Assessment of the environmental performance of the Adelaide Desalination Plant based on a review of all documentation provided in compliance with EPA licencing requirements: June-2014

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AdelaideAqua Pty Ltd

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By

Prof. Anthony Cheshire B.Sc. Ph.D. MAICD

Science to Manage Uncertainty

Adelaide, South Australia.

http://www.science-to-manage-uncertainty.com.au

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EXECUTIVE SUMMARY

Purpose

This document represents an assessment of the environmental performance of the Adelaide Desalination Plant based on a review of all documentation provided in compliance with EPA licensing requirements for the construction and operation of the Adelaide Desalination Plant (ADP) over the period February 2009 to 12-Dec-2013. The various monitoring reports were associated with the construction (including commissioning) of the desalination plant (by AdelaideAqua D&C Consortium – AAD&C) from February 2009 to 12-Dec-2012 and to the operation of the desalination plant (by AdelaideAqua Pty Ltd) from 12-Dec-2012 to 12-Dec-2013.

Background

AdelaideAqua Pty Ltd (AAPL) is the operator of the Adelaide Desalination Plant at Port Stanvac, South Australia. Operation of the ADP requires the discharge of reject water to the marine environment; this activity was originally conducted under a licence issued to AAD&C by the Environment Protection Authority of South Australia (EPA Licence Number 26902) and subsequently under another licence issued to AAPL (EPA Licence Number 39143). These licences authorised AAD&C and AAPL to undertake a series of activities of environmental significance under Schedule 1 Part A of the Environment Protection Act 1993 (the Act). The licences had specific requirements in relation to "Discharges to Marine Waters" that are the subject of this report.

Section 14 (305-626) of the licence requires that the licensee must ensure that:

1. An independent review of all marine monitoring is conducted by independent specialist(s) as approved in writing by the EPA prior to the review commencing;
2. All marine monitoring from the period commencing with the issue of the licence and ending 12 months after project handover of the 100 GL desalination plant is included in the review; and
3. The full results of the review are provided to the EPA not more than 18 months after project handover of the 100 GL desalination plant.

The EPA has also advised that prior to appointment, the independent reviewer must be able to demonstrate to the EPA that:

1. They will use their own professional judgment;
2. They will take appropriate specialised advice when the issue is outside their expertise;
3. Their opinions will be reached independently;
4. In forming opinions, they will not be unduly influenced by the views or actions of others who may have an interest in the outcome of the review; and
5. They must declare any real or apparent conflict of interest.

With the approval of the EPA, Anthony Cheshire (the author of this report) was selected by AdelaideAqua Pty Ltd (AAPL) to undertake this review.

Approach

The EPA required the Independent Reviewer to undertake a technical review of all marine monitoring results from the commencement date of the Licence 26902 (AAD&C) until 12 December 2013 (12 months after plant handover) in order to address 3 key issues around the environmental performance of the desalination plant these being:

1. Environmental impact assessment;
2. Risk management;
3. Design validation.

The synthesis provided in this report is based upon the conclusions drawn from a critical review of some 377 written reports and/or data sets provided by AAPL in compliance with their various licence obligations. Documentation variously comprised information relating to 21 different Licence Conditions that were authored by staff at AAD&C, AAPL or by experts contracted by the parties for that purpose. Each report and data set was reviewed and key issues that pertain to the EPA Licence Conditions have been aggregated into a series of summary reports (Cheshire 2014a-u).

Findings

Environmental Impact Assessment and Biota Characterisation

The results confirmed the findings from previous studies that there is a general north-south gradient in the structure of biological communities along the Adelaide Metropolitan Coast and communities at Port Stanvac are broadly consistent with what would be expected based on geographic location. Overlying this is evidence that the past management of this site (through the exclusion zone that has operated since the mid 1960's) has resulted in intertidal reef communities that have a higher overall abundance and diversity, when compared to other intertidal reefs along this coast, where human traffic and gleaning has been effectively unrestricted.

Importantly, there was no evidence for adverse impacts on any of these ecosystems from either the construction or operation of the ADP.

Risk management

A comprehensive set of data on plant operation and water quality has been compiled that allows an assessment of the plant impact on a variety of indices including conductivity, temperature (salinity), dissolved oxygen, pH, trace metals and nutrient concentrations. Collectively these data provide a complete picture of both the natural variability in key water quality parameters for the Adelaide metropolitan coast as well as information about how these parameters change associated with the operation and discharge from the Adelaide Desalination Plant.

The most compelling result is that, in general, water quality is largely unaffected by the operation of the plant (outside of the 100 m mixing zone) and this is a result of the rapid dilution of the saline concentrate that is achieved through the diffuser array.

Design validation

The series of studies targeted to validating the design of the diffuser have focused on both typical operating conditions but also, and arguably more importantly, on the effectiveness of the diffuser during dodge tide and low wind conditions which are the most adverse for mixing and dilution of the discharge.

The results show that mixing of the saline concentrate on discharge is generally sufficiently rapid to achieve a 50:1 dilution within 100 m of the outfall which indicates that near-field mixing of the discharge is providing the necessary level of environmental protection.

Conclusions

The environmental monitoring that has been undertaken to support the design and operation of the Adelaide Desalination Plant was comprehensive in terms of ecosystems covered (benthic infauna, reefs, plankton communities through to fish), physico-chemical parameters assessed (salinity, pH, temperature, dissolved oxygen, chlorine, metals and inorganic nutrients) and physical processes monitored (tidal and wind induced flow and mixing). On balance there is no evidence of an environmental impact. While there is some evidence of minor perturbations in ecosystem structure and function (some sites show transient changes over time that are not consistent with those seen elsewhere) these cannot be attributed to the construction or operation of the plant.

INTRODUCTION

Aims and Objectives

This report aims to provide an overview of the results of the environmental monitoring program for the ADP and to specifically address the requirement from the EPA that the Independent Reviewer is to undertake a technical review of all marine monitoring results from the commencement date of the Licence 26902 through to 12 December 2013 (12 months after plant handover) in order to assess the environmental impact of the desalination plant.

Each Licence Condition (in Licence 26902 and/or Licence 39143) required the collection or analysis of data that would address one or more of the three key objectives of the environmental monitoring program these being:

1. Environmental impact assessment – whereby the data and analyses are used to assess whether or not there is evidence for an environmental impact that has resulted from either the construction or operation of the plant

2. Risk management – whereby the data are used to assess whether the operation of the plant has the potential to compromise environmental values in the vicinity of the plant associated either with the intake of seawater or discharge of the saline concentrate.

3. Design validation – whereby the data are used to validate the design of the outfall diffuser array and particularly to quantify the spatial extent of the mixing zone of the saline concentrate.

The review has also identified some opportunities to improve the analysis of monitoring data collected to this point in time in order to enhance our understanding of the results. No recommendations are made in relation to future monitoring or analysis.

Environmental Impact Assessment and Biota Characterisation

Licence Conditions 1-4, 5 (in part)

In broad terms the assessment of impact has two primary objectives;

1. To characterize ecological communities in the vicinity of the ADP and at selected reference or "control" locations; and
2. To determine whether or not there is any change in these communities in the vicinity of the ADP that can be attributed to the construction or operation of the plant.

By and large these assessments look for changes in the structure of representative communities from key ecosystems including intertidal and subtidal reefs, soft-bottom systems and plankton communities. These assessments are complemented by an additional set of studies that aim to characterise the nature of fish communities (from both reefs and soft-bottom systems) as well as plankton communities (primarily associated with the intake waters).

General characterization of biota

Licence conditions 1-5 had a role in improving our knowledge about the various ecological communities present at Port Stanvac and more generally along this section of the Adelaide Metropolitan Coast. These data are important in that they provide background information about the nature of the ecosystems and provide a picture of the natural history of the area. While not all such studies will lend themselves directly to an analysis of environmental impact, these data provide a basis for better defining the requirements of longer term monitoring by characterizing and quantifying the ecological assets and environmental values of this region and particularly in identifying sensitive indicators of environmental condition that have utility in impact assessment.

Survey design and analysis for environmental impact assessment

The overall design of the monitoring programs used for each of Licence Conditions 1, 2 and 4 (intertidal reefs, subtidal reefs and infauna) embodied a more specific focus on direct assessment of environmental impact and thereby adopted the logic of Underwood (1984) through the use of the statistical methods available in the PERMANOVA utility in the PRIMER+ multivariate statistical analysis package (Anderson et al., 2008). In general terms these monitoring programs were designed for a Beyond-BACI analysis of the changes in a series of putatively[1] impacted sites (at Port Stanvac) versus those at control or reference sites. In each case reference sites have been selected at locations both to the north and south of the ADP construction zone at a distance that is deemed to be outside the zone of influence but close enough to Port Stanvac to be representative of the region in general.

This series of analyses were used to compare the Port Stanvac sites (putatively impacted sites) to the reference sites; this comparison allows an assessment of the 'desalination' factor. In this design, sites are treated as random and in some cases sites were nested within locations (e.g. North Reference, South Reference and Port Stanvac). Data were collected over 'time' through a series of surveys generally from early 2009, prior to any construction or operation of the plant, through to the end of 2012 when the plant was fully operational. 'Time' was incorporated into the design where it was treated as orthogonal to 'desalination' thereby allowing for tests of temporal consistency between the Port Stanvac sites and the reference sites (Anderson et al., 2008). The key focus of the analysis was therefore on whether Port Stanvac had a temporal trajectory that was different from the temporal trajectory at the reference sites (i.e. whether or not there was a significant "desalination × time" interaction term).

In more general terms this approach is based on the premise that in nature any location (or site) is likely to differ from any other site in one way or another. Similarly, sites will change over time due to seasonal and/or inter-annual variability in the myriad of environmental drivers that affect the ecology. In assessing an impact it is therefore important to recognise

[1] The term "putatively impacted" is used because the analysis of environmental impact starts with the null hypothesis that there are no differences at the "impact" sites when compared to the "control or reference" sites. The monitoring program collects data that is used to test this null hypothesis and only if the analysis disproves the null hypothesis can one conclude that the site has been impacted.

that sites may well be different to one another for reasons not associated with the impacting process. In such cases, even if this difference is between control and impact sites, this is not evidence in and of itself, of an environmental impact. Similarly, sites may change through time and even if there is a change from before the impact (construction or operation of the ADP) when compared to after the impact this is not evidence of an impact *per se*; it may simply represent seasonal or other temporal variability. In essence, an impact can only be defined if the change through time at the impact sites is different to the change through time at the control sites. This change through time is referred to as the 'temporal trajectory' and a difference is identified as a significant 'time by treatment' interaction term in the 2-factor ('time' by 'treatment') analysis.

Monitoring to support risk management

Licence Conditions 5 (in part), 6-14, 19

Although primarily undertaken to support characterisation of biota (see above) the assessment of plankton entrainment was also undertaken as part of the overall risk management with the aim of determining whether removal of phyto-, zoo- or ichthyo-plankton from the system (via the water intake) was likely to be of significance.

More generally the monitoring to support risk management involved quantifying selected water quality parameters for both the input and output flows. Essentially the monitoring aimed to determine whether discharge water differs from intake water in any manner other than what would be expected from simply concentrating the dissolved constituents in the intake stream (associated with the removal of fresh water). In this sense the monitoring looked at key water quality parameters including dissolved oxygen, pH, conductivity (salinity), temperature and the concentrations of selected inorganic nutrients, metals and certain additives including chlorine.

An assessment of whole of effluent toxicity was also undertaken to provide a broad based assessment of the adequacy of a 1:50 dilution factor as a guiding principle in assessing risks associated with the discharge.

Monitoring to validate diffuser design and operation

Licence Conditions 15-18, 20-21

Monitoring that contributed to the design validation aimed to determine whether or not the operation of the plant was consistent with the design parameters. In particular, whether the outfall diffuser was able to achieve sufficient mixing of the discharged saline concentrate so that it was rapidly diluted thereby minimising the spatial scale of any resultant impact. In broad terms the objective was to ensure that mixing of the discharge occurred within 100 m of the outfall diffuser array such that a dilution of at least 50:1 was achieved (a dilution which would minimise the potential for any adverse impacts from the saline concentrate).

Marine noise (Licence Condition 19) was also assessed to ensure that the operation of the plant did not create underwater noise.

RESULTS BY LICENCE CONDITION

1 *Intertidal Reef*

Surveys were undertaken to provide baseline data that could be used to characterise intertidal reef communities and also to assess the extent to which the construction and/or operation of the ADP has had an impact on the intertidal environment in the region of Port Stanvac.

Specific objectives were to apply standardized survey methods in order to assess the spatial and temporal variability in:

- Mobile gastropod abundances;
- Percent cover of sessile organisms; and
- Sediment depth.

Data on intertidal reefs were collected consistent with the licence requirements, and the results of these surveys have been analysed and reported (summarized in Cheshire 2014a). While none of the original reports provided a complete analysis of the data in the form required to determine whether or not an environmental impact had occurred, a subsequent analysis of the data (Ramsdale 2014) was undertaken which specifically addressed this question. This analysis concluded that while there was evidence of a time by treatment interaction, the source of that interaction was attributable to two out of the twelve sampling events, and of limited extent with the overall differences between treatments remaining essentially unchanged. On this basis the differences would appear to be transient and there is no evidence of a persistent change in the communities.

The monitoring reports focused primarily on describing and quantifying the extent to which intertidal communities varied from one site to another at each discrete sampling event. These analyses consistently reported that, in general, the Port Stanvac Zone has higher abundances, cover and in many cases diversity of intertidal floral and faunal species or lifeforms (see for example Figure 1 taken from Stewart and Dittmann 2012).

Overall, the differences between Port Stanvac and the control locations are likely to be attributable to the fact that the intertidal zone at Port Stanvac has been protected for many years from human trampling and gleaning (due to the exclusion zone that was imposed over this area dating back to the operation of the Exxon Mobil refinery from the mid-1960's through to 2003). In effect, the exclusion zone is acting like a marine protected area and the ecological values within the Port Stanvac region, defined by abundances and species richness, are generally higher than in surrounding areas.

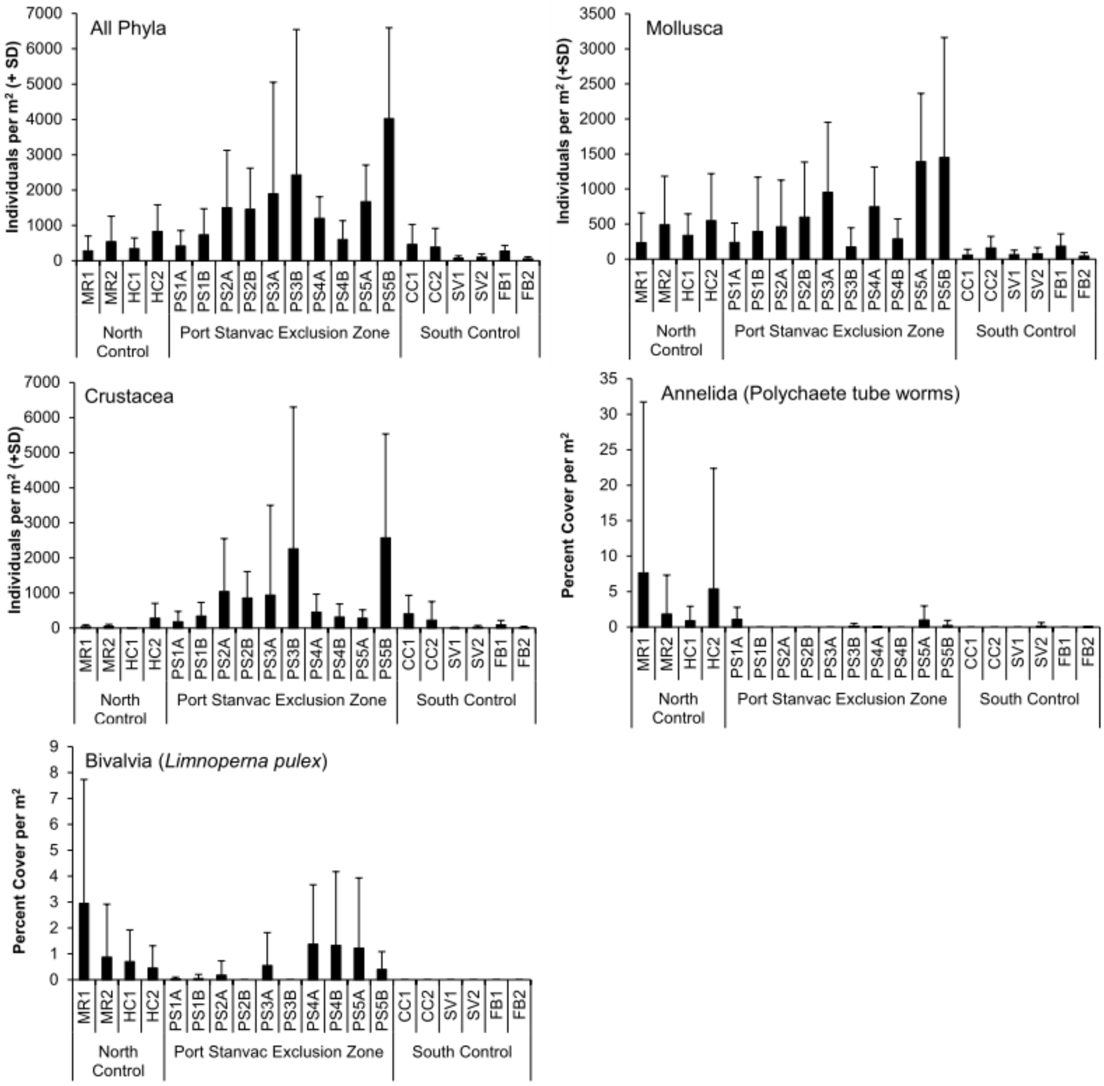

Figure 1 - Mean abundances (+SD) for all phyla, Mollusca, Crustacea, Annelida, and Bivalvia from the summer 2012 intertidal survey encompassing three zones; North Control, Port Stanvac Exclusion Zone and South Control (after Figure 4. Stewart and Dittmann, 2012). Note that Port Stanvac has a higher (but quite variable) number of all phyla (viewed collectively), and this is primarily due to the relative number of molluscs and crustaceans.

2 *Subtidal Reef*

Surveys were undertaken to provide baseline data that could be used to characterise subtidal reef communities and also to assess the extent to which the construction and/or operation of the ADP has had an impact on the subtidal environment in the region of Port Stanvac and these studies have been summarized (Cheshire 2012b).

Specific objectives were to apply standardized survey methods in order to:

- Collect data on reef communities through intensive SCUBA-based surveys (using the Reef Health protocols) of subtidal reefs at Port Stanvac; and
- Provide AAPL and AAD&C with detailed reports of the findings of surveys that would form a comprehensive environmental monitoring regime.

The overall design of the subtidal reef monitoring program provided a robust framework for assessing whether or not there had been an environmental impact associated with the construction and early stage operation of the ADP.

The analysis of these data concluded that while there was some evidence of a time by treatment interaction the source of that interaction was with small scale sample differences and was not attributable to the construction or operation of the desalination plant.

Importantly the reports also made reference to the large amount of historical data that exists for a number of the reference sites used in this study and went on to discuss the monitoring program in the context of a range of issues that pertain to the ecological status and condition of coastal environments along this region of the Adelaide metropolitan coast. Specific reference has been made to the fact that this section of coastline is subjected to numerous land based influences associated broadly with catchment management and particularly with storm and waste water disposal. A critical feature of this is that the coastline has a documented history of loss of both seagrasses and reefal communities (see for example Cheshire et al. 1999 and Connell et al. 2008) on this basis any analysis needs to be cognizant of the fact that the "reference sites" exist in an area where coastal community condition is rapidly changing. On this basis any detection of a time-by-treatment interaction needs to clearly identify the source of the interaction and be clear about whether or not it is directly or indirectly attributable to the effect of the desalination plant, as distinct from the broader impacts of coastal management frameworks across this region.

In essence, a broader understanding of the management of the Adelaide metropolitan coast can only strengthen our capacity to interpret information from these studies. Specifically, the historical data provides a context that allows an analysis of whether or not any changes that do occur are likely to have resulted from the ADP operation and also whether any such changes have impacted negatively on ecological function of the reefs.

3 Baited underwater video

The baited underwater video monitoring had the objective of characterising fish communities in the region of the ADP. Monitoring was undertaken using stereo video survey techniques with the aim of quantifying the species richness and abundance of fish in two different habitats (reef and soft-bottom communities) close to the diffuser (within the 50:1 dilution zone) and to compare these with fish communities in similar habitats at a site more distant from the diffuser (outside the 100:1 dilution zone). Assessments were made twice per year.

Analysis of the data demonstrated that there were significant differences in the fish communities in terms of total abundance and species richness, through time, between sites, seasons and years. These differences have been characterised in terms of both species richness and abundances and are augmented by data on fish sizes. Some of the results from these surveys have suggested that reefs in the Port Stanvac region may act as breeding or nursery sites for selected fish species particularly including the Port Jackson shark.

Fish community monitoring has been conducted consistent with the specific Licence Conditions (see summary in Cheshire 2014c). The data collected to this time provide the basis for characterising the fish communities present at the Port Stanvac site and for comparing and contrasting those to fish communities at a location further to the north.

This monitoring program had the principal objective of characterising fish communities in the region and it was not designed to provide a basis for impact assessment. On this basis one cannot use the results to determine whether or not the construction or operation of the ADP has had an environmental impact. The survey was un-replicated (in space) with only one study location in the Port Stanvac Zone and one location in the Reference Zone (acknowledging that each location was further sub-divided into a softbottom and reefal site). Therefore, any changes or differences that are seen in fish community structure will provide additional information about the species that are present but cannot be used to infer whether or not there has been an impact from the construction or operation of the desalination plant.

4 Infauna survey

Surveys were undertaken to provide baseline data that could be used to characterise softbottom infaunal communities and also to assess the extent to which the construction and/or operation of the ADP has had an impact on infauna in the region of Port Stanvac.

These studies were primarily focused on quantitative characterization of both macro- and meio-fauna. A variety of survey techniques have been used (see summary in Cheshire 2014d) including suction samples, dredge samples, a box corer and a HAPS corer. These methods have varying utility and each device will sample a somewhat different aspect of the community; on this basis they have been useful in obtaining data across a wider variety of soft-bottom infaunal and epi-benthic (sessile and sedentary) invertebrate taxa than would have been obtained from just one such sampling device.

Not surprisingly for a coastal softbottom community the suite of studies broadly concluded that the macro-infauna was dominated by polychaetes, crustaceans and molluscs while the meiofauna was dominated by nematodes, crustaceans and polychaetes. Due to differences in sampling methodologies it is neither useful nor valid to compare between sampling methods but Loo et al. (2014) reported that the macrofauna comprised 98 discrete taxonomic groups spread across ten phyla while the meiofauna comprised around 40 taxonomic groups across 8 phyla (based on surveys using the HAPS corer which is arguably the most versatile and consistent sampling device for infaunal systems).

Whilst the diversity of sampling devices has been useful in capturing a wide range of taxa, that may not have been so effectively surveyed using a single methodology, the use of different sampling techniques from one survey to another has made the measurement of change through time quite problematical. This has been further complicated by the decision to change the location of the northern reference sites to a new location immediately prior to the final two surveys in 2012-2013[2]. On this basis it is not possible to do a single analysis to determine whether or not there is a consistent temporal trajectory (between control and impact sites) that covers the entire four year period. However, the final two surveys do

[2] The latter two surveys (conducted by SARDI in June 2012 and February 2013) used a different location for the North Control Sites relative to that used during all previous surveys; this was based on SARDI's assessment that the original location used by Flinders University was not appropriate as the benthic communities at the Flinders site were dominated by seagrasses and rhodoliths and therefore were qualitatively and quantitatively dissimilar to the benthic communities being sampled at both Port Stanvac and at the South Control location.

provide the basis for a somewhat more limited analysis using a consistent sampling system (the HAPS corer). This analysis did not find any evidence of a different temporal trajectory at Port Stanvac when compared to that observed at the reference sites and on this basis one can assume, at least for the time period covered by these surveys, that there was no evidence of an impact associated with the operation of the plant.

5 Plankton

The plankton monitoring program was designed primarily to characterise the plankton communities in the region of the ADP, to assess changes in plankton communities over time and also to provide an assessment of the risk to plankton communities due to the operation of the ADP. In order to achieve this, the plankton monitoring has been designed to provide data on ecological condition as well as to support a broader approach to risk management.

The specific objectives for the monitoring program (as defined in Ayala 2013) were:

- To identify plankton species (phytoplankton, meso-zooplankton and micro-zooplankton) to species level, where possible;
- To provide a comparison of plankton abundance and composition found at Port Stanvac to other regions in Gulf St Vincent with particular reference to potentially harmful species;
- To examine seasonal variation in rates of primary and secondary productivity; and
- To provide detailed reports of the findings of the above surveys sufficient for a decision to be made on the likely environmental impacts to the plankton community of a desalination plant.

The latter dot-point is of arguable relevance in that it is not a requirement of the licence condition and in fact the design of the monitoring program would not allow any assessment of the effect of the ADP on plankton communities.

The work undertaken provides a comprehensive description of the structure (taxa present) and productivity (primary and secondary) of phyto-, zoo- and ichthyo-plankton communities at the Port Stanvac site. While the numbers of the various species and types of plankton are quantified these estimates are not used to statistically analyse change through time or between stations at any one time. Furthermore, while the comparative data are presented it is not possible to draw any conclusions about the significance of differences that are reported. The reports do make reference to the broader literature and other comparable studies which helps to put the results into a broader environmental context.

The overall conclusion from the first part of this study is that there is evidence of a seasonal peak in abundance of plankton (April-June; Figure 2) and it was suggested that this may be a regular occurrence in this region being broadly similar to patterns identified for south-western Spencer Gulf. While van Ruth (2012) makes the argument for this seasonal variation there is no underpinning statistical analysis to support the conclusion and a visual assessment of the seasonal data (Figure 2) lends little credence to the assertion.

Even if true, one must view the comparison to Spencer Gulf with some caution because the context for the Spencer Gulf work was an assessment of the tuna farming zone near Port Lincoln. The comparison, therefore, is made in respect of an area that is subjected to very different conditions both in terms of the natural ecology as well as management; the tuna farming zone in Spencer Gulf being adjacent to an area with a seasonal coastal upwhelling and is also an area with intensive aquaculture production and the associated seasonal fluxes in nutrient discharge. No similar processes operate within the region of the ADP.

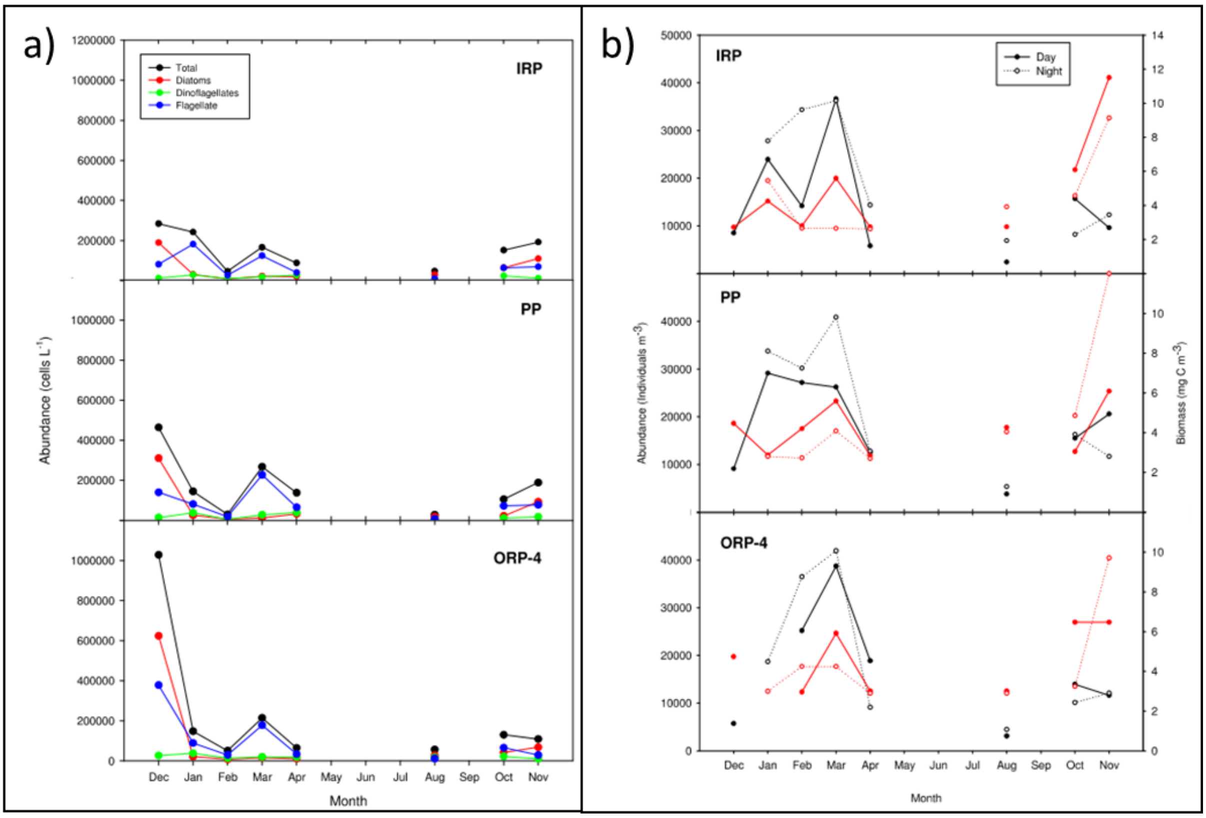

Figure 2 - Plankton variation over an annual cycle (Dec 2010 to Nov 2011); a) Phytoplankton, b) Zooplankton. While the author (van Ruth 2012) argues there is evidence for an April-June peak this is not evident from a visual analysis of these data.

The work has identified the presence of potentially harmful/toxic phytoplankton bloom species (HABs) but notes that these were infrequent and at low abundances. There is no indication that these have any specific association with the construction or operation of the ADP and such species have previously been reported from metropolitan coastal regions around Adelaide (McDowell and Pfennig, 2013).

In the plankton monitoring report published in March 2012, van Ruth (2012) speculates on apparent differences in the composition of the phytoplankton community between 2009-10 and 2010-11. While data were presented that show differences from one year to another the design of the monitoring program does not allow any interpretation of such differences in the context of the operation of the ADP (in essence the design is not replicated and there are no suitable control locations to support such an analysis[3]). The differences that were noted could be due to any number of factors and the speculation contained in the report is not supported by either the accompanying data or analysis.

[3] Importantly this was never an objective of the study and cannot be used to support a *post-hoc* interpretation of the results in this manner.

Later reports in the series and particularly those published between October 2013 and April 2014 provide a more tightly focused data set that assesses the plankton entrained into the ADP intake. These data are intended to provide an assessment of the potential for plankton to be removed from the Gulf by the ADP. While providing good data on the relative numbers of various plankton species the data are not analysed in a way that quantifies the effective rate of removal, or that puts these data into a meaningful context. For example, one can make a rough estimate of the impact of the removal of fish eggs through the ADP by using the estimate for the numbers of eggs per L in the intake water for selected species (e.g. Australian sardine which is easy to visually identify).

A simple calculation for Australia sardine would be as follows:

Equation	Parameter (Source)	Value	Units
A	Number of eggs in intake water (from monitoring)	10 or 0.01	eggs/m^3 or eggs/L
B	Spawning season intake volume (production data & Ward et al. 2012)	200 or 67×10^9	GL/annum or L over 4 month spawning season
C= A x B	Eggs removed	$0.01 \times 67 \times 10^9$ = 0.67×10^9	eggs
D	Specific fecundity (Ward et al. 2012 & Ward and Staunton-Smith 2002)	15,000*0.1*120 = 180,000	eggs/sardine/season
E	Average sardine size (Ward et al. 2012)	50	g/sardine
F=C/D	Number of fish required to produce eggs (includes multiplier for sex ratio)	$2*0.67 \times 10^9/180{,}000$ = 8,000	sardines
G=E*F	Total biomass required to produce eggs	8,000*50 = 400 = 0.40	kg tonne
H	Total allowable catch (Ward et al. 2012)	30,000	tonne
I=G/H	Percent of TAC	**0.40/30000 =** **0.001%**	Equivalent % increase over existing commercial harvest rate

What this calculation suggests is that the ADP has about the same effect as increasing the current fishing effort by 0.001%; even if the actual removal rate were 1000 times higher it would hardly constitute a significant impact and on balance the ecological/environmental impact of egg entrainment (at least for Australian sardine) would appear to be trivial.

This approach is purely illustrative and may well be subject to a much more detailed scrutiny before adoption but it does demonstrate a way in which the results of this monitoring program can be contextualized to provide at least a semi-quantitative estimate of the effect size.

This approach, at least in the context of those icthyoplankton species that are easily identified, provides a more objective basis for analysing and interpreting the results and explaining the results in terms that have a relationship to broader resource management arrangements.

6 *Water quality profile*

The aim of the study was to characterise the water quality of the Port Stanvac region, by measuring a series of parameters across the water column. These parameters comprised:

- Salinity (conductivity)
- Dissolved oxygen
- pH
- Chlorophyll a
- Turbidity
- Water temperature

These parameters are important in the context of the desalination process because the pre-treatment and reverse osmosis process can result in the production of a waste stream with an elevated salinity, changed pH and lower levels of suspended solids relative to the influent water. The operation relies upon mixing of the saline concentrate on discharge to dilute salinity back to near ambient values; pH is adjusted as necessary while the reduction in suspended solids is not seen as being an impact but even so the dilution effect will result in mixing of the receiving waters so this is addressed in a similar manner to salinity.

This monitoring program had the objectives of assessing ambient water quality at increasing distances from the outfall diffusers in order to report on both the natural variability (daily, seasonally, annually) and the near-field effect of the outfall (which is implicitly a test of the effectiveness of the diffusers) (Figure 3).

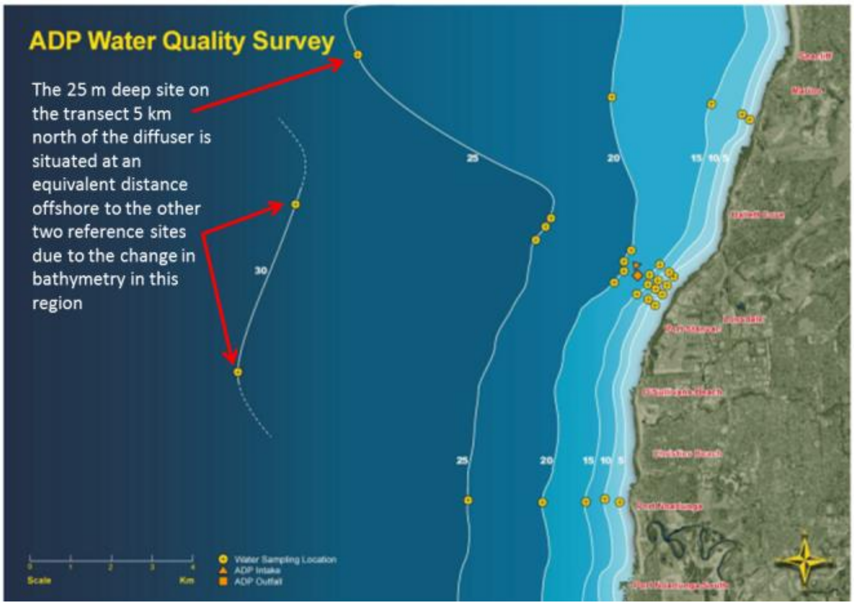

Figure 3 - Map showing locations of study sites (adapted from the various reports by Kildea et al.) Note that the 25 m depth contour deviates to the northwest, heading offshore in the vicinity of the northern-most monitoring transect. The 25 m site is thus situated approximately 10 km off-shore and is taken as one of the reference sites for the study.

The key feature of the results from this monitoring program was that, across a range of ambient current flow and plant operating conditions, the mixing from the diffuser was generally rapid and thereby resulted in effective dilution of the saline concentrate very quickly after discharge. Indeed, the results of these reports can be compiled into a single analysis (data provided by Tim Kildea) that illustrates the relationship between plant production volumes (ML/d or MLD) and the difference in salinity (delta ppt) observed at the 100 m stations when compared to ambient conditions (Figure 4).

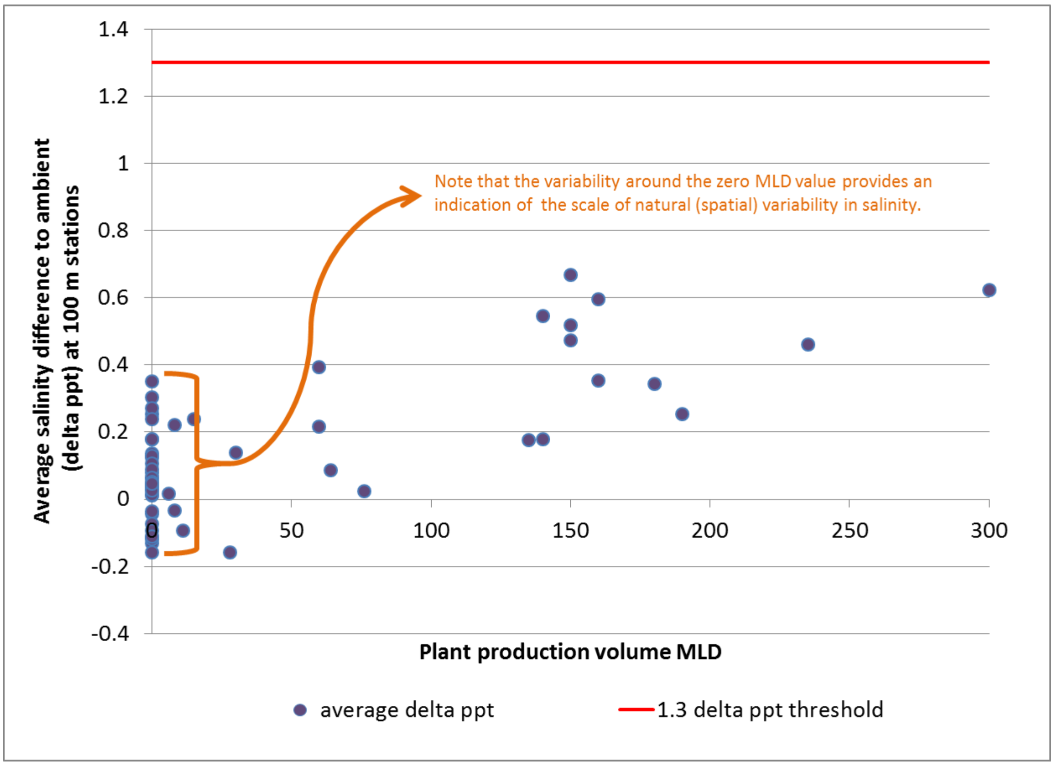

Figure 4 - Relationship between production volumes and the 24 h averaged differences in salinity, at various locations 100 m from the diffusers, relative to ambient values measured over the same period. Variability is attributable to differences in tidal flow and wave induced mixing on the various sampling dates as well as spatial variation in salinity across the region. This plot provides an index of the effectiveness of the ADP diffusers after accounting for differences in production volumes (and thereby the volume of saline concentrate discharged). Note the red line indicates the 1.3 delta ppt value which is the compliance target for the diffusers; in all cases the observed salinity was well below this value.

This analysis suggests that when the plant is operating at maximal production volumes (300 MLD) the salinity is typically elevated by an average of 0.7 ppt (parts per thousand) at the monitoring stations 100 m from the outfall diffusers (although this varies in relation to prevailing tidal and weather conditions). The natural variability is such that this value may vary by ± 0.3 ppt depending on prevailing conditions. This variation is against a background of ambient salinity that is typically in the region of 35-36.5 ppt.

While this result demonstrates the effect of the discharge on salinity in the surrounding waters, the results can also be extrapolated to other water quality parameters which would be expected to show the same dilution response. Overall the data from this monitoring program suggest that there is no evidence of adverse impacts on water quality in the surrounding environment associated with these parameters. DO is naturally variable with typical values of around 90%-110% saturation[4] while ambient values for pH tend to be close to 8.1 (8.0-8.2).

The results of the water quality monitoring program provide good evidence that the operation of the plant across the range of values from low to high production volumes generally has only a limited effect on water quality in the immediate vicinity of the diffuser and this effect rapidly diminishes towards ambient conditions within the first 100 m or so from the outfall.

While the results presented under this Licence Condition only relate to the water quality conditions under typical or more general operating conditions for the plant, the results from Licence Conditions 20 and 21 address the more specific case when tidal and weather conditions are at their most adverse (i.e. during a dodge tide with low tidal and wind driven mixing).

Importantly the results presented in Figure 4 also illustrate the scope of natural variation in ambient salinity on a spatial basis (i.e. differences between the ambient levels at the intake and outfall stations when the plant is not operating) which is graphically represented by the variability around the daily production value of 0 MLD (left hand y-axis).

7 Seawater characteristic - Ambient salinity

Monitoring of ambient salinity was intended to provide data on the salinity of intake water over the period of plant construction and operation up to the end of December 2013. In fact (and consistent with other conditions), data has been recorded since January 2012 which is after the early phase testing (including first water runs; Appendix A) but before the major operational testing (SP1 and SP2 full production; Appendix A).

These data provide a comprehensive data set on intake water salinity over an extended period. Data have come from both the intake line and from sites in the general vicinity of the intake and thereby provide a good basis for estimating the typical variations in salinity over time (Figure 5).

[4] While DO values are sometimes given as % saturation they can also be reported as ppm or mg/L. The actual value (mg/L) for DO at 100% saturation is entirely dependent on ambient salinity and temperature with warmer saltier water having a lower oxygen holding capacity than colder fresher water. Typical variations at 100% saturation between winter (15 ^{o}C, 35 ppt) and summer (20 ^{o}C, 36.5 ppt) would be 8.14 vs 7.32 mg/L respectively.

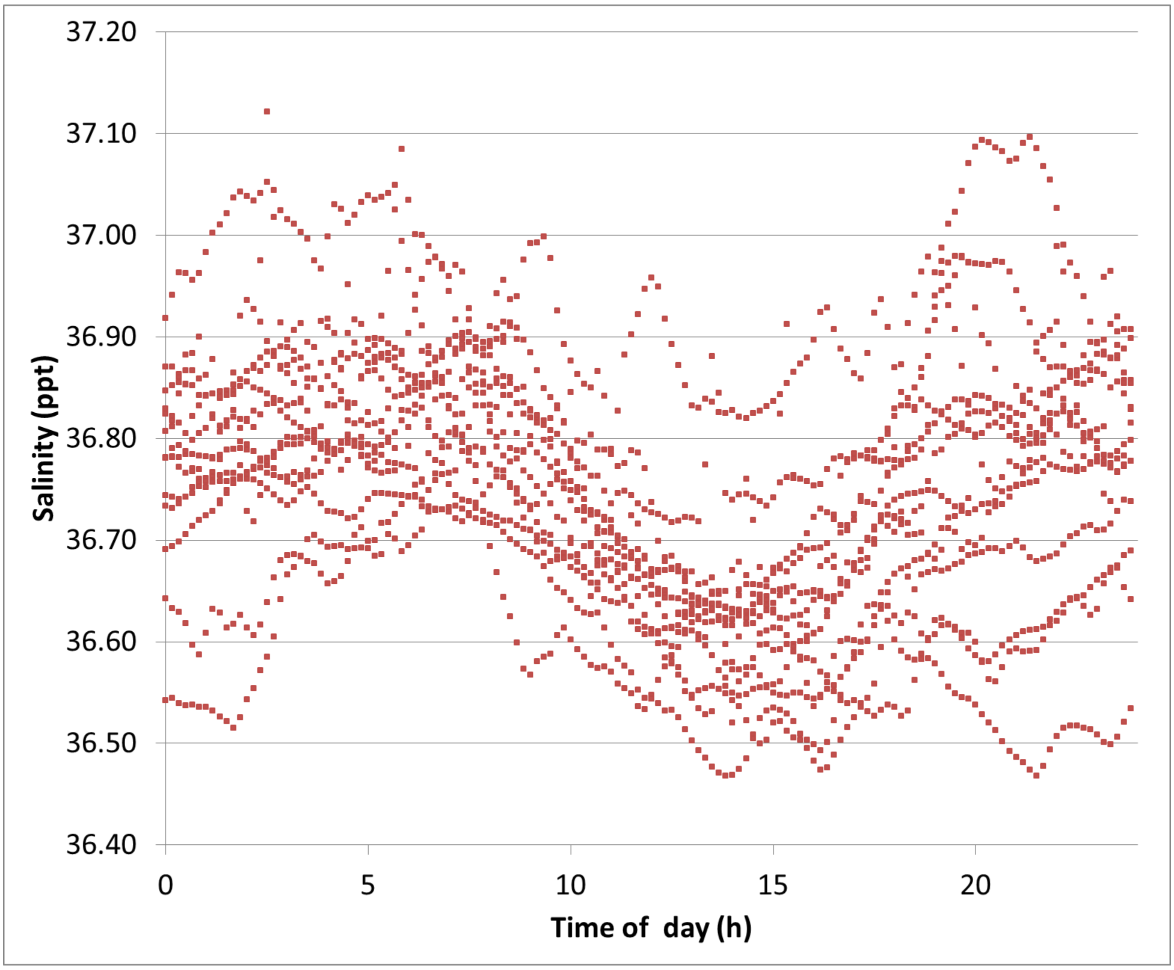

Figure 5 - Data showing salinity measured at the ambient monitoring station every 10 minutes over a 14 day period in June 2013. The horizontal axis shows time of day (0,24 = midnight). These data illustrate the short term variability in ambient salinity (driven by tidal and wind driven circulation patterns) against which the background effect of the diffused discharge is being realized.

The results from this monitoring program have provided a comprehensive dataset on ambient salinity that can be used to parameterize models (e.g. to assess effectiveness of the diffuser) and to support a broader interpretation of the impact of the plant on ambient water quality. In this respect we can see for example, that salinity at this time of year is varying by around 0.8 ppt over the course of a two week period with many of these excursions occurring within a single day. It is reasonable to assume therefore that the biota in this region have adapted to a variable salinity environment and are unlikely to be affected by changes in ambient conditions of the order realized outside the 100 m mixing zone (see also discussion related to Licence Conditions 16 & 17 and 20 & 21).

8 Seawater Characteristics - Intake every 10 Minutes

Monitoring of ambient water quality extended the data collected in Condition 7 and was intended to provide data on a broader suite of physico-chemical properties of the intake water over the period of plant construction and operation up to the end of December 2013. Data has been recorded since January 2012 which was after the early phase testing (including first water runs; Appendix A) but before the major operational testing (SP1 and SP2 full production; Appendix A).

These provide high resolution data on key water quality parameters including conductivity, temperature, pH and dissolved oxygen and thereby provide a basis for describing how ambient conditions vary over both short (10's of minutes to hours) and longer (days, weeks and months) time intervals. As with condition 7 the data can be used to describe discharge water quality (Licence Condition 11) by allowing us to assess, in quantitative terms, the extent to which the saline concentrate discharge differs from the source water moving into the plant. This in turn provides a basis for evaluating the potential for impact on ambient conditions within and beyond the mixing zone.

9 Seawater Characteristics - Analyse Weekly

This Licence Condition has provided a comprehensive set of data on intake seawater "character" which in this context means quantitative estimates of the concentrations of:

- A variety of metals (Al, Cd, Cr, Cu, Fe, Pb, Mn, Hg, Ni, Zn, both soluble and total)
- Total nitrogen (as N)
- Total phosphorus (as P) and
- Suspended solids.

In effect this Licence Condition complements Licence Condition 13 which reports on an identical set of analyses for the discharge water. Collectively these two Licence Conditions allow an assessment of whether or not the operation of the ADP results in an addition of any of the listed substances.

Currently the Licence Condition makes a simple assessment about whether or not the concentrations of the target elements/compounds exceed the water quality guidelines. Arguably this is a very conservative approach in that it could be argued that the simple act of removing water increases the concentration of a substance without necessarily increasing the actual amount of that substance. On this basis one could trigger a water quality guideline without ever actually adding to the pollution load.

It is recognized that many compounds act based not on total load but on concentration but given that the diffuser acts to rapidly dilute the concentration then a more effective approach might be to make a mass-balance assessment that compares the total load between input and output and responds in a situation where the output load has increased.

While none of the data have been analysed or reported in this manner, one could treat the data collected under this Licence Condition and marry up the records with those collected under Licence Condition 13 (by matching sample dates for the inputs and outputs). The data could then be assessed using a mass-balance approach wherein the total load of any element (e.g. Aluminium) would be expected to remain constant between the intake and outfall. This analysis would need to take account of the concentrating effect of the desalination process but, in essence, the change in concentration of the target metal would be expected to be equivalent to the change in salt concentration (which is a direct measure of water removal). The general approach would be to test whether:

Intake volume (L) x [Metal (μg/L) >= Output volume (L) x [Metal μg/L]

Alternatively one could simply make the assumption that, where there was no loss or gain of the target compound, the ratio of the target compound between input and output would be the same as the ratio of the salt concentrations between input and output. In this case the test (using Aluminium) would be whether:

$$Input_{[Al]}/Output_{[Al]} <= Input_{Salinity}/Output_{Salinity}$$

Clearly there are practical limitations to this approach in that many of these target elements/compounds are simply recorded as being below detectable limits on both the inflow and outflow. However, such cases are not materially important because, if a value is below the detectable limit on discharge then there is no need to respond to this finding. Importantly, if a value is substantially elevated (on a mass balance basis) in the effluent, then this would provide a basis for looking more closely to assess whether or not there is evidence of an extraneous input that is resulting in a discharge that is in excess of the intake quantity.

Finally, in the situation where the intake concentration was below detectable levels then one would trigger an alert if the effluent concentration was at least double the minimum detectable value.

10 Seawater Characteristics - Intake Volume

Data on intake volume should be considered in context with Licence Condition 11 (Discharge monitoring – daily volume). Collectively these two monitoring programs provide data on the operation of the plant both in terms of total production volumes (difference between input and output volumes over time is a measure of freshwater produced) but they also provide a basis for linking data on salinity of the discharge (Licence Condition 12). In broad terms the data on intake and discharge volumes can be related to the discharge salinity as follows:

$$DischargeSalinity = IntakeSalinity \times (IntakeVolume/DischargeVolume).$$

In essence the discharge salinity will increase proportionally to the amount of water removed which is given by the ratio of intake to discharge volumes.

These data provide the basis for modelling plant production and the impact that this has on discharge salinity as well as on understanding the relationship between discharge volume and changes in the ambient salinity of receiving waters.

11 Discharge Monitoring - Daily Volume

See discussion under Licence Condition 10 above.

12 Discharge Monitoring - Discharge every 10mins

See discussion under Licence Condition 8 above.

13 Discharge Characteristics - Analyse Weekly

See discussion under Licence Condition 9 above.

14 Ecotoxicity Testing

The ecotoxicity testing used selected marine organisms to determine the toxicity of the saline concentrate discharge on a whole of effluent basis. Samples collected from the desalination plant were used in a series of chronic tests with appropriate sensitivity and ecological relevance to the study area. The aim of the work was to determine, from a whole-of-effluent ecotoxicology standpoint, whether a 50:1 dilution of the saline concentrate discharged from the plant was sufficient to provide for protection of biota in receiving waters.

The ecotoxicology monitoring program used 3 test species (mussel, polychaete worm and sea urchin) to assess the toxicity of the saline concentrate discharged from the Adelaide Desalination Plant. For the mussels the test used was a 48 h larval survival test, the sea-urchin was tested via a 72 h larval survival test and the polychaete was assessed using a 14 day growth and survival test. For each test a sample of saline concentrate was subjected to a serial dilution typically comprising 0% (effectively the seawater control), 6.3%, 12.5%, 25%, 50% & 100% (the latter being equivalent to the undiluted saline concentrate) and the performance of the test organism was then assessed in each of these media. Typically the results showed a progressively increasing negative response across the concentration series. These tests were used to obtain quantitative estimates for a number of key parameters relevant to an assessment of the ecotoxicology of the discharge including:

- NOEC - No observable effect concentration - the concentration whereby the test result is no different to performance in the control (0%);
- LOEC - Lowest observable effect concentration - the lowest concentration at which there is an observable difference when compared to the control; and
- IC10 - Discharge concentration required to cause a response in 10% of the test organisms.

These parameters allowed an assessment of the performance of the ADP in the context of the dilution targets set during the design and pre-commissioning phases of the project. The key performance criteria was whether or not a dilution factor within the mixing zone of 50:1 will provide the necessary level of protection for the organisms being assessed. In particular, the assessment of the necessary level of protection is made in the context of the IC10 value for the test organisms.

The results from this series of tests demonstrate that a 50:1 dilution is more than adequate, at least for the test taxa. Indeed, the test results indicated that the required dilution ratio was actually in the order of 15-32:1 (see also Condition 20 below). It needs to be noted that this assessment built in a factor of 2, to the experimental results in order to address the broader environmental risks (associated with the discharge of a saline concentrate) and a factor of 10, to address the acute risks.

The conclusion from this monitoring is that in all cases the 50:1 dilution target was conservative (given the concentration of the saline discharge and the effectiveness of the ADP diffuser) and that if the operation of the desalination plant meets these performance criteria (i.e. achieving a 50:1 dilution within the mixing zone) this will be sufficient to mitigate the ecotoxicological risks from discharging a saline concentrate to the environment.

15 DO and pH monitoring

The objective of the DO and pH monitoring program was to ensure that DO (dissolved oxygen) and pH (measure of acidity or basicity) were not adversely impacted by the discharge of saline concentrate into receiving waters. DO is a critical measure of ecosystem health in that oxygen is essential for all life and pH is a physico-chemical property of seawater that regulates many chemical and bio-physical processes in marine ecosystems (e.g. shell formation in molluscs, the growth of calcified algae or activity of nitrifying bacteria).

DO is generally close to saturation levels in well mixed coastal waters (typically 6.5 to 9 mg/L although this varies with temperature) while pH is strongly buffered in seawater at a more or less constant level of between 8.0-8.2 pH units (Skirrow 1975) although recent anthropogenic impacts on global CO_2 levels have started to push marine pH into more acidic levels (in some cases as low as 7.4 in coastal waters).

The desalination process involves adjustment of the pH of water prior to being fed to the second reverse osmosis pass in order to improve operational performance as well as for chemical cleaning of the membranes, chlorine content and subsequently this may affect the DO of the discharge (specifically in the case of overdosing the chlorine-reducing agent). Normal plant operations include neutralization (to readjust pH and reduce all chlorine) and monitoring to ensure effluent pH and DO are returned to ambient levels. It is necessary therefore to monitor these parameters to ensure that discharge waters do not impact on ambient water quality.

The results for DO and pH monitoring were uniformly good, there was no evidence of any event when these critical water quality parameters were compromised. In all cases DO was above the critical threshold level of 6 mg/L and pH was consistently at or close to 8.1.

16 Salinity 100m

The purpose of the monitoring program was to provide high resolution data on the salinity at a series of points 100 m from the ADP diffuser. Such data provide a basis for monitoring the receiving environment and for evaluating the diffuser performance. Four CTDs were moored at 100m to the North, South, East and West (MP1-MP4) of the discharge line and provided observations of conductivity and temperature at 10 minute intervals.

These data provide a basis for evaluating the effectiveness of the diffuser in mixing the saline concentrate discharged from the ADP and ensuring that adequate levels of mixing occur within the specified mixing zone (i.e. that a 50:1 dilution is achieved within 100 m from the diffusers). This measurement links to the other key water quality parameters (Licence Condition 15: DO and pH) in that it provides a measure of the extent to which the spatial scale of the potential impact is limited to the area in the immediate vicinity of the discharge.

Results from the salinity monitoring demonstrate that the diffusers effectively mix the discharge water with surrounding water and thereby generally achieve the 50:1 dilution within the 100 m zone.

17 Salinity 200m

While the purpose of the monitoring program was to provide high resolution data on the salinity at a series of points 200 m from the ADP diffuser the data actually collected are limited in their coverage to a significant extent (Cheshire 2014q) and the requirement to collect data under this Licence Condition was removed in April 2012.

In large part this condition was linked to Licence Condition 16 (see above) in that it provided a backup to the data otherwise collected 100 m from the outfall and would have allowed an assessment of the level of mixing that was achieved within 200 m of the diffuser. In fact, the performance measured at the 100 m stations demonstrated that the required level of dilution (50:1) was being routinely achieved and therefore there was no further need for this additional set of data (at least for the purposes of risk management).

18 Currents

This Licence Condition had the objective of providing current data that could be used to support modelling and/or additional interpretation of the data collected under other Licence Conditions. In and of itself the current data have no real use in assessing the performance of the ADP as there is no meaningful impact of the ADP on current flows in the region other than in the turbulent stream in the immediate vicinity of the diffuser (see modelling results provided under Licence Condition 21).

Data were obtained using an ADCP (acoustic doppler current profiler) moored at the seabed near the ADP outfall using one of the 100m buoy sites described (MP1, MP2, MP3 or MP4). Data were collected over a period starting in January 2011 (prior to the commencement of any construction work) until February 2014 (a total of just over 3 years; Cheshire 2014r). The ADCP was used to measure current speed and direction.

19 Marine Noise

The marine noise monitoring program had the objective of assessing underwater noise over a period that included the plant operating at various rates. The assessment was based on acoustic data collected over a 5 day period from 19-Nov-2012 through to 23-Nov-2012. This period included three days when the plant was operating (at around 240-270 MLD; i.e close to full capacity), a day where operations were intermittent and a day when the plant was not operating. The results were compared to the defined assessment criteria (the SPL - Sound Pressure Levels - should not exceed 120 dB re 1 µPa).

The data were considered in relation to:

a) the number of times when the total underwater noise level exceeded the 120 dB re 1 µPa threshold value; and

b) the extent to which the underwater noise environment changed from the period the plant was operating to the period when the plant was not operating (effectively a treatment vs control comparison).

Over the 5 days where data were recorded there were 7 periods when a value >120 dB re 1 µPa was documented; none of these appeared to be related to the operation of the plant. Indeed, four of the events can be ignored as they related to the operation of the acoustic modem used to transmit the sound data that was being recorded (in essence the noise was caused by the equipment being used to transfer the noise measurement data). The remaining 3 events were not attributable to plant operations although 1 event appeared to be caused by a pump or engine (not determined). In all cases exceedances were of short duration and none exceeded an SPL of 130 dB re 1 µPa.

The underwater noise environment did not appear to change from when the plant was operating at near full capacity to when it was turned off. Although there has not been any statistical analysis of the data for these periods one can make a visual assessment of the data provided in Figure 3 of Evans (2012; Figure 6). This figure is a graph of underwater noise over time (and also shows intake and outfall volumes over the corresponding period); there are no apparent changes in the average SPL associated with whether or not the plant is operating.

The data provided cover a relatively short period of operation (one five day period). Notwithstanding, for the first 3 days, the plant was operating at near maximal capacity and it is reasonable to expect that the data obtained are representative of typical plant operations.

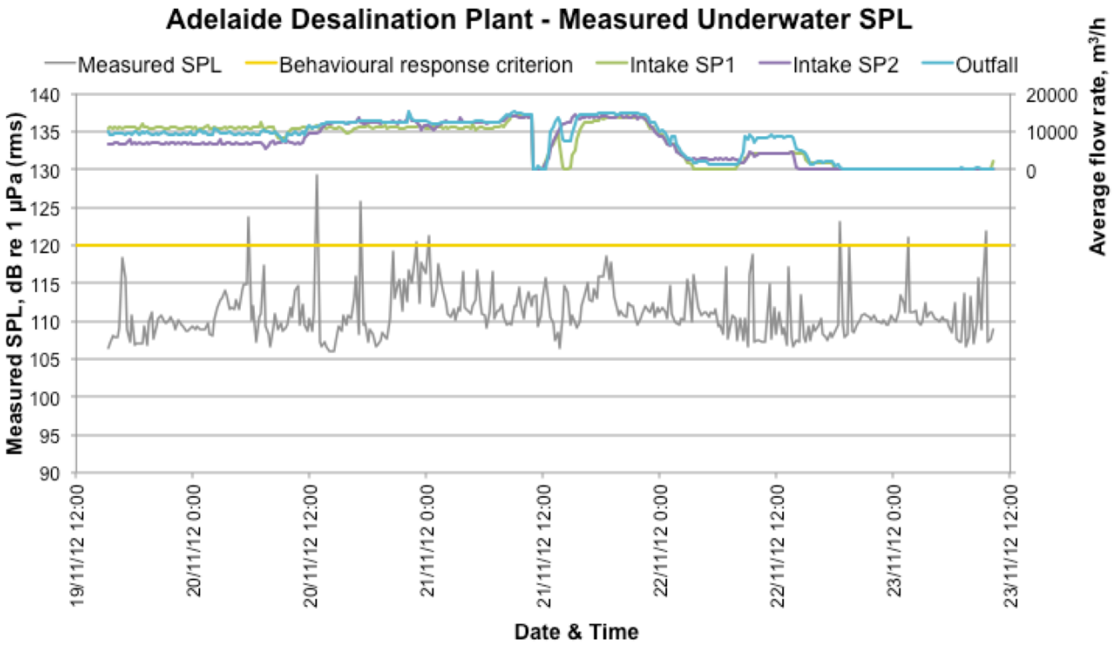

Figure 6 - Measured underwater SPL (sound pressure level) vs plant operation (defined by flow rate). Note the yellow line which represents the 130 dB re 1 µPa threshold value (after Figure 3; Evans 2012)

20 Diffuser performance validation (a)

This licence condition was designed to validate the diffuser performance when the plant was operating at 10% of full capacity (i.e. average saline discharge of around 30 MLD).

This licence condition had the aim of verifying the performance of the diffusers under real-life (*in-situ*) conditions with the plant operating at 10% of full capacity. In essence the study provided a basis for confirming one of the critical design parameters for the plant (that the diffusers could deliver a 50:1 dilution of the effluent stream under worst case operating conditions (dodge tide and low wind).

The study involved the collection of data from a series of CTD profiles that were taken vertically across the water column at selected locations along with two horizontal profiles using a towed CTD that variously sampled at different depths through the water column. The data were processed to provide a 2D contour map of seabed salinity and dilution with increasing distance from the diffusers. The study ran over 21-Oct-2011 which was a period when a dodge tide coincided with low wind conditions the “worst case scenario for ambient mixing”.

The 2D map showing dilution contours provided the basis for evaluating the performance of the diffuser and allowed conclusions to be drawn about the capacity for the diffusers to meet the operating requirements (a 50:1 dilution within 100 m) under these conditions of low ambient mixing (Figure 7).

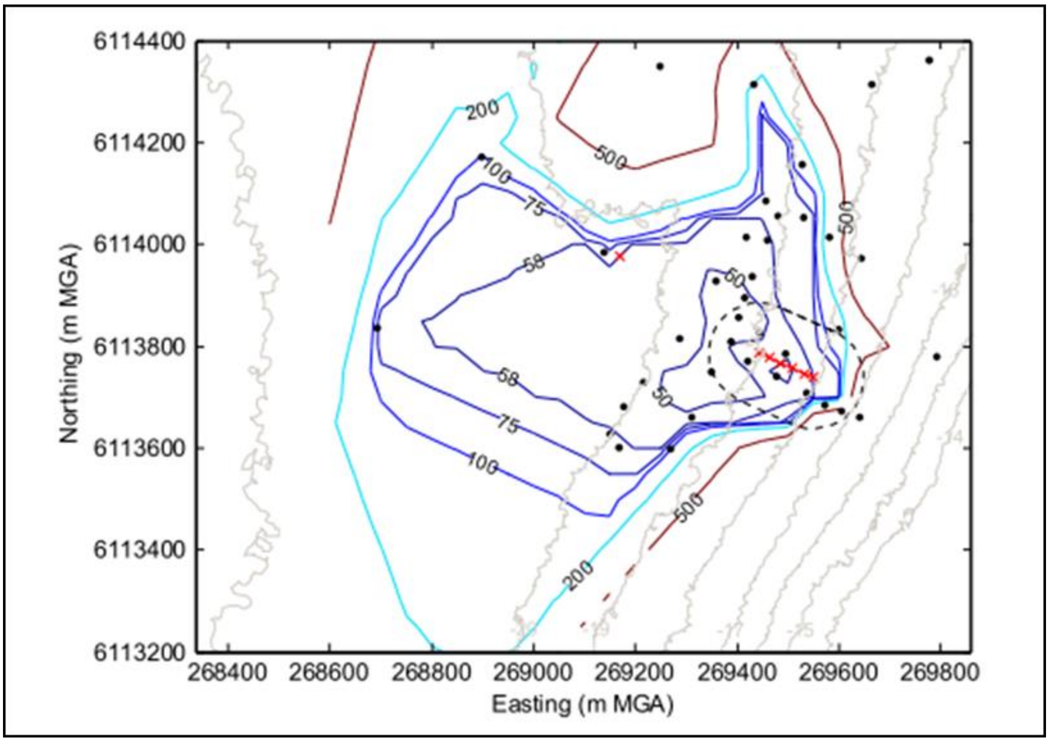

Figure 7 - Map showing dilution contours during dodge tide (after Figure 4.4 in Strickland, 2012)

The study concluded that the diffuser was generally operating consistent with the design specifications although under dodge tide conditions the 50:1 contour did extended outside of the 100 m mixing zone. Notwithstanding this result it is relevant to note that the ecotoxicology analyses argued that the requisite dilution level to provide for environmental protection was between 15:1 and 32:1 (see Condition 14 above), thus suggesting that even under adverse mixing conditions the discharge is unlikely to cause an environmental impact (Hobbs, 2013). This is particularly so given that such exposures would generally be of relatively short duration.

21 Diffuser performance validation (b)

This licence condition was designed to validate the hydrodynamic model that was used in the design of the outfall diffusers. Water Technology Pty Ltd was contracted to develop and validate the final design of the outfall diffuser for the ADP; in part this required the development of a hydrodynamic model that utilized the salinity and current data collected during the monitoring program and these data were then used to demonstrate:

- Initial dilution of the saline concentrate discharge equivalent to 50:1; and
- Rapid dispersion of the saline concentrate into the surrounding sea water.

Validation of the diffuser design was undertaken by comparing a range of hydrodynamic and salinity measurements obtained from around the outfall (when operating at 100% capacity during a dodge tide) to a modelled hindcast of the hydrodynamic and desalination plant operating conditions over the same period. The validation of the model was expected to complement (and extend) the studies reported under Licence Condition 20 which was essentially the same other than it undertook an evaluation of the plant operating at 10% capacity.

These studies evaluated a core element of the design of the outfall in that the process by which the saline enriched brine is discharged and mixed into the receiving water is critical to managing the environmental risk associated with the operation of the plant. The diffuser array causes the waste water stream to rapidly mix with surrounding waters and thereby dilutes the waste stream such that the spatial scale of the mixing zone is kept to a minimum. The level of dilution achieved is a key performance measure and importantly needs to be in the order of 50:1 within 100 m of the diffusers to ensure that any increases in salinity associated with the operation of the plant do not have a measureable impact on surrounding environments.

In an earlier phase of the work the EPA provided a critique of the original modelling report (Gubbin, 2013). This critique noted that there was a marked discrepancy between the modelled current flows in the vicinity of the diffuser when compared to the measured flows; importantly the critique noted that the hydrodynamic model under-represented the observed current velocities in the near vicinity of the diffuser. By and large the model failed to accurately estimate the velocities during a dodge tide event but more generally did not accurately reflect the amplitude of velocity changes across tidal cycles (although it did model the tidal frequency with a high degree of fidelity).

While the detail of the critique is correct it is not clear what purpose is served by the criticism and the finding does not have any real relevance to the assessment of environmental effect: importantly now that the ADP has been built and operated under a variety of weather and tidal conditions, there is a substantial quantity of empirical data on the rate of dilution of the waste stream. These data, comprise actual field measurements, and are therefore much more valuable than any model prediction[5] and allow us to conclude that dilution is rapid and occurs over a spatial scale that will achieve the level of environmental protection that is being sought.

[5] The fact that the model hindcast does not capture the observed reality is somewhat of a moot point and is largely due to the fact that the model was starved of parameterization data from the local region. The closure of the marine baseline monitoring station at Port Stanvac meant that the model needed to rely on a phase-shifted set of data from Thevanard (over 400 km away on the coast of the Great Australian Bight) for data on shelf waves and meteorological forcings. Given this the model could not be expected to deliver a result which was consistent with the observed real-time outcomes.

DISCUSSION

This report has been developed from a review of 377 documents and data files that individually related to one or other of the 21 EPA Licence Conditions (see above). Each of these documents/files was assessed in the context of the various licence conditions and the findings compiled into a series of separate reports (Cheshire 2014a-u). A synthesis of the results from these studies provides information on the environment at Port Stanvac, the management of risks associated with discharges to the marine environment and a validation of the design of the outfall diffusers.

Environmental Impact Assessment and Biota Characterisation

Licence conditions 1-5 provided a basis for characterising biota across a series of key environments including intertidal and subtidal reefs, softbottom communities as well as fish and plankton communities. The results confirmed the findings from previous studies that there is a general north-south gradient in community structure along the Adelaide Metropolitan Coast and to a large extent communities at Port Stanvac are broadly consistent with what would be expected based on its geographic location.

Overall it can be concluded:

1. There was some evidence (particularly from the intertidal reef studies) that the history of management at Port Stanvac, through the imposition of an exclusion zone since the mid 1960's, has created an environment which has been beneficial to the local ecology and this is reflected in the typically higher diversity and abundances of many invertebrate species at Port Stanvac when compared to areas both to the North and South (a 'hot-spot' in the terms of Benkendorff et al).
2. Fish communities are consistent with those found more broadly along the coast but there is evidence that some species (e.g. Port Jackson sharks) may use this as a breeding or nursery area.
3. Softbottom communities are unremarkable when compared to those elsewhere reflecting the natural character of communities in this region of Gulf St Vincent.
4. Plankton communities are largely unremarkable although some HAB species have been identified albeit in low numbers.

There was no strong evidence for adverse impacts on any of these systems from either the construction or operation of the ADP. Although both the analysis of data on reef community structure for the intertidal and subtidal reefs demonstrated significant time by treatment interactions, these were assessed as being unrelated to the ADP and/or transient in nature.

Risk management

A comprehensive set of data on plant operation and water quality has been compiled that allows an assessment of the plant impact on a variety of key indices including conductivity, temperature (salinity), dissolved oxygen, pH, trace metal and nutrient concentrations. Collectively these data provide a complete picture of both the natural variability in key water quality parameters for the Adelaide metropolitan coast (ambient and intake line measurements) as well as the manner in which these parameters change associated with the operation and discharge from the Adelaide Desalination Plant (measurements from the discharge and in the vicinity of the diffusers).

The most compelling result is that, in general, water quality is largely unaffected by the operation of the plant outside of the 100 m mixing zone and this is mainly through the rapid dilution of the saline concentrate that is achieved through the diffuser array.

There is an opportunity to refine the analysis and thereby improve the interpretation of the data that has been obtained through some of the monitoring arrangements; in particular the data from licence conditions 9 and 13 on the characteristics (trace metal and nutrient – N & P – concentrations) of water taken in and subsequently discharged from the plant. The Licence Condition required a simple assessment about whether or not the concentrations of the target elements/compounds exceeded the water quality guidelines. Arguably this was a very conservative approach in that it could be argued that the simple act of removing water increases the concentration of a substance without necessarily increasing the actual amount of that substance. On this basis one could trigger a water quality guideline without ever actually adding to the pollution load. These data could be better understood in the context of a mass-balance approach whereby the loads in both input and output were compared and discrepancies explained.

Design validation

The series of studies targeted to validating the design of the diffuser have focused on both typical operating conditions but also, and arguably more importantly, on the effectiveness of the diffuser during dodge tide and low wind conditions which are the most adverse for mixing and dilution of the discharge.

The results show that mixing of the saline concentrate on discharge is generally sufficiently rapid to achieve a 50:1 dilution within 100 m of the outfall. While this result was not always achieved (e.g. under conditions of a dodge tide with low wind driven mixing) such periods are of limited duration and irrespective meet with the requisite dilution levels indicated by the ecotoxicology data which suggested that environmental protection should be achieved with a minimum dilution of between 15:1 and 32:1.

There are three issues that need to be considered in this context:

1. Periods of poor mixing resulting from a combination of dodge tides with low wind or other mixing occur very infrequently; but
2. When such events do occur the level of mixing is still above the 15-32:1 level indicated by the ecotoxicology studies; and
3. The biota in SA Gulfs is already adapted to a naturally variable salinity although this exposure is generally realized over time frames of weeks to months rather than days.

On balance therefore, the mixing on discharge is expected to provide the level of environmental protection being sought from the design criteria. Having said this, there may be an argument for a greater level of caution in plant operation when dodge tides coincide with periods of low wind, particularly during late summer when salinities are already elevated due to evaporation (noting that any discharge will add to whatever salinity values occur naturally).

CONCLUSIONS

The environmental monitoring that has been undertaken to support the design and operation of the Adelaide Desalination Plant is comprehensive in terms of ecosystems covered (benthic infauna, reefs, plankton communities through to fish), physico-chemical parameters assessed (salinity, pH, temperature, dissolved oxygen, chlorine, metals and inorganic nutrients) and physical processes (tidal and wind induced flow and mixing). This provides a strong basis for both an analysis of and conclusions about the likely environmental and ecosystem effects associated with the construction, testing and early phase operation of the plant. On balance there is no evidence of an environmental impact and while there was some evidence of minor and transient perturbations in ecosystem structure and function these cannot be attributed to the construction or operation of the plant. In essence, the process represents an excellent example of a risk based approach to environmental protection and management and provides a model that could (and arguably should) be emulated in respect of other developments across the State.

REFERENCES

Ayala, V. (2013) Adelaide Desalination Project EN-MP-08-A2 Marine Monitoring Protocols. Published by AdelaideAqua Pty Ltd pp 37.

Anderson, L. et al. (2008) PERMANOVA+ for PRIMER: Guide to Software and Statistical Methods.

Cheshire, A.C. (2014a). Review of intertidal reef monitoring licence conditions for the Adelaide Desalination Plant, June 2014. Report 1 in a series prepared for AdelaideAqua Pty Ltd by Science to Manage Uncertainty pp: 8.

Cheshire, A.C. (2014b). Review of subtidal reef monitoring licence conditions for the Adelaide Desalination Plant, June 2014. Report 2 in a series prepared for AdelaideAqua Pty Ltd by Science to Manage Uncertainty pp: 9.

Cheshire, A.C. (2014c). Review of baited underwater video monitoring licence conditions for the Adelaide Desalination Plant, June 2014. Report 3 in a series prepared for AdelaideAqua Pty Ltd by Science to Manage Uncertainty pp: 8.

Cheshire, A.C. (2014d). Review of infauna monitoring licence conditions for the Adelaide Desalination Plant, June 2014. Report 4 in a series prepared for AdelaideAqua Pty Ltd by Science to Manage Uncertainty pp: 10.

Cheshire, A.C. (2014e). Review of plankton monitoring licence conditions for the Adelaide Desalination Plant, June 2014. Report 5 in a series prepared for AdelaideAqua Pty Ltd by Science to Manage Uncertainty pp: 10.

Cheshire, A.C. (2014f). Review of water quality profile monitoring licence conditions for the Adelaide Desalination Plant, June 2014. Report 6 in a series prepared for AdelaideAqua Pty Ltd by Science to Manage Uncertainty pp: 12.

Cheshire, A.C. (2014g). Review of seawater characteristic - ambient salinity monitoring licence conditions for the Adelaide Desalination Plant, June 2014. Report 7 in a series prepared for AdelaideAqua Pty Ltd by Science to Manage Uncertainty pp: 15.

Cheshire, A.C. (2014h). Review of seawater character - intake every 10 minutes monitoring licence conditions for the Adelaide Desalination Plant, June 2014. Report 8 in a series prepared for AdelaideAqua Pty Ltd by Science to Manage Uncertainty pp: 11.

Cheshire, A.C. (2014i). Review of intake seawater character - analyse weekly monitoring licence conditions for the Adelaide Desalination Plant, June 2014. Report 9 in a series prepared for AdelaideAqua Pty Ltd by Science to Manage Uncertainty pp: 13.

Cheshire, A.C. (2014j). Review of seawater character - intake volume monitoring licence conditions for the Adelaide Desalination Plant, June 2014. Report 10 in a series prepared for AdelaideAqua Pty Ltd by Science to Manage Uncertainty pp: 10.

Cheshire, A.C. (2014k). Review of daily discharge volume monitoring licence conditions for the Adelaide Desalination Plant, June 2014. Report 11 in a series prepared for AdelaideAqua Pty Ltd by Science to Manage Uncertainty pp: 11.

Cheshire, A.C. (2014l). Review of discharge characteristics – physical properties (every 10mins) monitoring licence conditions for the Adelaide Desalination Plant, June 2014. Report 12 in a series prepared for AdelaideAqua Pty Ltd by Science to Manage Uncertainty pp: 17.

Cheshire, A.C. (2014m). Review of discharge character (metals, N, P and suspended solids) - analysed weekly monitoring licence conditions for the Adelaide Desalination Plant, June 2014. Report 13 in a series prepared for AdelaideAqua Pty Ltd by Science to Manage Uncertainty pp: 13.

Cheshire, A.C. (2014n). Review of ecotoxicity testing licence conditions for the Adelaide Desalination Plant, June 2014. Report 14 in a series prepared for AdelaideAqua Pty Ltd by Science to Manage Uncertainty pp: 8.

Cheshire, A.C. (2014o). Review of DO and pH monitoring licence conditions for the Adelaide Desalination Plant, June 2014. Report 15 in a series prepared for AdelaideAqua Pty Ltd by Science to Manage Uncertainty pp: 10.

Cheshire, A.C. (2014p). Review of salinity 100m monitoring licence conditions for the Adelaide Desalination Plant, June 2014. Report 16 in a series prepared for AdelaideAqua Pty Ltd by Science to Manage Uncertainty pp: 11.

Cheshire, A.C. (2014q). Review of salinity 200m monitoring licence conditions for the Adelaide Desalination Plant, June 2014. Report 17 in a series prepared for AdelaideAqua Pty Ltd by Science to Manage Uncertainty pp: 9.

Cheshire, A.C. (2014r). Review of ADCP (currents) monitoring licence conditions for the Adelaide Desalination Plant, June 2014. Report 18 in a series prepared for AdelaideAqua Pty Ltd by Science to Manage Uncertainty pp: 10.

Cheshire, A.C. (2014s). Review of marine noise monitoring licence conditions for the Adelaide Desalination Plant, June 2014. Report 19 in a series prepared for AdelaideAqua Pty Ltd by Science to Manage Uncertainty pp: 8.

Cheshire, A.C. (2014t). Review of diffuser performance validation (a) monitoring licence conditions for the Adelaide Desalination Plant, June 2014. Report 20 in a series prepared for AdelaideAqua Pty Ltd by Science to Manage Uncertainty pp: 6.

Cheshire, A.C. (2014u). Review of diffuser performance validation (b) monitoring licence conditions for the Adelaide Desalination Plant, June 2014. Report 21 in a series prepared for AdelaideAqua Pty Ltd by Science to Manage Uncertainty pp: 8.

Cheshire, A. C., D. J. Miller, and R. Stewart. 1999. Effect of dispersed sediment plumes from beach sand replenishment dredging on recruitment of phaeophycean algae to rocky reefs in Gulf St. Vincent, South Australia. A report to the Environmental Protection

Authority of South Australia, published by the Department of Environmental Biology, University of Adelaide.

Connell, S. D., B. D. Russell, D. J. Turner, S. A. Shepherd, T. Kildea, D. J. Miller, L. Airoldi, and A. Cheshire. (2008). Recovering a lost baseline: missing kelp forests from a metropolitan coast. Marine Ecology Progress Series 360:63-72.

Evans, T. (2012). Adelaide Desalination Plant Operational Underwater Noise Monitoring. Resonate Acoustics.

Gubbin, T., (2013). Adelaide Desalination Plant Outfall Modelling Validation Report Review. Letter to AAPL from the Operations Division, Environment Protection Authority.

Hobbs, D. (2013). Interpretation of Adelaide Desalination Plant ecotoxicity reports. Letter and accompanying analysis to AAPL from Hydrobiology.

Loo, M.G.K., Mantilla, L. and Moody, I. (2014). Adelaide Desalination Project Infauna Survey June 2012 and February 2013 Final Report.. South Australian Research and Development Institute (Aquatic Sciences), Adelaide.. Note: SARDI Publication No. F2014/000214-1. SARDI Research Report Series No. 764. 95pp.Ramsdale, T. (2014) Supplementary analysis of intertidal survey data for the Adelaide Desalination Plant. Flinders University of South Australia. Pp 6.

McDowell, L-M. and Pfennig, P. (2013). Adelaide Coastal Water Quality Improvement Plan (ACWQIP). A plan that covers the issues, challenges and a way forward for water quality improvement for Adelaide’s coastal waters. Published by: Water Quality Branch, SA Environment Protection Authority.

Skirrow, G. (1975). The dissolved gases – carbon dioxide. In: Riley J.P. and Skirrow, G. (eds) Chemical oceanography. Academic Press, New York.

Stewart T.D.C. & Dittmann, S. (2012) Adelaide Desalination Plant Intertidal Monitoring Summer 2012, Flinders University, Adelaide

Strickland, D. (2012). Adelaide Desalination Plant Discharge Dispersion - Final Report. Published by Cardno (NSW/ACT) Pty Ltd. Pp 31.

Underwood, A.W. (1984) On beyond BACI: sampling designs that might reliably detect environmental disturbances. Ecological Applications 4:3-1

van Ruth, P., (2012). Adelaide Desalination Project Plankton Characterisation Study - Phase 2. South Australian Research and Development Institute (Aquatic Sciences).

Ward, T., Burch, P. and Ivey, A.R. (2012) South Australian Sardine (Sardinops sagax) Fishery: Stock Assessment Report 2012. SARDI Publication No. F2007/000765-4. SARDI Research Report Series No. 667. Pp. 101.

Ward, T. and Stauton-Smith, J. (2002) Comparison of the spawning patterns and fisheries biology of the sardine, *Sardinops sagax*, in temperate South Australia and sub-tropical southern Queensland. Fisheries Research 56: 37-49.

Appendix A KEY DATES IN PLANT CONSTRUCTION AND OPERATION

The following provides a list of key dates in the construction and operation of the plant. This material provides background to the review and in particular places the analysis and interpretation of each of the monitoring reports into context with the activities that were occurring on-site in the period leading up to the monitoring event.

Date	Activity
01-Feb-2009	Construction activities commenced
16-Nov-2009	Maritime platform arrived on site
08-Jul-2010	Maritime platform completed operations
01-Jun-2011	First discharge and first intake of seawater
14-Oct-2011	First Water – plant production was (30 MLD)
21-Mar-2012	SP1 – Full production from first half the plant (150 MLD)
31-May-2012	SP2 – Full production from second half of the plant (150 MLD)
24-Oct-2012	Performance test – plant running at full production for 7 days (150 MLD)
07-Nov-2012	Performance test – plant running at full production for 7 days (150 MLD)
21-Nov-2012	Reliability test – continuous running at various production rates
12-Dec-2012	Plant handover from commissioning