Integrated Monitoring and Modelling Strategy

for the

Black Ross Water Quality Improvement Plan

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Table of Contents

1. INTRODUCTION

The Water Quality Improvement Plans (WQIPs) for the catchments of Great Barrier Reef (GBR) aim to reduce the amount of nutrients, sediments and pesticides reaching the marine receiving waters of the Great Barrier Reef lagoon as part of the Reef Water Quality Protection Plan (Reef Plan). WQIPs are being developed for several of the GBR catchments including the Douglas Shire (Mossman and Daintree catchments), Barron, Tully/Murray, Burdekin, Mackay Whitsunday and Burnett Baffle catchments. Regional water quality planning in the Fitzroy region is being incorporated into the Regional NRM Plan. As part of the WQIP process, monitoring and modelling strategies need to be developed to ensure that the sources of pollutants can be identified and quantified. Once the WQIP is implemented, the water quality benefits of remedial works also need to be monitored and modelled.

Of the WQIPs being developed for the GBR, the Townsville Region (population ~160,000) is the only urban based WQIP, with the region being the largest urban and industrial centre of the GBR catchment area (ABS, 2007). The Black Ross WQIP has the following objectives:

- Identify the key threats to water quality;
- Set water quality targets;
- Identify measures to meet those targets and;
- Recommend adaptive management strategies.

In contrast to the other WQIPs of the GBR, the Townsville Region is characterised by considerably smaller catchment areas (e.g. stormwater drains) with several point-source contributions including sewage treatment plants and industrial inputs. The different land uses in the region also mean that there are different water quality issues to address. Therefore a water quality monitoring and modelling strategy needs to be developed specifically for the Black Ross WQIP.

Previous monitoring in the Townsville Region is largely restricted to low flow (ambient) conditions through Creek to Coral/Conservation Volunteers Australia (CVA) Creek Watch community monitoring, Townsville and Thuringowa City Councils (stormwater drains), and industry compliance monitoring. Event flow monitoring has been conducted by the Australian Centre for Tropical Freshwater Research at selected sites in the 2005/06 (limited sites), 2006/07 and 2007/08 wet seasons for the Black Ross WQIP to identify water quality issues and sources in the region and to provide baseline water quality data (Liessmann et al., 2007). At this time modelling of pollutant export to the GBR is limited to the SedNet/ANNEX models of sediment and nutrient export from main waterways in the region (Bluewater Creek, Black River, Bohle River, Ross River and Alligator Creek) (Brodie et al., 2003; McKergow et al. 2005a; 2005b; Fentie et al., 2006; Kinsey-Henderson and Sherman, 2007). Comparisons between the modelled and monitored loads are highly variable (Liessmann et al., 2007). As part of the Black Ross WQIP further modelling is currently being undertaken using the E2 model and the Model for Urban Stormwater Improvement Conceptualisation (MUSIC). These models are more sensitive to the altered catchment processes associated with the urbanised landscape, and the limited topography of these small coastal catchments.

This report outlines a monitoring and modelling strategy for the Black Ross WQIP. The report includes a framework for both catchment and marine ecosystem health. Since the main aim of the Black Ross WQIP is to reduce sediment, nutrient and pesticide export to the GBR, we present a coupled monitoring and modelling approach to measure, assess and report on the effectiveness of the WQIP.

2. BACKGROUND

2.1. Current Monitoring Overview

Catchment ecosystem health (low flow) monitoring activities

Monitoring efforts to date in the Black Ross WQIP region have largely been of an ambient nature. Such monitoring is usually conducted during low flow conditions at regular intervals, with the objective of determining waterbody ecosystem condition, and/or trends over time. Within the region these efforts consist of a combination of community, State and Local Government, and industry compliance monitoring, as outlined below:

- Council water quality monitoring activities such as the TCC *Urban Stormwater Quality Management Plan* (www.soe-townsville.org), and public health monitoring;
- Conservation Volunteers Australia *CreekWatch* groups (supported by Creek to Coral) including Louisa, Sach's, Mundy, Stuart, Town Common and Bohle River CreekWatch, (www.soe-townsville.org/creekwatch);
- Other Landcare group activities (also supported by CVA and C2C) e.g. Bluewater Landcare Group;
- Qld Dept. Natural Resources and Mines flow gauge and groundwater monitoring;
- Compliance monitoring conducted by private industry or hired consultants.

The location of these activities are illustrated in Figure's 1 and 2 below.

Marine ecosystem health (loads-based) monitoring activities

Catchment exports

More recently the Australian Centre for Tropical Freshwater Research, James Cook University established an event-based water quality monitoring program for the Black Ross WQIP, which included the sampling of a number of the regions' major watercourses (e.g. Black River, Bohle River, Ross River, Bluewater Creek, Stuart Creek and Alligator Creek) as well as other smaller waterways which drain the dominant land uses within the region (see Figure 1). The study focused on examining contaminant exports to the marine environment and was not aimed at assessing ambient water quality or the health of aquatic ecosystems within the catchment.

The sampling program focused on the 2006/07 wet season, with additional sampling conducted in the 2007/08 wet season at the major waterways of the region (Ross, Black and Bohle Rivers) to develop additional contaminant load data for these systems. Sampling was also conducted during this wet season at five urban and industrial waterways to develop event mean concentrations (EMC's) for these land use types in tropical systems. The contaminant loads and EMC's resulting from this program will be used as input data into con-current modelling efforts also being undertaken for the Black Ross WQIP.

Chlorophyll monitoring

Long term chlorophyll-a monitoring started widely across the GBR in 1991 (GBRMPA Long Term Program) and results have been published regularly including in Steven et al. (1995) and Brodie et al. (1997; 2007). Several sites lie in a transect across the GBR shelf waters off Townsville. Other studies along this transect pre-date the GBRMPA Program and chlorophyll-a data is available in this area in Revelante and Gilmartin (1982), Walker (1981) and back to the 1970's.

Flood plume monitoring

Flood plumes from the Burdekin River have been studied over a long period beginning with the work of Wolanski and colleagues (Wolanski and Jones, 1981; Wolanski and van Senden, 1983) in the late 1970's, through the studies of Devlin and colleagues in the 1990's (Devlin et al., 2001; Devlin and Brodie 1995), most recently by Brodie and colleagues (Brodie et al., 2004; Lewis et al., 2006) and currently under the MTSRF initiative. With the advent of high overpass frequency satellite sensors such ad MODIS, plumes from the Burdekin are now able to be tracked day by day and some estimate of their composition made as they change through time.

Other Relevant Monitoring in Marine Environment

Other relevant monitoring in the marine environment includes SeagrassWatch (DPI&F and associated community groups such as CVA), the AIMS Long Term Coral Reef Monitoring Program and the AIMS Inshore Reef Water Quality Monitoring Program.

A large number of one off water quality monitoring programs have also occurred in Burdekin coastal and marine waters, including:

- Dredging of the Townsville Harbour channel;
- Nelly Bay Harbour development;
- The Strand redevelopment;
- Queensland Nickel outfall monitoring.

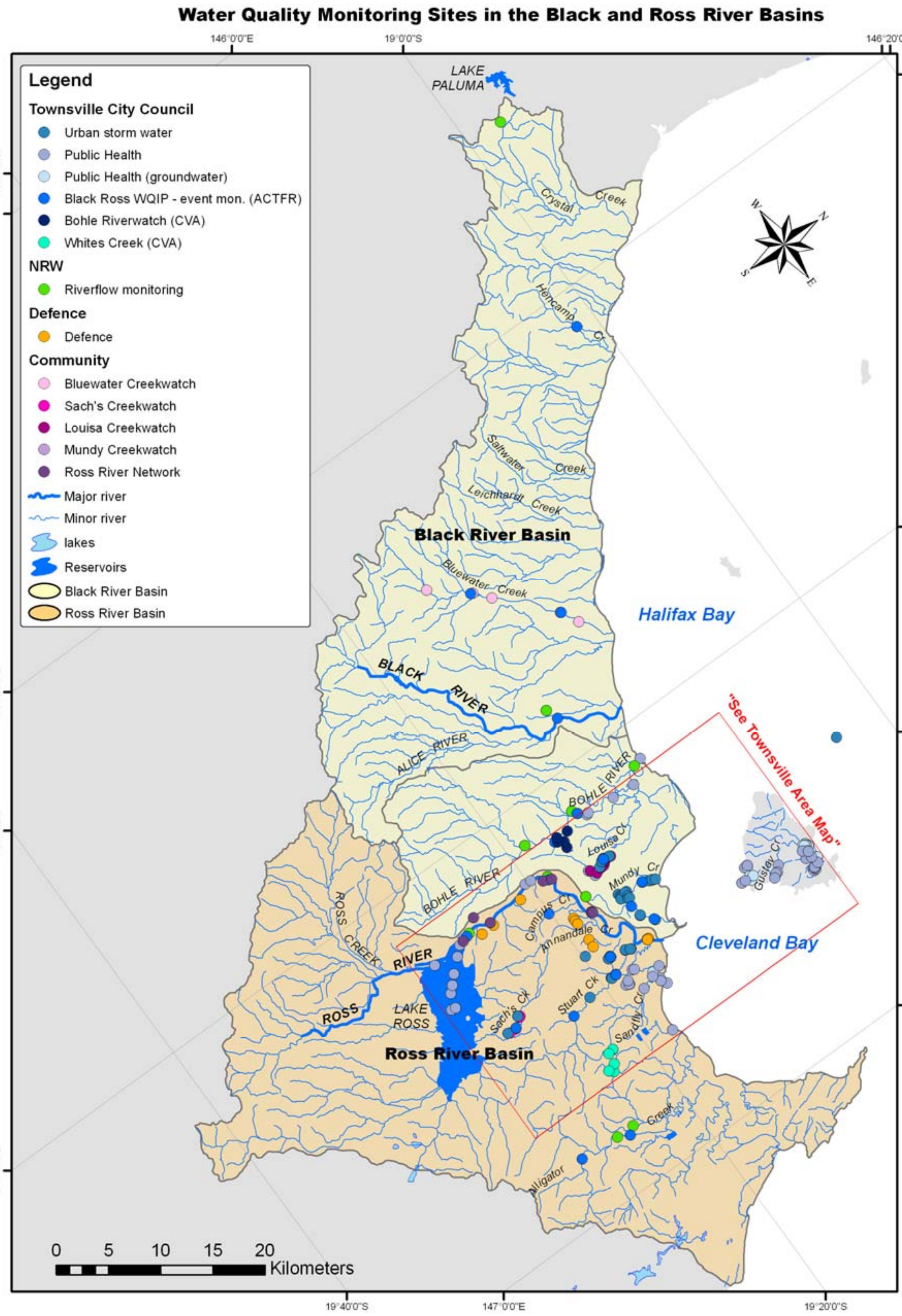

Figure 1: Map of water quality activities throughout the Black Ross River Basins. Monitoring programs have been separated into community and agency-based monitoring.

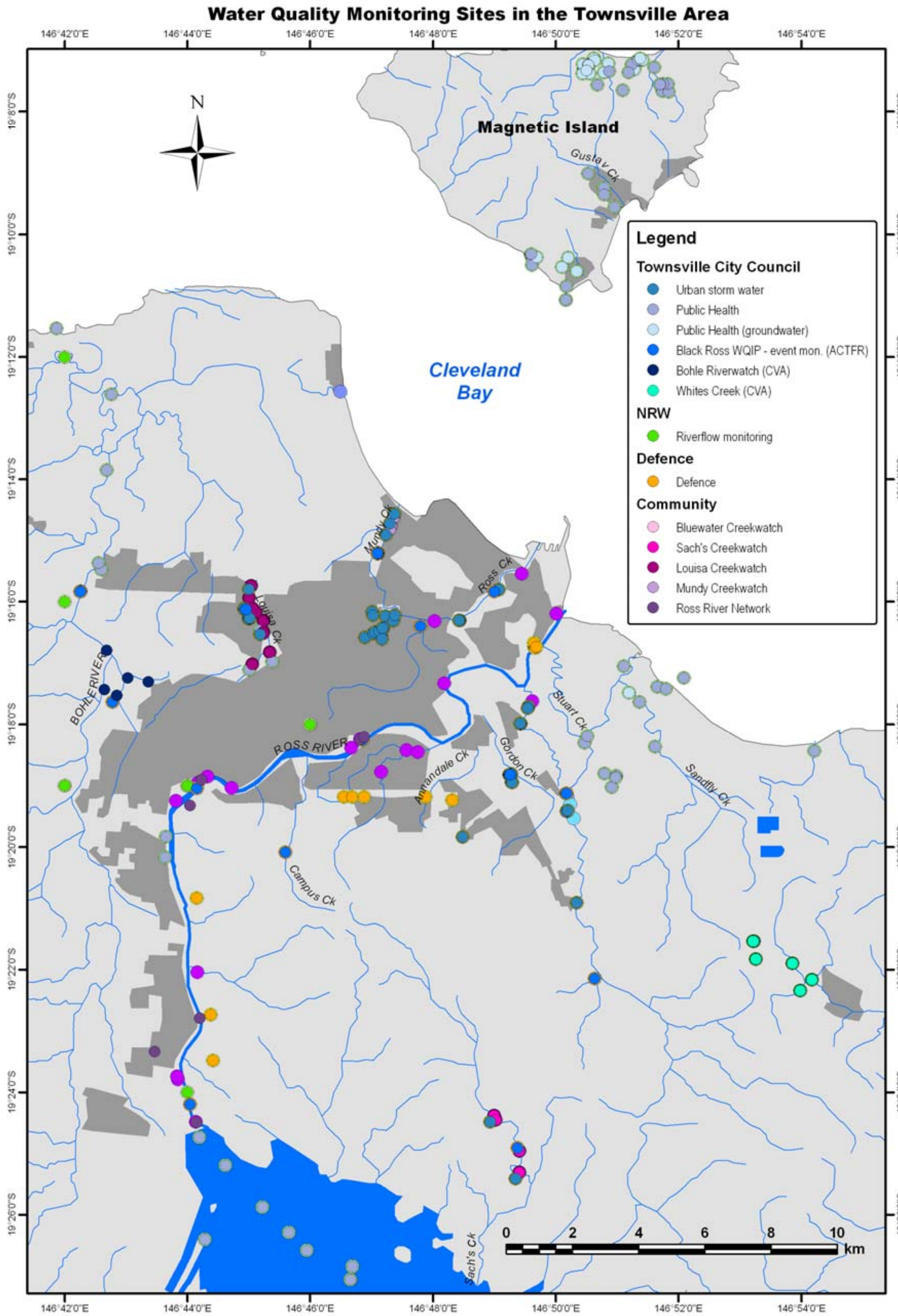

Figure 2: Map of water quality activities throughout the Black Ross River Basins.

2.2. Current Modelling Overview

Catchment scale modelling

Recent catchment scale modelling has been run in the Black and Ross Basins using SedNet and its nutrient analogue ANNEX. SedNet was applied across Australia for the National Land and Water Resources Audit (NLWRA). Later the Black and Ross Basins were included as part of modelling sediment and nutrient dynamics of the Great Barrier Reef Catchment Area (GBRCA) using an updated and improved version of SedNet/ANNEX. Results were published in Brodie et al. (2003) and McKergow et al. (2005a; 2005b). The models were improved and run across most of the GBRCA with a variety of land use modification scenarios including various levels of pasture cover (Fentie et al., 2006). Further refinements to the SedNet and ANNEX models have recently been conducted by Kinsey Henderson and Sherman (2007). A summary of the model export data from the Townsville Region are provided in Liessmann et al. (2007).

Another form of modelling has been used across the GBR catchments by Furnas (2003). In this case catchments have been divided on the basis of rainfall into 'wet' and 'dry' catchments and characteristic flow versus sediment and nutrient concentration models developed from long-term monitoring data from seven of the major rivers. Based on these models loads of sediments and nutrients can be estimated for all major GBRCA rivers including those with little or no monitoring data (Furnas, 2003). The data for the Black and Ross Basins from this model and from previous similar works are summarised in Liessmann et al. (2007).

Receiving waters modelling

A number of models have been used to derive conclusions about the dispersion of materials from the GBR catchments into the GBR lagoon, the subsequent exposure of marine ecosystems and potential risks to their ecological sustainability (e.g. King et al., 2002; Devlin et al., 2003; Maughan et al., 2008). The Devlin et al. (2003) exposure model classes the receiving waters adjacent to the Black and Ross Basins (e.g. Cleveland and Halifax Bays) as a 'moderate' exposure risk (Fig. 3). Similarly, Maughan et al. (2008) ranked the exposure of the receiving waters adjacent to the Black and Ross Basins as 'medium' for DIN and 'low' to 'medium' for herbicides (Fig 4a-d). As expected a similar pattern exists for suspended sediment and TP, where there is a 'low' risk across the receiving waters except for the water close to the mouth of the Black River, where the risk is 'medium' to 'high'.

A model connecting chlorophyll a concentrations in the GBR lagoon between Bowen and Cape York to nitrate discharge from rivers from the Burdekin to the Normanby was used by Wooldridge et al. (2006) to estimate the reduction in nitrate needed to achieve water quality guideline concentrations of chlorophyll a in certain parts of the GBR. Models have also been developed using measured changes in GBR lagoon turbidity (measured as clarity) to link changed turbidity to coral reef health (Wolanski et al., 2003; 2004; Wolanski and De'ath, 2005).

Socio-economic modelling

A model incorporating elements of social and economic factors associated with risk as well as the exposure factors was used by Greiner et al. (2005) to prioritise catchments in terms of their risk to GBR ecosystem health. This model ranked the Black Basin as relatively low in terms of ecological impact of pollution, but relatively high in social impact of pollution prevention and in economic impact of pollution. Similarly, the Ross Basin ranked high in economic impact but was in the moderate range of ecological and social impacts.

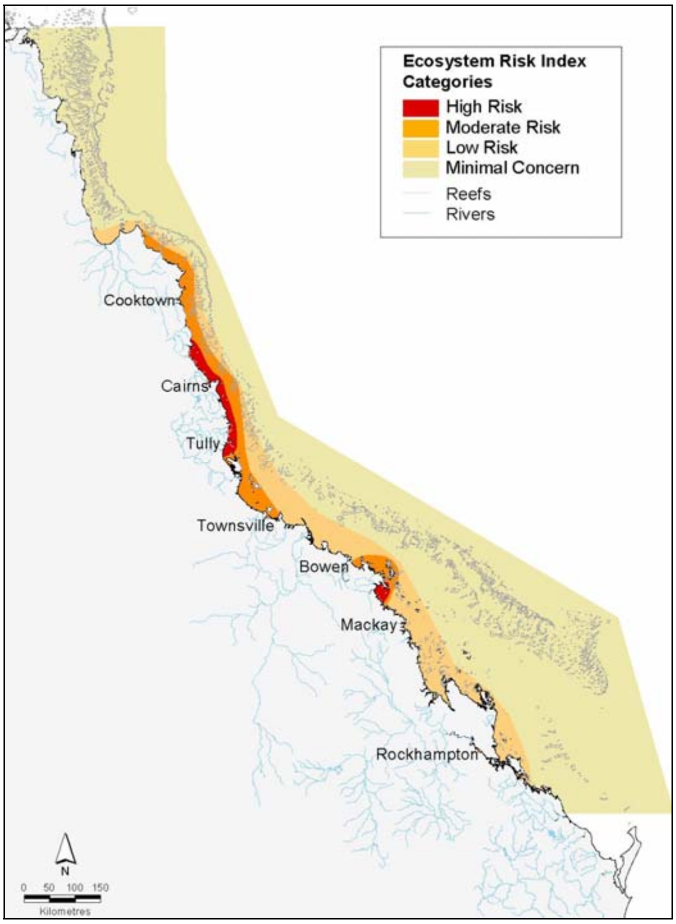

Figure 3: Relative exposure of GBR ecosystems to terrestrial contaminants (Devlin et al., 2003).

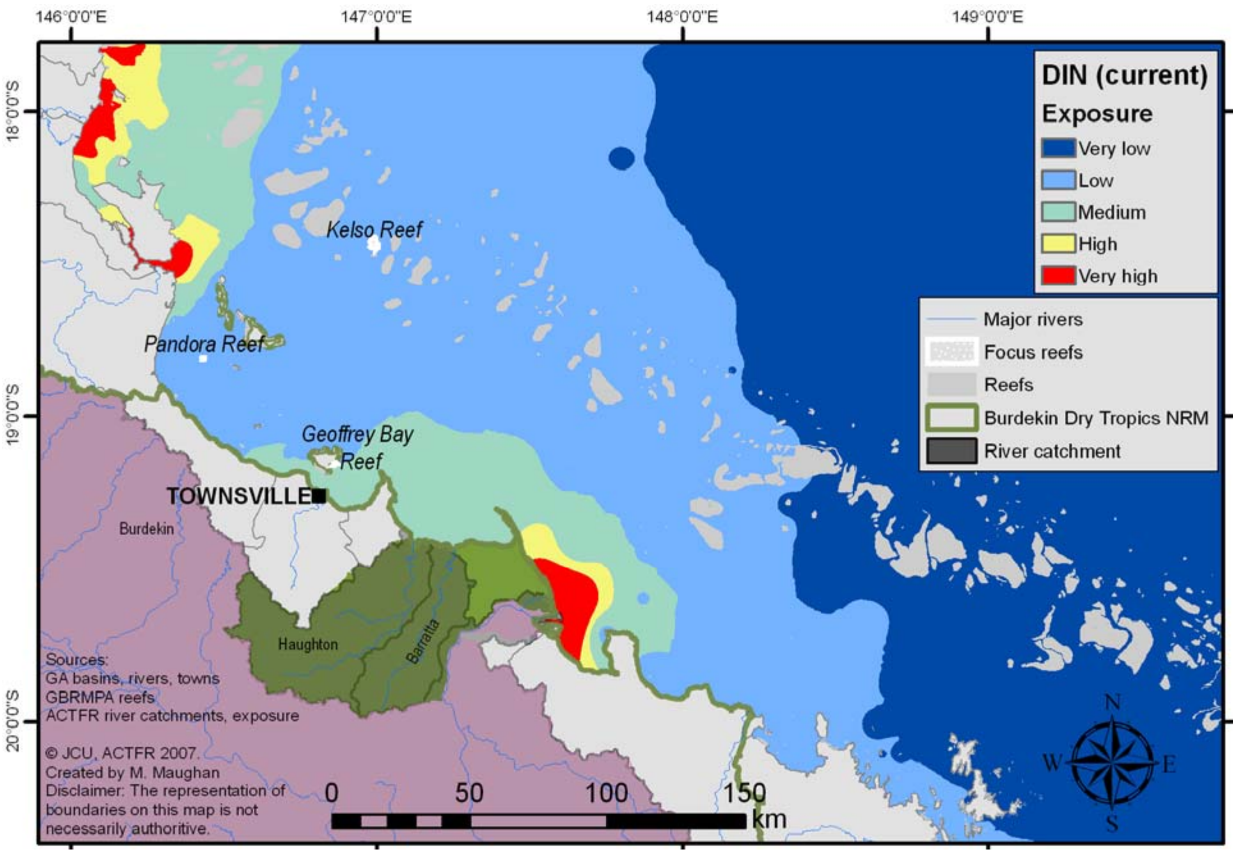

Figure 4a: DIN exposure in the Burdekin Region (Maughan et al., 2008)

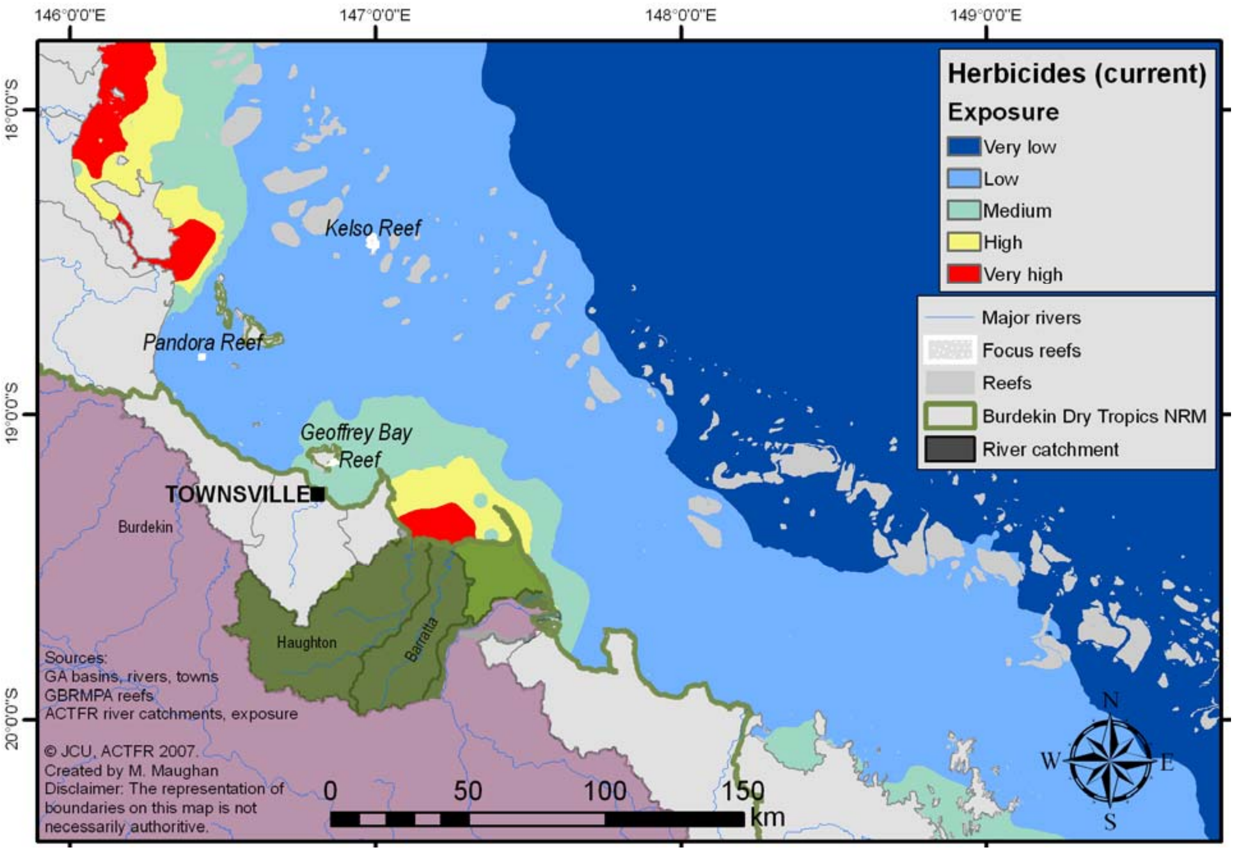

Figure 4b: Herbicide exposure in the Burdekin Region (Maughan et al., 2008)

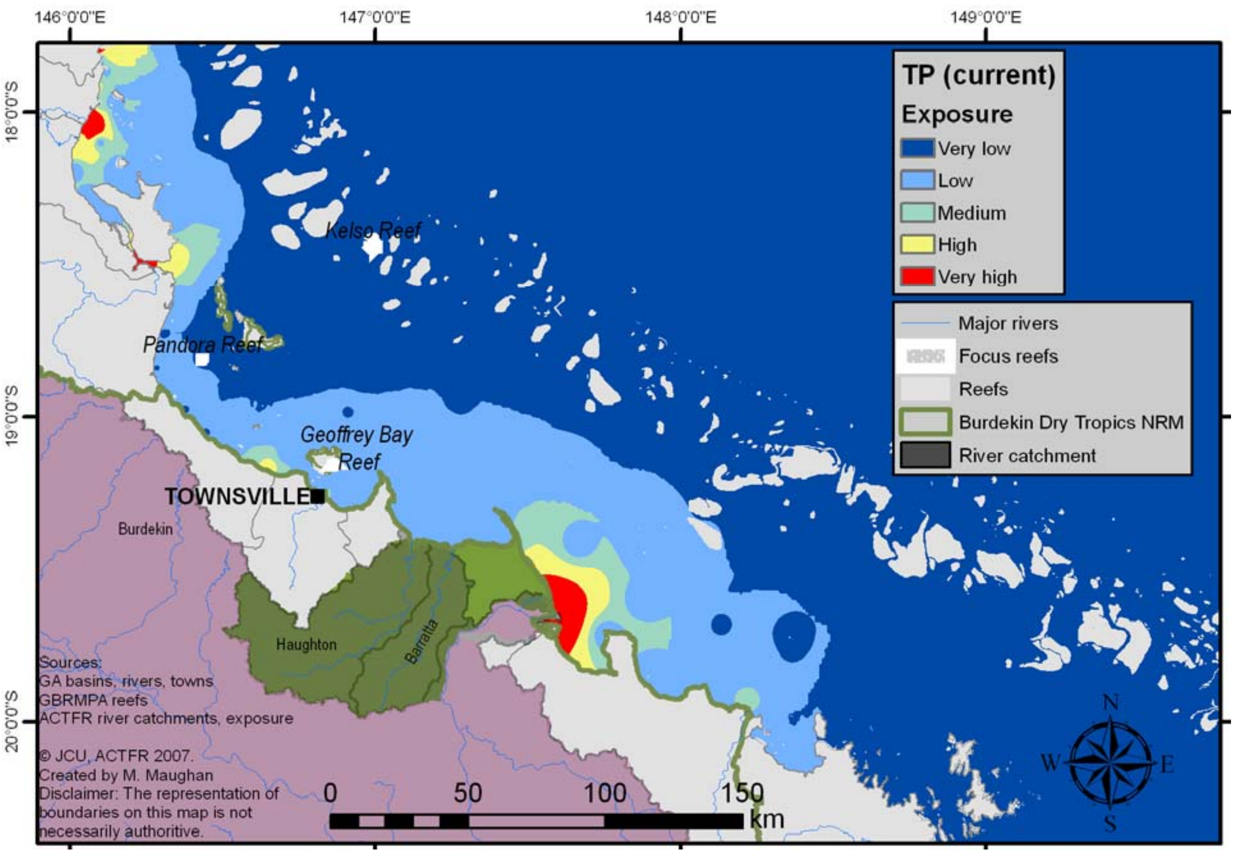

Figure 4c: TP exposure in the Burdekin Region (Maughan et al., 2008)

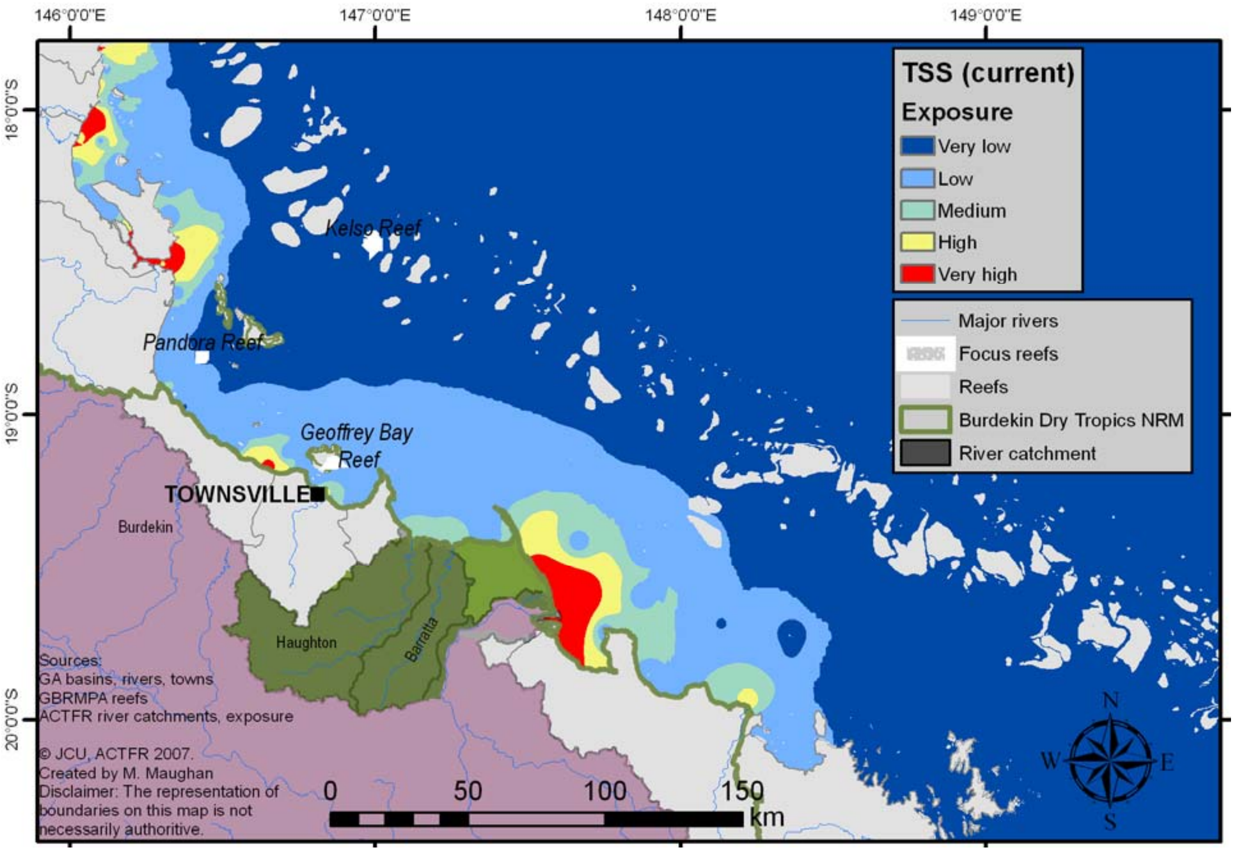

Figure 4d: TSS exposure in the Burdekin Region (Maughan et al., 2008)

3. MONITORING AND MODELLING STRATEGY

3.1. Introduction

The WQIP process provides an opportunity to better coordinate monitoring and modelling activities within the region, where previously there has been a lack of coordination of the water quality data collected by various community groups, government departments and other agencies. Additionally, there has been limited modelling efforts specific to the region, with those conducted not necessarily relevant to the smaller coastal catchments of the region, or sensitive to the altered catchment processes that occur in the urbanised landscape.

Although the coupled modelling and monitoring approach provides managers with a better understanding of the water quality signals and trends that result from improved land uses (e.g. bio-retention basins) to allow appropriate feedback to government and community, some auditing of the uptake of improved management practices is also required. Such auditing will be an integral part of the Black Ross WQIP implementation, particularly during the first phase of implementation where monitoring data particularly will be limited, and auditing will be the primary means of feedback.

The following document provides a monitoring and modelling strategy for the region (this section), as well as an outline for future plan development (section 4). The strategy is presented in three sections:

(i) Catchment Ecosystem Health Framework, *relating to instream waterways and wetlands;*

(ii) Marine Ecosystem Health Framework, *linking catchment management actions to marine ecosystem health*; and

(iii) Social and economic Framework, *linking socio-economic indicators and management action uptake to water quality outcomes*.

3.2. Catchment Ecosystem Health Framework

Although it is recognised that a number of ambient monitoring projects have been undertaken by various organisations and agencies within the Townsville region, there is currently a lack of a specific or collective monitoring strategy. The development of an ambient monitoring strategy for catchment ecosystem health is necessary for the following objectives:

- determine baseline status and trends of water quality;
- identify and prioritize high quality and degraded waters;
- evaluate success of water quality management program;
- assessing attainment of water quality standards;
- support local effort to monitor or improve water quality;
- providing background data for planning and evaluating water classifications (environmental values) and water quality objectives;
- identifying locations in need of additional attention e.g. remediation.

Figure 5 outlines the key steps in developing an ambient monitoring strategy for catchment ecosystem health. This component will also be the primary means of continued community engagement within the region. Assessment tools and water health indexes/report cards will be used as a means of communicating sub-catchment freshwater ecosystem health to the broader community.

Currently Federal and State (QLD) water quality guidelines are likely to be to generic to be effectively applied to water quality data collected in the Black Ross WQIP, and can only be used broadly in comparison exercises. As such there may be a need for the development of local water quality guidelines for this tropical urban setting. Although guidelines are traditionally only developed for the ambient context, the important role stormwater flow events play on local and downstream water quality required the development of guidelines for these high flow events also. The data collected in the recent event monitoring project for the Black Ross WQIP will provide the starting point of such development.

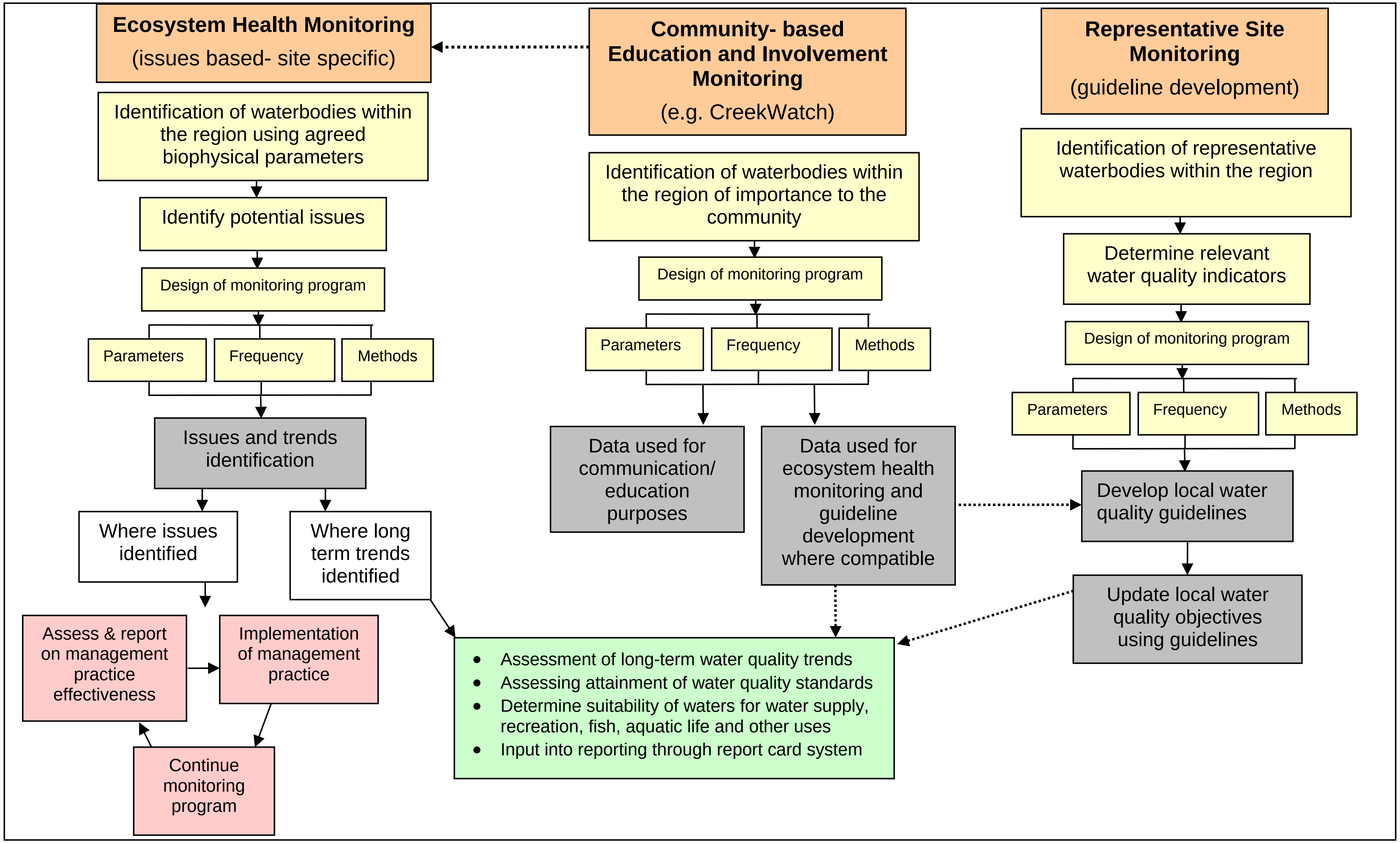

Figure 5: Catchment Ecosystem Health Framework

3.3. Marine Ecosystem Health Framework

A coupled monitoring and modelling approach is recommended for assessing the water quality impact of improved land management practices on receiving waters (i.e. instream freshwater waterbodies, wetlands, mangroves and the adjacent estuarine/marine waters), as changes in water quality as a result of catchment management actions are likely to be measured only at the smaller sub-catchment/land use scale.

Information Box 1: System Noise and Lag Times

Although land managers want to know the impact at the end-of-catchment, catchment variability, or "noise" (Fig. 1, Appendix 1), and lag times associated with particular management actions (Fig. 2, Appendix 1) limit the detection of water quality changes or trends at this scale (Stow et al. 2001; Osidele et al., 2003). The extent of system "noise" will also vary depending on what water quality parameter is being measured. For instance, sediment lag times will be significantly longer that reductions in dissolved inorganic phosphorus or pesticide concentrations in waterways, where management actions to reduce these later two parameters (i.e. sewage treatment plant upgrade; reduction in pesticide application during wet season months) may result in reductions in concentrations within 1-2 years. Table 1 (Appendix 1) outlines approximate timeframes for detecting water quality trends/signals at varying spatial scales as a result of management actions for different water quality parameters. These parameters include suspended sediment and associated particulate nutrients, gross pollutants, dissolved nutrients (i.e. nitrate) and pesticides. The timeframes are based on current scientific understanding.

Presented below is the coupled monitoring and modelling approach, with the steps outlined through a flow chart (Figure 6). Data under steps one and three have already been collected through the Black Ross WQIP event monitoring program (ACTFR). The MUSIC and E2 models are currently being used to conduct Step 4, which, aside from determining current scenario end-of-catchment contaminant loads, will inform the WQIP target setting process. Step 2 is currently being developed under the MTSRF project (see section 3.4). The remaining steps can only be conducted once management actions are in place.

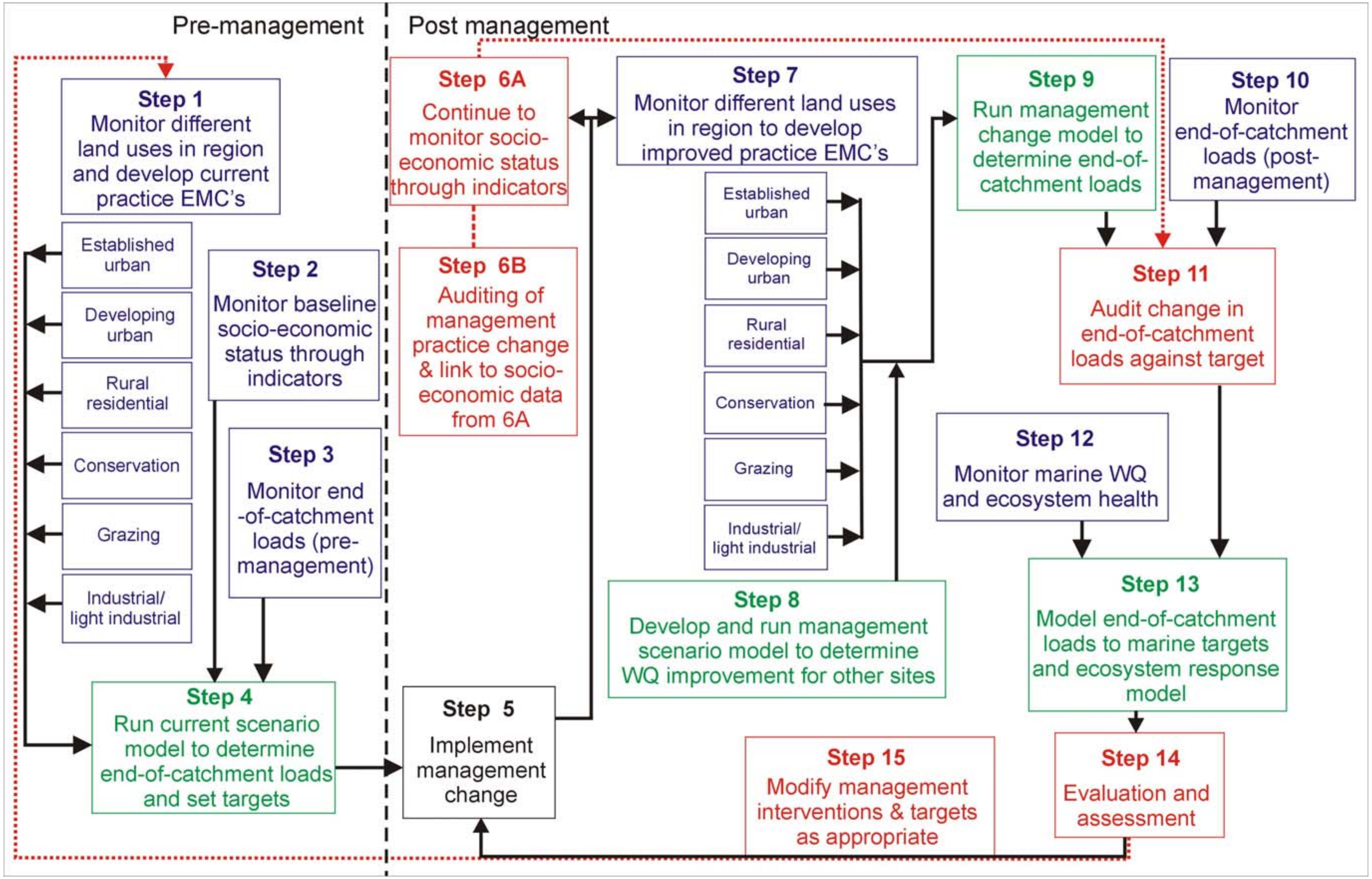

Figure 6: Flow chat outlining process for assessing management effectiveness and response for marine ecosystem health, with monitoring (blue), modelling (green) and auditing (red) processes coloured accordingly.

Process for Assessing Management Effectiveness and Response

Pre Management Intervention

Step 1: Monitor contaminant runoff from different land use types (e.g. established urban, developing urban, industrial, rural residential etc) to develop event mean concentrations (EMC's) (*this gives us input data to parameterise models in Step 3*).

Step 2: Monitor baseline socio-economic current status through indicators (e.g. Gooch MTSRF indicators and current status of management practice uptake) to meet requirements of chosen socio-economic model.

Step 3: Monitor end-of-catchment runoff, and calculate end-of-catchment contaminant loads (pre-management) to "validate" the modelled output in Step 4.

Step 4: Run suitable catchment model using input data from Step 1 (and 2) to determine *current scenario end-of-catchment contaminant loads* (validated using monitoring data at end-of-catchment scale from Step 3). Information used to set and revise water quality targets.

Post Management Intervention

Step 5: Implement prioritised management practices for the different land use types, potentially starting at demonstration sites to validate practices and encourage uptake; progressively move into wider adoption over time.

Step 6a: Use indicators from Step 2 (socio-economic status) to develop regular surveys to assess community capacity to undertake management interventions.

Step 6b: Audit management practice change and link to socio-economic data from 6a to assess adoption of management intervention uptake.

Step 7: Monitor contaminant runoff from these "management change" sites e.g. monitoring runoff at an urban development site (cleared land), where sediment retention practices are being implemented (*this gives us input data to parameterise models in Step 8*)

Step 8: Using data from Step 7 for different management scenarios and an indication of uptake from Step 6, develop and run a model (e.g. MUSIC) for each of these scenario types to determine water quality improvements at other sites with the same management scenarios implemented. Ideally the model will incorporate socio-economic parameters to balance cost effectiveness and water quality outcomes.

Step 9: Run suitable catchment model (e.g. E2) using input data from Step 7 and 8 to determine *"management change" scenario end-of-catchment contaminant loads*.

Step 10: Monitor end-of-catchment runoff, and calculate end-of-catchment contaminant loads (post-management) to "validate" the modelled end-of-catchment output from Step 9.

Step 11: Audit the end-of-catchment contaminant load (from Steps 6, 9 and 10) against the targets set in Step 4 to assess the effectiveness of management.

Step 12: Monitor estuarine and inshore marine water quality and ecosystem health (e.g. Marine Monitoring Program) in locations relevant to detecting responses from improved management.

Step 13: Link end-of-catchment loads to marine ecosystem health targets (assuming that local marine water quality guidelines are available) using an ecosystem response model if possible.

Step 14: Evaluation, Assessment & Reporting: Determine effectiveness of management intervention strategies (end-of-catchment and marine ecosystem; Steps 11 and 13) and report on these through a standardised report card system.

Step 15: Modify and implement management interventions and targets as appropriate (based on information collected in Steps 1 through 14). This step links to the WQIP adaptive management strategy.

Note Bayesian Belief Network modelling and other decision support tools, such as the Wetlands DSS tool can be utilised within the modelling components of this framework to inform management decision making.

3.4. Social and Economic Framework

A social and economic framework has recently been developed for the WQIP regions across the Great Barrier Reef by members of the Reef Water Quality Partnership Scientific Advisory Panel (see Appendix 2). The basis of this framework has been incorporated into the flowchart outlining the process for assessing management effectiveness (Figure 6). The indicators provided in this framework (Appendix 2) could be utilised in Step 2 of this flow chart to conduct the baseline assessment.

Indicators more specific to the Black Ross WQIP are currently being developed by Gooch et al. (2008) under the Marine and Tropical Sciences Research Facility (MTSRF) Project 4.9.7. *Understanding and enhancing social resilience: science and management integration.* In a coastal community such as Townsville where residents rely on water for a variety of economic and recreational activities, and where certain activities (such as mineral processing and transport and housing development) adversely impact upon water quality, social resilience to changes in water quality is highly desirable. Some water quality impacts may be controlled through legislation, but others are due to the action (or sometimes inaction) of individual residents. A measure of the ability of Townsville residents' willingness and ability to respond pro-actively to changing water quality is fundamental in managing for community scale resilience. In undertaking a literature review Gooch et al. (2008) discovered that indicators of community scale social resilience are not well documented, and they found only one framework that referred to resilient communities. Wolfenden et al. (2007) used four properties of socio-ecological systems to identify possible indicators of resilience in irrigation communities. These properties are described in detail by Walker et al. (2006). Wolfenden et al. (2007) see a resilient community as being responsive and innovative in the face of change. They suggest that indicators measuring each of four attributes could help to build a picture of how resilient a community might be.

The four attributes are:

- *Resilience* – the ability of a system to maintain essentially the same structure, function, purpose and identity;
- *Adaptability* – the ability of a system to respond to change;
- *Transformability* – the ability of a system to change its current trajectory when facing adversity;
- *Scale* – the synergistic influence of systems operating at different scales.

Gooch et al. (2008) are developing indicators that tie in with these properties, and a modified Pressure-State-Response framework to build a picture of a community that is resilient to changes in water quality. This is presented in Figure 7. The overall aim in developing social resilience indicators is to build the capacity of Townsville residents to change their behaviour in relation to particular water quality issues. The project is being conducted in three stages: (i) baseline data gathering; (ii) an intervention strategy (Community-Based Social Marketing (CBSM)); and (iii) post-intervention data gathering.

<u>(i) Baseline data gathering</u> – obtained through written surveys and workshop discussions to identify issues of concern among different groups; how people make judgments about water quality; on what sort of evidence these judgments are based; what specific actions/behaviours that residents are willing and able to do to improve water quality; what might be some barriers to actually doing what they would like to do; and what might be some benefits of being able to act in particular ways. Asking residents to identify cues/criteria that are used to make judgments about water quality will help to see whether different residents have different levels of awareness about water quality issues, and if these affect their willingness and ability to act in ways that improve water quality. Through this process, a range of specific actions that residents are willing and able to do to help improve water quality in Townsville's waterways will be identified. This will form the foundation on which to build a CBSM strategy that will help enhance the benefits and reduce the barriers to adopting particular behaviours that will help improve water quality of waterways in the Townsville area (McKenzie Mohr, 2000).

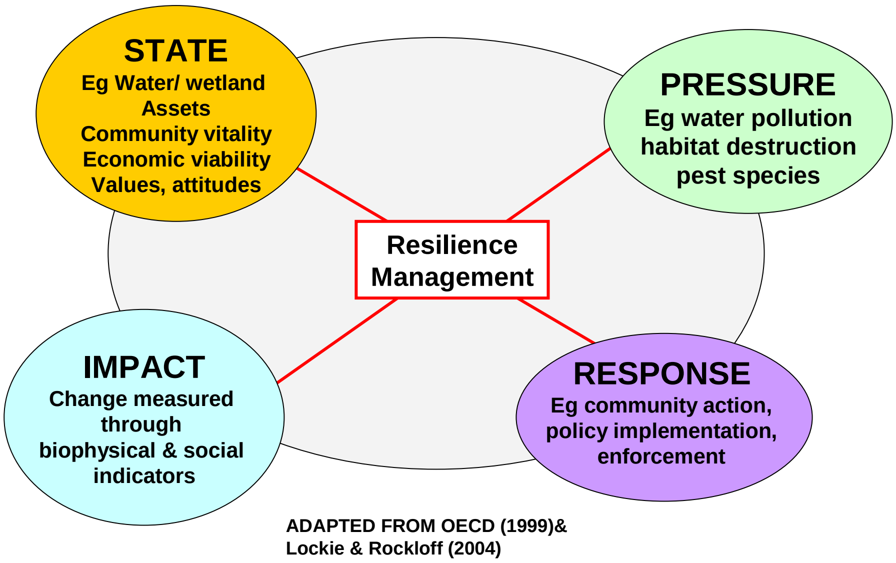

Figure 7: Conceptual Model for Social Resilience Indicators

Once a strategy is designed (but *before* strategy implementation) a stratified random survey will be mailed out to Townsville residents, sometime in 2009. This will gather baseline data about residents' ability and willingness to adopt the desired behaviour(s) identified through the workshops and written questionnaires. Barriers and/or benefits will be classified according to the following indicator domains, previously identified in the literature. For example:

- social - peer pressure;
- economic – costs, incentives;
- human/personal – habits of mind;
- cultural – traditions;
- institutional – lack of policy enforcement;
- ecological – degree of habitat degradation.

(ii) The intervention strategy (CBSM)

Depending on future funding arrangements, JCU researchers and Townsville City Council staff hope to develop a CBSM strategy that can be implemented and evaluated over a 12 month period. This will take the form of an intervention to reduce the barriers and increase the benefits of the desired behaviour(s), so that residents are motivated to change to the desired behaviour. A pilot of the strategy will be implemented, and after modification (and funding), the strategy may be implemented across Townsville. CBSM has specific steps that we will follow including the following:

- selecting desired behaviour and target audience – e.g. best management practices for residents;
- identifying barriers and benefits to a behavioural change;
- developing a strategy that uses effective "tools";
- piloting the strategy; and
- evaluating the strategy once it has been implemented across a community (McKenzie Mohr, 2000).

(iii) Post-intervention

Finally, the baseline residential survey could be repeated (depending on time and funding), to see whether the CBSM strategy led to an increased adoption rate of the desired behaviour. The strategy may need to be adjusted, then implemented again, and a further survey implemented (again, depending on time and funding). Thus, the survey can be modified and repeated over time to monitor changes in behaviours as well as the community's capacity to be pro-active in the face of changing water quality. It is envisaged that this ongoing survey will be integrated into the Black Ross WQIP monitoring and reporting activities, with the information gathered to be used to inform management action adaptation strategies.

3.5. Monitoring Types

Water quality monitoring is undertaken for a variety of purposes, a number of which were recently identified through the *Reef Water Quality Partnership's* generic 'Draft Reef WQIP Monitoring and Modelling Strategy Approach'. These monitoring types include:

- Background/baseline monitoring,
- Identifying contaminant sources;
- Issues monitoring;
- Transport and processing of contaminants in catchments;
- Defining status and trend;
- Assessing management effectiveness;
- Assessing ecosystem response;
- Monitoring to produce a reporting product; and
- Research.

Three primary monitoring types as outlined above will be required under the Black Ross WQIP, including:

- Background/baseline monitoring;
- Identifying contaminant sources; and thirdly;
- Assessing management effectiveness.

Secondarily, these monitoring types as outlined above may also be required under the Black Ross WQIP, including:

- Monitoring to produce a reporting product; and
- Assessing ecosystem response in freshwater environments.

Table 1 describes these three primary monitoring types, and also includes a description of their current status. The second and third monitoring activities (identifying contaminant sources and assessing management effectiveness) are integrated, and include a modelling component as we cannot monitor at all temporal and spatial scales. This coupled monitoring and modelling approach is outlined in the following section.

Table 1: Types of monitoring activities required under the WQIP, including an explanation of each monitoring type, the current status of each type and links to modelling.

Monitoring Type	Description	Status
Monitoring for the collection of background/ baseline information	• Monitoring carried out to understand the spatial and temporal range of water quality parameters important to aquatic ecosystem health in water bodies at a range of scales: - Stormwater drain; - Sub-catchment; - Catchment; - Receiving waters (estuarine & marine); - Freshwater plumes. • Assess natural variability of water quality parameters in time and space; • Used to design a monitoring program in which the signal (the result we are seeking) can be separated from the noise (the natural variability); • Gather reference site data to design water quality guidelines or criteria. • Conduct baseline socio-economic assessment through indicators (e.g. population pressures, identify management practices)	• Already conducted in many of the regions waterways in both ambient and event flow conditions • Event flow conditions monitored over successive wet seasons and varying sized flow events providing reference data for water quality guidelines • Ambient flow data collected by council and CVA also has potential to develop local water quality guidelines for low flow conditions • Socio economic data not collected on a routine basis.
Monitoring to identify contaminant sources	• Monitoring carried out to identify (and quantify) the sources, in terms of land uses and activities, of contaminants from the landscape to waterways; • In these programs the landscape will be divided into different land uses and potential pollutant sources (e.g. sugarcane cultivation, metallurgical industry, urban, sewage treatment plant) determined and the water quality characteristics of each land use characterised through monitoring sites downstream of each land use/source.	• Event flow monitoring program has identified water quality issues from the varying land uses within the region; • Event Mean Concentrations (EMC's) currently being developed from different land uses within the region to feed into catchment models
Monitoring to assess the effectiveness of improved management efforts in the catchment	• Monitoring carried out to determine whether management intervention to reduce contaminant sources is changing contaminant concentration/ loadings; often at small scale; • Will normally have a trend or comparison element, such as a comparison data from before the intervention was implemented; • Important for input into catchment scale modelling that is specific to land use/land types in the region. • Monitoring adoption and uptake of management practices.	• End-of-catchment (event) monitoring conducted to determine sediment and nutrient loads to compare with modelled outputs • Monitoring is required once management intervention activities are implemented through the WQIP process

3.6. Modelling Tools

The following section outlines a range of potential modelling tools that can be utilised to assist the Black Ross WQIP gain a better understanding of catchment to reef processes and water quality impacts from the catchment to the Cleveland and Halifax Bays. A description of each model has been provided as well as the likely application and use within this region. The Queensland Government's *Water Quality Modelling for the Great Barrier Reef Catchment and Lagoon* (Trevor and Hammill, 2008) Report for the Reef Water Quality Partnership has been used for model descriptions. The review and gap analysis of receiving-water water quality modelling in the GBR conducted by Webster et al. (2008) has also been used (ChloroSim description).

It is likely that a combination of these modelling tools are required to provide the linkages between end-of-catchment (river) pollutant loads (i.e. suspended sediment, nutrient or herbicides) and an ecosystem health target (i.e. seagrass, reef etc). As management interventions are implemented within the catchment, the associated changes in end-of-catchment loads, and the resultant influence on the marine ecosystem health target will also need to be modelled.

E2 (discharge)

E2 is an integrative whole-of-catchment modelling platform using the Catchment Modelling Toolkit (CMT) as its primary source of component models and tools. In E2, the model structure and algorithms are not fixed. They are flexibly defined by the user for a particular catchment management problem. Users can choose from a suite of available component model options. Model selection requires the user to be familiar with the detail, applicability and data requirements of component models, and the implications of joining component models.

The E2 Model can be and is currently used by a number of NRM groups to assess the water quality impacts of on ground works investment. In terms of catchment management E2 can be used:

- to inform the user about average concentrations of sediment and or nutrients exported from subcatchments;
- for scenario comparisons that enable end user to compare land use change implications on water quality and assist in identifying which subcatchments certain best management practices can be implemented and what outcomes can be expected;
- to run different climate scenarios to determine the change hydrology and pollutants with different climate regimes;
- to provide indicative results to assist in target-setting at the appropriate scale (Note: users need to understand the uncertainty around the output results, which depends on the level of confidence around the outputs based on validation data);
- to evaluate progress against targets if changed land use or management changes are incorporated into the model to see cumulative effect at subcatchment scale;
- to inform monitoring by identifying where data gaps are in system. It could also assist in prioritising where monitoring should occur based on export loads.

<u>Application and use</u>*: The Black Ross WQIP has already engaged WBM consultants to run the E2 model on the Black Ross catchments. The E2 model will be used to determine current pollutant loads, and as appropriate, determine water quality and flow requirements for target setting. Event Mean Concentration (EMC) data for different land uses within the region generated from the sub-catchment monitoring in the 2006/07 and 2007/08 wet seasons (Liessmann et al., 2007; Lewis et al., in prep) will assist the model in generating accurate pollutant loads.*

MUSIC Model

Model for Urban Stormwater Improvement Conceptualisation (MUSIC) is an aid to decision-making enabling users to evaluate conceptual designs of stormwater management systems to ensure they are appropriate for their catchments. MUSIC simulates urban stormwater systems enabling users to evaluate conceptual designs of stormwater management systems to meet water quality objectives.

MUSIC enables urban catchment managers to:

- Determine the likely water quality emanating from specific catchments;
- Predict the performance of specific stormwater treatment measures in protecting receiving water quality;
- Design an integrated stormwater management plan for each catchment;
- Evaluate the success of specific treatment measures, or the entire catchment plan, against a range of water quality standards.

Application and use: The MUSIC model is currently being applied under the Black Ross WQIP to support the E2 model with greater detail in the urban areas, and to allow for management scenario modelling to be conducted.

ChloroSim Model

ChloroSim is a spatial model of water quality, in the central and northern sections of the GBR lagoon using chlorophyll *a* concentration as a proxy (Wooldridge et al., 2006). The model uses flood plume extent and minimum salinity data (as predicted by the MECCA flood plume modelling) to relate predicted dilution ratios to dissolved inorganic nitrogen (DIN) and chlorophyll *a* concentrations for specified river discharges and nitrate loads. ChloroSim provides a methodology that links a quantitative river discharge parameter (DIN) with a quantitative indicator of health in the marine environment (Chl *a* concentration), thus providing a means to estimate the level of reduction in fluxes of a land-sourced material (DIN) necessary to achieve specified lagoonal water quality standards. ChloroSim relies on regional in-situ observations of chlorophyll for parameter estimation, and on a spatial description of flood plume dilution factors. It is only applicable under wet season conditions, and its application is limited to the central and northern GBR, using the MECCA flood plume modelling of King et al. (2002), at that same spatial resolution.

Application and use: This model can be used to link end-of-catchment nitrate loads with chlorophyll concentrations (indicator of biological productivity), and will be useful in setting targets for catchment nitrate concentrations. The chlorophyll dataset (GBRMPA Long Term Monitoring Program and others; see section 2.2) within Cleveland Bay is amongst the longest collected within the Great Barrier Reef lagoon and thus long term trends can be examined.

SLIM Model (hydrodynamics)

Secondgeneration Louvain-la-Neuve Ice-ocean Model (SLIM) is an ocean model that is based on an adaptive, unstructured grid, relies on the finite element method and resorts to parallel computing algorithms to solve the governing equations.

SLIM is being developed to simulate the circulation in the World Ocean for studying the Earth's climate system, and will also be tested for a range of geophysical flow problems, including the

- assimilation of sea-ice data,
- circulation in the shelf break region,
- representation of an extended range of space and time scales, exploration of an extra-terrestrial oceanography problem.

This model is used to study the spread of pollutants, and the distribution of water-born organisms with a swimming ability (i.e. non passive) in the whole GBR. The implementation of SLIM on the GBR (Lambrechts et al., 2008) extends from Fraser Island to Cape York Peninsula, at a scale of 200 m near coasts, reefs and islands, and a coarser scale (up to several km elsewhere) for the whole GBR in one run (> 1 million grid points) using parallel computing.

<u>Application and use</u>: *Modelling physical processes within Cleveland and Halifax Bays at high resolution will assist in the understanding of the dispersal of terrestrial based pollutants in the marine environment from the adjacent catchment area.*

HOME Model (Reef Health)

HOME is a deterministic, ecological model of coral and algal abundances on coral reefs. It is based on processes of:

- Hydrology (riverine water, nutrient and sediment runoff);
- Oceanography (connectivity and self-seeding of reefs, river plumes, nepheloid layers);
- Meteorology (wind during and after mass spawning; cyclones);
- Ecology (coral reef cover as determined by competition for space between algae and corals, and influenced by COTS population dynamics, river plumes, plankton, herbivorous and carnivorous fish, sediment and nutrients).

The model can be used to predict the future health of individual coral reefs (using algal cover as a proxy measure of reef health) in the Great Barrier Reef as impacted by global warming, ocean acidification, and watershed management (control of pastures and farming for their leachate of sediment and nutrients). The model can be used in deciding what level of control land use is appropriate to maintain and/or restore a given area of reef (Trevor and Hammill 2008). For a more detailed explanation of this model, and how it has been successfully applied at a broad scale across the central Great Barrier Reef see Wolanski et al. (2004) and Wolanski and De'ath (2005).

<u>Application and use</u>: *This model can be used to predict the health of reefs within Cleveland and Halifax Bays as a result of improved water quality outcomes from the Black Ross WQIP. This model will also provide data to set targets for water quality parameters. The application of this model on Cleveland and Halifax Bays would act as a pilot study for wider application across the Great Barrier Reef lagoon.*

Reef Exposure Model (proportion of influence from Burdekin, Ross, Haughton)

The Reef Exposure model is a statistical model of hydrodynamic transport that simulates probabilities of river plume dispersion, dilution and sedimentation. The model relies on a function which simulates the probabilities of river plume water being forced in certain directions from the river mouth. The function is based on modelled and observed plume behaviour actually driven by winds, tides and coriolis. It uses output from MECCA.

The Risk Exposure model used widely to identify areas of the GBR exposed to high pollutant exposure and thus prioritise catchments for management. The model is presently being applied to show the effect of different loads of pollutants (derived from credible catchment management scenarios) from individual catchments. The model can be used in 'reverse' to link exposure at a particular reef to a particular and identified set of rivers.

<u>Application and use</u>: *This model can be used to identify the extent of terrestrial based pollutants in the marine environment from the adjacent catchment area, and identify areas in the marine environment most at risk from individual pollutants.*

4. MONITORING AND MODELLING PLAN DESIGN

This strategy provides an overview of the existing monitoring and modelling activities within the Black Ross WQIP region, as well as a framework for future activities for both catchment and marine ecosystem health. Further development of this strategy to include detailed program design will support the management actions and investment priorities of the region implemented through the Black Ross WQIP. To ensure this program design adequately reflects the actions and investment priorities of the WQIP, it is recommended that the program is designed in consultation with all relevant organisations to the region through a workshop format (see Appendix 3 for recommended attendees).

Future monitoring and modelling plans

- **Loads-based water quality monitoring**
  - Critical sub-catchment and end of river sites (to inform and validate modelling)
  - Flood plume extent and composition (to inform and validate modelling)
- **Ecosystem health and ambient WQ monitoring**
  - Urban Stormwater Quality Management Plan
  - Community monitoring
  - Reference site monitoring (to develop local WQ guidelines)
  - Seagrass and reef monitoring
  - Marine WQ monitoring (compliment GBR MMP)
- **Compliance monitoring**
  - Heavy industry, STP's and other ERA's
  - Discharge standards (permit conditions) and receiving water quality monitoring
  - Data availability and commercial sensitivity issues
- **Community based education and involvement**
  - Water quality monitoring, catchment tours, tree plantings, etc
- **Socio-economic monitoring**
  - Baseline and ongoing surveys (based on indicators – MTSRF project)
- **BMP uptake auditing**
  - Baseline and ongoing surveys (i.e. % of developers undertaking water sensitive urban design)
- **Modelling Plan**
  - Establish base model
  - Update base models with information collected through event monitoring program
  - Re-run model using updated scenarios based on information collected in BMP auditing and socio-economic monitoring
  - Model effectives of BMP's and validate against information collected in event and ambient WQ monitoring programs
- **Decision Support Modelling (BBN, Wetlands DSS)**
  - Establish base model
  - Update base models with information collected through event monitoring program
  - Re-run model using updated scenarios or other information

5. REFERENCES

ABS 2007. Australian Bureau of Statistics (http://www.abs.gov.au/website).

Bartley, R., Post, D., Kinsey-Henderson, A. and Hawdon, A. 2007. Estimating sediment loads in Great Barrier Reef catchments: balance between modelling and monitoring In: Proceedings of the 5th Australian Stream Management Conference. Australian rivers: making a difference. Eds.Wilson, A.L., Dehaan, R.L., Watts, R.J., Page, K.J., Bowmer, K.H., & Curtis, A. Charles Sturt University, Thurgoona, New South Wales.

Bartley, R., Fitch, P., McJannet, D. 2005. Issues associated with measuring end of catchment sediment and nutrient loads in the Great Barrier Reef catchments. OzWater 2005 Conference, Townsville, May 2005.

Brodie, J., McKergow, L.A., Prosser, I.P., Furnas, M., Hughes, A.O. and Hunter, H. 2003. Sources of sediment and nutrient exports to the Great Barrier Reef World Heritage Area. ACTFR Report No. 03/11, ACTFR, James Cook University, Townsville, 208 pp.

Devlin, M., Brodie, J., Waterhouse, J., Mitchell, A., Audas, D. & Haynes, D., 2003. Exposure of Great Barrier Reef inner-shelf reefs to river-borne contaminants. In: Proceedings of the 2nd National Conference on Aquatic Environments: Sustaining our aquatic environments- Implementing solutions. Queensland Department of Natural Resources and Mines, Brisbane, Australia.

Fentie, B., Duncan, I., Sherman, B.S., Read, A., Chen, Y., Brodie, J. and Cogle, A.L. 2006. Sediment and nutrient modelling in the Burdekin NRM region. Volume 3. In: The use of SedNet and ANNEX models to guide GBR catchment sediment and nutrient target setting. Ed A.L Cogle, C. Carroll and B.S. Sherman. Department of Natural Resources Mines and Water, Brisbane. QNRM06138.

Furnas, M. 2003. Catchments and corals: Terrestrial runoff to the Great Barrier Reef. Australian Institute of Marine Science, Townsville, 334 pp.

Greiner, R., Herr, A., Brodie, J., & Haynes, D., 2005. A multi-criteria approach to Great Barrier Reef catchment (Queensland, Australia) risk assessment. *Marine Pollution Bulletin*, **51**(1-4): 128-137.

Gooch, M., Cullen, L. Manning, C. & Butler, J. 2008. Developing indicators of social resilience to changes in water quality – Townsville case study. Paper presented to the MTSRF Annual Conference, Cairns, April 29, 2008.

King, B. McAllister, F. Done, T. 2002. Modelling the impact of the Burdekin, Herbert, Tully and Johnstone River plumes on the Central Great Barrier Reef. CRC Reef Research Centre Technical Report No 44, CRC Reef Research Centre, Townsville.

Kinsey-Henderson, A. and Sherman, B. 2007. SedNet loads reported in the Meat and Livestock Australia Burdekin SedNet Model for selected sites. CSIRO Land & Water Client Report for BDTNRM CCI.

Lambrechts, J., Hanert, E., Deleersnijder, E., Bernard, P., Legat, V., Remacle, J., and Wolanski, E. 2008. A high-resolution model of the whole Great Barrier Reef hydrodynamics. *Estuarine, Coastal and Shelf Science*, in press.

Lewis, S., Bainbridge, Z., Brodie, J. In prep. Water quality monitoring of Black Ross Basins: 2007/08. ACTFR Report No. 08/04 For the Black Ross WQIP. ACTFR, James Cook University, Townsville.

Liessmann, L., Lewis, S., Bainbridge, Z., Brodie, J., Faithful, J. and Maughan. M. 2007. Event-based water quality monitoring of the Ross and Black River Basins during the 2006/07 wet season. ACTFR

Report No. 07/09 for the Townsville Thuringowa Creek to Coral CCI. ACTFR, James Cook University.

Lockie, S. & Rockloff, S. 2004. Decision Frameworks: Assessment of the Social Aspects of Decision Frameworks and Development of a Conceptual Model. Coastal CRC Citizen Science Discussion Paper, Centre for Social Science Research, Central Queensland University, Rockhampton.

McKenzie-Mohr, D. 2000. New Ways to Promote Pro-environmental Behaviour: Promoting Sustainable Behaviour: An Introduction to Community-Based Social Marketing *Journal of Social Issues*, **56** (3), 543–554.

McKergow, L.A. Prosser, I.P. Hughes, A.O. Brodie, J. 2005a. Sources of sediment to the Great Barrier Reef World Heritage Area. *Marine Pollution Bulletin*, **51**: 200-211.

McKergow, L.A. Prosser, I.P. Hughes, A.O. Brodie, J. 2005b. Regional scale nutrient modelling: exports to the Great Barrier Reef World Heritage Area. *Marine Pollution Bulletin*, **51**: 186-189.

Mackay Whitsunday NRM Group. 2007. Water Quality Improvement Plan Working Draft Monitoring Strategy (Integrated Monitoring Program). Mackay Whitsunday Natural Resource Management Group, 5 June 2007.

Maughan, M., Brodie, J., Waterhouse, J. 2008. Reef exposure model for the Great Barrier Reef Lagoon. ACTFR Technical Report No.07/19. ACTFR, James Cook University, Townsville. Pp. 162.

Organisation for Economic Co-Operation and Development (OECD) (1993) Core set of indicators for environmental performance reviews: A synthesis report by the Group on the State of the Environment OCDE/GD(93)179 *Environment Monographs*, **83**, Paris.

Osidele, O., Zeng, W. and Beck, M. 2003. Coping with uncertainty: A case study in sediment transport and nutrient load analysis. J. *Water Resources Planning and Management*, **4**: 345-355.

Rattray, D., Silburn, D., Owens, J. and Barlow, L. 2006. Combining ‘paddock models’ and geographical information systems can be a powerful tool in catchment planning. 30th Hydrology and Water Resources Symposium, Launceston, Tasmania, 4-7 December 2006.

Stow, C., Borsuk, M. and Stanley, D. 2001. Long-term changes in watershed nutrient inputs and riverine exports in the Neuse River, North Carolina. *Water Research*, **35**: 1489-1499.

Trevor, C. and Hammill, B. 2008. Water quality modelling for the Great Barrier Reef catchment and lagoon. Report for the Reef Water Quality Partnership. Queensland Department of Natural Resources and Water; Brisbane.

Walker, B., Gunderson, L., Kinzig, A., Folke, C., Carpenter, S., & Schultz, L. 2006. A handful of heuristics and some propositions for understanding resilient in social-ecological systems. *Ecology and Society*, **11**(1).

Webster, I.T., Brinkman, R., Parslow, J.S., Prange, J., Steven, A.J. and Waterhouse, J. 2008. Review and gap analysis of receiving-water water quality modelling in the Great Barrier Reef. Report to Department of Environment, Water, Heritage and the Arts.

Wolanski, E. and De’ath, G. 2005. Predicting the impact of present and future human land-use on the Great Barrier Reef. Estuarine, *Costal and Shelf Science*, **64**: 504-508.

Wolanski, E., Richmond, R.H., Davis, G. and Bonito, V. 2003. Water and fine sediment dynamics in transient river plumes in a small, reef-fringed bay, Guam. *Estuarine, Coastal and Shelf Science*, **56**: 1029-1043.

Wolanski, E., Richmond, R. and McCook, L. 2004. A model of the effects of land-based, human activities on the health of coral reefs in the Great Barrier Reef and in Fouha Bay, Guam, Micronesia. *J. Marine Sciences*, **46**: 133-144.

Wolfenden, J, Evans, M., Essaw, D., Johnson, F., Sanderson, A., Starkey, G. & Wilkinson, B. 2007. Resilience management: a guide for irrigated regions, communities and enterprises. Technical Report No. 01/07. CRC for Irrigation Futures.

Wooldridge, S. Brodie, J. Furnas, M. 2006. Exposure of inner-shelf reefs to nutrient enriched runoff entering the Great Barrier Reef Lagoon: Post-European changes and the design of water quality targets. *Marine Pollution Bulletin*, **52**: 1467-1479.

6. APPENDIX

Appendix 1:

Information Box 1 (system noise and lag times) figures

Information Box 1 Figures

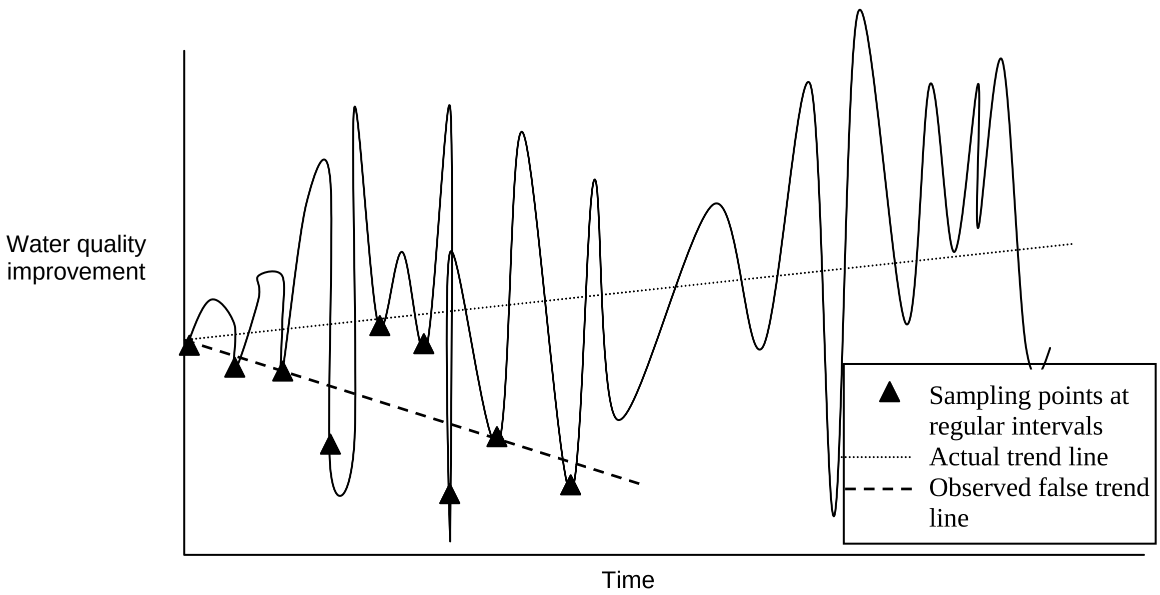

Figure 1: Water quality trend difficult to detect due to “noise” within the catchment, where “noise” might be size of catchment, or rainfall intensity and duration.

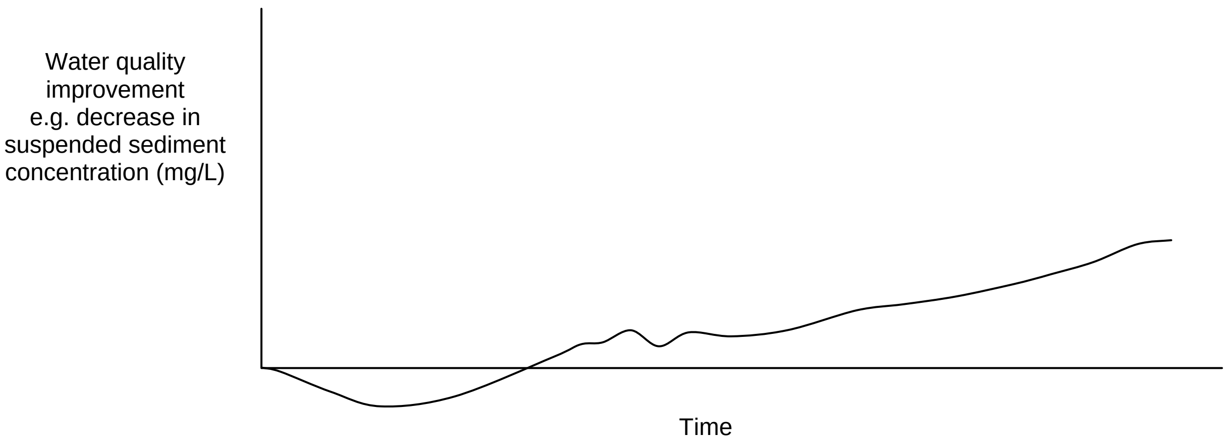

Figure 2: Water quality change/improvement lag time associated with the replanting of riparian vegetation as a sediment buffer on a local waterway, where water quality may temporarily decrease due to the initial planting/growth stage before longer term improvements in water quality occur.

Table 1: Approximate timeframes for detecting water quality trends/signals at varying spatial scales as a result of remedial management actions with the catchment. Based on current understanding and assumes at least average wet season flows to occur each year.

Water quality parameter	Management actions/ remediation activities	Timeframe of water quality trends/signals being detected at different spatial scales			
		Local (Immediate drainage line/waterway)	Sub-catchment	End-of-Catchment scale	Estuarine & marine
Suspended sediment and associated particulate nutrients	Sediment and erosion control mechanisms for urban development (cleared land) e.g. silt curtains *E.g. urban development site*	• Immediate - when next rain event occurs *Local drainage line*	• Change likely to be detected within a wet season, but variable depending on proportion of total catchment area *Tributary to Ross River*	• Dilution of signal as only small % of total catchment area under development at any one time, and catchment variability or "noise" is high • Requires modelling from local to end-of-catchment scale *Ross River*	• Limited likelihood of detecting signal from this management action due to influence of larger Burdekin system, except very close to the river mouth *Nelly Bay compared to Middle Reef closer to river mouth*
	Constructed wetlands in newly established suburb where water sensitive urban design (WSUD) has been implemented *E.g. newly established suburb with WSUD*	• Months-years for wetland to become established as effective sediment trap • Initial construction may see temporary increases in erosion • Wetlands will trap coarse material more efficiently than finer material (i.e. rocks and sand compared to fine silts and clays)- applies to all scales *Local drainage line*	• Change likely to be detected within a wet season, but variable depending on proportion of catchment and the size of the wetlands *Tributary to Ross River*	• Dilution of signal as only small % of total catchment area under development at any one time, and catchment variability or "noise" is high • Requires modelling from local to end-of-catchment scale *Ross River*	• Limited likelihood of detecting change in course material concentrations in estuary • Extremely limited in marine environment (even close to river mouth) as more effective at trapping coarser material - also issue for assoc. part nutrients as predominately attached to fines *Ross Ck estuary*

Water quality parameter	Management actions/ remediation activities	Timeframe of water quality trends/signals being detected at different spatial scales			
		Local (Immediate drainage line/waterway)	**Sub-catchment**	**End-of-Catchment scale**	**Estuarine & marine**
Litter	Gross pollutant traps *E.g. a GPT on Ross River tributary*	• Immediate effects • Measurable by amount of litter trapped in the GPT *Ross River tributary*	• Change likely to be detected within a wet season, but variable depending on proportion of catchment with GPT's *Ross River*	• 2-7 years; may be time lags due to existing rubbish in the system. Variable depending on proportion of catchment with GPT's *Ross River*	• Limited capacity to monitor in marine environment *Local marine environment/beaches*
Dissolved nutrients **(i.e. nitrate, phosphate)**	Reduction of fertiliser use in urban lands (i.e. backyard, council parks, golf courses,) (e.g. use of native vegetation vs. exotics; wise use of detergents) *E.g. small urban suburb*	• Change unlikely to be detected over shorter timeframes- but maybe detected within a 5-10yr period depending on rate of adoption of improved practices within the suburb *Suburban drain e.g. Kern Drain*	• Unlikely to be detected at this scale as suburb only small proportion of total catchment • Depends on adoption rates over wider catchment area influencing this creek *Tchooratippa Creek*	• As grazing is dominant land use in this catchment, water quality signal from smaller urban area likely to be diluted. Other point sources such as sewage treatment plant may add additional catchment "noise" *Bohle River*	• Limited likelihood of detecting signal from this management action in the coastal waters due to dilutions from the larger catchment (e.g. Bohle River) and from sea water mixing *Halifax Bay*
	Upgrade of sewage treatment plants/reduction of sewage overflow during high rainfall events e.g. advanced secondary from secondary treatment plant *E.g. Advanced secondary treatment plant*	• Immediate effects *Output pipe into river*	• Immediate effects if the sewage treatment plant was initially a major source of total N/P load *Little Bohle River*	• Immediate effects on chronic (low flow conditions) however dilution effect will occur during major event flows, making signal difficult to detect *Bohle River*	• Limited likelihood of detecting signal from this management action in the coastal waters during event conditions due to dilutions from the larger catchment (e.g. Bohle River) and from sea water mixing • Possibly could detect signal during low flow conditions in near coastal waters *Halifax Bay*

Water quality parameter	Management actions/ remediation activities	Timeframe of water quality trends/signals being detected at different spatial scales			
		Local (Immediate drainage line/waterway)	**Sub-catchment**	**End-of-Catchment scale**	**Estuarine & marine**
Pesticides	Use alternative products with less potential for offsite transport *E.g. small urban suburb*	• Change detected in next wet season due to relatively low half life (e.g. diuron half life in soil is 90 days, therefore probable complete life less than 2 years) *Suburban drain*	• Change detected in next wet season *Tributary to Ross River*	• Change detected in next wet season; dilution effect depending on proportion of uptake within catchment • May be below analytical detection limits *Ross River*	• Changes likely to be detected within the resulting floodplume (e.g. Ross River), however signal may be difficult to detect if the coastal waters are also influenced by the Burdekin River plume • Due to sea water mixing signal likely to be stronger closer to the river mouth. *Cleveland Bay*
	Reduction in use *E.g. small urban suburb*	• Change detected in next wet season due to relatively low half life (e.g. diuron half life in soil is 90 days, therefore probable complete life less than 2 years) *Suburban drain*	• Change detected in next wet season *Tributary to Ross River*	• Change detected in next wet season; dilution effect depending on proportion of uptake within catchment • May be below analytical detection limits *Ross River*	• Changes likely to be detected within the resulting floodplume (e.g. Ross River), however signal may be difficult to detect if the coastal waters are also influenced by the Burdekin River plume • Due to sea water mixing signal likely to be stronger closer to the river mouth. *Cleveland Bay*

Appendix 2:

RWQP Scientific Advisory Panel - Social Economic Framework

GBR Wide Social and Economic Framework (from RWQP Scientific Advisory Panel)

This framework has been developed to guide the collection and interpretation of social and economic information relevant to enhancing water quality improvement. This in turn can then guide the design of efficient policies and practices. This framework is not intended to be totally comprehensive and other information will be required. However, the framework does outline the key elements and requirements common to virtually all social and economic dimensions of water quality management.

Management context

This framework is essential for effective water quality management as there are likely to be significant time lags between management change and resource condition response. Detection of changes in water quality issues of concern (sediment, nutrients and pesticides) are likely to be on longer time scales than the funding cycles that support them.

Social and economic information collected under this framework will not only provide foundational information about the anticipated impacts and uptake of management options but also essential measures of achievement of intermediate outcomes during plan implementation phases. The diagram in Figure 1 below highlights the multiple role of social and economic information in the policy development and implementation process. The main stakeholders in water quality management are rural and peri-urban land managers and this group is identified as a priority for research under this framework.

Assumptions and intentions underpinning the framework

The process of populating the framework with data is intended as a co-managed research process where researchers work closely with managers to tailor the research to management needs and local contexts. Baseline data is a fundamental first step in the implementation of the framework concentrating on the drivers of actions that create risks to water quality and the impediments to practice change.

Surveys must be based on current recommended practice for specific land uses so must be tailored to each region. The resulting data will require some translation back into the planning process and this is best achieved when managers are most familiar with the research and its intention. It is also understood that the resulting data and information will require some interpretation in order to meet various audience communication requirements. The RWQP has an important role in developing regional capacity in research, monitoring and interpretation of social and economic information.

The framework

As shown, Figure 1 identifies the need for social and economic information in four key areas:

1. **Baseline assessment** to: understand the social and economic values associated with the GBR; the drivers of management practices that create risks to GBR resource condition and trend (RCT); and to understand the broad benefits and costs of actions to enhance RCT.
2. **Policy design** (including modification to existing policy), to ensure effective and efficient policies are developed that account for social and economic impediments to changing practices.
3. **Policy implementation** to achieve desired changes. It is assumed that the actions targeted under the policy implementation phase are developed based on science and will lead to changes in the resource condition trend. This is the area where the linkages with biophysical sciences are vital to result in on-ground actions.
4. **Monitoring and evaluation** of social and economic drivers and values to feedback into a comparison of the baseline assessment to measure change, and a feedback to inform policy design (adaptive management). Note: key feedback loops are indicated by dashed lines.

These components are examined in greater detail in Table 1. Examples of potential indicators are also provided in Table 2.

Figure 1: A social and economic framework for water quality improvement in the GBR region.

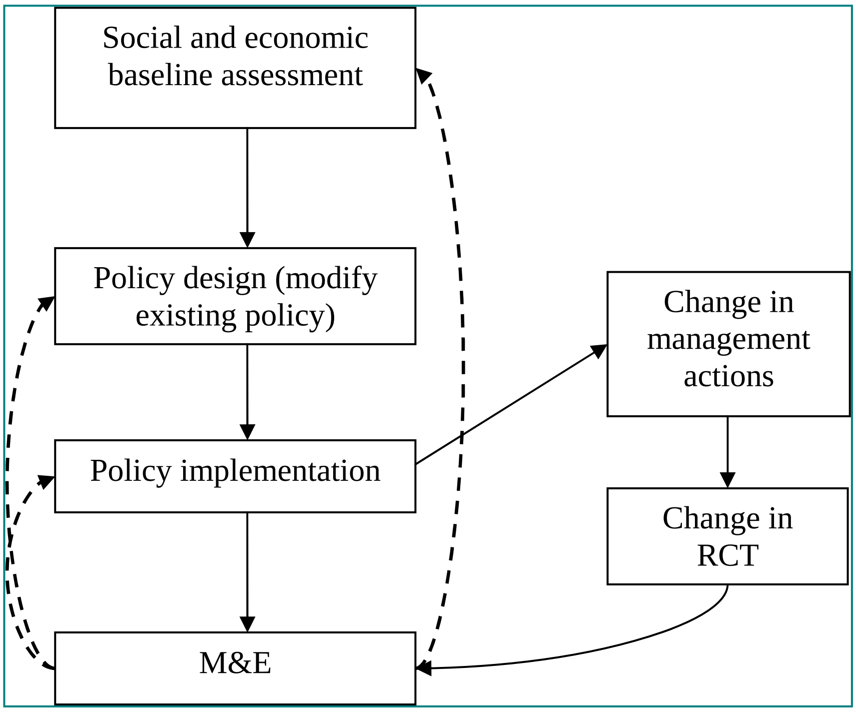

Table 1: Framework components, actions, results and contributions to water quality (from RWQP SAP)

Social and Economic Framework for the RWQP SAP			
FRAMEWORK COMPONENT	**ACTION**	**RESULT**	**CONTRIBUTION TO WATER QUALITY**
Baseline	▪ Primary data collection / landholder, community by sector, institutional data collection - Aspirations - capacities - influences - attributes of practices - outcomes - community by sector - landholder by sector - institutional capacity - industry ▪ Review of existing research on users and impactors ▪ Secondary data indicators	▪ Baseline data for M & E ▪ Landholder level data ▪ Community level data	▪ Inform policy design and implementation
Policy design :	▪ Policy target (e.g. fertiliser reduction) ▪ Constraints/impediments (e.g. 5 capitals, attributes, aspiration) ▪ Sequencing of constraints ▪ Opportunities (e.g. activity generated, new practices) ▪ Identify winners / losers ▪ Selecting appropriate policy tools/incentives to overcome constraints e.g. market based instrument awareness programme ▪ Institution most appropriate to deliver tool (institutional arrangements for implementation)	▪ Informed efficient set of policies, policy levers and responsible institutions	▪ Cost effective policy, programmes and projects

	ACTION	RESULT	CONTRIBUTION TO WATER QUALITY
Policy implementation	▪ Industry and community engagement ▪ Product development ▪ Communication./extension/ engagement ▪ Delivery ▪ Governance ▪ Probity ▪ Reporting	▪ On ground action ▪ Local ownership	▪ Change in the resource condition and trend
Monitoring and Evaluation	▪ Resource condition – link to marine & terrestrial monitoring ▪ Land management practices - who's adopted - who's changed ▪ Re-assess drivers & influences & contribution (or not) to change and tools, incentives and arrangements used ▪ Benefits (value of industries, attitudes/values, use of park, rec fishing etc, com surveys end users) ▪ Regional variability ▪ Policy – design and implementation ▪ Link to other NRM monitoring and evaluation (eg MERI)	▪ Continuous improvement ▪ Feedback to policy design and implementation ▪ Longitudinal data demonstrating change	▪ Better water quality

Table 2: Potential indicators for the RWQP social and economic framework (from RWQP SAP)

Objective: *Improvement in land uses resulting in water quality improvement*

Framework component	Indicator suite	Example indicators (primary =P, secondary =S)	Informs what	Relevant existing work/ Regionally specific info
Baseline	Baseline community indicators.	▪ Population pressures (number / structure), labour market makeup, broad community resilience (S).	▪ Broad community makeup.	▪ ABARE data extraction.
	▪ Broad economic influences (power structures).	▪ Sector (e.g. sugar, tourism) trends, drivers and potential risks to / from change in water quality (S).	▪ Economic trends, risks and market constraints.	▪
	▪ Individual aspirations.	▪ Env, soc and econ attitudes and aspirations relevant to enterprise management (P).	▪ Tradeoffs between TBL outcomes.	▪ Landholder surveys;
	▪ Wellbeing and satisfaction.	▪ Quality of life (P & S).	▪	▪
	▪ Capitals (human, social, financial, natural, built).	▪ Qualifications, free financial capital etc (P & S). General capacities and participation (P).	▪ Capacity to change practice and resilience.	▪
	▪ Influences.	▪ Market, sector, social, policy regulation (P & S).	▪	▪
	▪ Attributes and values of practices.	▪ Public/ private benefit, compatibility, trialability, observability, acceptability, values etc (P & S).	▪ Likelihood of adoption to inform policy design.	▪
	▪ Characterise practices.	▪ Identify practices, eg. pesticide and fertiliser application rates, methods of application, WSUD, stocking rates (S). Several sources of data required.	▪ Change in practice.	▪ Terrain (other regions?), BSES, landholder surveys,
	▪ Risk to asset	▪ Perceptions (P).	▪	▪
	▪ Use indicators	▪ Guest nights, reef visits, fishing, recreation, Indigenous use and interests, infrastructure & services (P & S)	▪ Utilisation of GBR.	▪
Policy design tailored to requirements	Process monitoring ▪ S&E assessment of key policies, programs	Examples ▪ Utilising several indicators, undertake formal SEIA. Information to inform prioritisation of what, who, where, how, when.	▪ Rationale for policy and instrument choice.	▪ Regional bodies, WQIPs, Binney et al WQIP project, GBRMPA/ Access Economics, MBI assessment, MATs. Range of techniques.
	▪ Desired outcomes/ targets	▪ Program logic.	▪	▪
	▪ Engagement and communication (community and industry)	▪ Industries engaged, model adopted, involvement of regions. ▪ Stakeholder analysis / network mapping.	▪ Likely ownership, responsibility and uptake of policy.	▪

Objective: *Improvement in land uses resulting in water quality improvement*

Framework component	Indicator suite	Example indicators (primary =P, secondary =S)	Informs what	Relevant existing work/ Regionally specific info
Policy implementation	▪ Governance and institutional. ▪ Policy environment ▪ Funding resources ▪ Capacity ▪ Institutional arrangements ▪ Alignment ▪ Stakeholders	▪ Partners meet contractual obligations, assessment of institutional arrangements. ▪ ▪ ▪ ▪ ▪ ▪	▪ Redesign of policy, was the policy implemented. ▪ ▪ ▪ ▪ ▪ ▪	▪ ▪ ▪ ▪ ▪ ▪ ▪
M&E	▪ Monitoring baseline ▪ Evaluating change ▪ M&E implementation ▪ M&E design	▪ Evaluate change in indicators to redesign policy. Cost benefit analysis. ▪ Implementation process and content. ▪ % of target businesses utilising target management actions (P & S). Uptake / compliance. ▪ Adoption of practice, continuation of practice(P & S).	▪ Redesign of policy, informs update of baseline data. ▪ Effectiveness of policy. ▪ Success / failure of policy intervention.	▪
	▪ Uptake / compliance ▪ Outcomes	▪ ▪ Expected outcomes	▪ ▪	▪ ▪

Appendix 3:

Recommended attendees for monitoring and modelling plan design

Recommended attendees:

- Black Ross WQIP Manager (Chris Manning), Program Support (John Gunn);
- ACTFR Catchment to Reef Research Group (Jon Brodie and Zoe Bainbridge);
- ACTFR Water Quality Scientist (Barry Butler or Damien Burrows) ;
- AIMS (Britta Schaffelke);
- Burdekin Dry Tropics NRM Rep (Ian Dight or Diana O'Donnell);
- Conservation Volunteers Australia (Evan Kruckow);
- EPA (Andrew Moss, Niall Connolly);
- GBRMPA (David Haynes);
- James Cook University (Margaret Gooch; MTSRF Project);
- Main Roads (Simon O'Donnell);
- Reef Water Quality Partnership (Jane Waterhouse);
- Townsville City Council (Citiworks) (Karen Bird; Adam Sadler);
- Townsville City Council (Citiwater) (Peter Mockeridge);
- Townsville Port Authority (Melinda Louden);
- WBM (Modelling rep).