Water for a Healthy Country

Science challenges to support diffuse pollution management in the Great Barrier Reef

Robert Ferrier
Water for a Healthy Country

Science challenges to support diffuse pollution management in the Great Barrier Reef

Robert Ferrier
Water for a Healthy Country is one of six National Research Flagships established by CSIRO in 2003 as part of the National Research Flagship Initiative. Flagships are partnerships of leading Australian scientists, research institutions, commercial companies and selected international partners. Their scale, long time-frames and clear focus on delivery and adoption of research outputs are designed to maximise their impact in key areas of economic and community need. Flagships address six major national challenges: health, energy, light metals, oceans, food and water.

The Water for a Healthy Country Flagship is a research partnership between CSIRO, state and Australian governments, private and public industry and other research providers. The Flagship aims to achieve a tenfold increase in the economic, social and environmental benefits from water by 2025.

This research was funded through the CSIRO National Research Flagship Collaboration Fund. For more information on the Collaboration Fund go to: www.csiro.au/org/ps1e.html

© Commonwealth of Australia 2007 All rights reserved.
This work is copyright. Apart from any use as permitted under the Copyright Act 1968, no part may be reproduced by any process without prior written permission from the Commonwealth.


DISCLAIMER
You accept all risks and responsibility for losses, damages, costs and other consequences resulting directly or indirectly from using this site and any information or material available from it.

To the maximum permitted by law, CSIRO excludes all liability to any person arising directly or indirectly from using this site and any information or material available from it.

For more information about Water for a Healthy Country Flagship visit or the National Research Flagship Initiative at www.csiro.au.
‘Water is not a commercial product like any other, rather, a heritage which must be protected, defended, and treated as such.’

EU Water Framework Directive 2000
Contents

Abbreviations............................................................................................................. v

Acknowledgments.................................................................................................... vi

1. Introduction..........................................................................................................1

2. Objectives of fellowship .....................................................................................2

3. Key issues ............................................................................................................3

4. Key findings .........................................................................................................4

5. Water for a Healthy Country: Great Barrier Reef.............................................6
   5.1. Defining the system ........................................................................................6
   5.2. Beyond Reef Plan ............................................................................................7
   5.3. Towards an effects-based strategy .................................................................11
   5.4. Managing change ..........................................................................................16
   5.5. Discussion ......................................................................................................19

6. References..........................................................................................................23

Appendices................................................................................................................26

Appendix A: EU Water Framework Directive in context ........................................... 26
   A.1 The planning cycle .......................................................................................... 28
   A.2 Responsible authorities ................................................................................. 29
   A.3 Characterisation .............................................................................................. 29
   A.4 Environmental monitoring ............................................................................. 36
   A.5 Environmental objectives .............................................................................. 37
   A.6 Program of measures ..................................................................................... 39

Appendix B: Timetable of the implementation of the Water Framework Directive ...... 41

Appendix C: Economic elements within the implementation cycle of the Water Framework Directive (WATECO 2003) ................................................................. 42

Appendix D: Definitions of the five ecological status classes ................................. 43

Appendix E: Quality elements to be used for the assessment of ecological status within the WFD ................................................................. 44

Appendix F: Priority substances – the development of a specific daughter directive to the WFD ................................................................. 45

Appendix G: Identification and designation of heavily modified and artificial water bodies................................................................. 46
## Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIMS</td>
<td>Australian Institute for Marine Science</td>
</tr>
<tr>
<td>ANZECC</td>
<td>Australian and New Zealand Environment and Conservation Council</td>
</tr>
<tr>
<td>ARMCANZ</td>
<td>Agriculture and Resource Management Council of Australia and New Zealand</td>
</tr>
<tr>
<td>AWB</td>
<td>artificial water body</td>
</tr>
<tr>
<td>BMP</td>
<td>best management practices</td>
</tr>
<tr>
<td>CAP</td>
<td>Common Agricultural Policy</td>
</tr>
<tr>
<td>CIRCA</td>
<td>Communication and Information Resource Centre Administrator</td>
</tr>
<tr>
<td>CIS</td>
<td>Common implementation strategy</td>
</tr>
<tr>
<td>DIN</td>
<td>dissolved inorganic nitrogen</td>
</tr>
<tr>
<td>DPIF</td>
<td>Department of Primary Industries and Fisheries</td>
</tr>
<tr>
<td>EC</td>
<td>European Community</td>
</tr>
<tr>
<td>EPA</td>
<td>Environmental Protection Agency</td>
</tr>
<tr>
<td>EQS</td>
<td>environmental quality standard</td>
</tr>
<tr>
<td>GBR</td>
<td>Great Barrier Reef</td>
</tr>
<tr>
<td>GBRMPA</td>
<td>Great Barrier Reef Marine Park Authority</td>
</tr>
<tr>
<td>GBRWHA</td>
<td>Great Barrier Reef World Heritage Area</td>
</tr>
<tr>
<td>GEP</td>
<td>good ecological potential</td>
</tr>
<tr>
<td>GES</td>
<td>good ecological status</td>
</tr>
<tr>
<td>HMWB</td>
<td>heavily modified water body</td>
</tr>
<tr>
<td>MEP</td>
<td>maximum ecological potential</td>
</tr>
<tr>
<td>NRM</td>
<td>natural resource management</td>
</tr>
<tr>
<td>RBD</td>
<td>river basin districts</td>
</tr>
<tr>
<td>Reef Plan</td>
<td>Reef Water Quality Protection Plan</td>
</tr>
<tr>
<td>RWQP</td>
<td>Reef Water Quality Partnership</td>
</tr>
<tr>
<td>SEPA</td>
<td>Scottish Environment Protection Agency</td>
</tr>
<tr>
<td>TMDL</td>
<td>total maximum daily load</td>
</tr>
<tr>
<td>UN</td>
<td>United Nations</td>
</tr>
<tr>
<td>WFD</td>
<td>Water Framework Directive</td>
</tr>
<tr>
<td>WfHC</td>
<td>Water for a Healthy Country</td>
</tr>
</tbody>
</table>
Acknowledgments

I would like to thank the Water for a Healthy Country National Research Flagship (WfHC) for the opportunity and support to undertake this Fellowship. In particular, Warwick MacDonald, former Science Director WfHC for his interest, guidance and advice.

This fellowship would not have been possible without contribution, comment and discussion with fellow researchers, stakeholders and agency staff who gave their time so freely, and I thank them most sincerely for their input.


Australian Institute of Marine Science staff included: Miles Furnas, Katharina Fabricius and Britta Schaffelke.

Great Barrier Reef Marine Park Authority staff included: Frances Verrier and David Haynes.

James Cook University staff included: Jon Brodie and Brian Roberts.

Members of the Cardwell Shire Floodplain Program and the Burdekin Dry Tropics Natural Resource Management also assisted.
1. Introduction

Dr Robert Ferrier leads Catchment Management research at the Macaulay Institute, Aberdeen, Scotland – the UK’s leading land use research institute – and is also an Honorary Research Fellow in the School of Physical Sciences, at the University of Aberdeen, Scotland. His research has focused on the development and application of predictive modelling approaches for the evaluation and implementation of effects-based European environment policy. Dr Ferrier has championed the global issue of diffuse pollution as one of the major challenges affecting land and water management in the coming decades. The wider research program at the Macaulay Institute focuses on the hydrological and hydrochemical consequences of environmental change (land use and climate primarily), and subsequent impacts on aquatic ecology. The group links biophysical and ecological scientists with social scientists and economists to deliver a holistic approach to water resource management and provide an evidence base for policy development and support.

This research program is in part structured to provide knowledge to underpin the implementation of the EU Water Framework Directive (WFD). The WFD represents the most substantial waters legislation from the European Union to date. Its aim is to establish a new integrated approach to the protection, improvement, and sustainable use of Europe's rivers, lakes, estuaries, coastal waters, wetlands and groundwaters.

The WFD continues to implement objectives that protect particular uses of the water environment from the effects of pollution. However, it also introduces new, broader ecological objectives, designed to protect and, where necessary, restore the structure and function of aquatic ecosystems themselves, and thereby safeguard the sustainable use of water resources. Future success in managing Europe’s water environment will be judged principally on the achievement of these ecological goals.

Another fundamental challenge is the introduction of a basin planning process system that must be produced in a participative and consultative manner. This provides the decision-making framework within which proportionate and cost-effective combinations of measures to achieve environmental objectives can be designed and implemented.

It is against this background that Dr Ferrier was awarded a Water for a Healthy Country (WfHC) National Research Flagship fellowship to visit and collaborate with CSIRO, university and agency scientists and colleagues during the period May to August 2006.
2. Objectives of fellowship

The overall aims of the fellowship were to:

- enhance the scientific basis for sustainable watershed management based on shared knowledge linking European and Australian approaches;
- evaluate if principles of the EU WFD represent a pertinent model for management of Australian basins;
- assess how the WFD concept of 'ecological status' and environmental thresholds could provide appropriate impacts-based targets for management, and the consequences of this for future monitoring strategies;
- undertake a pilot evaluation of WFD principles in the Great Barrier Reef (GBR) catchment; and
- provide an European perspective to research within the WfHC initiative in other key catchment areas.
3. Key issues

- Are the principles of diffuse pollution assessment and management consistent between activities in Europe and Australia?
- Does promoting a systems-level approach to GBR science and the land-to-sea continuum provide a mechanism for integration and delivery?
- Is it possible to adopt an effects-based approach linking diffuse pollution to ecological impacts and to integrate this within a wider socioeconomic system framework?
- Do current objectives for water quality management in the GBR adequately address the potential threat of diffuse pollution? What are the options through which to effect further change in the longer term?
- How can science provide the necessary underpinning through which to inform and support policy development?
- Is there potential for adopting ecologically based targets for water resource management in a wider context and in other catchment areas?
4. Key findings

- Research addressing the challenge of large-scale diffuse pollution and management within the context of the GBR is of global significance and to be welcomed.

- It is encouraging that an interdisciplinary approach to ecosystem research is being promoted by CSIRO through the Water for a Healthy Country initiative, in relation to the GBR. Research is aiming to underpin both the biophysical understanding of ecosystem function, connectivity and resilience, and in the wider aspects socioeconomic systems behaviour. This is potentially leading edge and parallels developing research in Europe.

- Current research suggests that an effects-based diffuse pollution policy could be developed for the GBR, including regional and sectoral source apportionment, and subsequent target setting. Ecological response in the lagoon could guide the setting of thresholds or standards for land-based diffuse pollution. (This would be consistent with the adoption of aquatic ecosystem protection criteria [ANZECC and ARMCANZ 2000], and similar in approach to those in the European Water Framework Directive, and the US Clean Water Act total maximum daily load approach). Links between cause and effect should be consolidated and an adaptive framework for effects-based management developed. The development of appropriate predictive dynamic models (through which to address hysteresis and timelags) should be supported either in-house or through enhanced collaboration.

- It is unclear whether the delivery of Reef Water Quality Protection Plan (Reef Plan) targets as stated will adequately address the issue of diffuse pollution and its management in the GBR. Uncertainty in the ecological consequences of Reef Plan implementation has not yet been adequately evaluated; therefore the consequence of implementing best management practice across all sectors is not known. The recent formation of the Reef Water Quality Partnership, composed of community and government agencies, articulates the process of developing targets, monitoring and reporting and this is to be welcomed. The level of environmental protection achievable through Reef Plan should be critically evaluated as a priority.

- Science must look beyond Reef Plan, identifying key challenges now that will have resonance in the future. What are the research requirements and information that will be required to inform and help develop policy in the next 20 years? Any potentially more rigorous future management options will require increasingly robust biophysical underpinning, and socioeconomic evaluation. Currently there is too much focus on Reef Plan implementation and a longer-term vision identifying research needs to support future policy should be developed.

- Reef Plan has generated momentum within the stakeholder community in relation to the adoption of best management practices and this should be encouraged, but in order to ensure aspirations are not compromised there should also be a realisation that further measures may be required to protect the reef and lagoon. The consequences of this and the ability to build capacity through which to respond to this challenge should be evaluated.

- Although collaboration between the partner organisations in GBR research is strong, it could be strengthened through the consolidation of a shared vision of system-level issues and more formalised data, information, and monitoring coordination. This requires greater integration of ecosystem scientists (terrestrial, aquatic, marine, etc.), and disciplines (environmental, social and economic). The contributing partners all have different remits and expertise and it is important that structures are in place through which to ensure continuity of effort in relation to diffuse pollution issues. Given that land-based industries are the principal source of diffuse pollutants, CSIRO should take the lead in developing a platform for increased coordination of diffuse pollution research in relation to the GBR. This integration should be supported as a new initiative based on
the principles of systems science, generating conceptual understanding, identifying areas that require additional support, integrating uncertainty, and enhancing existing and developing new partnerships as required. The program requires visionary leadership and committed management, and potentially, additional skills and resources.

- The various Australian Government, state, and regional resource management strategies in relation to the GBR are complex and poorly integrated and do not reflect a system-level approach. Institutional analysis should be carried out to identify ‘friction points’ within and between different strategies and to consider what options are available to streamline objectives and operational procedures.

- Socioeconomic and biophysical science integration requires a critical mass within both domains, further resourcing of the former should be considered a priority, and greater integration of CSIRO biogeochemists and aquatic ecologists within the GBR node should be promoted. Management should reappraise skills and resource allocation against science plan deliverables, and should identify gaps.

- The specific understanding of wetland function and how this has been influenced by management requires further strategic research by CSIRO. There is a need to evaluate the wider systems-level functions of wetlands as ‘reactor vessels’ in the context of the GBR, and especially pollutant delivery.

- The wider activities of Water for a Healthy Country are developing national capacity in relation to diffuse pollution, resource allocation, and other pertinent aspects of land and water management. This will be of increasing importance in the coming decades, and it is important to ensure that critical mass is maintained beyond the life time of the science plan.

- Water for a Healthy Country should look past national commitments and consider how to enhance a greater international profile through collaborative research and platform initiatives. Water for a Healthy Country should seek greater engagement with the International Human Dimensions Programme on Global Environmental Change and the United Nations (UN) Environment Programme, in particular the Land Ocean Interactions in the Coastal Zone theme. Also the Integrated Coastal Area and River Basin (UN Environment Programme), and the Integrated Coastal Area Management (UN Education and Scientific and Cultural Organization) initiatives. Additionally there is merit in pursuing collaboration in the forthcoming European Framework 7 Programme. Consideration should be given to formalising such engagement as an identifiable goal of the program.

- Ecologically based target setting places the environment as the central benchmark of quality, releasing potential even in highly managed systems. The WFD challenges all member states to attempt to achieve good ecological status or potential for all waters by 2015. Where more than legislation covers a particular water body the default is always to the most stringent criteria – invariably ecosystem protection. Consideration should be given to the consequences of adapting an ecosystem protection-based, rather than a use-based approach to management of Australian water bodies. (Both natural and highly managed surface systems, and for groundwater in relation to landscape continuity and function).
5. Water for a Healthy Country: Great Barrier Reef

5.1. Defining the system

The Great Barrier Reef (GBR) extends along the north-east Australian continental shelf for 2000 km. The Great Barrier Reef World Heritage Area (GBRWHA) is the world’s largest marine protected area. The contributing land area to the GBRWHA approximates to 423 000 km$^2$ in which grazing is the major land use (>70%) in the upland areas with floodplain areas (<5%) under sugar and other crops (Gilbert and Brodie 2001). Large areas of savannah, woodland and forest have been cleared or thinned to support grazing and significant areas of freshwater and coastal wetlands have been lost to cropping (Brodie 2006). Rivers draining this area provide the transport and delivery route for pollutants generated within the landscape to enter the GBR Lagoon.

River exports of nitrogen and phosphorus have increased several-fold as catchments have been converted from natural vegetation to intensively used grazing and cropping systems. Estimated increases in terrestrial nutrient loading from the GBR catchment range from 2 to 5 times for nitrogen and 4 to 10 times for phosphorus over the last 150 years (Brodie et al. 2003, Furnas 2003). Similarly, whole catchment modelling suggests that hillslope erosion rates on grazing land are 2 to 6 times greater than pre-European levels with serious consequences for both soil and water quality.

The coral reefs of the GBR are of two main types: the fringing reefs (c.750 reefs) which occur inshore on the coast and are more susceptible to land-based impacts, while those of the main reef (c.2000 reefs) that occupy a band on the outer part of the continental shelf are rarely influenced by land-based impacts. Evidence suggests that increased loads of nutrients are reaching and influencing inner shelf reef and benthic ecosystems of the GBR. The changed inputs have resulted in measurable increased phytoplankton biomass in affected areas of the GBR Lagoon (Furnas et al. 2005) and reef degradation in areas adjacent to coastal agriculture (Fabricius and De’ath 2004, Fabricius et al. 2005). Evidence from other geographical locations suggests that by the time widespread effects are identified, the reef systems would be irreversibly damaged.

The generation of both nutrients and suspended solids is from diffuse sources and although transport processes and impacts are different, remediation measures have to operate by focusing on land stewardship, involving different sectors (agriculture, industry, urbanisation, recreation) and over potentially large spatial scales. Diffuse pollution management, since it must necessarily address the actions of individual citizens rather than private and public entities, requires a different approach to traditional command and control strategies for point sources of pollution.

Taking a whole systems approach to the issue of diffuse pollution and its management therefore is a requirement for the protection of the GBR, and the key challenge for science is to provide a platform for the development and implementation of robust environmental policy through which to achieve long-term protection. The system has to represent both the source and sinks of the pollutants (their generation, transport and ecological impacts) and therefore must not be constrained by administrative boundaries or abstract spatial divisions, but by boundaries relevant to the point of impact. The holistic approach to ecosystem management must be to link the mountains to rivers and to seas, ensuring interconnectivity and feedback. This ecological response train sits within a nested socioeconomic system that encompasses the GBR catchment in its widest spatial context, the overall sustainability of which requires a link between ecological protection, economic development and human welfare.

CSIRO science must embrace this approach if it is to identify critical areas of uncertainty, sharpen research focus against specific objectives, reconcile top-down bottom-up approaches to effectively link community-based projects within larger structured programs, and enhance critical mass in relation to systems science. Identifying and assessing institutional and sectoral
barriers to change, ensuring equity in decision making, creating a shared vision across all institutional levels, and balancing authority and responsibility in achieving longer-term goals, are all essential components of this approach.

As a contribution to that overall vision this report aims to comment on:

- moving the science vision forward through promoting a systems-level approach to GBR science and the land-to-sea continuum;
- possible mechanisms for the development of an effects-based approach linking diffuse pollution to ecological impacts;
- potential mechanisms through which to effect change;
- highlighting of potential pressure points within the research effort; and
- the need for an overarching mechanism for integration.

5.2. Beyond Reef Plan

The Reef Water Quality Protection Plan (Reef Plan) (The State of Queensland and Commonwealth of Australia 2003) has been formulated to specifically address the issue of broadscale diffuse pollution from the catchments draining into the GBR. In this regard, it is a globally significant document in that it acknowledges that diffuse pollution is a major driver of change, and that for reef protection there need to be time-based objective targets for reducing this source of pollution. In addition it highlights the important role of wetland ecosystems in natural attenuation of pollution, and looks towards the conservation and rehabilitation of these critical ecosystems.

The strategies in the document provide actions to minimise pollutant movement from the land to the sea and highlight the important role of stakeholder participation in managing diffuse pollution. The central goal of Reef Plan is **halting and reversing the decline in water quality entering the reef within 10 years** (i.e. by 2013). Reef Plan provides a long-term mechanism for environmental management which addresses the need for better integration of Australian Government and state legislation and the wide range of supporting funding available for environmental impact assessment and planning. This suggests a move towards the adoption of a systems-based approach to resource management.

The document acknowledges that the management of the GBRWHA is complex, balancing social and economic factors as well as environmental concerns in a multi-use environment. The GBR ‘catchment’ supports a considerable number of industries and associated employment, valued at $15 600 million, in addition to the immense non-use value of the GBR in global terms as a world heritage site. Diffuse pollution is only one driving factor influencing the environmental integrity of the GBR. Others such as tourism, climate change, outbreaks of invasive species, fishing and natural threats must also be factored into this complex picture. Protecting the outstanding universal value of the GBR is a substantial task and one where the critical question must be – are the measures that are currently being taken likely to ensure the value of the GBR for present and future generations? (McGrath and Schaffelke 2004). A similar question therefore, must also be asked in relation to the management of diffuse pollution within the GBR – will the measures in Reef Plan deliver ecosystem protection both now and into the future? What is the pivotal role of Reef Plan in integrating best scientific understanding and principles, and providing a framework for energising the adoption of best management practices through which to meet the key objectives of:

- reducing loads of pollutants from diffuse sources in the water entering the reef; and
- rehabilitating and conserving areas of the reef catchment that have a role in removing water-borne pollutants.

The institutional footprint of Reef Plan is substantive. The key implementers of the document are the regional natural resource management (NRM) bodies that are responsible for the
development of regional NRM plans which are submitted to the Australian and Queensland governments for accreditation, setting out short- and long-term management objectives and specific implementation strategies. There is a special responsibility on the regional NRM bodies in the reef catchment areas that requires them to take into account the agreed outcomes of Reef Plan. In addition, a raft of governmental agencies – Department of the Environment and Water Resources, Department of Agriculture, Fisheries and Forestry, Great Barrier Reef Marine Park Authority (GBRMPA) and the Queensland government Department of Natural Resources and Water, Department of the Premier and Cabinet, Environmental Protection Agency (EPA) and the Department of Primary Industries and Fisheries (DPIF) – have incorporated the goals and objectives of Reef Plan into their strategic plans. Landholders, industry organisations and community groups are all seen as adopting the principles of Reef Plan.

Supporting scientific research includes the Water for a Healthy Country National Research Flagship GBR Catchments node which aims to provide solution science to support landholders, decision makers, and the community with the implementation of the Reef Plan. This occurs specifically by undertaking science through which to improve water quality, wetland integrity and productivity, while enhancing regional communities and protecting marine-based industries of the reef from declining water quality. Additional contributions came from Cooperative Research Centre for the Great Barrier Reef World Heritage Area which included the Association of Marine Park Tourism Operators Pty Ltd, Great Barrier Reef Research Foundation, James Cook University, University of Queensland, the science arms of the key Queensland Agencies, Queensland Seafood Industry Association, Sunfish Queensland Inc., GBRMPA, DPIF, and the Australian Institute for Marine Science (AIMS) who also have a particular role in relation to monitoring. The Marine and Tropical Science Research Facility now engages research providers to contribute to progressing some of the Reef Plan research needs.

Reef Plan’s strength lies in its strong development of collaborative and community-based approaches to resource management. Collective action in relation to the adoption of best management practices by different sectors is to be warmly welcomed and provides a benchmark for good husbandry and duty of care. It promotes self management approaches, provides education and extension, and economic incentives for adoption of the Reef Plan principles, and acts as a focus for the development of partnerships, information sharing, and in establishing evaluation and monitoring procedures. Reef Plan has therefore placed environmental protection high up the agenda in relation to the future management of the GBR. Importantly, the implementation of Reef Plan is supported by the recent development of the Reef Water Quality Partnership (RWQP), which has been designed to provide a coordination role and in particular, draw in the regional NRM groups. The RWQP, composed of community and governmental agencies, provides a valuable framework for enabling top down and bottom up dialogue. In particular, the RWQP workplan articulates a process of developing targets, and monitoring and reporting on management issues, pollutant loads and receiving water health. The RWQP is also supported by a Scientific Advisory Panel established to provide strategic technical advice for the priority issues.

Reef Plan highlights the importance of wetlands as a component part of catchments that have a role in removing water-borne pollutants. This is only one attribute of these ecosystems that additionally provide other natural functions such as flood control, groundwater recharge, coastal protection, nursery areas for fisheries and migration staging posts, as well as being critical biogeochemical reactors, carbon stores and gaseous flux attenuators. Wetlands also have properties that have direct value to humans as a resource for food production (both terrestrial and aquatic production), natural resources such as timber and land for recreation and development. Understanding the importance of anthropogenic influences on the natural processes and capital of wetland and coastal ecosystems is a crucial factor in relation to the development of sustainable environmental protection policies.

Given that all of the above provides a positive template for the management of diffuse pollution, it is perhaps important to consider whether Reef Plan’s stated objectives to halt and reverse the decline in water quality entering the reef within 10 years, will appropriately address the issue of diffuse pollution impacts within the longer term.
Does Reef Plan provide the necessary blueprint for the sustainable long-term management of diffuse pollution as part of the GBR management strategy? Firstly consider the aims of Reef Plan. Halting and reversing water quality within ten years is the stated target, but this does not address the boundary requirements of by how much, where and by when in relation to long-term management. There is existing damage, especially to inshore reefs that are showing impacts consistent with deterioration in water quality (Furnas et al. 2005, Fabricius 2005), so the status quo of an increasing trend is not an option. Given current levels of pollution, what would be the chronic long-term effect of maintaining (halting) pollution? Similarly, if water quality was improved (reversing) by how much should it be improved and by when to ensure no further impacts from diffuse pollution? This raises further issues on what constitutes an appropriate ‘target’ for recovery within the reef and its associated ecosystems (Target used in this context refers to an indicator of ecological integrity and not the Aspirational, Resource Condition, and Management Action Targets as specified in the NRM plans). Are they based on criteria of maintenance and no deterioration, or are they based on recovery of ecosystems to some given 'standard' of quality? Is this at all feasible given social demands, and will target setting be disproportionately expensive. Therefore Reef Plan does indeed provide a mechanism for diffuse pollution management in relation to pollutant generation but not necessarily in terms of diffuse pollution impact. One interesting issue within the Reef Plan itself is that there are no specific targets for individual contributing catchments or even indicative targets for proportional reductions, although some preliminary values have been proposed (Brodie et al. 2001).

Natural resource management plans have been developed to sustainably manage regional natural resources within specific regions of the GBR catchment, such as the Burdekin Dry Tropics Region (BDTB 2005). In such plans, the aim is to:

- identify the critical assets of the regions;
- review the current state of these assets;
- identify issues that threaten them; and
- establish a list of actions to minimise these threats.

Water quality issues are addressed using the Australian and New Zealand Environment and Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) (2000) guidelines but only on water bodies (freshwater and groundwater) within the region of the plan, and not on its sphere of influence which may include the lagoon and reef. Lagoon-based targets focus solely on the adoption of Reef Plan principles on reducing diffuse pollution through the adoption of best management practices, which do not include catchment-specific targets.

An approach to the setting of water resource targets has been addressed within the European Community (EC) of countries by the recent Water Framework Directive (WFD) (EC 2000, Appendix A) in a move away from traditional 'use-based' management of waters. This legislation (now transposed into law) requires member states to ensure no further deterioration in the ecological quality of all aquatic environments (rivers, lakes, wetlands, groundwaters, transitional estuarine waters and coastal waters). It also aims to achieve 'good status' for all waters by 2015. It requires an assessment of the ecological status of water bodies before ensuring that the appropriate environmental objectives are set for these water bodies through basin management processes. This requires the establishment of a five-tier classification (high, good, moderate, fair, poor, bad) scheme to reflect the ecological status of water bodies as measured by the condition of specific biological, hydromorphological and chemical and physico-chemical quality elements. In order to assess deviation as a result of anthropogenic pressures the WFD also requires the consolidation of a reference condition for each water body type – a description of the biology quality elements that would exist at high status, where there have been little or no disturbances by human activity. The objective of setting reference condition standards is to enable the assessment of current ecological quality against these standards (i.e. the degree of degradation). (Reference conditions can be specified by identification of appropriate sites representing high ecological quality, modelling, paleolimnological techniques, expert guidance or a combination of these approaches.) The WFD subsequently requires the development of appropriate environmental quality standards (EQS) for chemistry, hydrology and morphology.
that relate to this five-point classification scheme. These establish the necessary thresholds through which to deliver the aim of good ecological status by 2015. In addition, the standards needed to protect important sites identified as ‘Protected Areas’ (such as RAMSAR and ‘Natura 2000’ sites designated under the European Commission Habitats [1993] and Birds Directives [1979] legislation), may be more or less stringent than those required to achieve good status. In such cases the WFD specifies that the most stringent objective for that site should apply.

If similar principles were applied to the GBR region, specific environmental standards and conditions based on best available knowledge would need to be developed to define the environmental conditions supporting healthy ecosystems within the lagoon and reef. This requires knowledge of the current status of different reef and lagoon communities and some measure of their current degradation against an understanding of their long-term dynamics (bearing in mind that there may be a shifting baseline in relation to reference conditions). The development of thresholds whereby ‘impact’ can be linked to physico-chemical and habitat criteria that have resonance with river water quality targets would then form the basis of an effects-based approach to management of diffuse pollution. Finally, there needs to be appropriate monitoring of both the cause and effect to determine efficacy of any catchment-based amelioration mechanisms whether singly or in combination.

For example, when setting chemical thresholds, information is required on what generates an ecological impact. Is it:

- loads versus concentrations (system understanding requires both)?
- seasonal loads or effective concentrations linked to biotic response at given time?
- species characterisation (e.g. total nutrient or biologically reactive nutrient)?
- more appropriate to identify a chemical–biological standard such as chlorophyll a or enzyme activity?
- difficult-to-assess biodiversity impacts against a single stress factors – perhaps recent gene expression and ecotoxicogenomics approaches (stress ecology) may offer innovative opportunities.

Ecosystem drivers are complex and a range of other biophysical controlling factors such as resuspension, biological recycling, immobilisation and gaseous loss will have influence, but it should be possible to factor at least some of these attributes into appropriate typological classification. Near-shore processes such as nutrient resuspension may, for example, require a downward revision of any river-borne contributions. The aim should be to develop classification and impact or risk methodologies based on current understanding. Such approaches are organic and require revision as science and understanding are improved. Further monitoring and data collection therefore can be specifically targeted to reduce uncertainty, perhaps focusing solely on the particular biological element that responds to a given pressure (e.g. nutrient enrichment and phytoplankton reflected in a suitable marker such as chlorophyll a). Additionally in a management context is it feasible to undertake source apportionment on the importance of different sectoral contributions? Is the delivery of a biologically available nutrient at a low level throughout the year (say from an industrial or waste water contribution) as important as peak concentrations during episodes where land-based sources dominate?

In summary, Reef Plan and the research underpinning its implementation, does not take a truly ecosystems-based approach to diffuse pollution management in the catchment–coastal continuum rather the focus is on reduction in diffuse pollution generation. Caution is required in making any assumption that water quality improvement as defined within Reef Plan will result in no further ecosystem deterioration as a result of diffuse pollution pressures. Let us consider a possible scenario 20 years into the future. There may have been substantive change in behaviour among resource managers in relation to diffuse pollution through the adoption of best management practices, and concentrations and pollutant delivery may have been reduced, although there is no tangible improvement on reef and lagoon ecosystems. Indeed they may be continuing to decline. Therefore, emphasis cannot solely be placed on delivering reductions in river water quality without considering the consequences of appropriate thresholds in the target ecosystems (i.e. the reef and lagoon ecosystems). Without such links it would be difficult to
envision how one might also manage apportioned contributions from different sectors in future revisions of water quality management.

### 5.3. Towards an effects-based strategy

When looking to develop, evaluate and implement any future policies beyond Reef Plan, there is a requirement to define ecosystem pathways from source to receptor, linking between the generation of pollutants and their impacts (Table 1). Such effects-based strategies have formed the basis in Europe and North America for environmental policy such as control strategies for transboundary atmospheric pollution (Bull et al. 2001), and for developing evidence-based health and social policy (Weil et al. 2003). They provide useful contextual model systems, that could be pertinent to the management of diffuse pollution in the GBR.

<table>
<thead>
<tr>
<th>Environmental effects-based approaches require key component parts that need to be identified, namely:</th>
</tr>
</thead>
<tbody>
<tr>
<td>the critical ecosystem load or threshold (i.e. the pollutant load below which significant harmful effects on specified ecosystem elements does not occur – potentially end-of-river loads or combined river/land flux in the GBR context, and source apportioned sectoral contributions); and</td>
</tr>
<tr>
<td>the critical level or threshold of pollutants (i.e. the concentration threshold above which adverse effects on specified ecosystem elements does occur – ecological responses such as changes in primary production in the GBR context).</td>
</tr>
</tbody>
</table>

This concept is similar to that in the US where water quality criteria relate to the effect of a pollutant and the context of the specific water use (including narrative statements), and water quality standards, which represent the legally enforceable load or limitation for use in regulation (McCutcheon et al. 1993). Against ANZECC Guidelines exceedance of the water quality guidelines (numerical concentration limit or narrative) represent the trigger values for action, while water quality objectives represent the water quality targets agreed between stakeholders and through which measures of management performance can be assessed.

In the GBR, one could consider that the mechanisms to generate critical loads result from activities in the management and transport domains, and that critical levels are a result of influences in the reactive and impacts domains. By working back from the causal chain of defining critical limits (aka EQS), through coastal biogeochemical processes and transport to end-of-river loads, and ultimately to pollutant generation processes, land management and downstream lagoon impacts can be linked.

The critical level generating any given ecological response will be influenced by a number of sources of which the largest (annual and seasonal input) is diffuse pollution from the land. Other factors such as the influence of neighbouring rivers, resuspension and point sources are all additional contributors, and it is important in the GBR context that source is appropriately apportioned.
But critical levels of what?

Ecological responses in the reef lagoon are generated by a number of factors, and recent condition assessments have shown an apparent decline in reef condition (van Woesik et al. 1999). The difficulty has been to identify which pressures have been specifically responsible for this decline. Natural forces such as cyclones, along with outbreaks of the crown of thorns starfish, coral bleaching due to temperature changes and water quality have all been cited as pressure drivers both singly and in combination (Fabricius 2005). There is however, strong evidence that enhanced levels of inorganic nutrients in the GBR lagoon are quickly taken up by phytoplankton, a response which is expressed through elevated levels of chlorophyll a concentration (Brodie and Furnas 1994, Moss et al. 2005, Wooldridge et al. 2006). Although individual concentration thresholds for nutrients such as nitrogen can be misleading as an index of water quality in lagoon and coastal systems, measurements focused on primary production are more robust (NRC 1993). Recently, a quantitative river discharge parameter dissolved inorganic nitrogen (DIN) concentration has been correlated with a quantitative response parameter in the marine environments (chlorophyll a concentration as an indicator of phytoplankton biomass) (Wooldridge et al. 2006). This opens up the opportunity for the development of a more robust effects-based approach to management of diffuse pollution in the GBR.

In a management context the key factor would be to ensure that the critical level (i.e. ability of the ecosystem to sustain function without experiencing measurable degradation (such as a change in state) is not being compromised. This would subsequently be managed by focusing on the appropriate critical load. Because of the event-based nature of the diffuse pollution load delivery and inherent year to year variability, the critical load would ideally represent a probabilistic standard rather than a specific numeric criterion.

A pertinent question for present evaluation would therefore be ‘Does the implementation of Reef Plan deliver a reduction in diffuse pollution to the critical load?’ If it does not, what are options for closing the gap, by what time, and how realistic are they?

This also represents a similar platform to that of the US EPA’s total maximum daily loads (TMDL) that was championed through the Clean Water Act (EPA 1999). This quality-based standards approach follows the following procedures:

- define the boundaries of the system and the receiving waters within it;
- identify the pollutant for the development of the specific TMDL;
- assess current exceedance of the system from that pollutant;
- source apportion contributions from various sectors or locations;
- plan load allocations to meet objective (multiple scenarios);
- include safety margin (‘unallocated assimilated capacity’); and
- develop implementation plan and monitor success.

The process involves stakeholder integration and consultation throughout, using multiple scenarios to develop regionally focused management plans. TMDL thresholds could potentially be set within the GBR for primary production (chlorophyll a) based on a specific nutrient load to the lagoon. Subsequent thresholds could be evaluated for different ecosystems (e.g. extent of sea grass beds) and for other pollutants (e.g. sediment, specific synthetic compounds). Specific applications of the approach have historically focused on perennial systems, but conceptually there is no reason that seasonal thresholds for episodic systems could not be evaluated. (The use of the term ‘daily’ in the TMDL concept is a bit of a misnomer given that most are actually based on annual or seasonal loadings). A review of the potential pressures and impacts of agricultural diffuse pollution and of various water quality standards for waters in the GBR highlights that there are potentially enough links between cause and effect to develop an apportioned critical load approach (Table 2). The GBRMPA has also developed Interim Marine Water Quality Guidelines for the Great Barrier Reef Marine Park which are currently under review. When released, these guidelines would form the basis for further work.
### STATE IMPACT THRESHOLD / EQS

#### Pressure: sediment

<table>
<thead>
<tr>
<th>Pressure: sediment</th>
<th>Impact</th>
<th>Threshold / EQS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased total suspended solid load</td>
<td>Turbidity, Sedimentation</td>
<td>Turbidity (Moss et al. 2005)</td>
</tr>
<tr>
<td></td>
<td>Loss of sea grass (Longstaff 2003, Schaffelke et al. 2005)</td>
<td>Zostera threshold: 15 mol photon /m²/d</td>
</tr>
<tr>
<td></td>
<td>Loss of corals (multiple impacts, Fabricius et al. 2003)</td>
<td>Target: As a function natural level? Decrease by given time?</td>
</tr>
<tr>
<td></td>
<td>Increased [TSS]</td>
<td>What is the tolerance of corals to TSS?</td>
</tr>
</tbody>
</table>

#### Pressure: nutrient

<table>
<thead>
<tr>
<th>Pressure: nutrient</th>
<th>Increased phosphorus load [PO4]?</th>
<th>Increased [DIN]; Elevated [NO3]; Elevated [NH4]; Turbidity (as a consequence of increased primary production)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Increased primary production</td>
<td>Macrophyte response (see Schaffelke et al. 2005)</td>
</tr>
<tr>
<td></td>
<td>Observed [nutrient]? Not necessarily a good measure</td>
<td>Preferred; Chlorophyll (Chl) a Phytoplankton biomass</td>
</tr>
<tr>
<td></td>
<td>Increased nitrogen load [DIN]; Elevated [NO3]; Elevated [NH4]</td>
<td>(Secondary processing and deposition as marine snow; increased threat from Acanthaster planci)</td>
</tr>
<tr>
<td></td>
<td>Loss of corals</td>
<td>Impact on reef community dynamics</td>
</tr>
<tr>
<td></td>
<td>Presence of toxic algae (health issues)</td>
<td>N Guidelines exist (Moss et al. 2005) though not thought rigorous enough?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ambient Chl a offshore: 0.3 ug/L Upper threshold in lagoon: 0.6 ug/L Wooldridge et al. (2006) have identified quantifiable link between DIN and Chl a</td>
</tr>
</tbody>
</table>

#### Pressure: agricultural chemicals

<table>
<thead>
<tr>
<th>Presence, and increased levels of Agri-chem* (includes pesticides, herbicides, and other synthetic compounds)</th>
<th>Bioaccumulation</th>
<th>Selected impacts on ecosystem functionality – loss of key taxa?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Elevated concentration in sea grass meadows (Duke et al. 2005)</td>
<td>Non reversible damage occurs at [Diuron] 0.1 ug/L Ecotoxicological</td>
</tr>
<tr>
<td></td>
<td></td>
<td>EQS in environment (sediments) or biota – use existing ANZECC values Target for remediation;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No presence in the environment? (too challenging?)</td>
</tr>
</tbody>
</table>
Pressure: changes in flow

<table>
<thead>
<tr>
<th>Increased freshwater flow</th>
<th>Low salinity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Faster flows</td>
<td>Altered hydrology</td>
</tr>
<tr>
<td>Increased frequency of events</td>
<td>Hydroecological; Migration</td>
</tr>
<tr>
<td></td>
<td>Recruitment</td>
</tr>
<tr>
<td></td>
<td>Habitat alteration</td>
</tr>
</tbody>
</table>

Potential to reduce capability of wetlands to act as reactor vessels?

Flow dynamics?

Pressure: land cover

<table>
<thead>
<tr>
<th>Loss of habitat</th>
<th>Altered biogeochemical processes</th>
<th>Loss of landscape function</th>
<th>Recruitment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loss of habitat</td>
<td>Altered biogeochemical processes</td>
<td>Loss of landscape function</td>
<td>Recruitment</td>
</tr>
</tbody>
</table>

Natural estuarine processes result in less nitrogen and phosphorus being delivered to the GBR lagoon than is exported from the catchment (Davies and Eyre 2005) in 'natural' conditions: how to quantify?

Table 2: State, impact and possible indicator thresholds for various pressures.

The setting and implementation of critical loads such as these is an adaptive process. Present understanding of cause and effect provides the basis for the development of initial indicator thresholds, which should be used to prioritise additional monitoring requirements, and identify key science challenges through which to reduce uncertainty. Revision is an essential component.

A crucial factor in managing the impact of diffuse pollution on the lagoon is the recovery delay time following intervention or remediation. Natural attenuation processes induce a hysteresis in ecosystem response following the removal of any anthropogenic pressure. Such delayed responses vary considerably from place to place but form a general sequence of changes in (hydro) chemistry, followed by subsequent recovery in biology. The delay between meeting suitable chemical thresholds and achieving biological recovery is a function of additional ecosystem processes such as recruitment and food web linkages, and indeed whether a change in state has occurred.

A hypothetical recovery delay function for different ecosystems, under the implementation of a different policy implementation strategy is shown in Figure 1. It assumes that any present day status quo scenario is inducing a continued decline in a given environmental quality index. A proposed policy reduction of an environmental pressure over the period of 2005 to 2015 (i.e. reducing diffuse pollution load in a given time frame) is presented. Different recovery trajectories are generated dependent upon the time of the implementation of the policy such that a step change implementation in 2015(a) will produce a slower rate of future recovery than a step change implementation in 2005 (c). A linear policy implementation (b) may result in no change in status by 2015 but does highlight future recovery. Hence the way that any given policy is implemented has a direct effect on expected recovery. Should the ecosystem show a greater degree of hysteresis (e.g. driven by large stores or long residence times) recovery is considerably slower (a). In this hypothetical example the reduction in environmental pressure to value (?) is to the critical load value set for environmental protection.

Time is also an important factor and recent evidence suggests (Furnas 2005) that diffuse pollution is currently having an acute impact on the ecology of the lagoon. It is possible however that sub-critical load levels may induce a long-term chronic effect should a change in lagoon storage, resuspension, and biotransformation become an important delivery mechanism, and this should be evaluated.

Taking this approach further, evidence to suggest long time lags to recovery and concerns about environmental improvement may result in social and political pressures to accelerate the
recovery process. A key question therefore is perhaps not 'What is the critical load of pollutants that is necessary to protect an ecosystem in the long term?', but 'What is the critical load of pollutants that is necessary to protect an ecosystem by a given time in the (potentially near) future? The explicit inclusion of time scales to desired recovery requires a further revision of the critical load to provide a target load for management. This target load approach could be applied to individual ecosystems, clustered sites or regional populations in the GBR within an integrated assessment framework. Such an assessment requires a time-based evaluation of ecosystem response and therefore relies on the use of dynamic modelling approaches.

Variability in ecosystem characteristics, data, and model uncertainty must be realised as integral parts of any assessment exercise. The strength of this approach however, lies in providing a biophysical and ecological framework for time-based resource management into which other economic, political and social constraints on future responses and actions can be factored (Jenkins et al. 2003).

Irreversibility and maintenance of 'changed state' conditions may be the only option for setting management targets that are not disproportionately costly. Indeed other confounding long-term factors such as climate change or societal pressures may influence not only the rate of any expected recovery but also potential or desired end points.

Figure 1: Hypothetical recovery curves following an implementation of policy to reduce and environmental pressure to the critical load value below which recovery is expected.
5.4. Managing change

There are many different ways to design effective adaptive management approaches for mitigating the effects of diffuse pollution on receiving waters. Societal objectives for the future of the natural resource in question influence the development of a management strategy through which to deliver goals and objectives. Similarly, the success of any plan relies on behavioural responses to the different strategies or policy alternatives. The overall design of any management strategy must be tailored to the specific situation as 'no one size fits all'. National, regional and site-specific criteria have been used and a combination of all may be required depending on the specific objective of the management approach.

It is important that targets for mitigation are linked to cause and effect criteria and that a management strategy is developed against these principles and appropriately monitored to determine efficacy. Where large time delays would need to be factored in, modelling approaches should provide the basis for compliance assessment. Targets can be developed, through the nomination of an arbitrary value in reduction (e.g. 50%), or through the reduction to a value commensurate with some previous condition (e.g. pre-European). The optimum approach is to invoke a time-based criterion through which to effect a critical load threshold (target load) linked to impact response of the receptor. Success of the effectiveness of any strategy must be on this ecological response (measured or modelled depending on the timescale) and not on action indicators such as the scale of uptake of any particular amelioration or best management practice.

So what options are available for the development of policy?

Previously, diffuse pollution management has been implemented either through a series of voluntary or mandatory measures, or a combination of both. The central aim of these approaches is to ensure greatest benefit at least cost. They also need to be adaptable and equitable. The balance between the adoption of the polluter or beneficiary pays approach, and the choice of mechanisms appropriate to the GBR requires further evaluation.

Setting of target loads for the ecosystems of the GBR could represent the cumulative end-of-river contributions in relation to pollutant loading and further source apportionment. This would potentially open up a mechanism for specifying emissions or pollutant limits and for therefore encouraging emissions or permit trading, although this would have to be fully assessed as an option. This may allow for greater flexibility in how targets are met including offsetting emissions reductions from other sources. This approach however needs governments to set standards that are monitored and enforced, and for polluters/emitters to determine compliance. The advantage of such an approach is that it combines the certainty of regulatory approaches with the cost-effectiveness of economic incentives.

A key measure of success of Reef Plan has been the development and implementation of water quality improvement plans in a number of contributing catchments. For example, the Douglas Shire Water Quality Improvement Plan (Davies 2006) has informed other initiatives and has assisted local government in determining environmental values and water quality objectives. Interim water quality projects include agricultural best management practices, protection of priority riparian areas, water quality benchmarking and monitoring. These community and regionally led initiatives are an important measure of success of the Reef Plan and show an impressive amount of local engagement between state, local government, producers, stakeholders and public.

Reef Plan supports the enhancement of voluntary measures operating at a stakeholder and community level maintained in part through incentives to deliver improvements in water quality. It is important therefore that there is a connection between land-based management, subsequent water quality improvement, critical loads and EQSs, and/or critical levels. Elucidating the efficacy of different best management practices (BMP) within catchments, to identify specific 'hotspots' for more stringent management and to consider how to achieve target thresholds through voluntary and regulatory approaches is an important component of the potential success of Reef Plan. The question is how best can changes in land management be
brought about to ensure sustainability in its widest context? Are there really win:win options and what is necessary to ‘oil the wheels of change?’ In Europe, agricultural policy is shifting attention from a production-based approach towards environmental quality and wider land stewardship issues, including addressing the issue of diffuse pollution through soil and water management.

The Common Agricultural Policy (CAP) was set up as a system of agricultural subsidy that represents over 40% of the European Union budget. Originally established to provide economic security for European farmers and to guarantee the production of a certain quantity of key commodity products, substantive reforms to this policy are now underway with a phased transfer from specific crop production to land stewardship. This will affect the pattern of crops grown in different regions of Europe and will also make land use changes easier. Of particular importance therefore is the alignment of CAP reform and the aims of the WFD, although compliance with WFD is not part of the statutory management list for CAP.

Support from the CAP will be conditional on statutory management requirements directly linked to farming, covering environmental, animal welfare, food safety and occupational safety aspects. Agricultural production will have to be carried out according to these statutory management requirements, and land will have to be maintained in good agricultural and environmental condition. Failure to do so will result in part or total loss of direct support. Statutory management requirements are also supported by the codes of good farming practice many of which are of relevance for achieving the objectives of waters-based legislation such as the WFD, and the Nitrates Directive (which aims to control loss of agricultural nitrogen). These are all components of a cross compliance approach to meeting policy objectives.

As part of the reform of the CAP a new system of land management contracts has been introduced to Scotland. These are intended to have social and economic as well as environmental benefits, and there has been concurrent establishment of an education and outreach network to increase knowledge transfer, and the establishment of example ‘monitor farms’ to provide a benchmark for best management practice within the industry. Feedback suggests that the latter have been most useful in changing attitudes and practices among the farming community. An important philosophy in diffuse pollution management outreach is that of the ‘treatment train’ – namely, to reduce the overall input of excess nutrient into the system through better fertiliser management and precision techniques; to ensure that nutrients in the soil:water:plant system are not mobilised outside the production zone; and to ensure that any nutrients mobilised within the landscape do not reach groundwaters, streams and rivers, rather they are immobilised within other features such as wetlands, riparian vegetation and buffers. One must add a cautionary note here that processes such as wetland de-nitrification, while reducing levels of inorganic nitrogen in run-off waters, generates greenhouse gasses. Should this be a substantive flux then such ‘pollutant swapping’ must be factored in to any holistic evaluation.

The challenge in both Europe and the GBR therefore is how to develop mechanisms through which to sustain the reduction of diffuse pollution to levels where no deterioration in ecological integrity of aquatic ecosystems occurs. In Scotland, consultation is underway to evaluate the implementation of regulatory measures with reference to diffuse pollution. A scheme of National General Binding Rules, Registration and Licensing is proposed (Table 2). These are based on the premise that diffuse pollution sources and impacts are not equitably split throughout the landscape and that biophysical and management factors result in a mosaic of pollutant generation, transport and downstream consequences.

Most of the national-scale general binding rules are present in existing guidance and codes of good practice and it is envisaged that any risk-based regulation would be through a ‘light touch’, setting compulsory standards for all sectors. The objective is that through incentives such as CAP compliance and land management contracts there is a collective ‘raising of the bar’ in relation to implementing BMPs across the agricultural sector, ensuring an enhanced level of stewardship. An additional supportive approach through the provision of advice and information on current and future BMPs is also proposed concurrent with regulatory approaches. Additionally National General Binding Rules principles will apply to all land management sectors including forestry and recreation (such as golf course development).
This scheme of General Binding Rules is similar to that promoted through Reef Plan although monitoring and auditing of compliance across the sector is stronger in the UK example. There is a realisation however, that in order to achieve the overall objective of reaching good ecological status in all waters by 2015, more than just the adoption of National General Binding Rules will be required. This will be in the form of registration (with potential impact assessment) and even licensing (for persistent issues) in specific spatial locations. Registered areas would be located in or within specific catchments where identifiable actions above National General Binding Rules would be required. This may be as a result of particular geomorphological attributes within catchments combined with particular land use and/or its management. Additional BMPs, attenuation mechanisms, or changes to land management may be required within these locations to meet the requirements of the WFD and it is envisaged that incentives would have to be made available in these critical areas. Licensing would only be used in areas of persistent problems and non compliance.

<table>
<thead>
<tr>
<th>National General Binding Rules</th>
<th>GBRules providing general authorisation for certain activities and applied nationally</th>
<th>Basic good management practices agreed in consultation with the sector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Targeted General Binding Rules with registration</td>
<td>Targeted GBRules in impacted catchments where national GBRules are judged to be insufficient</td>
<td>More detailed management practices agreed in consultation with sector</td>
</tr>
<tr>
<td>Licence</td>
<td>Licence applied in areas of persistent problems</td>
<td>Detailed site specific conditions to be developed</td>
</tr>
</tbody>
</table>

Figure 2: Potential structure for the development of General Binding Rules for diffuse pollution.

Source: http://www.scotland.gov.uk/Publications/2005/12/12152505/25063

There may be much merit in evaluating a similar scheme throughout the Great Barrier Reef Marine Park and its catchments. National General Binding Rules and the adoption of BMP across sectors is a central theme of Reef Plan, and notable success has been reported (The State of Queensland and the Commonwealth of Australia 2005). The question still remains as to whether this will be enough to ensure the long-term sustainability of the GBR, its ecology, and communities. The problems of diffuse pollution management are global in nature, only the drivers and ecosystems differ, but it is a central issue to the maintenance of ecological integrity in aquatic systems. An effects-based approach as proposed here ensures rigour in linking cause and effect and provides a platform through which to evaluate future management options. Defining contributions to the critical load of pollutants would involve setting riverine and sectoral targets, directly linked to lagoon ecology.

Providing a framework to assess targets and timescales is only one component of socioeconomic systems analysis. Generating a mechanism through which to facilitate shared visions is also essential and an important aspect of the research challenge is to evaluate the extent to which any top down effects-based approach is de-coupled from the predominantly social bottom up community-focused initiatives. Developing appropriate structures through which to dovetail components is a major issue.
5.5. Discussion

It is most evident that much high quality and innovative collaborative research has and is being conducted within the GBR science community and this should be consolidated and supported. However, the interaction between the terrestrial and aquatic science community, policy, resource managers and stakeholders both on land and in the lagoon (which is highlighted in many documents) is more difficult to reconcile. There appear to be many people busy doing excellent work, all paddling in the same direction – but not necessarily all in the same boat! CSIRO science must support the challenges beyond Reef Plan and not only on providing a basis for its implementation. Further evolution not revolution is required, based on increasing interdisciplinary activity, enhancing critical mass and generating innovative hypotheses. The key factors focus on developing a systems-level approach to GBR science and the land-to-sea continuum to:

- link pollution to impact;
- integrate biophysical with social and economic dimensions; and
- develop an overarching mechanism for integration.

This will expand the relevance and skills base beyond the GBR.

Looking beyond Reef Plan, it is important to anticipate the key science understanding that needs to be planned and championed now to ensure robust management of issues such as diffuse pollution in the future. Effectiveness of given management measures cannot be effectively assessed through meeting specific targets linked to action indicators such as those championed in the regional NRM plans.

Diffuse pollution is only one factor involved in a broader umbrella of GBR sustainability issues, but it is one where momentum through Reef Plan has been established and it is important that aspirations of stakeholders are dovetailed with quality supporting science to inform policy. These should include:

- the development of cause and effect thresholds;
- delivering ecological quality targets based on the lagoon ecosystems (are there common denominators to describe impacts in complex systems?);
- critical loads for management linked to end of river targets; and
- an evaluation of present and proposed BMP adoption strategies.

This will require strategic science to:

- underpin links between chemistry, environmental factors and ecological response (impacts domain);
- the enhancement/development of reactive domain models evaluating the spatial and temporal delivery of critical thresholds;
- management and delivery domain models linking land management, wetland attenuation, end of river fluxes and the establishment of critical loads; and
- an integrated assessment framework pulling these components together linked to other economic, political and social modelling approaches such as those being developed within the Reef Catchment Futures Program of the WfHC.

This requires research synergy. Presently there is no CSIRO marine science involvement within WfHC as it is presumed that this role will be fulfilled by AIMS. AIMS is involved in the determination of factors affecting reef health of which diffuse pollution is only one driver. Although existing research aims to provide lagoon modelling and define cause and effect (the recent work by Wooldridge is a good example of this), there may be merit in examining in more detail whether there is critical mass in this area, and if not, how this key area might be further
supported through collaboration. Such collaboration requires specific mechanisms to ensure interaction and engagement against specific scientific objectives or the process will always be subject to other pressures. It is because of this that current WfHC project composition is not well integrated against higher-level systems objectives (which are missing). For example, how are the three WfHC stream objectives of 'build capacity/reduce erosion/improve water quality' linked together, and with other research providers 'to protect the Reef by 2013'? This may in part reflect a lack of critical mass in the research effort (at a systems-level), or too close a focus on only supporting Reef Plan implementation issues. There is a potential for greater input from CSIRO biogeochemists and aquatic ecologists to the GBR research effort, and the challenging aims of determining systems-level solutions (land-to-sea continuum) needs further resourcing to deliver. The integration of socio-economists within the GBR science platform is providing a leading edge but requires additional support to consolidate critical mass.

The specific understanding of wetland function and how this has been influenced by management still requires further strategic research. Although there is information on biogeochemical cycles and pathways in wetland systems, and the impact of anthropogenic activity on ecosystem function, there is a requirement to evaluate the wider systems-level functions of wetlands as 'reactor vessels' in the context of the GBR, and especially pollutant delivery. The main questions are:

- do managed wetland areas act as a sink or source of pollutants? and
- how can these contributions be apportioned against other diffuse and point sources during event-based transport?

Although the focus of this report has been on evaluating a systems approach linking land and sea, it is important to consider the impacts of diffuse pollution and land use on the freshwater and estuarine aquatic environments. Land management has significantly altered the hydrology and hydrochemistry of wetland environments, damaging the natural integrity of freshwater habitats, altering hydromorphology in river channels and the chemistry of ephemeral systems. The potential loss of nursery areas for fish through the demise of mangroves and coastal wetland systems could be significant. Setting targets for the management of these ecosystems is through the adoption of the ANZECC water quality guidelines which are use based. In a WFD context, ecological quality would provide the basis for future target setting and requirements would need to be assessed and options for remediation evaluated, including an assessment of disproportionality. What would be the consequences of adopting more rigorous quality standards for these ecosystems in relation to environmental protection and land management? Are remediation targets achievable even if desirable? Is there spatial continuity in protected or key habitats to ensure their true value? Further consideration should be given to such science challenges and the nature of CSIRO’s role.

Finally, the integration of scientists and their activities within the context of a GBR systems approach needs to be at a range of levels:

- between biophysical and ecological science disciplines (hydrochemistry, hydrology, coastal process and oceanography, marine ecology); and
- to develop a common impacts framework integrating land to river to sea.

It should take a systems-level approach that links ecosystem components including the nature and timing in the generation of pollutants, their movement through the land–water continuum, their delivery to different ecosystems within the lagoon and reef complex, and an assessment of the ecological impact in these different ecosystems. Recent research by Wooldridge et al. (in press) has highlighted that links between cause and effect can be shown for different parts of the GBR, bringing forward the opportunity for future development of catchment-based target setting.

This integration should support these recent developments and develop up a targeted program of research through which to measure success of management options, based on simple indices that can be source apportioned. This requires a reappraisal of monitoring and data capture, which should ensure:
long-term observational surveillance of anthropogenic drivers;
robustness of classification systems linking to ecological impacts; and
reduced uncertainty.

Additionally, are there opportunities for the use of new and emerging ecotoxicogenomic approaches to represent ecosystem integrity and identify systems under stress. (Who is developing such approaches? Are they targeted towards multiple stress factors? How can information be factored into the assessment of GBR health?). This integration should provide the biophysical underpinning to a broader socioeconomics systems program.

Further integration requires a common understanding of the problem to be resolved and in many cases a simple conceptual model is the most effective way to do this. The conceptual model (adaptive management framework) will lay out the main aspects of the socioecological system and the interrelationships within the system (and the important external drivers and feedback loops). This will be achieved by linking biophysical characterisation (geochemical, hydrological, morphological and ecological) with socioeconomic analysis (demographic, land use, economic, political, institutional, policy, cultural). Model construction will make explicit the various assumptions underpinning individual science approaches and the values that different contributors assign to different forms of knowledge (technical, local, experiential, procedural). It is important then to identify the consequences of various actions (potential scenarios) and to build capacity through knowledge sharing. Subsequently the effort should be directed to defining targets for recovery and timelags, and to identify resilient future states for GBR in a changing environment. Again this should aim to consolidate activities within and to enhance clustering around WfHC Reef Catchment Futures program.

A recent document produced by GBRMPA (2005) on research needs for the protection and management of the Great Barrier Reef Marine Park identifies both the relationships between pollutant generation and impacts, and the identification of critical thresholds within the priority knowledge timeframe of 1 to 3 years. Interestingly, an evaluation of the effectiveness of Reef Plan in halting and reversing water quality received a lower priority (3–5 years). Given the consequences of Reef Plan not meeting longer-term objectives, research should be undertaken to evaluate the socioeconomic consequences of further designation and legislation within the GBR. Issues include:

- the consequences of current and potential future adoption of BMPs (Are they effective enough? What are the constraints to uptake, and is this auditable across the individual sectors? Can it be auditable if completely voluntary?);
- potential mandatory compliance through the development of nutrient management zones (Is this a possible mechanism for prioritising change? Incentives or legislation? What would be the consequences of this on existing industry and community lead initiatives?);
- how can natural resource and marine park management 'targets' be better integrated (What is the shared vision? What are the institutional and social mechanisms for delivering integrated land-sea management?); and
- is legislative reform required to deliver reef protection, or can existing regional structures combined with partnerships with industry and stakeholders and participation public achieve the required output?

Finally, for successful integration, a formalised mechanism of engagement for contributors, (including the provision of intellectual and operational 'space') and a method for absorbing transaction costs associated with such a commitment must be provided. Should resources be made available for such a process, then it is important that there is a move away from 'business as usual' and a clear commitment to interdisciplinary action by involved parties. Proactive engagement must be seen as a priority. (Start with a blank canvas, describe the system and level of understanding and uncertainty, develop an integration strategy and science plan, identify measures of success, and seek independent review of progress).
The scientific challenges to support robust policy developments are a priority for the wider sustainable future management of the reef. Movement to a systems-based approach provides the mechanism through which to tackle such complex socio-environmental management issues. The integration of the science community within the wider context of the Reef Water Quality Partnership is an important opportunity to enhance an holistic systems-based vision for diffuse pollution management in the GBR.
6. References


Appendices

Appendix A: EU Water Framework Directive in context

Waters legislation in Europe gathered pace in the 1970s and early 1980s, followed by a second wave in early 1990s. Most of this water policy was use-based rather than focusing on ecological integrity. In 1995, the European Commission was requested by Council of Ministers & Environment Committee to produce a coherent water policy aiming to draw together much of the existing independent and somewhat disparate directives (Figure A1) to provide greater synergy, reduce point of tension between sister directives and a more integrated approach. In 1997, the European Commission proposal for the Water Framework Directive was developed and in 2000, the Directive was published (CIRCA 2003a–e). The requirements of some old water legislation (e.g. the Freshwater Fish Directive) have been reformulated in the Water Framework Directive to meet modern ecological thinking. After a transitional period, these old directives will be repealed. Other pieces of legislation (e.g. the Nitrates Directive and the Urban Wastewater Treatment Directive) must be coordinated in river management plans under the WFD.

Figure A1: Water framework Directive in relation to previous EU waters-based legislation.

The European Union (EU) WFD is a complex environmental directive, but one with principles that have been developed to be simple, flexible and familiar. This is required because the WFD is to be implemented by 25 member states, Norway, and a number of accession countries – a complex socioeconomic assemblage of cultures, traditions, languages and histories in terms of environmental management and objective setting. The WFD is a major departure from conventional environmental protection legislation in several ways. It obliges member states to take a holistic, inclusive, ecological approach to water management: it also requires the quality ‘status’ of water bodies be measured using ecological rather than just traditional physical and chemical parameters, with more emphasis on the biological quality of a water body.

There has been much investment to date in undertaking supporting research on defining the terms of reference for the implementation of the WFD in Europe from an ecological, social and economic perspective. This has been collated and the reader is directed to the comprehensive documentation of the Common implementation strategy (CIS) for the water framework directive (CIRCA 2003a–e) hosted by the Communication and Information Resource Centre.
Administrator (CIRCA) website, which covers all aspects of the WFD (http://forum.europa.eu.int/Public/irc/env/wfd/library). The subsequent text provides a summary of the major points of the directive and its implementation but is by no means a comprehensive summary of all aspects and it is advisable to consult directly to the CIS literature.

The WFD functional unit is based on river catchments or collections of river catchments (river basin districts), rather than traditional political divisions such as counties or regions. 'River basins' or 'catchments' are made up of lakes, rivers, streams, groundwater and estuaries – and all the land that surrounds them and drains into them. The WFD thus promotes a more integrated, holistic approach to water management, and one that transcends national borders.

Involvement of the public is a key requirement: the WFD puts consultation, public involvement, stakeholder engagement and access to information at the heart of its development and specifically states that 'the active involvement of all interested parties' must be encouraged by every member state. It is anticipated that this will enhance community, industry and stakeholder input to the management of water resources in Europe, which has previously been weak in many situations.

Main objectives of the WFD are to:

- protect and, where necessary, to improve the quality of all inland and coastal waters, groundwater and associated wetlands and to prevent their further deterioration;
- promote the sustainable use of water;
- enhance protection and improvement of the aquatic environment through specific measures for the progressive reduction of discharges, emissions and losses of priority substances and the cessation or phasing-out of discharges, emissions and losses of the priority hazardous substances; and
- lessen the effects of flooding and drought.

It has overall aims of:

- no further deterioration in the ecological quality of aquatic environments; and
- achieving 'good status' for all waters by 2015.

A key concept underlying the WFD is that of integration which is seen as the major focus of management of water protection with the regional planning process (so-called river basin districts [RBD]) (CIRCA 2003a). These represent a mountain-to-seas continuum and management must embrace the complete hydrological cycle.

This involves integration of:

- environmental objectives, combining quality, ecological and quantity objectives for protecting highly valuable aquatic ecosystems and ensuring a general good status of other waters;
- all water resources, combining fresh surface water and groundwater bodies, wetlands, coastal water resources at the river basin scale;
- all water uses, functions and values into a common policy framework (i.e. investigating water for the environment, water for health and human consumption, water for economic sectors, transport, leisure, water as a social good);
- disciplines, analyses and expertise, combining hydrology, hydraulics, ecology, chemistry, soil sciences, technology engineering and economics to assess current pressures and impacts on water resources and identify measures for achieving the environmental objectives of the directive in the most cost-effective manner;
- water legislation into a common and coherent framework including integration of all significant management and ecological aspects relevant to sustainable river basin planning including those that are beyond the scope of the WFD such as flood protection and prevention;
• a wide range of measures, including pricing and economic and financial instruments, in a common management approach for achieving the environmental objectives of the Directive (programs of measures are defined in river basin management plans developed for each river basin district – a collection of individual catchments and water bodies specified by each member state);
• stakeholders and the civil society in decision making, by promoting transparency and information to the public and by offering an unique opportunity for involving stakeholders in the development of river basin management plans;
• different decision-making levels that influence water resources and water status (local, regional or national) for an effective management of all waters;
• water management from different member states, for river basins shared by several countries, existing and/or future member states of the European Union.

A.1 The planning cycle

In order to achieve the overall aims, the WFD promotes an objective-based approach for adaptive management based on a planning cycle composed of four main elements (Figure A2), against a formalised timetable (Appendix B):

- **characterisation**: including an assessment of water bodies at risk of not achieving The Directives objectives as a result of man-made pressures;
- environmental **monitoring** informed by the characterisation;
- setting of **environmental objectives**; and
- design and implementation of a **program of measures** to achieve these environmental objectives.
A.2 Responsible authorities

In order to ensure consistent implementation throughout Europe the WFD specifically states that ‘Member States shall ensure the appropriate administrative arrangements, including the identification of the appropriate competent authority, for the application of the rules of this Directive within each river basin district lying within their territory’.

In most situations, the competent authority nominated has been the relevant national governmental environmental body. (e.g. the Scottish Environment Protection Agency or the Environment Agency [England and Wales] and the Environment and Heritage Service [Northern Ireland]).

Where the situation arises that a river basin covers the territory of more than one member state it is assigned to an 'international river basin district'. At the request of the member states involved, the European Commission has acted to facilitate the assigning to such international river basin districts. Under such conditions each member state must ensure that appropriate administrative arrangements, (including the establishment of an appropriate competent authority) are in place for the application of the rules of the WFD within the portion of any international river basin district lying within its territory. Collaboration between member states on trans-boundary management of large river basins is underpinned by the common objectives of the WFD.

A.3 Characterisation

The WFD requires that all water body types (inland and coastal waters, groundwater and associated wetlands, modified water bodies) within each specified RBD to be split into water bodies. These represent the classification and management unit of the directive. A range of factors will determine the identification of water bodies. Some of these will be determined by the requirements of the WFD and others by practical water management considerations (Figure A3).
Figure A3: Hierarchical approach to defining water bodies

The purpose of assigning water bodies to a physical type is to ensure that valid comparisons of its ecological status can be made. For each type 'reference conditions' that represent the condition of the type in pristine condition must also be described. These form the benchmark from which all deviation as a consequence of human activity can be assessed, as they form the 'anchor' for classification of the water bodies status or quality (see Section A.3.i of the WFD). An additional set of assessment criteria have been determined for water bodies that have been subject to extensive historical physical modification (see Section A..3.ii of the WFD).

Concomitant with the classification of ecological status is the identification of anthropogenic drivers generating impacts on the ecological integrity of receiving waters. The WFD therefore adopts the driver – pressure – state – impact – response analytical framework.

To assign a single classification and effective environmental objectives to a water body it may be necessary to divide an area that is of one type further into two or more separate water bodies. Water bodies may not spread over two types because reference conditions and hence environmental objectives are type specific.

The need to keep separate two or more contiguous water bodies of the same type depends on the pressures and resulting impacts. For example, a discharge may cause organic enrichment in one water body but not in the other. Such an area of one type could therefore be divided into
two separate water bodies with different classifications. If there were no impact from the discharge it would not be necessary to divide the area into two water bodies as it would have the same classification and should be managed as one entity. The WFD only supports the subdivision of water bodies where there is a requirement for the effective application of the directives objectives, in effect reducing the number of management units to those specifically linked to definitive impacts (CIRCA 2003b).

In addition to biophysical characterisation, there is a requirement in the WFD for a economic appraisal of water and its uses. Overall, the main functions of the economic analysis include (WATECO 2003):

- carrying out an economic analysis of water uses in each RBD;
- assessing trends in water supply, water demand and investments;
- identifying areas designated for the protection of economically significant aquatic species;
- designating heavily modified water bodies based on assessment of impact (including economic impact) on existing uses and costs of alternatives for providing the same beneficial objective;
- assessing current levels of cost-recovery;
- supporting selection of a program of measures on the basis of cost-effectiveness criteria;
- assessing the potential role of pricing in programs of measures – implications on cost-recovery;
- estimating the need for potential (time and objective) derogation from the WFD’s environmental objectives based on assessment of costs and benefits and of costs of alternatives for providing the same beneficial objective;
- assessing possible derogation resulting from new activities/modifications, based on assessment of costs and benefits and costs of alternatives for providing the same beneficial objective; and
- evaluating costs of measures to identify cost-effective ways to control priority substances.

In the first phase on the WFD implementation, key criteria have been identified for primary analysis. These include the:

- **economic analysis of water uses** – What is the economic significance of water in river basin districts? What are key economic drivers influencing pressures and water uses? How will these economic drivers evolve over time, and how will it influence pressures? How will water demand and supply evolve over time, and which problems is it likely to cause?

- **economic assessment of potential measures for reaching good water status** – What is the least-costly set of measures that will ensure good water status? How much will it cost to reach good water status? What is the likely economic impact of proposed measures on key economic sectors/water uses? How do we determine whether the costs of achieving good water status are considered to be disproportionate so that derogation may be appropriate? (Should cost be disproportionately expensive, lower objectives can be set for individual water bodies, but only after a full assessment of achieving good ecological status (GES) has been undertaken [WATERCO 2003]).

- **assessment of the recovery of the costs of water services** – How much do the current water services cost? Who pays for these costs, and what is the current cost-recovery level? What impact on cost-recovery is likely from the proposed programs of measures?
Although the different elements of the economic assessment appear throughout the Directive the principles should be well integrated into the policy decision and management cycle (Appendix C).

A.3.1 Reference conditions, ecological quality ratios and the definition of good ecological status

The WFD requires member states to assess the ecological status of water bodies and then ensure that appropriate environmental objectives are set for these water bodies through the river basin management process. This requires the establishment of a five-tier classification scheme to reflect the ecological status of surface water bodies as measured by the condition of specific biological, hydromorphological, and chemical and physico-chemical quality elements. Description of these normative classes is given in Appendix D.

The relevant elements, and the specific conditions required for these elements in each of the classes of the classification schemes, depend partly on the water category and type to which the water body belongs, and on whether the body is artificial or heavily modified (See Modified Water Bodies). Biological elements for different surface water categories are listed in Appendix E.

The water body type reference condition is a description of the biological quality elements that exist, or would exist, at high status (i.e. with no, or very minor disturbance from human activities). The objective of setting reference condition standards is to enable the assessment of ecological quality against these standards. The reference condition is a description of the biological quality elements only. Reference conditions can be specified by identification of appropriate sites representing high ecological quality, modelling and paleolimnological techniques, expert guidance, or a combination of these approaches.

Within the WFD, reference conditions are described as follows:

Type specific biological reference conditions shall be established, representing the values of the biological quality elements … for that surface water body type at high ecological status.

The values of the biological quality elements (Appendix E) must be taken into account when assigning water bodies to any of the ecological status classes. In order to ensure comparability, the results of the biological monitoring systms are expressed as ecological quality ratios for the purposes of ecological classification. The ratio is expressed as a numerical value between zero (worse class) and one (best class consistent with the specification of reference conditions) (Figure A4).

Figure A4: Ecological quality ratio. The sizes of the bands differ because the boundaries between classes must align with the normative definitions, not a simple percentage. Note that all the deviations are measured from the reference condition.

In defining biological reference conditions, criteria for the physico-chemical and hydromorphological quality elements at high status must also be established (see Figure A5).
High ecological status incorporates the biological, physico-chemical and hydromorphological elements. The values of the hydromorphological quality elements must be taken into account when assigning water bodies to the high ecological status class (i.e. when downgrading from high ecological status to good ecological status). For the other status classes, the hydromorphological elements are required to have 'conditions consistent with the achievement of the values specified for the biological quality elements.' Similarly values of the physico-chemical quality elements must be taken into account when assigning water bodies to the high and good ecological status classes (including the development of criteria for priority pollutants – Appendix F).

It is recognised that some member states in Europe may have few or no water bodies at high status and may need to use reference conditions established in another member state for the same type. Pressures such as diffuse pollution and land-use patterns are indirect pressures that member states are required to control under the WFD.

Figure A5: Indication of the relative roles of biological, hydromorphological and physico-chemical quality elements in ecological status classification according to the normative definitions presented in Appendix D.

However, it is unrealistic to base reference conditions upon historic landscapes that no longer exist in modern Europe and this should be factored into the assessment. Importantly, high status provides the direction, not the target, for restoration. A most critical issue in implementing the WFD will be setting the borders between the high, good and moderate classes, as this determines whether management action is necessary.

A3.2 Groundwaters
The Directive also requires that groundwater bodies be characterised into aquifer types and further subdivision into manageable units based on:

- geological boundaries;
• groundwater divides (i.e. through surface water catchments);
• flow lines within an aquifer; and
• modelling of groundwater movement.

There are two status classes for groundwater – good and poor – and these are defined on the basis of:
• impact on surface waters and terrestrial ecosystems;
• avoidance of saline risks or other intrusions;
• exceedance of the available resource as evidenced by changes in groundwater levels; and
• compliance with Article 17 (EU standards for nitrates, pesticides, etc.).

Further there is a requirement to identify and reverse any significant and sustained upward trends in the concentration of pollutants. The WFD provides specifications on the identification of trends in pollutant concentrations originating from diffuse and/or point sources.

A.3.3 Modified water bodies

Clearly many of Europe’s water bodies have been subjected to substantive historical changes. In this situation it is not viable to identify ecological ratio changes or normalised reference conditions representing un-impacted environments.

In response to these concerns the finalised WFD allows member states to designate surface water bodies, that have been physically altered by human activity, as 'heavily modified' under specific circumstances. If the specified uses of such water bodies (i.e. navigation, hydropower, water supply or flood defence) or the 'wider environment' would be significantly affected by the restoration measures required to achieve good ecological status and if no other better, technically feasible and cost-effective, environmental options exist, then these water bodies may be designated as 'heavily modified' (HMWB) and good ecological potential (GEP) is the environmental objective.

HMWBs are bodies of water which, as a result of physical alterations by human activity, are substantially changed in character and cannot, therefore, meet 'good ecological status'. Artificial water bodies (AWB) are water bodies created by human activity (such as canals and ponds) and that have been created in a location where no water body existed before and that have not been created by the direct physical alteration, movement or realignment of an existing water body. Criteria for the identification and designation of heavily modified and artificial water bodies is shown in Appendix G.

Instead of 'good ecological status', the environmental objective for HMWB and for AWB is GEP, which has to be achieved by 2015. The concept of HMWB was created to allow for the continuation of these specified uses that provide valuable social and economic benefits but at the same time allow mitigation measures to improve water quality.

GEP is a less stringent objective than GES because it makes allowances for the ecological impacts resulting from those physical alterations that:
• are necessary to support a specified use; or
• must be maintained to avoid adverse effects on the wider environment.

This means that appropriate objectives can be set for the management of other pressures, including physical pressures, not associated with the specified use, while ensuring that the adverse ecological effects of the physical alteration can be appropriately mitigated without undermining the benefits they serve.

The objective setting process for HMWB and AWB should be in line with the same general principles as applied for natural water bodies. The environmental objectives for natural, artificial and heavily modified water bodies are set in relation to reference conditions. For HMWB and AWB the reference condition is the maximum ecological potential (MEP). The MEP is the state
where the biological status reflects, as far as possible, that of the closest comparable surface water body taking into account the modified characteristics of the water body. With regards to its biological status the GEP accommodates ‘slight changes’ from the MEP.

The designation of HMWB and AWB, the definition of the MEP, the identification of GEP as well as the program of measures to achieve the relevant environmental objectives will be part of the river basin management plans that are to be published by 2008 as first consultation drafts and 2009 as final plans. These have to be revised every six years (CIRCA 2003d).
A.4 Environmental monitoring

Monitoring programs are required within the Directive to establish a coherent and comprehensive overview of water status within each river basin district, and must permit the classification of all surface water bodies into one of five classes and groundwater into one of two classes.

Monitoring information from surface waters is required for:

- the classification of water body status;
- supplementing and validating risk assessment procedures;
- the efficient and effective design of future monitoring programs;
- the assessment of long-term changes in natural conditions;
- the assessment of long-term changes resulting from widespread anthropogenic activity;
- estimating pollutant loads transferred across international boundaries or discharging into seas;
- assessing changes in status of those bodies identified as being at risk in response to the application of measures for improvement or prevention of deterioration;
- ascertaining causes of water bodies failing to achieve environmental objectives where the reason for failure has not been identified;
- ascertaining the magnitude and impacts of accidental pollution;
- assessing compliance with the standards and objectives of Protected Areas; and
- quantifying reference conditions (where they exist) for surface water bodies.

Monitoring information from groundwater is required for:

- providing a reliable assessment of quantitative status of all groundwater bodies or groups of bodies;
- estimating the direction and rate of flow in groundwater bodies that cross Member States boundaries;
- supplementing and validating the impact assessment procedure;
- use in the assessment of long-term trends both as a result of changes in natural conditions and through anthropogenic activity;
- establishing the chemical status of all groundwater bodies or groups of bodies determined to be at risk);
- establishing the presence of significant and sustained upwards trends in the concentrations of pollutants; and
- assessing the reversal of such trends in the concentration of pollutants in groundwater.

To affect this program of assessment three levels of monitoring activity are established.

- **Surveillance**
  - validate risk assessment
  - all quality elements - large spatial network @ low frequency (yearly)
  - long-term data on natural and / or widespread anthropogenic change

- **Operational**
  - establish status of at risk water bodies using EQRs
• all water bodies receiving discharge of priority hazardous substances
• similar at-risk water bodies can be grouped
• only quality elements most sensitive to risk pressure are evaluated

Investigational
• cause of exceedance unknown
• surveillance shows at-risk
• pollution events

The WFD specifies quality elements for the classification of ecological status that include hydromorphological, chemical and physico-chemical elements supporting the biological elements. For surveillance monitoring, parameters indicative of all the biological, hydromorphological and all general and specific physico-chemical quality elements are required to be monitored. For operational monitoring, the parameters used should be those indicative of the biological and hydromorphological quality elements most sensitive to the pressures to which the body is subject, and all priority substances discharged and other substances discharged in significant quantities. The ecological status classification of a body of water is to be represented by the lower of the values for the biological and physico-chemical monitoring results for the relevant quality elements classified in accordance with the normative definitions.

A.5 Environmental objectives

The setting of environmental objectives (through setting environmental quality standards and conditions) is critical to the successful implementation of the WFD aims of achieving 'good status' for all waters by 2015. Currently Europe is involved in a process of intercalibration and consolidation of classification schemes for the biological elements underpinning the classification of ecological status. The setting of environmental objectives provides an important bridge between ensuring ecological targets are met and providing methodologies for stakeholders and agencies to deliver positive changes to the water environment (Figure A6).

Environmental standards and conditions have gone out to consultation in the UK, and this development is seen as an iterative process both in relation to the setting of standards, thresholds and inherent uncertainty, and the requirement for additional supporting monitoring. Present proposals represent the current best scientific understanding of the links between chemistry, hydrology and ecology.

![Figure A6: The role of environmental quality standards and conditions in bridging between biological quality elements and management activities](image-url)
For each category of surface water body, environmental standards that support the biological components representative of that type of aquatic environment are required. Standards are being defined for the relevant class boundaries (high, good, moderate, poor, bad) for the biological elements. These include:

- morphological standards;
- hydrological standards;
- water quality standards for general physico-chemical elements; and
- chemical pollutant standards for priority pollutants (EQSs that are currently being set by Europe) (see Appendix F).

There are two different ways in which EQSs have been used in decision making:

- the direct model is used in situations where there is a strong link (with a high degree of confidence) between any given activity and the compliance with a specific standard; and
- the indirect model approach applies where there is not enough confidence to suggest that simple failure of a standard causes damage or risk.

In the latter situation there may be the requirement to not only measure compliance with a given numeric standard but to obtain supporting information that links cause and effect. For example the setting of a particular standard for nutrients combined with a monitoring of phytoplankton may suggest that the original environmental standard may not sufficiently address ecological response. Perhaps a different standard based on seasonal delivery of a nutrient may be more appropriate and this would be developed within later interactive cycles of the WFD.

Setting these EQSs provides a context for the development and application of measures to ensure no further deterioration of the aquatic environment. Therefore many of the activities that could potentially harm the water environment can be controlled by permitted activities such as discharge consenting, pollution prevention and abstraction licensing. The setting of ‘permit limits’ to control potentially damaging activities is translated into the development of national or community legislation through the development of general binding rules or codes of good practice.

For example, recent legislation in Scotland (The Water Environment (Controlled Activities) (Scotland) Regulations 2005) has been transposed to limit direct point discharges such as organic and inorganic effluents, fish farms, thermal effluents and surface water run-off form urban areas to water courses from activities such as abstraction, impoundments and engineering works. Different levels of control are used to deliver the overall package of measures:

- **general binding rules** represent the simplest level of control. They cover specified activities and define conditions that provide the necessary level of environmental protection. As activities are undertaken in compliance with the specified conditions, the general binding rules provide the authorisation. The operator will not have to report to the responsible authority (in this case the Scottish Environment Protection Agency [SEPA]) because these activities are considered to be very low risk.

- **Registrations** allow for the assessment of small-scale activities that individually pose a small environmental risk but which cumulatively can result in environmental harm. Operators must apply to SEPA to register these activities. A registration is only valid as long as the water user complies with the application details. A registration will therefore include details of the scale of the activity and its location; and the authorisation is only valid as long as the activity is carried out within these constraints. A risk assessment procedure would be undertaken for registered activities.

- **Licences** allow for site-specific conditions to be set to protect the water environment. A licence will be ‘person’-specific in that it will require the identification of a ‘responsible person’ who will be responsible for ensuring that the terms of the licence are complied
A responsible person can be an individual, a company or a partnership. Licensing would require a risk assessment and regular reviewing.

Further legislation on the development of controlled activities regulations for diffuse pollution is in consultation.

A.6 Program of measures

The ultimate aim of the WFD is to prevent deterioration of water status and to try to restore all waters to 'good' ecological status by 2015. A key component of this process is the assessment of the overall health of the aquatic ecosystems, both now and into the future. Specific environmental standards and conditions are therefore needed to assess and define the wider environmental conditions that support a healthy ecosystem, and these have been defined on best available knowledge. These standards then provide a basis for setting objectives in river basin management plans, and the development of a program of measures through which to address them. The objective-setting process of river basin management planning provides flexibility to set less stringent objectives where the achievement of 'good' status is technically infeasible or disproportionately expensive. If uncertainty about the effectiveness of any measure is high, a less stringent objective could be set, but this should not justify deferring from at least trying to achieve good status. Guidance on coordination, public participation and stakeholder engagement in the development and consultation phases of the preparation of the program of measures within the development of river basin management plans is detailed in CIRCA (2003e).

Within the WFD, there is an appreciation that ecosystem hysteresis and natural attenuation processes are critical in determining the rate and magnitude of recovery. In particular Article 4 (Environmental objectives) specifically states that 'where natural conditions are limiting, no deadline need to be established for achieving good ecological status'. In reality this means that once measures that are technically feasible and not disproportionately expensive had been taken into consideration the conditions of the WFD have been met. For example, a flood event may be required to naturalise river channel conditions or once a water quality objective has been met, biological components may require colonisation process before a naturalised ecosystem is established. The pattern of ecosystem hysteresis in response to the removal of a specific external pressure will influence the rate and magnitude of recovery. Additionally, the rate of recovery is also dependent on scale and emergent properties at larger spatial scales influence must be factored into any analysis. Similarly, 'confounding factors' such as global environmental change will influence the nature of the recovery response, and influence the equilibrium state of the recovering ecosystem. It is worth remembering that the aim of the WFD is to achieve good ecological status not a return to high status in all water bodies of Europe. In many situations the present altered state of severely degraded aquatic environments, means that recovery to pristine or natural conditions is not ecologically or potentially desirable. This could be disproportionately expensive in the short-term or with existing technologies, and indeed the current state of the aquatic environment may provide additional ecosystem services above those present historically.

References


and Ecological Potential. Office for Official Publications of the European Communities, Europa


Appendix B: Timetable of the implementation of the Water Framework Directive

Technical feasibility, disproportionate costs or natural conditions may mean that member states may not always reach good water status for all water bodies of a river basin district by 2015. These circumstances will be specifically explained in the river basin management plans, the WFD offers the opportunity to member states to engage in two further six-year cycles of planning and implementation of measures.

<table>
<thead>
<tr>
<th>Year</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>Directive adopted</td>
</tr>
</tbody>
</table>
| 2003 | Transpose into national law  
Identify river basin districts and competent authorities  
Identify draft register of intercalibration sites |
| 2004 | Characterisation of water bodies, including heavily modified water bodies  
Review pressures and impacts and identify sites at risk of not meeting the environmental objective of ‘good status’  
Establish register of protected areas  
Undertake economic analysis of water use  
Final register of intercalibration sites |
| 2006 | Comprehensive monitoring programs operational |
| 2007 | Repeal some directives |
| 2008 | Publish draft river basin management plans which will include a first draft of the classification of water bodies |
| 2009 | River basin management plans produced to include final classification of the ecological status of water bodies  
Program of measures for each river basin district |
| 2010 | Water pricing policies contribute to environmental objectives |
| 2013 | Repeal some directives |
| 2015 | ‘Good’ status to be achieved |
Appendix C: Economic elements within the implementation cycle of the Water Framework Directive (WATECO 2003)
## Appendix D: Definitions of the five ecological status classes

The five ecological status classes are referred to as the normative definitions.

### Annex V Table 1.2. General definition for rivers, lakes, transitional waters and coastal waters

<table>
<thead>
<tr>
<th>Status</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>High status</strong></td>
<td>There are no, or only very minor, anthropogenic alterations to the values of the physicochemical and hydromorphological quality elements for the surface water body type from those normally associated with that type under undisturbed conditions. The values of the biological quality elements for the surface water body reflect those normally associated with that type under undisturbed conditions, and show no, or only very minor, evidence of distortion. These are the type specific conditions and communities.</td>
</tr>
<tr>
<td><strong>Good status</strong></td>
<td>The values of the biological quality elements for the surface water body type show low levels of distortion resulting from human activity, but deviate only slightly from those normally associated with the surface water body type under undisturbed conditions.</td>
</tr>
<tr>
<td><strong>Moderate status</strong></td>
<td>The values of the biological quality elements for the surface water body type deviate moderately from those normally associated with the surface water body type under undisturbed conditions. The values show moderate signs of distortion resulting from human activity and are significantly more disturbed than under conditions of good status.</td>
</tr>
<tr>
<td><strong>Poor status</strong></td>
<td>Water showing evidence of major alterations to the values of the biological quality elements for the surface water body type and in which the relevant biological communities deviate substantially from those normally associated with the surface water body type under undisturbed conditions shall be classified as poor.</td>
</tr>
<tr>
<td><strong>Bad status</strong></td>
<td>Water showing evidence of severe alterations to the values of the biological quality elements for the surface water body type and in which large portions of the relevant biological communities normally associated with the surface water body type under undisturbed conditions are absent, shall be classified as bad.</td>
</tr>
</tbody>
</table>
Appendix E: Quality elements to be used for the assessment of ecological status within the WFD

<table>
<thead>
<tr>
<th>Annex V 1.1.1. RIVERS</th>
<th>Annex V 1.1.2. LAKES</th>
<th>Annex V 1.1.3. TRANSITIONAL WATERS</th>
<th>Annex V 1.1.4. COASTAL WATERS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BIOLOGICAL ELEMENTS</strong></td>
<td><strong>HYDROMORPHOLOGICAL ELEMENTS SUPPORTING THE BIOLOGICAL ELEMENTS</strong></td>
<td><strong>CHEMICAL AND PHYSIOCHEMICAL ELEMENTS SUPPORTING THE BIOLOGICAL ELEMENTS</strong></td>
<td></td>
</tr>
<tr>
<td>- Composition and abundance and age structure of fish fauna</td>
<td>- Hydrological regime</td>
<td>- General</td>
<td></td>
</tr>
<tr>
<td>- Composition and abundance of aquatic flora</td>
<td>- Hydrological regime</td>
<td>- General</td>
<td></td>
</tr>
<tr>
<td>- Composition and abundance of benthic invertebrate fauna</td>
<td>- Hydrological regime</td>
<td>- General</td>
<td></td>
</tr>
<tr>
<td>- Composition, abundance and age structure of fish fauna</td>
<td>- Hydrological regime</td>
<td>- General</td>
<td></td>
</tr>
<tr>
<td>- Composition, abundance and age structure of fish fauna</td>
<td>- Hydrological regime</td>
<td>- General</td>
<td></td>
</tr>
<tr>
<td>- Composition, abundance and age structure of fish fauna</td>
<td>- Hydrological regime</td>
<td>- General</td>
<td></td>
</tr>
<tr>
<td>- Composition, abundance and age structure of fish fauna</td>
<td>- Hydrological regime</td>
<td>- General</td>
<td></td>
</tr>
</tbody>
</table>

3 Phytoplankton is not explicitly included in the list of quality elements for rivers in Annex V 1.1.1, but is included as a biological element in Annex V 1.2.1. It should therefore be possible to use phytoplankton as a separate element, if needed and appropriate especially in low and large rivers where phytoplankton may be important. The other aquatic flora specifically referred to in the normative definitions for rivers (Annex V 1.2.2.) are macrophytes and phytoenobos.

4 The other aquatic flora specifically referred to in the normative definitions for lakes (Annex V 1.2.2.) are macrophytes and phytoenobos.

5 The other aquatic flora specifically referred to in the normative definitions for transitional waters and coastal waters (Annex V 1.2.3. and Annex V 1.2.4.) are macroalgae and angiosperms.
Appendix F: Priority substances – the development of a specific daughter directive to the WFD

For substances on the list identified as priority hazardous substances, the WFD requires measures aimed at ending all emissions within 20 years (from 2001). Priority substances should not exceed EQS that are being developed and member states must show detail of measures to reduce their emissions. Further review of EQS and timescales is expected before 2009.

Priority hazardous substances:
brominated diphenylether (pentabromodiphenylether only), C10-13-chloroalkanes, cadmium and compounds, hexachlorobenzene, hexachlorocyclohexane (HCH), hexachlorobutadiene, mercury and compounds, nonylphenols, polyaromatic hydrocarbons (PAH), pentachlorobenzene, tributyltin compounds

Priority substances (under review as PHS)
anthracene (PAH), atrazine, chlorpyrifos; di(2-ethylhexyl)phthalate (DEHP), diuron, endosulfan, isoproturon, lead and compounds, naphthalene (PAH), octylphenols, pentachlorophenol, simazine, trichlorobenzenes, (1,2,4-trichlorobenzene), trifluralin;

Priority substances:
alachlor, benzene, brominated diphenylether (apart from Penta), chlorofenvinphos, 1,2-dichloroethane, dichloromethane, fluoranthene (PAH), nickel and compounds, trichloromethane (chloroform).
Appendix G: Identification and designation of heavily modified and artificial water bodies

Further detail can be found in: