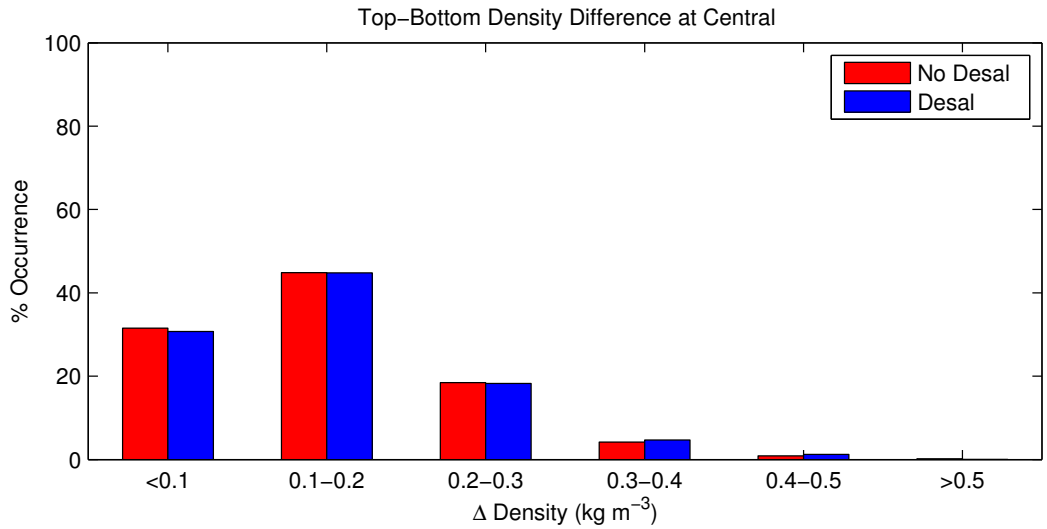

Figure 9. Percentage occurrence of top-bottom simulated density difference at the central station with and without the desalination plant.

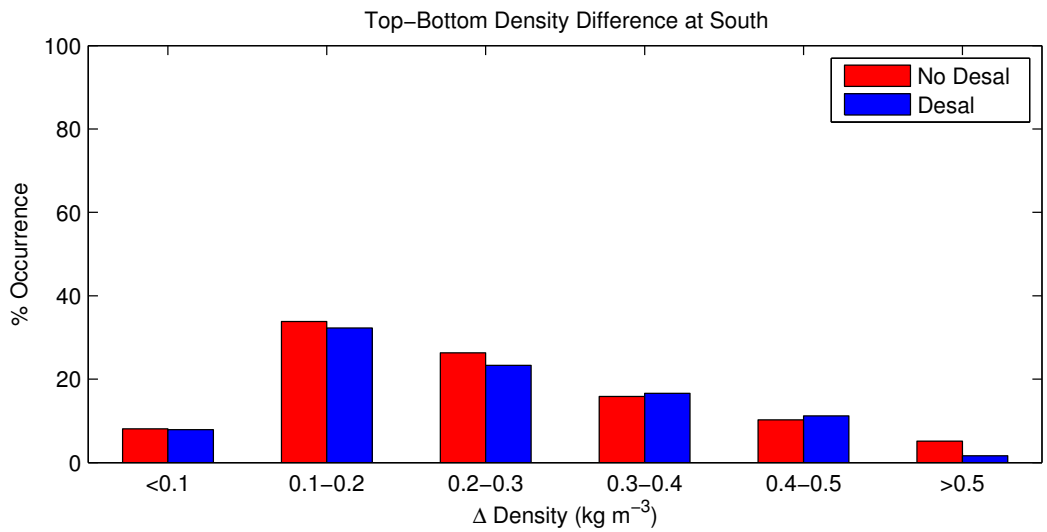

Figure 10. Percentage occurrence of top-bottom simulated density difference at the south station with and without the desalination plant.

3.2 Dissolved Oxygen

Comparison of simulated dissolved oxygen saturation with and without the desalination plant saline effluent shows no difference in the duration or extent of dissolved oxygen drawdown events (Figure 11). Histograms of the dissolved oxygen saturation at the three stations (Figure 12-Figure 14) indicate that despite slight differences in simulated stratification (Figure 8-Figure 10), there is insufficient difference to cause a change in dissolved oxygen concentrations. This result is in line with expectations based on the stratification results presented in the previous section, and is

supported by the findings on the dynamics of the saline effluent plume as described in the following section.

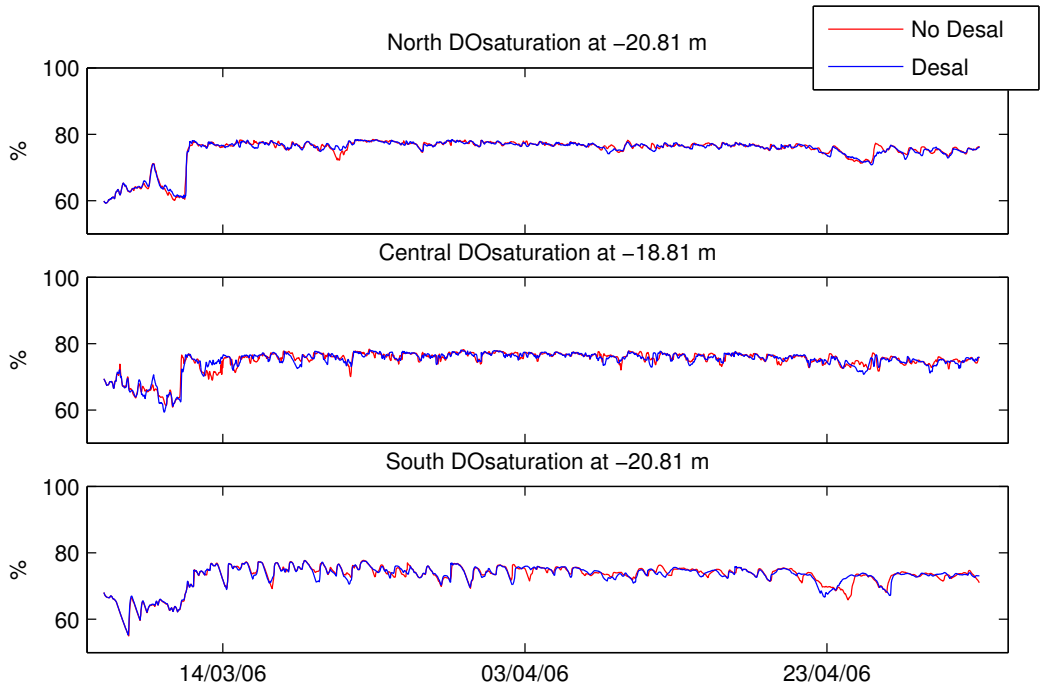

Figure 11. Comparison of simulated bottom dissolved oxygen saturation for the base case control simulation (no saline effluent) (blue lines), and the case with the saline effluent (red lines) from the desalination plant for the autumn simulation. Top panel corresponds to the northern station, middle panel to the central station and the bottom panel to the southern station.

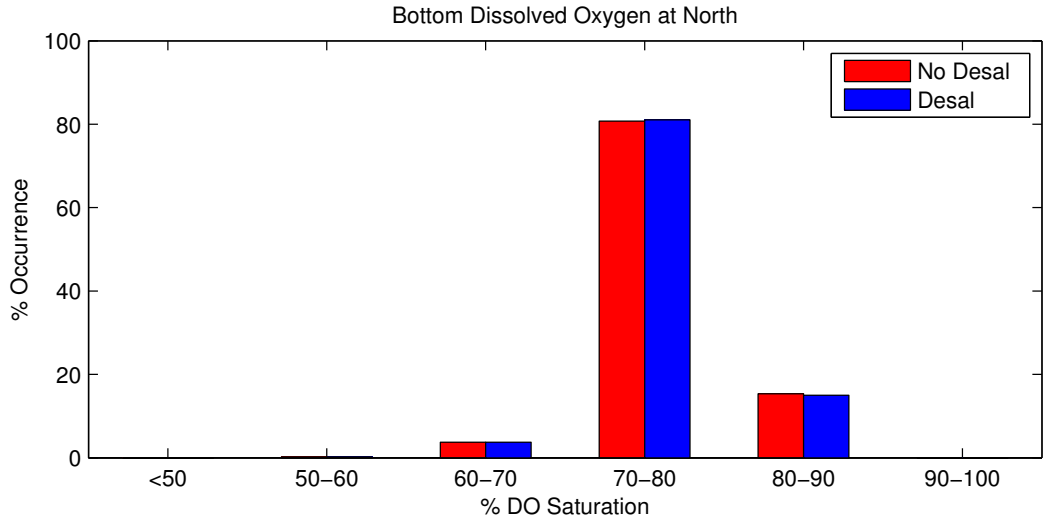

Figure 12. Percentage occurrence of simulated bottom dissolved oxygen saturation at the north station for the case with and without desalination.

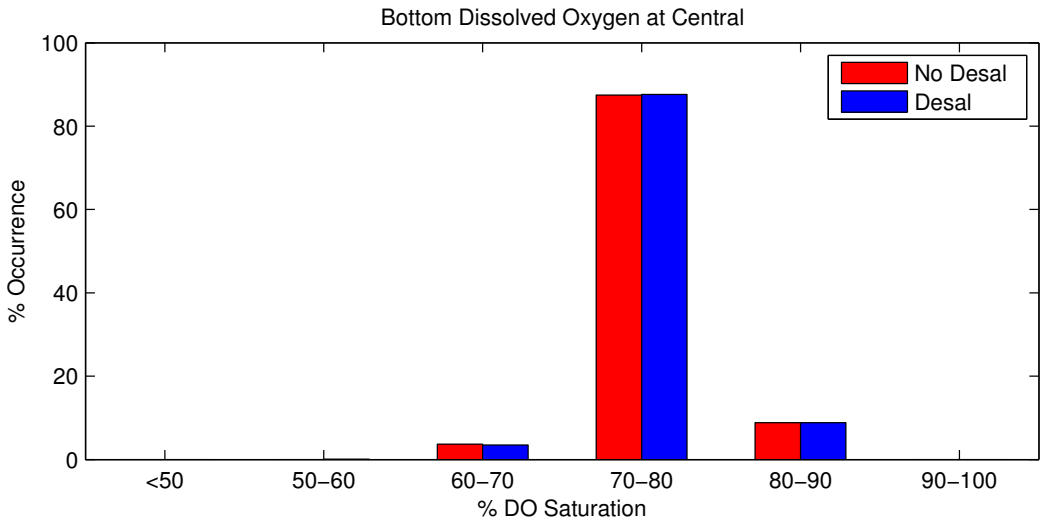

Figure 13. Percentage occurrence of simulated bottom dissolved oxygen saturation at the central station for the case with and without desalination.

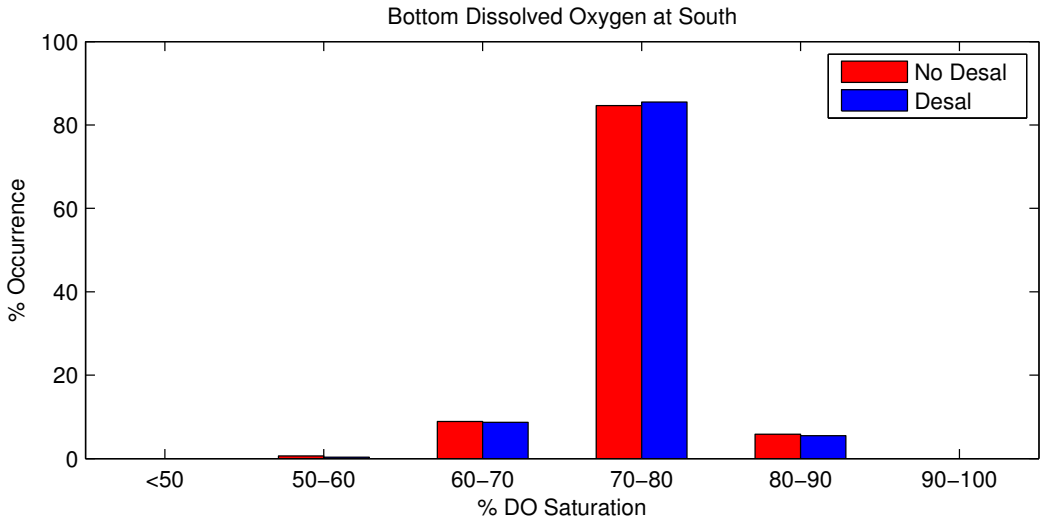

Figure 14. Percentage occurrence of simulated bottom dissolved oxygen saturation at the south station for the case with and without desalination.

4 Saline Effluent Plume

4.1 Field Experiment Summary

Two field experiments were conducted under calm conditions, with the first conducted in December 2006 where the saline effluent discharge was 50% of full capacity, and the second in April 2007 where the saline effluent discharge was 83% of full capacity. The effectiveness of the diffuser in mixing the saline effluent with the background waters of Cockburn Sound is a function of flow rate, with the lowest dilution occurring at low flow rates (Wallis 2006). Therefore, the worst case conditions (that is, the least-diluted plume) will occur under low flow rates and calm conditions, which was exactly the conditions under which the field experiments were conducted (Okely et al 2007). The dynamics of the saline plume are briefly summarised in this section.

Each experiment included the release of Rhodamine WT dye, released from the diffuser over approximately a 20 minute period. This dye was traced for three days to determine the dilution of a single parcel of water released from the diffuser, with dilution determined by dividing the released Rhodamine WT concentration (prior to the diffuser) by the measured Rhodamine WT concentration, as the background concentration of dye was zero. Note that all dissolved material present in that parcel of water, salt included, will dilute with the background concentration at the same rate. The non-zero background concentration of salt is irrelevant, as the dye test is a direct indicator of the effectiveness of the diffuser and any dilution greater than 45 indicates the diffuser is performing as expected.

4.2 Plume Characteristics

The behaviour of the saline effluent plume is demonstrated in Figure 15, which compares the measurements with the simulation results in April 2007. The measurements indicated that the saline plume decreased in thickness from the diffuser both north and south along the length of the shipping channels, becoming more diluted with distance from the diffuser. ELCOM predicted both the vertical and horizontal extent of the plume, and the also dilution of the plume down from the initial discharge salinity of approximately 65 psu down to the range of 36.8 – 37.4 psu measured in the field during the experiment (Figure 15).

To complement the snapshot presented in Figure 15, composite figures are presented for the two field experiments conducted in December 2006 (Figure 16) and April 2007 (Figure 17). These data demonstrated the general trend of the saline effluent layer thickness and the density difference across the water column decreasing with distance from diffuser. This is shown most clearly in the April 2007 data (Figure 17), as opposed to the December 2006 data, for which interpretation was

complicated by intricate horizontal and vertical stratification patterns associated with the Verve Energy power station thermal discharge (Okely et al 2007).

Within 500m of the exit of Stirling Channel, 45% of the profiles measured detected no saline effluent plume, and for an additional 38% of profiles the saline effluent plume was less than 1m thick (Figure 18) and less than 0.6 kg m^{-3} above the background density. This is within the range of naturally occurring density differences in the Sound (Figure 7). Note the regions in which the plume was observed (indicated by the filled black circles in the upper left panel of Figure 16 and Figure 17) matches well with the spatial extent predicted by the modelling (Figure 6).

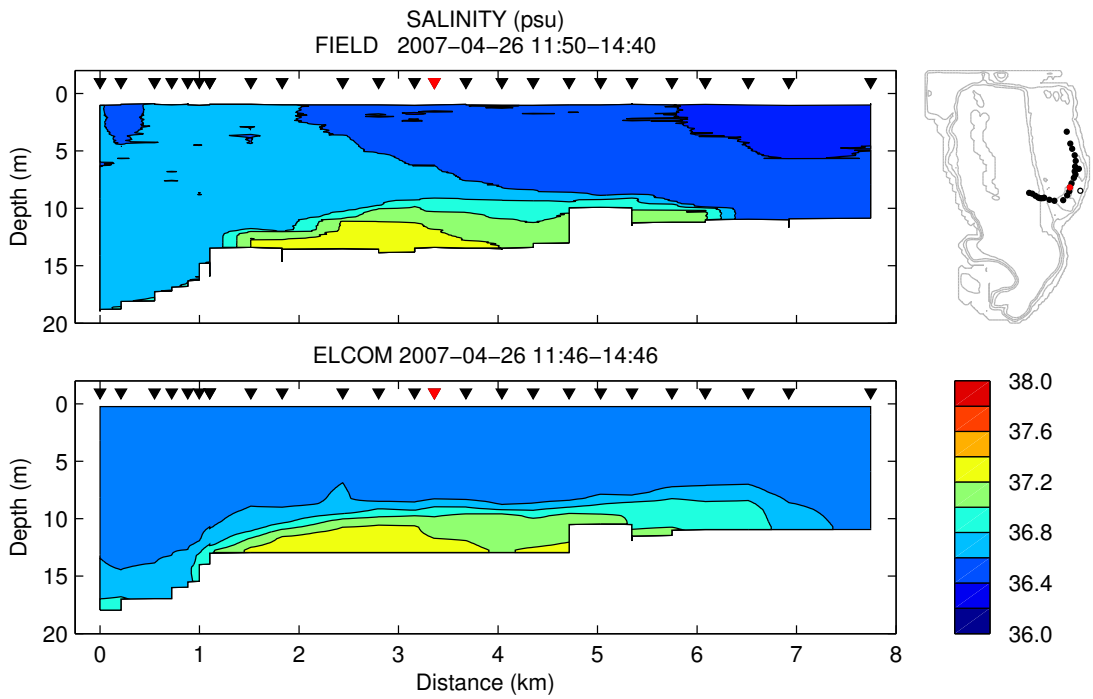

Figure 15. Transect of measured (upper panel) and simulated (lower panel) salinity along the main shipping channel and off the shelf during the middle of the day on 26 April 2007. The triangles at the top of each panel indicate the measurement points (indicated on the map in the upper right corner), with the red triangle indicating the station immediately offshore of the diffuser.

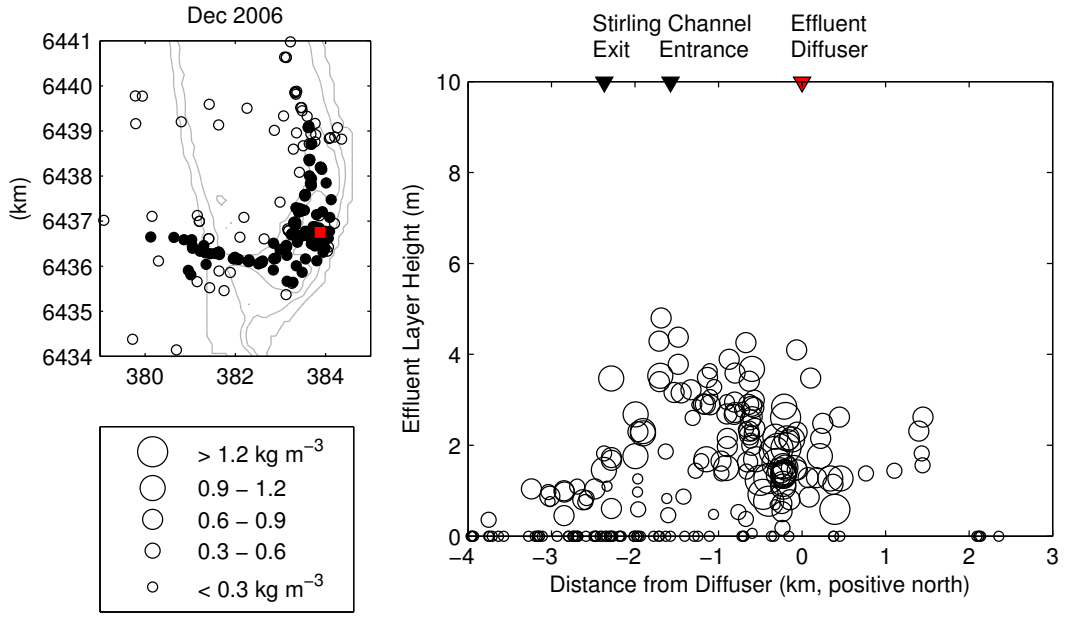

Figure 16. Saline effluent layer characteristics from profiles taken during the December 2006 experiment. Top left panel shows locations of profiles; filled circles indicate profiles where saline effluent layer was present, open circles indicate no saline layer, and the red marker is the location of the diffuser. Right panel shows height of saline effluent layer in profile as a function of distance from the diffuser. Circle size indicates density difference between water immediately overlying saline effluent layer and maximum density in profile.

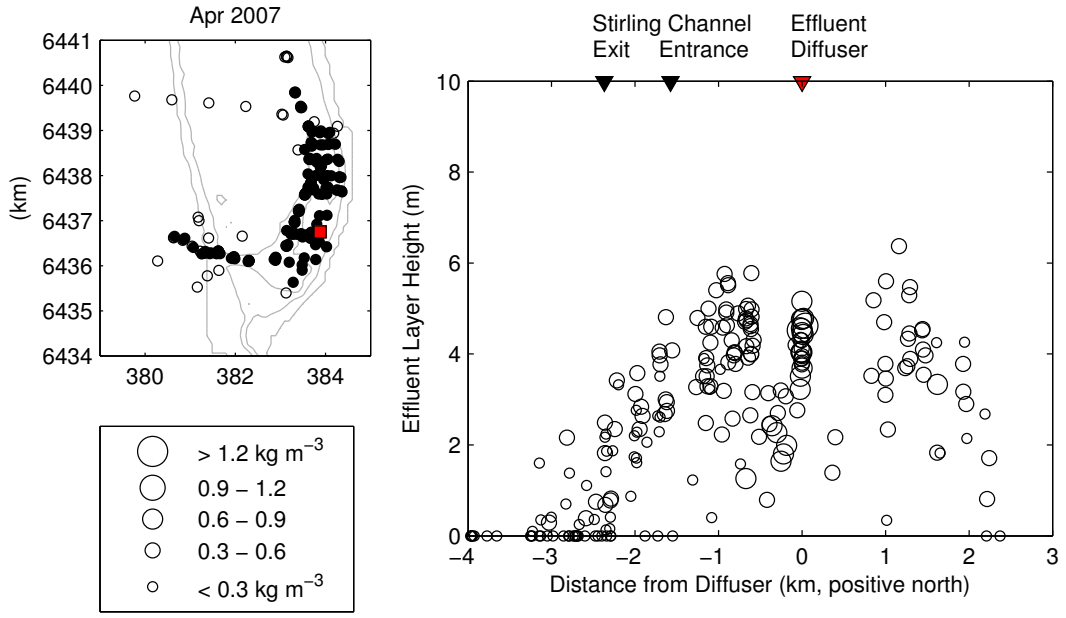

Figure 17. Saline effluent layer characteristics from profiles taken during the April 2007 experiment. Top left panel shows locations of profiles; filled circles indicate profiles where saline effluent layer was present, open circles indicate no saline layer, and the red marker is the location of the diffuser. Right panel shows height of saline effluent layer in profile as a function of distance from the diffuser. Circle size indicates density difference between water immediately overlying saline effluent layer and maximum density in profile.

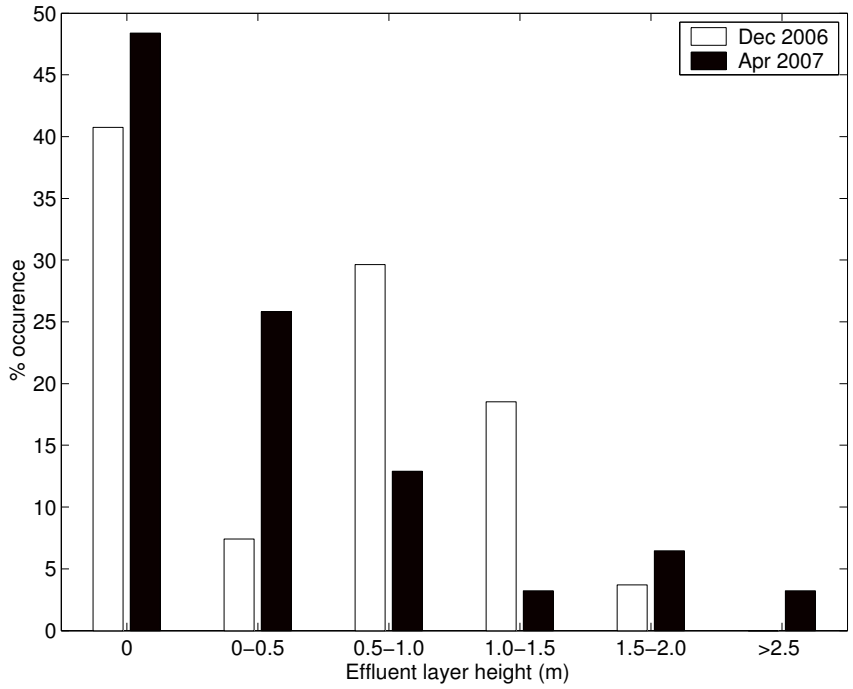

Figure 18. Histogram of saline effluent layer heights in profiles made off shelf from the Stirling Channel exit. Data are separated according to each field experiment.

4.3 Dilution of Saline Effluent

Dilution of the saline effluent was examined in the field experiments via Rhodamine WT dye tracing, and in the simulations through the use of conservative tracers. The design dilution of the diffuser was 45 times, meaning that 1 litre of hypersaline effluent (approximately 65 psu) will be diluted with 45 litres of background seawater (approximately 36 psu) within 50 metres of the diffuser, resulting in a dilute plume of salinity approximately 36.6 psu or 0.6 psu above background. The initial conditions in the vicinity of the diffuser are shown in Figure 19, which demonstrates the dye plume generated in the saline effluent plume. This dilution of the initial dye plume was traced for both field experiments for 3 days, and the comparisons between the measured and simulated range of dilutions are presented in Figure 20 and Figure 21. The field measurements indicated that within 36 hours of the release the saline effluent was diluted more than 1000 times with the background salinity. The simulation results using ELCOM predicted both the range of dilution measured on a particular day and the increased dilution as time passed (Figure 20, Figure 21), giving increased confidence in the model results

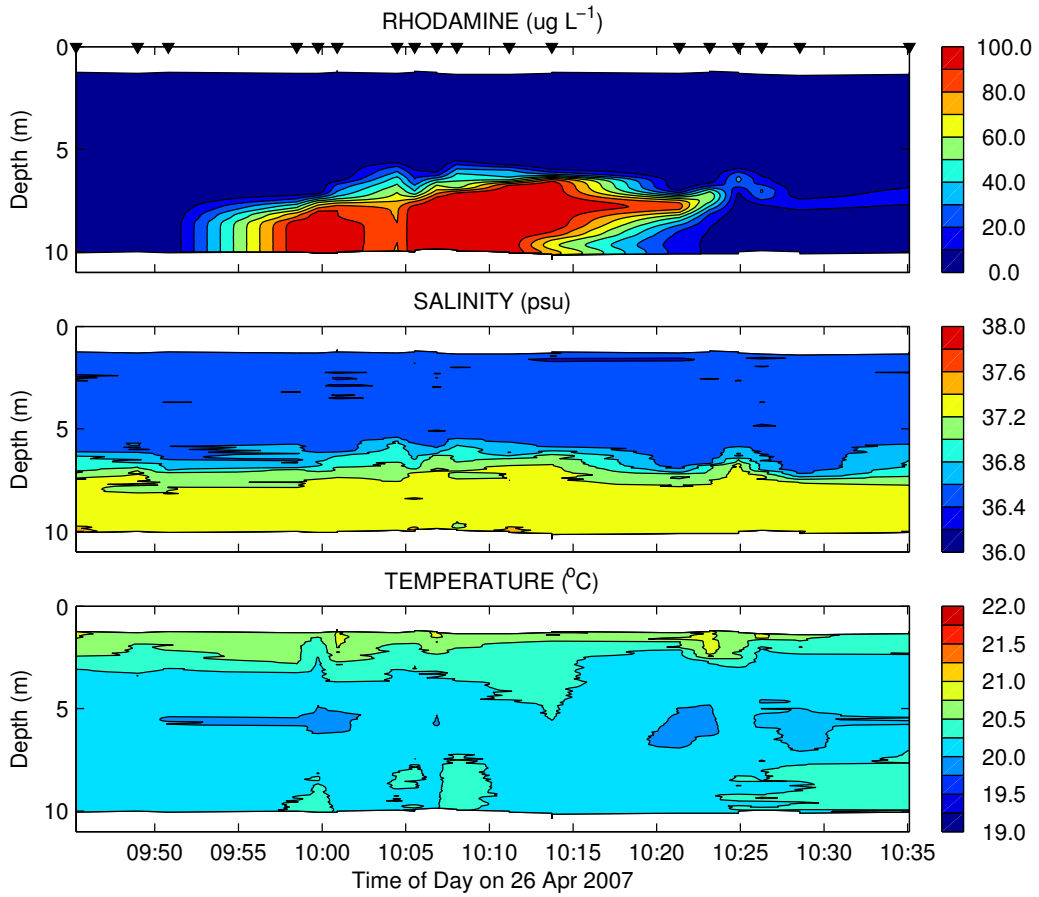

Figure 19. Time contour of profile data collected at the diffuser during dye release on 26 Apr 2007: rhodamine dye concentration (top panel), salinity (middle panel) and temperature (bottom panel).

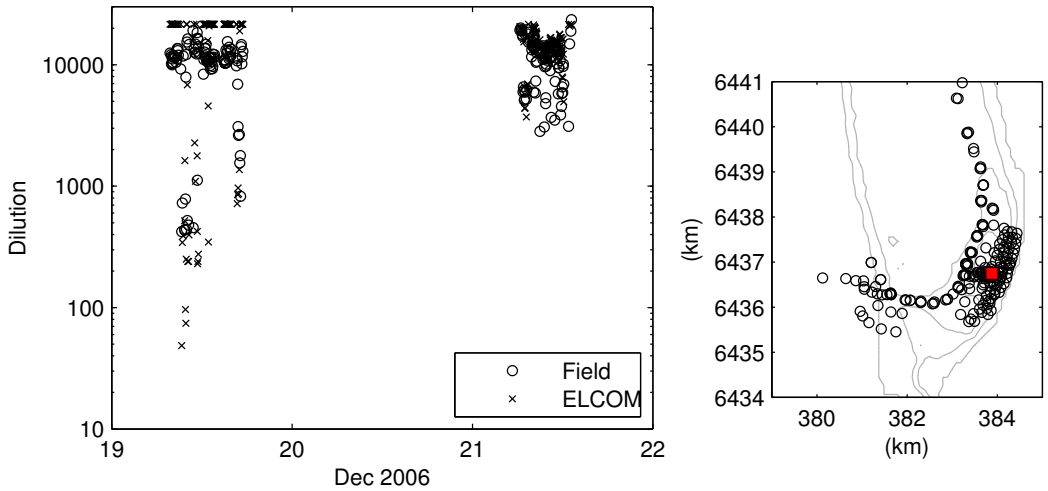

Figure 20. Dilution of the saline effluent during the December 2006 experiment, showing measured (open circles) and simulated ELCOM results (crosses). The right panel shows the location of the field samples relative to the bathymetry in the east of Cockburn Sound in the vicinity of the shipping channels, with the red square indicating the location of the diffuser.

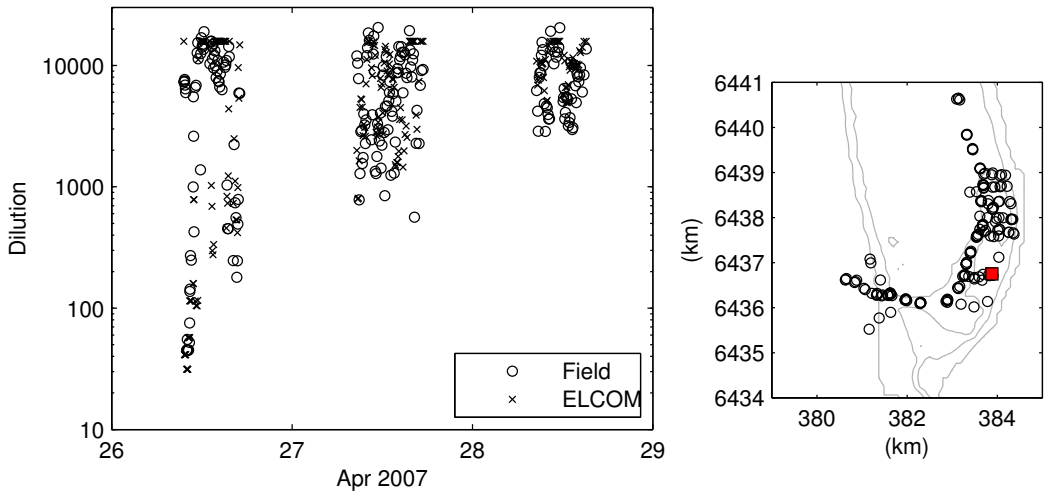

Figure 21. Dilution of the saline effluent during the April 2007 experiment, showing measured (open circles) and simulated ELCOM results (crosses). The right panel shows the location of the field samples relative to the bathymetry in the east of Cockburn Sound in the vicinity of the shipping channels, with the red square indicating the location of the diffuser.

5 Stratification and Dissolved Oxygen

Monitoring data collected at the north, central and southern stations (Figure 1) by the Water Corporation during 2007 is presented to demonstrate the agents responsible for stratification in Cockburn Sound, and the associated dissolved oxygen response. Three data series are presented from three different data sources. The first comes from regular sampling conducted by MAFRL for the Water Corporation ("DO Monitoring"), the second from the Real-Time Management System (RTMS) ("DO RTMS"), and the third from manual sampling conducted by the Water Corporation when the RTMS stations were non-operational ("DO Manual"). All data streams, whilst recording episodes of oxygen depletion, demonstrate clearly that Cockburn Sound is not an oxygen stressed environment, with levels typically above 70% saturation.

Data collected at the southern station (Figure 22) indicates that temperature was the dominant stratifying species (as opposed to salt) for the period January – May 2007. In late January and mid-March, two periods of dissolved oxygen depletion were observed that were associated with triggers in the Water Corporation licence conditions for operation of the Perth Seawater Desalination Plant. In both cases, the stratification at that time was due to temperature, not salt, and so there is no relationship between the oxygen depletion and the desalination plant saline effluent.

Stratification at the central (Figure 23) and northern (Figure 24) stations was more likely to be due to salt than temperature, particularly at the northern station. The data seems to suggest a spatial gradient of temperature stratification in the south, salt stratification in the north and a combination in the central part of the Sound. During the late-January and mid-March events, dissolved oxygen depletion (<80% saturation) was not observed at either the northern or central stations.

Measurements of stratification and dissolved oxygen depletion at all the stations show a clear relationship between stratification strength and dissolved oxygen depletion (Figure 25), confirming the conceptual model of dissolved oxygen consumption in the Sound being dominated by sediment consumption. These data clearly indicate a spatial gradient in dissolved oxygen depletion, such that for a certain stratification, oxygen depletion in the south will be greater than in the central station, which in turn will be greater than in the north. These data are in agreement with sediment characteristics, which show a greater proportion of fine material in the south of Cockburn Sound (Oceanica 2007).

A simple model, based on field data of dissolved oxygen drawdown and stratification, can be developed as an independent check on the impact of the desalination plant on dissolved oxygen in the deep waters of Cockburn Sound. Based on data presented in Figure 25, the lines-of-best-fit

give dissolved oxygen drawdown of 86%, 42% and 24% per kg m^{-3} of top-bottom density difference for the south, central and north stations respectively. Based on the validated simulation presented in section 3.1, the difference in the 90th percentile values for stratification at the south, central and north stations with and without desalination is 0.03, 0.00, and 0.01 kg m^{-3} respectively, giving a conservative estimate of additional dissolved oxygen drawdown due to the desalination plant of 2.6%, 0% and 0.24 % for the south, central and north stations respectively.

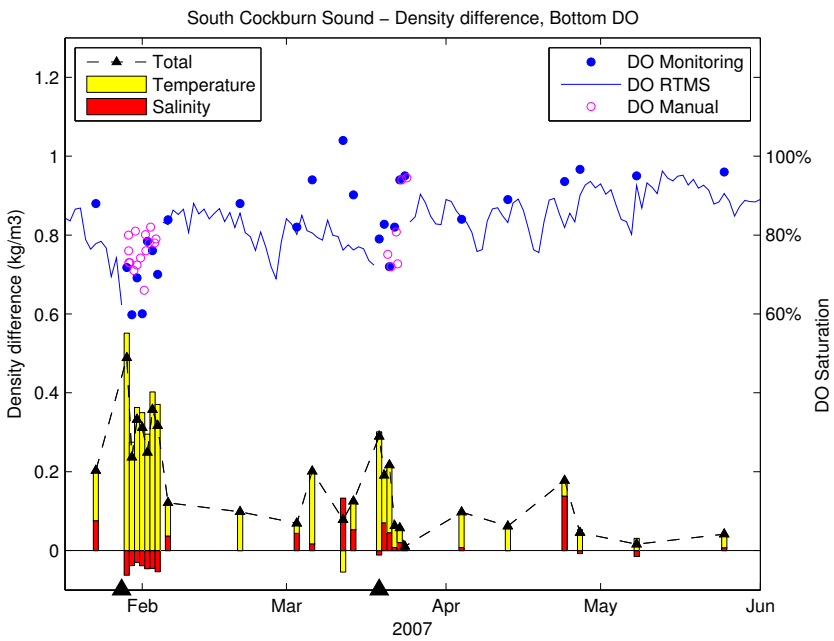

Figure 22. Density difference between top and bottom measurements in profiles at South station (triangles); bars indicate density difference due to top and bottom temperatures using mean salinity (yellow) and density difference due to top and bottom salinity using mean temperature (red); bottom dissolved oxygen saturation is also shown (blue circles). Triggers for the EPA licence are marked with large triangles on the bottom axis on January 28 and March 19 2007.

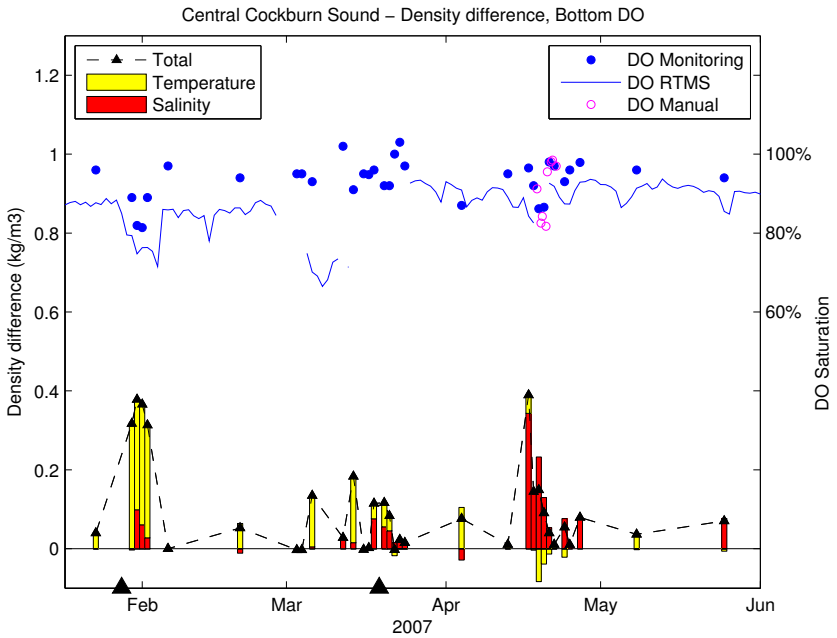

Figure 23. Density difference between top and bottom measurements in profiles at Central station (triangles); bars indicate density difference due to top and bottom temperatures using mean salinity (yellow) and density difference due to top and bottom salinity using mean temperature (red); bottom dissolved oxygen saturation is also shown (blue circles). Triggers for the EPA licence are marked with large triangles on the bottom axis on January 28 and March 19 2007.

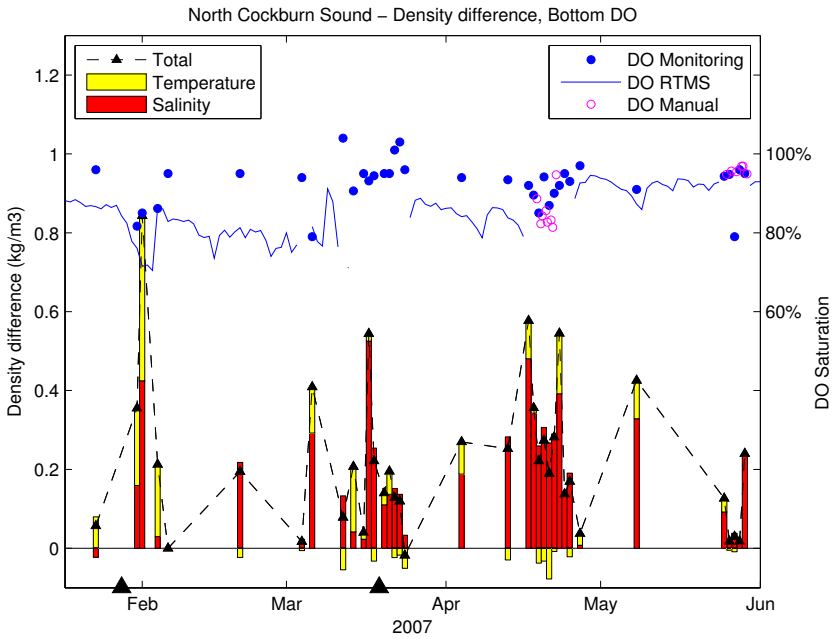

Figure 24. Density difference between top and bottom measurements in profiles at North station (triangles); bars indicate density difference due to top and bottom temperatures using mean salinity (yellow) and density difference due to top and bottom salinity using mean temperature (red); bottom dissolved oxygen saturation is also shown (blue circles). Triggers for the EPA licence are marked with large triangles on the bottom axis on January 28 and March 19 2007.

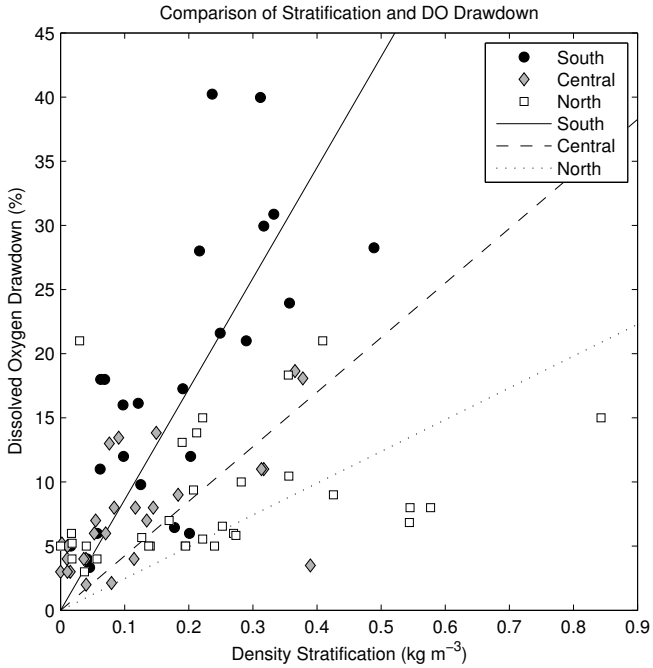

Figure 25. Dissolved oxygen drawdown in bottom measurement (difference from saturation) compared to density difference between top and bottom measurements in profiles at South, Central and North stations. Lines of best fit have been added to aid the discussion.

6 SUMMARY

This report provides a summary of work presented in Okely et al 2006, Okely et al 2007, and Yeates et al 2006 covering modelling, monitoring and field investigations into the dynamics of the saline effluent plume entering Cockburn Sound from the Perth Seawater Desalination Plant. It is not intended to provide detail on any of these individual studies, but rather a holistic overview of the conclusions drawn from each of the three reports.

The objectives of these investigations were to:

a) Determine the impact of the desalination plant saline effluent on stratification in the Sound
b) Determine the impact of the desalination plant saline effluent on dissolved oxygen in the Sound

The conceptual model developed of the Sound based on these detailed investigations is that stratification in the Sound is highly episodic, not seasonal, and is driven by the combination of meteorological fluxes and boundary (tidal) inputs. Analysis of the oxygen budget demonstrated that the dominant process responsible for oxygen depletion in Cockburn Sound is oxygen consumption by the sediments, whereas the dominant source of oxygen is atmospheric transfer at the air/water interface.

The mechanism under which the desalination plant saline effluent might therefore impact upon dissolved oxygen conditions in the Sound is that the duration of episodic stratification events must increase, due to the saline effluent discharge, to the point whereby oxygen consumption by the sediment causes significant additional depletion compared with conditions prior to plant operation. Modelling investigations indicate that, even in the case of extremely calm weather conditions unlikely to ever be experienced in Cockburn Sound, severe oxygen depletion compared to the conditions prior to plant operation are unlikely to be experienced.

The combination of field experiments and numerical modelling has lead to a detailed understanding of the dynamics of the saline effluent plume, and has shown that the dynamics of the plume is the primary reason for the absence of cause-and-effect between the desalination saline effluent discharge and dissolved oxygen. Under calm conditions, the saline effluent from the plant leaves the diffuser vertically, forming a significantly diluted plume with an initial height of approximately 4-5 metres above the bed in the vicinity of the diffuser. The negative buoyancy of the saline effluent causes the plume to plunge to the sea floor where it spreads laterally following the depth contours of the Sound. The plume travels radially under gravity until it intersects the dredged shipping channels, where it is present as a semi-permanent feature (dependent on wind conditions) approximately 2-3 metres above the bed. Once in the shipping channels the plume

moves both to the north and south under gravity. Measurements made during two experiments at the exit of Stirling Channel under very calm (worst-case) conditions indicate the plume was undetectable 45% of the time, and between 0 and 1.0m thick 33% of the time. At all times the plume was undetectable approximately 500m from the exit of Stirling Channel, even for the cases where the plume was more than 1m thick at the exit. Thus, from an initial height of approximately 4-5m above the seabed in the vicinity of the diffuser, the lateral spreading and vertical mixing of the plume sees it completely mixed within 500m of the exit of Stirling Channel. There is therefore no possibility of a saline plume from the desalination saline effluent entering the deep waters of Cockburn Sound (> 10m) and sufficiently prolonging stratification such that dissolved oxygen is drawn down to low levels.

7 References

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