NATIONAL WATER QUALITY MANAGEMENT STRATEGY

An *Introduction* to the Australian and New Zealand Guidelines for Fresh and Marine Water Quality

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2000

Australian and New Zealand Environment and Conservation Council
and Agriculture and Resource Management Council of Australia and New Zealand

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Printed in Australia on recycled paper for the Australian and New Zealand Environment and Conservation Council and the Agriculture and Resource Management Council of Australia and New Zealand.

Environment Australia Cataloguing-in-Publication:

An introduction to the Australian and New Zealand guidelines for fresh and marine water quality/Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand.

p. cm.

(National water quality management strategy ; no. 4a)

ISBN 0 9578245 2 1
ISSN 1038 7072

1. Water quality — Australia — Measurement. 2. Water quality — New Zealand — Measurement. 3. Water — Pollution — Environmental aspects — Australia. 4. Water — Pollution — Environmental aspects — New Zealand. 5. Water quality management — Australia. 6. Water quality management — New Zealand. I. Australian and New Zealand Environment and Conservation Council. II. Agriculture and Resource Management Council of Australia and New Zealand. III. Series

628.161′0994–dc21

Text: Julie Freeman

Design and layout: Clockwork Communicators

Photography: *Front cover (from top left)* — child drinking, Ministry for the Environment, New Zealand; Logan River (Qld), Qld EPA; Maori war boat, Photosource New Zealand Limited Image Library; Hereford, Qld EPA; irrigation channels, Bruce Cooper, NSW DLWC; monitoring, Bruce Cooper; Bondi Beach (NSW), Brian Robson; Rakaia River, South Island, New Zealand, Clint McCullough, ERISS; aquaculture, Qld EPA; Beenleigh Rum distillery (Qld), Qld EPA; Cultural ceremony on upper Katherine River (NT), Diane Lucas [*'Because our great grandmothers and grandfathers been here before, their spirits are still here. Now the spirits smell your sweat and it goes down to the deep water and makes it alright for you to be here, without any harm.'* — Margaret Oenpelli and Penny Long, Barunga, NT. The washing of people by spraying water on their head is an Arnhem Land ceremony for newcomers to country to keep away bad health for people and water.]

Back cover — Copeton Dam (NSW), Bruce Cooper

page 6 — red lotus lilies, billabong on West Alligator River (NT), Ben Bayliss, ERISS; *page 10* — Australian *Daphnia carinata*, used for toxicity testing, showing eggs, Moreno Julli, Centre for Ecotoxicology, NSW EPA; *page 13* — estuary, Qld EPA; *page 16* — irrigation, Heather Hunter, Qld DNR; *page 18* — cow and calf, Lesley Johnson, Qld DNR; oyster beds, Agriculture, Fisheries & Forestry, Australia; *page 20* — divers, Qld EPA; *page 22* — sampling macroinvertebrate communities in Micalong Creek (NSW), Philip Sloane, CRCFE ACT.

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October 2000

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The Water Quality Guidelines…

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An Introduction to the *Water Quality Guidelines*

Summarises the main features of the Australian and New Zealand Guidelines for Fresh and Marine Water Quality *(the* Water Quality Guidelines*) to help readers understand and use the documents.*

The *Water Quality Guidelines* Volume 1

Chapter 1
Introduction

Briefly describes the scope of the Water Quality Guidelines *in terms of:*

- *why and how the Guidelines were revised, and*
- *the philosophical basis governing the Guidelines.*

Chapter 2
A framework for applying the Guidelines

Provides the water quality management framework for applying the Guidelines, including:

- *an outline of key steps in this framework including environmental values, water quality guidelines and water quality objectives, and where stakeholders are involved in decision making; and*
- *an overview of some important issues that underpin the way Guidelines should be applied.*

Chapter 3
Aquatic ecosystems

Recommends water and sediment quality guidelines that will sustain the ecological health of aquatic ecosystems. Includes:

- *guidelines for different ecosystem types and for three different levels of protection,*
- *default generic guidelines as well as detailed advice on deriving site-specific guidelines, and*
- *holistic assessment of water and sediment quality, including the use of biological indicators.*

Chapter 4
Primary industries

Provides water quality guidelines recommended to sustain primary industries and to protect human consumers of food products.
Guidelines are applicable to:

- *irrigation and general water use,*
- *livestock drinking water, and*
- *aquaculture and human consumers of aquatic foods.*

Chapter 5
Recreational water quality and aesthetics

Summarises the water quality guidelines recommended to protect designated waters for recreational activities, such as swimming and boating, and to preserve the aesthetic appeal of these waters.

Chapter 6
Drinking water

Introduces the concept of safe and aesthetically pleasing drinking water, at the point of use, and refers the reader to the relevant Guideline documents.

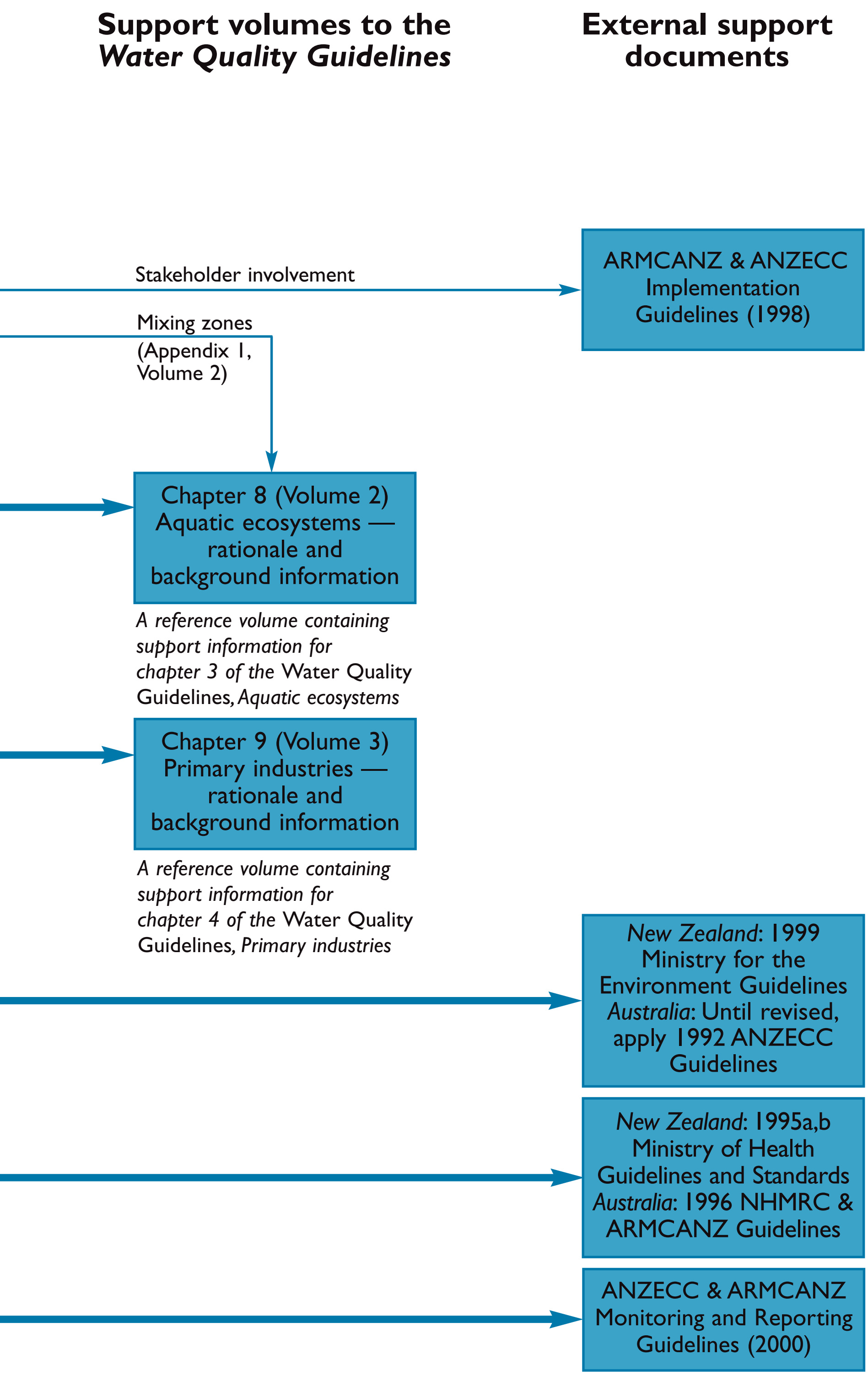
Chapter 7
Monitoring and assessment

Provides advice on collecting and analysing data for physical, chemical and biological indicators and, for a range of scenarios, makes recommendations on the number and mix of indicator types that should be considered when monitoring aquatic ecosystems.

KEY

- Should be read by all users
- Environmental values supported by the Guidelines
- Support chapters/ volumes/ documents

at a glance



Volume 1 is the main part of the *Water Quality Guidelines*. It provides a framework for water resource management, and states specific water quality guidelines for each environmental value and the context within which they should be applied.

Part 2 is a CD-ROM, which contains the *Water Quality Guidelines* support volumes, databases and software to enable the user to understand the rationale and calculate site-specific trigger values, if needed. In particular, support Volumes 2 and 3 from the CD-ROM provide technical information for aquatic ecosystems, and primary industries (irrigation and general water uses, stock drinking water, aquaculture and human consumers of aquatic foods) respectively.

The majority of users will not need all tables and can tailor the *Water Quality Guidelines* for their own use by printing relevant tables (e.g. from the key tables listed at the back of this Introduction), and extra figures from the electronic PDF documents on CD-ROM, or downloading them from the Environment Australia Website. A divider is supplied to enable users to store this personalised kit in the front of the *Water Quality Guidelines* folder.

1 Introduction

The main objective of the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (the *Water Quality Guidelines*) is:

> to provide an authoritative guide for setting water quality objectives required to sustain current, or likely future, environmental values [uses] for natural and semi-natural water resources in Australia and New Zealand.

The *Water Quality Guidelines* have been prepared as part of Australia's National Water Quality Management Strategy (NWQMS) and relate to New Zealand's National Agenda for Sustainable Water Management. They provide government and the general community (particularly catchment/water managers, regulators, industry, consultants and community groups) with a sound set of tools for assessing and managing ambient water quality in natural and semi-natural water resources. They are not meant to be applied directly to recycled water quality, contaminant levels in discharges from industry, mixing zones, or stormwater quality, unless stormwater systems are regarded as having conservation value.

The NWQMS provides a framework for water quality management that is based on policies and principles that apply nationwide. In particular, the strategy is based on the philosophy of ecologically sustainable development (ESD). This can be defined as '[development] using, conserving and enhancing the community's resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be increased'.

The guidelines are not mandatory, nor should they be regarded as such. The vast range of environments, ecosystem types and food production systems in Australia and New Zealand require a critically discerning approach to setting water quality objectives. The NWQMS aims to achieve sustainable use of water resources by protecting and improving their quality while maintaining economic and social development. A three-tiered approach — national, State or Territory, and regional or catchment — is required.

Ultimately, it is the responsibility of local stakeholders and State and Territory or regional governments to agree on the level of protection to be applied to water bodies. State or Territory and/or local jurisdictions are encouraged to use these national water quality guidelines to formulate their own regional guidelines or specific water quality objectives. Each State or Territory uses its own water planning and environmental policy tools to establish a framework that is compatible and consistent with the agreed national guidelines.

The *Water Quality Guidelines* provide recommendations that water managers can use to guide practice and formulate policy, taking into account local conditions and associated costs and benefits. The result should be more efficient and cost-effective environmental management.

A 'roadmap' on pages 2–3 of this Introduction describes the layout of the *Water Quality Guidelines* and external support documents. It will enable users to identify the chapters or other materials relevant to them. Key tables are listed on page 23 of this Introduction, while a glossary of key terms is contained in Appendix 1, Volume 1 of the *Water Quality Guidelines*. Volume 1 also contains an index.

Philosophical basis of the Guidelines

Increased scientific understanding of the complexity of ecosystems and food production systems has led to new ways of managing water quality. Traditional scientific and management approaches may not deal well with contemporary water quality issues. In their place, holistic, best-practice approaches are being taken to ensure that water resources are managed sustainably.

We now recognise that all aspects of the environment are interdependent. Environmental values (or uses), in particular, are interdependent, and cannot be considered in isolation. Nor can influences on the environment be considered in isolation. Clearing of river bank vegetation and effects of nutrients from urban stormwater can give rise to algal blooms. Construction of dams can lead to reduction in water flow and temperature downstream. Spills of toxic chemicals or inappropriate use of pesticides can kill fish. Types of ecosystems or food production systems, interactions, cumulative effects and modifying factors must all be examined in studying water quality.

Improvement in water quality resulting from improved management of all aspects of water use benefits all users. Long-term sustainability in agriculture requires the adoption of management practices that maintain productivity and minimise the off-farm movement or leaching of potential aquatic contaminants.

The *Water Quality Guidelines* recognise the interdependence of all aspects of the aquatic environment and uses of water. Previous water quality guidelines and water quality literature dealt with only two categories of waters (freshwater and marine). They applied single values to physical, chemical and biological indicators or factors that can have adverse effects on water quality, aquatic ecosystems or agricultural production systems, without taking into account other factors that might reduce or exacerbate their effects.

The new *Water Quality Guidelines* consider the protection of up to six ecosystem types and a range of factors that can influence the effects of specific contaminants. Generally, the *Water Quality Guidelines* also apply to the quality of groundwater since the environmental values that they protect relate to above-ground uses (e.g. irrigation, drinking water, animal or fish production and maintenance of aquatic ecosystems). However, little is known of underground aquatic ecosystems and the fate of many organic chemicals in groundwater systems differs from above-ground systems. Care is therefore needed when applying the *Water Quality Guidelines* to groundwater.

Sustainable use

The fundamental objective of both the National Water Quality Management Strategy in Australia and the Resource Management Act in New Zealand is the sustainable use and management of water resources in an environmental, economic and social context. Integrated catchment management (ICM) is essential to achieving this objective. ICM encompasses all aspects of environmental management within a catchment, including water quality, and recognises the interdependence of environmental values. Within the ICM framework, all stakeholders — landowners and the community, in partnership with relevant government agencies — identify environmental values to be protected and formulate specific water quality objectives.

Cooperative best management

Environmental regulation and management in Australia and New Zealand are currently undergoing major change. Both countries have moved towards best practice and cooperative best management. This requires a shift from control to prevention, from a focus on prescriptive regulation to a focus on outcomes, and an emphasis on cooperation rather than direction. The *Water Quality Guidelines* encourage industry, governments and communities to work cooperatively to maintain or improve the quality of water bodies.

Cooperative best management involves a range of tools, for example:

- memoranda of understanding,
- impact assessment,
- catchment management plans, and
- monitoring.

Water or environmental quality

Before investing in local water quality management strategies, managers need to be sure that water quality is the key issue in the water body under consideration. Water (and sediment) quality, while important, is only one aspect of management. In many parts of Australia and New Zealand water quality is reasonably good, but management goals for maintaining aquatic ecosystems are not met because of loss or degradation of habitat, particularly riparian vegetation. In such cases, it may be best for managers to allocate resources to improve flow, riparian vegetation or habitat in order to achieve their goals.

Management focus on issues

The *Water Quality Guidelines* aim to protect environmental values through management goals that focus on issues (concerns or potential problems). For example, they focus on toxicity of a chemical, soil salinity or animal health rather than the concentration of specific chemicals and salts. The water quality concern or problem (e.g. toxicity, sodicity, algal blooms, decrease in dissolved oxygen, loss of biodiversity) should be identified, so that the environmental processes that contribute to it can be examined. Appropriate water quality indicators can then be determined and relevant guidelines selected.

Continual improvement

Continual improvement should be a fundamental principle guiding water quality management. In badly polluted waters, managers may need to set several intermediate levels of water quality to be achieved in well-defined stages, until the required water quality objective is finally met.

In waters whose quality is higher than the level specified in set water quality objectives, attention should be given to preventing contamination from all sources, particularly for highly modified water resources. Wherever possible, managers are encouraged to aim to improve the quality of natural and semi-natural water resources rather than allow it to degrade.

Integrated assessment

Water quality, ecosystem health and the surrounding environment are all intimately connected. For protection of aquatic ecosystems, the *Water Quality Guidelines* have been broadened to include biological assessment of such ecosystems, which should accompany investigation of physical and chemical indicators in assessing impacts on ecosystem health. They include sediment guidelines, and provide advice on how to determine suitable environmental flows in rivers and streams. Similarly, the *Water Quality Guidelines* for irrigation consider potential impacts on soils and the wider environment as well as on the crops and pastures being produced.

For truly integrated water quality assessment, it is important that broadscale issues be considered across whole catchments where appropriate. For example, while water quality objectives might be met in riverine ecosystems, the cumulative effects of discharges and contaminant build-up downstream (e.g. in wetlands or estuaries) should also be considered when water quality criteria are set.

Water quality management framework

Long-term management of any water resource requires:

- clear definition of environmental values, or uses;
- a good understanding of links between human activity (including indigenous uses) and environmental quality;
- setting of unambiguous management goals;
- identification of appropriate water quality objectives, or targets; and
- effective management frameworks, including cooperative, regulatory, feedback and auditing mechanisms.

Water resource management is most effective when national, state and regional powers and responsibilities are consistent and, wherever possible, integrated. Australia and New Zealand both have a regional or local government framework in place. In Australia, responsibility for the management of natural resources mostly rests with the States and Territories. In New Zealand, primary responsibility for water management rests with regional councils.

Define
PRIMARY MANAGEMENT AIMS
(including environmental values, management goals and level of protection)

↓

Determine appropriate
WATER QUALITY GUIDELINES
(tailored to local environmental conditions)

↓

Define
WATER QUALITY OBJECTIVES
(specific water quality to be achieved)
taking account of social, cultural, political and economic concerns where necessary

↓

Establish
MONITORING AND ASSESSMENT PROGRAM
(focused on water quality objectives)
after defining acceptable performance or decision criteria

↓

Initiate appropriate
MANAGEMENT RESPONSE
(based on attaining or maintaining water quality objectives)

Figure 1 The framework for applying the guidelines

The *Water Quality Guidelines* provide a framework that water managers can use to implement a broad national management strategy at a local level (figure 1). Terms used in this framework are explained below.

'Environmental values' is the term applied to particular values or uses of the environment. The *Water Quality Guidelines* recognise the following environmental values:

- aquatic ecosystems,
- primary industries (irrigation and general water uses, stock drinking water, aquaculture and human consumers of aquatic foods),
- recreation and aesthetics,
- drinking water,
- industrial water (no water quality guidelines are provided for this environmental value), and
- cultural and spiritual values (no water quality guidelines are provided for this environmental value).

Cultural and spiritual values can be taken into account through the process of establishing the specific water quality objectives for a particular water resource.

The roadmap on pages 2–3 indicates which chapters of the *Water Quality Guidelines* deal with particular environmental values.

These environmental values may be important for a healthy ecosystem or for public benefit, welfare, safety or health. They require protection from the effects of pollution and inappropriate land management practices. Identification of community needs and wants is an essential step in defining environmental values for a particular water resource.

Associated with each environmental value are 'guidelines' or 'trigger values' for substances that might potentially impair water quality (e.g. pesticides, metals or nutrients). If these values are exceeded, they may be used to trigger an investigation or initiate a management response. Where two or more agreed environmental values apply to a water body, the more conservative, or stringent, of the associated guidelines should be selected as the water quality objectives. These are the specific or detailed targets that managers will aim to meet in order to protect the agreed value of the water body. In the absence of a clear and agreed set of environmental values for a particular water resource, managers should take a conservative approach and assume that all *appropriate* environmental values apply by default. For example, drinking water would not apply as a default environmental value for nearshore marine waters, but ecosystem protection and recreation would apply.

Once the environmental values to be protected have been decided, the *level of protection* of environmental or water quality necessary to maintain each value should be determined.

Management goals that describe precisely and in detail what is to be protected can then be formulated. A management goal could be to eliminate or reduce the occurrence of algal blooms, to improve livestock health and productivity, to minimise the occurrence of fish kills, or to increase biodiversity and ecosystem health. Management goals should be defined according to community needs and desires and after consultation with stakeholders. They should be achievable and measurable and should be realised through clear management plans.

A ***water quality guideline*** is a recommended numerical concentration level (e.g. of a contaminant) or a descriptive statement (e.g. visual appearance of a water body) that will support and maintain the designated use of a particular water. Water quality guidelines are provided for chemical and physical parameters of water and sediment, as well as biological indicators. They form the basis for determining water quality objectives.

A ***water quality objective*** goes a step further than a water quality guideline. It is a numerical concentration level or descriptive statement used by managers to measure and report on performance. Water quality objectives are targets agreed between stakeholders, or set by local authorities. These then become the indicators, or measures, of success in meeting agreed goals.

Although it is based on scientific water quality guidelines, a water quality objective may be modified by other inputs such as social, cultural, economic or political constraints. The process of modifying guidelines to establish water quality objectives would normally involve considering costs and benefits. The community might decide, after such consideration, to allow a longer period to achieve the desired water quality or even accept a lower water quality.

Tailoring guidelines for local conditions

It is not possible to develop a universal set of specific guidelines that apply equally to the very wide range of ecosystem types or production systems, in varying degrees of health, in Australia and New Zealand. Environmental factors can reduce or increase the effects of physical and chemical parameters at a site and these factors can vary considerably across the two countries. A framework is provided that allows the user to move beyond single-number, necessarily conservative values, to guidelines that can be refined according to local environmental conditions — that is, to developing site-specific guidelines. This is a key message of the *Water Quality Guidelines*.

Numerical and descriptive guidelines provided in the *Water Quality Guidelines* are intended to help managers establish water quality objectives that will maintain ecosystems and meet the needs of people who use a water resource. The *Water Quality Guidelines* provide risk-based decision frameworks wherever possible, simply to help the user refine guideline trigger values for local and/or regional use. (These frameworks are most explicitly developed for the management of aquatic ecosystems.)

The frameworks hinge on the use of guideline 'trigger values' (equivalent to the 1992 guideline default values). Guideline trigger values are concentrations of a chemical or nutrient that, if exceeded, have the potential to cause a problem and so trigger a management response. (This could include further investigation or management action.)

If the level of a particular chemical or nutrient exceeds the trigger value specified in the *Water Quality Guidelines*, managers may obtain additional information to determine whether the default trigger value is appropriate. For toxicants in water, the *Water Quality Guidelines* include an extensive database and software package, which managers can use to calculate trigger values relevant to local conditions. For example, a given trigger value may be too stringent in a water body where high turbidity reduces the amount of the chemical available to biota.

Should managers decide that the cost of developing trigger values tailored to local conditions is too high, they have the option of applying the default trigger values, which are necessarily conservative by nature. Should stakeholders all agree that the economic, social, cultural or political concerns outweigh the environmental benefit achieved by meeting the recommended guidelines, they may decide to accept a lower level of protection or consider alternative management, including land use practices. Conversely, should stakeholders agree that the environmental benefits are of overriding importance, then the recommended guidelines should prevail and management strategies should be implemented to ensure that they are achieved.

Benefits of site-specific guidelines

It is not mandatory to use decision frameworks, but they can reduce the amount of conservatism incorporated in the guideline trigger values. This can produce values more appropriate to a particular water resource. Although tailoring guidelines to local conditions requires more work in some cases, it results in much more realistic management goals. It therefore has the potential to reduce costs for industry. The case study below illustrates the benefits of applying a decision tree.

Case study: Cost savings to industry through use of a decision tree

The Lower Molonglo Water Quality Control Centre (LMWQCC) treats all of Canberra's sewage, which is discharged to the Molonglo and Murrumbidgee River systems. In 1995, the LMWQCC was asked by ACT Electricity and Water (ACTEW) to establish that the concentrations of copper being discharged were not detrimental to the receiving waters. Most samples taken from just downstream of the discharge point exceeded the guideline values for copper current at the time (ANZECC 1992), and so a decision tree approach was applied, similar to that advocated in the revised *Water Quality Guidelines*.

The steps taken included:

1. considering whether water hardness should modify the guideline, i.e. make it less stringent;
2. considering the form and type of copper, including the way in which it could be made less bioavailable by complexation to dissolved organic matter and adsorption to sediments (through speciation modelling and complexation studies); and
3. assessing the resulting concentration of copper against available (published) toxicity data, and effluent toxicity assessment.

Waters downstream of the discharge point are naturally soft, and after application of hardness correction factors copper concentrations in most samples still exceeded the guideline value.

Results of speciation modelling and complexation capacity studies showed that free copper that was not bound up by dissolved organic matter and sediments (i.e. the more toxic form of copper) was below the guideline value. Published toxicity data also indicated that aquatic organisms would be unlikely to be affected by these concentrations of free copper. Also, toxicity testing of effluent carried out with a copper-sensitive freshwater alga showed no evidence of toxicity.

Outcomes

(i) Copper discharged with sewage effluent did not contain free copper at concentrations likely to be a hazard to aquatic ecosystems.

(ii) At the time the study was conducted, the steps involved in applying the decision tree cost the Lower Molonglo treatment plant somewhere in the order of $10 000.

(iii) The study saved the plant tens of millions of dollars that it might otherwise have spent had the water needed to be treated to remove copper.

(iv) If the same study were conducted today, the estimated cost to industry would be of the order of $500 for modelling and complexation studies. In this study, free copper was below the guideline value and so toxicity testing would be unnecessary; costs to conduct a freshwater alga test today are of the order of $2000.

2 Guidelines for aquatic ecosystems

Aquatic ecosystems comprise the animals, plants and micro-organisms that live in water, and the physical and chemical environment and climatic conditions with which they interact. Aquatic ecosystems vary considerably within and between tropical and temperate zones. The *Water Quality Guidelines* provide guidelines for biological and physico-chemical indicators of water and sediment quality that will protect the ecological health of aquatic ecosystems, both freshwater and marine.

The physical components (e.g. light, temperature, mixing, flow, habitat) and chemical components (e.g. organic and inorganic carbon, oxygen, nutrients) of an ecosystem largely dictate what lives in that ecosystem, and the structure of the food web. Natural physical and chemical water quality variations can have important consequences for aquatic ecosystems. Human activities can cause variations in the living and non-living components of a system that can lead to biological changes more dramatic than those that occur naturally.

The physical, chemical and biological aspects of water and sediment provide valuable indications of the overall health of the ecosystem.

The indicators

Biological indicators such as algae, macrophytes, macroinvertebrates and fish are continuous monitors of water quality, integrating the effects of past and present exposure to contaminants or pressures. Biological assessment provides information on biological or ecological changes that may result from changes in water quality but may also result from changes in physical habitat (e.g. increased temperature) or biological interactions (e.g. introduction of exotic species or diseases). Biological assessment is a vital part of assessing changes in aquatic ecosystems. It is the key tool used to assess achievement of management goals and water quality objectives. To this end, responses of biological indicators can be regarded as the end point in the decision trees used for physical and chemical indicators.

Physical and chemical stressors include the natural water quality parameters, nutrients, biodegradable organic matter, dissolved oxygen, turbidity, suspended particulate matter, temperature, salinity, pH and changes in flow regime. Physical and chemical stressors are major contributors to changes in aquatic ecosystems, such as nuisance growth of aquatic plants, smothering of organisms living in aquatic environments, and stress to or death of native freshwater fish. They may also modify the effects of toxicants. The *Water Quality Guidelines* classify physical and chemical stressors into two broad types, those having direct and those having indirect effects on ecosystems.

'***Toxicants***' is the term given to chemical contaminants such as metals, aromatic hydrocarbons, pesticides and herbicides that can potentially have toxic effects at concentrations that might be encountered in the environment.

Sediments are a sink for many contaminants. They are also habitats, food sources and refuges for many biological communities. Sediments influence surface water quality, and can act as a source of contaminants to benthic organisms and, hence, potentially to the aquatic food chain. Sediments are assessed to define contaminant concentrations above which a likely risk is posed to ecosystem health. Such assessments can be used by managers to decide whether remediation or restoration is necessary.

Integrated assessment

Natural aquatic ecosystems should not be considered as static environments. Their fauna and flora populations fluctuate in accordance with seasonal and long-term climatic influences, as well as the effects of changes to land use and vegetation cover within their catchments. The *Water Quality Guidelines* promote assessment that integrates biological and chemical monitoring of surface waters and sediments to assess progress towards achieving the goals of ecosystem protection. The holistic approach advocated in the *Water Quality Guidelines* manages issues rather than single stressors. The aquatic environment must be managed to consider changes to all aspects — polluted sediments, reduction in stream flow, removal of habitat (e.g. by draining of wetlands) and changes in catchment land use.

Site-specific guidelines

The concept of tailoring guidelines for local conditions was discussed on page 8 of this Introduction to the *Water Quality Guidelines*. This development towards site-specific guidelines is most advanced for aquatic ecosystems. Through a number of approaches, expanded upon below, the application of guidelines to all Australian and New Zealand aquatic environments is improved. Overall, it should result in more relevant guidelines and thereby provide better and more cost-effective environmental protection.

In the new *Water Quality Guidelines*, a greater emphasis is placed on the use of **reference sites**. Measures and values for biological and many chemical indicators (particularly physical and chemical stressors) from suitable local reference waters are the benchmarks for assessing and maintaining biological diversity at a site.

The most relevant guidelines are those tailored for **different ecosystem types**. Default guideline values for up to six ecosystem types (upland rivers and streams, lowland rivers, freshwater lakes and reservoirs, wetlands, estuaries, and coastal and marine) are provided.

The *Water Quality Guidelines* adopt an innovative **risk-based approach** (not full quantitative risk assessment). In this approach, the old single-number guidelines (see ANZECC 1992) are regarded as guideline trigger values that can be modified into regional, local or site-specific guidelines. Decision frameworks help users tailor the default guidelines to local environmental conditions. This can be done by taking into account factors such as variability of the particular ecosystem or environment, soil type, rainfall and the level of exposure to contaminants. The availability of data, expertise, resources and time will determine which steps in the framework are used.

Ecosystems may have been modified to various degrees and it is unrealistic to impose a uniform management goal or regulatory framework across different locations. In reality, there is a 'spectrum' of ecosystem conditions. However, to assist users, guidelines are provided for three ecosystem conditions, with a **different level of protection** recommended for each:

- high conservation/ecological value systems;
- slightly to moderately disturbed systems (where the guidelines will mostly be applied); and
- highly disturbed systems.

Applying the guidelines for aquatic ecosystems

Common to the application of all indicator types (biological, physical and chemical, toxicant and sediment), the primary management aims, including management goals and level of protection, are first determined (figure 1, p. 7). Preliminary steps in determining appropriate guideline trigger levels are also common to all indicator types, including determining a balance of indicator types and selecting relevant and specific indicators.

From this point, however, it is convenient to consider guidelines application separately for biological indicators and non-biological indicators (physical and

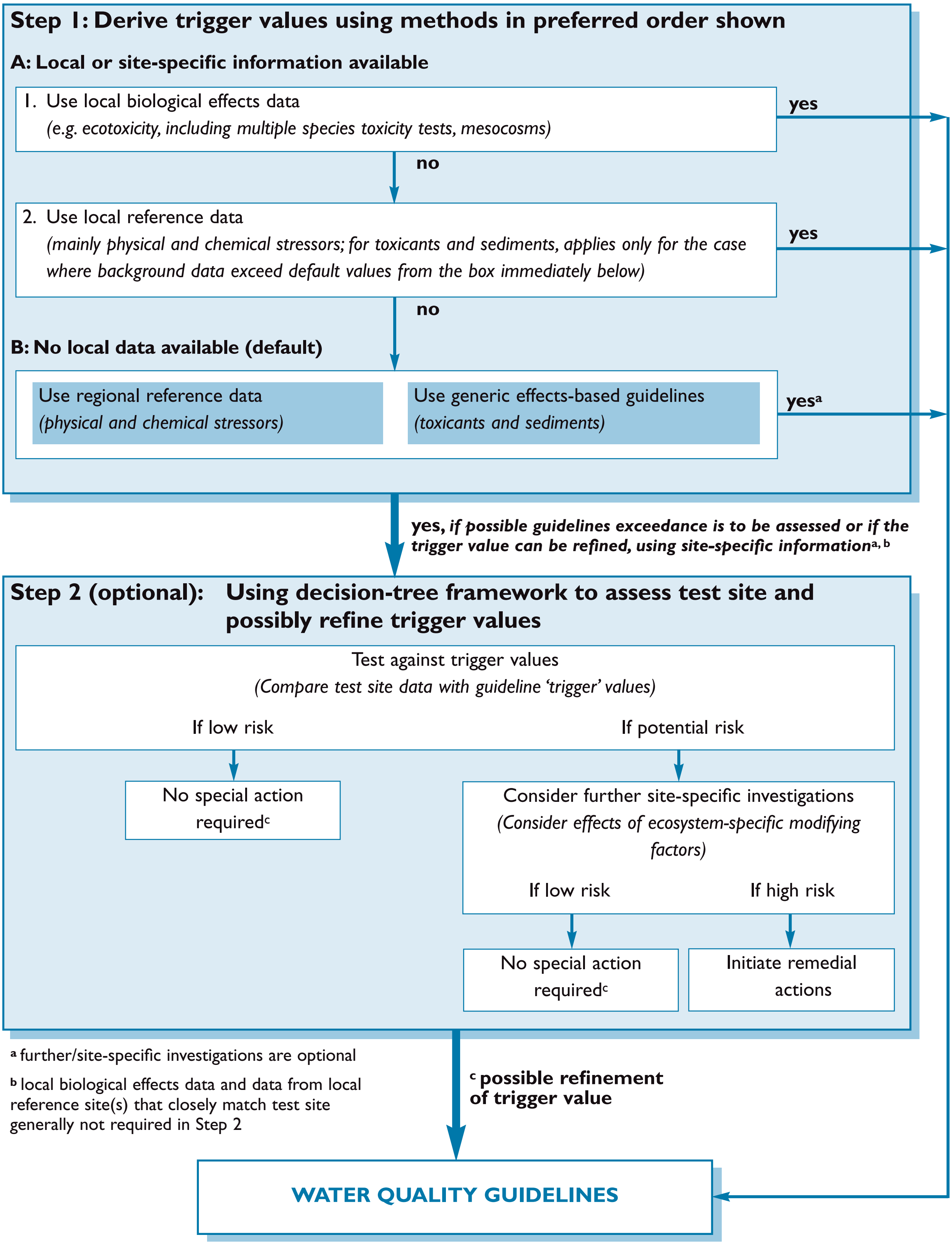


Figure 2 Procedures for deriving and refining water quality guidelines, and assessing test sites, for physical and chemical stressors and toxicants in water and sediment. Step 1B (dark shading) indicates the most likely point of entry for users requiring guideline trigger values.

chemical stressors and toxicants in water and sediment). For non-biological indicators, decision trees provide options to refine guidelines, bringing values closer to those that may elicit a biological response at a particular site. Conversely, for biological indicators, the measured responses are the management targets or end points in the decision trees that apply for other indicators. A different framework, therefore, is provided for the application of biological indicators.

Biological indicators

Comparison of biological indicators at the site(s) of interest with the same indicators from relatively natural or unimpacted sites is the basis for detecting and assessing important changes in ecological health. The steps involved in biological assessment follow a general framework. After management goals have been determined, specific indicators are selected through appropriate *assessment objectives*. There are three such objectives:

- broad-scale assessment — quickly determining the extent of a problem;
- early detection — pre-empting/preventing irreversible or important damage, habitat loss etc.; and
- biodiversity or ecosystem-level response — assessing the ecological importance of impact.

The *Water Quality Guidelines* provide advice on which indicators to select for specific water quality issues (e.g. nutrients, metals) and suitable methods of assessment (protocols). They outline procedures for formulating management decision criteria, and interpreting results to assess whether water quality objectives are being achieved.

Physical and chemical stressors and toxicants in water and sediment

Step 1 of figure 2 describes procedures for deriving water quality guidelines for physical and chemical stressors and toxicants in water and sediment. The preferred approach to deriving guideline trigger values is to use local information: ecological effects data, if available, or local reference data (mainly physical and chemical stressors). However, in many cases default values will be used for decision making because local information is not yet available or there are not likely to be benefits in further refining the values beyond the default values provided in the *Water Quality Guidelines*.

Default guidelines for physical and chemical stressors are based on regional reference data for five climatic/geographical regions across Australia and New Zealand: south-east Australia, south-west Australia, tropical Australia, south central Australia — low rainfall area, and New Zealand. Default guidelines for toxicants in water and sediment are derived from biological effects (i.e. toxicological) databases from Australia/New Zealand and overseas; the data have been divided into statistical bands so that more or less stringent guideline trigger values may be selected, depending upon stakeholders' decision on the level of protection to be afforded to the particular ecosystem. An example of this is for most toxicants in slightly to moderately disturbed ecosystems, where trigger values are recommended that protect 95% of species with 50% confidence.

After deriving guideline trigger values, users may proceed to step 2 of figure 2, which provides guidance on the use of a decision tree. If data from a test site exceed the trigger value, the decision trees are used to determine if the test values are inappropriately (unnecessarily) 'triggering' potential risk and hence management response. For this, ecosystem-specific modifying factors are introduced to assess test data. The decision trees also enable the guideline trigger values to be adjusted and refined. The decision trees will be most relevant to users who have selected the default guideline values. Thus, using the *Water Quality Guidelines*, managers may assess guidelines' exceedance or derive guidelines for specific sites, taking into account factors such as:

- background concentrations;
- analytical limits;
- locally important species;
- physical and chemical water quality modifiers, such as suspended/dissolved organic matter, pH, temperature, salinity, hardness and speciation;
- interactions; and
- data quantity, quality and extent in time.

While it is not mandatory to use decision frameworks, they are recommended so that the resulting guidelines are relevant to the site. Users wanting to undertake site-specific assessments to refine trigger values to be used for regulatory purposes will need to obtain prior agreement from the relevant State or Territory or regional authorities. The guideline trigger values are based on 'bioavailable' concentrations, and hence measurements of total concentrations may overestimate the amount of chemical that causes biological effects at that site. As a consequence, the use of the decision frameworks will, in most cases, *increase* (i.e. make less stringent) guideline concentrations at the site. Alternatively, some steps in the frameworks guide users towards better measurements of the 'bioavailable' concentrations at the site.

Case study: Applying the guidelines to a lowland river

A hypothetical large river has a forested upper catchment, while its lowlands and flood plains have been extensively cleared for agriculture. A medium-sized city is located just upstream of the tidal limit and downstream of a series of weirs. Part of the river has received waste from a smelter sited near the river. This discharge has contaminated the sediments with cadmium.

The following steps show how the guidelines may be used to define specific water quality objectives for managing environmental problems, especially heavy metal impacts.

Define the water body — A lowland river. The upper section is only slightly to moderately disturbed, but the section below the weirs is highly disturbed.

Establish the environmental values — Aquatic ecosystem protection, recreational water quality and aesthetics, and primary industries are established in consultation with stakeholders.

What information is available — Physical and chemical monitoring data are available for the disturbed section but biological data are scant.

Determine the level of protection — The target for management is to return ecosystem features in lower sections of the river from a highly disturbed condition to slightly to moderately disturbed.

Identify key environmental concerns — An agreed concern is possible toxicity to aquatic biota arising from cadmium in water and particularly in sediments.

Define management goals — To maintain a quality of water suitable for recreation and aesthetics; enhance aquatic ecosystem health (improve conditions for native fish, retain sediment quality that will maintain natural biota, improve understanding of the ecosystem); and protect downstream environmental values such as aquatic ecosystems, aquaculture or agricultural water supplies for irrigation and stock.

Determine appropriate guideline trigger levels for selected indicators

First, determine a balance of indicator types and other requirements based on level of protection and local information constraints. The situation involves highly disturbed ecosystems where water and sediment quality are of concern; little is available in the way of pre-disturbance data and the long-term management goal is improvement in river health. The *Water Quality Guidelines* recommend water and sediment physico-chemistry, and rapid biological assessment and/or quantitative biodiversity measurement.

Next, identify all indicators relevant to the environmental concerns and management goals, then determine guideline trigger levels and specific indicators to be applied.

Determine guidelines, define water quality objectives and establish a monitoring and assessment program

The steps for each of the broad indicator types are described below. For this case study, we assume that the stakeholders (different catchment agencies, utilities and industries) have agreed that the water quality objectives are the same as the water quality guidelines.

Given the broad-scale nature of the environmental problems in the catchment, different catchment agencies, utilities and industries pooled resources for the monitoring and assessment program. Additional savings in resources were made in the sampling program by sharing reference site data held by agencies conducting similar monitoring programs in the region.

Biological indicators

The primary biological assessment objectives have been determined as biodiversity or ecosystem-level response and catchment-wide assessment. The biological indicator selected is composition and structure of macroinvertebrate communities, to be measured by rapid biological assessment (RBA) and quantitative biological assessment.

RBA showed many fewer macroinvertebrate families than expected in the river in the vicinity of historical pollution sources and around the city, indicating substantial impacts on water and/or habitat quality. Key point sources of contamination in the river arising from urban, agricultural and industrial wastewaters during high-flow events were shown to contribute to much of the deterioration in river health. This was demonstrated using a combination of RBA and quantitative assessment methods, with repetitive sampling at sites upstream and downstream of suspected contamination sources and from suitable reference sites.

Toxicants

Cadmium has been identified as a toxicant requiring investigation. A monitoring program is designed and implemented, based on the decision criterion that action is triggered if the 95th percentile of the test distribution exceeds the guideline value. Cadmium total concentrations of 1.0 µg/L are found in the water. Water in the river has a median hardness of 80 mg/L $CaCO_3$ (moderate) and so the relevant trigger value is 0.54 µg/L. This last value is 2.7 × the low hardness trigger value of 0.2 µg/L. Options are to:

- use the trigger value as an objective and develop management strategies to meet this, or
- conduct further studies to determine if any site-specific factors might modify the guideline value.

The decision is made to conduct a further inexpensive study to determine the dissolved cadmium concentration. The dissolved cadmium concentration is 0.022 µg/L, which is below the guideline value for moderate hardness. The risk of adverse biological effects is therefore considered to be low.

Sediment quality

Cadmium has been identified as requiring investigation. The sediment cadmium at 5 mg/kg dry weight is above the interim sediment quality guidelines (ISQG)-low trigger value but below the ISQG-high value. Background cadmium measured in the surrounding soils and upstream river sediments is below the ISQG-low value, indicating that original levels in the river were also low and that elevated levels can be attributed to the industrial discharge. Further investigation is required to determine whether these levels pose a hazard to aquatic life. This will involve examining factors controlling availability to biota, and then acute toxicity and chronic toxicity testing if results indicate these are needed. If the results indicate a high risk of biological impact, remedial action will be required.

Next steps in management

The steps already taken have shown that aquatic biota are adversely affected by various pollution sources and that cadmium concentrations in the sediments may be toxic. Further investigation is required to derive site-specific guidelines. Also needed are management strategies to reduce the levels of these indicators, in accordance with the philosophy of continual improvement, and continued monitoring and assessment to evaluate progress. The biological assessment program will be an important component. Where site-specific guidelines indicate a high risk of an impact occurring, remediation programs should be developed.

3 Guidelines for primary industries

Both the quality and the quantity of water resources are critical issues for agriculture and aquaculture in Australia and New Zealand. Water quality is also of major importance for the protection of human consumers of food products. Primary industries, along with other urban and industrial development, have increased the demand for good-quality water, but at the same time have exerted escalating pressures on the quality of the water resources that are available. Assessment of water quality for primary industries therefore requires balanced consideration of productivity issues and the possible adverse impacts of these enterprises on downstream water quality.

The *Water Quality Guidelines* can be used at the broad level to assist in defining water quality objectives for catchments in which irrigation use is prevalent. They can also help individual irrigators assess the suitability of water for their uses, and possible mitigation measures to reduce any impacts.

In Australia, in particular, both the irrigation and livestock industries rely heavily on groundwater in addition to surface water. Groundwater is also an important source of stock water in parts of New Zealand. Thus the guidelines provided in the *Water Quality Guidelines* for these industries are applicable (where appropriate) to both surface water and groundwater quality.

Irrigation and general water use

Agricultural practice in Australia and New Zealand is often dependent on irrigation, because of climatic constraints. In Australia, in particular, agriculture is predominantly based in areas of limited rainfall with a heavy reliance on the use of surface water and groundwaters for irrigation of crops and pastures.

An important goal of the *Water Quality Guidelines* is to maintain the productivity of irrigated agricultural land while protecting associated water resources, in accordance with the principles of ecologically sustainable development. In terms of water quality, the focus for sustainable farming systems is on adopting management practices that maintain productivity and minimise the off-farm movement or leaching of potential aquatic contaminants. Key off-site issues include soil erosion, landscape salinity, fertiliser and pesticide management, livestock access to streams, and safe disposal of effluent from intensive animal industries.

Soil, plant and water resource issues have been taken into account in developing the water quality guidelines for irrigation use (see table 1). The guidelines for irrigation water quality include trigger values for:

- biological parameters;
- salinity and sodicity;
- inorganic constituents (specific ions, including heavy metals and nutrients); and
- pesticides and radiological contaminants.

Table 1 Key issues concerning irrigation water quality effects on soil, plants and water resources

	Key issues
Soil	Root zone salinity Soil structural stability Build-up of contaminants in soil Effects on soil biota Release of contaminants from soil to crops and pastures
Plants	Yield Product quality Salt tolerance Specific ion tolerance Foliar injury Uptake of toxicants in produce for human consumption Contamination by pathogens
Water resources	Deep drainage and leaching below root zone Movement of salts, nutrients and contaminants to groundwaters and surface waters
Other important factors	Quantity and seasonality of rainfall Soil properties Crop and pasture species and management options Land type Groundwater depth and quality

A new five-step approach has been developed for assessing irrigation water salinity and sodicity, with software provided so users can determine the suitability of their water on a site-specific basis. This allows soil type, rainfall and other local factors to be taken into account and gives irrigators more flexibility in their management.

In addition, trigger values for heavy metals and metalloids have been developed using an internationally recognised approach. Two trigger values for water are included (for short-term and long-term use), generally in conjunction with an associated trigger value for the soil under irrigation. A similar approach has been used to develop long-term and short-term trigger values for nitrogen and phosphorus in irrigation water.

For the first time, the *Water Quality Guidelines* deal with the corrosion and fouling potential of waters used for general on-farm water use. These characteristics are important considerations in the maintenance of farm equipment (pumps, pipes etc.) but can also be applied more widely where corrosion and fouling are of concern.

Livestock drinking water

Good-quality drinking water is essential for successful livestock production. Poor-quality drinking water may reduce animal production or impair fertility; in extreme cases, stock may die. Water quality requirements for livestock may differ between animal species, stages of growth and animal condition.

Contaminants in drinking water can produce residues in animal products (e.g. meat, milk and eggs), adversely affecting their saleability and/or creating human health risks. Animal industries themselves can impair water quality downstream (e.g. through faecal contamination). The need for an integrated approach to land and water management in rural catchments is clear.

The scope of the *Water Quality Guidelines* for livestock drinking water includes biological, chemical and radiological constituents that can affect animal health. Guidelines for the commonly occurring blue-green alga, *Microcystis*, and its toxins have been included in the *Water Quality Guidelines* for the first

time. Significant revisions of trigger values for sulfate and magnesium are other notable features of the revised guidelines for livestock drinking water.

Aquaculture and human consumers of aquatic foods

This is the first time guidelines have been provided for aquaculture industries in Australia and New Zealand. Recreational and commercial fisheries are based on wild populations of fish, crustacea and shellfish species, which are supported by natural habitats and food webs. The guidelines for the protection and maintenance of aquatic ecosystems should therefore be applied to protect these wild animal stocks.

Aquaculture involves the production of food for human consumption, fry for recreational fishing and natural fisheries, ornamental fish and plants for the aquarium trade, raw materials for energy and biochemicals, and a number of items for the fashion industry. The need for satisfactory water quality to maintain viable aquaculture operations is well accepted. Poor water quality can result in loss of production of culture species, and can also lower the quality of the end product. Aquaculture also has the potential to have an impact on water quality for downstream users and this is to be addressed through other environmental values.

Aquaculture is a burgeoning industry in both Australia and New Zealand. About sixty aquatic species are currently being farmed, but only limited information is available on the water quality requirements of many of these species and on the requirements of larval and juvenile stages of their life cycles. Trigger values for aquaculture should therefore be considered as interim guidelines. In developing these guidelines, the objective has been to:

- promote the quality of water necessary to protect a wide range of aquatic animals and plants cultured by existing and future aquaculture activities; and
- protect human consumers of harvested aquatic food species from a variety of sources, including aquaculture and commercial, recreational and indigenous fishing.

Guidelines for protecting aquaculture species

The *Water Quality Guidelines* provide a basis for aspects of aquaculture management, such as:

- environmental planning and management,
- environmental assessment and monitoring requirements,
- appropriate environmental zoning and legislation,
- selection of appropriate species and suitable sites,
- site capacity,
- farm design criteria,
- stocking densities and feeding regimes, and
- production schedules.

The guidelines do not deal with effluent water quality from aquaculture activities, however, and aquaculturists need to manage their operations with downstream water quality in mind.

As an initial approach, guidelines have been derived for the protection of freshwater and marine species.

Given the large number of aquaculture species in Australia and New Zealand, and the general lack of information on most of them, all finfish, mollusc and crustacean species were divided into eight indicative groups. Efforts were then directed at reviewing toxicity and tolerance data for one or two representative species within each of those groups, the species being chosen according to the level of production and availability of scientific data. Where discrepancies in the data were identified, the more conservative data were generally used.

The guidelines are provided under the following four categories:

- physico-chemical stressors,
- inorganic toxicants,
- organic toxicants, and
- pathogens and biological contaminants.

General guideline values for freshwater and saltwater (brackish and marine water) aquaculture uses are recommended. In addition, specific guideline values have been provided for species groups where information was available on their water quality requirements.

Water quality guidelines for the protection of human consumers of aquatic foods

The Australia New Zealand Food Authority (ANZFA) develops and administers uniform (statutory) standards for chemical contamination in foods (including aquatic foods). Unlike the water quality guidelines, the ANZFA food standards are enforceable through legislation. In addition to those for chemical contaminants, guidelines are provided for:

- viral contaminants,
- bacterial contaminants,
- natural toxins,
- parasites, and
- off-flavour compounds (which cause tainting of aquatic animal flesh).

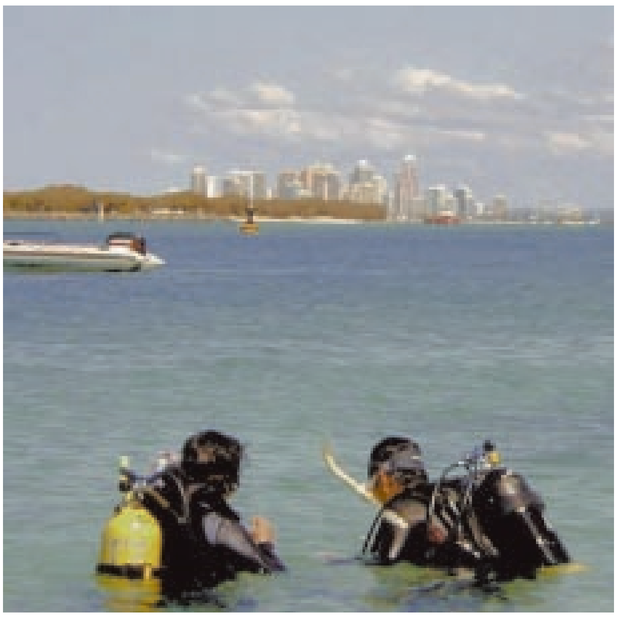
The *Water Quality Guidelines* are consistent with and do not duplicate this work.

4 Guidelines for human health values

Recreational water quality and aesthetics

Chapter 5 of the *Water Quality Guidelines* deals with recreational water quality and aesthetics. Water-based recreational activities are popular with Australians and New Zealanders. Much of the coastline in both countries is inaccessible for recreational purposes, resulting in high pressures on areas that are accessible. The same situation applies to estuarine and freshwater rivers and lakes, especially those close to urban centres. Guidelines are necessary to protect these waters for recreational activities, such as swimming and boating, and to preserve their aesthetic appeal. Factors considered include:

- microbiological characteristics;
- nuisance organisms (macrophytes, phytoplankton scums, filamentous algal mats, blue-green algae, sewage fungus and leeches); and
- physical and chemical characteristics (pH, temperature, toxic chemicals and surface films).



Recreational guidelines accommodate two categories of sporting activity:

- sports such as swimming or surfing in which the user comes into frequent direct contact with water, either as part of the activity or accidentally (primary contact); and
- sports such as boating or fishing that generally involve less-frequent body contact with the water (secondary contact).

A third recreational category concerns the passive recreational use of water bodies, mainly as pleasant places to be near or to look at (no body contact).

Guidelines for users in New Zealand

In New Zealand, water managers should refer to *Recreational Water Quality Guidelines* (Ministry for the Environment 1999). This document and the draft supporting manual can be downloaded from: *http://www.mfe.govt.nz/about/publications/water_quality/beaches-guidelines.htm.*

The revised New Zealand guidelines were trialled over the 1999–2000 bathing season. This trial period will be followed by consultations. Any recommendation to the Minister for the Environment regarding a National Environmental Standard will be made after these consultations.

Guidelines for users in Australia

Guidelines for recreational water quality and aesthetics are currently being prepared for Australian users. When completed, they will replace the current section of the *Water Quality Guidelines*, in accordance with NWQMS requirements and National Health and Medical Research Council (NHMRC) statutory procedures. It is intended that the new guidelines should be based largely on recommendations from the World Health

Organization (WHO). Until these guidelines are revised and endorsed, users should apply the guidelines from the *Australian Water Quality Guidelines for Fresh and Marine Waters* (ANZECC 1992). These guidelines are reproduced in the *Water Quality Guidelines.*

Drinking water

Chapter 6 of the *Water Quality Guidelines* deals with drinking water. Drinking water should be safe to use and aesthetically pleasing. Guidance on what constitutes good-quality drinking water is provided for New Zealand by *Drinking-water Standards for New Zealand* (New Zealand Ministry of Health 1995a) and the *Guidelines for Drinking-water Quality Management* (New Zealand Ministry of Health 1995b). In Australia, similar guidance is provided by the *Australian Drinking Water Guidelines* (NHMRC and ARMCANZ 1996), a companion document of the National Water Quality Management Strategy.

For more information on the Australian Drinking Water Guidelines, readers may wish to refer to:
http://www.health.gov.au:/nhmrc/publicat/synopses/eh19syn.htm

The Drinking Water Guidelines are intended to meet the needs of consumers and apply at the point of use, for example at the tap. They are applicable to any water intended for drinking, irrespective of its source (municipal supplies, rainwater tanks, bores, or point-of-use treatment devices) or where that water is to be used (in homes, restaurants etc.). The *Water Quality Guidelines* summarise the key issues contained in the Australian Drinking Water Guidelines.

The Drinking Water Guidelines devote a chapter to the microbiological quality of drinking water, since the most common and widespread health risk associated with drinking water is contamination, either directly or indirectly, by human or animal excreta and micro-organisms contained in faeces. Micro-organisms, including pathogenic organisms, may enter water supplies at every stage of the collection and distribution cycle. Emphasis is placed on the need for an active watershed protection program, including an emergency plan for responding to major pollution events such as spills or contamination. Detailed advice is given on the problems of surface and groundwater supplies, and approaches to their management.

The Drinking Water Guidelines also discuss the problems of small water supplies, regarded as those serving fewer than 1000 people, and individual household supplies.

Guideline values

The individual guidelines in the Drinking Water Guidelines cover a wide range of measurable characteristics, compounds or constituents that can potentially be found in water and affect its quality. They fall into the following categories:

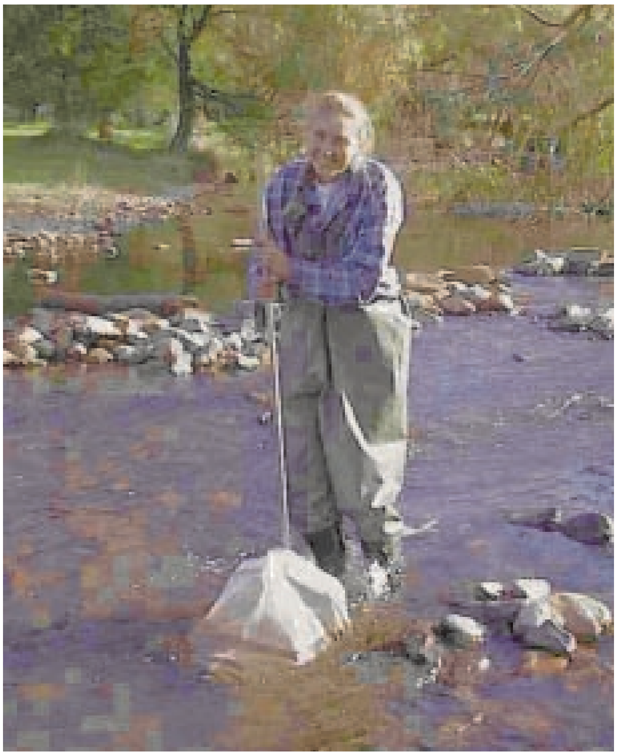
- micro-organisms (including bacteria, protozoa, toxic algae and viruses);
- physical characteristics;
- radionuclides; and
- chemicals (including inorganic chemicals, organic compounds, organic disinfection by-products, and pesticides).

5 Monitoring and assessment

The *Water Quality Guidelines* both contain, and refer to, information on the practicalities of collecting and analysing data for the measurement of water quality. This information is based on the national framework for monitoring water quality and reporting on the outcomes. The national framework aims to raise the standard of water monitoring in Australia and should help ensure that programs are more consistent. This will allow data to be better compared across regions and over time.

For *basic, general* details of how to plan a monitoring program, the *Water Quality Guidelines* (through chapter 7) refer the reader to the *Australian Guidelines for Water Quality Monitoring and Reporting* (the Monitoring Guidelines). Both the Monitoring Guidelines and accompanying summary document set out a framework for developing a monitoring program. The framework outlines in broad terms:

- how to define monitoring program objectives, and the principles for both designing monitoring studies and implementing an effective sampling program;
- laboratory analyses, choosing suitable techniques for data analyses and data interpretation; and
- mechanisms for reporting of the results and reaching conclusions.



Chapter 7 of the *Water Quality Guidelines* complements the Monitoring Guidelines in that it contains information that is both very *specific* to issues raised in earlier chapters of the Guidelines and, for selected topics, of a *more detailed* nature for the experienced reader. Among the specific and/or detailed topics that are covered in chapter 7 and that are relevant mainly to aquatic ecosystems are:

- recommendations on a balance of indicator types to apply under different situations;
- extensive advice on biological assessment; and
- for physico-chemical indicators of water and sediment, information on how to compare test data with guideline trigger values.

Key tables in the Water Quality Guidelines

Important tables from the *Water Quality Guidelines*, including tables of default guideline trigger values, that users may need to refer to are listed below.

Environmental value and table description	Reference
Aquatic ecosystems	
Water quality issues and recommended biological indicators for different ecosystem types	Table 3.2.2
Regional values for physical and chemical stressors	Tables 3.3.2–3.3.11
Values for toxicants	Table 3.4.1
Values for sediments	Table 3.5.1
Primary industries: irrigation and general water use	
Values for coliforms, salinity and other major ions, nutrients, general toxicants, natural physical and chemical indicators, radiological contaminants	Tables 4.2.2–4.2.15
Primary industries: livestock drinking water quality	
Values for salinity, metals and radiological contaminants	Tables 4.3.1, 4.3.2 and 4.3.3 respectively
Primary industries: aquaculture and human consumers of aquatic foods	
Values for physico-chemical stressors and toxicants	Tables 4.4.2 and 4.4.3 respectively
Recreational water quality and aesthetics	
Values for recreational waters	Table 5.2.2
Values for recreational purposes: general chemicals and pesticides	Tables 5.2.3 and 5.2.4 respectively

References

ANZECC 1992. *Australian water quality guidelines for fresh and marine waters*. National Water Quality Management Strategy Paper No 4, Australian and New Zealand Environment and Conservation Council, Canberra.

ANZECC & ARMCANZ 1994. *Policies and principles: A reference document*. National Water Quality Management Strategy Paper No 2, Australian and New Zealand Environment and Conservation Council & Agriculture and Resource Management Council of Australia and New Zealand, Canberra.

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