Annual monitoring summary

Onkaparinga Estuary

12 June 2013

Prepared for: Adelaide & Mt Lofty Ranges Natural Resources Management Board

Government of South Australia
Adelaide and Mount Lofty Ranges
Natural Resources Management Board

Consultant: Peri Coleman

Delta Environmental Consulting

12 Beach Road, St Kilda SA 5110

Telephone: 08 8280 5910

Facsimile: 08 8280 5179

Email:consulting@deltaenvironmental.com.au

Website: www.deltaenvironmental.com.au

LIMITATIONS STATEMENT

The sole purpose of this report and the associated services performed by Delta Environmental Consulting is to provide a summary of annual monitoring at the Onkaparinga Estuary in accordance with the scope of services set out in the contract between Delta Environmental Consulting ('Delta') and AMLNRMB ('the Client'). That scope of services was defined by the requests of the Client, by the time and budgetary constraints imposed by the Client, and by the availability of access to the site.

Delta derived the data in this report primarily from visual inspections, examination of records in the public domain and interviews with individuals with information about the site. The passage of time, manifestation of latent conditions or impacts of future events may require further exploration at the site and subsequent data, analysis and a re-evaluation of the findings, observations and conclusions expressed in this report.

In preparing this report, Delta has relied upon and presumed accurate certain information (or the absence thereof) relative to the site, provided by government officials and authorities, the Client and others identified herein. Except as otherwise stated in the report, Delta has not attempted to verify the accuracy or completeness of any such information.

The findings, observations and conclusions expressed by Delta in this report are not, and should not be considered, an opinion concerning environmental or operational liability. No warranty or guarantee, whether express or implied, is made with respect to the data reported or to the findings, observations and conclusions expressed in this report. Further, such data, findings, observations and conclusions are based solely upon site conditions and information in existence at the time of the investigation.

This report has been prepared on behalf of and for the exclusive use of the Client, and is subject to and issued in connection with the provisions of the agreement between Delta and the Client. Delta accepts no liability or responsibility whatsoever for or in respect of any use of or reliance upon this report by any third party.

Document history

Initial (internal) review: 12/06/2013 (PC)

First draft issued for review: 12/06/2013 (PC)

Final version released:

GLOSSARY

benthic growing on the bed of a river, lake or sea

dip sample: a single scoop of water

eutrophic: an environment with high availability of nutrients

indigenous: native to Australia or more locally (eg indigenous to Mt Lofty Ranges)

isohaline: contours of equal salinity

MSL: mean sea level

native: as for indigenous - native to Australia

morphogroup: amalgamated groups of related organisms at various taxonomic resolutions

oligotrophic: an environment with low availability of nutrients

periphytic microalgae such as diatoms that grow attached to the surface of submerged items

practical quantation limit: lowest concentration for reliable analysis

spring tide: tides that occur after the new & full moons

storm tide or storm surge: additional water level resulting from meteorological conditions

stratification: layers (of salinity or temperature) in a water body

weed: a plant out of place (may apply to indigenous & endemic plants as well as exotics)

Contents

Tables

Figures

1. Executive Summary

This current program of water quality monitoring in the estuary commended in July 2008. Continued data collection in the estuary of the Onkaparinga over the past five years has resulted in a database of information that may be used to robustly characterise the estuary.

The quantity of environmental flows released to the river this year were sufficient to establish a positive salinity gradient along the estuary for a period of more than nine months, instead of the generally inverse gradient that had become a feature of the estuary over the last decades.

Characteristic reduction in pH (typical in the majority of estuaries) along the river from the mouth to the head of the estuary occurs in the Onkaparinga. The range in pH has narrowed and the data have displayed reduced variability since the implementation of the environmental flows trial.

The dissolved oxygen data displays a typical temporal trend of higher oxygen concentrations in winter and lower concentrations in summer. Dissolved oxygen concentrations in some locations fell below 4mg/L (the level required for fish health) on several occasions in the Summer of 2012-13. Despite those events, the dissolved oxygen concentrations this year were generally more stable and varied over a narrower range than in previous years. This is likely a result of the addition of freshwater flows, as freshwater can hold a greater concentration of oxygen than saline water.

Discharge of high turbidity water to create a small near shore turbidity plume is likely to have happened occasionally over the period from October 2012 to the present, as there have been occasional periods of heavy rain, particularly this Autumn, and additional freshwater flows from the environmental flows trial. Despite the latter, the overall averages for turbidity in the estuary have fallen over this year.

Measurement of ammonium recommenced in October 2012. Once the environmental flows trials started in April 2013 the ammonium concentrations in the river became undetectable.

Microbiologically the overall estuary continues to have relatively poor water quality. The average summertime *E. coli* counts at Sites 2, 5, 7 and 10 exceed the EPA's Environment Protection (Water Quality) Policy upper limit of 150 cells/100mL for *E.coli*.

Plankton counts were incorporated in the main monitoring program in October 2012, and the data added to that collected over a ten month period in 2010. The water near the mouth of the estuary has consistently low plankton counts. Other sites have been more variable. The extended dry season that ran into late summer and early autumn of 2013 was associated with high numbers of dinoflagellates (*Prorocentrum micans* and *Prorocentrum minimum*) which reached bloom proportions at Site 10 (Market Square at Old Noarlunga). Since the start of the second year of environmental flows (April 2013), the bloom has dissipated seaward.

A study of periphytic diatoms in the river (Coleman 2012), conducted in the first Springtime of the environmental flows trial, in October 2012, found similar findings in regard to abundance and assemblage distributions as an earlier study (Thomas 1978). The earlier study had been conducted at a time when flows in the river were not as restricted as they have been for the past decade. Productivity (as revealed by abundance data) was highest in the fresher sites in the estuary.

A trial of “generic diatom indices” (a metric that measures the relative abundance of genera of diatoms that are sensitive to specific aspects of the environment) suggests this techniques has potential to be a useful tool for bioassessment of estuarine and other saline water bodies. The indices were readily able to separate out sites where organic loading to the waterway was high, where dissolved oxygen is often low and to detect the pH gradient that exists along the estuary.

Saltmarsh Transect 2 was revisited this year and a new location surveyed for Transect 3, which had been impacted by the Seaford rail extension. The results of all transect recordings have been provided separately as each was undertaken, but they are also attached to this report in the appendices. Copies of the surveys were also supplied to DEWNR this year as input into their Marine Parks monitoring program.

Adelaide & Mount Lofty Ranges NRM Board implemented an eradication program to remove planted, and then naturalising, *Avicennia marina* from the estuary (Cook and Coleman 2010) and the success of this action was confirmed by a full inspection of the riverbank, conducted by kayak on 26 May 2013.

The development of educational signage, to be placed where watercraft enter the river (the Canoe Club at Saltfleet Bridge, Perry’s Bend car park and Market Square) may prevent further intentional introductions.

The field data sheets for each monitoring run contain a wealth of information on fauna and recreational uses of the estuary. All field sheets for the entirety of the monitoring period (five years) have been provided to the AMLR NRM Board as electronic files and also archived by the consultants. They are available should more detailed analysis ever be required.

Several recommendations are detailed in the Section 4 of the report:

- **Continue with the environmental flows trial:** There have been clear changes in the chemical and physical water quality parameters measured in the estuary since environmental flows were implemented. Biological benefits that are likely the result of the increased flows have been observed in plankton, benthic diatoms, fish spawning, and vegetation colonisation.

- **Monitoring shallow groundwater nutrient contributions:** With the increased hydraulic head that the new Noarlunga Downs stormwater treatment wetlands will apply to the ammonia-rich substrate of SA Water's decommissioned Christies Beach Sludge Drying Lagoon, it is recommended that monitoring of bores between the wetlands and the river be reinstated, using micro purge methods to determine the discharge rates and longevity of the ammonia concentrations under lying the new wetlands.

- **Involvement of Friends of Onkaparinga Park:** The local community may appreciate an information session that presents an update of the monitoring program, as it has been several years since the results of this monitoring program were last reported to the local community.

- **Target coliform hotspots:** As in previous reports it is recommended that the source of coliforms within the river be identified. Once identified, actions to reduce human health risks can be developed. We recommend that SA Water, the EPA and the Onkaparinga Council continue their efforts to identify any unsewered houses in the Old Noarlunga area.

- **Mangrove education:** The AMLR NRM Board has completed a mangrove removal program. Developing educational signage, to be placed where watercraft enter the river (the Canoe Club at Saltfleet Bridge, Perry's Bend car park and Market Square at Old Noarlunga) may prevent further intentional introductions.

2. Introduction

The *Onkaparinga Estuary Rehabilitation Action Plan* (Hydro Tasmania Consulting and Eco Management Services 2006) recommended the design and implementation of an estuarine monitoring program. In response to this recommendation the Adelaide & Mount Lofty Ranges NRM Board contracted Delta Environmental Consulting to review extant estuarine monitoring, undertake a gap analysis and recommend a monitoring regime. The *Onkaparinga Estuary Monitoring Program* (Cook and Coleman 2007) was consequently developed and is being implemented currently.

Delta undertakes fortnightly monitoring of the Onkaparinga Estuary as specified in the monitoring program. During the five years of monitoring, additional monitoring has been undertaken for a short period under the auspices of the Department of Transport, Energy and Infrastructure (DTEI). Additionally, some specific “topical” monitoring of bacterial concentrations, mangrove extent and diatom distribution has been undertaken to address management aspects of the estuary.

Attribute	Fortnightly	Seasonal
Sample site observations	X	
Water temperature	X	
pH	X	
Turbidity	X	
Water salinity	X	
Dissolved oxygen	X	
Plankton counts (Sites 1, 2, 5, 7, 9, 10, 11, 12 only)	X	
Ammonia (NH_4-N) (Sites 1, 2, 5, 7, 9, 10, 11, 12 only)	X	
Total coliforms & *E. coli*		X (fortnightly at locations 2, 5, 7 & 10, during summer each year)
Benthic diatoms		X (one study in 2012, using periphytometers over a fortnight, in springtime at several locations along the estuary)
Saltmarsh transects		X (one of three pegged transects is monitored annually, in rotation)

Table 1 - Parameters and frequency

Results of the monitoring program have been provided to the NRM Board fortnightly through the program. Quality assured data has been provided that allows assessment of the following;

- Seasonal water quality characteristics,
- Impact of environmental flow releases on the estuary's health, and
- Water quality issues during the summer recreational period.

The locations of NRM sampling, aspects being monitored by NRM and the monitoring frequency are shown in Table 1 and Figure 1.

Figure 1 - Sampling locations

Sites 1, 2, 5, 7, 9, 10, 11 and 12 are in the main body of the river and contain water at all times and have been sampled at every visit. Sites 3 (discharge from saltmarsh into river), 4 (saltmarsh in off-stream oxbow of river), 6 (discharge from stormwater treatment wetland) and 8 (discharge from stormwater treatment wetland) contain water ephemerally and have been sampled when there has been sufficient water.

During May 2013, construction of the new Noarlunga Downs stormwater treatment wetlands advanced sufficiently that the discharge area at Site 6 was decommissioned and all water in that wetland was rerouted into the new wetlands. A new discharge location may become available once the wetlands are completed, but currently there is no access to the site.

Monitoring data is posted on the Adelaide & Mt Lofty Ranges NRM Board website. The aim of this summary report is to review the data obtained over the entirety of the monitoring program (5 years).

3. Results of monitoring

3.1 Overview

Over the monitoring period (January 2008 – current), data collection has enabled Delta staff to characterise the estuary with a degree of reliability. By June 2013, one hundred and forty-eight monitoring runs had been undertaken.

Parameter	Samples	Average	± 2 SD (95%)
pH	1321	7.98	7.26 - 8.71
Dissolved oxygen (mg/L)	1258	7.10	2.52 – 11.67
Temperature (^{o}C)	1330	18.0	9.7 – 26.4
Electrical Conductivity (mS/cm^2)	1327	43.5	6.7 – 80.3
Turbidity (NTU)	1286	18	0 – 85
Ammonia (NH_4-N)	471	0.04	0 – 0.21
Total plankton (cells per mL)	488	6705	0 – 51,406
Total coliforms (cells per 100mL) Summer months only.	316	1582	0 - 7698
E. coli (cells per 100mL) Summer months only.	316	341	0 – 1355

Table 2 - Whole of estuary water quality characterisation

The following sections provide detailed discussion of the results from monitoring the Onkaparinga estuary. Graphs for each applicable parameter are provided in the appendices, and should be viewed in conjunction with the text.

3.1.1 Sampling adequacy

To provide an adequate data set for each site, at least eighty independent samples are required, to cover the majority of environmental variables within an estuary (summer, winter, high tide, low tide, wet year, dry year etc). The one hundred and forty-eight sampling events that have occurred allow for robust analysis of most parameters, in the riverine sampling sites, on a site by site basis as well as providing data to be amalgamated into estuary-wide averages.

The parameters of riverine ammonium and plankton were not sampled continuously prior to the last 18 months and these two parameters have only been sampled on 59 and 61 events respectively. As sampling of these parameters occurred both before and after the implementation of environmental flows to the river (a significant change in management), the site by site data is not yet fully representative, although the estuary-wide averages are robust.

The unpredictable nature of stormwater sampling makes capturing samples difficult in a fixed time-increment sampling program. As a result of recommendations in the 2011 report on this monitoring program, the NRM Board removed the stormwater sampling component of the program. Stormwater data that was collected up until June 2011 is, however, available in the dataset for the monitoring program and is also presented in *Appendix 6.1*.

3.2 Estuarine physico-chemical parameters

3.2.1 Salinity

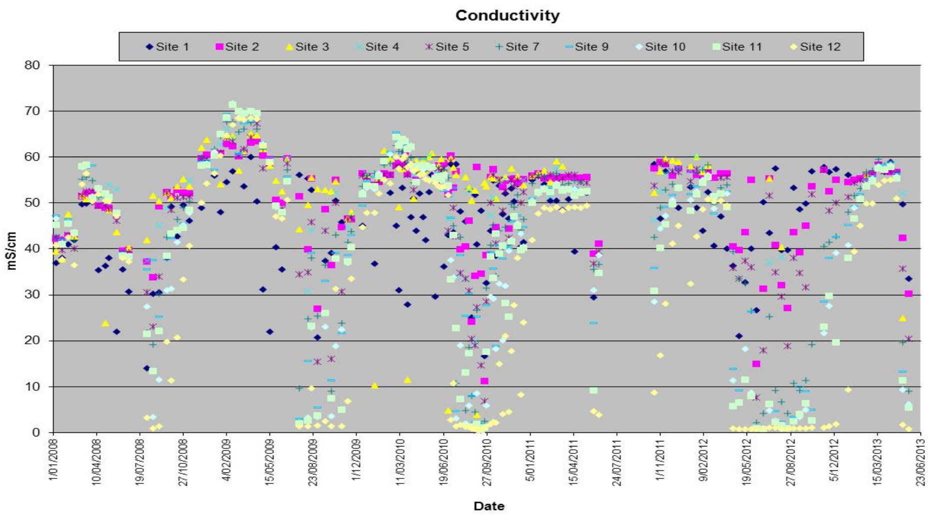
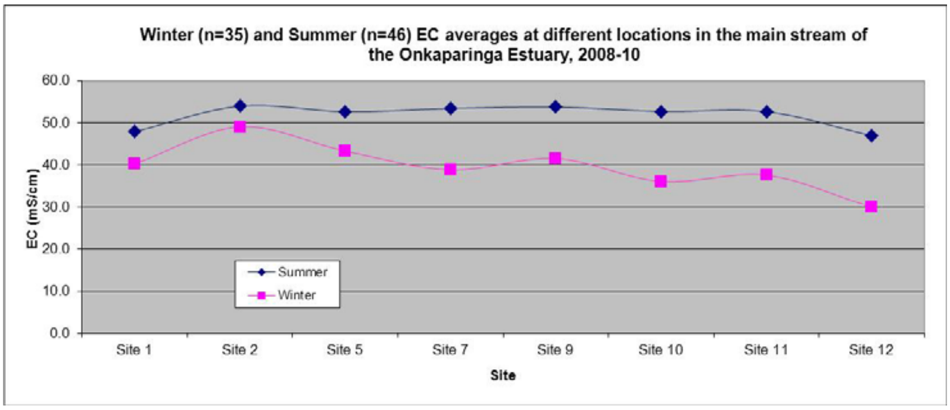


Figure 2 - Individual site salinity readings

As reported in earlier annual reports, the most significant change to water quality in the estuary since settlement has been the increased impoundment and diversion of water from the catchment. Environmental flows were reported to have reached lower than 25% of the pre-European flows in the Onkaparinga River, and at most times (92%) in recent decades no freshwater flow at all has been observed directly below Clarendon Weir (DEH 2005).

The result of this reduction in flows had been the "inverting" of the salinity gradient in the estuary. Salinities upstream were actually higher than salinities at the river mouth for much of each year. In 2012 the Adelaide and Mount Lofty Ranges NRM Board instituted a program of environmental flows in the river. One of the benefits was hoped to be a return to a more typical estuarine salinity gradient.

The raw readings for the entire five years of monitoring, shown in Figure 2, reveal the low salinity period experienced last winter (2012) extended for a longer period of time than the low salinity periods of 2008-2011. Looking at the data more closely, a distinct change in the salinity gradient along the estuary can be seen since the introduction of the environmental flows (Figure 3). This held true even with the extremely long dry summer experienced through 2012-13.



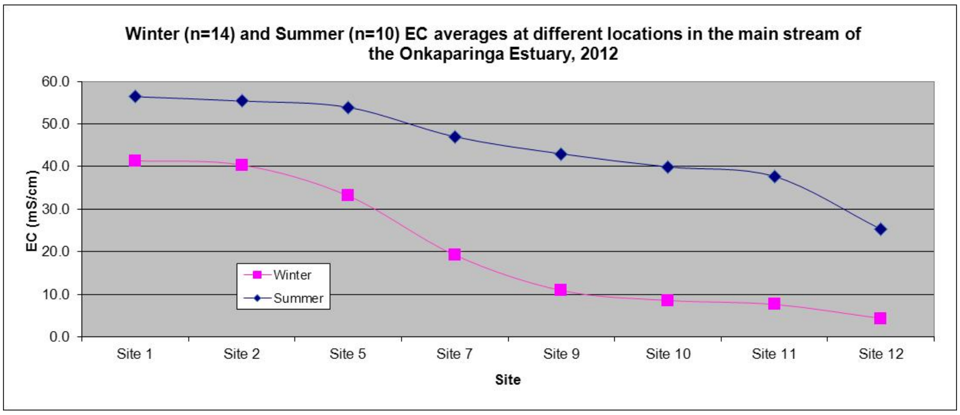


Figure 3 - Salinity gradients, prior to and post environmental flows

Prior to the environmental flow releases, only Site 12 (the Swing Bridge at Old Noarlunga) had salinity averaging below that of seawater (Site 1) during summer. Even in winter three of the inland sites averaged a higher salinity than seawater. Since the environmental flows no site has averaged in excess of seawater salinity, as measured at Site 1.

As an aside, the post-environmental flows only include one year of data, and that year was unusual in that the summer Gulf seawater salinities were extremely high (compare the summer Site 1 averages in the upper and lower graphs of Figure 3). This was a result of an extremely long dry summer. With negligible rainfall the evaporation from the Gulf, a semi-enclosed water body, was sufficient to raise salinities significantly. More saline water hold heat well, and holds oxygen poorly, and so conditions in the entire Gulf would have been challenging by the end of February and beginning of March. Despite this, the newly established "positive" salinity gradient in the estuary was maintained well into January.

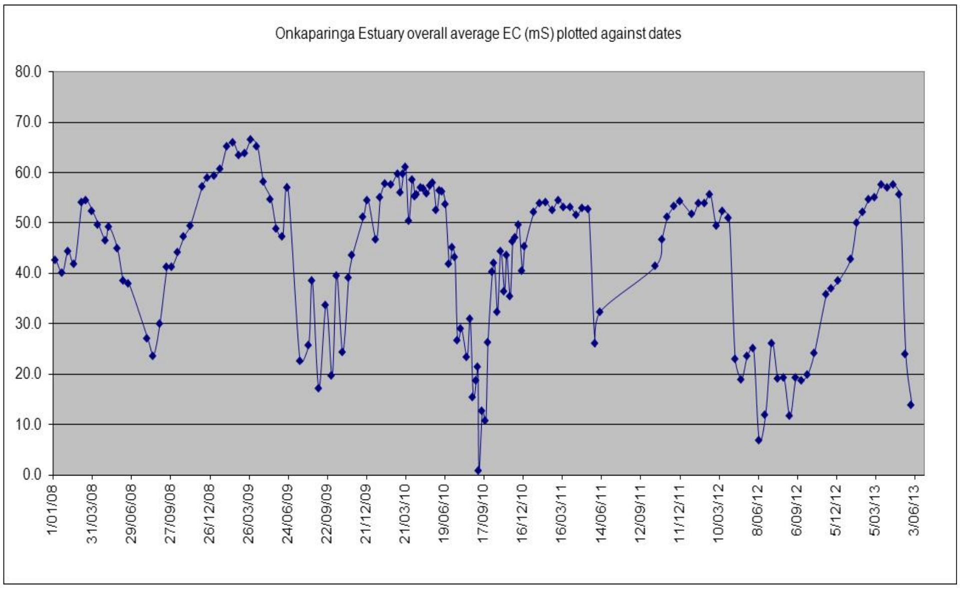


Figure 4 - Spatially averaged salinity

Across the estuary, the spatially averaged salinity (Figure 4) clearly illustrates the extended period of lower salinity over the winter of 2012. In a "typical" positive estuary (which the Onkaparinga was, historically) one may expect the spatially averaged electrical conductivity to vary between one and two thirds that of seawater for much of the year. This was the case from early April 2012 up until mid-January 2013.

There were concerns that areas of the river that had been dredged in the past were functioning as "bath-tubs" with deeper pools of water rarely flushing and containing a stratified deeper, hypersaline layer of water. Once the environmental flows were implemented, a data logging water quality meter was used fortnightly to measure salinity in a vertical profile at one of the deeper parts of the river (the Patapinda Bridge). The deeper layer of hypersaline water at that location dispersed within 6 weeks of the extra flows becoming available.

A data logger attached to a kayak was towed upstream and then downstream on 26 May 2013, a few weeks after the first environmental flows for 2013 were released. The upstream logging took place as the tide dropped to a very low point, during a Spring tide. After the kayak reached shallow water in the Horseshoe Bend between Patapinda Bridge and Paringa Parade, it reversed its course. During the journey downstream a very large incoming tide was encountered.

The trace of the data logger (Figure 5) shows the effects of the environmental flow release, with a generally falling salinity between the mouth of the river and Horseshoe Bend. The deep pool that was dredged in the past in the river at Old Noarlunga (between South Road Bridge and Patapinda Bridge) shows as a spike in the salinity data. Because the logging took place during a very low tide the stratified layer of more saline water in the lower part of the water column was detected and can be seen as a "spike" in the data on either side of the "turnaround" point. The strong incoming tide mixes unevenly into the river water, as can be seen by the large spikes in salinity recorded during the downstream logging run.

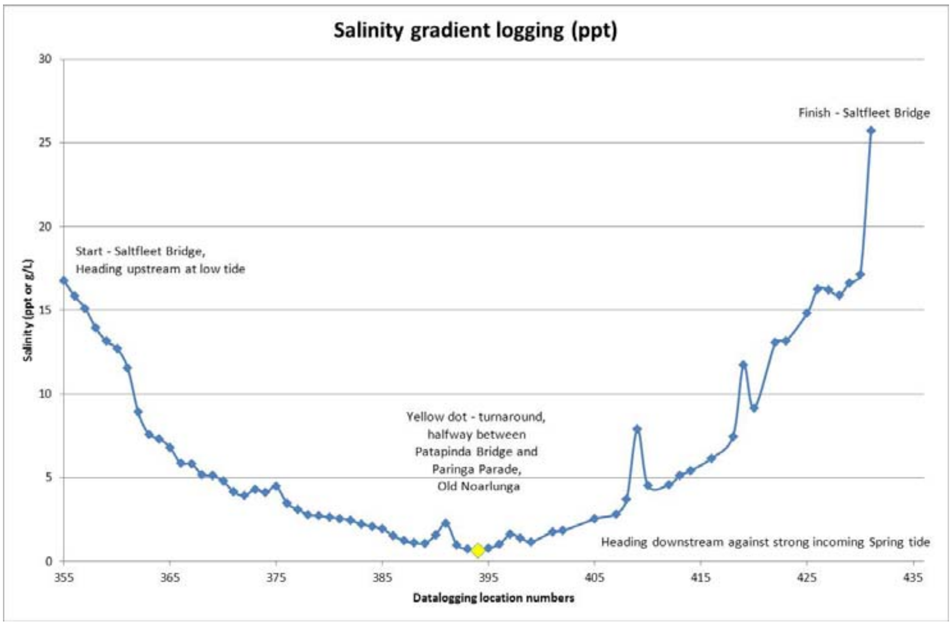


Figure 5 - Salinity data logging

3.2.2 pH

Estuarine pH usually varies downwards from the mouth towards the zone beyond tidal influence. This holds true along the main stream of the Onkaparinga estuary (Figure 6).

Sites 3, 4, 6 and 8 are located off the main stream of the river. Water depth and presence in these locations is variable and so they are sampled less frequently, as conditions allow. Site 3 is the discharge point for a salt marsh that receives input from stormwater and its pH is similar to that of seawater. Site 4 is a large oxbow. The water is shallow, becomes extremely hot or cold as conditions determine, is well wind mixed and sedimentation rates are high. As a result the pH of the site is very variable. Site 6 is the overflow from a stormwater treatment wetland and the pH from this site reflects the fact that the water from this source is fresh. The discharge from this site has recently been diverted into the new Noarlunga Downs stormwater treatment wetlands. Site 8 is another stormwater treatment wetland overflow and there has been no discharge from this location since monitoring commenced in 2008.

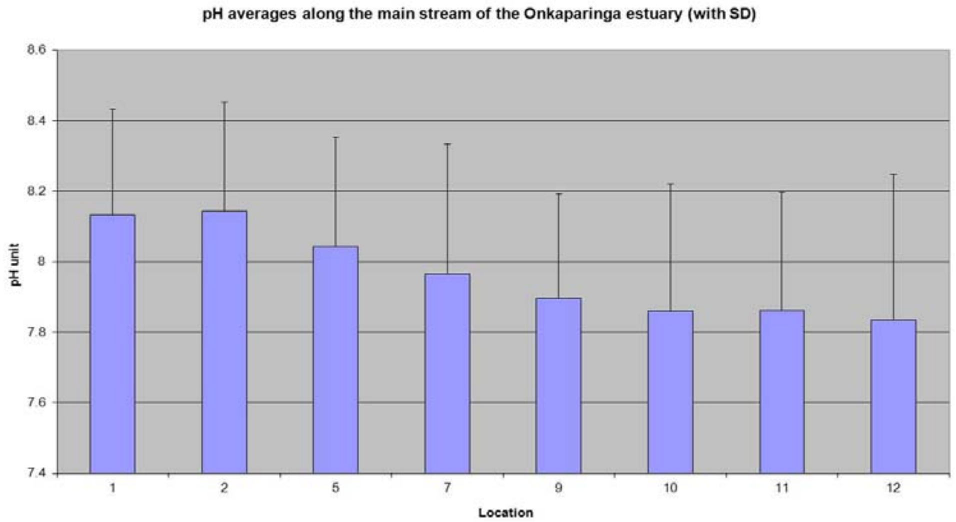


Figure 6 - Riverine pH values

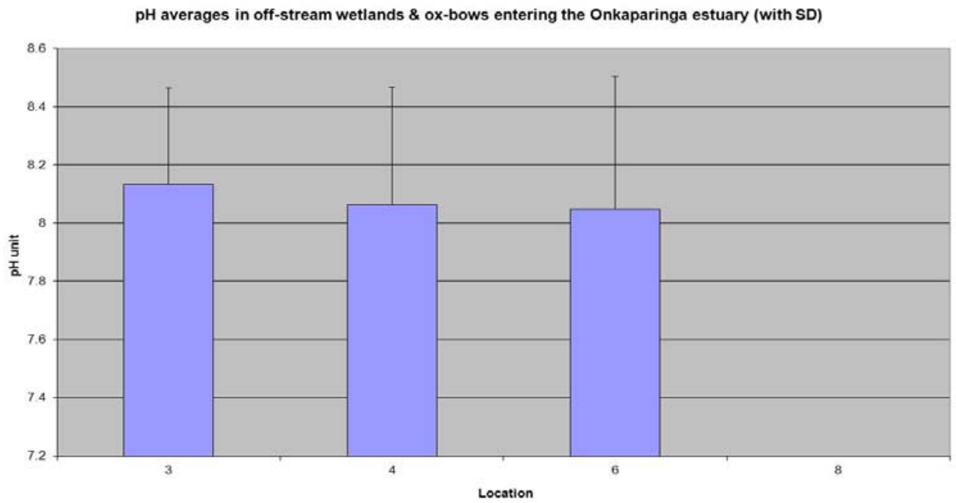


Figure 7 - pH averages at off-stream locations

There has been a distinct change in the pH patterns in the estuary since the environmental flow regime was initiated in April 2012 (see Figure 8). Since the regular flows have been reinstated, there are fewer pH excursions, with the overall range being much narrower than it was.

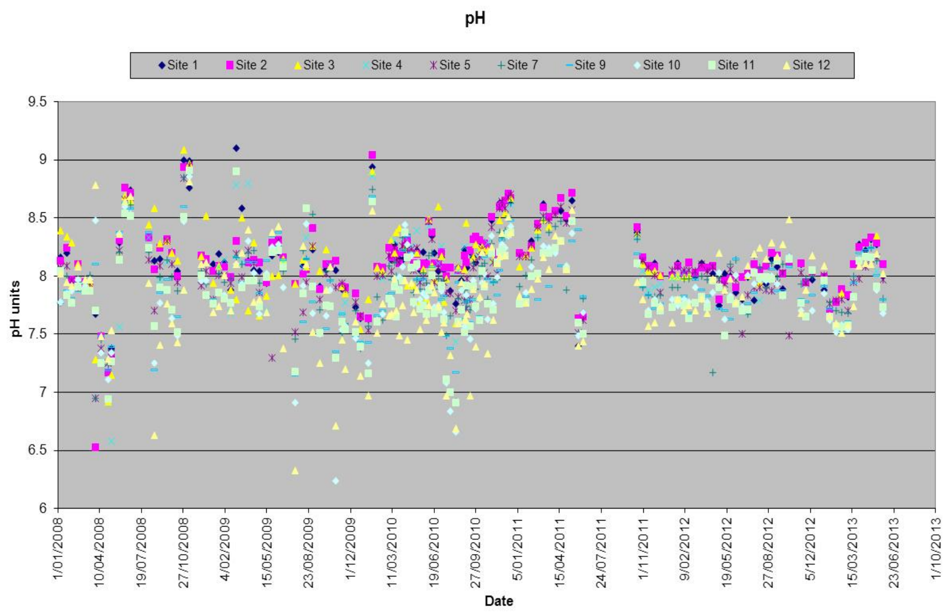


Figure 8 - pH readings

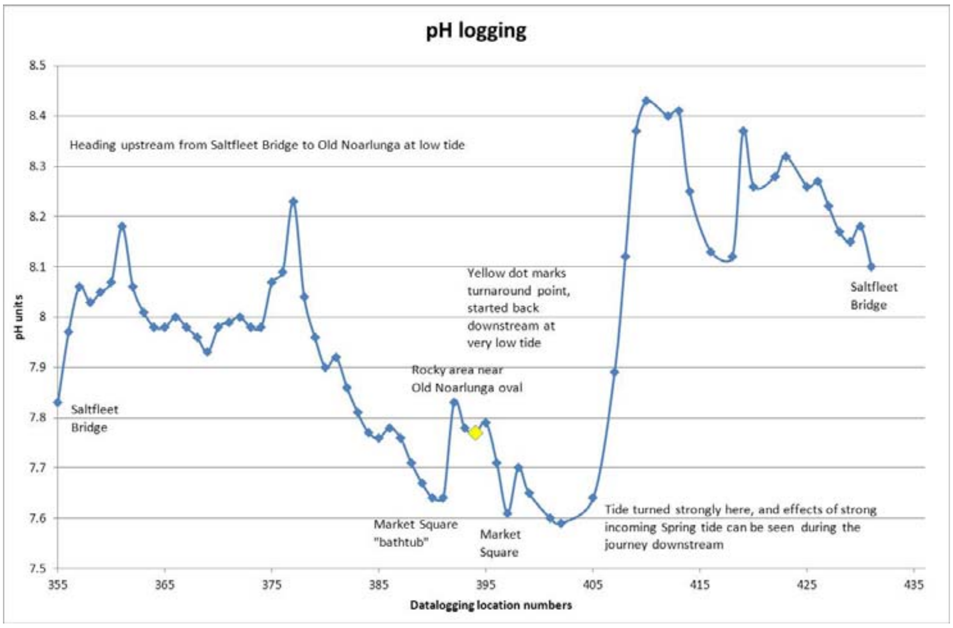


Figure 9 - pH logging

On 26 May 2013 a data logger attached to a kayak was towed upstream and then downstream (Figure 9). The low tide journey upstream revealed the expected reduction in pH as the water became fresher, although the pH was higher in the rocky riffle areas of the Horseshoe Bend. The effect of the strong incoming, very large, Spring tide is remarkable. The graph shows that pH may change significantly depending on tidal stage, even in those areas that are considered to be “marine” near the river mouth.

3.2.3 Dissolved oxygen

When displayed graphically, the dissolved oxygen data continues to display a typical temporal trend of higher oxygen concentrations in winter and lower concentrations in summer. Warm water holds less dissolved gas, and so oxygen concentrations in the water column tend to be lower in summer than in winter.

This year the overall range has been narrower than in the recent past, with fewer episodes of extreme super-saturation or anoxia. Warm, nutrient-rich water often suffers from plankton blooms that cause oxygen super-saturation in the daytime, along with occasional extreme overnight depletion of the gas (anoxia). This can lead to fish kills. While dissolved oxygen concentrations at some locations fell below 4mg/L in in the later part of the extended long dry summer of 2012-13, these events were of less intensity than those observed in the summers of 2009-2010 and 2010-2011.

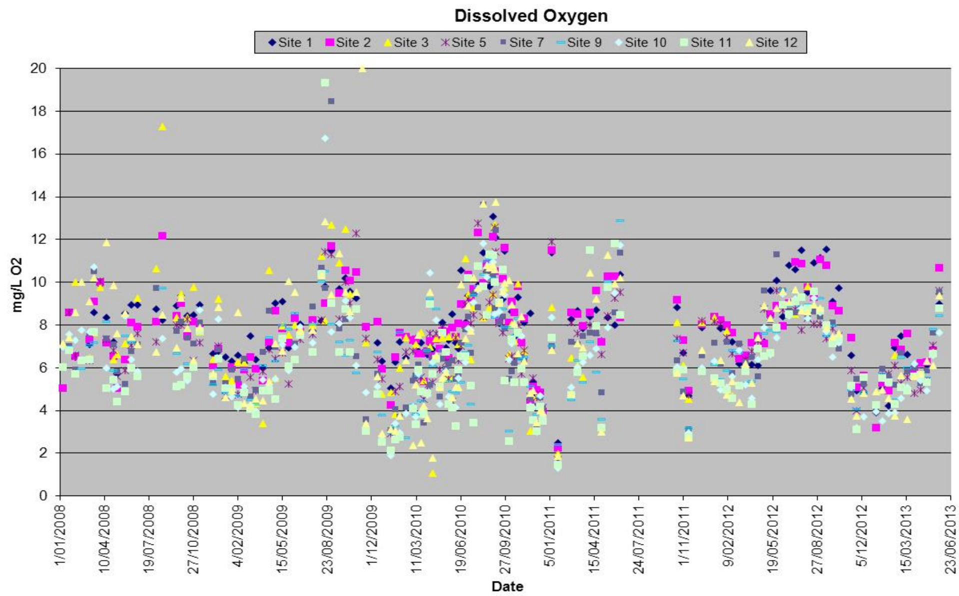


Figure 10 - Dissolved oxygen measurements

Fish kills did occur in March this year, however it is unlikely that low oxygen concentrations would fully explain the event, as the concentrations were only marginally below the level that causes distress to fish, and few fish were seen "lapping' at the water surface. The fish kill coincided with a bloom of the red tide dinoflagellate *Prorocentrum minimum*.

3.2.4 Turbidity

The turbidity average of the estuary remained 18 NTU when this year's data was added to that of the remainder of the five year monitoring period. 95% of samples over that period were less than 85 NTU, reflecting a small reduction in extreme turbidity events compared to the 95% level reported in 2011.

This was an unexpected improvement, as it had been thought that the regular release of water to the estuary may increase the overall turbidity. It is possible that the regular fresh water releases allowed vegetation to establish along the banks upstream in the catchment and this may have meant a lower sediment load into the estuary that would occur from more widely spaced run-off events.

The sites nearest the sea (Sites 1 and 2) would have met the EPA's EPP (Water Quality) guidelines for marine waters (10 NTU) on most occasions. Further inland the turbidity, and variability, increases.

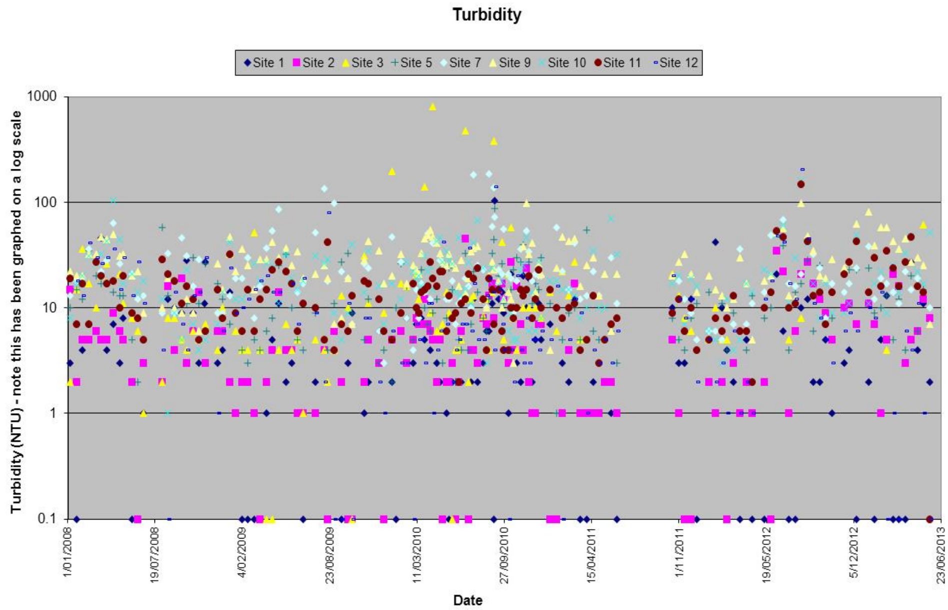
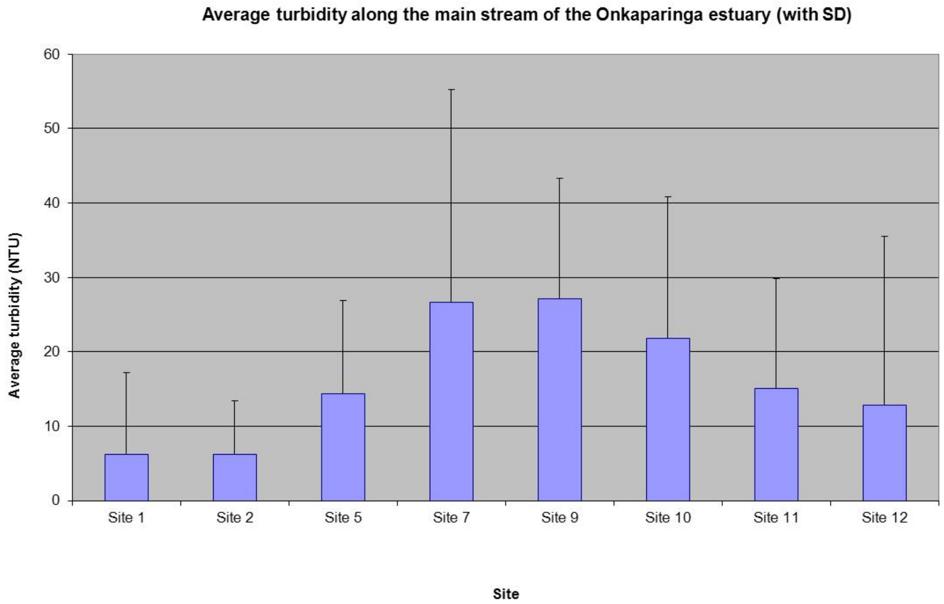


Figure 11: Turbidity data for entire monitoring program (log scale)

In many estuaries tidal forces push salinity upriver beneath the outflowing river water. The turbulence causes suspension of sediment and other particulate material present on the river bed. At the same time, dissolved material in the river water flocculates when it comes into contact with the carbonate-rich salt wedge. Where this occurs an estuarine turbidity maximum (ETM) is visible. ETM's are often associated with areas of accreting mud flats and banks.



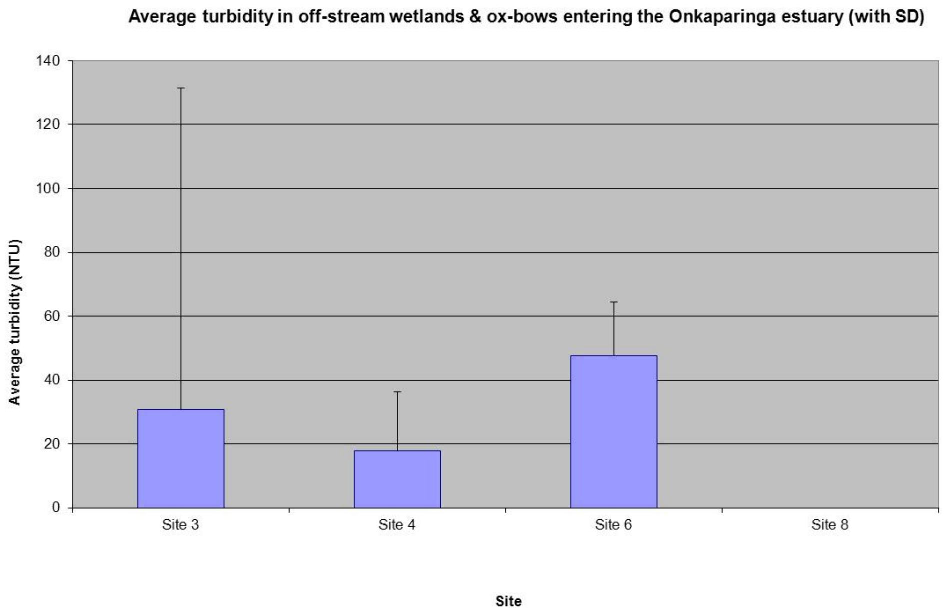


Figure 12 - Turbidity averages for each location

Sites 7, 9 & 10 are main–stream sampling locations and occur about where one might expect the estuary's "turbidity maxima" to occur, and so the high turbidity may reflect the aggregation of fine particles from the catchment as a result of combination with the carbonates contained in marine-influenced water. An alternative point of view is that this area is where there have been many recent urban developments including road works, and that these disturbances may have contributed to the high turbidity.

The turbidity at Sites 7, 9 and 10 continues to average over 20 NTU, although Site 7 shows some improvement from 2011.

3.2.5 Temperature

The water temperature within the estuary has varied from 8.2°C to 29°C over the entire monitoring program. The temperatures during each monitoring run tended to have less variability during winter than during summer. This summer was long and dry, but not particularly hot. Peak summer water temperatures were generally below 25°C this year, a little cooler than the summers of 2008-2010. Average water temperatures during the middle of winter were generally 10-15°C, similar to 2010-11, and a little cooler than the preceding two winters of 2008-10.

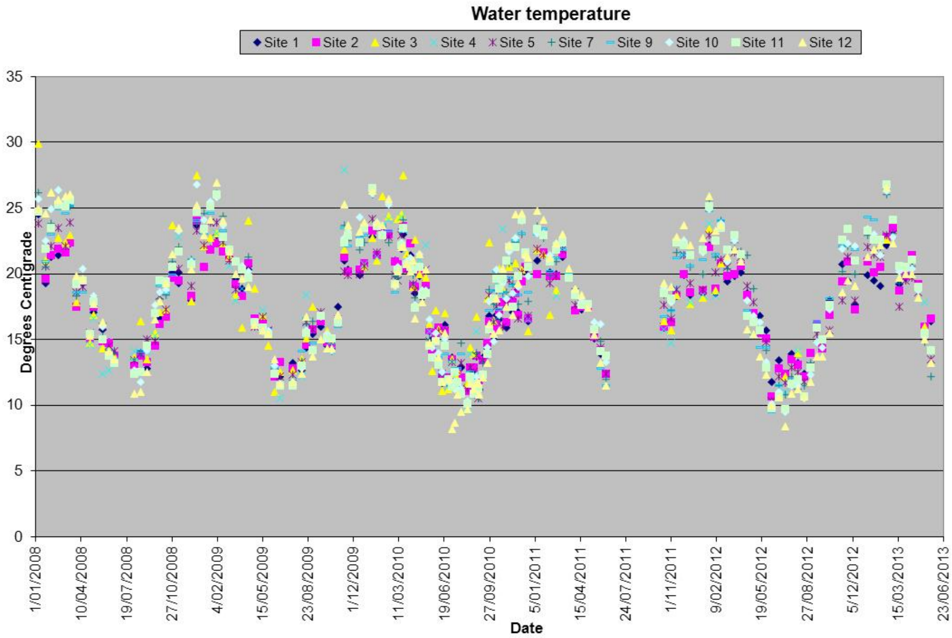
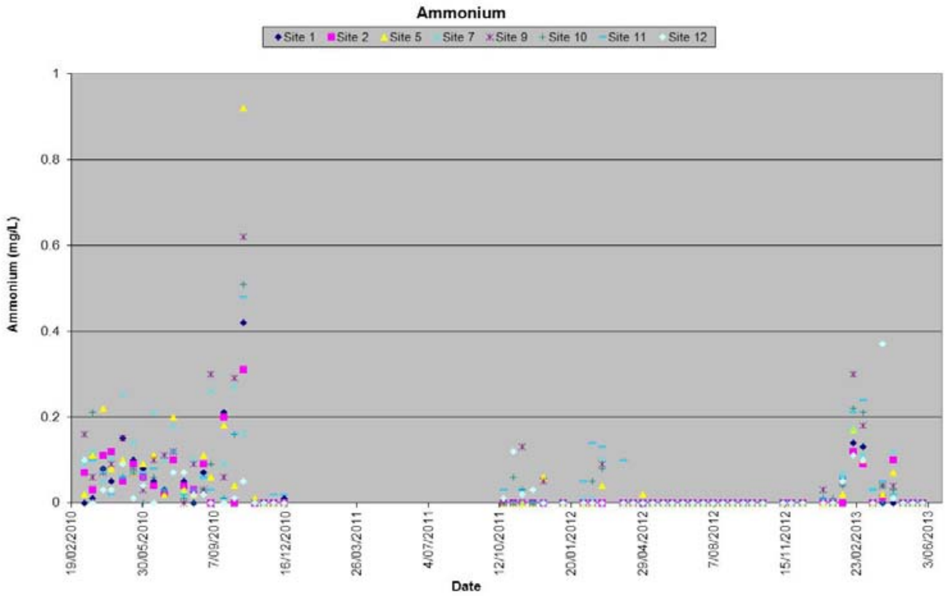


Figure 13 - Temperature readings

3.2.6 Riverine ammonia

Ammonium was sampled in the river over twenty-one sample events during a ten month period in 2010, producing one hundred and eighty-eight samples. Since October 2011 a further 283 samples have been collected and analysed.



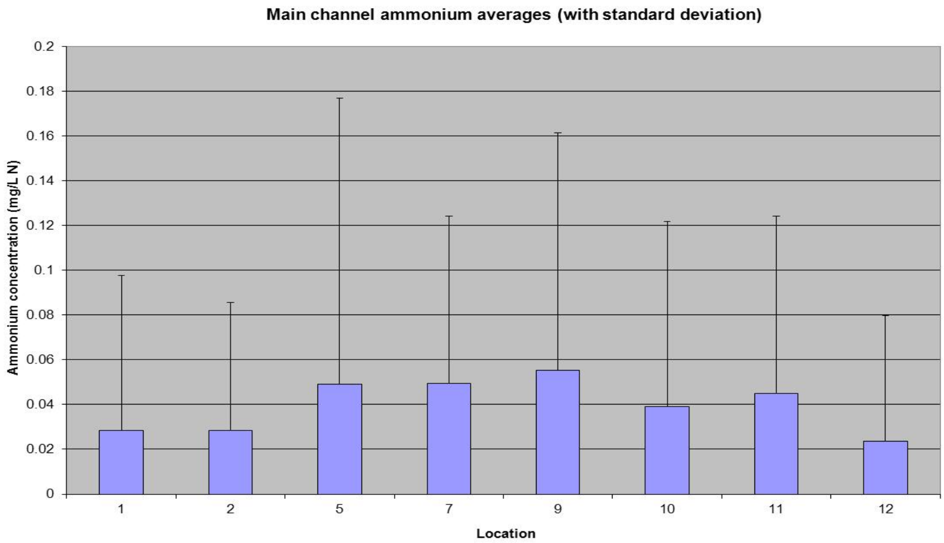


Figure 14 – Riverine ammonium along the main channel of the estuary

Since the introduction of environmental flows in April 2012 the ammonium concentration became, and generally remained, undetectable until late summer after an extended period of dry weather. Of the 283 samples tested since the last report, only six equalled or exceeded the EPA's Environment Protection (Water Quality) Policy upper limit of 0.2mg/L–N for ammonium in marine waters. This is approximately 2% of samples, an improvement on the previous monitoring period which had 11% non-compliant samples. The policy also has an upper limit for freshwaters (0.5 mg/L) which has not been exceeded since the introduction of the environmental flows. As the study area is estuarine both guidelines may be relevant at different seasons.

The eight month period of "undetectable" ammonium readings from the start of May 2012 has resulted in an overall lowering of the long term ammonium averages for each site along the river.

It has been suggested, in past reports, that the large central hump in ammonium concentration occurs adjacent to the now abandoned sludge lagoons. In fact, the average ammonium concentration (in all weathers, all flow and tidal conditions) decreases with distance from the sludge lagoons. The ammonium is possibly not "recent" ammonium - it may have built up over the operating period of the lagoons, despite the low permeability of the lagoons. Ammonium, like many things, can travel faster by molecular diffusion (specifically Fickean diffusion) through clay barriers than would be suggested by using calculations based on the barrier's hydraulic permeability. So while the water in the lagoons did not seep detectably, the ammonium could have diffused its way down into the groundwater (Telfer *et al*, 2005).

Since then ammonium may have gradually seeped into the estuary with natural groundwater movement. When the initial stormwater wetland was built up-gradient of the abandoned lagoons the hydraulic gradient of the groundwater became relatively steep, driven by the head of water in the wetland cells. This is likely to have increased the rate at which this "slug" of ammonium is moving into the estuary.

It is not known whether the construction of the new Noarlunga Downs wetlands on the old sludge lagoons site included remediation of the underlying substrate. If any ammoniated substrate still remains, it is possible that the new ponds will apply a further pressure head that could see increased discharge of ammonia to the river. Eventually the deposit will be exhausted, but it is not known how much ammonium remains in the substrate to be discharged, or the rate of discharge.

While the environmental flows trial has benefited the situation, monitoring of shallow bores between the wetlands and the river could provide useful information on whether, and for how long, this area will continue to impact on estuarine water quality.

3.3 Estuarine biological parameters

3.3.1 Coliforms

Over the entire monitoring period total coliforms and *E.coli* have been sampled at sites 2, 5, 7 and 9 on 78 occasions yielding 310 samples. Several other sites have been sampled on single occasions for an additional 6 samples.

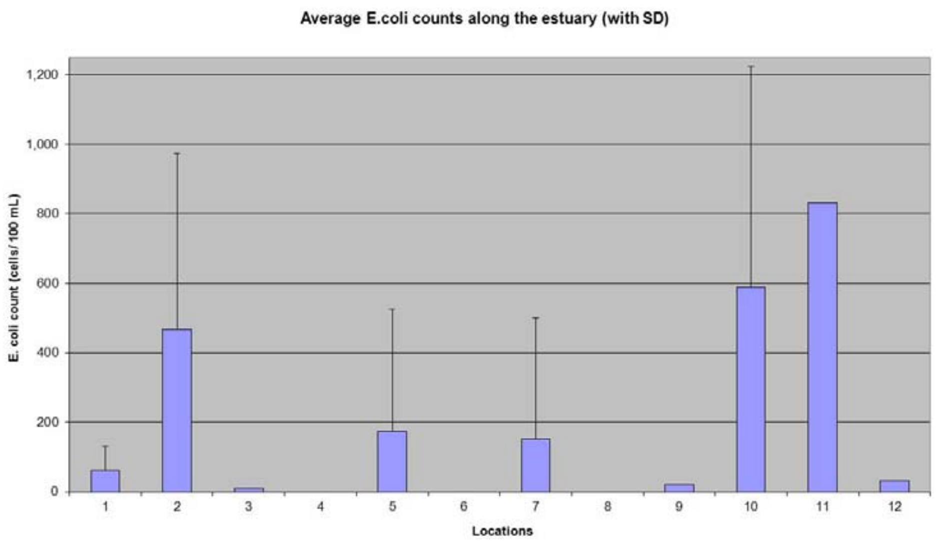


Figure 15 – E.coli readings along the estuary

In Figure 15, the regular sample sites show a standard deviation error bar. The single sample sites (those with no error bar) provide interesting observations, however single samples cannot be assumed to reveal the average conditions at those sites.

The average counts over the entire monitoring period at the four sites are at, or exceed, the EPA's Environment Protection (Water Quality) Policy upper limit of 150 cells/100mL for *E.coli*. There has been no reduction in coliform counts since the introduction of the environmental flows.

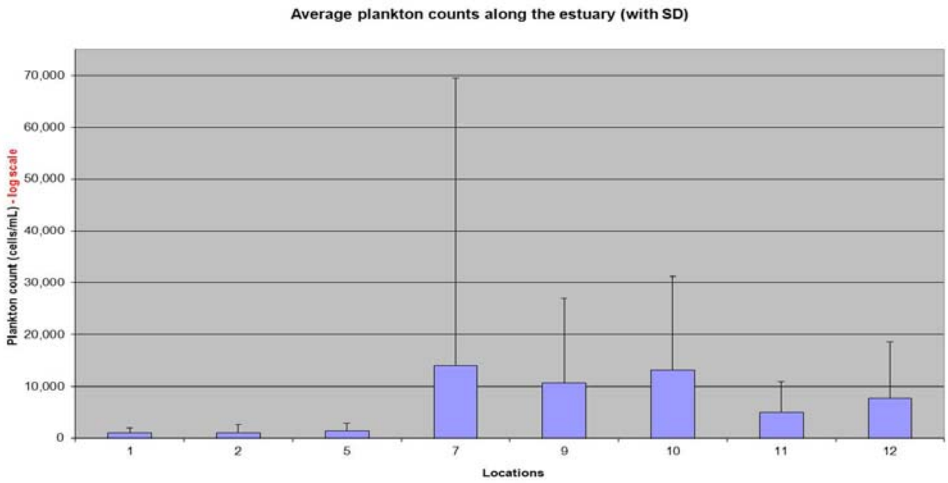
Table 3 - E. coli averages

Site	**2**	**5**	**7**	**10**
Average	467	173	150	588

E. coli is usually hosted in the intestines of warm-blooded animals, including humans and dogs. It is also carried by a small percentage of birds that have been in contact with mammalian waste.

The most significant concern is that sites with the highest average counts (sites 2 and 10) are also sites with high visitor usage, which increases public exposure to these bacteria. Both areas with the highest coliform counts are relatively deep pooled areas, both have stratification within the water column during some or all of the year, both have been dredged in the past, both are close to bridges that host large numbers of feral pigeons and both have shallower areas downstream. Additionally, Old Noarlunga contains some dwellings that are unsewered. This means these two sites are likely to become stagnant, and collect nutrient and bacteria-rich sediments.

3.3.2 Plankton



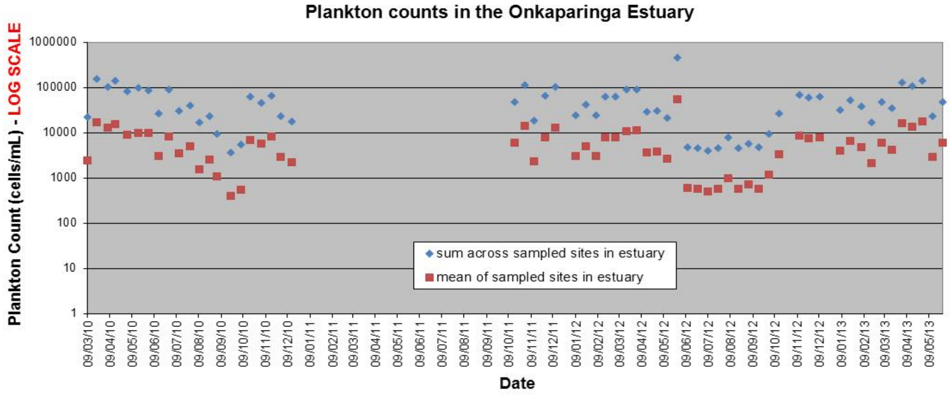


Figure 16 – Plankton at each site and over the entire estuary

Plankton counts were incorporated in the main monitoring program in October 2012, and the data added to that collected over a ten month period in 2010. The water near the mouth of the estuary has consistently low plankton counts. Other sites have been more variable, as evidenced by their standard deviations (the upper diagram in Figure 16). This variability reflects the “boom and bust” nature of planktonic populations in eutrophic water bodies, which is also evident in the “across the estuary” counts displayed in the lower graph.

Counts of plankton exceeding 50,000 cells per mL are considered to be “blooms”. Blooms are more common in the upper reaches, from Perry’s Bend inland. In October 2011 there were several high counts of euglenophytes and small prasinophytes in the lower salinity sites (Sites 9-12). These high counts moved seaward as the season warmed up. A large bloom of small dinoflagellates occurred at Site 7 (Perry’s Bend) in May 2012, before the effect of the environmental flow regime resulted in a series of regular low counts that lasted until springtime.

In the lead up to Christmas 2012 increased counts of picoplankton (very small plankton, most likely cyanobacteria) were noted in the upper reaches as the salinity of the river started to increase.

The extended dry season that ran into late summer and early autumn of 2013 was associated with high numbers of dinoflagellates (*Prorocentrum micans* and *Prorocentrum minimum*) which reached bloom proportions at Site 10 (Market Square at Old Noarlunga). A request for advice from Professor Gustaaf Hallegraeff at the University of Tasmania brought the following response,

> “*Prorocentrum micans* can cause water discolorations but has no human health significance… Dense blooms of *P. minimum* have been repeatedly associated with fish kills (most likely by generating low oxygen conditions at night), but have also occasionally been associated with shellfish mortality (eg Wonboyn Lake NSW). The precise mechanism of the latter is not clear, but there is no evidence that chemicals of human health significance are involved.”

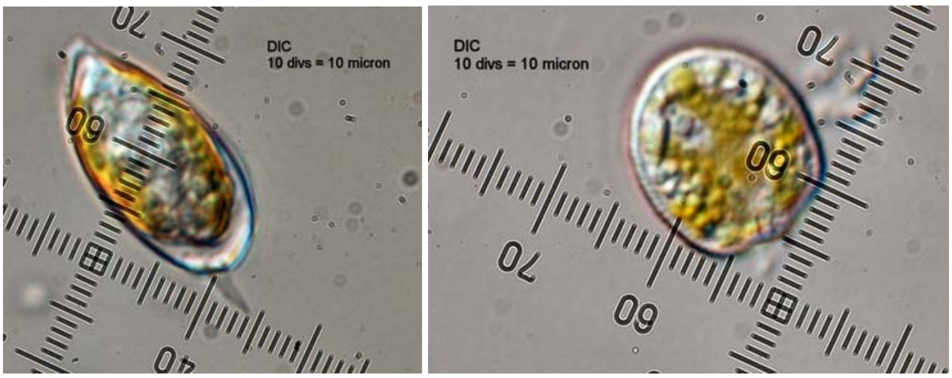


Figure 17 - Prorocentrum micans (L), P minimum (R)

Since the start of the environmental flows for 2013, the bloom has dissipated seaward.

Mean counts of the plankton data, sorted into morphogroups at each location, are provided in Table 4. Desmids colonised the freshwater end of the estuary (Sites 10-12) after environmental flows were instituted. Downstream (Sites 7 & 9), where nutrients and salinity increase with proximity to SA Water's decommissioned WWTP lagoons, abundances increase and the samples contain a wide variety of plankton. Seaward of Site 5, the counts are lower where tidal flushing with low nutrient water occurs.

Table 4 - Mean plankton morphogroup counts, before (above) and after (below) environmental flows began

Site	Sample "n"	Desmids	Colonial & filamentous chlorophytes	Flagellate chlorophytes	Euglenophytes & prasinophytes	Cryptophytes	Dinoflagellates	Other chromophytes	Diatoms	Cyanophyta	Pico plankton	Other plankton (incl protozoans, forams etc)
1	34	0	0	12	88	202	130	5	301	7	5	15
2	34	0	2	7	73	112	224	7	248	8	2	17
5	34	0	2	26	120	174	323	12	412	14	0	19
7	34	0	3	29	2882	848	3984	27	504	8	0	130
9	34	0	0	3101	2293	1631	5294	86	456	13	1909	285
10	34	0	0	680	4173	828	6878	162	488	8	1303	128
11	34	0	3	103	1337	557	2397	29	386	10	525	47
12	34	0	7	416	865	1261	4488	278	783	10	763	51
Site	**Sample "n"**	**Desmids**	**Colonial & filamentous chlorophytes**	**Flagellate chlorophytes**	**Euglenophytes & prasinophytes**	**Cryptophytes**	**Dinoflagellates**	**Other chromophytes**	**Diatoms**	**Cyanophyta**	**Pico plankton**	**Other plankton (incl protozoans, forams etc)**
1	27	0	2	2	125	341	318	0	347	10	0	4
2	27	0	0	8	191	554	548	0	232	4	0	10
5	27	1	0	6	246	607	427	2	264	4	60	8
7	27	4	2	26	1212	1254	17393	2	429	0	238	24
9	27	4	4	52	897	1306	2456	4	635	6	0	24
10	27	44	10	32	931	540	7895	4	464	0	1321	12
11	27	30	14	58	585	315	2197	8	416	4	714	12
12	27	84	32	35	853	693	4154	4	470	7	0	28

3.3.3 Diatom study

Different diatom species may occupy planktonic or benthic habitats. Those that are benthic dwellers are less mobile and so the assemblage of benthic diatoms at a location provides an integrated reflection of physico-chemical conditions at that site over a more extended period than a single sampling event.

Studies of benthic diatoms in the estuary of the Onkaparinga have been conducted in the past (Thomas, 1978) and generic diatom indices (relationships between diatom genera and habitat conditions) have been used to assess water quality impacts locally in the Barker Inlet and Port River estuary (Coleman, Cook & Eden, 2007).

In October 2012 several periphytometers were placed at some of the sampling locations for a fortnight in order to compare the current assemblages to those recorded by Thomas in 1978 and to determine whether benthic microalga can further inform our understanding of estuarine conditions in the Onkaparinga.

While only 125 (75 common) species were recorded compared to the over 300 (96 common) recorded by Thomas in 1978, that earlier study was conducted over three years with multiple sampling events each year. The current study, conducted during the environmental flows trial of 2012, has similar findings in regard to abundance and assemblage distributions to the earlier study, which took place at a time when flows in the river were not as restricted as they have been for the past decade.

There was a clear order of magnitude difference in abundance between the “freshwater” site at Old Noarlunga and the other three sites, with the fresher site being the most productive. Increased productivity of the periphytic element of the habitat would appear to be a positive outcome of the environmental flows trials being conducted in the river currently.

Table 5 - Diatom abundance (productivity)

	River Mouth	**Perry’s Bend**	**South Road Bridge**	**Swing Bridge, Old Noarlunga**
Abundance (diatoms /mm^2)	50	95	32	760

Use of “generic diatom indices” a metric that measures the relative abundance of genera of diatoms that are sensitive to specific aspects of the environment, appears to have potential to be a useful tool for bioassessment of estuarine and other saline water bodies. The indices were readily able to separate out sites where organic loading to the waterway was high, where dissolved oxygen is often low and to detect the pH gradient that exists along the estuary.

Details of the study have been provided under a separate cover (Coleman 2012) and the microscope photography has been made available to the NRM Board to act as a Herbarium of the common species encountered.

3.4 Vegetation of the estuary

3.4.1 Salt marsh transects

Vegetation transects have previously been installed in the saltmarsh at several locations along the estuary. Transect One is located in the extensive saltmarsh west of Saltfleet Street and has been recorded in March 2008 and October 2010. Transect Two is in the oxbow saltmarsh near the Noarlunga Oval and has been recorded in November 2008 and February 2013. Transect Three was located at the SA Water WWTP and was recorded in October 2009. The transect location was impacted by the construction of the Seaford Rail Bridge and so a New Transect Three (actually two short transects) was established at Perry's Bend. This was surveyed for the first time in May 2012.

The results of all transect recordings have been provided separately, as each was undertaken but they are also attached to this report in the appendices. Copies of the surveys were also supplied to DEWNR this year as input into their Marine Parks monitoring program.

The revisited transects are not showing signs of change to the vegetative assembly. The very small differences in measurements are likely to be the result of using a long tape to measure transects rather than using a surveying theodolite.

3.4.2 Grey mangrove, *Avicennia marina*

The Adelaide & Mount Lofty Ranges NRM Board has implemented an eradication program to remove planted, and then naturalising, *Avicennia marina* from the estuary (Cook and Coleman 2010).

On 26 May 2013 an inspection of the river bank was made by kayak (Figure 18). It was noted that all known existing plants had been eradicated and no new specimens were recorded.

Developing educational signage, to be placed where watercraft enter the river (the Canoe Club at Saltfleet Bridge, Perry's Bend car park and Market Square) may prevent further intentional introductions.

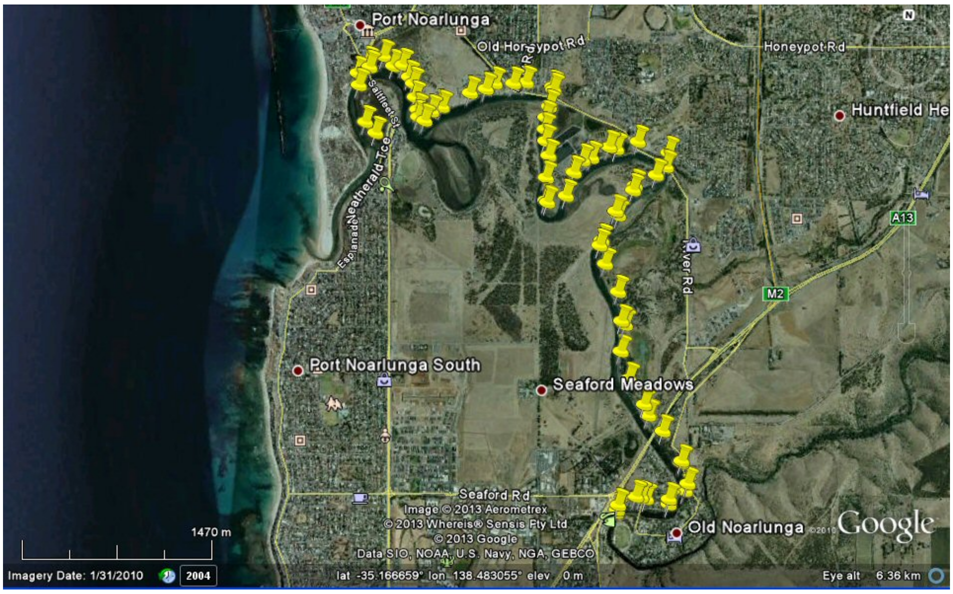


Figure 18 - Course of survey, 26 May 2013

3.5 Observations

During each monitoring event, recreational visitation and site fauna usage is noted. These observations are reported each fortnight in the sampling event field sheet that is provided to the NRM Board.

3.5.1 Bird observations

Bird usage varies throughout the estuary, with the main shorebird usage occurring on the flats and salt marshes between Site 2 & Site 7. Ducks, corellas and pigeons appear to prefer the more anthropogenic landscapes through Old Noarlunga, and fishing birds are generally seen in the deeper waters of the main channel.

Corellas, feral pigeons and other land-based birds at Old Noarlunga and at the estuary mouth shelter under the bridges and in nearby trees. They are having impacts on the river via faeces and degraded riparian tree health. At Old Noarlunga other common species include native Pacific Black and Australian Wood ducks (they are observed in mixed flocks which include introduced mallards, hybrids, and domestic ducks and geese). Cormorants and egrets are common throughout the estuary and silver gulls congregate at the estuary mouth.

Less common birds, yet still a noteworthy portion of the counts, include a suite of migratory and resident waders (some of which overwinter), pelicans, swans, sacred ibis, spoonbills, darters and white faced herons. These are most commonly found in the proximity of salt marshes at the lower end of the estuary.

3.5.2 Recreational visitation

The dominant human usage of the estuary is fishing, followed closely by walking (often with a dog), picnicking, bike riding and canoeing. The most popular sites are the two sites nearest the river mouth and Market Square at Old Noarlunga.

The field data sheets for each monitoring run contain a wealth of information on these uses and could be analysed to produce a recreational value for the estuary if required at some later point. All field sheets for the entirety of the monitoring period (five years) have been provided to the AMLR NRM Board as electronic files and also archived by the consultants. They are available should more detailed analysis ever be required.

3.6 Environmental flows

The AMRLNRM Board and partners have developed a program to trial (over three years) the provision of environmental water flows downstream of SA Water's metropolitan water supply reservoirs in the western Mount Lofty Ranges.

Previous annual reports (Coleman 2011) detailed concerns about estuarine health that were related to the small quantum of freshwater entering the estuary. Continued monitoring of the estuary, combined with the undertaking of specific studies such as the diatom study, allow some tentative conclusions to be drawn about the environmental flows trial after this first year.

The extra freshwater has made a visible change to several parameters that are measured in the regular monitoring program. The fresh water, although a little muddy at times, has diluted the deep holes containing high salinity water at Old Noarlunga. The most dramatic chemical changes have been the establishment of a positive winter/spring/early summer salinity gradient and a reduction in ammonium concentrations in the river.

A notable physical change is an increase in water borne sediment in the upper reaches of the estuary, above the Turbidity Maxima area during winter and spring.

Biological responses to these changes have been swift. Salinity reductions have resulted in desmids being recorded in the plankton counts of the lower salinity sites, for the first time since this monitoring program was established. Common species include *Ankistrodesmus* and *Closterium*. Highly productive benthic diatom communities formed in the upper estuary in spring, and a new cohort of samphires sprouted along the previously bare lower benches of the river in the middle estuary.

The reduction in ammonium concentration may have been responsible for the high survival rate of fish spat in the estuary this year. At times the water was milky with "boils" of spat. Large flocks of little black cormorants visited the estuary in the 2012 Springtime and were seen herding small fish up and down the river. The flocks were accompanied along the adjacent shores by white-faced herons and great white egrets that caught any fish that tried to escape the cormorants by swimming into the shallows.

Additional sediment supply into the estuary effectively settles out in the central parts of the estuary, especially along the lower benches of the river along the central estuary, providing a good media for new samphire colonisation and burying (sequestering) carbon. This is the mechanism that makes saltmarsh one of the most effective of carbon sinks.

4. Recommendations

- **Continue with the environmental flows trial:** There have been clear changes in the chemical and physical water quality parameters measured in the estuary since environmental flows were implemented. Biological benefits that are likely the result of the flows have been observed in plankton, benthic diatoms, fish spawning, and vegetation colonisation.

- **Monitoring shallow groundwater nutrient contributions:** With the increased hydraulic head that the new Noarlunga Downs stormwater treatment wetlands will apply to the ammonia-rich substrate of SA Water's decommissioned Christies Beach Sludge Drying Lagoon, it is recommended that monitoring of bores between the wetlands and the river be reinstated, using micropurge methods to determine the discharge rates and longevity of the ammonia concentrations under lying the new wetlands.

- **Involvement of Friends of Onkaparinga Park:** The local community may appreciate an information session that presents an update of the monitoring program, as it has been several years since the results of this monitoring program were last reported to the local community.

- **Target coliform hotspots:** As in previous reports it is recommended that the source of coliforms within the river be identified. Once identified, actions to reduce human health risks can be developed. We recommend that SA Water, the EPA and the Onkaparinga Council continue their efforts to identify any unsewered houses in the Old Noarlunga area.

- **Mangrove education:** The AMLR NRM Board has completed a mangrove removal program. Developing educational signage, to be placed where watercraft enter the river (the Canoe Club at Saltfleet Bridge, Perry's Bend car park and Market Square at Old Noarlunga) may prevent further intentional introductions.

5. References

Coleman P (2012) *Diatom Study: Onkaparinga estuary*. Prepared for the Adelaide and Mount Lofty Natural Resources Management Board. Delta Environmental Consulting. Adelaide.

Coleman P (2011) *Annual monitoring summary: Onkaparinga Estuary 6 September 2011*. Prepared for the Adelaide and Mount Lofty Natural Resources Management Board. Delta Environmental Consulting. Adelaide.

Coleman P, FS Cook & RN Eden (2007) *TIPS monitoring report for 2007*, Consultant report for TRUenergy. Delta Environmental Consulting. Adelaide.

Coleman PSJ and FS Cook (2007) *Review of current estuarine monitoring, gap analysis and recommendations.* Prepared for the Adelaide and Mount Lofty Natural Resources Management Board. Delta Environmental Consulting, Adelaide.

Cook FS and Coleman P (2010) *Annual monitoring summary: Onkaparinga Estuary 13 August 2010*. Prepared for the Adelaide and Mount Lofty Natural Resources Management Board. Delta Environmental Consulting. Adelaide.

Cook FS and Coleman P (2010) *Mangrove (Avicennia marina) survey: Onkaparinga River estuary*. Prepared for the Adelaide and Mount Lofty Natural Resources Management Board. Delta Environmental Consulting. Adelaide

Cook FS and Coleman P (2009) *Annual monitoring summary: Onkaparinga Estuary 11 July 2009*. Prepared for the Adelaide and Mount Lofty Natural Resources Management Board. Delta Environmental Consulting. Adelaide.

Cook FS and R Eden (2007) *Monitoring Program: Onkaparinga Estuary* Prepared for the Adelaide and Mount Lofty Natural Resources Management Board. Delta Environmental Consulting, Adelaide

Mannin, (2006) *Onkaparinga Estuary Rehabilitation Action Plan*. Prepared for the Adelaide and Mount Lofty Natural Resources Management Board by Eco Management Services Pty Ltd. Adelaide.

Sinclair Knight Merz (2003) *Determination of Environmental Water Requirements of the Onkaparinga River Catchment 2003*, Consultant report for AMLRNRM Board. Sinclair Knight Merz, Adelaide.

Telfer A, C Palfreyman, R Aldam & G White (2005) *Christies Beach Sludge Drying Lagoons Stage 2, 3 & 5.* Consultant report to SA Water. Australian Water Environments. Adelaide.

Thomas DP (1978) *The ecology of diatom epiphytes of Zostera sp. in the Onkaparinga estuary, South Australia (1974-1977)*, PhD Thesis, University of Adelaide, Adelaide.

6. Appendices

6.1 Water quality data

6.2 Vegetation transect sheets