ADELAIDE DESALINATION PROJECT

WATER QUALITY CHARACTERISATION STUDY

March 2012

Report prepared by

Australian Water Quality Centre

This publication may be cited as

Kildea, T.N. and Andreacchio, L. (2012) Adelaide Desalination Project: Water Quality Characterisation Study. March 2012. Australian Water Quality Centre, Adelaide. 23 pp.

Revision History

Date	Document status	Author	Reviewer
29/5/2012	Draft	TK	
29/5/2012	Reviewed by SA Water	TK	LA
29/5/2012	Submitted to AA	TK	AA

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1 Introduction

In December 2007, the South Australian Government announced the proposal to construct a reverse osmosis seawater desalination plant at Port Stanvac. The Adelaide Desalination Project was initiated to provide metropolitan Adelaide with a sustainable and secure supply of drinking water. The project aims to deliver a climate independent water source that will supplement and secure the metropolitan area's water supply and reduce the reliance on traditional water sources, such as the River Murray.

A multi-national consortium, AdelaideAqua, compromising McConnell Dowell Constructors, Abigroup Contractors, ACCIONA Agua, and United Utilities Australia, were awarded the contract to design, build, operate and maintain the plant for 20 years. As AdelaideAqua D&C Consortium, the joint venture between McConnell Dowell Constructors, Abigroup Contractors and ACCIONA Agua will deliver the 50 GL plant in 2011, with the 100 GL plant to be fully operational by the end of 2012.

Port Stanvac was selected as the preferred site for the Adelaide Desalination Plant (ADP) due to accessibility of relatively deep seawater, good oceanographic dispersion characteristics, its proximity to the water supply network, suitable land availability and lower construction costs (EIS 2008).

The initial development phase of the Adelaide Desalination Project identified a number of important environmental issues to take into consideration when operating the plant (SA Water 2009), in particular minimising the impact of discharging saline concentrate into the sea. Mathematical models were used to predict the extent and intensity of the saline concentrate plume around the point of discharge (Adelaide Aqua 2010). The results from the plume dispersion models predict that the saline concentrate rapidly disperses and that the majority of the time salinity concentrations are no greater than 0.6 parts per thousand (ppt) above ambient, 100 metres from the diffuser. The rapid dispersion of saline concentrate is important, as this minimises potential impacts to plants and animals from high salinity concentrations.

To adequately monitor any potential environmental impacts of the saline concentrate discharge on local marine ecosystems, it is important to understand baseline conditions prior to the operation of the desalination plant. Natural ecosystems are dynamic and are constantly changing with time. There may be substantial natural variation within the ecosystem, which if not taken into account, makes it difficult to determine what is natural and what is directly related to anthropogenic impacts.

The scope of this study is to characterise ambient water quality to determine what the natural variation is, before the desalination plant becomes operational, in the Port Stanvac region.

Specific aims for the study are:

1. To conduct monthly water column profiling 100 m, 500 m and 5 km north and south of the Adelaide Desalination Plant outfall, at a water depth of 5 m, 10 m, 15 m, 20 m and 25 m; and
2. To conduct monthly water column profiling of three offshore reference sites to determine natural changes in background concentrations in Gulf St Vincent.

2 Methods

2.1 *In situ* water quality assessment

In situ water quality in the Port Stanvac region are assessed monthly, using an instrument (YSI 6600 series V4 sonde; specifications provided in Table 1, Section 2.2) that measure a variety of different parameters. The parameters measured include:

- Conductivity (μS/cm);
- Dissolved Oxygen (mg/L);
- pH;
- Chlorophyll *a* (μg/L);
- Turbidity (NTU); and
- Water temperature (degrees Celsius)

Depth profiles are undertaken by lowering the instrument through the water column at a rate of approximately 0.2 metres per second. Data are logged and stored every two seconds, which included the instruments position (longitude and latitude) and depth (metres) in the water column.

An additional three parameters are empirically calculated from the data obtained from the water quality instrument. These parameters are:

Specific Conductivity

Electrical conductivity is a measure of a water's ability to conduct electricity and therefore a measure of the water's ionic activity and content. The higher the concentration of ionic (dissolved salts) constituents, the higher the conductivity. Conductivity of the same water changes substantially as its temperature changes. To allow seasonal comparisons to be for a particular water body, conductivity is standardised to a temperature of 25 ^{o}C. Specific conductivity is defined as the standardisation of conductivity to 25 ^{0}C. Specific conductivity (μS/cm) is calculated from conductivity and temperature using the formula:

$$EC_{25^{\circ}C} = \frac{EC_T}{1 - 0.02\,(25 - T)} \qquad \text{[Equation 1]}$$

Where:

EC_{25C} is Specific Conductivity normalised to 25^{o}C (μS/cm)

EC_T is Conductivity (µS/cm) recorded at ambient water temperature (T)
T is ambient water temperature (^oC)

This calculation assumes a temperature correction factor of 2% for every degree Celsius difference from 25 ^oC.

Calculation of Total Dissolved Solids

The AWQC has undertaken significant work in calculating total dissolved solids (TDS) from specific conducitivity measurements, to provide a measure of the concentration of salt in solution (g/L). Through the analyses of hundreds of water samples across South Australia, a relationship between electrical conductivity (EC) and salinity (TDS) has been derived (Equation 2).

TDS is a measure of the combined content of all inorganic and organic substances contained in seawater, of which salt is the dominant constituent. Total dissolved solids concentration (g/L) is calculated from specific conductivity using the empirically formula:

$$TDS = ((0.548 \times EC) + (2.2 \times 10^{-6} \times EC^2) - (2.06 \times 10^{-12} \times EC^3))/1000 \quad \text{[Equation 2]}$$

Where:

TDS is Total Dissolved Solids (g/L)
EC is specific conductivity (µS/cm) normalised to 25^oC (based on 2% per degree difference from 25 ^0C).

Conversion of TDS from g/L to ppt

Salinity, expressed as parts per thousand, is calculated from TDS by dividing by seawater density (Equation 3). Seawater density varies with salinity, temperature and pressure (i.e. water depth). To simplify the calculation it was assumed that the seawater in the region had an average density of 1.026 g/ml, based on a salinity of 37 psu and a water temperature of 20 ^oC at a depth of 15 metres.

$$Salinity\ (ppt) = TDS/1.026 \quad \text{[Equation 3]}$$

Where:

TDS is Total Dissolved Solids (g/L)

2.1.1 Sampling sites

Water quality profiles were conducted at a number of sites along the Pt Stanvac coast, based on the distance from the ADP diffuser and the water depth in the region. Sampling sites (Figure 1) are located 100 m, 500 m and 5000 m north and south of the ADP diffuser, at a water depth of 5 m, 10 m, 15 m, 20m and 25 m.

There were no 25 m depth sites 500 m and 5000 m north of the diffuser, due to limited water depth in the region.

Three references sites, approximately 10 km offshore adjacent to Hallett Cove, Port Stanvac and Port Noarlunga at a water depth between 25 m to 30 m, were also sampled to determine natural changes in background concentrations in Gulf St Vincent.

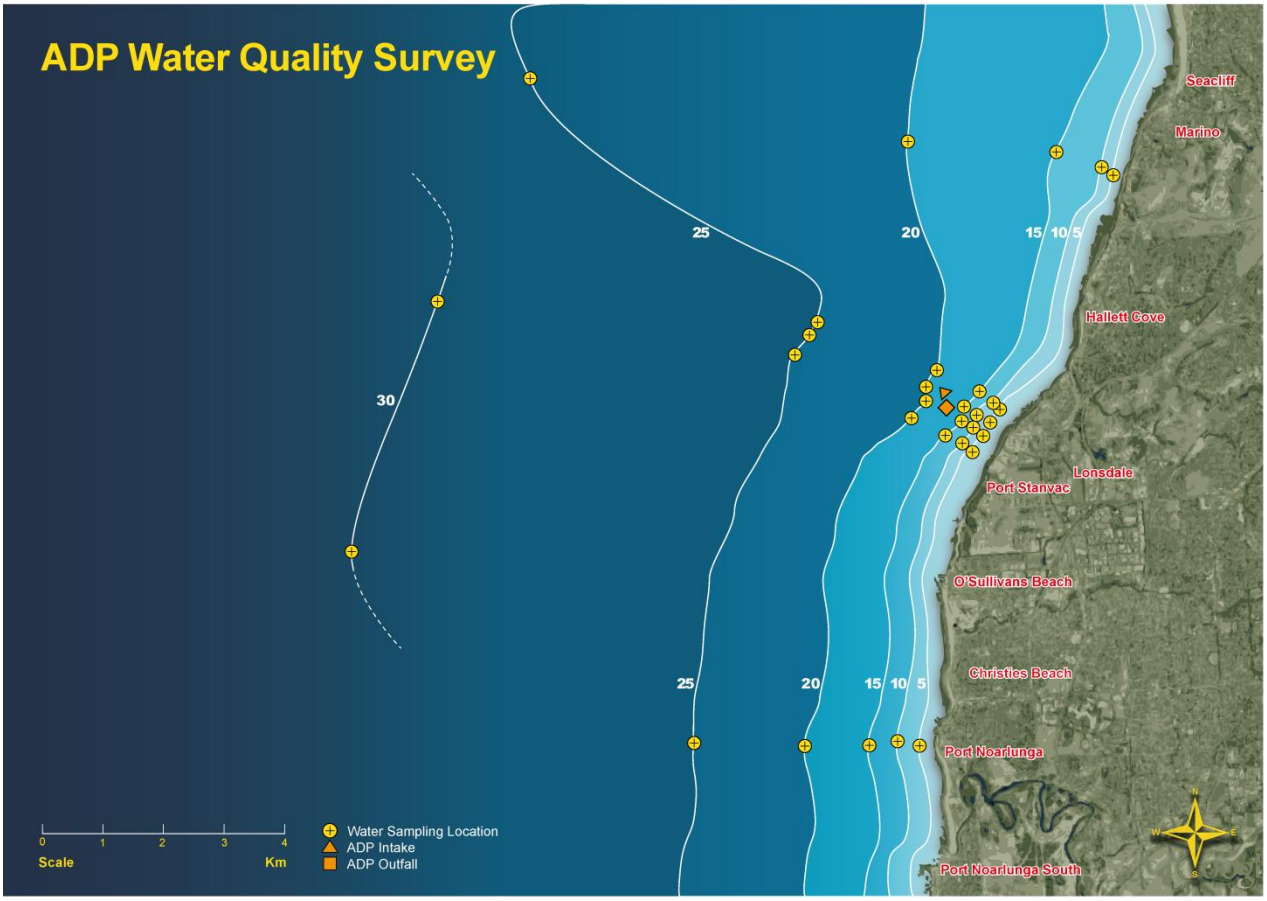


Figure 1 ADP water quality survey. Depth contours are marked in metres; contours are an estimate of depth in the region. Yellow circles denote water quality sites during the study. Red diamond represents the ADP diffuser and red triangle is the intake location. The survey area is approximately 10 km by 10 km.

2.2 Instrument Specifications

Table 1. YSI 6600 series V4 sonde specifications detailing range, accuracy and resolution

Parameter	Sensor Type	Range	Accuracy	Resolution
Specific Conductivity	4 electrode cell with autoranging	0-100 mS/cm	+/- 0.5% of reading + 0.001 mS/cm	0.001 mS/cm to 0.1 mS/cm (range dependent)
Water temperature	Thermistor	-5 to 45 ^{o}C	+/- 0.15 ^{o}C	0.01 ^{o}C
Dissolved Oxygen	Optical, Luminescence lifetime	0-50 mg/L	+/- 1% of reading or 0.1 mg/L (whichever is greater)	0.01 mg/L
pH	Glass combination electrode	0-14 units	+/- 0.2	0.01 units
Turbidity	Optical, 90^{o} scatter, with mechanical cleaning	0-1000 NTU	+/- 5% of reading or 2 NTU (whichever is greater), relative to calibration standards	0.1 NTU
Chlorophyll *a*	Optical, fluorescence, with mechanical cleaning	0-400 µg/L Chl; 0-100 Percent Full Scale (% FS) Fluorescence Units	No specification provided	0.1 µg/L Chl; 0.1% FS

2.3 Quality Control/Assurance

Individual sensors are calibrated before each sampling trip, using procedures outlined in the YSI technical manual. Conductivity and pH standards are prepared by AWQC's Analytical Quality Control Laboratory to ISO 9001 requirements. Turbidity is calibrated using a standard solution (ACR Standard Turbidity Solution 4000 NTU) diluted to 40 NTU.

2.4 Data analysis

The main focus of this report is to characterise the water quality in the area potentially influenced by the saline concentrate discharged from the Adelaide Desalination Plant to determine the natural variability that exists in the region.

Descriptive statistics are used to summarise the data, based on the method utilised by Gaylard (2004), in assessing water quality along the metropolitan coast in the report *Ambient Water Quality of the Gulf St Vincent Metropolitan Coastal Waters. Report No. 2: 1995.2002*.

The mean and standard deviation are calculated each month for each of the individual water quality parameters, using the data collected from the whole region across all depths. Standard deviation is a widely used measurement of variability or diversity used in statistics and probability theory. It shows how much variation or "dispersion" there is from the average

(mean, or expected value). A low standard deviation indicates that the data points tend to be very close to the mean, whereas high standard deviation indicates that the data are spread out over a large range of values.

The water quality data are summarised monthly as:

- Spatial plots of salinity and dissolved oxygen concentrations on the seafloor, for the Port Stanvac region;
- Spatial plot of water temperature on the seafloor;
- Spatial plot of chlorophyll concentration, one metre below the surface; and
- Vertical profiles for temperature, specific conductivity, TDS, turbidity, dissolved oxygen (mg/L) and pH, plotted against depth for each sampling location

Spatial plots are derived using the grid-based graphic program Surfer 8 (Golden Software Inc.), which interpolates irregularly spaced XYZ data into a regularly spaced grid. The grid is then used to produce an image map to show how concentrations (salinity, DO or Chl *a*) or water temperature change across a defined area. The data are interpolated using the "Natural Neighbour" algorithm, which is a geostatistical gridding method used to express the spatial trends that occur for each of the different parameters. Natural neighbour generates good contours from data sets containing dense data in some areas and sparse data in other areas. It does not generate data in areas without data and does not extrapolate Z grid values beyond the range of data.

3 Results and Discussion

3.1 Tide and sampling times

Table 2 Tide times and height above lowest astromical tide on the 28th March 2012.

Time (hours)	Height (metres)
01:58	0.39
07:43	1.94
13:26	0.40
19:54	2.51

Water quality survey commenced at 08:34 hr and was completed by 12:14 hr.

3.2 Adelaide Desalination Plant performance

Saline concentrate was not discharged to the marine environment on 28th March 2012.

3.3 Salinity

Average salinity concentration in the region surveyed on 28th March 2012 was 36.1 ppt (±0.1 ppt). Salinity concentrations in the survey region ranged between 36.0 ppt and 36.2 ppt (Figure 14; see Section 4).

The average salinity concentration, 100 metres from the diffuser location, was 36.1 ppt (±0.1 ppt; Figure 2 and Figure 3)

There was no evidence of haloclines forming in the region (Figure 14; Section 4), during the water quality survey.

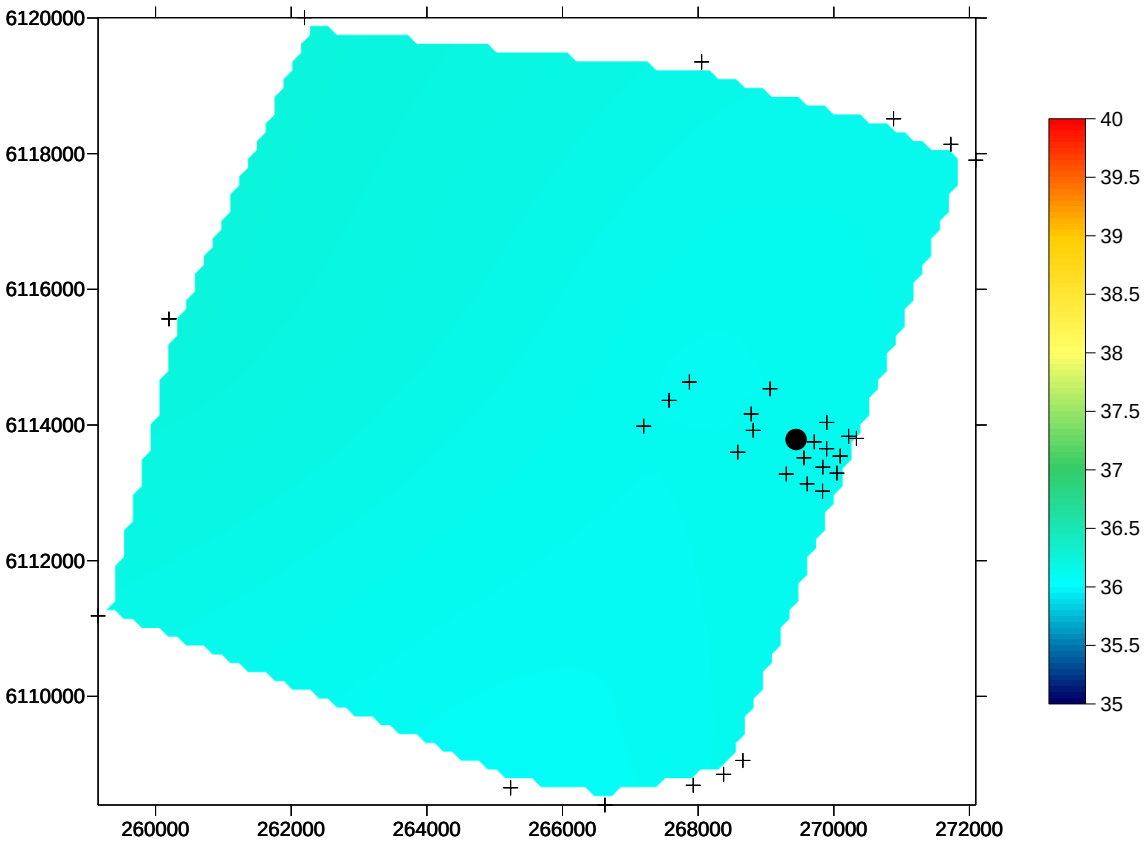


Figure 2 Spatial change in salinity concentration (parts per thousand), on the seafloor, in the Port Stanvac region. The coloured scale bar represents changes in salinity concentration between 35 ppt and 40 ppt (sensor error ±0.1 ppt). X coordinates refer to eastings and Y coordinates refer to northings measured in metres. Black dot represents position of ADP outfall. Black crosses represent water quality sampling locations (also refer to Figure 1).

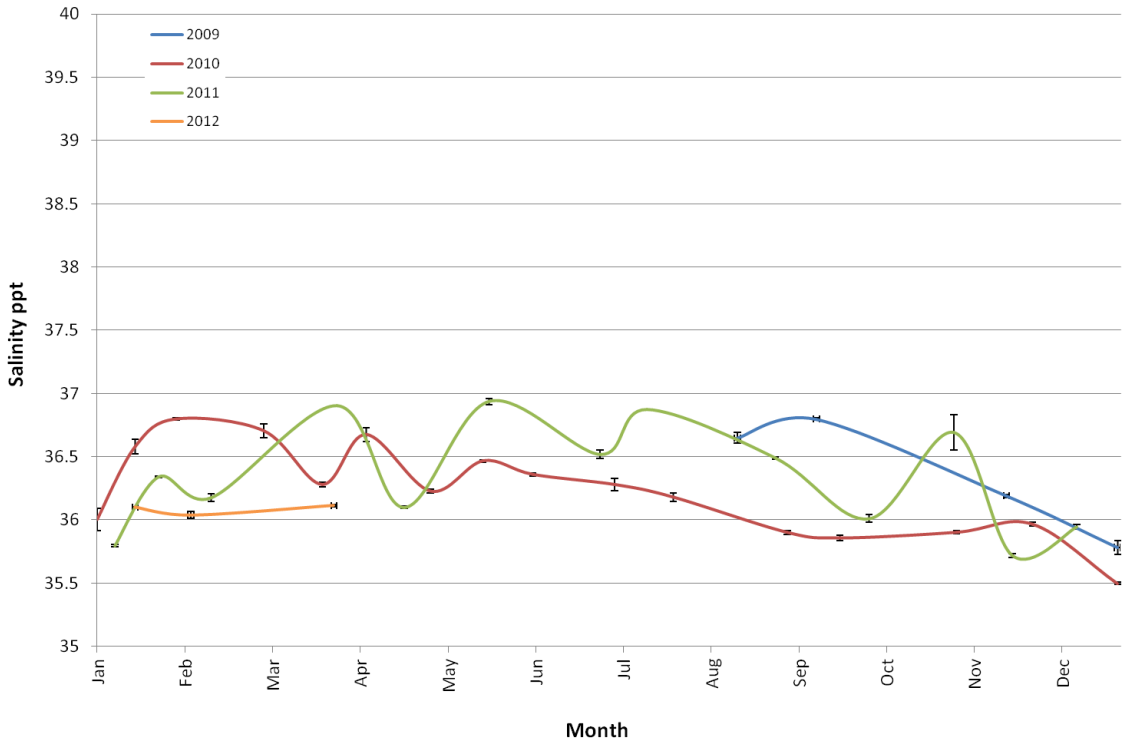


Figure 3 Average salinity concentration (ppt) on the seafloor, 100 metres from the diffuser location at a depth of 15 m to 20 m. Error bars represent standard deviation. Note that the Adelaide Desalination Plant started to discharge saline concentrate intermittently from September 2011.

3.4 Water temperature

Average water temperature in the region surveyed on 28th March 2012 was 20.2 °C (±0.1 °C). Water temperature in the survey region ranged between 20.0 °C and 20.6 °C (Figure 10).

The average water temperature, 100 metres from the diffuser location was 20.1 °C (±0.1 °C; Figure 5 and Figure 5).

Surface waters were generally warmer than the water temperature close to the seafloor, by 0.2 °C to 0.6 °C (Figure 10; Section 4). There was evidence of stratification occurring in the water column at a depth of 5 m. It is not clear whether the stratified layer persisted across changes in the tidal cycle.

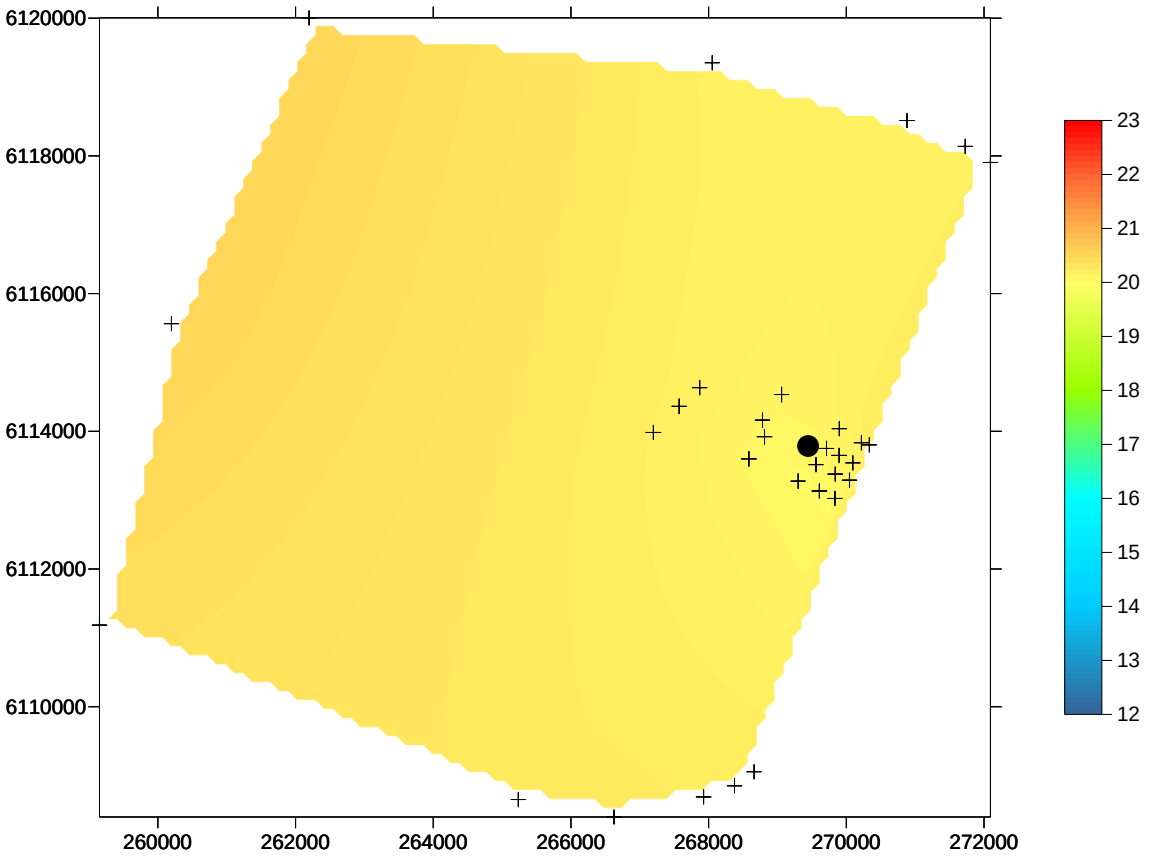


Figure 4 Spatial change in water temperature, on the seafloor, in the Port Stanvac region. The coloured scale bar represents temperature changes between 12 °C and 24 °C (sensor error ±0.15°C). X coordinates refer to eastings and Y coordinates refer to northings measured in metres. Black dot represents position of ADP outfall. Black crosses represent water quality sampling locations (also refer to Figure 1).

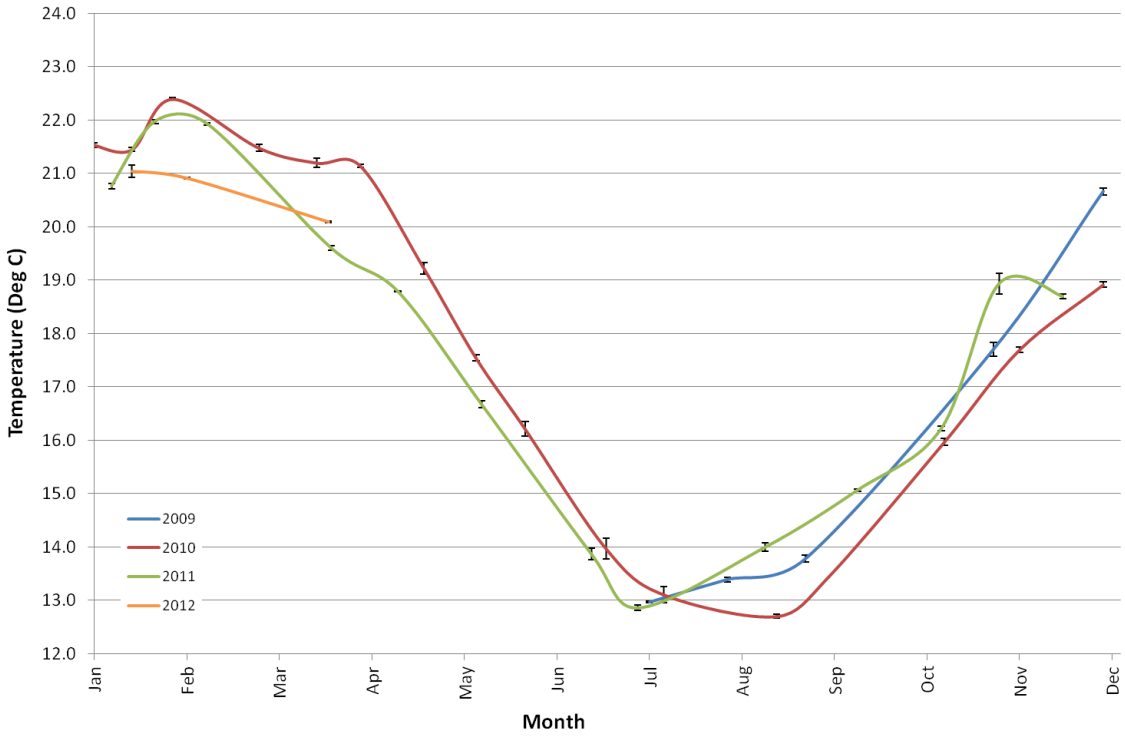


Figure 5 Average water temperature (degrees Celcius) on the seafloor, 100 metres from the diffuser location at a depth of 15 m to 20 m. Error bars represent standard deviation. Note that the Adelaide Desalination Plant started to discharge saline concentrate intermittently from September 2011.

3.5 Dissolved Oxygen

Average dissolved oxygen concentration (mg/L) in the region surveyed on 28th March 2012 was 7.2 °C (±0.1 mg/L), this equates to an average oxygen saturation of 99 %. Dissolved oxygen concentrations in the survey region ranged between 6.9 °C and 7.5 °C (Figure 4; Section 4).

Average dissolved oxygen concentration on the seafloor, 100 metres from the diffuser location was 7.2 mg/L (±0.1 mg/L; Figure 6; Figure 7 and Figure 8).

Dissolved oxygen concentrations were generally greater at the surface than on the seafloor (Figure 11; Section 4).

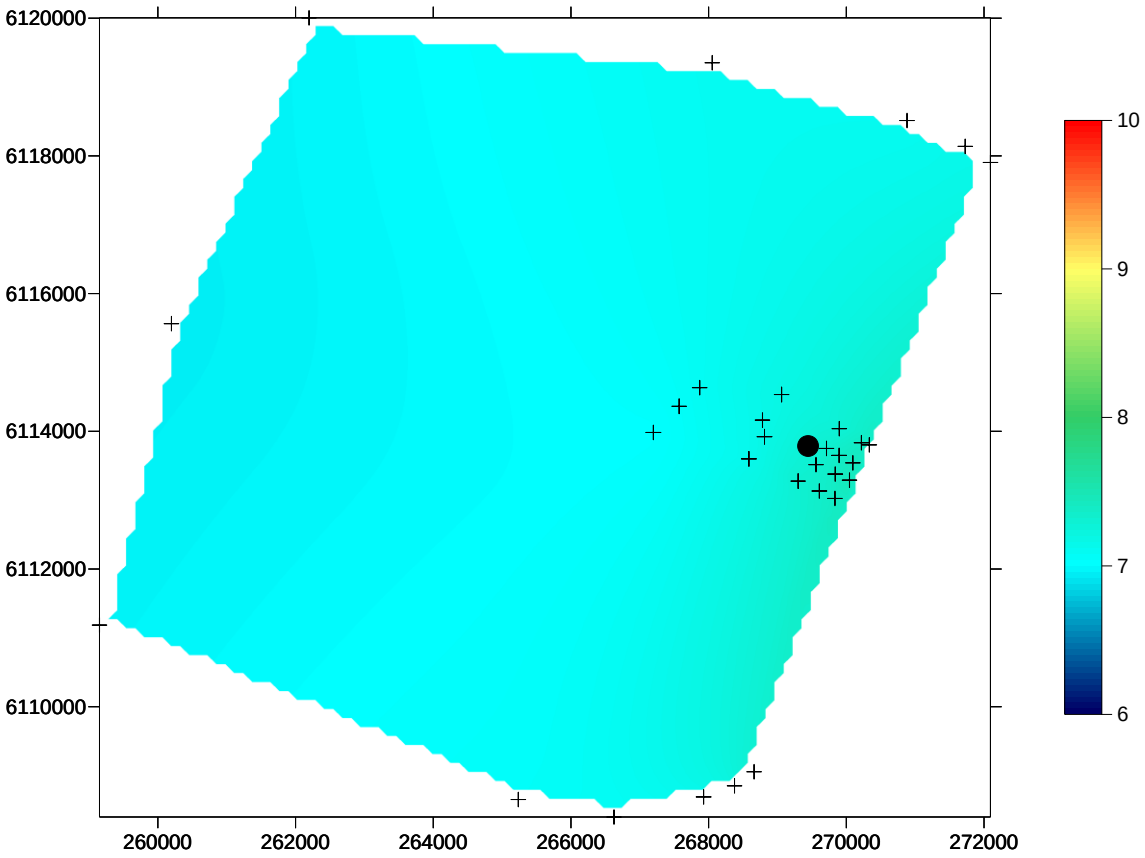


Figure 6 Spatial change in dissolved oxygen concentration (mg/L), on the seafloor, in the Port Stanvac region. The coloured scale bar represents dissolved oxygen concentrations between 5 mg/L and 10 mg/L (sensor error ±0.1mg/L). X coordinates refer to eastings and Y coordinates refer to northings measured in metres. Black dot represents position of ADP outfall. Black crosses represent water quality sampling locations (also refer to Figure 1).

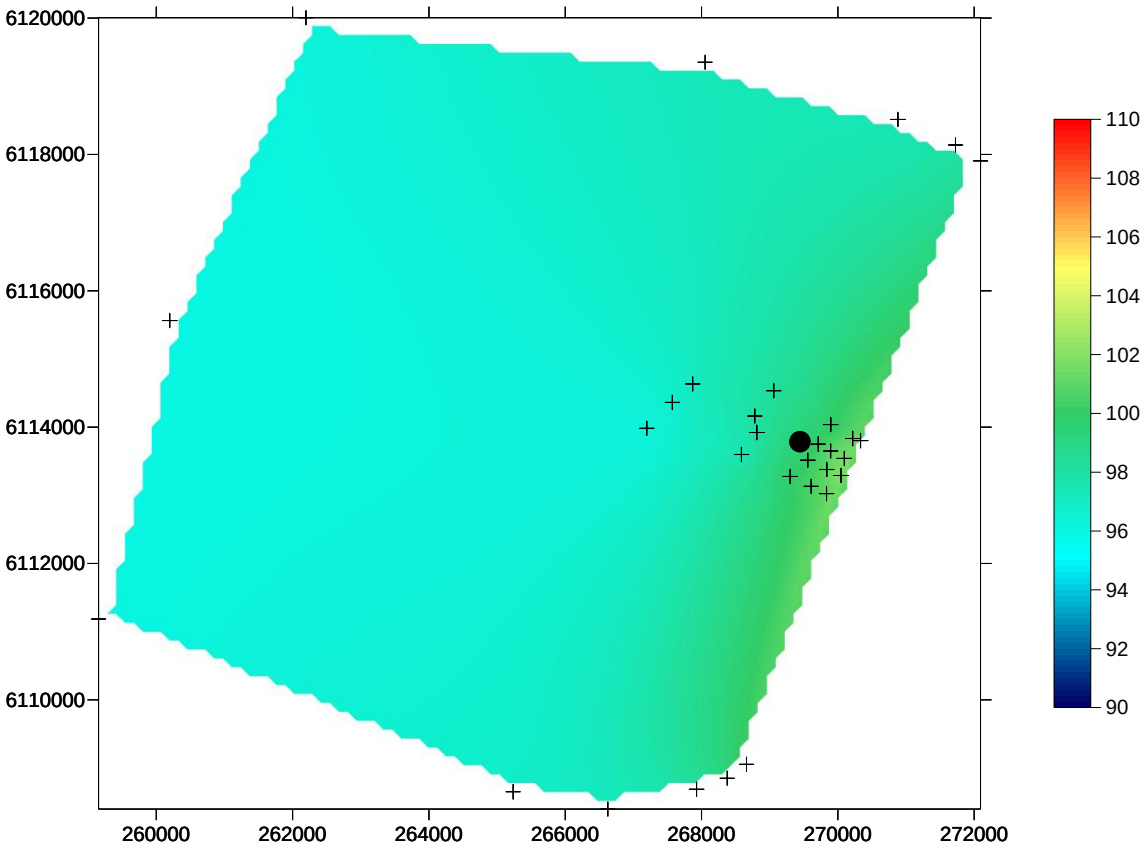


Figure 7 Spatial change in dissolved oxygen (percent saturation), on the seafloor, in the Port Stanvac region. The coloured scale bar represents dissolved oxygen concentrations between 90 % and 110 % (sensor error ±1%). X coordinates refer to eastings and Y coordinates refer to northings measured in metres. Black dot represents position of ADP outfall. Black crosses represent water quality sampling locations (also refer to Figure 1).

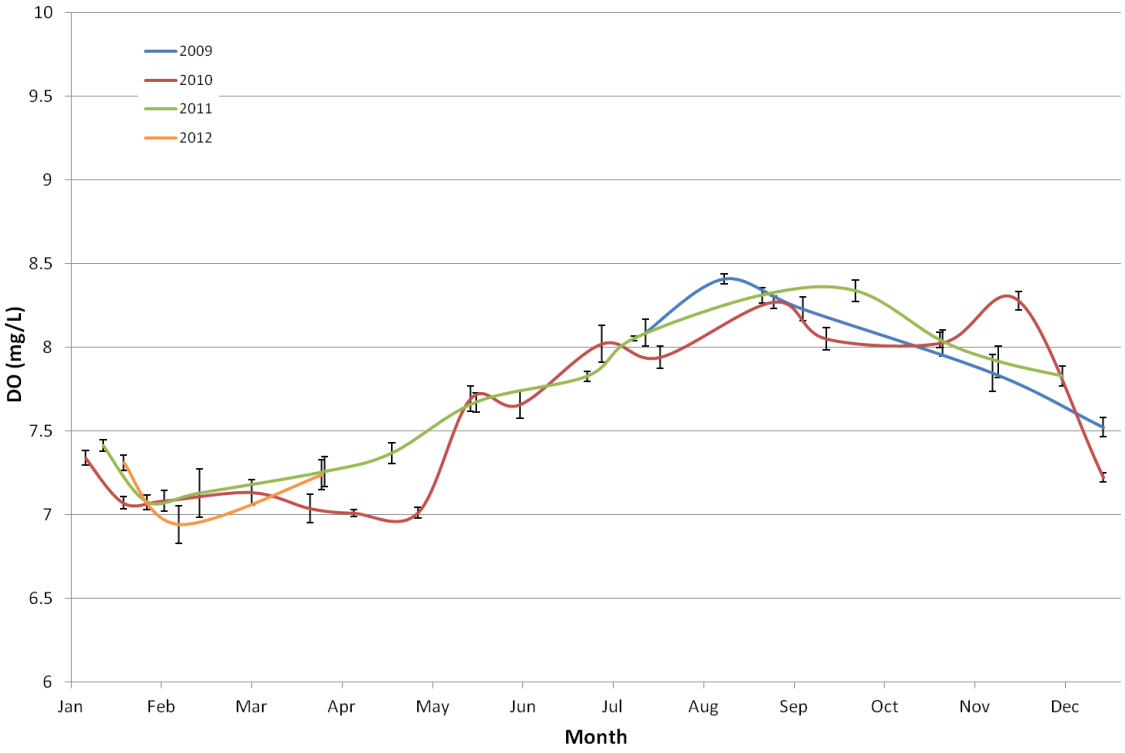


Figure 8 Average dissolved oxygen concentration (mg/L) on the seafloor, 100 metres from the diffuser location at a depth of 15 m to 20 m. Error bars represent standard deviation. Note that the Adelaide Desalination Plant started to discharge saline concentrate intermittently from September 2011.

3.6 Chlorophyll

Chlorophyll concentrations in the region were generally less than 1 μg/L (Figure 9; sensor sensitivity is ±1 μg/L).

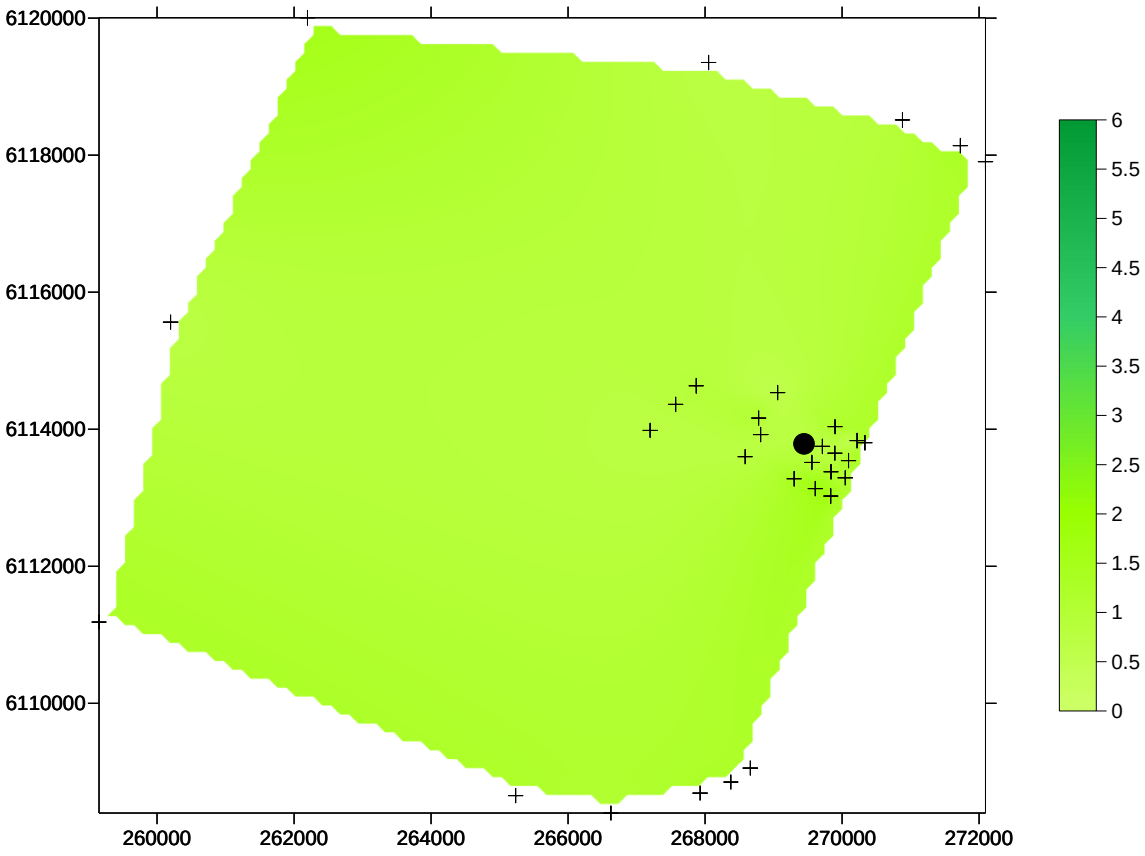


Figure 9 Spatial change in chlorophyll a concentration, one metre below the surface, in the Port Stanvac region. The coloured scale bar represents a change in chlorophyll concentration between 0 μg/L and 6 μg/L. Note sensor sensitivity is ±1 μg/L. X coordinates refer to eastings and Y coordinates refer to northings measured in metres. Black dot represents position of ADP outfall. Black crosses represent water quality sampling locations (also refer to Figure 1).

3.7 Turbidity

Turbidity in the water column was less than 2 NTU, throughout the region (Figure 12).

The sensor's accuracy is ±2 NTU, therefore when turbidity concentrations are less than 2 NTU the sensor may provide a reading that falls between -2 and 2 NTU. This was observed at all sites.

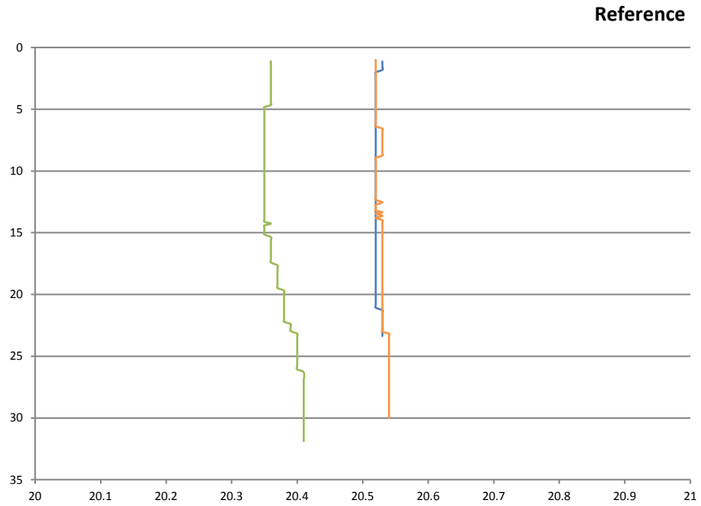
3.8 pH

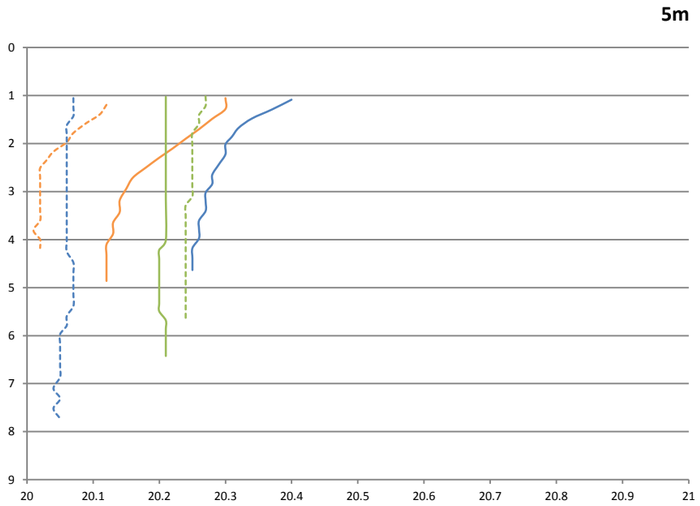
Average pH in the water colum was 8.2 (±0.2 pH unit). Seawater is highly buffered due to high concentrations of bicarbonate ions in solution and as a consequence pH remains constant (Figure 13).

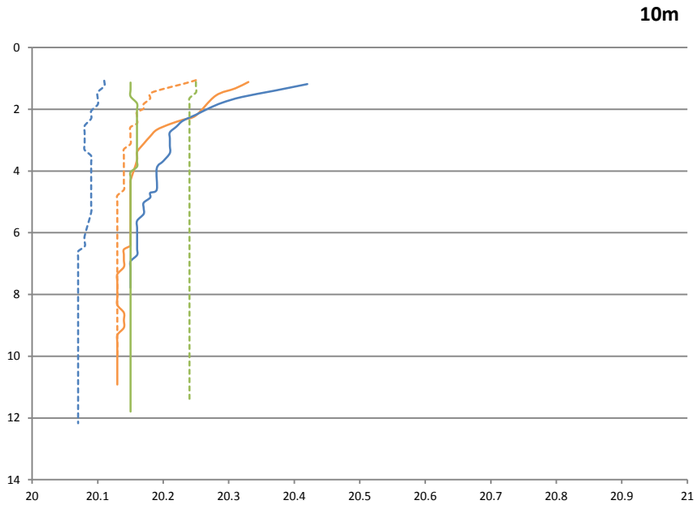
4 Vertical profiles

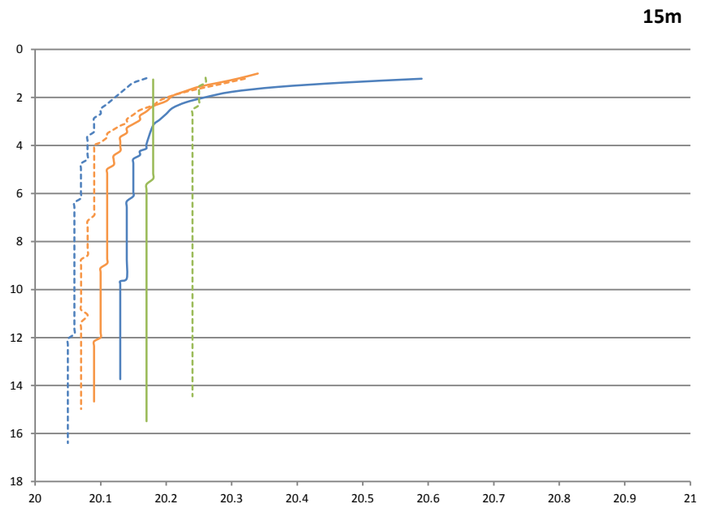
The following graphs illustrate specific conductivity (μS/cm), total dissolved solids (g/L) temperature (degrees Celsius), dissolved oxygen (mg/L), turbidity (NTU) and pH, relative to depth for May 2011. Water column profiles were undertaken 5km, 500m and 100m north and south of the outfall diffusers at water depths of 5m, 10m, 15m, 20m and 25m. Water column profiles were also undertaken at three control sites, approximately 10 km offshore adjacent to Hallett Cove, Port Stanvac and Noarlunga. The legend below applies to all graphs.

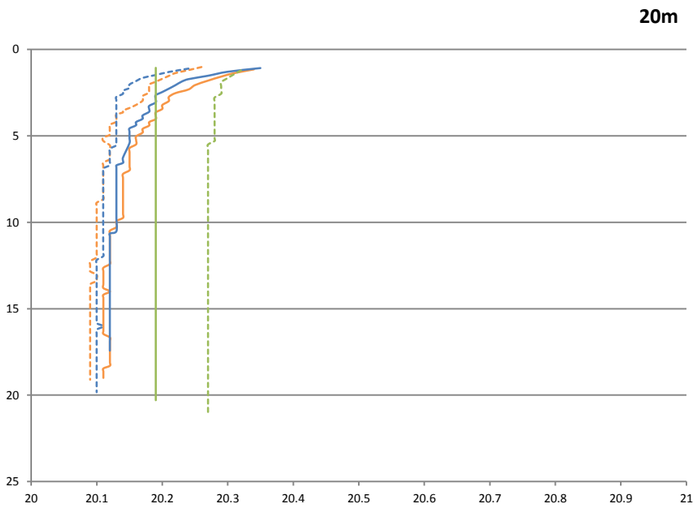
Dotted lines represent water quality profiles conducted south and solid lines are sites north of the diffuser location. Orange represents 100 m, blue 500 m and green 5 km either north or south of the diffuser. Water quality profiles were conducted at a depth of 5 m, 10 m, 20 m and 25 m. There were no 25 m profiles undertaken north of the diffuser due to insufficient water depth. Control sites were located approximately 10 km offshore, adjacent to Hallett Cove (blue), Port Stanvac (orange) and Noarlunga (green).











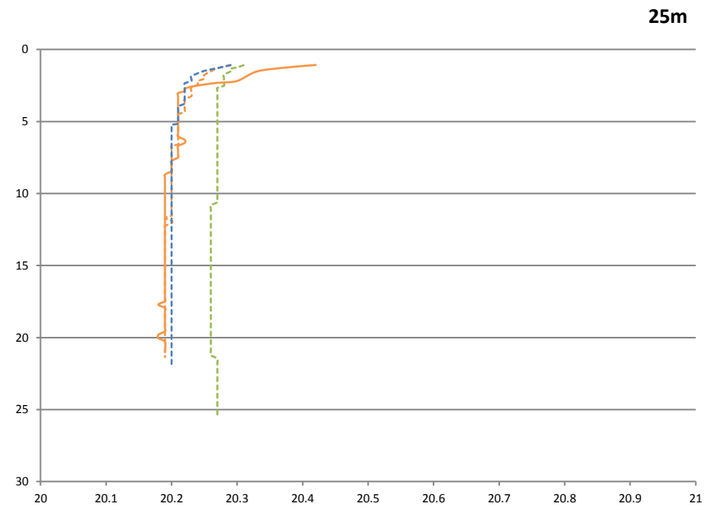


Figure 10 Change in water temperature (x axis; degrees Celsius) at different depths (y axis; metres) throughout the water column. Water quality profiles were conducted at a depth of 5 m, 10 m, 15 m, 20 m, 25 m and 10 km offshore (Reference sites); north (solid lines) and south (broken line) of the ADP diffuser. Orange represents 100 m, blue 500 m and green 5 km either north or south of the diffuser.

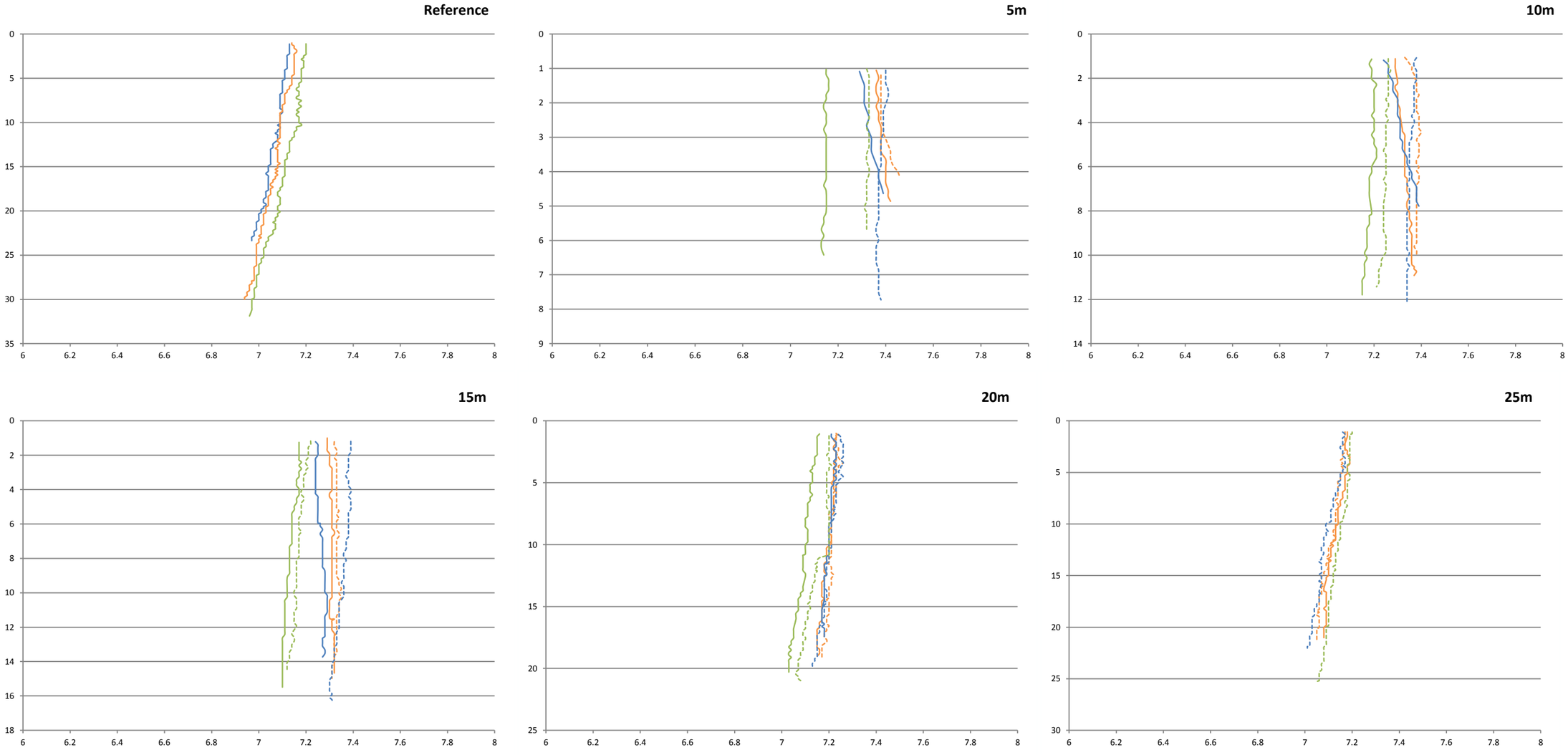
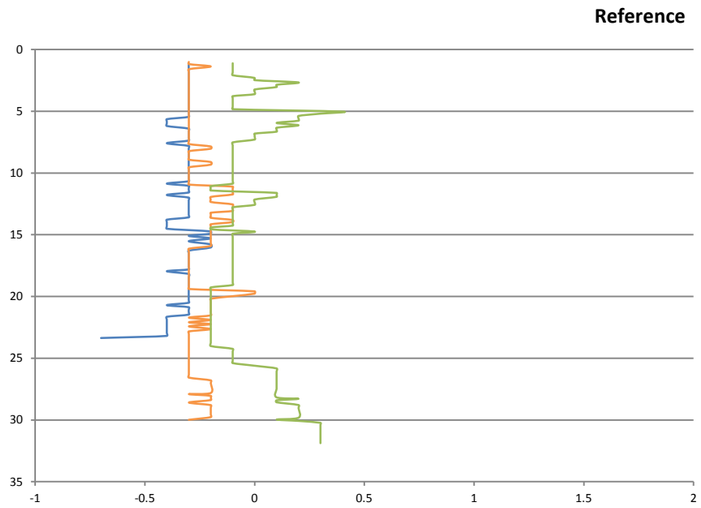
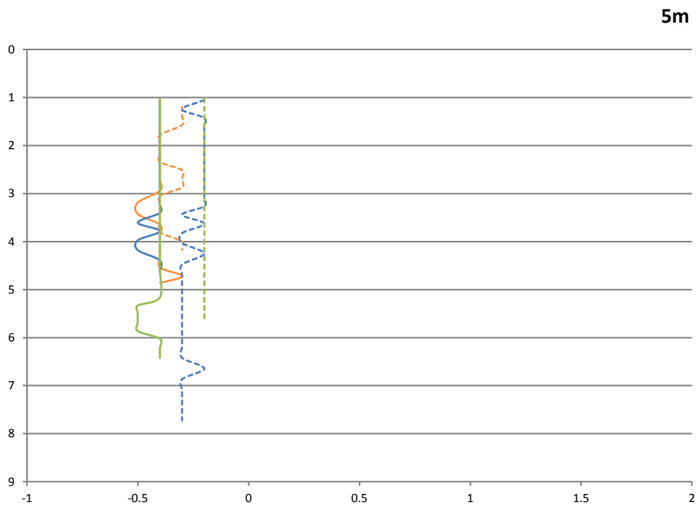
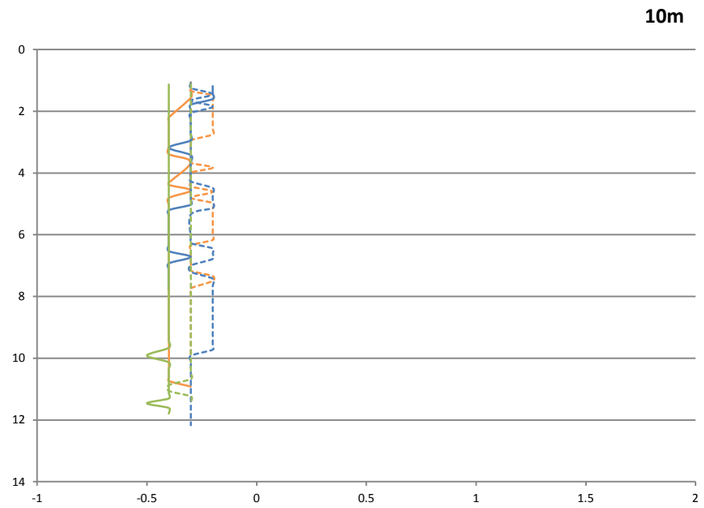
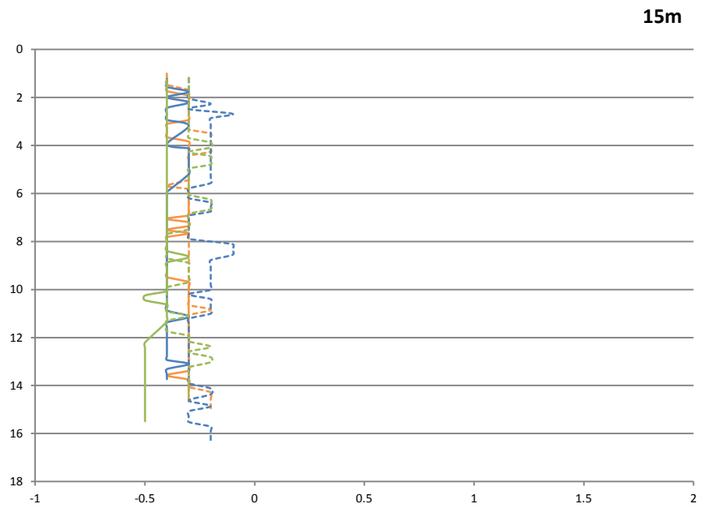


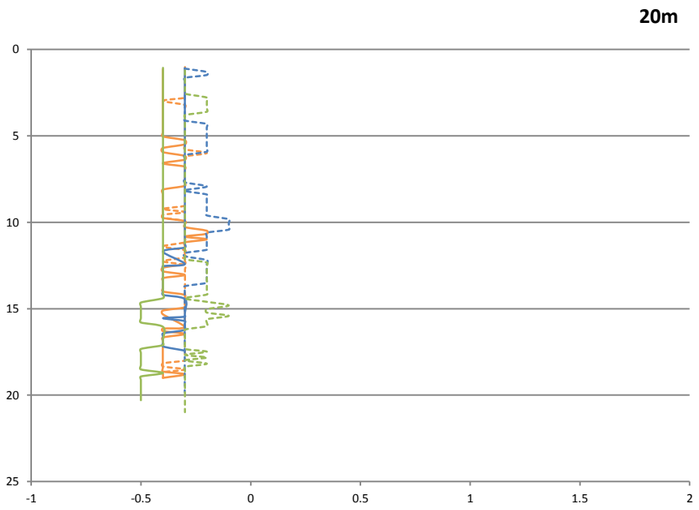
Figure 11 Change in dissolved oxygen (x axis; mg/L) at different depths (y axis; metres) throughout the water column. Water quality profiles were conducted at a depth of 5 m, 10 m, 15m, 20 m, 25 m and 10 km offshore (Reference sites); north (solid lines) and south (broken line) of the ADP diffuser. Orange represents 100 m, blue 500 m and green 5 km either north or south of the diffuser.











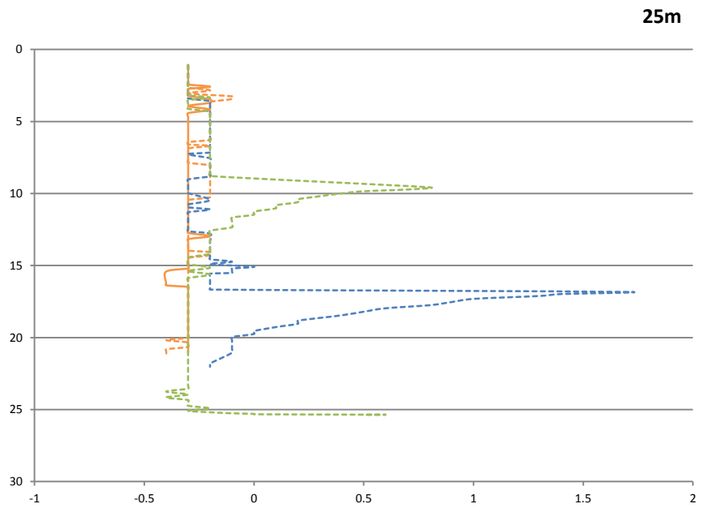
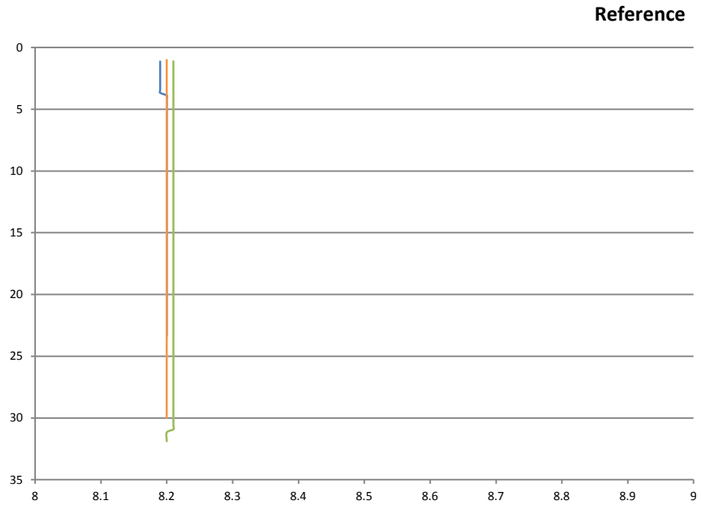
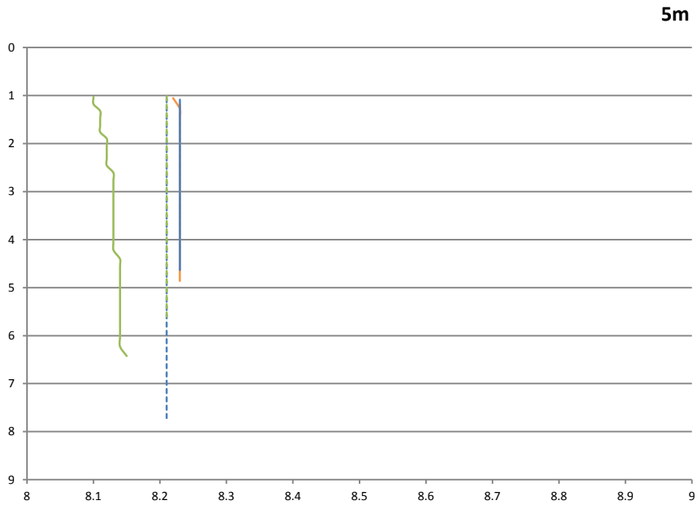
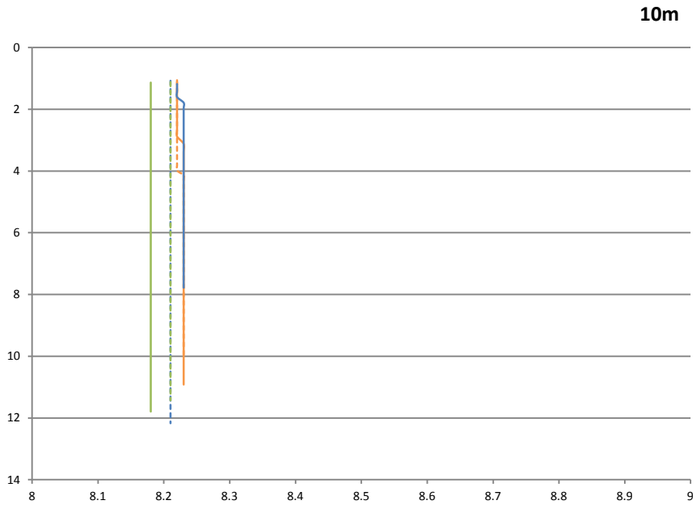
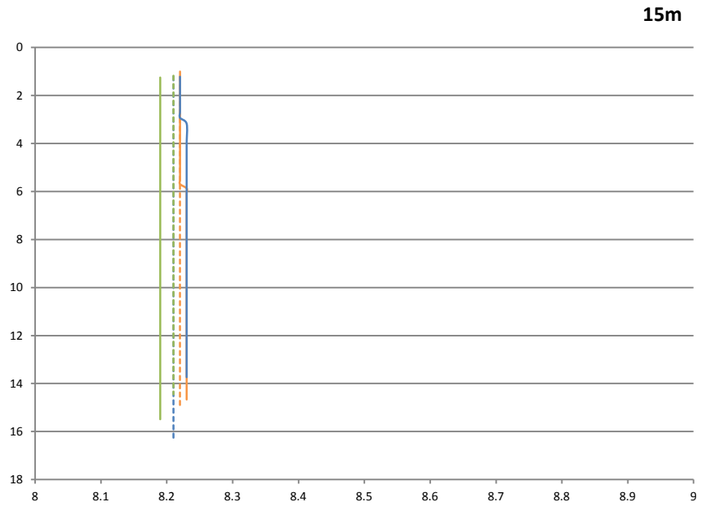


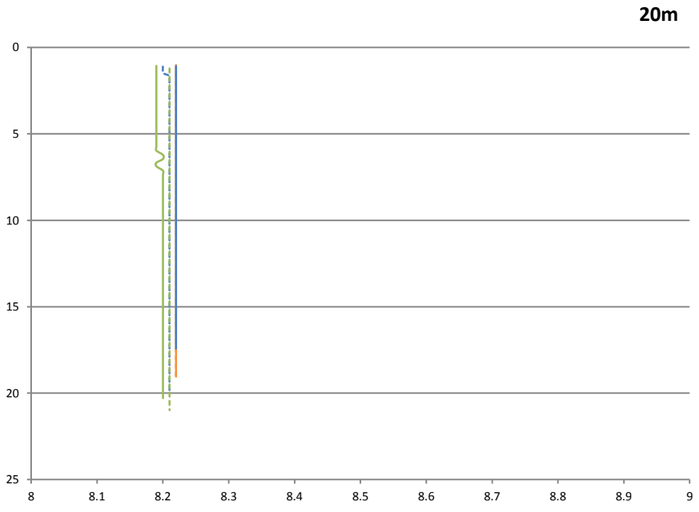
Figure 12 Change in turbidity (x axis; NTU) at different depths (y axis; metres) throughout the water column. Water quality profiles were conducted at a depth of 5 m, 10 m, 15m, 20 m, 25 m and 10 km offshore (Reference sites); north (solid lines) and south (broken line) of the ADP diffuser. Orange represents 100 m, blue 500 m and green 5 km either north or south of the diffuser.











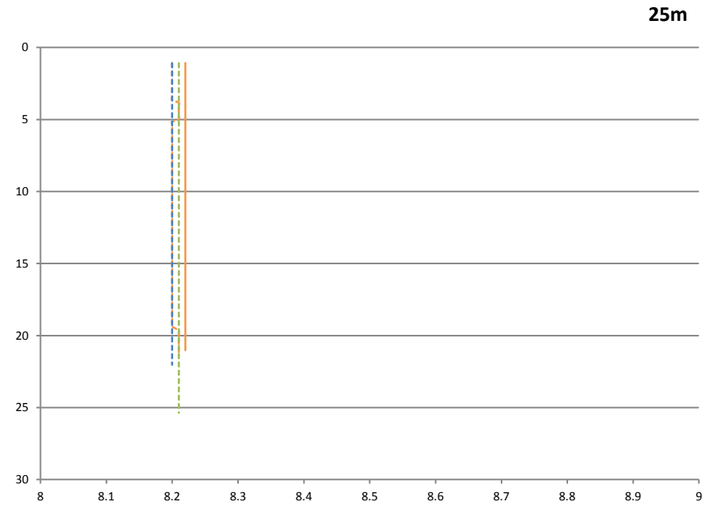


Figure 13 Change in pH (x axis; pH units) at different depths (y axis; metres) throughout the water column. Water quality profiles were conducted at a depth of 5 m, 10 m, 15m, 20 m, 25 m and 10 km offshore (Reference sites); north (solid lines) and south (broken line) of the ADP diffuser. Orange represents 100 m, blue 500 m and green 5 km either north or south of the diffuser.

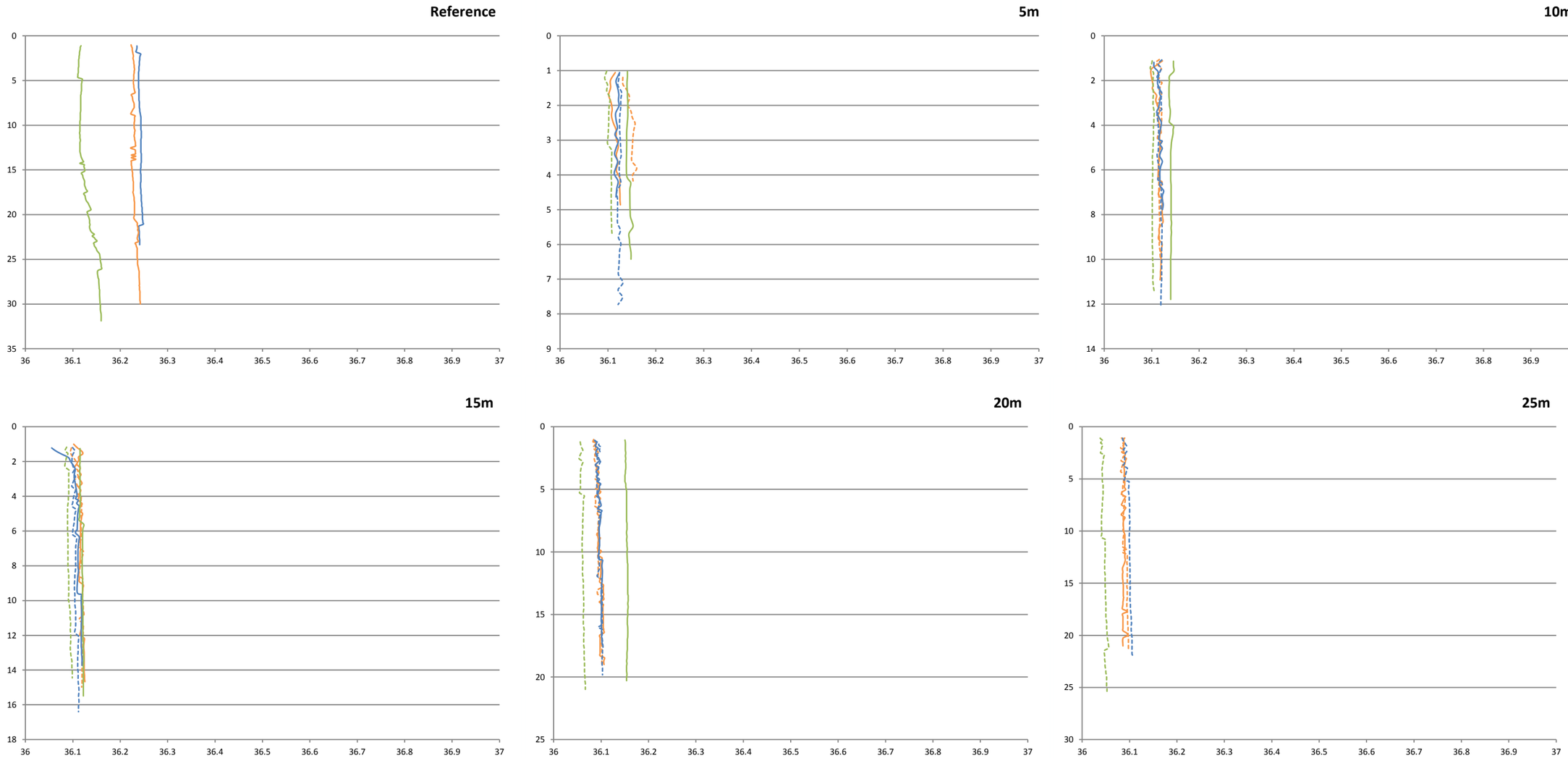


Figure 14 Change in salinity (x axis; ppt) at different depths (y axis; metres) throughout the water column. Water quality profiles were conducted at a depth of 5 m, 10 m, 15m, 20 m, 25 m and 10 km offshore (Reference sites); north (solid lines) and south (broken line) of the ADP diffuser. Orange represents 100 m, blue 500 m and green 5 km either north or south of the diffuser.