ADELAIDE DESALINATION PROJECT

WATER QUALITY CHARACTERISATION STUDY

September 2013

Report prepared by

Australian Water Quality Centre

This publication may be cited as

Andreacchio, L. and Kildea, T.N. (2013) Adelaide Desalination Project: Water Quality Characterisation Study. September 2013. Australian Water Quality Centre, Adelaide. 19 pp.

Revision History

Date	Document status	Author	Reviewer
26/09/2013	Draft	LA	
12/11/2013	Internal review		TK
	Submitted to AA		

Cover photo

Bulls eyes 20 m from the ADP diffuser, April 2013

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1 Table of Contents

2 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 Trility, were awarded the contract to design, build, operate and maintain the plant for 20 years. As of December 2012, the plant has become fully operational producing drinking water which is used by SA Water to supply metropolitan Adelaide.

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 time salinity concentrations are no greater than 0.6 parts per thousand (ppt) above ambient, 100 metres (m) 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 gain an understanding of baseline conditions. 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.

Since 2009 a variety of water quality parameters, including salinity and dissolved oxygen, have been regularly measured off the coast of Port Stanvac, covering an approximate area of 100 square kilometers (km^2).

The scope of this study is to characterise water quality in the Port Stanvac region and compare previous years data, to determine the variation in water quality, during the operation of the desalination plant .

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, 18m, 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.

3 Methods

3.1 *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 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°C (µS/cm)
EC_T is Conductivity (µS/cm) recorded at ambient water temperature (T)
T is ambient water temperature (°C)

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

Calculation of Total Dissolved Solids

The AWQC has undertaken significant work in calculating total dissolved solids (TDS) from specific conductivity 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°C (based on 2% per degree difference from 25 °C).

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 °C at a depth of 15 m.

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

Where:

TDS is Total Dissolved Solids (g/L)

3.1.1 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.

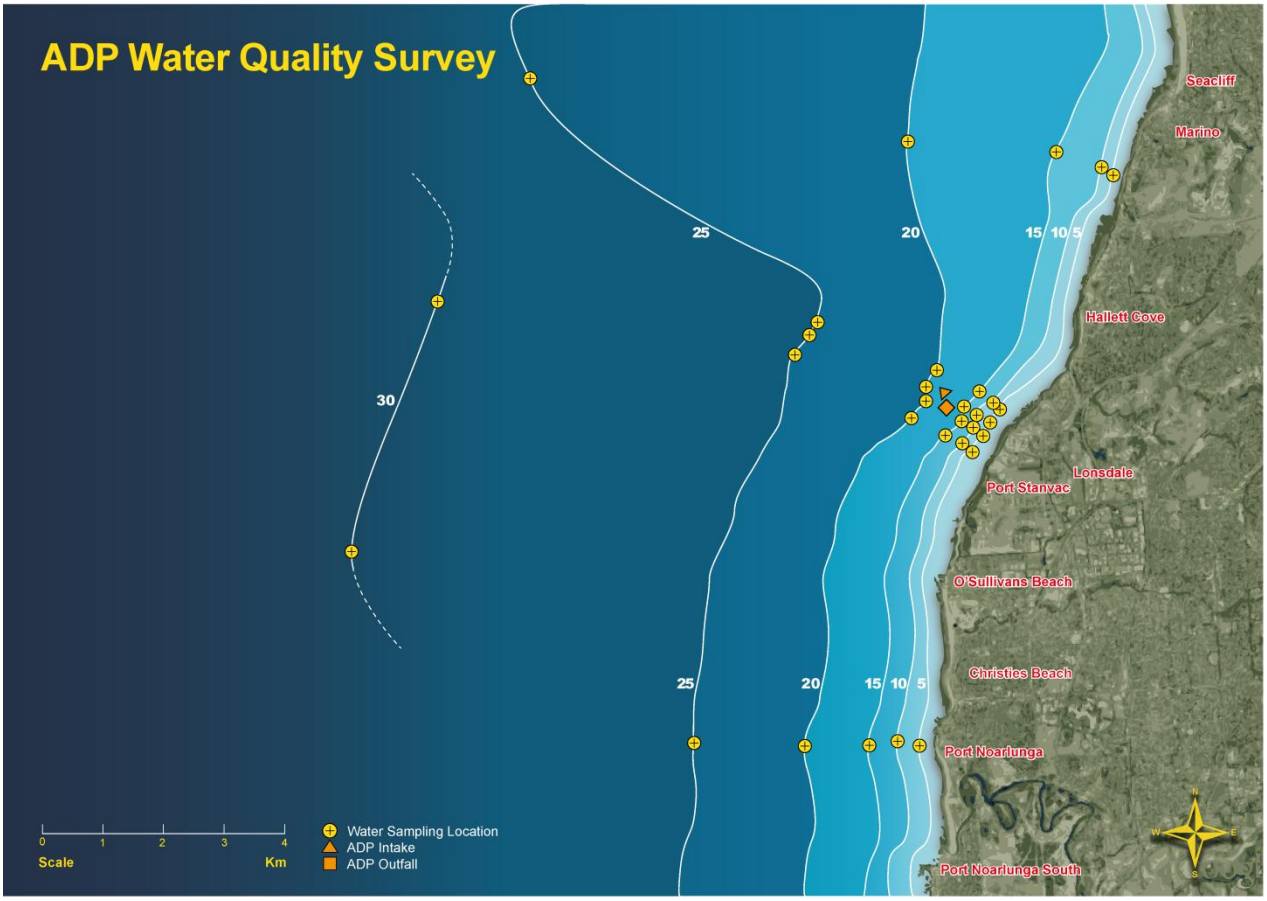

Figure 1 ADP water quality survey. Depth contours are marked in metres; contours are an estimate of depth in the region. Yellow circles denote water quality sites during the study. Red diamond represents the ADP diffuser and red triangle is the intake location. The survey area is approximately 10 km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

3.2 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

3.3 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.

3.4 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 December 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 for June 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

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.

4 Results

4.1 Tide and sampling times

Table 2 Tide times and height above lowest astromical tide on the 24th September 2013.

Time (hours)	Height (metres)
06:10	2.50
12:28	0.44
18:17	2.03

Water quality survey conducted on the 24th September 2013, commenced at 10:30 hr and was completed by 14:30 hr. The tidal range during this period was approximately 2.06 m.

4.2 Adelaide Desalination Plant daily production rate

The Adelaide Desalination Plant production rate on the 24th September 2013, was 160 megalitres per day (MLD). Saline concentrate was discharged to the marine environment with a concentration of approximately 71 ppt.

4.3 Salinity

Average salinity concentration in the region surveyed was 36.3 ppt (±0.1 ppt). Salinity concentrations on the seafloor ranged between 36.1 ppt and 37.0 ppt (Figure 2). Profiles showed salinity concentrations were highest 100m north and south of the diffuser in 18 m of water (Figure 2).

The average salinity concentration on the seafloor, 100 metres north and south of the ADP diffuser at a depth of 15 to 18 m, was 36.8 ppt (±<0.2 ppt;

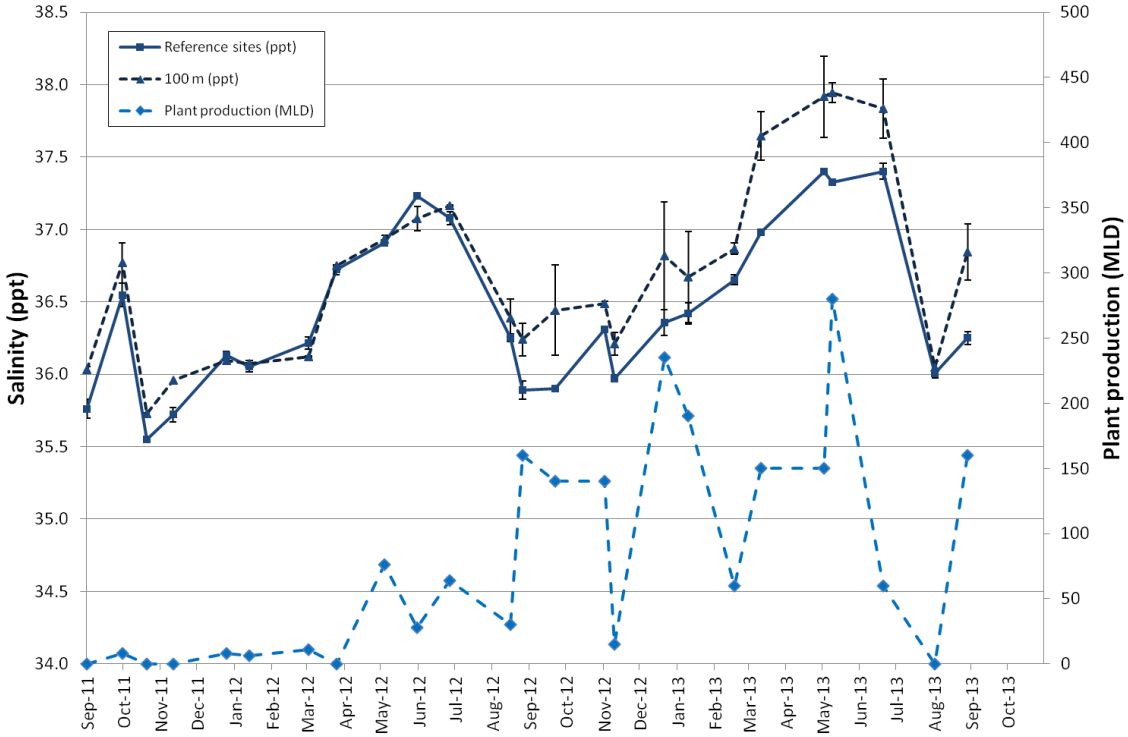

Figure **3**). Average salinity concentrations were on average 0.5 ppt higher on the seafloor 100m from the ADP diffuser (36. 8 ppt) when compared to offshore reference sites (36.3 ppt;

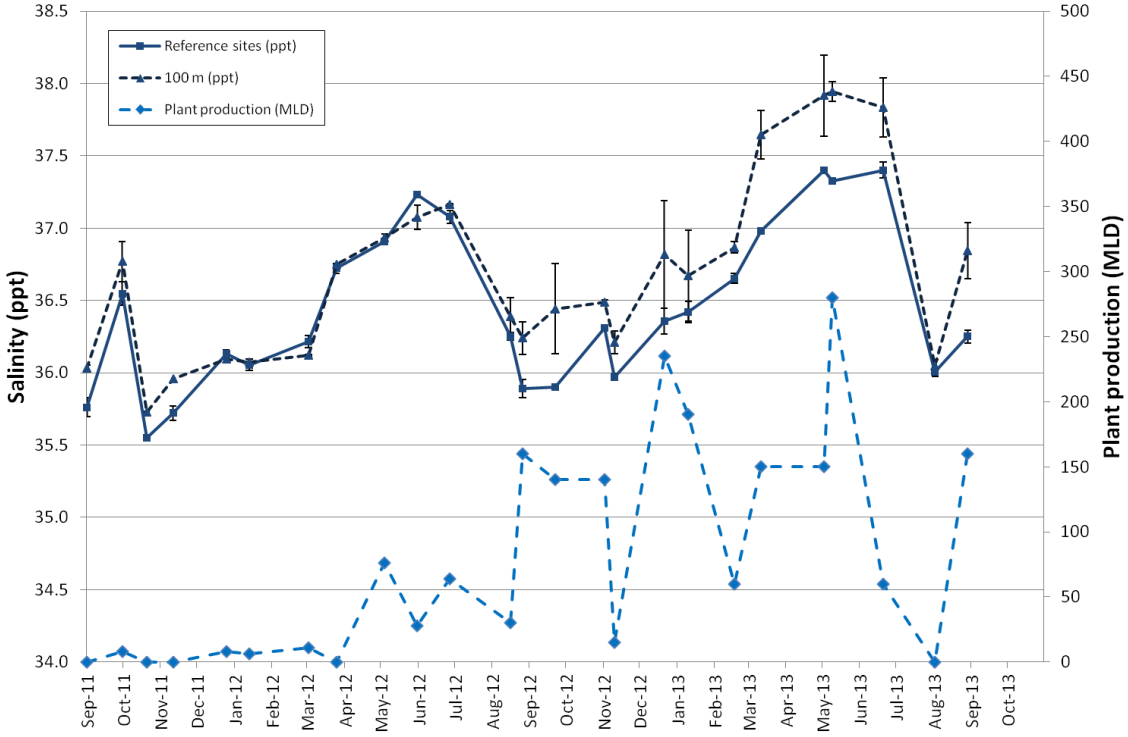

Figure **3**).

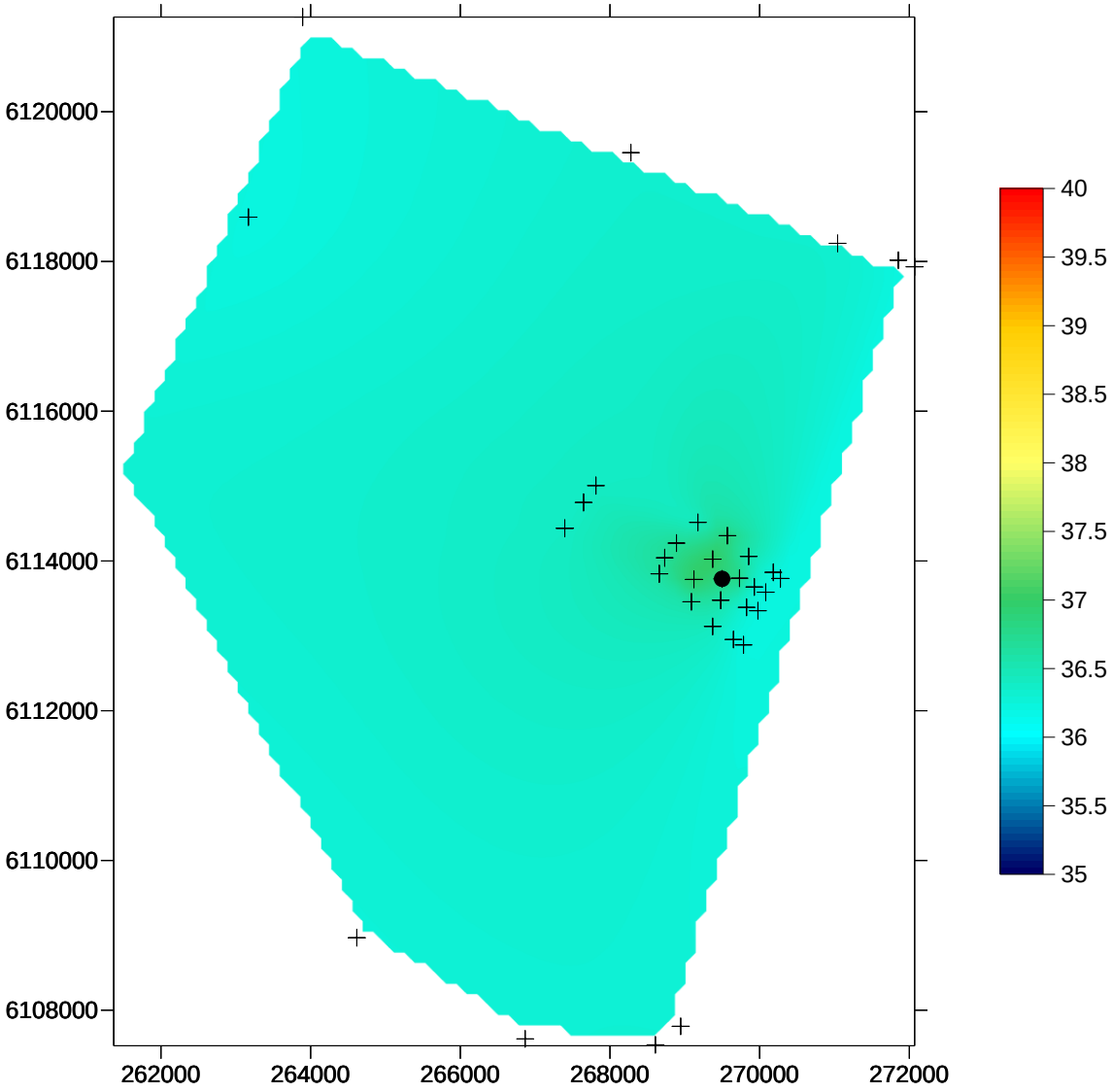

Figure 2 Spatial change in salinity concentration (ppt), on the seafloor, in the Port Stanvac region. The coloured scale bar represents changes in salinity concentration between 35 ppt and 40 ppt (sensor error ±0.1 ppt). X coordinates refer to eastings and Y coordinates refer to northings measured in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

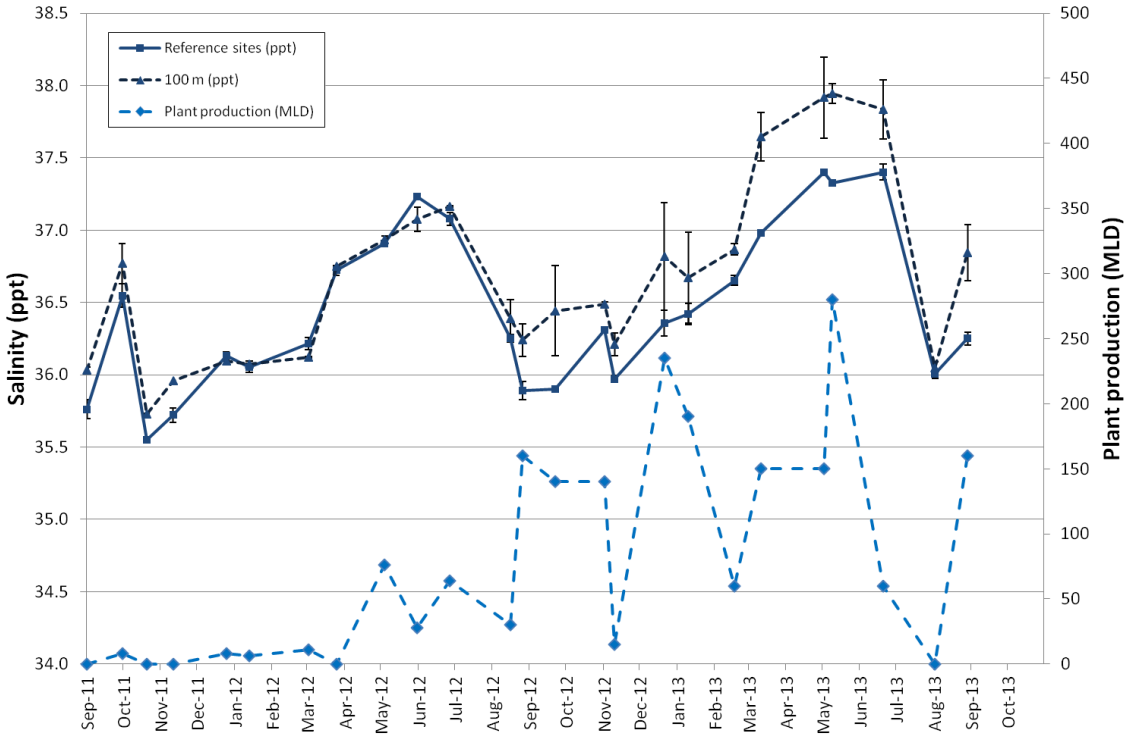

Figure 3 Comparison of average salinity concentration (ppt) on the seafloor, between reference locations and sampling sites located 100 m from the Adelaide Desalination Plant diffuser. Error bars represent standard deviation. Secondary y axis represents the daily production rate (MLD) on the day of the water quality survey. Note that the Adelaide Desalination Plant started to discharge saline concentrate, intermittently to the marine environment, from September 2011. Maximum plant production is 300 MLD.

4.4 Water temperature

Average water temperature in the region surveyed was 16.0 ^{o}C (±0.4 ^{o}C). Water temperature on the seafloor ranged between 15.3 ^{o}C and 17.2 ^{o}C, temperatures were warmer inshore compared to the 10 km offshore sites (Figure 4).

The average water temperature on the seafloor, 100 m north and south of the ADP diffuser at a depth of 15 to 18 m, was 16.1 ^{o}C (±0.1 ^{o}C; Figure 5). Water temperature was on average 0.7 ^{o}C higher on the seafloor at 100m fom the ADP diffuser than compared to reference sites (Figure 5). Water temperatures 5 km north and south of the ADP diffuser at a depth of 15 m were similar to those observed around Pt Stanvac (approximately 16.1 ^{o}C). Differences observed between the diffuser and reference sites are likely to be natural and are consequence of the warmer weather heating the shallower water close to the coast.

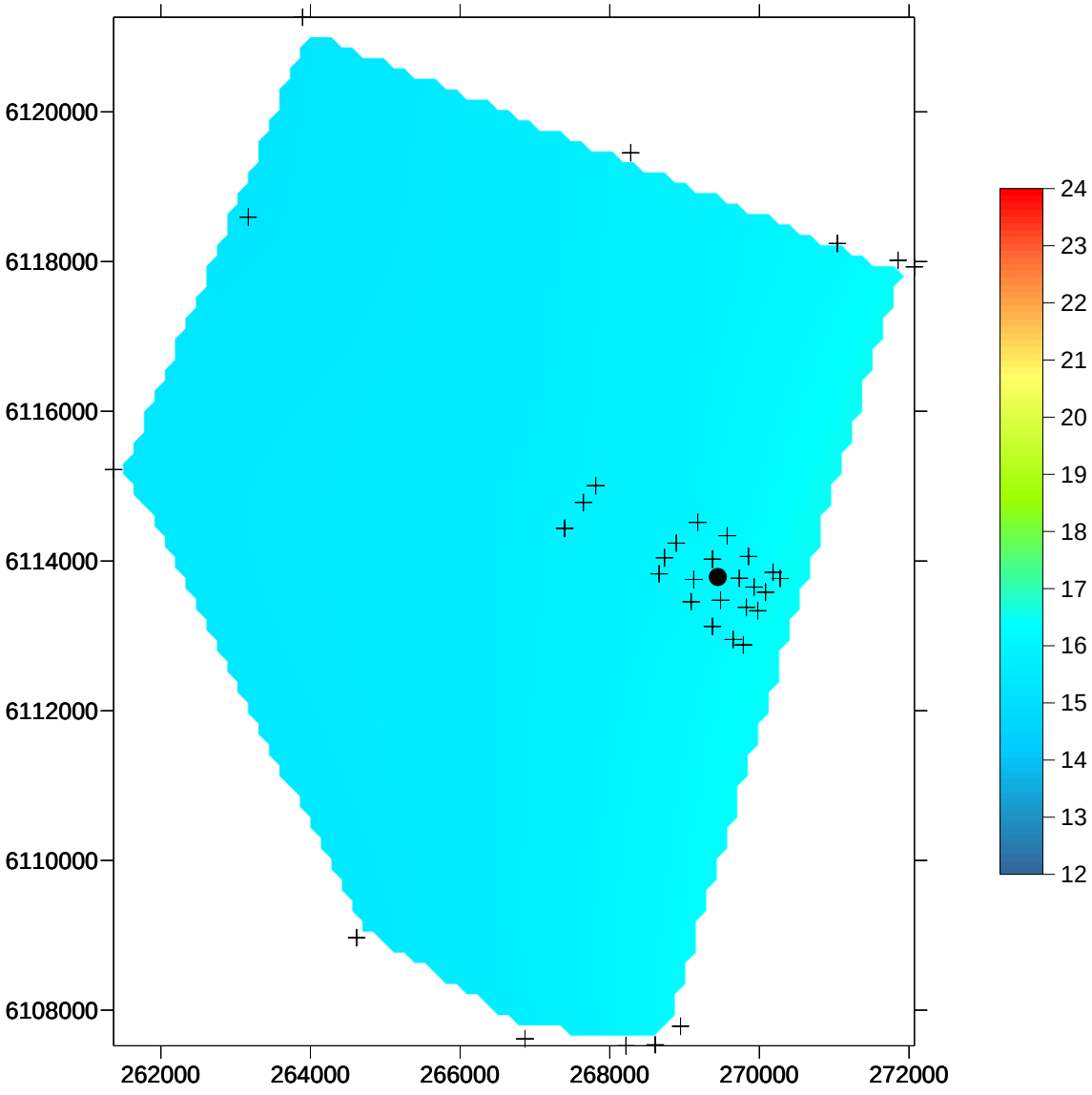

Figure 4 Spatial changes in water temperature, on the seafloor, in the Port Stanvac region. The coloured scale bar represents temperature changes between 12 °C and 24 °C (sensor error ±0.15°C). X coordinates refer to eastings and Y coordinates refer to northings measured in metres. Black dot represents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

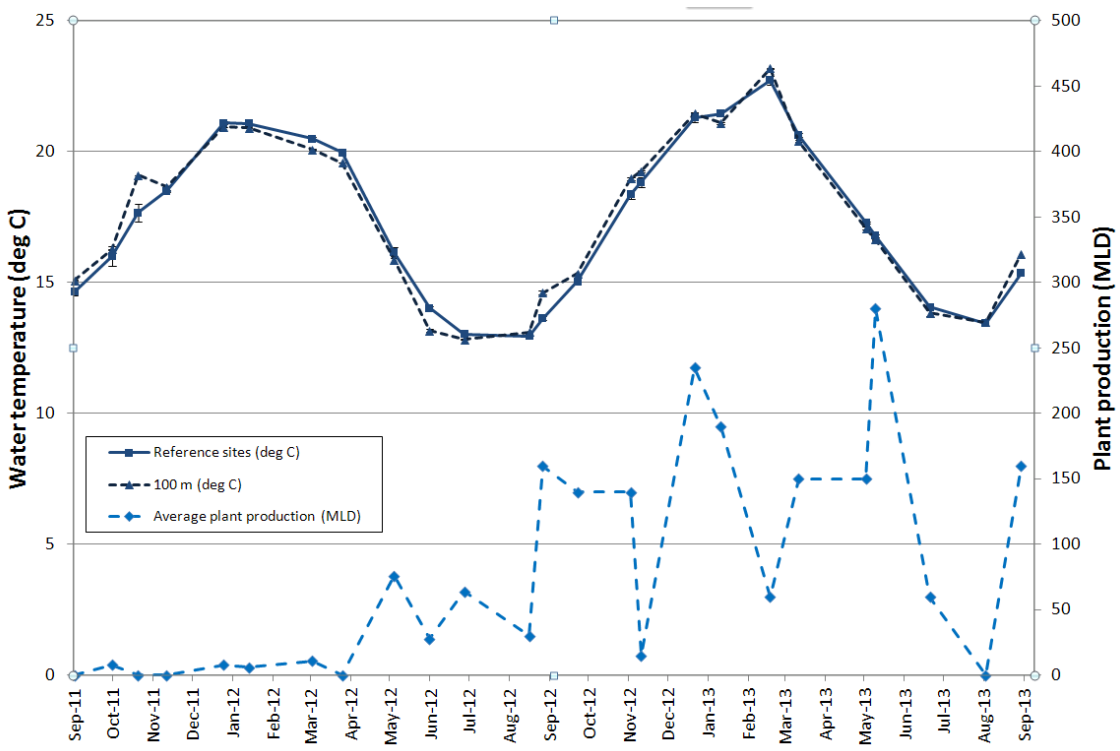

Figure 5 Comparison of average water temperature (degrees Celcius) on the seafloor, between reference locations and sampling sites located 100 m from the Adelaide Desalination Plant diffuser. Error bars represent standard deviation. Secondary y axis represents the daily production rate (MLD) on the day of the water quality survey. Note that the Adelaide Desalination Plant started to discharge saline concentrate, intermittently to the marine environment, from September 2011. Maxium plant production is 300 MLD.

4.5 Dissolved Oxygen

Average dissolved oxygen concentration (mg/L) in the region surveyed was 7.5 mg/L (±0.1 mg/L), this equates to an average oxygen saturation of 95.6 % (Figure 6 and Figure 7). Dissolved oxygen concentrations on the seafloor ranged between 7.4 mg/L and 7.6 mg/L.

The average dissolved oxygen concentration on the seafloor, 100 m north and south of the ADP diffuser at a depth of 15 to 18 m, was 7.5 mg/L (± <0.1 mg/L; Figure 8). Average dissolved oxygen concentrations, on the seafloor, were slightly higher at the reference locations (7.6 mg/L) when compared to 100m diffuser sampling sites (7.4 mg/L; Figure 8). Dissolved oxygen concentrations across the region are greater than 6 mg/L, which is the Environment Protection (Water Quality) Policy (2003) criterium for a healthy aquatic marine ecosystem.

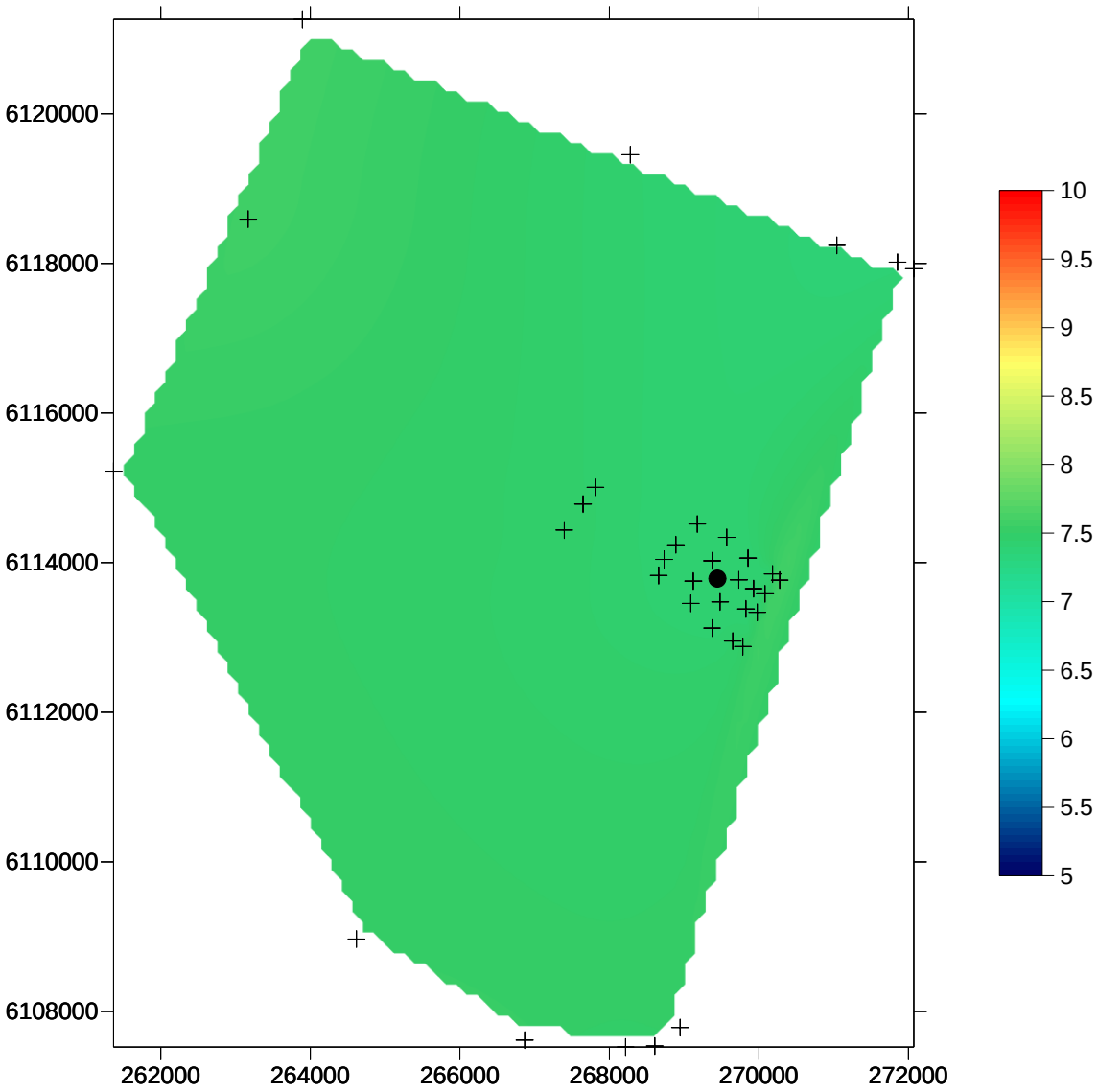

Figure 6 Spatial changes in dissolved oxygen concentration (mg/L), on the seafloor, in the Port Stanvac region. The coloured scale bar represents dissolved oxygen concentrations between 5 mg/L and 10 mg/L (sensor error ±0.1mg/L). X coordinates refer to eastings and Y coordinates refer to northings measured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

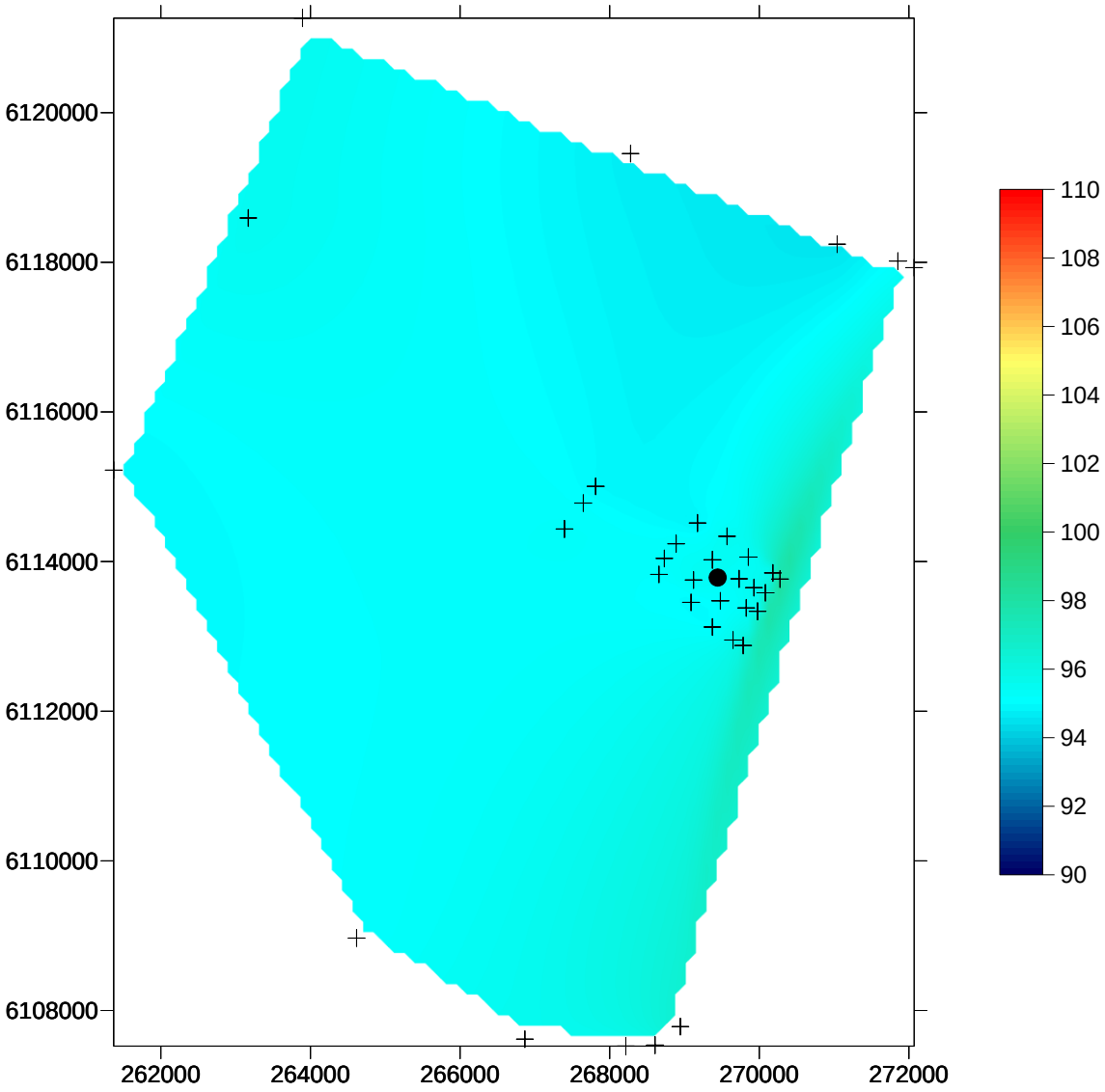

Figure 7 Spatial change in dissolved oxygen (percent saturation), on the seafloor, in the Port Stanvac region. The coloured scale bar represents dissolved oxygen concentrations between 90 % and 110 % (sensor error ±1%). X coordinates refer to eastings and Y coordinates refer to northings measured in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

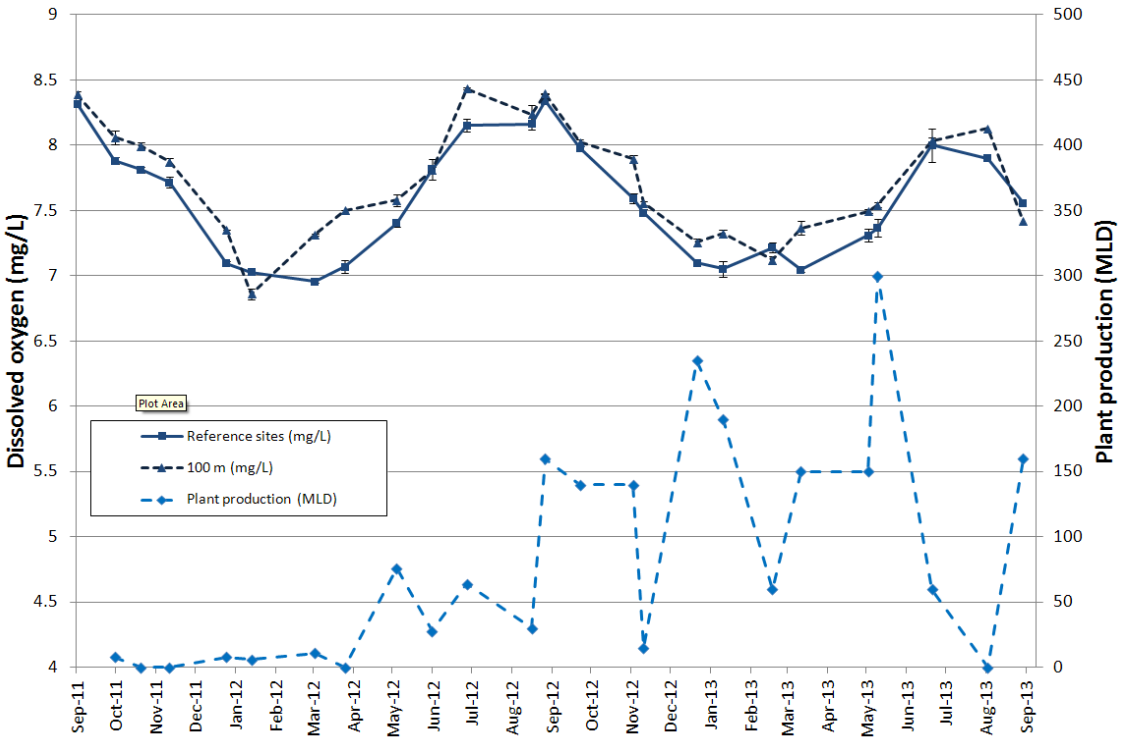

Figure 8 Comparison of average dissolved oxygen concentrations (mg/L) on the seafloor, between reference locations and sampling sites located 100 m from the Adelaide Desalination Plant diffuser. Error bars represent standard deviation. Secondary y axis represents the daily production rate (MLD) on the day of the water quality survey. Note that the Adelaide Desalination Plant started to discharge saline concentrate, intermittently to the marine environment, from September 2011. Maxium plant production is 300 MLD.

4.6 Chlorophyll

Chlorophyll concentrations in the region surveyed were generally less than 2 μg/L (Figure 9; sensor sensitivity is ±3 μg/L dependent on backscatter in the water column).

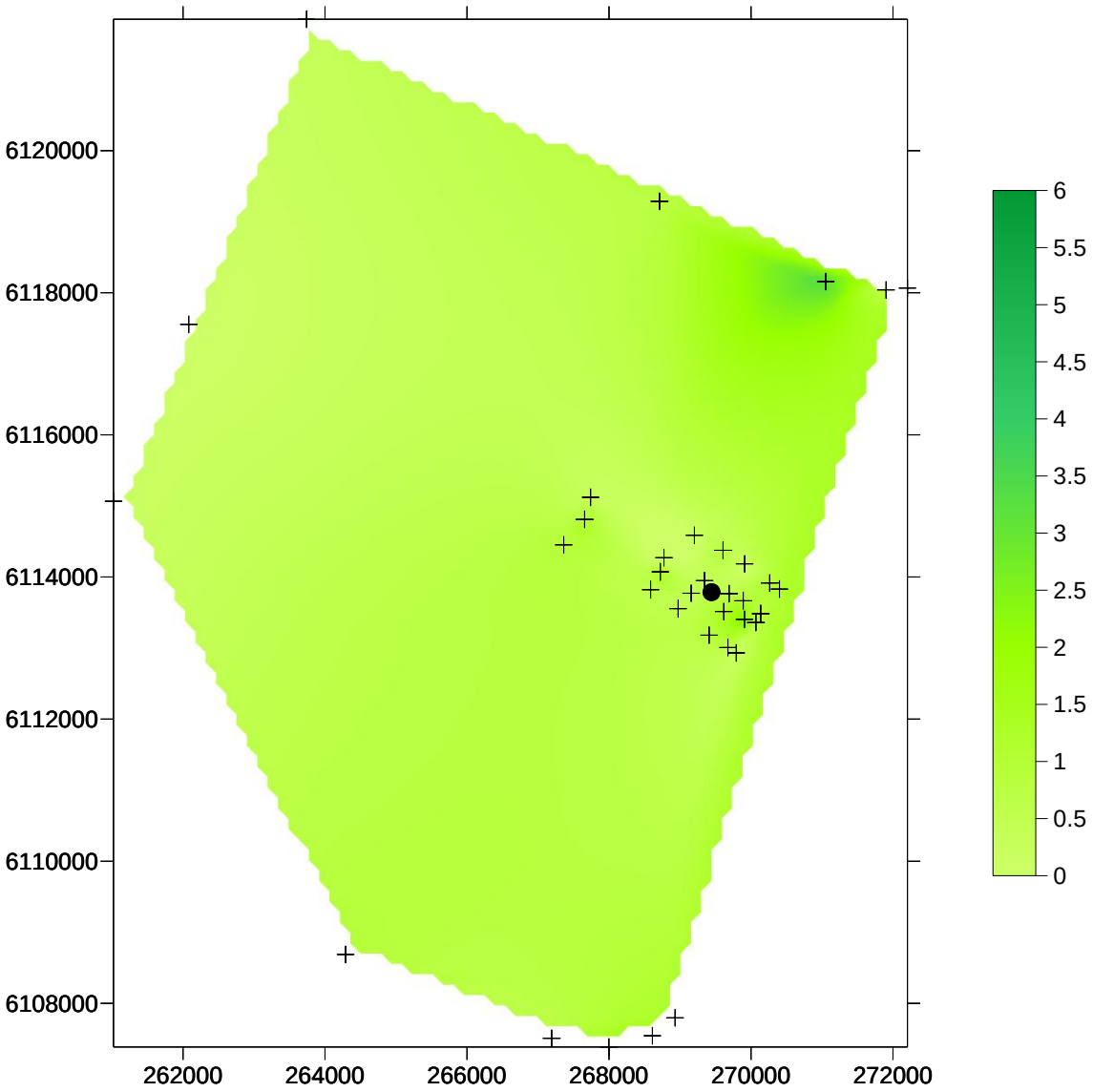

Figure 9 Spatial changes in chlorophyll a concentration, one metre below the surface, in the Port Stanvac region. The coloured scale bar represents a change in chlorophyll concentration between 0 μg/L and 6 μg/L. Note sensor sensitivity is ±3 μg/L. X coordinates refer to eastings and Y coordinates refer to northings measured in metres. Black dot represents position of ADP outfall. Blue crosses represent water quality sampling locations (also refer to Figure 1).

4.7 Turbidity

Turbidity in the water column surveyed were generally less than 2 NTU. 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. Higher than usual turbidity was observed at some inshore sites, caused by swell and rainfall.

4.8 pH

Average pH in the water colum, in the region surveyed was 8.1 (± <0.1 pH unit). Seawater is highly buffered due to high concentrations of bicarbonate ions in solution and as a consequence pH remains constant.