Background report for the Adelaide Coastal Water Quality Improvement Plan

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Report 5 **Adelaide Coastal Water Quality Improvement Plan Monitoring and Assessment Framework**

Adelaide Coastal Water Quality Improvement Plan

Monitoring and Assessment Framework

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Abbreviations

ACWQIP – Adelaide Coastal Water Quality Improvement Plan

ACWS – Adelaide Coastal Waters Study

AMLR NRM – Adelaide and Mt Loft Ranges Natural Resource Management

ASR – Aquifer Storage and Recovery

CBD – Central Business District

CDOM – Coloured Dissolved Organic Matter

DEH - Department of Environment and Heritage

DWLBC - Department of Water, Land and Biodiversity Conservation

ECM – Estuarine, Coast and Marine

EPA – Environment Protection Authority

EWS – Engineering and Water Supply

GIS – Geographic Information System

MATs – Management Action Targets

MCMF – Marine and Coastal Managers Forum

MERF – Monitoring, Evaluation and Reporting Framework

PIRSA - Primary Industries and Resources South Australia

Pm_{10} – Particulate matter to 10 microns

Port Waterways WQIP – Port Waterways Water Quality Improvement Plant

RCTs – Resource Condition Targets

TBD – To be determined

TKN – Total Kjeldahl Nitrogen

WSUD – Water Sensitive Urban Design

WWTP – Wastewater Treatment Plant

$\delta^{15}N$ - Stable nitrogen isotope

Executive summary

Background

The Adelaide Coastal Water Quality Improvement Plan (ACWQIP) sets stringent long-term targets for the improvement of water quality (specifically total nitrogen, total suspended solids and coloured dissolved organic matter) for the Adelaide metropolitan coast. Implementation of a monitoring program to inform progress towards the ACWQIP targets is a necessary step to ensure management interventions are leading to outcomes that are in line with the goals of the ACWQIP.

A monitoring regime for the Adelaide coast was developed as part of the Adelaide Coastal Waters Study (ACWS; Henderson *et al*. 2006).

Scope

Develop a draft monitoring and modelling plan that identifies progress and effectiveness of the ACWQIP:

- that uses existing monitoring and modelling where available
- details where further information is needed to be collected
- prioritises and costs additions to the monitoring and modelling plan and
- identifies if these gaps can be filled through strategic enhancement of other monitoring and modelling plans.

In this report the regime developed by Henderson *et al.* (2006) was compared with the current and proposed monitoring frameworks for relevant stakeholders in the region. The results from this comparison were then considered against the requirements for the ACWQIP. Following this review, a stakeholder consultation workshop was held to confirm the nature of current and proposed monitoring (including indicators, frequency, spatial distribution and reporting mechanisms).

Additional data needs have been identified (see below) as have the opportunities to develop strategic partnerships with other agencies to deliver a more comprehensive monitoring program (whilst minimising costs).

Findings

The assessment of existing monitoring programs revealed several significant gaps in the capacity for these programs to fully inform the progress of the ACWQIP. In summary, the indicators required to inform managers about progress towards the targets of the ACWQIP, comprise:

- Input water quality to the coast, including domestic wastewater, stormwater, industrial wastewater, groundwater and atmospheric inputs
- Coastal water quality
- Sediment stability
- Ecosystem health
- Physical processes (tides, wind, currents).

Input waters

The bulk of wastewater discharges to the Adelaide coastal waters region are covered by existing EPA licences although it is recommended that changes are made to these licence arrangements so that “end-of-pipe” monitoring reports on pollutant loads, rather than simply concentrations in receiving waters. In addition, it is recommended that sampling of receiving waters is augmented with additional research to comprehensively determine the "sphere of influence" of wastewater discharges using stable nitrogen isotope signatures in seagrass meadows.

While there is little existing monitoring of the stormwater loads to the coast, the proposed monitoring and evaluation framework proposed in the AMLR NRM regional plan is set to monitor 80-85% of the stormwater inputs (on a volume basis). Engagement with Local Government instrumentalities in the region may provide a mechanism to monitor the remainder.

Groundwater input monitoring is expected be covered by the AMLR Monitoring, Evaluation and Reporting Framework (MERF), and the data collected should be suitable for informing the ACWQIP.

Atmospheric inputs (especially particulate matter dryfall) need to be estimated based on the sampling program already undertaken by the EPA.

Coastal water quality

The EPA currently takes responsibility for coastal water quality monitoring and have planned to modify the existing beach and jetty sampling program to better inform progress towards the ACWQIP.

Sediment stability

No significant changes are required to the existing sediment stability and sediment profiling sampling programs that are currently being run by the Department of Environment and Heritage Coast Protection Branch. However, a number of additional indicators have been identified to ensure that the existing program can better inform the ACWQIP (see below).

Ecosystem health

Ecosystem health condition parameters are not currently quantified in a way that can reasonably inform the ACWQIP. The measures that need to be developed include many of those previously identified during the Adelaide Coastal Waters Study. These new sampling programs need to be developed so as to provide relevant information to the ACWQIP, especially with reference to seagrass and reef condition throughout the region. These could be based on some existing programs (with modifications), such as Reef Health.

The workshop attendees generally agreed that further expensive ongoing monitoring of physical processes in the region is not warranted and could be discontinued.

Recommendations

Recommendation 1: The interaction between the ACWQIP and the AMLR NRM Board should be formalised via the EPA representation on the Board and the results of the monitoring reported collaboratively.

Rationale: The stakeholder workshop revealed that there was significant potential for synergies between some of the existing and planned monitoring programs, and the requirements of the ACWQIP. The most significant synergies exist between the ACWQIP requirements and the existing and planned monitoring developed under the auspices of the Adelaide and Mount Lofty Ranges Natural Resource Management Board (AMLR NRM) Monitoring, Evaluation and Reporting Framework (MERF).

Recommendation 2: An ACWQIP technical working group should be established to ensure ongoing coordination of monitoring and reporting between relevant stakeholders. The TWG should be constituted with an independent chair.

Rationale: There is a need to establish an ACWQIP technical working group to take on the role of ensuring that monitoring programs and reporting frameworks are co-ordinated into the future. This group should be established with representation from key stakeholders and should take a leading role in addressing the following key issues:

1. The monitoring zones as defined by the ACWS need to be reviewed particularly with respect to the realignment of zones 4 and 5 within zones 1 and 2 respectively.
2. The spatiotemporal framework for coastal water quality monitoring from beaches and jetties is currently under review by the EPA. This review should include input from the working group with the aim of determining the balance between sampling frequency, spatial resolution and logistic constraints.
3. The potential for telemetry based water samplers should be more fully investigated with a view to developing a multi-agency funding proposal. Integration of the resulting data within the coastal water quality framework can then be assured.
4. There is a need to develop a seagrass health assessment framework that integrates the range of sampling tools identified by Henderson *et al.* (2006) within a mutually supportive spatiotemporal hierarchy. This health assessment could take a lead from the well established and respected Reef Health program. Seagrass Health data are needed for coastal areas of particular concern, which may include areas with close proximity to inputs as well as areas that are likely to experience future changes associated with population and climate change influences. The results from the stable nitrogen isotope studies would inform the process of site selection.
5. Reef Health sampling should continue using the the methodology and locations employed in earlier reef health assessments (see Turner *et al.* 2007). Further work is required on the indices used to assess reef status. While most existing indices should be retained, other indices along the lines of those identified in Turner *et al.* (2007) should be considered.
6. Both seagrass and reef health assessments need to be referenced against appropriate control locations.
7. The working group needs to determine an appropriate proxy measurement for CDOM.
8. Sediment stability investigations should incorporate monitoring of sediment grain size and cliff stability particularly in high risk areas (e.g. the southern metropolitan coast).
9. The benefits from including commercial and recreational fisheries stock assessment data as another mechanism for ecosystem health assessment should also be investigated.
10. The availability, parameterisation and outputs from various mass balance water flow models available for the Adelaide metropolitan coast as well as the Port Waterways should be examined with a view to determining their use in supporting ACWQIP objectives, in particular projections relative to changes in management activity.

Conclusion

This report identifies the parameters that need to be monitored to plot progress in achieving the objectives of the ACWQIP. The need to monitor these parameters has been agreed to by the relevant stakeholders who have also agreed where responsibility sits for specific elements of the monitoring, assessment and reporting program.

Introduction

Numerous studies have established that the health of seagrass ecosystems on the Adelaide metropolitan coast is strongly reliant on water quality. Since settlement, there has been a substantial increase in the nutrient and sediment loads delivered to coastal nearshore systems with a concomitant loss of between 4000-5000 ha of seagrasses from the nearshore region since the 1940s (see Westphalen *et al.* 2004 for a review). The need to understand the drivers of seagrass decline on the Adelaide coast culminated in the Adelaide Coastal Waters Study (2001-2006). The study brought together data on current and historical inputs and water quality, hydrodynamic modelling, seagrass ecology and ecophysiology, and remote sensing, this multi-agency investigation aimed to determine both the existing condition of seagrass systems and causal mechanisms for seagrass loss on the Adelaide metropolitan coast (Fox *et al.* 2007). Fourteen major recommendations came from the ACWS, including the need for further reductions in nutrient and suspended solids to nearshore waters (See Fox *et al*. 2007). Six of the recommendations from the ACWS relate to development of monitoring initiatives.

In addition to seagrass loss, there has also been substantial degradation of reefs along the Adelaide metropolitan coast. This loss has been attributed to the overall decline in coastal water quality and particularly due to increases in sedimentation (Turner and Cheshire 2002, Turner *et al.* 2007, Connell *et al.* 2008).

In response to the recommendations of the ACWS, the South Australian Environmental Protection Authority (EPA) is developing the Adelaide Coastal Water Quality Improvement Plan (ACWQIP), which specifies substantial reduction targets for nutrients (specifically total nitrogen), total suspended solids (TSS) and Coloured Dissolved Organic Matter (CDOM) from terrigenous inputs to the metropolitan coast. These targets are aligned to specific input types, including wastewater, stormwater and industrial sources.

The Port River/Barker Inlet estuary was excluded from the ACWS, although the closure of the Port Adelaide Waste Water Treatment Plant (WWTP), creation of the Adelaide Dolphin Sanctuary, a major redevelopment program within the upper Port River as well as the high conservation value of some areas has prompted a need for the development and implementation of a water quality improvement plan for this system (EPA 2005). The Port Waterways WQIP has a primary focus on nutrients (mostly nitrogen) and chlorophyll *a*, but unlike the ACWQIP, there are no targets for suspended solids (EPA 2005). Importantly, the draft ACWQIP is aimed at incorporating the Port Waterways Water Quality Improvement Plan (EPA 2005).

There is a need to develop an assessment strategy for the implementation of the ACWQIP that encompasses;

- Assessment of stakeholder progress with respect to achieving ACWQIP water quality targets through management intervention and activity.
- Observing improvements in natural resource condition, including coastal water quality and ecosystem health.
- Integration within current and planned monitoring and reporting frameworks.

Aims

In light of the above needs, the aims of this study were to;

- Develop an understanding of the current stakeholder investment, monitoring, assessment and reporting environment. In particular, this includes the catchment management framework being developed by the AMLR NRM Board.

- Identify and contrast proposed monitoring developed in the course of the ACWS in light of the ACWQIP.
- Engage with stakeholders through a workshop with the aims of;
    - Identifying/confirming the spatial framework for ACWQIP monitoring,
    - Reviewing current monitoring relative to the proposed monitoring framework suggested by the ACWS with consideration given to the indicators to be employed and the spatiotemporal sampling strategy.
    - Identify an appropriate mechanism for reporting progress against ACWQIP targets.

Approach

Development of a monitoring, assessment and reporting framework for the ACWQIP was undertaken on the basis that the process should coincide as much as possible with current activities. However, stakeholders with interests in coastal water quality and marine ecosystem health include a number of government agencies and industries with differing needs and motivations. The major stakeholders include;

- Environment Protection Authority (EPA),
- SA Water,
- Department of Environment and Heritage (DEH),
- Department of Water, Land and Biodiversity Conservation (DWLBC),
- Primary Industries and Resources South Australia (PIRSA),
- Adelaide and Mt Lofty Ranges Natural Resource Management Board (AMLR NRM) and
- Penrice Soda Holdings Ltd.

Relevant published works on the proposed monitoring for coastal water quality and ecosystem condition in the Adelaide region were reviewed with respect to the outcomes of the ACWS study as well as current monitoring activity undertaken by each stakeholder. Information that formed the basis of the review came from a recommended monitoring strategy developed as a component of the ACWS (Henderson *et al.* 2006) as well as supporting documentation on montoring activity (Dobbie *et al.* 2005). In addition, the final report from the ACWS (Fox *et al.* 2007) and various input studies for wastewater (Wilkinson *et al.* 2003), stormwater (Wilkinson *et al.* 2005a), groundwater (Lamontagne *et al.* 2005) and atmospheric inputs (Wilkinson *et al.* 2006) were also reviewed.

The integrated Environmental Monitoring Program (EMP) proposed by Henderson *et al.* (2006) outlines approaches for obtaining data on physical and biological processes along the Adelaide coast including water quality and associated seagrass condition. Importantly, this recommended plan was aligned within the framework of current (at that time) monitoring activities (see Dobbie *et al.* 2005, Henderson *et al.* 2006), such that synergies might be developed across a range of agencies. However, the EMP did not identify which agencies/stakeholders might be engaged to fill the gaps in the proposed monitoring regime. Furthermore, the development of the plan also predated the overall recommendations of the ACWS (see Fox *et al.* 2007) and consequently, there are no objectives or assessment criteria for management targets and related activity.

Results of the review were employed as the basis of a workshop with representatives of the major stakeholders held in Adelaide on June 16th 2008. In addition to the EMP review, participants were also presented with a summary of the ACWQIP and the background to a recently completed monitoring framework for the Adelaide and Mt Lofty Ranges NRM Board. Workshop participants were then asked to consider each aspect of the proposed monitoring strategy in light of current and proposed assessment frameworks with the aim of confirming/identifying the required indicators, the spatiotemporal sampling requirements and an appropriate reporting mechanism.

A list of the workshop participants and the agenda is presented in Appendix A.

The summary table of the recommended EMP from the ACWS that was employed in the workshop (derived from Henderson *et al*. 2006) is presented in Appendix B.

Overview of environmental monitoring & reporting needs for the ACWQIP

Background

While there are a large number of stakeholders with interests in coastal water quality and ecosystem health in the Adelaide region, three organisations have significant, wide ranging responsibilities, including the South Australian EPA, the AMLR NRM Board and the DEH Coast Protection Board.

Apart from its role as the principal driver of the ACWS and the development of the ACWQIP, the EPA has the responsibility for licensing of outfalls (e.g. SA Water, Penrice) into coastal waters a component of which includes compliance water quality monitoring and reporting. The EPA also has the authority to dictate and enforce targets for coastal inputs (such as those identified in the ACWQIP).

The AMLR NRM Board has wide ranging responsibilities for terrestrial and aquatic systems across the Adelaide metropolitan area, Mt Lofty Ranges and the Fleurieu Peninsula. The AMLR NRM Board has set stringent long term (20 year) regional targets for stormwater management (75% usage) and wastewater inputs (100% reused; AMLR NRM 2008) that have substantial implications for management of natural resources in the coastal region, and the progress towards the goals of the ACWQIP. The approach to meeting these self imposed targets are the focus for investments in on-ground works within the framework of their strategic plan, with annual reporting against short term goals with strategic summaries every 3-5 years.

The Department for Environment and Heritage (DEH) Coast Protection Branch maintains annual monitoring of beach and subtidal sand fluxes. Sand movements are based on measurements from a series of 39 rod lines approximately every 500 m along the Adelaide coast extending 1-2 km perpendicular to the shore, augmented with data from beach profiling and photopoints (DEH 2000). These ‘rodlines’ are accurately mapped and may form the basis for seagrass health monitoring in terms of locating permanent quadrats, transects and other sampling points (see Henderson *et al.* 2006). Along with acoustic mapping, DEH also undertakes the periodic aerial photography that has formed the basis for seagrass loss estimates (e.g. Hart 1997, Cameron 2003).

Monitoring for the ACWQIP must therefore occur within a broader assessment landscape that encompasses:

- EPA licence compliance monitoring,
- AMLR NRM targets, assessment and reporting strategies, including stormwater inputs (catchment management), coastal water quality and marine ecosystem health,
- DEH capability and current monitoring
- Other monitoring undertaken by organisations licensed to discharge (e.g. SA Water and Penrice) and
- targeted monitoring required by the ACWQIP to encompass gaps in the above.

Objectives

The monitoring strategy for the ACWQIP must encompass a range of objectives including:

1. progress with management activities and programs aimed at meeting the ACWQIP water quality targets,

2. direct measurements of input and coastal water quality,
3. indicators of ecosystem health (in particular seagrass and reef habitats),
4. activities aimed at understanding the broader environmental context for the observed changes in water quality and ecosystem functioning, and
5. assessments that align changes in water quality and ecosystem health with community values and expectations.

Spatial framework

Results from the stakeholder workshop confirmed that monitoring assessment and reporting should employ the same broad spatial framework as the ACWS (Figure 1). Whereas some simplification of these areas was discussed at the workshop (in particular the lack of need for the offshore zones - Zones 4 and 5), changes to this spatial framework would require additional public communication and consultation which would extend beyond the timeframe for this study. However, a review of the spatial framework is recommended wherein Zone 4 and Zone 5 are incorporated into the adjacent coastal zones (Zones 1 and 2 respectively). Some consideration might also be given to the Adelaide metropolitan catchment areas identified by Weber (2008) and how these relate to coastal monitoring zones.

Coastal inputs and indicators to be considered

The EMP developed by Henderson *et al.* (2006) as part of the ACWS proposed investigations across five main areas:

1. Land based inputs – stormwater, wastewater, industrial, groundwater and atmospheric
2. Coastal water quality
3. Sediment stability in the nearshore zone
4. Physical processes, and
5. Seagrass (or ecosystem) health

Importantly, it needs to be recognised that coastal water quality, physical processes and sediment stability all have implications for ecosystem health and environmental values (Figure 2). These facets may also influence other elements of the broader coastal system (including each other). For example, in addition to terrestrial inputs, coastal water quality, sediment stability and physical processes there is a “biological uptake” group (Figure 2) that along with the extant flora may comprise fast growing weedy/ephemeral organisms (either macro- or micro-algae) that could mask the presence of high nutrient levels through very rapid (but otherwise temporary) uptake and storage. Accounting for this group within the framework offered by Henderson *et al.* (2006) is problematic, although it may be included as a component of water quality (high chlorophyll *a* levels), high seagrass epiphyte loads and/or high levels of cover on artificial seagrass.

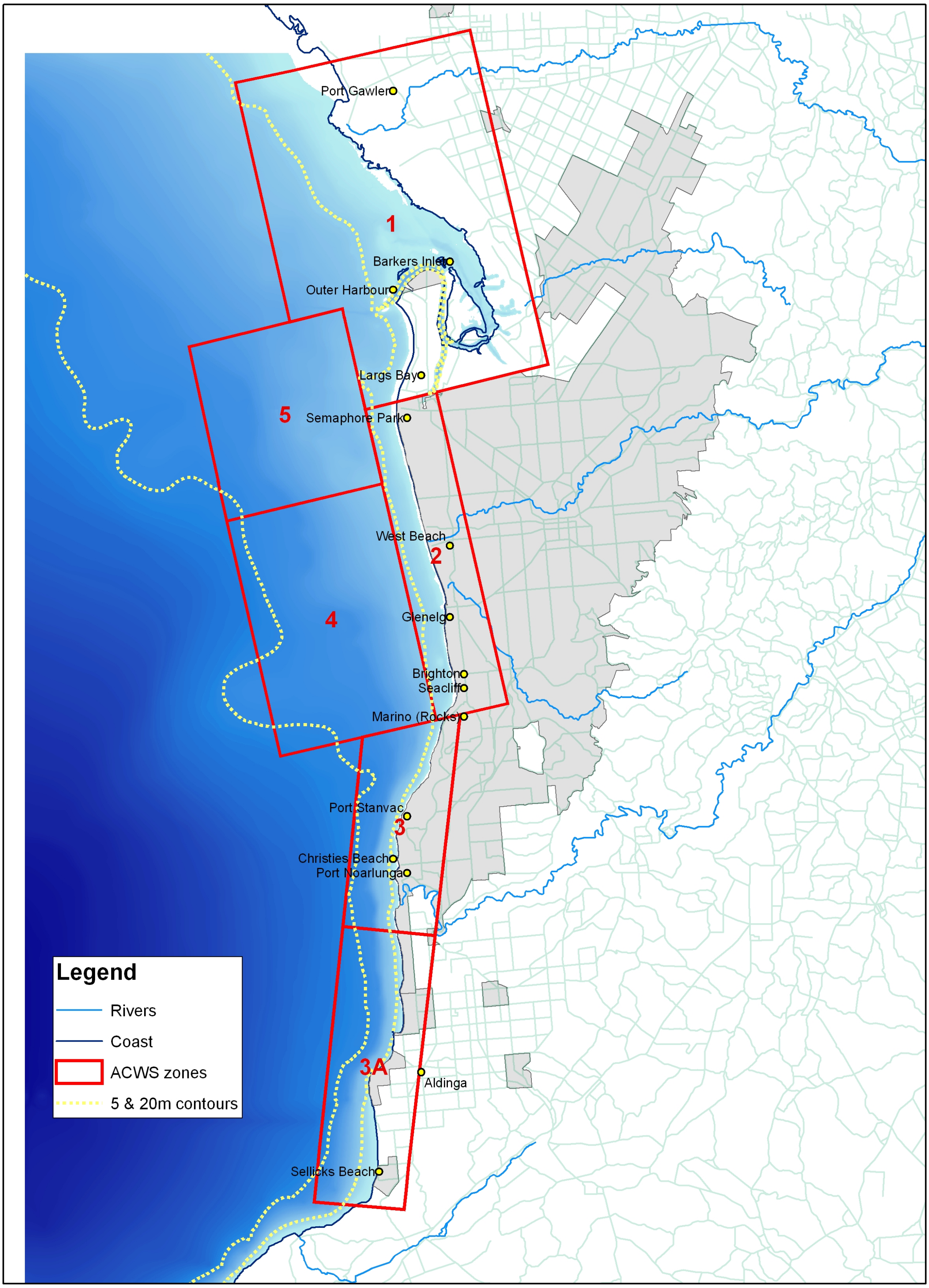

Figure 1 - Map of the Adelaide metropolitan coast showing each of the ACWS study zones. These zones were also used as part of designation of targets for the Water Quality Improvement Plan.

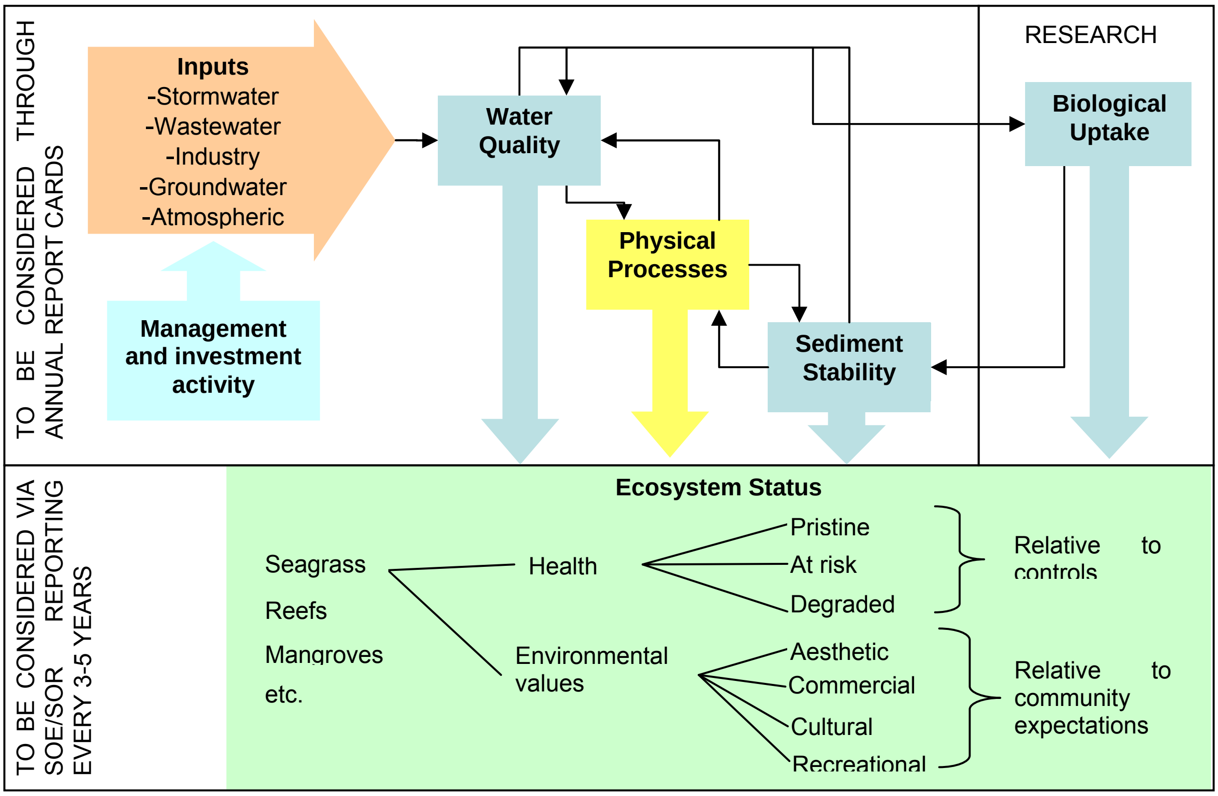

Figure 2 - Schematic showing each aspect of the monitoring as suggested by Henderson *et al.* (2006) aligned with monitoring processes for inputs, coastal water quality and sediment stability as well as ecosystem health/environmental values.

Resource condition monitoring

The indicators used to measure the implementation of the ACWQIP need to encompass management activities, resource condition and environmental values (Figure 2). However, this report focuses on the monitoring required for resource condition indicators, rather than management activities and environmental values. Management actions aimed at meeting ACWQIP targets are dependant upon the investment approach adopted by each of the relevant stakeholders. These management actions will comprise a diverse array of strategies and engagements with licensing authorities (chiefly the EPA), the assessment of which is beyond the scope of this report. However, the "Monitoring, Evaluation and Reporting Framework" (MERF) relates directly to the regional plan, developed by the AMLR NRM Board, and it has been structured to report against the progress of independent management actions across all agencies.

The monitoring and assessment framework developed for the ACWQIP therefore focuses on the indicators and sampling required to assess the outcomes of management activity with respect to each of the five main areas of concern identified by the Henderson *et al.* (2006).

A set of recommended resource condition indicators for estuarine, coast and marine systems has been proposed for the assessment of Estuarine, Coastal and Marine (ECM) habitat integrity as a component of the National Monitoring & Evaluation Framework (NM&EF; von Baumgarten 2007; Table 1)

Many of the indicators identified for ECM (Table 1**)** require a degree of interpretation for application in the field setting, particularly those related to ecosystem health. Within a reef system, species composition and cover may need to be constrained to larger canopy forming macro-algae within a predetermined area (e.g. 50 m transects). Similarly, species of the seagrass *Posidonia* can be difficult to differentiate in the field setting and are virtually impossible to differentiate with most remote sensing systems.

While there are systems for sampling the health status in both reefs and seagrass beds, it is critical that the application of these assessments is spatio-temporally consistent. For any long-term, large-scale monitoring regime the maintenance of consistency in sampling is a major challenge and it is important that the sampling regime is simple in terms of application but rigorous with respect to data quality.

Elsdon *et al.* (2007) considered the spatiotemporal variability of a number of water quality parameters along the South Australia coast with the aim of developing appropriate monitoring practices for NRM. The parameters considered included; temperature, salinity, pH, secci depth, chlorophyll a (Chl a), ammonia/ammonium (NH_3/NH_4^+), total Kjeldahl nitrogen (TKN), total nitrogen (TN), and nitrate and nitrite (NO_x). Results indicate that Total Nitrogen (TN) as well as Nitrate and Nitrite (NO_x) and secci depth measures were the best parameters to use for spatially referenced questions (differences between locations), while changes within sites across time were best considered with total ammonia (or TN) as well as secci depth. It should be noted that this does not mean to infer that other parameters need not be measured.

Table 1 outlines the minimum set of indicators required for large scale, long term estuarine, coastal and marine monitoring frameworks. The role of these indicators is to encourage a greater level of consistency in environmental monitoring and reporting and is not intended to be exclusive. The Marine and Coastal Managers Forum (MCMF) has recommended these indicators to the NRM Chief Executives Group and the MERF developed by the AMLR NRM Board has a mechanism for review and adoption of these indicators where appropriate (AMLR NRM 2008).

The draft ACWQIP has specific targets for total nitrogen and suspended matter. However, observations of total nitrogen and suspended solids alone are unlikely to inform managers as to water quality with respect to seagrass (and/or reef) health. A discussion document developed by the EPA for water quality in terms of indicators, sampling locations and frequency (Gaylard and Duncan UNPUBLISHED) recommended the following indicators be considered;

- Total nitrogen
- Total ammonia
- Oxidised nitrogen
- Total phosphorus
- Soluble phosphorus
- Water clarity (measured via Secci disk)
- Chlorophyll *a*

It should be noted that all of the above align with the water quality indicators identified in the ECM indicators for coastal water quality (Table 1).

Table 1 - List of resource condition indicators for estuarine, coast and marine environments developed by the Estuarine, Coastal and Marine Habitat Assessment, elements of which will be included in the MERF. Note the "pest species listed above" relates to the priority species employed in community monitoring and thus relates to species that can be identified in the field setting (Neverauskas pers.com.).

1. Animal or plant species abundance (includes extent, density, patchiness and cover) *Animal and plant species that have been selected include Seagrass, mangroves and saltmarshes.*	
Pest Species	• Pest species extent and abundance through targeted monitoring of likely recruitment sites such as artificial structures (jetty pylons, wharfs, artificial reefs etc) or impacted sites using simple methods such as fixed photographic points.
Beach/Sand Dunes	• Abundance and diversity of dune vegetation • Fauna diversity and abundance, especially birds • Pest Species presence and abundance recorded during other monitoring programs for species listed above.
Rocky Reefs	• Faunal diversity and abundance (subtidal and intertidal) • Macroalgae abundance and diversity • Abundance and extent of epiphytes • Pest Species presence and abundance recorded during other monitoring programs for species listed above.
Mangroves	• Change in the distribution and abundance of mangrove species • Mangrove area • Population structure and density of mangroves • Recruitment of mangroves • Fauna diversity and abundance • Infauna diversity and abundance • Bird diversity and abundance • Microphytobenthos diversity • Abundance and extent of epiphytes • Pest Species presence and abundance recorded during other monitoring programs for species listed above.
Saltmarshes	• Change in the distribution and abundance of saltmarsh • Saltmarsh area • Population structure and density • Faunal diversity and abundance • Microphytobenthos diversity • Abundance and extent of epiphytes • Pest Species presence and abundance recorded during other monitoring programs for species listed above.
Seagrasses	• Change in the distribution and abundance of seagrass • Seagrass area • Population structure and density of seagrass • Volume of seagrass wrack deposits on soft sediment beaches • Primary productivity of dominant species inhabiting seagrass habitats • Abundance and diversity of fish and crustaceans • Abundance and extent of epiphytes • Pest Species presence and abundance recorded during other monitoring programs for species listed above.

Unvegetated Soft Sediments	• Epifauna diversity and abundance • Infauna diversity and abundance specially major polychaetes • Bird diversity and abundance • Macro and microalgae including microphytobenthos • Pest Species presence and abundance recorded during other monitoring programs for species listed above.
2. Quality of Coastal waters assessed against national water quality guidelines	
Turbidity / water clarity	• Secci disc reading
Temperature	Considered a validation parameter for other indicators selected.
Nutrients	Dissolved nutrients in the water column: • Nitrogen TKN • Total Ammonia • Oxidised Nitrogen • Total Phosphorus • Soluble phosphorus
Chlorophyll	• Chlorophyll in the water column
3. Fish Stock Status	
Stock status of the main fisheries species targeted by commercial and recreational fishers	• King George Whiting • Garfish • Snapper • Calamary

Coloured Dissolved Organic Matter (CDOM) was identified by the ACWS as well as the ACWQIP as being an important factor for coastal ecosystem health (Fox *et al.* 2007). However, CDOM is not recognised as a recommended ECM water quality indicator (although Secci disc readings will integrate turbidity and CDOM levels; Table 1). Measurements of CDOM with respect to coastal water quality are relatively rare (see Dobbie *et al.* 2005), although SA Water reports CDOM as colour as a component of their compliance monitoring. In developing a model of Adelaide catchments, Weber (2008) employed Total Organic Carbon (TOC) as a proxy for CDOM. The workshop identified a need to investigate what measures might serve as proxies for indicating CDOM levels.

Current water quality monitoring is best described as sporadic and uncoordinated between the stakeholder groups in terms of both the frequency (daily, monthly or quarterly) as well the suite of parameters considered and the respective measurement units employed. For the purposes of both the ACWQIP and the MERF objectives, a consistent set of water quality parameters along the lines of those identified for ECM habitats (von Baumgarten 2007; Table 1) should be employed by all stakeholders, with the inclusion of new indicators, such as CDOM.

Reporting framework

There is considerable commonality in the both the objectives, targets and monitoring requirements for the ACWQIP and AMLR NRM Board with respect to coastal inputs and ecosystem status. It is therefore recommended that the ACWQIP targets be considered and developed to ensure the highest level of complementarity with the recently finalised Monitoring, Evaluation and Reporting Framework (MERF; AMLR NRM 2008). The MERF defines a structure for consideration of Resource Condition and Management Action Targets that are key elements of NRM in Australia. Resource Condition Targets (RCTs) represent the long term vision for the status of environmental assets (e.g. seagrass ecosystems, coastal water quality, stormwater retention/reuse, etc.) and tend to comprise long term (20 years or more) aspirations. In line with these aspirations, South Australian NRM boards are required to develop regional plans for monitoring, mitigation, control and rehabilitation projects and an associated investment strategy. Management Action Targets (MATs) represent assessment criteria for these NRM investments and are typically considered in relatively shorter timeframes (< 5 years). The MERF will form the basis for reporting by the AMLR NRM Board with respect to management activity and resource condition, the results of which will be used to evaluate current and future investment strategies in accordance with the associated NRM strategic and business plans. Importantly, the AMLR investment strategy includes reef health monitoring programs with respect to both the targeted assessment of reefs undertaken by SARDI Aquatics (and associated agencies; see Turner *et al.* 2007) as well as the caretaker role undertaken by Reef Watch (AMLR NRM 2008).

Within this framework, management progress toward meeting ACWQIP water quality targets and ecosystem health responses can delivered through a modest augmentation of the MERF, particularly given that the same indicators and datasets are to be considered in many instances. For example, "end of valley" water quality monitoring for stormwater can be used to report against the progress of AMLR NRM Board investments and activity within respective catchments, but this can also be used to report against ACWQIP water quality targets. There are a number of additional advantages including:

- The reporting timeframes will align well for ACWQIP targets.
- Reporting will occur against both management action <u>and</u> resource condition targets.
- Much of the data are to be collected by AMLR NRM for their own reporting with most of the remainder likely to come from the EPA.
- The monitoring and reporting framework developed by the AMLR NRM Board is relatively simple with ready application across a range of stakeholders (including government, industry and public sectors).
- Combining with AMLR NRM reporting adds weight to sustaining the longer term monitoring and assessment needs of both the ACWQIP and the AMLR regional NRM plan.

While the AMLR NRM Board may take responsibility for some of the reporting requirements, it will remain the responsibility of the EPA to engage with stakeholders in terms of meeting (or failure to meet) the designated targets. In addition, NRM reporting will most likely not include all of the Environmental Values identified by the EPA. Although there are economic, social and environmental indicators within the MERF, social factors are relatively new with respect to NRM monitoring (AMLR NRM 2008).

Intermediate reporting targets (8-10 years) were considered to be important by a number of workshop participants and may be useful given that the ACWQIP targets are slated for completion in 15 years (~ 2023). Such targets are outside the context of current NRM reporting framework and therefore would likely require independent reporting.

Land based inputs to Adelaide Coastal Waters

Five different pathways exist via which sediments, nutrients, toxicants and other pollutants enter Adelaide's coastal waters. These comprise:

- Stormwater runoff including rivers, creeks, pipes and drains,
- Treated wastewater from Bolivar, Glenelg and Christies Beach WWTPs,
- Industrial wastewater, in particular Penrice Soda Holdings Ltd in the Port River,
- Groundwater seepage and
- Atmospheric including rainfall and dryfall (dust) deposition.

Stormwater inputs

Wilkinson *et al.* (2005a) provides an excellent summary of the coastal inputs from major stormwater rivers, creeks and drains for the Adelaide region, including an overview of the monitoring programs from which the estimates were derived. Regular and ongoing sampling of rivers and creeks for flow rate, nutrients and suspended material has been limited to discharges from the Torrens River, Patawalonga Basin, Field Creek and Christies Creek with automated sampling analysed on a weekly basis (at least until 2005). Data for the other important riverine inputs comprising the Onkaparinga River and Pedler Creek appear to be limited to monthly grab samples that are difficult to compare to those obtained automatically (the latter are an integrated measure). Importantly, Wilkinson *et al.* (2005a) did not find any data collected on most of the larger stormwater drains and pipes in terms of either flow or contaminants. Between Largs Bay and Seacliff there are over 100 stormwater pipes and drains of various sizes but there is a paucity of data on discharge via these systems (Wilkinson *et al.* 2005a).

Stormwater inputs from rivers, streams, pipes and drains are primarily monitored by the AMLR NRM Board which has set an ambitious long term target requiring 75% retention and/or reuse over the next 20 years (AMLR NRM 2008). In addition, the Board has set criteria for improvements to the water quality of stormwater inputs, in particular reductions in turbidity and nutrient levels, which broadly align with targets specified in the ACWQIP. These targets present challenges given Adelaide's increasing population and the associated urbanisation both to the north and south of the CBD as well as the potential impact of global warming on catchment ecosystems. While there is substantial interest in improving stormwater infrastructure and retention, including Aquifer Storage and Recovery (ASR), encouraging or requiring rainwater tanks and water sensitive urban design (WSUD), the implementation of these approaches has a long way to go.

The targeted monitoring of stormwater inputs for the AMLR NRM region includes composite samplers for "end of valley" monitoring of all major creeks, streams and drains (estimated to encompass 80-85% of the total stormwater input). Along with upstream monitoring, this infrastructure will form a critical component of the catchment management strategy for the AMLR NRM Board, and is directly aligned with the monitoring needs of the ACWQIP.

There may be opportunity for engagement with some local government instrumentalities to obtain additional data on water volumes and quality in stormwater drains which cover some of the remaining 15% of stormwater inputs (particularly as some apparently minor drains could be quite significant in terms of output). However, it needs to be recognised that stormwater infrastructure in Adelaide is complex and there are a large number of inputs (pipes and drains) into the near shore region (Westphalen *et al.* 2004, Weber 2008) and this makes comprehensive coverage more difficult and expensive.

The stakeholder workshop identified the need to determine what constitutes environmental flows for rivers, creeks and streams in the Adelaide region. Putting aside the fact that most riverine inputs have been highly modified by urbanisation, the remaining wetlands and estuaries should receive attention under both AMLR NRM Board regional plan as well as the ACWQIP in terms of flow entitlements for environmental purposes.

Indicators

Indicators for stormwater should include those recommended for ECM for coastal water quality (von Baumgarten 2007; Table 1) with the addition of CDOM.

Sampling

Integrated (flow proportional) sampling should occur at all sites. The timing of sampling will be dictated by flow volumes.

Data on upstream events, in particular overtopping of weirs and dams should be included in reporting.

Data analysis and reporting

The AMLR NRM Board will collect and report on stormwater discharges (and catchment management activities in general) and resource condition both annually (report cards) and more comprehensively at 3-5 year time scales (AMLR NRM 2008).

Wastewater treatment plant outfalls

SA Water conducts both “end of pipe” monitoring for each outfall (or channel as in the case at Bolivar) as well as receiving waters monitoring as part of licensing requirements with the EPA. The latter comprises 15 sites across the metropolitan coast associated with the Glenelg and Christies Beach WWTPs as well as the Patawalonga and River Torrens discharges, although it should be noted, there is no receiving waters monitoring related to the Bolivar Outlet (Dobbie *et al.* 2006, Henderson *et al.* 2006).

“End of pipe” (or channel) measurements as required by EPA licensing should continue although with measurements need to be focussed on measurements of total pollutant load rather than simply the concentration of pollutants. Alignment of the indicators with those required by ECM habitats (Table 1) for coastal water quality is highly recommended, although this should not preclude measurement of factors not related to the ACWQIP such as bacteria and heavy metals, as currently required by the EPA.

Existing monitoring of the quality of receiving waters on the Adelaide coast should be continued at a routine level.

We would recommend that current monitoring be extended to incorporate an extensive assessment of stable nitrogen isotopes similar to that trialled in the ACWS. The ACWS study found that the influence of nutrients from wastewater had broad spatial impact (see Bryars *et al.* 2006). Stable nitrogen isotope surveys will aim to determine the spatial extent of wastewater nutrient impacts. This would provide more effective measurements of the movement of waste water derived nutrients through the system and improve greatly on current measures of dissolved nutrients (Bryars *et al.* 2006). Further, the health of selected seagrass beds can then be measured and interpreted directly against the exposure of ecosystems to wastewater derived nitrogen.

Indicators

"End of pipe" monitoring should report indicators that inform managers about total pollutant load rather than simply concentration. Consideration should be given to ensuring alignment between SA Water monitoring and the indicators required for ECM assessment (Table 1).

Stable nitrogen isotope ($\delta^{15}N$) measurements should be obtained from seagrasses (*Posidonia* leaves – note that *Amphibolis* is relatively patchy on the Adelaide coast).

Sampling

The ACWS sampling regime for stable nitrogen isotope measurement (see Bryars *et al.* 2006) collected four replicate seagrass samples (clump of leaves and roots) at 5 – 10 m depth from 16 sites between Sellicks Beach and Port Gawler and a further 8 sites around Gulf St Vincent. A single leaf from each replicate was used in the analysis. In the first instance, a similar regime might be adopted for ACWQIP monitoring, with data collected from each site at least annually.

A review of stable isotope measures as indicators of wastewater footprint, including the location and number of sites as well as sampling frequency should be undertaken after 3-5 years (in alignment with NRM reporting).

Data analysis and reporting

The EPA should work with SA Water to implement changes for end of pipe measurements to ensure that nutrient loads rather than simply concentrations are measured. This should include responsibility for seagrass sampling for stable isotope measures. Through its involvement in the ACWS stable isotope survey, SARDI Aquatics has expertise in this area and may be engaged by either SA Water or the EPA to undertake this monitoring and reporting.

ACWQIP reporting for input indicators (end of pipe) and stable isotope sampling should rest with the EPA.

Industrial inputs – Desalination plant

The proposed desalination plant at Pt Stanvac will discharge hypersaline water to Gulf St Vincent. There is not expected to be any substantive change in nutrient loads associated with the waste stream but there may be localised increases in concentration around the discharge pipe. While sludge generated by the plant is expected to be disposed of as land fill, there may be issues with respect to back-flushing of pipelines or additives employed in this operation, including antiscalants, coagulants and flocculants.

The EPA will define licensing requirements for the outfall (distance from shore, diffuser structures, etc) as well as permissible discharge levels, dilution factors and an associated monitoring regime.

Indicators

Indicators for desalination discharge waters should include those recommended for ECM for coastal water quality (Table 1) with the addition of other measurements as deemed appropriate by EPA licensing which will probably include dissolved oxygen and salinity profiles.

Sampling

Sampling of the desalination plant discharge should align with SA Water monitoring for other "End of pipe" outfalls.

The EPA may also require some receiving waters monitoring to verify that dilution criteria are being met.

Data analysis and reporting

Both water quality measurements as well as indicators of ecosystem status in the vicinity of the outfall should be reported on at least quarterly (and more frequently when the plant is first commissioned).

Industrial inputs – Penrice

The Penrice Soda Holdings Ltd discharge comprises a significant nitrogen input to Adelaide's marine environment (Wilkinson *et al.* 2005b). EPA data (EPA 2005) suggests that Penrice is the major contributor of nitrogen between Outer Harbour and Semaphore and accordingly have set a substantial reduction target under the ACWQIP.

Indicators

The current suite of load based indicators should be sufficient for ACWQIP reporting needs although clarification was been requested with respect to the units required by the current licensing arrangement.

It is recommended that the EPA undertake to clarify the measurement requirements and units required for the Penrice outfall monitoring as part of licensing arrangements.

Sampling

No changes are suggested to the current sampling regime.

Data analysis and reporting

No changes are required with respect to quarterly reporting arrangements between Penrice and the EPA.

The EPA shall have responsibility for reporting against ACWQIP targets.

Groundwater inputs

Groundwater discharge to the Adelaide metropolitan coast is estimated to be relatively small[1], with associated nitrogen inputs of < 50 ton N year^{-1}, although most observation wells are some distance from the coast and there is a high level of uncertainty associated with this assessment (Lamontagne *et al.* 2005). DWLBC maintains groundwater monitoring mostly related to salinity and water level through their Drillhole Enquiry System (DES; http://info.pir.sa.gov.a/des.desHome.html) and Obswell programs[2]. Recommendations from the ACWS input study for groundwater (Lamontagne *et al.* 2005) include a need for improved monitoring capacity.

In the future Aquifer Storage and Recovery (ASR) programs are likely to form an integral component of stormwater management for the Adelaide region. Current ASR programs require EPA monitoring for aquifer salinity, although input volumes and water quality data should also be collected as components of stormwater reuse.

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[1] Comprising less than 5% of total nitrogen inputs to this region.

[2] http://info.pir.sa.gov.au/obswell/new/obsWell/MainMenu/Menu

Indicators

Where required, indicators should align with those specified for ECM assessment (Table 1), but should also include salinity and water level measures.

Sampling

Given that groundwater discharge to coastal systems is considered to be low, there is arguably little need for targeted monitoring with respect to the ACWQIP. However, monitoring with respect to ASR inputs will be included as a component of AMLR NRM reporting.

Identification and sampling of groundwater sources closer to the coast may reduce the uncertainty identified in the Lamontagne *et al.* (2005) estimates.

Data analysis and reporting

Groundwater status is covered through AMLR NRM reporting, which should include the results from monitoring of ASR programs.

Atmospheric inputs

Wilkinson *et al.* (2006) considered wet and dryfall to be relatively minor in terms nitrogen inputs (~ 3% NOx, ~ 2% TKN and ~ 2% Total Nitrogen combined). However, the dryfall or dust deposition of particles less than 10 µm (PM_{10}) were estimated to account for ~18% (1,852 tonnes) of total annual input to coastal systems. Airborne particulates were also considered to be important in terms of a source for lead and copper input (Wilkinson *et al.* 2006).

There is no direct management of dryfall to coastal systems but, given the quantity involved, some measure of deposition should be obtained such that changes in other sediment inputs, in particular stormwater, can be put into context and are not masked or enhanced by alteration in the dryfall component.

Indicators

Atmospheric contribution to sediment loads should be reported relative to each monitoring zone based on dustfall measured in $\mu g\ m^{-3}$ of particles less than 10 µm (PM_{10}).

Sampling

The EPA currently conducts air quality monitoring (including PM_{10}) at 4 - 7 locations around the Adelaide metropolitan area (EPA 2007, http://www.epa.sa.gov.au/airindex.html#map). The Wilkinson *et al.* (2006) study was based on the data from one of these stations at Osborne in the north. Integration of the particulate data from across all air quality measurement stations would improve the estimate of coastal deposition.

Data analysis and reporting

The EPA Air and Noise Branch is currently responsible for monitoring and reporting on Adelaide's air quality including dryfall. While some reference to coastal water inputs might be achieved through this framework, a dedicated analysis and report should be developed every 3-5 years (in line with NRM reporting) through the ACWQIP.

Water quality and sediment stability

Coastal water quality

Originally Beach/Jetty sampling by the EPA was undertaken monthly (fortnightly in summer) at from 8 – 10 sites on the metropolitan coast (there is some confusion about the precise number and location of sites; see Gaylard 2004, Dobbie *et al.* 2005, Henderson *et al.* 2006). Sampling is now conducted quarterly.

In addition to monthly jetty and beach sampling, Henderson *et al.* (2006) suggested that mid and offshore sampling should be undertaken. However, given that there are solid arguments for discontinuing the receiving waters sampling by SA Water, including the availability of long term datasets and hydrodynamic models, expansion of the current EPA program would seem unwarranted and logistically problematic. Rather it is recommended that the current sampling regime continue, possibly with the inclusion of some event based sampling relative to rain and storm events, which would align more with stormwater sampling. There is also a need to better integrate compliance water quality sampling associated with dredging and beach sand replenishment operations.

The workshop noted that the current sampling regime predates the ACWS and as such does not align with its recommendations. Locations on the Adelaide coast with poor water quality have been identified, but there was no sampling relative to risks either in terms of seafood safety or threats to ecosystems. It was concluded that there was a lack of rigour in the current sampling regime and therefore a need to identify an appropriate balance between temporal (how often to sample) and spatial (how dense) needs relative to ecosystem condition and the ACWQIP. The EPA is in the process of reviewing the sampling strategy.

The workshop also considered the potential for some telemetry linked automated samplers, notably for turbidity in coastal systems using a similar structure to that employed in the Murray River. Although costly to set up, the ongoing costs for running this infrastructure is relatively low compared to employing a dedicated monitoring team and may cover some of the shortfall created by reducing the ongoing to quarterly from monthly as well as form a better mechanism for capture of event based samples. It should be noted that neither turbidity nor salinity are considered to be MCMF water quality indicators (Table 1). Further investigation of this approach should be undertaken with the view to identifying the total costs per unit and the potential for a joint bid from a range of agencies (chiefly EPA, DEH, AMLR NRM amongst others).

Indicators

Indicators should include those identified for ECM for coastal water quality (Table 1), although note that seafood safety and public health and amenity indicators would be included.

Sampling

A review of the current sampling regime is required wherein the spatiotemporal requirements for coastal water quality sampling are more rigorously defined relative to threats.

Investigation into the pros and cons of telemetry based sampling should be undertaken.

Otherwise quarterly jetty/beach monitoring should continue (with possible higher intensity in summer). The inclusion of event-based sampling as well as integration of dredging and beach replenishment monitoring data should be considered within this framework.

Data analysis and reporting

The EPA has a framework for reporting on coastal water quality monitoring (see Gaylard 2004), although the capacity to link the analysis and interpretation to input monitoring as well as ecosystem health would be more efficiently achieved through AMLR NRM reporting.

Sediment stability

Ongoing surveys into sand movements along the Adelaide metropolitan coast as part of the beach replenishment program have been undertaken by the Coast Protection Board (DEH) since 1975 (DEH 2000, 2006b). Sand fluxes have traditionally been estimated based on measurements from a series of 39 lines of brass rods approximately every 500 m along the Adelaide coast extending 1-2 km perpendicular to the shore, augmented with data from beach profiling and photopoints (DEH 2000). However, advances in technology (Global Positioning Systems and dual scan sonar) have been used to further augment the data from these transects (DEH 2006b).

While the measurements are obtained relative to the exposure of rods to the nearest centimetre, sand budgets for the coast are generally mapped in terms of the gain or loss of sand in cubic metres from different sections of the coast (DEH 2000). Sand fluxes along the coast are an important indicator of the energy environment as well as one of the major negative manifestations of seagrass loss and declines in reef health (Westphalen *et al.* 2004, Turner *et al*. 2007). Sediment stability mapping thus forms a critical indicator against which other factors (e.g. water quality and hydrodynamic processes) can be compared, with reference to ecosystem health.

Importantly, the rodlines form the basis for much of the survey recommendations from Henderson *et al.* (2006) in terms of locating other forms of monitoring (notably seagrass health sampling). Otherwise the Henderson *et al.* (2006) recommended approaches to sediment stability surveys are essentially a review and possible expansion of the existing rodlines program. However, the workshop identified a need to include investigations on sediment grain size analyses, cliff stability and intensive sampling targeted at high risk areas. The latter could potentially link more closely to coastal water quality sampling, in particular event-based observations as well as telemetry (should this be pursued).

Grain size data as well as identification and monitoring of high risk areas (including cliff erosion) can be included within the sand budget mapping. Importantly, sediment stability would appear to be a critical factor in the success of seagrass re-establishment (both naturally occurring and facilitated).

In addition, spatiotemporal documentation of dredging and sand dumping as part of port and harbour maintenance as well as beach sand replenishment operations need to be more rigorously established (Henderson *et al.* 2006).

Indicators

Indicators for sand budgets should be unchanged.

Sampling

No substantive changes to the current sampling and reporting regime with respect to sand budgets.

Sediment grain size analyses may be considered.

Cliff erosion monitoring, possibly based on photopoints (similar to beach sand observations).

Data analysis and reporting

Current reporting arrangements undertaken by DEH for sediment budget and beach replenishment program should continue. From the perspective of the ACWQIP, a more important output would be the generation of appropriately scaled GIS maps of the ensuing data, including the additional information on high risk areas and grain size.

Environmental Status of ACW ecosystems

Henderson *et al.* (2006) suggested that both coastal seagrass and reef ecosystems should be assessed to report on ecosystem health, although other habitat types might also be considered. The ECM indicators identified six coast and marine habitat types as well as two species related groups (von Baumgarten 2007; Table 1) including;

- Unvegetated soft sediment,
- Seagrasses,
- Saltmarshes,
- Mangroves,
- Rocky reef,
- Beach/dune systems,
- Pest species and
- Fishery stock assessments (commercial and recreational).

Seagrass and reef health should form the primary means of investigating ecosystem status with respect to the ACWQIP. Apart from the fact that the health of these systems on the Adelaide coast has been cause for concern (Fox *et al.* 2007, Turner *et al.* 2007), this approach also acknowledges that while both systems may be used as integrated measures of water quality, seagrasses are arguably more sensitive to nutrient levels while reefs tend to respond more to sediment deposition. Apart from the ACWS, there are also solid historical datasets for the distribution of seagrass on the metropolitan coast (extending back to the 1930s; Westphalen *et al.* 2004) as well as investigations into the status of reef systems as far back as the mid 1990s (Turner *et al.* 2007) and historical information about reef health including that reviewed in Connell *et al.* (2008).

While there are no specific targets for ecosystem health within the ACWQIP, the MERF has a general long term target "Halt in the decline of habitat and a trend toward restoration" for seagrass and reef habitats (amongst others; AMLR NRM 2008). This target acknowledges the need for a pragmatic approach to ecosystem health in that, even with favourable water quality conditions, recovery of these systems will be extremely slow, especially for *Posidonia* species (Kirkman 1998, Meehan and West 2000). The expectations for ecosystem health, given successful progress towards the ACWQIP targets is for a halting of degradation, and creating conditions wherein there is scope for recovery. However, it must be assumed that there will be no substantial reestablishment of seagrass systems, even over timelines of 20 years or more, unless remedial works to re-establish meadows in degraded areas are successfully undertaken.

The stakeholder workshop also supported the inclusion of fisheries data into ecosystem health assessments. This approach has the advantage of the protracted period over which historical data has been obtained and, in some instances, may be also serve to broaden the stakeholder engagement.

Seagrass

Current monitoring activity for seagrasses on the Adelaide metropolitan coast relates to periodic distribution mapping almost exclusively from aerial photography. Recent advances have shown that there is also potential to obtain additional data from dual frequency sonar surveys as well as side scan sonar/swath mapping. These could be conducted at ten yearly intervals and comprise a component of sediment stability observations by DEH. However, there appears to be little, if any, published data reporting on the results of seagrass distribution from acoustic surveys. While the available aerial photographic mapping may to a large degree circumvent the need to analyse the historical acoustic data, there is currently no formal framework for ongoing aerial photography on the Adelaide coast (Henderson *et al.* 2006), although DEH has just recently completed another survey (Fotheringham pers. comm.). The capacity to extract seagrass distributional data from acoustic surveys and to combine this with aerial survey data needs to be more thoroughly developed.

Other monitoring activity for seagrass health comprise numerous "one off" studies in terms of species composition, density and epiphyte load (e.g. EWS 1975, Moore 2006, Bryars *et al.* 2006, Bryars 2008) but there is otherwise no ongoing seagrass health assessment program for the Adelaide coast.

Airborne remote sensing was conducted as a component of the ACWS with the aim of identifying species distributions (Blackburn and Dekker 2006), but the results were of little practical value and this approach has been discounted as an ongoing monitoring tool.

The recommended monitoring requirements from the ACWS for seagrass health requires an approach incorporating aerial imagery, acoustic surveys, quadrats, permanent markers, video transects and diver transects variously spread across all ACWS zones (Henderson *et al.* 2006; Appendix B). In addition, the is a need to identify sites for seagrass monitoring at reference (or control) locations outside the ACWS area such as Wallaroo and Port Hardy in Spencer Gulf (Henderson *et al.* 2006) that will assist in placing changes in seagrasses on the Adelaide coast within an appropriate context.

The workshop broadly endorsed the sampling methods for seagrass health that were identified by the Henderson *et al.* (2006) proposal although it was concluded that a working group with appropriate expertise should be engaged to operationalise these monitoring tools such that each was employed within a mutually supporting framework. For example, video transects may be used to bridge the gap in scales between aerial photography and diver transects and quadrats, such that the latter can be more appropriately targeted. Conversely, the same video surveys may also indicate the spread of patches of seagrass with similar finer scale structure determined from quadrat sampling.

The stakeholder workshop also identified the need to monitor epiphyte loads on artificial seagrass as another integrated indicator of water quality (this component was considered by Henderson *et al.* (2006) as a part of coastal water quality – see Appendix B). Similarly to the surveys of seagrass distribution and density, the spatiotemporal sampling requirements for artificial seagrass monitoring need to be identified.

Indicators

The indicators identified by Henderson *et al.* (2006; Appendix B) include;

- Fixed quadrats – 25 × 25 cm (8 – 10 per site with four sites per zone):
    - Species composition,
    - *Posidonia* - shoot density,
    - *Posidonia* - leaf length,
    - *Posidonia* - leaf area index,
    - *Amphibolis* - plant density,
    - *Amphibolis* – number of leaf heads and

    - *Amphibolis* – number of leaves per leaf head.
- Permanent markers (may be associated with the 39 DEH rodlines);
    - decline or advance in the edge of a seagrass bed.
- Fixed diver transects – 100 to 200 m long (three per zone):
    - Presence/Absence at 1 m intervals, and
    - Species composition at 1 m intervals.
- Fixed video transects of variable length (three per zone):
    - canopy size,
    - canopy density, and
    - epiphyte loads.
- Aerial photography and possibly acoustic mapping:
    - seagrass distribution.
- Artificial seagrass models and epiphyte growth:
    - loads/counts as a mean dry weight.

The above broadly align with four (out of a total of eight) of the resource condition indicators specified by the MCMF (Table 1) including:

- Change in the distribution and abundance of seagrass,
- Seagrass area,
- Population structure and density of seagrass, and
- Abundance and extent of epiphytes.

Sampling

While the ACWS zones should be employed to establish the broader spatial sampling framework, other information might be used to target investigations to particular areas within zones. Some consideration might also be given to the stable isotope survey (discussed above) as an additional means of designating appropriate sampling areas.

Henderson *et al.* (2006) recommends different sampling intensities for each element of the sampling regime. However, the development of a more integrated and focussed approach will require assessment by the proposed working group. The number and distribution of samples for video transects, diver transects, permanent markers and quadrating will require an analysis of the system across a range of scales, starting with aerial images to target video transects that may themselves be employed in diver transects and quadrating. The ensuing target list of sites will then need to be prioritised against logistic constraints as well as the perceived level of risk. Certainly Holdfast Bay should be the focus for seagrass health investigations (ACWS zones 2, 3 and possibly 4; Figure 1). Appropriate control locations to compare and contrast with metropolitan coast sites also need to be identified.

Sampling should perhaps be conducted at least annually for quadrats, diver transects and permanent markers, with video surveys and aerial photography obtained every 3-5 years. However, a review along the lines of that proposed for the EPA coastal water quality monitoring may find that less frequent observations from a larger number of sites is a better approach to balancing data requirements and logistic concerns (and would be consistent with the timing of the Reef Health surveys).

Data analysis and reporting

Agencies with the capacity and capability to undertake seagrass health monitoring analysis and reporting includes DEH, SARDI and/or the Universities. However, seagrass monitoring will need a working group to both define and then coordinate operations and may include representation from a range of agencies (including the above). Analysis and reporting will also need to be integrated and/or aligned within the broader SOR/SOE reporting framework undertaken for the AMLR NRM Board, probably every 3-5 years.

Reef ecosystems

The health status of reef systems on the Adelaide metropolitan coast has been considered either as a component of comprehensive research programs or informally through a process of community monitoring. Comprehensive surveys of metropolitan reefs have occurred on three occasions since 1996 (see Cheshire *et al.* 1998a, Cheshire and Westphalen 1999, Turner *et al.* 2007), with reporting from a fourth survey currently in review. All these surveys identified a zone of degraded reefs in the northern metropolitan waters (roughly equating to ACWS zone 2), at risk reefs in a central area (approximating ACWS zone 3) and less impacted or "pristine" reefs in the south (ACWS zone 3A). Disturbingly, there is some indication that the degradation of reefs may be expanding to the south (Cheshire and Westphalen 1999) which correlates with the area of seagrass loss, water quality decline (Turner *et al.* 2007) and coastal urbanisation.

Informal reef monitoring undertaken on the Adelaide coast has been undertaken since 1997 by a community organisation called Reef Watch (http://www.reefwatch.asn.au/, Accessed June 2007). Both comprehensive and informal reef assessments employ a non-destructive sampling method based around Line Intercept Transects (LITs) that measure the percentage cover of community dominants over comparatively large areas of reef relative to traditional (i.e. quadrating) methods (Turner 2004). Importantly, this approach limited the need for highly resolved taxonomic knowledge (Miller *et al.* 1998, Turner *et al.* 2007) such that sampling can be undertaken by observers with relatively limited prior knowledge or training.

Indicators

The workshop considered that inclusion of reef health would be a critical component of the ACWQIP assessment program. Importantly, the categories for reef health status (i.e. degraded, at risk or pristine; Figure 2) offers a ready mechanism for alignment with water quality characteristics. However inclusion of reefs requires an improved set of simplified measurement indices to categorise reefs and a more rigidly implemented assessment program.

Earlier reef health surveys (1996 and 1999) considered relatively few factors in assessing reef status (Cheshire *et al.* 1998a, Cheshire and Westphalen 1999), including the coverage of;

- robust brown macro-algae,
- foliaceous brown macro-algae,
- encrusting red macro-algae,
- foliaceous red macro-algae,
- turf forming macro-algae and
- mussels.

Turner *et al.* (2007) expanded on these indices for the 2005 survey such that macro-algal and mussel cover were considered along with several other factors to provide a total of 11 indicators including;

- Cover based indicators
    - Areal cover of canopy-forming macroalgae
    - Areal cover of turfing macroalgae
    - Areal cover of mussel mats
    - Areal cover of bare substrate
- Abundance
    - Size and abundance of blue-throated wrasse
    - Abundance of site-attached fish
    - Abundance of mobile invertebrate predators
- Presence
    - Presence of invasive taxa
    - Presence of high sedimentation
- Species richness
    - Richness of macroalgae
    - Richness of mobile invertebrates

In addition, the Turner *et al.* (2007) survey included a mechanism for combining the above into an overall measure of reef status. However, the notion of reef health assessment is in need of further refinement (see Turner *et al.* 2007 for a critical assessment of the above).

To have any capacity to compare with earlier health surveys, the indices employed in the earlier surveys should be included, particularly as part of the community monitoring approach. Comprehensive surveys may serve as a mechanism for investigation of alternative reef health indices, although the basic indicator suite should be retained. A working group (possibly the same group as recommended for seagrass health assessment) should be engaged to identify the best approach to reef health assessment.

Sampling

Locations for sampling are more readily identified than for seagrass sites as there are relatively few reefs on the metropolitan coast, although sampling must include "at risk" sites in the southern Adelaide region (ACWS zone 3). As with seagrass health the assessment of reefs must be placed in context with appropriate control locations including sites further south (ACWS zone 3A) as well as other sites around the Fleurieu and Yorke Peninsulas.

The Reef Health survey methods (as defined by Turner *et al.* 2007) are widely accepted as providing a robust assessment tool and these should form the basis for sampling at each site. This approach should be reviewed by the working group to ensure that the survey specifically identifies any additional indicators that need to be considered.

Comprehensive reef health surveys have been somewhat sporadic with gaps of between 3 and 6 years between observations. As a component of the ACWQIP, reef health assessments will need to be more reliably scheduled to report on a 3-5 year basis, so as to coincide with regional NRM reporting.

Data analysis and reporting

Current tools for the analysis and interpretation of reef health are well accepted with recent work demonstrating their capacity to inform managers about changes in reef condition over time (Connell *et al*. 2008). The analysis and reporting systems currently used for the Reef Health surveys should be adopted and augmented with additional data (including from the community based Reef Watch program) as opportunity presents.

Physical processes

Physical processes as defined by Henderson *et al.* (2006) include wind, wave, tidal activity and storms (Appendix B). Rather than a formalised structure for integration of climate and oceanographic information as an overlay on other data layers, the stakeholder workshop concluded that this information should be obtained on an as needed basis mostly in line with event based monitoring.

Available models for the Adelaide metropolitan coast

Some consideration should be given to developing simpler or more accessible versions of the existing physical oceanographic models that were developed as part of the Adelaide Coastal Waters Study. These models examined the circulation and transport of suspended solids and nutrients within the region (see Pattiaratchi *et al.* 2006); such information is invaluable in supporting the analysis and interpretation of related water quality and environmental status data.

There are most probably a range of other models with potential to contribute to the ACWQIP, particularly those related to the Port Waterways.

There is also the recently developed catchment modelling for the Adelaide Coastal Waters region (see Weber 2008). Apart from flow/discharge levels from stormwater drains as well as rivers and streams, this model may provide valuable insights into terrestrial inputs, particularly as they relate to land usage and a number of contaminants including;

- total organic carbon,
- total phosphorus
- total nitrogen
- total suspended solids.

The range of available hydrodynamic/dispersion/input models for the Adelaide coast should be reviewed with respect to their capacity to contribute to ACWQIP monitoring.

Recommended monitoring program

ACWQIP observations

In line with the outcomes of the stakeholder workshop, a summary of the recommended approach to sampling and reporting for the ACWQIP is outlined below for:

- Land based inputs,
- Coastal water quality,
- Sediment stability and
- Ecosystem health.

Land based inputs

Water quality indicators are mostly those that were identified for EMC assessment (Table 1), although with some additions and alterations with respect to CDOM (or an appropriate proxy), salinity, antiscalants, coagulants and flocculants for the proposed desalination plant, water, $\delta^{15}N$ in seagrass leaves and PM_{10} measures for dust fall (Table 2).

The EPA should utilise the SA Water discharge compliance monitoring program to obtain data from wastewater outfalls in terms of total pollutant load rather than simply pollutant concentration[3]. In addition, receiving waters monitoring should be augmented with a stable isotope investigation of seagrasses, with the aim of monitoring the spatial extent effects from WWTP inputs (Table 2).

Table 2 - ACWQIP sampling requirements for land-based inputs. Indicators denoted in red are not included in the marine water quality indicators developed for ECM monitoring.

Recommended sampling	ACWS Zones	Frequency	Indicators
STORMWATER – AMLR			
Rivers, creeks, pipes and drains ('end of valley/pipe')	1,2,3,3A	Integrated flow proportional	Chlorophyll *a* as concentration Secci disc as distance in metres Temperature as ºC Nitrogen TKN as load Total Ammonia as load Oxidised nitrogen as load Total phosphorus as load Soluble phosphorus as load CDOM via proxy
WASTEWATER – SA Water			
Compliance monitoring for treated effluent from Christies Beach, Glenelg and Bolivar	1,2,3	Daily	Chlorophyll *a* as concentration Secci disc as distance in metres Temperature as ºC Nitrogen TKN as load

[3] Note that ongoing monitoring of concentrations in receiving waters will still be required to ensure that dilution is occurring within the agreed mixing zone but this should be augmented with load based monitoring.

Recommended sampling	**ACWS Zones**	**Frequency**	**Indicators**
WWTPs			Total Ammonia as load Oxidised nitrogen as load Total phosphorus as load Soluble phosphorus as load CDOM via proxy
Nitrogen isotope surveys	All	Annual	$\delta^{15}N$ ratios from *Posidonia* leaves
INDUSTRIAL INPUTS – Penrice and desalination plant operators			
Penrice outfall	1	Daily	Chlorophyll *a* as concentration Secci disc as distance in metres Temperature as ºC Nitrogen TKN as load Total Ammonia as load Oxidised nitrogen as load Total phosphorus as load Soluble phosphorus as load CDOM via proxy
Desalination plant outfall	2	Daily	Chlorophyll *a* as concentration Secci disc as distance in metres Temperature as ºC Nitrogen TKN as load Total Ammonia as load Oxidised nitrogen as load Total phosphorus as load Soluble phosphorus as load CDOM via proxy Salinity Antiscalents, coagulants and flocculants
GROUNDWATER – AMLR / DWLBC			
Well/bore monitoring	1,2,3,3A	Monthly	Temperature as ºC Nitrogen TKN as concentration Total Ammonia as concentration Oxidised nitrogen as concentration Total phosphorus as concentration Soluble phosphorus as concentration CDOM via proxy
ASR Inputs	All	Monthly	Chlorophyll *a* as concentration Secci disc as distance in metres Temperature as ºC Nitrogen TKN as load Total Ammonia as load Oxidised nitrogen as load Total phosphorus as load Soluble phosphorus as load CDOM via proxy
ATMOSPHERIC – EPA			

Recommended sampling	ACWS Zones	Frequency	Indicators
Dustfall	All	Monthly	Pm_{10} as µg m^{-3} translated into deposition per zone

Coastal water quality

Similar to land based inputs, coastal water quality observations should employ the indicators recommended for ECM monitoring (Table 1; Table 3), with additional indicators, including CDOM , turbidity and salinity derived from remote telemetry observations).

Table 3 – ACWQIP sampling requirements for coastal water quality. Indicators denoted in red are not amongst the marine water quality indicators identified for ECM monitoring.

Recommended sampling	Zones	Frequency	Indicators
COASTAL WATER QUALITY – EPA			
Jetty sampling (Under review)	1,2,3,3A	Under review	Chlorophyll *a* as concentration Secci disc as distance in metres Temperature as °C Nitrogen TKN as concentration Total Ammonia as concentration Oxidised nitrogen as concentration Total phosphorus as concentration Soluble phosphorus as concentration CDOM via proxy
Event based monitoring	As needed	As needed	Chlorophyll a as concentration Secci disc as distance in metres Temperature as °C Nitrogen TKN as concentration Total Ammonia as concentration Oxidised nitrogen as concentration Total phosphorus as concentration Soluble phosphorus as concentration CDOM via proxy
Telemetry based observations	All	Ongoing/ Event based	Turbidity Salinity Temperature

Sediment stability

Sediment stability sampling for the Adelaide coast should continue under the current regime. Supplementary investigations should be conducted for particle size analysis and cliff stability.

Results of sediment surveys should be incorporated with other monitoring (e.g. coastal water quality, ecosystems health and stable nitrogen isotope measures) as a GIS layer.

Table 4 - ACWQIP sampling requirements for sediment stability.

Recommended sampling	ACWS Zones	Frequency	Indicators
SEDIMENT STABILITY – DEH			
Beach profile/Brass rods	All	Annual	Sand budget mapping
Dual frequency sonar	All	Annual	Sand budget mapping
Side scan sonar / swath mapping	All	10 years	Sand budget mapping
Sand relocation and dredge operations monitoring	As needed	As needed	Sand budget mapping
Particle size analyses	All	Annual	Grain size composition as a component of sand budget mapping
Cliff stability	3, 3A	Annual	Photopoint surveys

Ecosystem condition

The framework for ecosystem health assessment requires the greatest level of input from the EPA (as well as from the ACWQIP working group – see below). Sampling approaches for reef systems should employ the methods outlined in Turner et el. (2007), with modifications to support the suite of indicators selected by the working group (those noted below are presented as suggestions but were not specifically identified at the stakeholder workshop).

Table 5 - ACWQIP sampling requirements for ecosystem health, including seagrass beds and reefs. Note that the indicators for reef systems are suggestive only and were not identified at the workshop. TND = To be determined.

Recommended sampling	Zones	Frequency	Indicators
SEAGRASS HEALTH – DEH / SARDI / Universities			
Fixed quadrats	2,3,3A, Controls	Annual	Species composition *Posidonia* - Shoot density *Posidonia* - Leaf length *Posidonia* - Leaf area index *Amphibolis* - Stem density *Amphibolis* - Number of leaf heads *Amphibolis* - Number of leaves per head
Permanent markers at rodlines	2,3 mostly	Annual	Distance from brass rod markers to edge of seagrass bed
Fixed 100-200 m diver transects	All, Controls	Annual	Presence/absence at 1 m intervals Species composition at 1 m intervals
Fixed video transects	All, Controls	2-3 years	Canopy size Canopy density Epiphyte loads
Aerial photography	All	5 years	Seagrass distribution
Dual frequency sonar	All	2-3 years	Seagrass distribution
Side scan sonar / swath mapping	All	10 years?	Seagrass distribution
Artificial seagrass epiphyte loads	TBD	Annual	Epiphyte loads/counts as a mean dry weight
Reef health LIT surveys as per Turner *et al*. 2007	TBD	3 years	Robust brown macro-algae Foliaceous brown macro-algae Encrusting red macro-algae Foliaceous red macro-algae Turf forming macro-algae Mussels cover

Summary - moving forward

There is a substantial amount of water quality monitoring undertaken that can be used to support the ACWQIP, but current monitoring is poorly coordinated. Not withstanding, the Monitoring, Evaluation and Reporting Framework (MERF), developed by the AMLR NRM Board (AMLR NRM 2008) offers the best available mechanism by which a range of stakeholders may contribute data to assist in reporting against water quality targets and the associated ecosystem status indicators. Importantly, the MERF integrates Management Action Targets (MATs) and Resource Condition Targets (RCTs) along with some capacity to report against community expectations (Environmental Values).

The framework described below is targeted at resource condition targets and recommends substantial use of the Resource Condition variables recommended for Estuarine, Coast and Marine (ECM) habitat assessment that have been endorsed by the EPA and the NRM Chief Executive Group (von Baumgarten 2007). The MERF may readily incorporate these indictors, although through a process of internal review against its own strategic plan. It should be noted that the ECM indicators are not an exclusive list, but rather define the minimum requirements for obtaining consistency in monitoring across large scales, long timeframes and by numerous stakeholders (as is the case for the ACW region). Many aspects of the monitoring component of the ACWQIP may by rendered as a component of the MERF through a regime of annual report cards and longer term (3-5 year) resource condition reporting. However, some aspects of the ACWQIP must be implemented through a targeted body (or working group) that could be jointly administered by the EPA and AMLR NRM Board.

It needs to be recognised that many aspects of the monitoring in particular sediment stability and seagrass mapping, are readily presented within a Geographic Information System (GIS) framework. GIS capability should be incorporated into the monitoring framework for the ACWQIP. All monitoring locations should be GPS referenced.

Need for a ACWQIP working group

A working group is required to co-ordinate delivery and review data analysis and reporting of seagrass and reef health monitoring programs and should comprise membership from a range of stakeholders with relevant expertise related to marine water quality and ecosystem health assessment. This should include stakeholders with responsibility for inputs and monitoring (including SA Water, EPA, DEH, PIRSA and AMLR NRM) as well as research organisations (in particular SARDI Aquatic Sciences and the Universities). This working group will need to consider a number of factors including;

1. The monitoring zones as defined by the ACWS need to be reviewed with respect to the realignment of zones 4 and 5 within zones 1 and 2 respectively.
2. The spatiotemporal framework for coastal water quality monitoring from beaches and jetties is currently under review by the EPA. This process should include input from the working group with the aim of determining the balance between sampling frequency, spatial resolution and logistic constraints.
3. The potential for telemetry based water samplers should be more fully investigated with a view to developing a multi-agency bid for funding. Systems are also required to support integration of the resulting data within the coastal water quality framework.
4. There is a need to develop a seagrass health assessment framework that integrates the range of sampling tools identified by Henderson *et al.* (2006) within a mutually supportive spatiotemporal hierarchy. The targeting of observations to areas of particular concern needs to be established, which may include choosing sites based on

proximity to inputs as well as using the results of stable nitrogen isotope studies to determine “hot-spots” and appropriate controls.

5. A mechanism for ongoing reef health assessments needs to be established. Sampling should follow the methodology and locations employed in earlier reef health assessments (see Turner *et al.* 2007). The indices used to assess reef status need to be further refined; while those listed below (Table 5) are known to be useful in inferring reef health within a relatively simple sampling framework, other indices along the lines of those identified in Turner *et al.* (2007) should be considered.
6. Both seagrass and reef health assessments need to be juxtaposed against appropriate control locations.
7. The working group needs to agree on a methodology for measurement of CDOM (or an appropriate proxy).
8. There is a need to determine management needs for environmental flows requirements from rivers, creek and streams in the Adelaide region.
9. Sediment stability investigations are required to better use information about sediment grain size, cliff stability and high risk areas. The latter could potentially link to coastal water quality sampling, in particular event-based observations as well as telemetry (see above).
10. The incorporation of results from commercial and recreational fisheries stock assessments should be evaluated particularly in the context of the spatial domain of current data collection and reporting relative to the ACW region.
11. The availability, parameterisation and outputs from various models available for the Adelaide metropolitan coast as well as the Port Waterways should be investigated with a view to determining their use in supporting ACWQIP objectives, in particular predictions that relate to changes in management of the ACW region.

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Appendix A – Workshop participants and agenda

Participants	
Tony Flaherty	AMLR NRM
Keith Smith	AMLR NRM
Patrick Stubbin	Penrice Soda Products Pty Ltd
Maylene Loo	SARDI Aquatic Sciences
Alex Gaut	Reef Watch
Greg Ingleton	SA Water
Tim Kildea	SA Water
Doug Fotheringham	DEH
Liz Barnett	DEH
Paul Manning	Eco Management Services Pty Ltd
David Duncan	EPA
Shaun Thomas	EPA
Linda-Marie McDowell	EPA
Peter Christie	EPA
Sam Gaylard	EPA
Peter Pfennig	EPA
Facilitators	
Anthony Cheshire	Balance Carbon Pty Ltd
Grant Westphalen	Balance Carbon Pty Ltd

Adelaide Coastal Waters Quality Improvement Plan Monitoring/Modelling Workshop
Level 7, SA Water House, 77 Grenfell Street, Adelaide
9:00 am to 4:00 pm Monday 16 June 2008
Morning/afternoon tea and lunch provided

Start Time	End Time	Time Allocated (mins)	Presenter/Facilitator	Title	Outcome/output
09:00	09:10	10	Anthony Cheshire	Welcome and introductions	Purpose in attending - MATs and RCTs
09:10	09:40	30	Peter Pfennig	ACWQIP - A summary of the program	Summary of objectives - management action targets (MAT's) and resources condition targets (RCT's) for delivery. EVs and stakeholder consultation.
09:40	09:50	10	Anthony Cheshire	Questions and discussion	
09:50	10:10	20	Keith Smith	AMLR NRM MERF	Summary of AMLR MERF and the broader monitoring and evaluation context with reference to Adelaide Coastal Waters
10:10	10:20	10	Anthony Cheshire	Questions and discussion	
10:20	10:40	20	Morning tea		
10:40	11:00	20	Grant Westphalen	Recommended monitoring - summary of ACWS reports 19 and Final.	Summary of current monitoring in context of ACWS recommendations
11:00	12:10	70	Group work / Anthony Cheshire	Validation of ACWS conclusions about current and recommended monitoring programs	Validate list of current activities AND Agree list of recommended monitoring
12:10	12:55	45	Lunch		
12:55	13:40	45	Group work / Anthony Cheshire	Strategy required to operationalise the monitoring program	List of agencies/institutions responsible for implementing monitoring activities. How to integrate data into reporting framework
13:40	14:25	45	Group work / Peter Pfennig	Management action targets for ACWQIP	Identification of indicators for MAT's and how to measure and integrate
14:25	14:45	20	Afternoon tea		
14:45	15:30	45	Group work / Anthony Cheshire	Conceptual model to support integration and reporting of monitoring results for ACWQIP	Group sessions to develop conceptual model for ACW region and strategies for reporting on monitoring programs
15:30	15:40	10	Anthony Cheshire	Conclusions and wrap up	

Appendix B – Summary table of the recommended Environmental Monitoring Program (Henderson *et al.* 2006)

Recommended sampling	Zones (see ACWS MAP)	Frequency	Indicators	Current measurements	Agency currently engaged	Capability to undertake sampling	Relationship to current programs
SEAGRASS HEALTH							
Fixed quadrats	2,3,3A*	Annual	Species composition	None		DEH/ SARDI/ Univ.	Additional
Fixed quadrats	2,3,3A*	Annual	*Posidonia* - Shoot density	None		DEH/ SARDI/ Univ.	Additional
Fixed quadrats	2,3,3A*	Annual	*Posidonia* - Leaf length	None		DEH/ SARDI/ Univ.	Additional
Fixed quadrats	2,3,3A*	Annual	*Posidonia* - Leaf area index	None		DEH/ SARDI/ Univ.	Additional
Fixed quadrats	2,3,3A*	Annual	*Amphibolis* - Plant density?	None		DEH/ SARDI/ Univ.	Additional
Fixed quadrats	2,3,3A*	Annual	*Amphibolis* - Number of leaf heads?	None		DEH/ SARDI/ Univ.	Additional
Fixed quadrats	2,3,3A*	Annual	*Amphibolis* - Number of leaves per head?	None		DEH/ SARDI/ Univ.	Additional
Fixed quadrats	2,3,3A*	Annual	Quadrat photographs	None		DEH/ SARDI/ Univ.	Additional
Permanent markers	2,3 mostly	Annual	Distance from brass rod markers to edge of seagrass bed	Current rodlines only?	DEH Coast & Marine		Modification
Fixed 100-200 m diver transects	All (more in 4, 5)*	Annual	Presence/ absence at 1 m intervals	None		DEH/ SARDI/ Univ.	Additional
Fixed 100-200 m diver transects	All (more in 4, 5)*	Annual	Species composition at 1 m intervals	None		DEH/ SARDI/ Univ.	Additional
Fixed video transects	All*	2-3 years	Canopy size?	None		DEH/ SARDI/ Univ.	Additional
Fixed video transects	All*	2-3 years	Canopy density?	None		DEH/ SARDI/ Univ.	Additional
Fixed video transects	All*	2-3 years	Epiphyte loads?	None		DEH/ SARDI/ Univ.	Additional
Aerial photography	All	5 years	Distribution	Distribution	DEH Coast & Marine		Formalise
Dual frequency sonar	All	Annual	Distribution	Distribution	DEH Coast & Marine		No change
Airborne remote sensing (i.e. CASI)	All	5 years?	Distribution	None		DEH Coast & Marine	Additional
Side scan sonar / swath mapping	All	10 years?	Distribution	Distribution	DEH Coast & Marine		No change
REEF HEALTH MONITORING	ALL	?	ESTABLISHED	PERIODIC/ SPORADIC	SARDI/ Reef Watch		Additional

* Need for reference monitoring sites in areas outside the ACWS zones such as Port Hardy or Wallaroo?

Recommended sampling	Zones (see ACWS MAP)	Frequency	Indicators	Current measurements	Agency currently engaged	Capability to undertake sampling	Relationship to current programs
SEDIMENT STABILITY							
Beach profile/ Brass rods	All	Annual	Sand budget mapping?	Beach profile/ Brass rods	DEH Coast & Marine		No change
Extended some lines	All	Annual	Sand budget mapping?			DEH Coast & Marine	Modification
Add further lines	1,3,3A	Annual	Sand budget mapping?			DEH Coast & Marine	Modification
Dual frequency sonar	All	Annual	Sand budget mapping?	Dual frequency sonar	DEH Coast & Marine		No change
Side scan sonar / swath mapping	All	10 years?	Sand budget mapping?	Side scan sonar / swath mapping	DEH Coast & Marine		No change
Sand relocation and dredging operations monitoring							
INPUTS - STORMWATER							
Rivers and creeks ('end of valley')	1,2,3,3A	Flow proportional	Nutrients	Varies (grab & flow proportional)	AMLR/ DWLBC		Standardise sampling
Rivers and creeks ('end of valley')	1,2,3,3A	Flow proportional	CDOM	Varies (grab & flow proportional)	AMLR/ DWLBC		Standardise sampling
Rivers and creeks ('end of valley')	1,2,3,3A	Flow proportional	Physical water quality	Varies (grab & flow proportional)	AMLR/ DWLBC		Standardise sampling
Field River as a particular gap	3	Flow proportional	Nutrients, CDOM, physical water quality	Grab samples	AMLR/ DWLBC		Additional
Stormwater drains and pipes	1,2,3,3A	Flow proportional	Flow rates			AMLR/ DWLBC	Additional
Stormwater drains and pipes	1,2,3,3A	Flow proportional	Nutrients			AMLR/ DWLBC	Additional
Stormwater drains and pipes	1,2,3,3A	Flow proportional	CDOM			AMLR/ DWLBC	Additional
Stormwater drains and pipes	1,2,3,3A	Flow proportional	Physical water quality			AMLR/ DWLBC	Additional

Recommended sampling	Zones (see ACWS MAP)	Frequency	Indicators	Current measurements	Agency currently engaged	Capability to undertake sampling	Relationship to current programs
INPUTS - WASTEWATER							
Current compliance monitoring for treated effluent from Christies Beach, Glenelg and Bolivar WWTPs	1,2,3	?	?		SA Water		
Current receiving waters monitoring for Glenelg and Christies Beach WWTPs	2,3	Monthly	?	Varies substantially between sites	SA Water/ EPA?		No change
Develop monitoring for Bolivar receiving waters	1	Monthly	As per Christies and Glenelg	None		SA Water	Additional
Nitrogen isotope sampling for seagrass leaves	All	Annually	Nitrogen isotope ratios	None		DEH/ SARDI/ Univ.	Additional
INPUTS - PORT RIVER/BARKER INLET							
Port River/Barker Inlet monitoring	1	Monthly	Nutrients and toxicants	?	EPA (note Penrice monitoring)		Modification
INPUTS - GROUNDWATER							
Regular monitoring	All	Monthly?	Nutrients and toxicants	Varies	AMLR/ DWLBC		
INPUTS - ATMOSPHERIC							
Regular monitoring	All	Monthly?	Dust fall and wet deposition		EPA		Additional

Recommended sampling	Zones (see ACWS MAP)	Frequency	Indicators	Current measurements	Agency currently engaged	Capability to undertake sampling	Relationship to current programs
COASTAL WATER QUALITY							
Jetty sampling	All	Monthly (fortnightly in summer)	Turbidity	Conductivity, pH, total dissolved solids, temperature, turbidity	EPA (quarterly)		No change?
Jetty sampling	All	Monthly (fortnightly in summer)	Nutrients	Ammonia, nitrate, nitrite, oxidized nitrogen, total Kjeldahl nitrogen, total nitrogen, total phosphorus, chlorophyll a, chlorophyll b	EPA (quarterly)		No change?
Jetty sampling	All	Monthly (fortnightly in summer)	Heavy metals	Heavy metals (8 types)	EPA (quarterly)		No change?
Jetty sampling	All	Monthly (fortnightly in summer)	Bacteria	Bacteria (4 types)	EPA (quarterly)		No change?
Mid and offshore sampling	1,2,3	Monthly?	Physical (light): attenuation, turbidity, total suspended solids, secci depth and/ or CDOM	None		EPA	Additional
Mid and offshore sampling	1,2,3	Monthly?	Nutrients: total nitrogen, oxidized nitrogen, ammonia, total phosphorus, phosphates	None		EPA	Additional
Mid and offshore sampling	1,2,3	Monthly?	Chlorophyll a	None		EPA	Additional
Mid and offshore sampling	1,2,3	Monthly?	Temperature	None		EPA	Additional
Mid and offshore sampling	1,2,3	Monthly?	Salinity	None		EPA	Additional
Artificial seagrass epiphyte loads	1,2,3	2 years	Epiphyte loads/ counts as a mean dry weight	None		EPA/ DEH/ SARDI	Additional
Remote sensing (MODIS)	All	?	Chlorophyll a	None		EPA	Additional
Remote sensing (MODIS)	All	?	CDOM	None		EPA	Additional
Remote sensing (MODIS)	All	?	Temperature	None		EPA	Additional
Event based monitoring	1,2,3	Not applicable	Salinity	None		EPA/ Licensee monitoring	Additional

Recommended sampling	Zones (see ACWS MAP)	Frequency	Indicators	Current measurements	Agency currently engaged	Capability to undertake sampling	Relationship to current programs
COASTAL WATER QUALITY CONTINUED							
Event based monitoring	1,2,3	Not applicable	Physical (light): attenuation, turbidity, total suspended solids, secci depth and/ or CDOM	None		EPA/ Licensee monitoring	Additional
Event based monitoring	1,2,3	Not applicable	Nutrients: total nitrogen, oxidized nitrogen, ammonia, total phosphorus, phosphates	None		EPA/ Licensee monitoring	Additional
Event based monitoring	1,2,3	Not applicable	Chlorophyll a	None		EPA/ Licensee monitoring	Additional
Event based monitoring	1,2,3	Not applicable	Temperature	None		EPA/ Licensee monitoring	Additional
PHYSICAL PROCESSES							
Wind	All	As needed	Speed and direction	Wind	Met Bureau/ National Tidal Centre		No change
Wave height	All	As needed	Height in metres	Wave height	Met Bureau/ National Tidal Centre		No change
Tidal ranges	All	As needed	Height in metres	Tidal ranges	Met Bureau/ National Tidal Centre		No change
Storm information	All	As needed		Storm information	Met Bureau/ National Tidal Centre		No change
Hydrodynamic model for risk mapping	All	Not applicable	?	None		SARDI/ CSIRO/ Univ.	Additional