Adelaide Desalination Plant Discharge Dispersion

Final Report

Prepared for MAJV

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1 Introduction

Cardno was engaged by MAJV to undertake an investigation of the salinity plume produced by the Adelaide Desalination Plant (ADP) at 10% production capacity, prior to operation at 20% production capacity or greater. The plume investigation was designed to assess the dispersion of saline concentrate from the diffusers under a ‘worst case’ scenario of low current and wind speed. These conditions were selected because they are associated with minimal ambient mixing, resulting in the largest plume footprint.

Investigation of the plume characteristics was designed to validate the outfall diffuser performance. Field investigations were, therefore, designed to measure dilution of the saline concentrate plume as a function of distance from the outfall.

1.1 Background and Context

The primary purpose of the ADP is to deliver a climate independent supply of a maximum of 100 GL of potable water per annum, to secure and diversify metropolitan Adelaide’s water supply system. The key elements of the ADP include the following:

- A seawater intake structure and connecting tunnel/s and pipelines,
- An outfall structure with diffusers and connecting tunnel/s and pipelines,
- Intake pumping station and screening system,
- Pre-treatment system and associated buildings,
- Reverse osmosis treatment system and associated buildings,
- Post-treatment system and associated buildings, and
- Waste treatment area, including solids thickening and dewatering.

One key aspect of the ADP is the requirement for the intake and outfall systems to meet specified performance criteria for design, construction and operation to ensure that environmental protection objectives are achieved. AdelaideAqua (2009) provide details of the design of the outfall system and discuss the legislative and contractual requirements of the project.

The EIS (SA Water, 2008) and Minister’s Conditions of Approval (Development Authorisation Conditions Gazetted June 2009) define specific environmental and engineering performance criteria to which the plant is required to comply

The EIS (SA Water, 2008) specified an initial dilution of 50:1, which was based on a nominal recovery rate of 45%. As the ADP has been designed for a recovery rate of 48.5%, the equivalent initial dilution has been revised to 58:1 to reflect the higher recovery. This is in accordance with discussions with the EPA (AdelaideAqua, 2009).

The report by AdelaideAqua (2009) demonstrates that the legal and contractual requirements for the design and construction of the intake and outfall systems of the ADP have been met.

With regards to compliance of the outfall, the structure is positioned within the prescribed envelope zone which utilises the localised hydrodynamics to assist in midfield advection and dispersion of the diluted saline concentrate stream without short circuiting with the intake zone.

1.1.1 Worst Case Scenario

AdelaideAqua (2009) conclude that the 'worst case' scenario for the 10% flow rate occurs at Dodge Tide. Numerical model simulations have determined that initial dilutions at the 10% outfall flow rate are estimated at 41:1 under quiescent ambient conditions (AdelaideAqua, 2009). Analysis of the simulation results showed that an ambient current near the bed of 20mm/s, which is typically exceeded during dodge tides, causes additional mixing resulting in a dilution at the impact point of greater than 58:1 (AdelaideAqua, 2009).

This report by Cardno provides dispersion monitoring of the outfall system to determine if the contracted system complies with predictions, by assessing the dispersion of saline concentrate from the diffusers under a 'worst case' scenario of dodge tide with low wind speed. The key outcomes described in the scope of works for this salinity plume study are defined below.

It should be noted that during field tests reported herein the near-bottom current was observed to drop below 20mm/s twice for short durations, the wind speed was less than 10 km/hr and hence it is considered the sampling exercise was carried out under environmental conditions reflecting the worst case dodge tide.

1.2 Scope of Work

The key outcomes to be achieved by the salinity plume study, described in Cardno's proposal, were as follows:

1. Determine the discharge trajectory,
2. Determine how far from the diffuser a 58 fold dilution is achieved,
3. Determine the vertical distribution of the saline concentrate plume downstream of the point of seabed impact,
4. Determine the ambient currents and density stratification when the dodge tide plume survey is undertaken, and
5. Determine the actual discharge and density of the saline concentrate during the plume survey.

2 Methods

2.1 Field Investigation

The preferred conditions for conducting the experiment were:

- Dodge tide,
- Low winds, and
- Saline concentrate discharging for at least 2 days prior to the experiment.

The plant has been undergoing various trials and operating for brief periods since about June 2011. The commissioning team were advised of the fortnightly dodge tide periods between September and November to provide forewarning of potential sampling windows (**Figure 2.1**) for the field exercise and need to commence plant discharge operation prior to the anticipated dodge tide sampling time. The rate of change of upper level with time (dh/dt) provides a representative measure of the likely tidal current (Figure 2.1). The Adelaide Coastal waters weather forecast was reviewed 4 days prior to each dodge tide window to assess whether the desired low wind condition was likely to occur on the intended sampling date. When the 3 conditions aligned the decision to implement the exercise was taken on the basis of the revised weather forecast 3 days prior to the dodge sampling event to provide sufficient time for the plant commissioning team to commence plant operation.

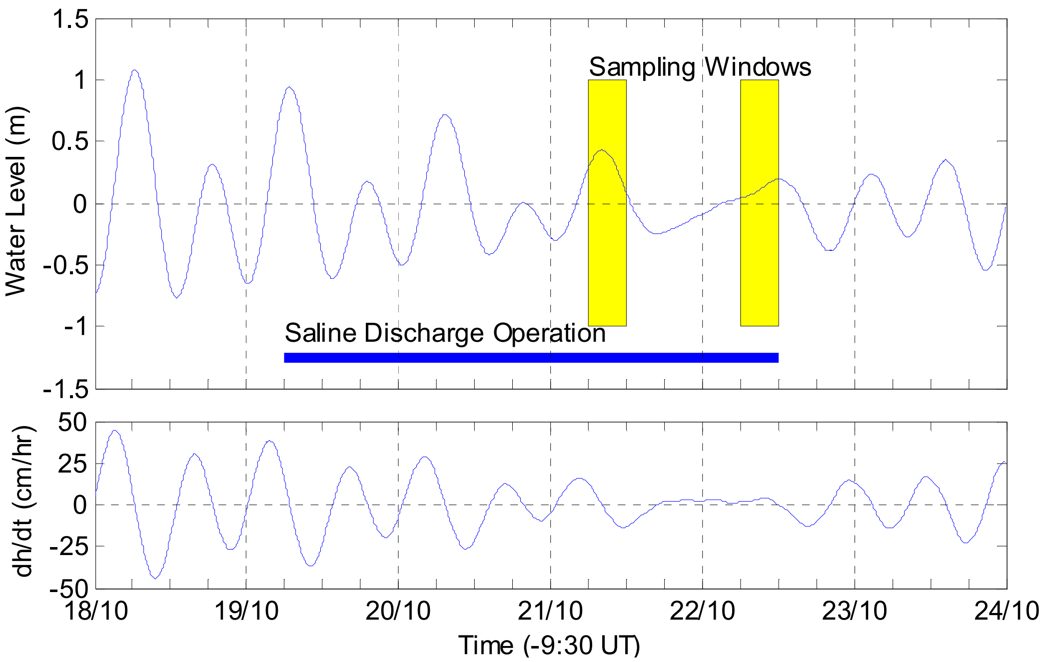


Figure 2.1: Potential dodge tide sampling window for October, 2011. Top window shows the water level, bottom window shows the rate of change in water level over time (dh/dt).

Field investigations were conducted on the dodge tide of Friday 21 October, 2011 between approximately 15:00 and 20:00 (Central Australian Summer Time) coinciding with a cool overcast day with light SE to E winds. The plant operation commenced at 09:00 19 October, 2011 some 2 days prior to the sampling exercise. The tide, weather and operation favoured the occurrence of low ambient mixing conditions required for a worst case scenario for the plume footprint.

Weather conditions on the day selected to undertake the field testing were observed to be calm seas, very low afternoon wind conditions and smooth surface waters, which is consistent with the practical worst case scenario conditions desired.

The field exercise focused on the collection of “FineScale” salinity data using two CTD (Conductivity, Temperature and Depth) instruments and the subsequent conversion of the conductivity, temperature and depth to salinity to resolve the near-bed saline concentrate plume footprint and its mixing characteristics. The CTD specifications are provided in Appendix A and the salinity measurement accessory is approximately $\pm$ 03 ppt. The CTD’s were used in vertical profile mode where the instrument is lowered vertically into and out of the dense saline plume at sites along transects in the vicinity of the discharge diffuser with particular focus on the downstream zone; and in tow mode where the instruments were towed at about 0.5 m/s and lowered up and down during the forward movement. The salinity was monitored in real-time with a display on the sampling vessel to ensure the instruments were within the plume (generally spreading along the bottom in a layer around 1m thick in the water depths of around 19 m).

A GPS was synchronised with the CTD probes and the vessel position recorded as a continuous track during the towing exercises. Waypoints were also recorded at profile sites. The profile sites locations and tow trajectories are shown in **Figure 2.2** along with the locations of the 6 diffuser risers and inlet structure.

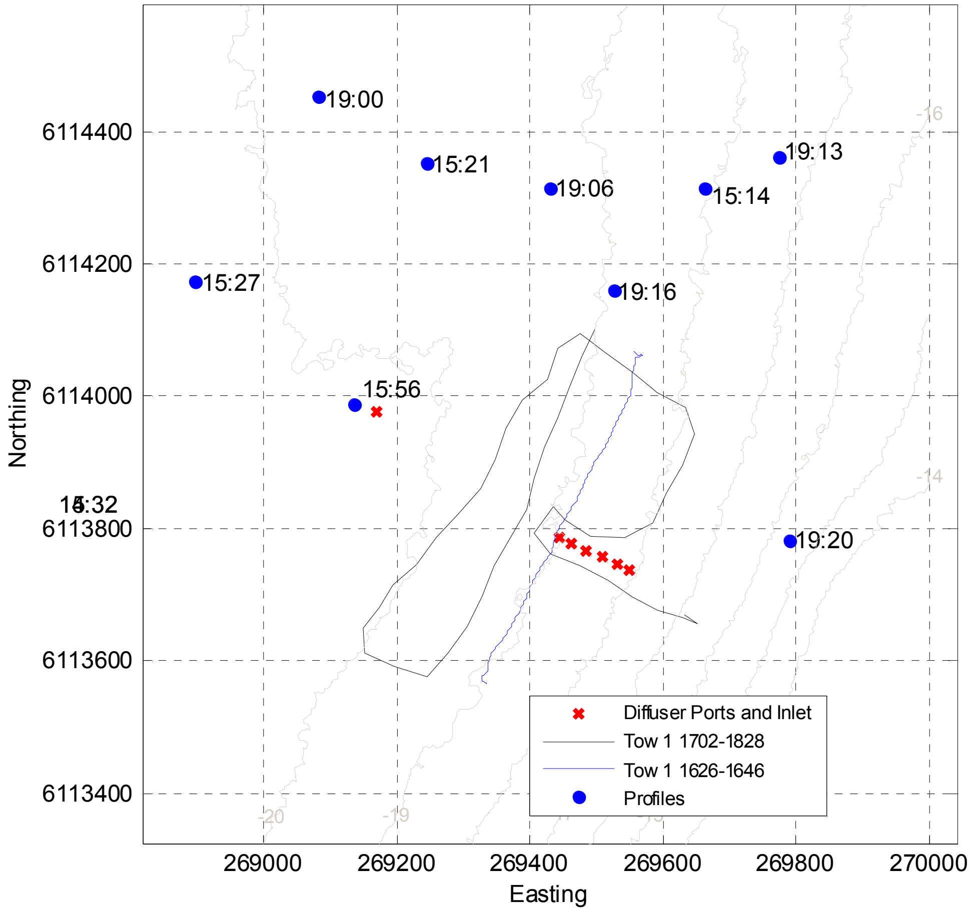


Figure 2.2: CTD Profile sites and tow tracks collected between 15:00 and 19:30 Friday 21 October, 2011.

2.2 Background and Plant Discharge Data

In order to determine dilution of the salinity plume, information on the salt concentration and discharge (flow rate) at the diffuser ports as well as the ambient seawater salt concentration are required. Salinity concentrations of the discharge as well as at 8 monitoring sites around the diffuser and 1 ambient monitoring site (**Figure 2.3**) as part of the ongoing monitoring of salinity in the diffuser area were provided by AdelaideAqua.

The ambient currents are measured by an Acoustic Doppler Current Profiler (ADCP) mounted on the seabed recording currents in 3m vertically averaged bins above the sensor each 10 minutes. The ADCP is located at monitoring site MP2 (**Figure 2.3**) in about 19 m water depth. The instrument comprises a 40 cm high housing deployed in a frame on the seabed. The acoustic transducers face upwards providing estimates of currents in 3 m vertical bins above a 3 m dead zone. Hence, the current measurements are provided in bins from 3 - 6 m, 6 - 9 m, etc to the near surface bin at 15 - 18 m. The ambient current data collected by the ADCP for the period 11:00 21 October to 12:00 22 October, 2011 was supplied by AdelaideAqua. Assuming that the measurement from the near bottom bin (3-6 m above the bed) provides a reasonable representation of the near bottom current. These data provide a measure of the approximate trajectory of the plume and to confirm the predicted low currents associated with the dodge tide.

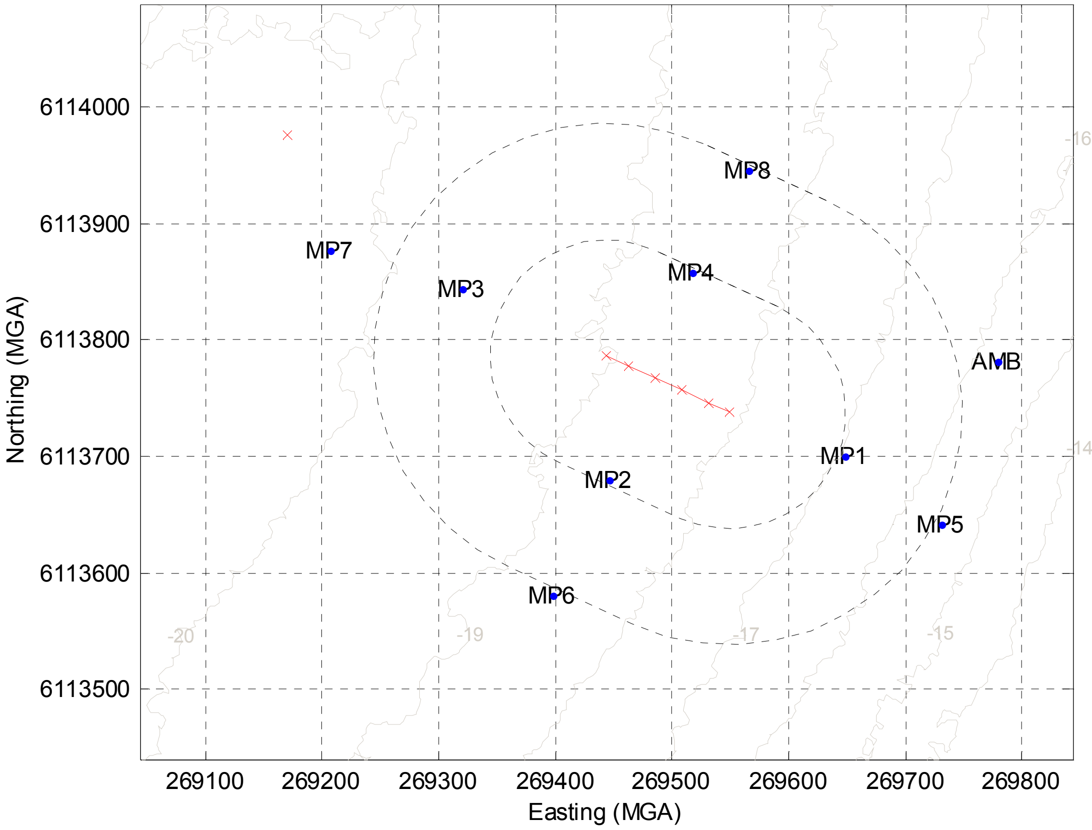


Figure 2.3 Adelaide Aqua near-bottom (0.1 m above bed) salinity monitoring sites.

AdelaideAqua also maintain a Meteorological Station at the plant and these data were used to describe the weather conditions during the sampling. The 15 minute interval wind speed and direction, rainfall, air temperature and humidity data was acquired from AdelaideAqua for the month of October.

The outlet discharge is monitored within the plant. The outlet salinity was determined by collecting 1L water samples each half hour from the saline concentrate holding tank, storing the samples and determining the salinity with the Seabird CTD sensor after the field data acquisition exercise.

Background information provided by AdelaideAqua are summarised in **Table 2.1**.

Table 2.1: Summary of data on plant operation and monitoring systems available from AdelaideAqua for the October sampling exercise

Data Set	Available		Comment
	From	To	
Ocean Ambient sites			
Currents - ADCP	11:00 21/10/11	12:00 22/10/11	Data not available for 19 and 20 Oct due to servicing
Salinity, Cond, Temp	11:00 21/10/11	12:00 22/10/11	<10% missing data

Data Set	Available		Comment
Real Time "Impact" Sites			
8 x Salinity, Cond, Temp	08:00 21/10/11	12:00 22/10/11	Data at 7 sites: 4x100m and 3 x 200m, <10% missing data
Intake			
Discharge (m^3/sec)	00:00 19/10/11	20:00 21/10/11	
Salinity, Cond, Temp	00:00 19/10/11	20:00 21/10/11	
Outlet Diffuser			
Discharge (m^3/sec)	00:00 21/10/11	20:00 21/10/11	
Salinity, Cond, Temp	00:00 21/10/11	20:00 21/10/11	
Brine Grab Samples Salinity	13:00 21/10/11	17:00 21/10/11	Half hourly 1 L samples collected from the outfall within Plant. Salinities determined using Seabird CTD instrument.

2.3 Analytical Procedures

2.3.1 Vessel CTD Tow Track

Vessel tracks and profile locations were derived from GPS track and waypoint files by interpolating the track (30 second samples) to the same sampling interval as the CTD sampling of 0.25 seconds. The tow information could then be transformed from time domain to spatial domain. The distance of each track point from the diffuser axis was also estimated to provide reference to the diffuser location. Tow data could then be transformed from time to space or distance north of the diffuser axis.

2.3.2 Determination of Salinity from CTD Data

Salinity and density are computed from the conductivity, temperature and depth data measured by the CTD. As the temperature and conductivity sensors have different response times and are physically separated on the probe the derivation of salinity needs to account for these differences to avoid (or at least minimise) spiking errors. The standard UNESCO (1981) equation of state for converting conductivity, temperature and depth readings to salinity (psu) and density (kg/m^3) were utilised. In addition the AdelaideAqua formula for converting conductivity and temperature to total dissolved salts (mg/L) and salinity (ppt) was also used as the formula preferred by SA government agencies. The latter salinity is referred to below as AA Salinity and generally gives lower values than the standard UNESCO formula at typical seawater salinities of 35-36 psu and slightly higher salinities at the typical saline concentrate values of around 70 psu. The AA salinity is generally adopted in this report.

2.3.3 Characterisation of the Salinity Plume

In order to visualise the plume characteristics the spatially variable salinity data were interpolated onto a regular grid to allow graphical presentation of salinity contours (or isohalines). As the plume spreads in the horizontal a horizontal bias was applied to the interpolation scheme used to interpolate between the non-uniform sampling points.

2.3.4 Estimation of Dilution

Dilution was estimated from the field salinity measurements using determinations of the discharge and ambient salinity concentrations. Dilution estimates, D(x,y,z) are calculated using the relationship:

$$D = \frac{[C_o] - [C_b]}{[C\ \ ] - [C_b]} \qquad \boldsymbol{ation\ 1}$$

$Where$:

$C_o = Concentration\ di\ \ charged\ at\ the\ Outfall\ Diffu\ \ er\ port$

$C\ \ = Concentration\ at\ Di\ \ tance\ x\ from\ the\ diffu\ \ er$

$C_b = Background\ ambient\ \ \ eawter\ concentration$

The measurement accuracy of the salinity data determines the effective maximum resolvable dilution. For the FineScale CTD profilers utilised for this study the salinity accuracy is approximately 0.03 ppt for the pumped CT cell when appropriate sensor matching algorithms are applied to the raw CTD data. For typical background (36.5 ppt) and discharge (≈ 70 ppt) salinities the maximum resolvable dilution is around 900.

Hence the use of the fine-scale Seabird profilers provides adequate resolution of dilution.

3 Data

3.1 Salinity Plume Data

CTD profiles were collected at several sites around the diffuser prior to the instruments being deployed in the tow mode as shown in **Figure 2.2**.

Table 3.1 presents details on the nominated output locations and the vertical profiles are presented in **Appendix A.**

Table 3.1: Sampling Times and Locations

Sample Time	Profile on Tow	East (m MGA94 Zone 56)	North (m MGA94 Zone 56)	Bed Level (m LAT)
15:12	P	269664	6114315	17.7
15:20	P	269246	6114352	18.8
15:25	P	268896	6114174	20.1
15:31	P	268690	6113836	20.6
15:39	P	268070	6112561	21.7
15:48	P	268795	6112997	20.2
15:55	P	269136	6113987	19.7
16:25-16:46	Tow			
17:00-18:25	Tow			
18:49	P	268700	6115263	20.4
18:56	P	268991	6114803	19.6
19:00	P	269082	6114452	18.9
19:06	P	269430	6114314	18.9
19:09	P	269457	6114720	18.8
19:13	P	269776	6114362	16.9
19:16	P	269526	6114159	18.6
19:20	P	268700	6115263	20.4

The tow data for the tow section between 16:25 and 16:46 are presented in **Figure 3.1** as a function of distance from the diffuser axis (positive being north of the diffuser). The figure highlights the instrument depth along the transect, the salinity along this track and the calculated dilution. The salinity increases as the instrument is lowered into the plume and decreases to the background salinity of the overlying water as it is hauled up. Dilution was estimated using **Equation 1** and the salinity values of the 69.38 ppt (discussed in the following section).

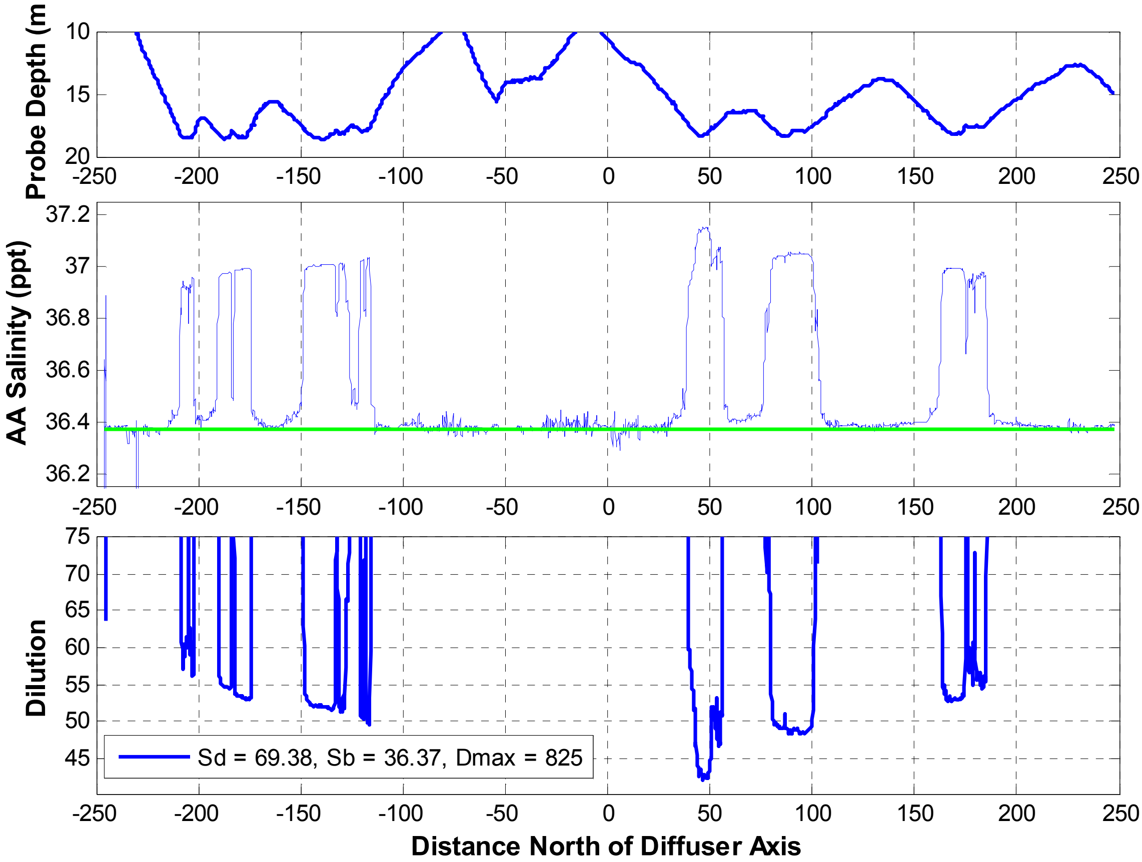


Figure 3.1: Tow data (16:25 to 16:46) showing the CTD depth, salinity and dilution estimates as a function of distance north from the diffuser axis

Vertical salinity profiles were compiled from the downcast sections of the tow data. These profiles are shown in **Figure 3.2** and demonstrate thickness of the plume is typically between 0.5 and 1.0 m above the bottom. The time and distance north (-ve south) of the diffuser axis are provided in the legends of each figure.

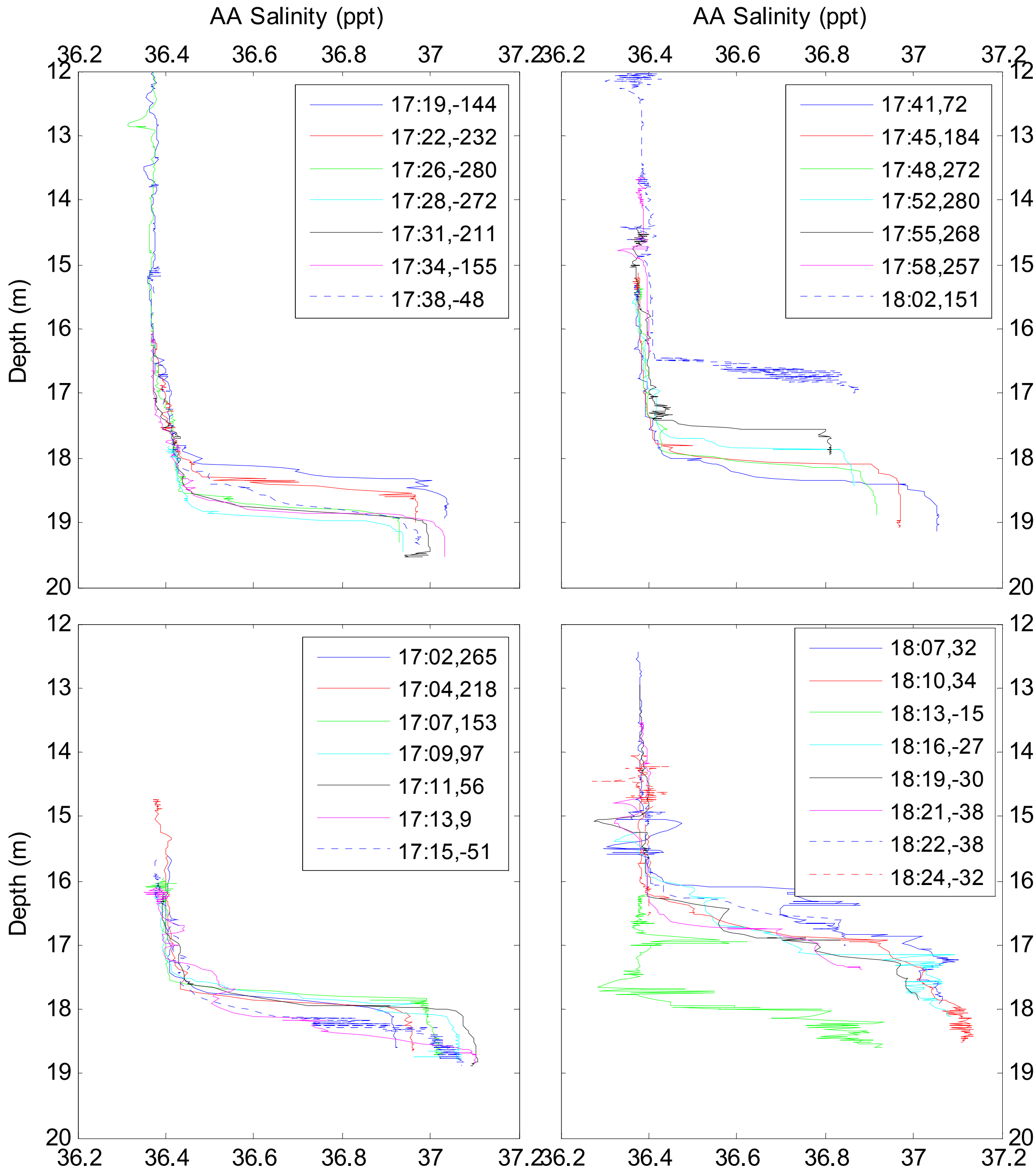


Figure 3.2 Vertical profiles compiled from downcast tow data at the times shown in the legend. The distance north of the diffuser axis (-ve south) for each profile is also indicated.

The intake salinity provided by Adelaide Aqua slowly decreased through the day from the 36.66 ppt at 13:00 (Australian Central Summer Time) to 36.45 at 17:30. The CTD salinity at 17:30 near the intake level was 36.37 ppt which is slightly lower (0.8 ppt) than the intake measurement which is within the measurement accuracy of the Adelaide Aqua sensors. The inlet discharge averaged 57.8 ML/day during the same period.

3.2 Discharge Data

Water samples collected each half hour from the outfall were analysed in the laboratory using the SBE19 CTD instrument. Samples were pumped through the conductivity and temperature cell for a few minutes and data recorded at 4 Hz (each 0.25 secs). These results were then averaged and are presented in **Table 3.2**. The five half hourly average salinities between 13:00 and 15:00 were then averaged to determine the discharge salinity of 69.28 ppt for the purposes of computing the dilution. As the water transfer time (and hence time lag between the outfall salinity measurement and time this water is discharged through the diffuser port) for the 10% flow (31 ML/day) through the discharge tunnel is about 3 hours the values recorded between 13:00 and 15:00 are deemed to be representative of the discharge salinity at the time, approximately 16:00 to 18:00, of the CTD measurements in the ocean.

Table 3.2: Outlet salinity (ppt - AA formula) data determined from 1 L water samples collected from the outlet tank within the plant and analysed by the Seabird CTD probe.

Time	Mean	Min	Median	Max	Stdev
13:00	67.79	67.73	67.79	67.81	0.01
13:30	70.93	70.66	70.98	71.16	0.09
14:00	72.16	71.99	72.16	72.30	0.04
14:30	72.12	72.00	72.11	72.29	0.06
15:00	63.38	63.06	63.40	63.54	0.06
15:30	54.98	54.77	54.99	55.16	0.06
16:00	53.27	53.08	53.27	53.35	0.04
16:30	62.79	62.63	62.78	62.97	0.06
17:00	65.42	65.30	65.41	65.53	0.04

The discharge flow rate is measured within the plant. Discharge data provided by AdelaideAqua indicated the plant discharge varied during the marine sampling period and the mean discharge over the period of measurements was 35.6 ML/day.

3.3 Nearfield Dispersion Estimates

The nearfield dispersion characteristics was estimated for the observed discharge data assuming flow through a duckbill valve according to the modified Roberts formula discussed in AdelaideAqua (2009). The actual duckbill flow characteristics were assumed to match the results of the laboratory experiments at 10% discharge (31 ML/day). Typical values for the characteristic variables in a quiescent environment are described in the AdelaideAqua (2009) report and illustrated in **Figure 3.3** (reproduced from the EIS document). Results in terms of the maximum and centreline height of rise y_t, impact distance x_i, dilution at the point of impact D_i, and salinity at x_i and y_t are listed in **Table 3.3**.

The estimates provided in **Table 3.3** indicate the discharge from each diffuser attains a height of about 2.8 m above the seabed and rapidly falls back to the seabed within about 3 m of the diffuser port. At this point of impact the centreline dilution is estimated as 20:1.

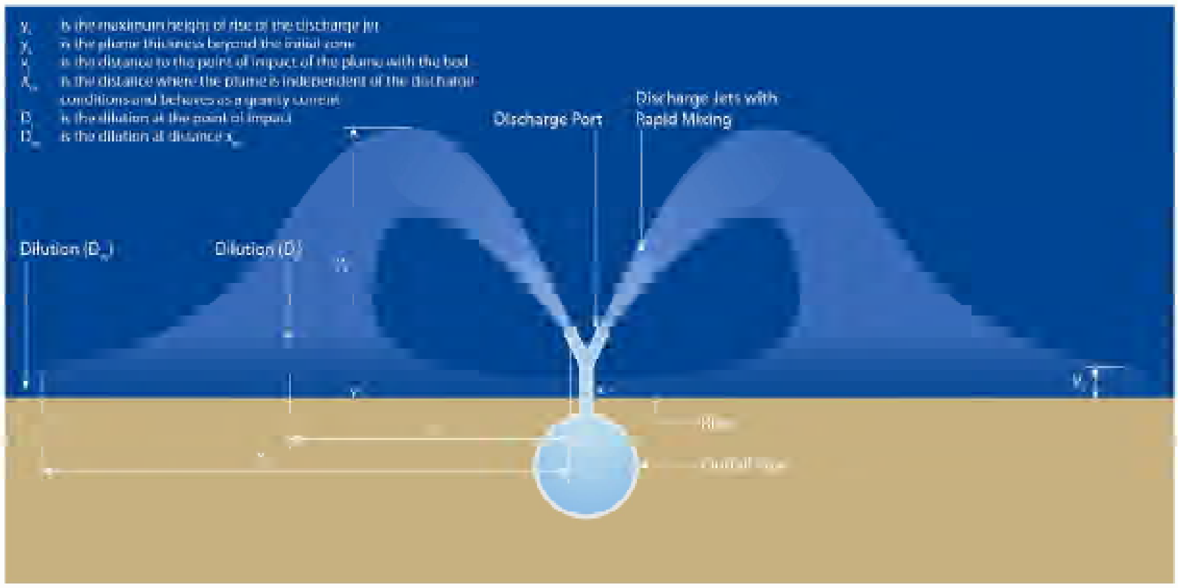


Figure 3.3 Schematic diagram of the nearfield flow dispersion characteristics. Figure reproduced from the EIS (2008).

Table 3.3 Parameter values and derived characteristics of the nearfield flow according to the formulae described in the AdelaideAqua (2009).

Parameter	Value		
Flow m^3/s	0.4123		
Flow per port (24 ports) m^3/s	0.01718		
Valve Area m^2	0.0077		
Circumference m	0.58		
Hydraulic diameter m	0.053		
Equivalent circle diameter m	0.099		
Exit velocity m/s	2.0		
Ambient S ppt, T °C, density kg/m^3	36.37	16.1	1026.8
Brine S ppt, T °C, density kg/m^3	69.3	17.1	1052.0
Derived Variables			
Froude Number Hydraulic	12.5		
Froude Number Equivalent Circle	9.2		
Impact Distance x_i m	2.2		
Dilution at x_i	20.0		
Height top y_{ta} m	1.8		
Height centreline y_t m	1.5		
Dilution at y_t	6.0		
Salinity at x_i ppt	37.9		
Salinity at y_t ppt	41.1		

3.4 Background Environmental Data

ADCP current data are shown in **Figure 3.4** for the three vertical averaging bins bounded by 3 to 6 m above bed, 6 to 9 m above bed and 12 to 15 m above bed. The instrument is moored in approximately 19 m water depth and the near surface bin (18 to 21 m above bed) is affected by surface interaction with the acoustic measuring system.

Up to 15:30 the currents show a period of southward flow of up to 50 mm/sec in the bottom layers and greater than 100 mm/sec the near surface indicating a weakly ebbing tide. After 15:30 the flow in the near bed layer changes to a northward flowing (flood tide) current consistent with the tidal predictions. The mid-depth layer (6-9 m above bed) fluctuates between the northward and southward flow indicating a velocity shear over the water column. The near surface current remains flowing to the south for the duration of the field sampling exercise while the current at depth flowed to the north.

Note plume sampling was undertaken between 15:00 and 19:30 during the weak flooding period of the dodge tide. Slack water near the bed occurred at 15:30. At around 21:00 the currents converge to a southward flow (ebb tide) over the water column.

During the period of northward flow the near bed current speed increases from slack water at 15:30 to around 50 mm/sec at 18:00 before slowly decreasing. Assuming the near-bed data at 3-6 m above bottom provide a reasonable representation of the direction of the dense saline concentrate plume between 0 and 1 m above bottom then it is reasonable to assume that during the sampling exercise (15:00 to 19:30) the plume was also flowing northward.

Salinity monitoring data (**Figure 3.5**) at the 9 measurement sites surrounding the diffuser indicate the plume is migrating across the area and affecting the different fixed sites at different times.

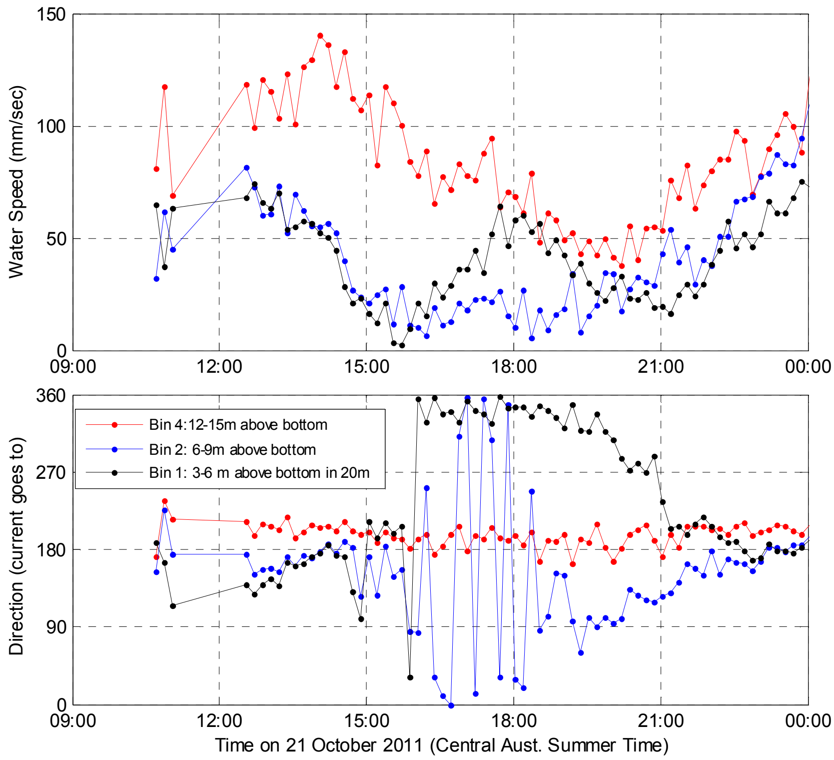


Figure 3.4 ADCP current meter results for the 3 bins (3-6m, 6-9m and 12-15m above bed).

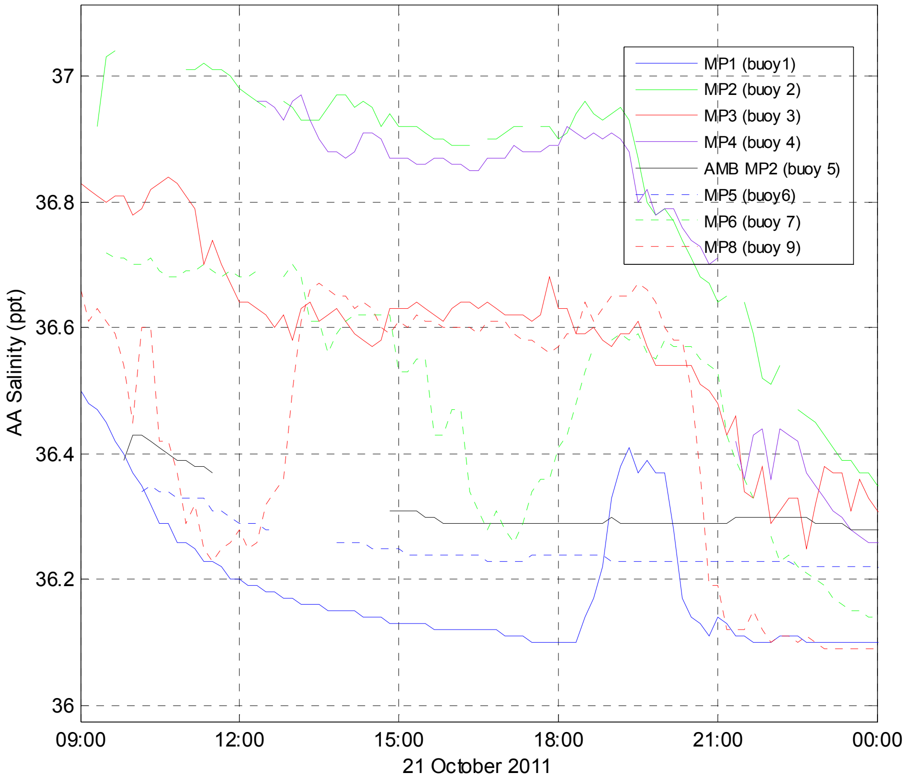


Figure 3.5 Near bottom (0.1 m above bed) salinity at Adelaide Aqua diffuser measurement sites (see Figure 2.2 for locations).

4 Results

4.1 Plume Trajectory

To demonstrate the likely trajectory of the plume a progressive vector diagram was derived from the current meter data (**Figure 4.1**). Prior to slack water in the lower layer near the bed the trajectory is predominantly southward (ebbing tide) and after slack the deep water trajectory is northward (black line in **Figure 4.1**). Note the near surface currents (blue line) flow toward the south for the whole period from 11:00 to 20:00, probably in response to the light offshore (easterly) winds that tend to drive southward flow near the coast. Currents at the mid-level from 6 to 9 m above bed flow southward from 11:00 to 14:00 then eastward from 15:00 to 20:00.

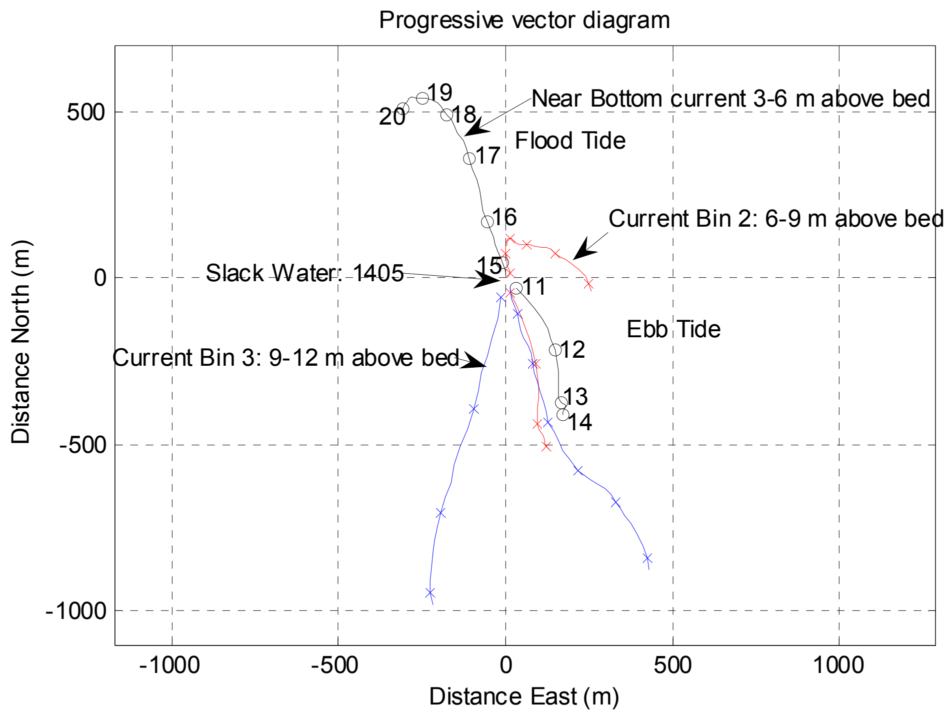


Figure 4.1: Progressive vector diagram indicating the plume trajectory prior to and after slack water at 15:30.

4.2 Salinity and Dilution

Near-bed salinity contours were derived from the Tow 2 (17:00-17:24) data collected during the flooding tide and are shown in **Figure 4.2**. This figure is focused on the bottom 3.5m of the water column and clearly indicates the narrow plume region. As can be seen in **Figure 2.2** the tow path is perpendicular to the axis of the diffuser and crosses the axis some 15m offshore from the last riser. Note the profiler tow path (dashed lines) is shown on the salinity contour plot and indicates the interpolation across the actual diffuser area from -25 to 100m and up to about 3m above the bottom.

Dilutions were estimated using equation 1 with background or ambient salinity C_b = 36.37 ppt and discharge salinity C_0 = 69.28 ppt.

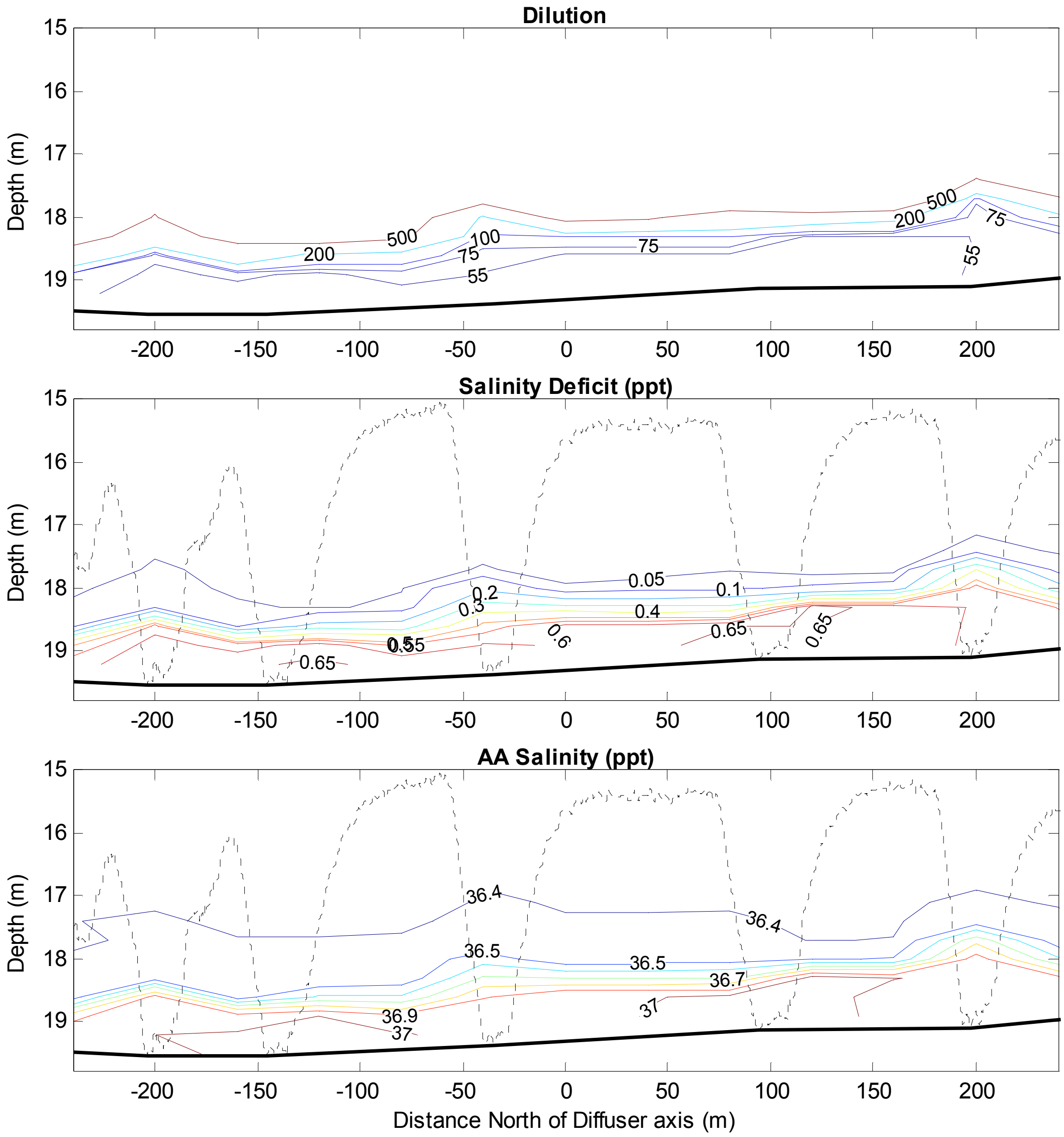


Figure 4.2: Salinity (S), Salinity deficit (S-36.75) and dilution (S0 =64.35, Sb = 36.75) derived from track data 17:00-17:24 offshore the end of the diffuser. CTD path is shown by the black dashed lines.

Plan views of the salinity (ppt) contours derived from the deepest points of downcast profiles are shown in **Figure 4.3** and derived dilution in **Figure 4.4**. These data indicate the plume extends offshore as expected for a gravitational downslope flow and both south and north of the diffuser. The plan view is consistent with the model outputs for the 10% flow case presented in Appendix A of AdelaideAqua (2009).

Figure 4.4 indicates the anticipated dilution of 41:1 for a 10% flow case is exceeded within 100m of the discharge.

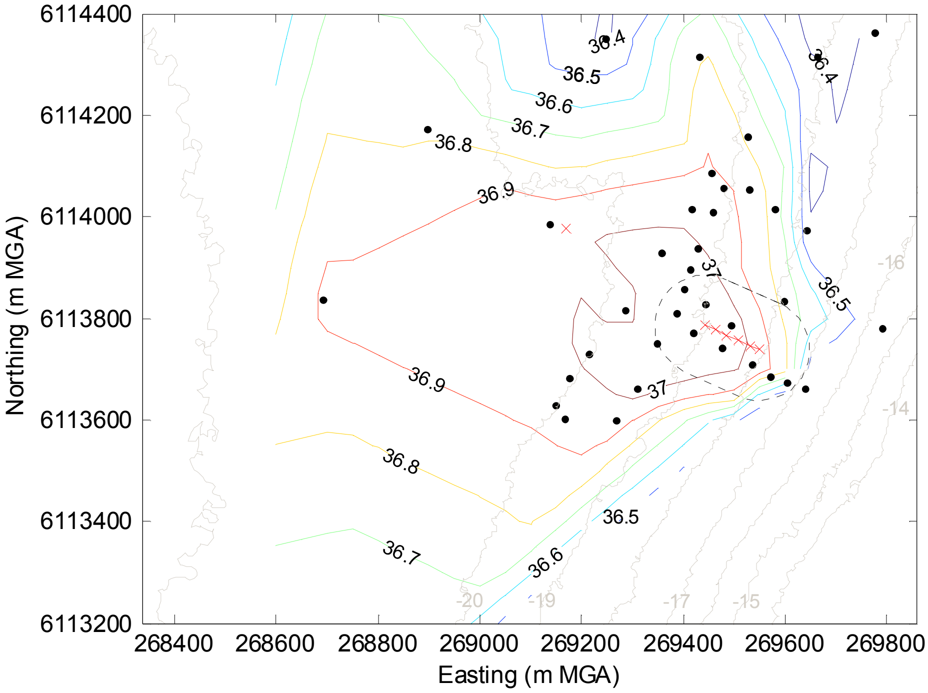


Figure 4.3: Salinity and dilution contours derived from the Tow 1 (16:25 to 16:46) data set

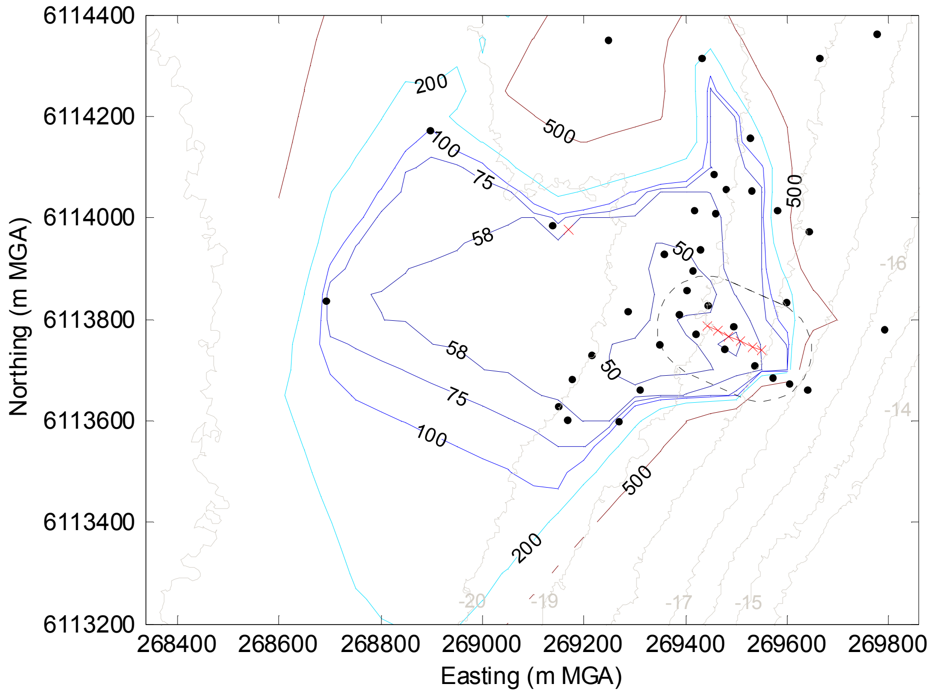


Figure 4.4: Bottom dilution (S_d = 69.28 ppt, S_b = 36.37 ppt) contours, discharge ports (red crosses) and 100 m radius (dashed black line).

4.3 Implications for Aquatic Life

An ecotoxicity assessment was previously undertaken by AdelaideAqua (2009) to establish the minimum dilution rate required to avoid adverse affects of saline concentrate and Clean in Place (CIP) chemicals on marine flora and fauna.

The calculated safe dilution factors for the saline concentrate and the chlorinated / dechlorinated saline concentrate indicated that the chlorination process increased the toxicity slightly when compared with the saline concentrate. The saline concentrate was calculated to require a dilution of 20:1 to protect 95% of species while the chlorinated / dechlorinated saline concentrate was calculated to need a dilution of 21:1. The safe dilution factor of 20:1 equates to a salinity concentration of 39ppt (AdelaideAqua, 2009).

The results presented above indicate the observed dilution is significantly greater than the safe dilution factor of 20:1 to protect aquatic life and the environment. Hence the potential risk to aquatic life due to salinity dispersal from the outfall structure is considered to be low.

5 Conclusions

A field monitoring exercise was conducted during the dodge tide of 21 October, 2011 to assess the dispersion characteristics of the saline concentrate discharge, at 10% flow from the AdelaideAqua Desalination Plant outfall system.

During field tests the near-bottom current was observed to drop below 20mm/s twice for short durations, the wind speed was less than 10 km/hr and hence it is considered the sampling exercise was carried out under environmental conditions reflecting the predicted worst case of low winds at dodge tide. In particular the dodge tide of 21 October, 2011 was sampled between 1500 and 1900 when the weak flooding tide resulted in an ambient near-bottom current of around 15 mm/s. The low swell and winds <5 km/hr were commensurate with the desired worst case dodge tide sampling conditions.

Under this worst case condition the dilution at 100 m from the diffuser was greater than the AdelaideAqua (2009) estimate of 41:1 dilution for 10% flow.

The results presented in this report generally align with the predictions made in the *Report – Intake and Outfall Systems Environmental Performance Summary* by AdelaideAqua (2009).

6 References

AdelaideAqua (2009) *Report – Intake and Outfall Systems Environmental Performance Summary*. Revision 1. 7 December 2009.

SA Water (2008) Proposed Adelaide Desalination Plant: Environmental Impact Statement

UNESCO (1981) The Practical Salinity Scale 1978 and the International Equation of State of Seawater 1980. Tech. Pap. Mar. Sci. **36**, 25pp

Appendix A

Seacat Profiler CTD

SEACAT Profiler CTD

SBE 19*plus* V2

The SBE 19*plus* **V2** (Version 2) Seacat Profiler CTD measures conductivity, temperature, and pressure (depth) and provides high accuracy and resolution, reliability, and ease-of-use for a wide range of research, monitoring, and engineering applications. The pump-controlled, T-C ducted flow configuration minimizes salinity spiking caused by ship heave and allows for slow descent rates without slowing sensor responses, improving dynamic accuracy and resolving small scale structure in the water column. The V2 is the most versatile successor in the line of *Personal CTDs* begun with the original SBE 19 SEACAT in 1987.

Compared to the previous 19*plus*, the 19*plus* V2 incorporates an electronics upgrade and additional features. The V2 has two additional (6 total) auxiliary A/D input channels. FLASH memory is increased from 8 to 64 MB, and one RS-232 data input channel is added. An optional Digiquartz® pressure sensor provides highest-accuracy pressure measurement. Data can be output in XML as well as ASCII and HEX formats. Firmware upgrades can be downloaded through the communications port by the user, without opening the instrument.

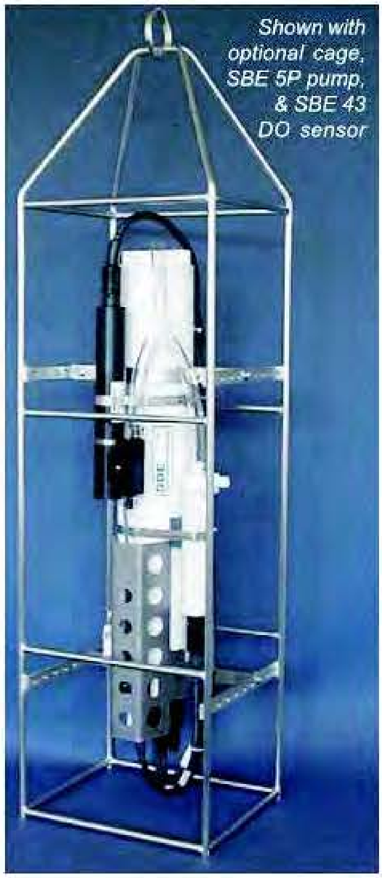
The 19*plus* V2 samples continuously at up to 4 scans per second (4 Hz) (2 Hz with Digiquartz®), is battery-powered and self-recording, and is commonly used in the field without a computer, recording up to 1000 individual profiles. Data can be uploaded to a PC and processed later, or can typically be transmitted in real time more than 100 meters to a PC for acquisition and display using SEASOFT software provided (maximum cable length is dependent on the number of auxiliary sensors, sampling rate, baud rate, and cable properties). The 19*plus* V2 can supply power to 7 external sensors and log their outputs with each CTD scan. Nine D-size alkaline batteries provide up to 60 hours of continuous operation when logging C, T, and P at 4 Hz (operation time is shorter if powering auxiliary sensors).

The 19*plus* V2 is easily integrated with an SBE 32 Carousel Water Sampler and is ideal for integration with the SBE 55 ECO Water Sampler. Both real-time and autonomous *auto-fire* operations are possible with any Sea-Bird CTD / Water Sampler system.

The 19*plus* V2 can operate in moored mode, recording time series measurements at user-programmable intervals. Moored mode is easily configured using setup commands and by removing the profiling T-C Duct and installing optional anti-fouling devices. (If profiling is not needed, the 16*plus* V2 Seacat Recorder offers greater moored-mode programming flexibility and a pressure sensor is optional.)

Accuracy, convenience, portability, software, and support: compelling reasons why the 19*plus* V2 is today's best low-cost CTD.

CONFIGURATION, OPTIONS, AND ACCESSORIES



A standard SBE 19*plus* V2 is supplied with:
- Plastic housing for depths to 600 meters
- Strain-gauge pressure sensor
- 64 Mbyte FLASH RAM memory
- 9 D-size alkaline batteries
- Glass-reinforced epoxy bulkhead connectors
- SBE 5M miniature pump with plastic housing for depths to 600 m, and T-C Duct

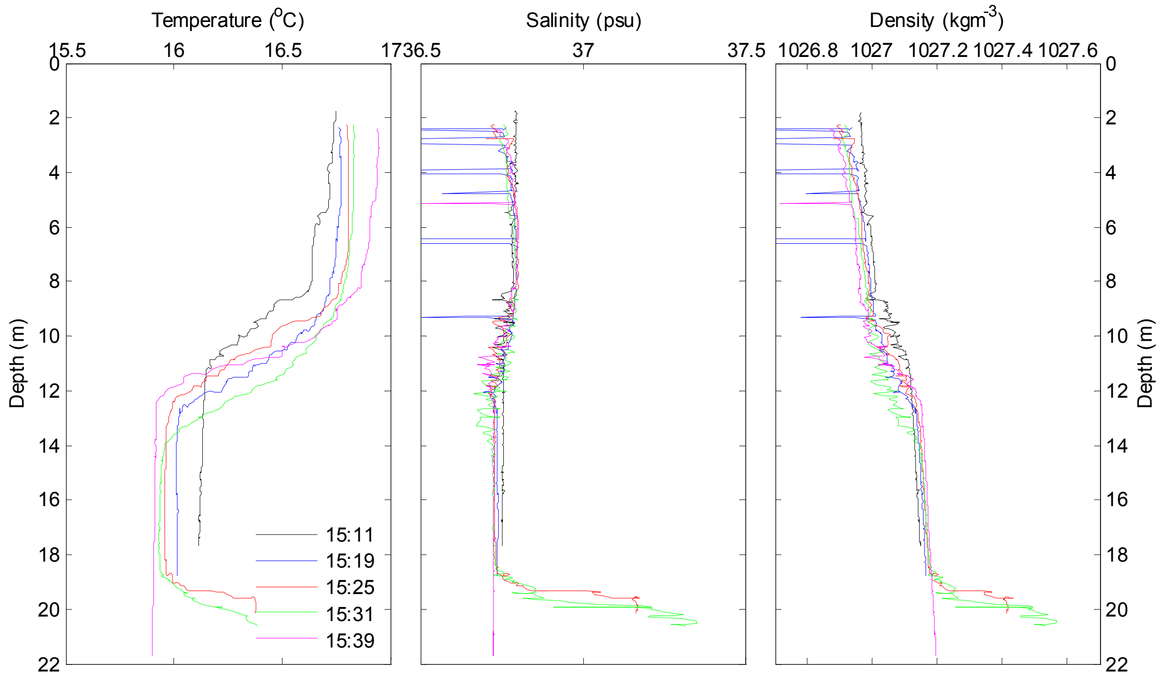
Options and accessories include:
- Titanium housing for depths to 7000 meters
- Wet-pluggable MCBH series connectors
- SBE 5M miniature pump with titanium housing for 7000 meters
- SBE 5P (plastic) or 5T (titanium) in place of SBE 5M for use with dissolved oxygen and/or other pumped sensors
- Digiquartz® pressure sensor
- Stainless steel protection cage
- Auxiliary sensors for Dissolved Oxygen, pH (Profiling mode only), fluorescence, radiance (PAR), light transmission, and optical backscatter (turbidity)
- Plastic shipping case
- Nickel Metal Hydride (NiMH) batteries and charger
- Moored mode conversion kit with anti-foulant device fittings
- Load-bearing underwater cables for hand-hauled, real-time profiling
- SBE 36 CTD Deck Unit and Power/Data Interface Module (PDIM) for real-time operation on single-core armored cable up to 10,000 meters

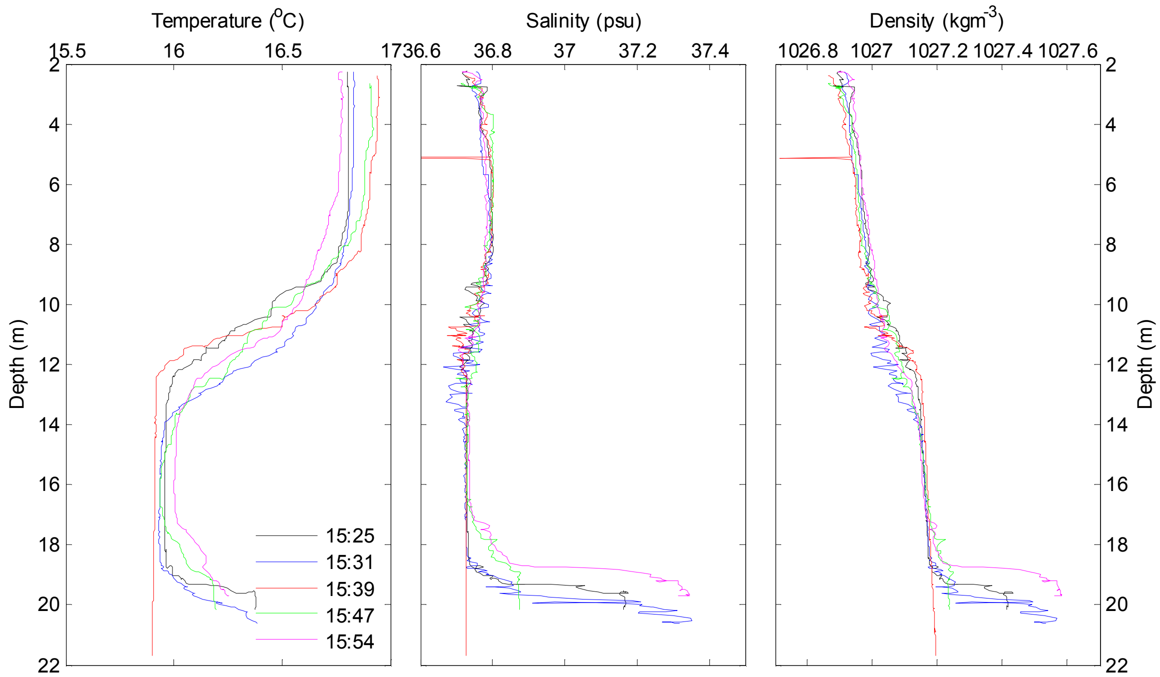
SOFTWARE

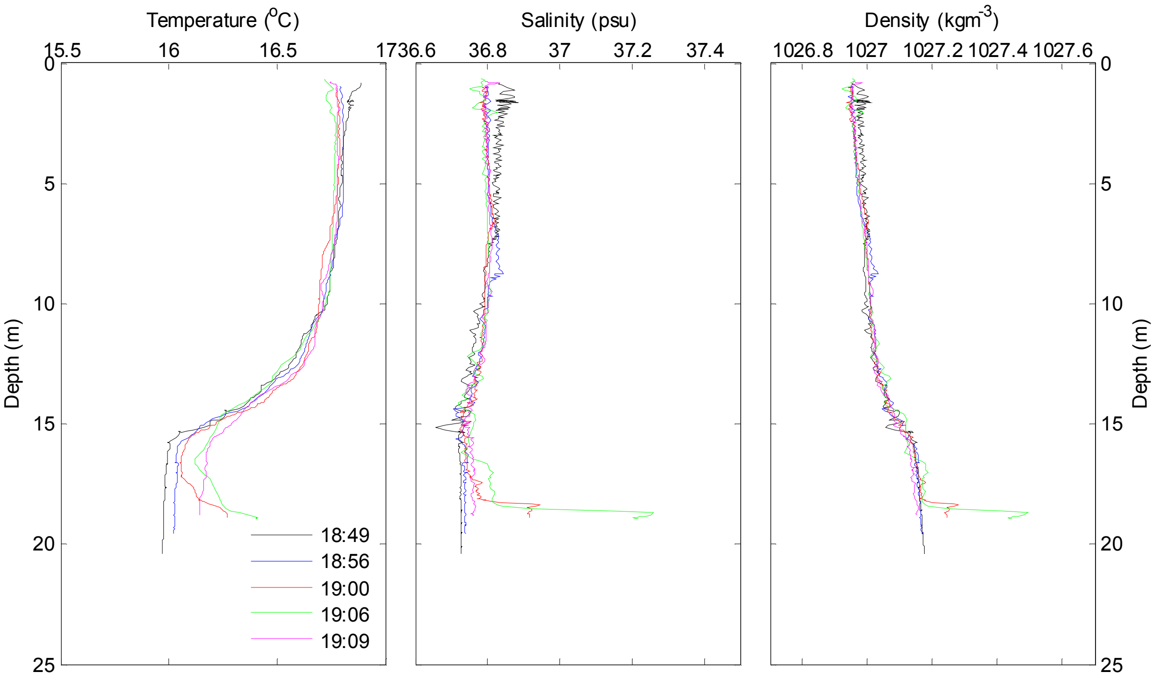
The SBE 19*plus* V2 is supplied with a powerful Windows 2000/XP software package, SEASOFT©-Win32, which includes programs for communication and data retrieval, real-time data acquisition and display, and data processing (filtering, aligning, averaging) and plotting.

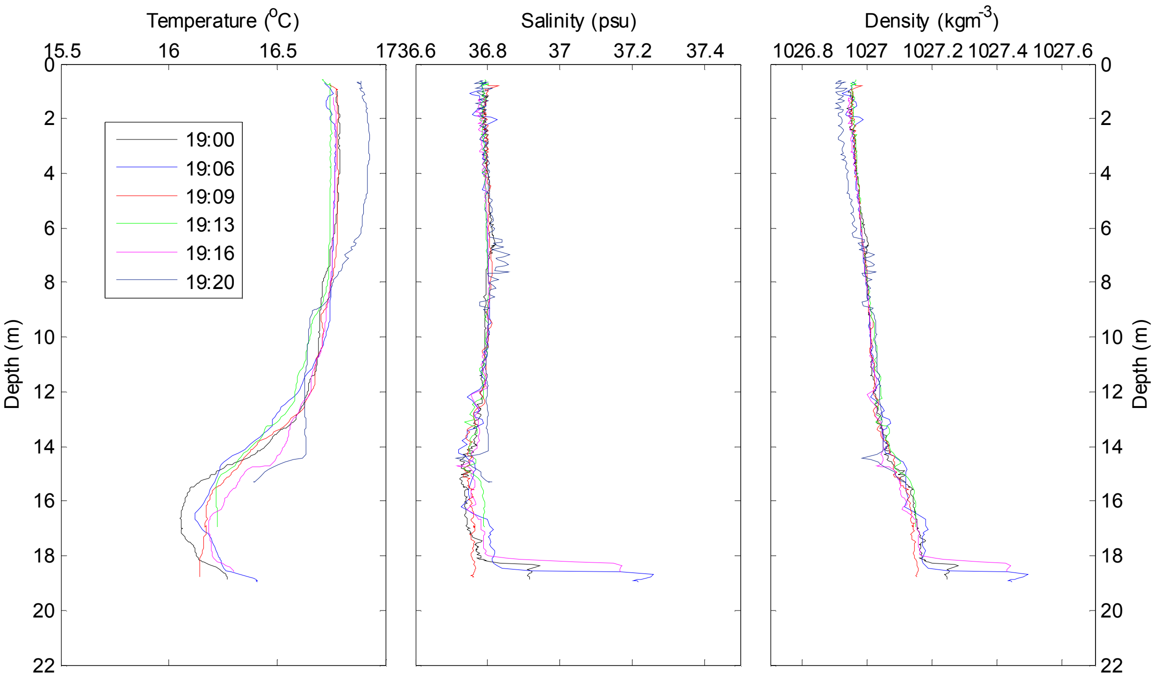
Appendix B

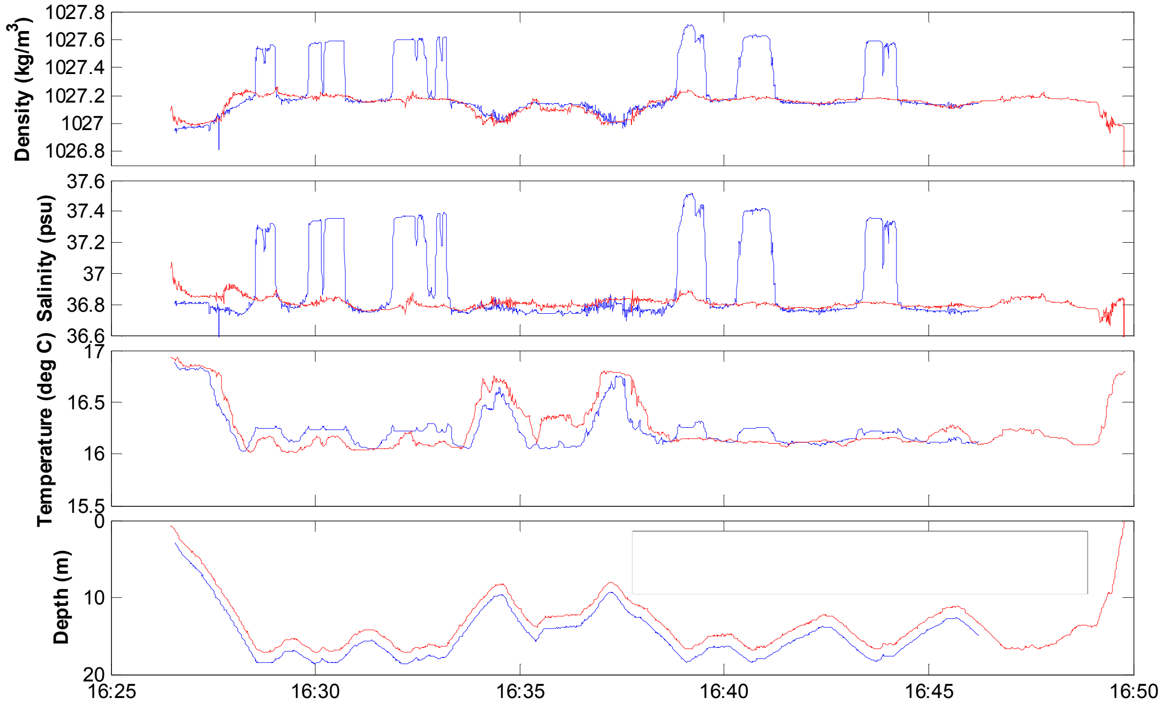
CTD Profiles and Tow Figures

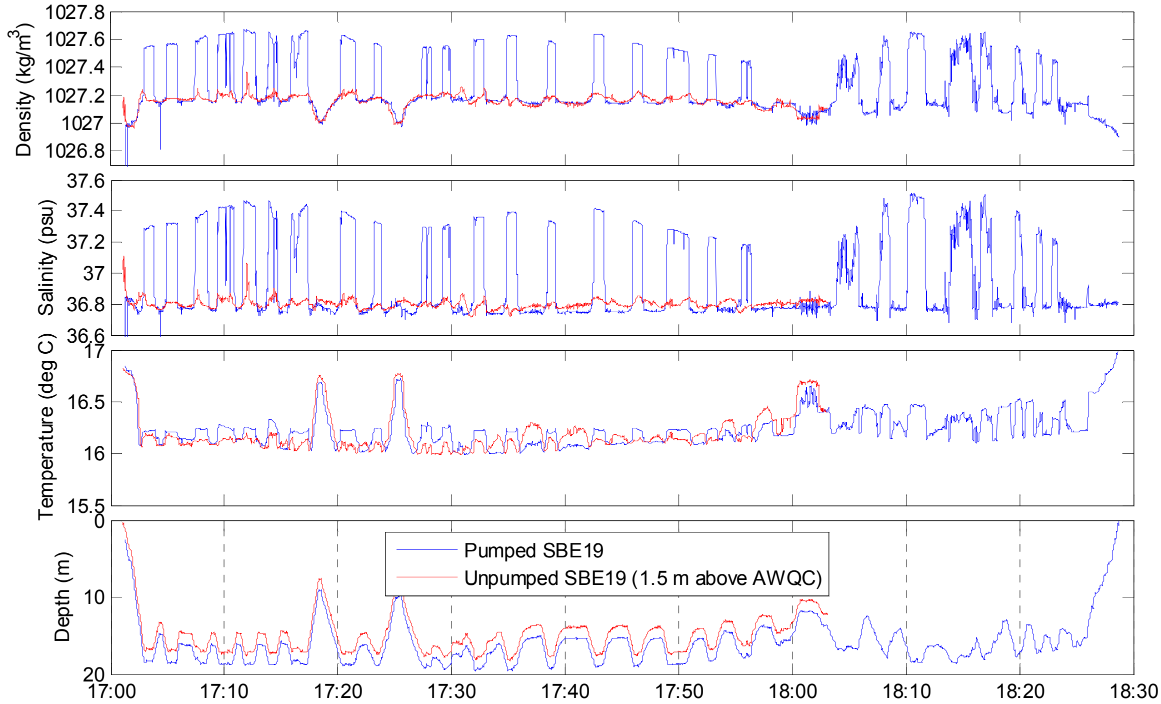

Temperature (°C)
Salinity (psu)
Density (kgm-3)
Depth (m)
15:11
15:19
15:25
15:31
15:39


Temperature (°C)
Salinity (psu)
Density (kgm-3)
Depth (m)
15:25
15:31
15:39
15:47
15:54


Temperature (°C)
15.5
16
16.5
17
Salinity (psu)
36.6
36.8
37
37.2
37.4
Density (kgm-3)
1026.8
1027
1027.2
1027.4
1027.6
Depth (m)
0
5
10
15
20
25
18:49
18:56
19:00
19:06
19:09


Temperature (°C)
15.5
16
16.5
17
Salinity (psu)
36.6
36.8
37
37.2
37.4
Density (kgm-3)
1026.8
1027
1027.2
1027.4
1027.6
Depth (m)
0
2
4
6
8
10
12
14
16
18
20
22
19:00
19:06
19:09
19:13
19:16
19:20


Density (kg/m3)
Salinity (psu)
Temperature (deg C)
Depth (m)
16:25
16:30
16:35
16:40
16:45
16:50


Density (kg/m3)
Salinity (psu)
Temperature (deg C)
Depth (m)
Pumped SBE19
Unpumped SBE19 (1.5 m above AWQC)
17:00
17:10
17:20
17:30
17:40
17:50
18:00
18:10
18:20
18:30