First International Environment Forum for Basin Organizations

Towards Sustainable Freshwater Governance

26-28 November 2014, Nairobi, Kenya

REVIEW OF EXISTING WATER QUALITY GUIDELINES FOR FRESHWATER ECOSYSTEMS AND APPLICATION OF WATER QUALITY GUIDELINES ON BASIN LEVEL TO PROTECT ECOSYSTEMS

Technical background document for theme 1: "Water Quality and Ecosystem Health"

UNEP

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Summary

Declining water quality has become an issue of global concern as it is causing major disturbances for water use, to ecosystems health and functioning, and to the biodiversity that ecosystems underpin. While international chemical and physical water quality guidelines and standards for drinking water and some other uses are well articulated and in place with better enforcement and reporting mechanisms for many governments and authorities, the same cannot be said of frameworks relating to water quality for the health of ecosystems. Moreover, around the world a large number of water treaties exist. However the issues in these treaties mostly deal with navigation, hydropower and water supply. Only 4% of all treaties deal with water pollution. Treaties protecting the ecosystem are very scarce. The declining water quality has become an issue of global concern as it is causing major disturbances for water use and ecosystem health. Therefore there is a strong need for water quality guidelines to protect ecosystems.

In most parts of the world water management is a public affair and the government on different levels plays an important role. In some regions functional organizations like river basin authorities, watershed authorities or aquifer authorities have a mandate to carry out water management. However there is a large diversity in the appearance of (river) basin organizations (RBOs). Also their mandate and task differ to a large extend. Most of the RBOs are established to solve problems on flooding and droughts, to improve navigation and to manage hydropower stations. Water quality problems and ecosystem protection were in most cases not the main trigger for establishing RBO's. From the eighties the role of the river basin approach in tackling water quality problems is increasing. Modern basin planning is increasingly developing ecological based objectives, related to species and ecosystems.

The purpose of this study is to identify and review existing Water Quality Guidelines (WQGs) that protect the health of (water) ecosystems and their respective mechanisms like institutional arrangements, processes, methodological approaches and reporting mechanisms. Water management regulations in some 15 states and regions were studied. The review has been focused on the objectives of the main water law and guidelines, the classes to score water quality in rivers and lakes, the indicators used to assess water quality, the institutional setting and the mandatory or voluntary use of water quality guidelines. All guidelines studied show that the objective is to protect human life and in most cases also to protect aquatic life. As most of the guidelines date from last century physical and chemical parameters are used as indicators, with a few exceptions.

The Australian/New Zealand Water Quality Guidelines, the European Union Water Framework Directive (EU WFD) and the guidelines developed by US EPA are selected for a more in-depth review, as these guidelines are based on a long-lasting experience and because they also provide most extensively new scientific-based approaches and tools for quality assessment of aquatic ecosystems.
The comparison of the guidelines provides a number of interesting findings and the following conclusions have been drawn.

- The used terminology concerning water quality guidelines, criteria and stressors is not uniform.
- The guidelines for aquatic ecosystem are mostly part of in a larger framework of

guidelines for water quality

- Quality classes for assessment of ecosystems are used for a number of reasons, e.g. to formulate present or future objectives, to present to present the ecosystem quality status in a transparent way and to create awareness by authorities and stakeholders
- The selection of indicators for water quality depends on the type of waters (lakes, rivers, wetlands, etc.), the management aims and the identified environmental concerns. Beside biological and physico-chemical indicators hydromorphological indicators are relevant for assessing ecosystem quality.
- Reference conditions play a major role in deriving biological and hydromorphological criteria. Numerical values or narrative descriptions of indicators are needed to classify the ecological status of aquatic ecosystems.
- Comprehensive guidelines are available for deriving criteria for toxic substances. It is clear that deriving water quality criteria is a complex process of integration of high-level scientific knowledge, taking into account a large number of uncertainties and of policy-definitions of protection levels. The resulting numerical criteria in the guidelines considered show sometimes large differences mainly due to differences in definition of the criteria level, the data used and safety factors applied.

WQGs need mechanisms to achieve objectives established in the guidelines. Therefore the role of (river) basin organizations in Integrated Water Recourses Management and in the application of WQGs has been reviewed. In many regions the basin organizations are the authorities to manage (river) basins and to achieve the objectives of the WQGs. Basin plans are produces and management strategies are worked out. There is a large diversity in the structure and mandate of a basin organization. The mandate varies from a legal entity as Basin Authority to a rather non-committal Advisory Board. For an effective process of application of WQGs compliance and legal mechanisms for enforcement are indispensable. Although basin organizations may play an important role in getting compliance and in enforcement of regulations, it strongly depends on the mandate, capacity and financing of the basin organization whether it will be effective. Legislation is a fundament for successful application of WQGs. However, the existing WQGs and related regulations show large differences in approaches. They may be voluntary, market based or mandatory or combinations of those approaches. However without solid enforcement the implementation of the WQG will hamper. Stakeholder participation and public participation is more and more recognized as one of the success factors for improving water quality and protecting ecosystems. In a number of WQG's the participation is strongly advised or even a legal duty.

The following recommendations for the deriving and application of water quality guidelines for aquatic ecosystems are formulated.

- Provide common terminology for water quality assessment for ecosystems
- Provide a common guideline for protection and restoration of fresh water ecosystems.
- Derive numerical water quality criteria for toxic substances on an international level**.**
- Acknowledge that reference values are needed to assess ecological status
- Strengthen the mandate and cooperation between authorities, stakeholders and states in basin organizations to protect and restore aquatic ecosystems.

1. Introduction

1.1. Background

Meeting growing human needs for water, food and energy without irreversibly degrading the ability of ecosystems to provide important goods and services is one of the most pressing challenges for society in the 21st century and is central to current notions of water security. Human population growth, accelerating economic activities, land use changes, and climate change increase pressures on the quality and quantity of global water resources. These factors are threatening freshwater systems as well as ecosystems in general. Declining water quality has become an issue of global concern as it is causing major disturbances for water use, to ecosystems health and functioning, and to the biodiversity that ecosystems underpin.

While international chemical and physical water quality guidelines and standards for drinking water and some other uses are well articulated (WHO 2003, WHO 2011) and in place with better enforcement and reporting mechanisms for many governments and authorities, the same cannot be said of frameworks relating to water quality for the health of ecosystems. UNEP, on behalf of the UN-Water TPA on Water Quality, and in cooperation with UNESCO, commissioned the Institute for Water Quality, Resources and Waste Management (IWAG-TU) at the Vienna University of Technology in Austria to undertake a scoping study[1] for developing water quality guidelines for aquatic ecosystems. The study provided an overview of some of the existing water quality guidelines and identified the lack of and the subsequent need for water quality guidelines for aquatic ecosystems. The scoping study recommended an international consultative, scientific process to develop and adopt the guidelines[2].

While acknowledging the availability of human use-oriented water quality guidelines, the UNEP Governing Council (GC) Decision 27/3 in February 2013 recognizes the absence of water quality guidelines for ecosystems. Water quality guidelines for ecosystems (WQG) are expected to serve as the basis for securing sustainable ecosystem services. It is recognized that there is a need for international water quality guidelines, which may be voluntarily used by Governments to maintain and improve the status of ecosystems to sustain the services they provide, as possible basis for managing water pollution and water quality, as they affect ecosystems.

A detailed review of existing WQGs is desirable before starting the development of international WQGs for ecosystems. In a large number of countries the protection and rehabilitation of freshwater biota is part of the water policy. It will be of importance to know which methods are used to assess the quality status of aquatic ecosystems and how quality objectives and standards are established. A further question is which approaches are used to protect freshwater ecosystems and which role WQGs play in improving the water quality. Moreover, which enforcement mechanisms are needed and available for effective

[1] Report available at: http://www.unwater.org/downloads/Scoping_study_final_report.pdf
[2] These recommendations were presented and discussed extensively at the 6th World Water Forum in Marseille (France) in March 2012.

implementation of the WQGs the answer to this question is needed at various scales (national, international, transboundary etc.).

1.2. Purpose

The purpose is to identify and review existing water quality guidelines that protect the health of ecosystems and their respective mechanisms (institutional arrangements, processes, methodological approaches and reporting mechanisms).

The review will focus on the following subjects:

- Identification of existing water quality guidelines which may be relevant for guidelines for freshwater ecosystems
- Analysis of water quality guidelines for freshwater ecosystems which are most up-to- date, effective and innovative with special attention to used quality classes, indicators and water quality criteria for ecological assessment
- Implementation and achievements of existing water quality guidelines for freshwater ecosystems
- Experiences with platforms for implementation and enforcement, e.g. organizational and institutional structures such as (River) Basin Organization

Recommendations will be made for establishing WQGs for ecosystems, for institutional arrangements and for enforcement mechanisms.

The review is based on public internet available documents and on publications.

1.3. Structure of the study

In Chapter 2 water policies in a number of countries will be analyzed to find out whether protection of aquatic ecosystems is regulated and how. The analysis will focus on the subject of the WQG (human uses and/or ecosystems), selected indicators for assessment and classification of aquatic ecosystems, the legislative authorities (involved at national, federal, catchment levels), on the character of the guideline (voluntary or mandatory) and public participation.

Chapters 3 to 5 deal with the structures analysis of a limited number of existing WQGs for ecosystems which may provide frameworks and approaches for the development of international WQGs for ecosystems. Guidelines developed in Australia/New Zealand, in the European Union and the United States are reviewed. Chapter 3 describes classes and categories used for the qualification of aquatic ecosystems and in Chapter 4 the main biological, physico-chemical and/or hydromorphological indicators used are described. In Chapter 5 numerical and narrative criteria for ecological assessment water are reviewed, as well as integrated assessment methods. Chapter 6 deals with the application of WQGs on basin level and general mechanisms for implementation of WQGs. Conclusions and recommendations are given in Chapter 7.

2. Protection of ecosystem health in existing water quality guidelines

A comprehensive examination has been undertaken to compare existing water quality guidelines (WQGs). Water laws and WQG's of 15 countries or groups of countries using the same guideline were selected to be reviewed. Besides a short description of the main law and guidelines concerning water quality policy for each country, the review has been focused on the following items

- Are the objectives human use and/or ecosystem oriented?
- Which kinds of indicators are described to assess the water quality: physico-chemical, biological and/or hydromorphological indicators?
- Are water quality classes defined an what is the number of classes?
- Which authority and/or management organization will implement the guidelines?
- Is the WQG mandatory of voluntary?
- Is public participation an obligation in the law?

In Annex 1 an overview of the main findings is presented for the countries. An explanation for each country or international region is given below.

2.1. Existing water quality guidelines

Australia and New Zealand

The joint Australian and New Zealand Guidelines for Fresh and Marine Water Quality have been established in 2000 (ANZECC/ARMCANZ , 2000a). The main objective was to provide an authoritative guide for setting water quality objectives required to sustain current, or likely future, environmental values (uses). In Volume 1 a framework for applying the guidelines is described as well as detailed guidelines for aquatic ecosystems, primary industries, recreational water quality and aesthetics, drinking water and monitoring and assessment. Volume 2 (ANZECC/ARMCANZ , 2000b) provides the rationale and background information for the guidelines for aquatic ecosystems and Volume 3 deals with the rationale and background information concerning the primary industry (ANZECC/ARMCANZ , 2000c). The guidelines are not mandatory. The National Water Quality Management Strategy outlines a three-tiered approach to water quality management i) the national level for establishment of a vision of achieving sustainable use, ii) state or territory level implementation through state water planning and policy process and iii) regional or catchment for complementary planning e.g. catchment strategies and implementation by relevant stakeholders. It is stated that, ultimately, it is the responsibility of local stakeholders and state or territory or regional government to agree on the level of protection to be applied to water bodies. The WQGs promote assessment that integrates biological and chemical monitoring of surface water and sediments. Procedures for deriving numerical trigger values for physical and chemical indicators are described and trigger values for those indicators are presented. Three ecosystem conditions are recognized: high conservation/ecological value systems, slightly to moderate disturbed systems and highly disturbed systems.

More recently an aquatic ecosystem toolkit has been published for identifying high ecological value aquatic ecosystems (Aquatic Ecosystems Task Group, 2012a). The objectives are

- to provide a nationally coordinated approach to policy development for relevant cross-jurisdictional issues within the aquatic ecosystems context
- to develop a national framework for the identification and classification of high ecological value aquatic ecosystems.

The Aquatic Ecosystems Toolkit consists of five modules.

1. National Guidelines for the Mapping of Wetlands (Aquatic Ecosystems) in Australia
2. The Interim Australian National Aquatic Ecosystems (ANAE) Classification Framework
3. Guidelines for Identifying High Ecological Value Aquatic Ecosystems (HEVAE)
4. Aquatic Ecosystem Delineation and Description Guidelines
5. The Integrated Ecological Condition Assessment (IECA) Framework (Available later in 2014).

Whilst the Aquatic Ecosystems Toolkit is not designed to replace existing tools or systems for identifying and classifying potential aquatic ecological assets, it has been developed to complement and build on other systems.

Brazil

The National Water Resource Policy is established in Law no 9,433 (Law 9,433,1997) and includes a National Water Resources Management System. The main objectives are to ensure the necessary access to water of an adequate quality, to ensure the rational and integrated use of water resources with a view achieving sustainable development and to prevent and protect against water crises due to either natural causes or the inappropriate use of natural resources.

The Law defines the river basin as the territorial unit for water resource planning. At institutional level a new organizational framework is introduced to regulate the areas of competence on federal, state and river basin level. Water agencies may serve as the executive secretaries of the River Basin Committees. The National Water Agency (ANA)is legally liable for the implementing the National Resources Management System and stimulate the creation of the river basin committees. In an detailed analysis of fifteen years Brazilian water resource management policy is concluded that the new institutional framework, including among others river basin committees and water agencies, is in line with international trends, and despite the major progress that was made, the implementation process still faces many challenges, especially in the least developed regions of the country (Veiga and Magrini, 2013).

Besides guidelines for drinking water quality, no other WQGs are available. An overview of freshwater quality in Brazil (ANA, 2012) shows that mainly physico- chemical indicators are used to describe the water quality. Also indicators for the microbiological trophic state are used, e.g. the growth of algae. The diagnoses of the water quality are presented through indices: the Water Quality index (WQI), the Trophic State Index (TSI) and the Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI). The use of new

indicators as bioindicators and ecotoxicological tests is recommended and currently used in the states of São Paulo, Minais Gerais and Paraná (ANA, 2012).
ANA identified four classes of surface freshwater bodies according to their uses. The uses consider are visual amenity, navigation, livestock watering, irrigation, fishing, recreation, human consumption, aquaculture and protecting and preservation of aquatic communities. A special class is defined for the preservation of aquatic communities and is mandatory for Conservation Units.

Canada
The Canada Water Act (1987) contains provisions for formal consultation and agreements with the provinces. Within the federal government, over 20 departments and agencies have special responsibilities for fresh water. In 1987 a Federal Water Policy was released , which has given focus to the water-related activities of all federal departments and which will continue to provide a framework for action in the coming years as it evolves in the light of new issues and concerns. The overall objective of the federal water policy is to encourage the use of freshwater in an efficient and equitable manner consistent with the social, economic and environmental needs of present and future generations. Part of the strategy is to encourage and support opportunities for public consultation and participation in the integrated planning.

The Canadian Water Quality Guidelines and subsequent updates (CCME, 2014a) are national science-based goals for the quality aquatic ecosystems. Guidelines are available for a number of uses and for the protection of aquatic life. Numerical guidelines for chemical substances are derived according to a general protocol (CCME, 2007). Factsheets concerning environmental toxicology and chemistry are presented for a large number of chemical pollutants (CCME, 2014b). Numerical guidelines are presented for the short term and for the long term, both for freshwater and marine aquatic ecosystems under the condition that sufficient data are available (CCME, 2014b, c). A Water Quality Index (WQI) is presented as a tool for simplifying the reporting of water quality data . Once the CCME WQI value has been determined, water quality can be ranked by relating it to one of the following five categories: excellent, good, fair, marginal and poor (CCME 2014d). Biological Indicators are not included in the index.
The numerical environmental quality guidelines are recommended values. Provincial and territorial jurisdictions may have or may develop their own science-based environmental assessment tools (e.g criteria, guidelines, objectives and standards). The legislative authority for implementation of the national Water Quality Guidelines lies primarily with each provincial or territorial jurisdiction.

China
The Environmental Protection Law of the People's Republic of China stipulates the objectives of water environmental preservation as "to ensure human health, maintain the effective use of water resources and the conservation of marine resources, maintain the ecological balance, and enhance the development of modern socialism. The legislative framework for water quality includes a general Environmental Protection Law, put into force in 1989, and the Law on Prevention and Control of Water Pollution (1984), in which ambient surface and groundwater quality standards were established (MoEJ,2012). The main water quality standards are COD, BOD, nutrients and some heavy metals and organic

contaminants. A systematic WQC (Water Quality Criteria) has been ongoing in China for several years, mainly referring to the WQC (system in the USA (Zhen-guang et al, 2013). They described that some important kinds of WQC have been studied, including aquatic life, biological, sediment quality lake nutrient and human health criteria focusing on the aquatic life criteria in the present phase.
The state of the surface water quality is expressed in in a range from Grade I to V. Physico-chemical WQC are established for each grade. The grades are described as follows:
Grade I: Mainly for headstream and the national nature preserves
Grade II: Mainly for drinking water resources in first-class protected areas, protected areas for precious fish, and spawning areas for fish and shrimp.
Grade III: Mainly for drinking water resources in second-class protected areas, protected areas for fish and swimming areas.
Grade IV: Mainly for industrial water resources and recreational use in which people do not contact water.
Grade V: Mainly for agricultural water resources and water areas required for landscape.

The State Environmental Protection Administration (SEPA) has a mission to prevent and control environmental pollution in the country through overall supervision and coordination of environmental protection management. Provincial and municipal governments also play important roles in pollution control with local legislations and standards. China has already a long history in river basin management. River basin authorities are under the jurisdiction of the Ministry of Water resources. The relationship between environmental protection plans of SEPA and the water resource protection plans are not fully clear. Public participation is still under development but may have potential environmental gains (Enserink and Koppejan, 2007).

Colombia
In “Decreto 1594” established in 1984 (Colombia, 1984) are quality criteria for the following uses of water presented drinking water, preservation of flora and fauna, agriculture, livestock, recreation, industry and transport. For each use a limited number of contaminants are considered, mainly physico-chemical indicators (nutrients, oxygen, pH, heavy metals and a few organic pollutants) and coliform bacteria. In “Decreto 1594” quality criteria for discharges are established, as well as regulations concerning discharges as licenses, monitoring and taxes. In the new “Decreto 3930” established in 2010 (Colombia, 2010), a number of regulations concerning discharges are adapted. However, the list of uses has not been changed and the quality criteria are not revisited.
Recently, the strategy to improve water policy and water management has been debated, mainly because of inundation problems. (Personal Comm. M. Hofstra, UNESCO-IHE).

European Union
In 2000 the European Parliament and the Council of the European Union established a framework for Community action in the field of water policy, (EC, 2000), commonly referred to as the EU Water Framework Directive (WFD). The WFD is a substantial piece of European legislation comprising 23 Articles and a large number of technical annexes. The overall aim of the Directive, as stated in Article 1 of the WFD, is to establish a framework for the protection of inland surface waters, transitional waters, coastal waters and groundwater which

- prevents further deterioration and protects and enhance the status of aquatic

ecosystems, and with regard to their water needs, terrestrial ecosystems and wetlands directly depending on the aquatic ecosystem
- promotes sustainable water use
- aims at the enhanced protection and improvement of aquatic environment through measures for the progressive reduction of discharges, emissions and losses of priority pollutants
- ensures the progressive reduction of pollution of groundwater
- contributes to mitigating the effects of floods and droughts.

The WFD is mandatory for all member states. Member states shall bring into force the laws, regulations and administrative provisions to comply with the directive. The implementation includes among others administrative arrangements within river basin districts, objectives and programs of measures specified in river basin plans, characterization and analysis of the environmental impact of human uses, monitoring of the status, public information and consultation and reporting.

Quality elements to characterize the ecological status include, biological, physico-chemical and hydromorphological indicators. Normative definitions for the assessment of the ecological status are based on these indicators and are given for rivers, lakes, transitional waters, coastal waters and heavily modified or artificial water bodies. Concerning the ecological status five classes are distinguished: high, moderate, good, poor or bad status. Results of chemical monitoring have to be presented in two classes: good or failing to achieve good. Member states shall design monitoring programs for indicators which are indicative of the status of each relevant quality element.

Member States shall encourage the active involvement of all interested parties in the implementation of this Directive, in particular in the production, review and updating of the river basin management plans. Member States shall ensure that, for each river basin district, they publish and make available for comments to the public, including users: time table and working program, overview of significant water management plans and the river basin plan.

India

The Water Quality Assessment Authority (WQAA) was constituted under the Environment (Protection) Act in 1986 by the Central Government to standardize methods for water quality monitoring and to ensure quality of data generated, including water quality management aspects.

In 2005 the WQAA decided that the data generated by different authorities on water quality should be used for the formulation of a water quality management plan to help restoration of water quality. The Central Pollution Control Board (CPCB,2008a) published guidelines for water quality management. plan. The guidelines present a step-wise activities required for formulation of action plan to restore water quality, including setting water quality objectives, source inventory, maintenance of sewage treatment plans, the options that may be considered for action and various water conservation measures and financing . The following beneficiaries were considered: local citizens, protection of environment, protection of Public health, protection of water resources (water supply, irrigation, other uses), protection of industrial use, enhanced property values and enhanced tourism.

Earlier five classes of surface waters in India were defined, based on the use of the water:

A. Drinking water source
B. Outdoor bathing
C. Drinking water source after conventional treatment

D. Propagation of Wild Life and Fisheries
E. Irrigation, Industrial cooling and Controlled Waste Disposal

Based on the classes of water, quality criteria were set for the different classes. In a guideline for water quality monitoring (CPCB,2008b) the indicators for the classification are mentioned (total coliform organisms, pH, dissolved oxygen and biological oxygen demand) and criteria are set for these indicators.

Also in 2008 guidelines for national lake conservation plan (NRCD, 2008) were provided with the aim to prevent pollution from point sources by intercepting, diverting and treating the pollution loads entering the lake. The interception and diversion works may include sewerage & sewage treatment for the entire lake catchment area. Public awareness and public participation and capacity building, as well as training and research in the area of Lake Conservation part of the activities mentioned in the guidelines. .

Indonesia

A framework for water environment management in Indonesia has been stated under an amended law concerning environmental protection and management Law No.32 of 2009. The aim of the Law is - among others - assuring human safety, health and life, assuring the continuation of life of creatures and ecosystem conservation, preservation the conservation of environmental functions and controlling the utilization of natural resources. In the Law thirteen preventing instruments are established, including quality standards of environment. Water Quality Criteria (WQC) are set as the benchmark for national water quality. The management of water quality and control of water pollution is regulated by the government order (decree) No. 82 of 2001 (MOE 2001). The criteria are the minimum standards set by the national government. Decree No. 82 assigns standard values of 46 parameters in four classes which are determined based on the type of water-usage:

Class I: drinking water

Class II: raw water for recreation, fishery, animal husbandry, irrigation

Class III: fishery, animal husbandry, irrigation, industry

Class IV: irrigation, industry.

Indicators used to monitor the ecosystem listed in the water quality standards are mostly physical and chemical parameters. A different classification scheme has also been set based on the calculation water quality index to classify the water bodies especially rivers. There are four classes set Class A (Good), B (slightly polluted), C (polluted) and D (heavily polluted) (MoE 2003). For lake management a draft guideline has been developed to evaluate the ecological status of national lake's ecosystem (MoE 2011). Three classes are set (1) Good, (2) Disturbed and (3) Damaged based on several following indicators: hydromorphology, trophic status, water quality, biodiversity , food web, eutrophication and carrying capacity (based on phosphor concentration). Management of water quality in Indonesia is divided within the three level governmental structures: Central (national/trans-boundary level), Provincial level and District/City level. This includes carrying out water quality monitoring.

In 1986 the River Basin Development Authorities Act came in to force. The development of river basin organizations in Nigeria was analyzed by Andeoti (2010). His findings were that there exist no water management structure at a lower (sub-basin) level and a management platform that incorporates the non-governmental stakeholders are lacking. A number of recommendations for improvement are presented in his publication.

Japan

As summarized by WEPA (MoEJ,2012) the two main objectives of protecting the water environment in Japan are the protection of human health and the living environment. In order to achieve both objectives, environmental standards for ambient water quality have been established in the Basic Environment Law as the acceptable water quality levels that should be maintained in public waters and groundwater. There are two kinds of environmental quality standards (EQS) for water: those for human health which are uniform standards applicable to all public water bodies throughout the country and those for conservation of the living environment (MoEJ, 1997). The EQS for human health include 27 toxic substances. The EQSs for conservation of the living environment include pH, BOD, suspended solids dissolved oxygen and total coliform. For lakes also EQS are established for total nitrogen and total phosphorus. The standard values are specified for different classes of water uses. Regulatory frameworks for ecological risk assessment and management of chemicals in Japan have been introduced since 2003 (Yamazaki, 2011). Yamazaki discusses the frameworks for different regulatory standards for conservation of aquatic life and discusses also possible improvements to the protocol for deriving criteria for toxic pollutants for conservation of aquatic life.
The Water Pollution Control Law, enacted in order to achieve the water quality targets, sets provisions for water quality conservation such as effluent regulations from factories and business establishments, ambient water quality monitoring, measurement standards for public water bodies, and the total pollutant load control system. which are applied to all public water bodies (MoEJ,2012).

In 1997 an amendment of the River Law inserted the “conservation and improvement of the river environment” as a principle goal. The River Law regards lakes as integral parts of the river system. The amendment also asked for strong public and stakeholder involvement. As described by Nakamura et al (2006) the river restoration was booming and in the period 1990 until 2005 23,000 restoration projects have been conducted. Following standardized protocols nationwide baseline information on ecosystem state of river corridors was gathered. This information includes data on fish, benthic invertebrates, plants, birds and other biota. River systems deemed important for the national economy and people's lives are designated as "Class A river systems" and administrated by the Minister of Construction. The others are designated as "Class B river systems" and administrated by the prefectural governors. A river basin approach is adopted. The River Bureau plans and implements a variety of projects to protect people from disasters caused by rivers, sediment, storm surge, and other natural phenomena, and to ensure sufficient water resources to support affluent lifestyles and develop attractive waterside environments. The River Bureau also drafts laws, manages river administration, issues licenses for water use, and maintains facilities for the proper management of rivers, sediment control, and coastal protection.

Kenya

The Water Act is the main legislation that regulates the water sector in Kenya. The Water Act came into force in 2002 . The Act has various objectives as description of the roles of various actors and the definition of water rights. The Act introduced a number of new water management institutions such as the Water Resources Management Authority (WRMA) to manage and protect Kenya’s water resources and Catchment Area Advisory Committees to enable the public and communities to participate in managing of water resources in each catchment and to support WRMA at the regional level.

The Water Act of 2002 regulates that a national water resources management strategy should be developed that prescribes the principles, objectives, procedures and institutional arrangements for the management, protection. use, development, conservation and control of water resources, and in particular, for i) determining the requirements of the reserve for each water resource, ii)classifying water resources and iii) identifying areas which should be designated protected areas and ground water conservation areas.
In 2014 a new Water Bill was sent to the National Assembly. It seems that the basin approach will be strengthened by the establishment of Basin Water Resources Committees and the development of basin area water resources strategies. Water quality and ecosystem objectives and regulations are not formulated in the new Water Bill.

Environmental regulation in Kenya is carried out by the National Environment Management Authority (NEMA). NEMA was established under the Environmental Management and Coordination Act Nr. 8 of 1999 and became operational in July 2002. Its role is to promote the integration of environmental considerations into government policies, plans, programs and projects. As regards the water sector in particular, NEMA is in charge of formulating water quality regulations. In the Environmental Management and Coordination, (Water Quality) Regulations of 2006 water quality standards are given for sources of domestic water, effluent discharges, water used for irrigation purposes and water used for recreational purposes. No criteria or standards are given for the ecosystem quality.

Nigeria
The Federal Environmental Protection Agency (FEPA) was established in 1988 by the Federal Government of Nigeria (FGH,1988). The FEPA has statutory responsibility for overall protection of the environment and its initial functions and priorities. The National Policy on the Environment was launched in 1989. The introduction of guidelines and standards was part of the implementation of the policy and the environmental pollution abatement strategy contained therein. The guidelines
and standards relate to six areas of environmental pollution control:
• Effluent limitations.
• Water quality for industrial water uses at point of intake.
• Industrial emission limitations.
• Noise exposure limitations.
• Management of solid and hazardous wastes.
• Pollution abatement in industries.
In 1991 "Interim Guidelines and Standards for industrial effluent, gaseous emissions and noise limitations " were published (FGH,1991). These guidelines provide a large number of effluent standards for industries, but no standards for the quality of surface waters. Classification of environmental pollutants to set effluent standards is based on several factors for example, toxicity, persistence, physico-chemical characteristics, etc. The environmental objectives and goals determined the mode of classification. However, in order to ensure that various categories of pollutants are considered, the 129 priority pollutants identified by the USEPA have been adopted by the Agency pending the availability of new scientific data locally.

Russia
More recently, in 2006, Russia re-wrote its water code (Russian Federation Water Code No.

174-03) to focus on integrated regional water management. The code's founding principles are that protection of water bodies (both surface and ground water) takes priority over use, that usage shall not harm the environment, and that utilization be prioritized toward drinking and other domestic purposes (Simpson 2007). Some of the code's innovations include its river basin approach, the introduction of integrated water basin management schemes, and civil society involvement in decision making.
In terms of water quality, the code sets maximum allowable concentrations (MACs) of chemicals, nuclear substances, microorganisms and other water quality indices. These norms are developed by responsible federal executive authorities for each water basin. These standards are mandatory and their violation is penalized. The environmental water quality standards are ecosystem oriented. In monitoring of water bodies chemical, hydrological and biological indicators are elaborated. For many chemical indicators threshold values are set (MACs). Values for key hydrologic indicators (e.g. water discharge) depend on the type of use of water body and are discussed and determined at the special governmental commission where all stakeholders take part. For water bodies that are used for drinking water supply, special pollution prevention zones are established.
Five water quality classes are defined when assessing water quality in a particular water body or a part of it. A system of regulations and bans is established for sewage discharges, along with dumping an discharges of harmful substances. In addition, a monitoring system is established, organized at the water basin level, to provide for regular observations on water quality and quantity, regimes of water use, data processing, and updating of a state water register. The state water register, to which there is free access, is a compilation of documentation on water bodies and water basins, water quality and quantity, water use, hydro-technical facilities, and water protection zones. It also assembles the agreements and decisions on water use.
Concerning public participation , in a review on the Volga Basin (CABRI-Volga,2006) is concluded that public participation and initiative in environmental decision making is on a lower level than in the EU and that insufficient coordination between stakeholders and their interests is a bottleneck in the problem-solving. At the same time, although the Volga Revival Program has been recently closed (2004) it has been a unique experience in basin-wide coordination and some of its participatory approaches had been successfully tested in practice.

South Africa

The concepts of Resource Quality Objectives and Resource Quality were introduced by the National Water Act of 1998 (DWAF, 1998). In this act a large number of water quality issues are regulated, e.g. regarding national and catchment management strategies, classification systems, for water resource, pollution prevention and the use of water.
However, already some years before, in 1996, the South African Water Quality Guidelines were published. The guidelines consist of eight volumes: (1) Domestic Water, (2) Recreational water, (3) Industrial water, (4) Agricultural Water Use: Irrigation, (5) Agricultural Water Use: Livestock watering, (6) Agricultural Water Use: Aquaculture, (7) Aquatic Ecosystems and (8) Field Guide. For the different uses Target Water Quality Ranges (TWQRs) are derived. An overview of TWQRs is presented in the Field Guide (DWAF, 1996b), but for a number of constituents no values were available for certain uses.
The guideline for Aquatic Ecosystems (DWAF, 1996a) provides TWQR's for four categories of physico-chemical constituents: toxic constituents (mainly inorganic and a few organic),

system variables as pH and Dissolved Oxygen, non-toxic inorganic as Total Dissolved Solids (TDS) and Total Suspended Solids (TSS) and nutrients. US, Canadian and Australian guidelines were used to derive TWQRs. The number of classes for ecosystem quality is limited to two: below or above the TWOR. The guideline doesn't include (narrative) biological quality objectives.
The National Water Act defines the catchment area as the basic geographic unit of water quality management. For each of the nineteen Water Management Areas a Catchment Management Strategy must be established in accordance with the requirements of the National Water Resources Strategy. The importance of public participation is emphasized by the National Environmental Management Act of 1998.

United States of America
The objective of the Clean Water Act (CWA) is to restore and maintain the chemical, physical and biological integrity of Nation's waters. The Act establishes the basic structure for regulating discharges of pollutants into the waters of the United States and regulating quality standards for surface waters. The basis of the CWA was enacted in 1948 and was called the Federal Water Pollution Control Act, but the Act was significantly reorganized and expanded in 1972. "Clean Water Act" became the Act's common name with amendments in 1972. An overview of the law and the major amendments is published by Copeland (2010). Under the CWA, US EPA has implemented pollution control programs such as setting wastewater standards for industry. A set national recommended water quality criteria for the protection of aquatic life and human health in surface waters for approximate 150 pollutants. These values provide guidelines for states and tribes to adopt water quality criteria (USEPA, 2014a). Tribes are native American Indian Tribes and Heritage Groups that are recognized by individual states for their various internal government purposes; further referred as states.

US EPA also provides technical support for states concerning the development of biological criteria and biological assessment programs. In 1990 and 1992 documents were published that provide guidance for development and implementation of narrative biological criteria, as part of a new priority for the development of Biological Water Quality Criteria (USEPA, 1990 and 1992). More recently, a primer on Using Biological Assessments to support Water Quality Management was published. Three tools are described: (i) Biological Assessment Program Review, (ii) The Biological Condition Gradient (BCG)and (iii) Stressor Identification and Causal Analysis/Diagnosis Decision System (ID/CADDIS) (USEPA, 2011). In 2013 a comprehensive biological assessment program review was published (USEPA, 2013).
It is the primary responsibility of states to prevent, reduce and eliminate pollution, to plan the development and use (including restoration, preservation, and enhancement) of land and water resources. Comprehensive pollution control plans have to be made for a basin or portion thereof.
The CWA requires public participation in the development, revision and enforcement of any regulation, standard, effluent limitation, plan or program. It is also stated that to the maximum extent possible, the procedures utilized for implementing of the CWA shall encourage the drastic minimization of paperwork and interagency decision procedures.

Vietnam
The Law on Environmental Protection (1993, revised 2005) is the principle law on

environmental protection including water, and stipulates that the objective of environmental protection is to ensure social progress in order to achieve national sustainable development. Environmental standards are also stipulated under the law.
In addition to the environmental law, the Law on Water Resources (1998), the Land Law (2003) and the Biodiversity Law (2008) complete the national legislation related to water and environmental management (MoEJ, 2012).
The physico-chemical water quality standards are established. The main parameters are BOD, COD, DO, TSS, N, P and metals. Four classes of in surface water quality standards are set:
Class A1: good for domestic water supply and other purposes in A2, B1 and B2
Class A2: good for domestic water supply, but suitable technology must be applied; conservation of aquatic life or other purposes in B1 and B2
Class A3: Good for irrigation or other purposes with demand for similar quality water or other purposes in and B2
Class A4: Good for water transportation and other purposes with demand for low quality water.

The Ministry of Natural Resource and Environment (MoNRE) is responsible for the management of the quality and quantity of water resources. Under MoNRE, the Vietnam Environment Administration (VEA), which was established in 2008 to strengthen institutional capacity to manage environmental issues, is responsible for policy planning, monitoring of compliance and provision of guidance to local governments. In implementation, local governments play an important role in environmental management, but the MoNRE takes a leading role in the promotion of environmental conservation activities through the implementation of environmental regulations and provision of guidance. The most important River Basin Organization in Vietnam is the Mekong River Commission (MRC).

2.2. Findings

- In all countries studied water laws and/or water quality guidelines have been established to protect human uses and in most cases also to protect aquatic life. Most of the laws and guidelines date from the eighties and nineteens of the past century and some have been adapted partly in recent years.
- All governmental frameworks include guidelines for physical indicators and chemical substances. They also provide strategies for pollution preventions, measures and/or regulations to prevent and reduce discharges of pollutants, although the number of pollutants considered are largely varying.
- However, only a few laws or guidelines focus more explicitly on the protection of the aquatic ecosystems by developing specific guidelines, by using biological and hydromorphological indicators and by taking into account other pressures than chemical pollution.
- The EU WFD may be considered as a framework on federal scale which has the most detailed and specified ecological objectives for different type of water bodies. The objectives are based on biological, hydromorphological and physico-chemical quality elements.
- In the last decade in the USA new methods have been introduced for biological

assessment to support water quality management. Australia developed an aquatic ecosystems toolkit for identifying high ecological value aquatic ecosystems. In some other countries initiatives have been taken to develop guidelines for aquatic ecosystem e.g Indonesia, or to add biological indicators in regular monitoring programs e.g. Brazil.

- In a large number of countries reviewed the water basin approach has been incorporated in water laws. In those countries , river basin organizations (RBO's) play a role in the implementation of integrated water resources management, as also described by Priscolli (2006?). However, RBO's vary considerable in form and function. Hooper (2006) describes nine types of river basin organizations among which advisory committee, authority, council and corporation.
- The importance of public participation has generally been acknowledge and has been laid down in law in most of the countries reviewed.

3. Classes for the quality status of ecosystems

Water quality classes are used in a large number of guidelines as well in assessments of water quality as for setting of quality objectives for different uses. In this review the application of quality classes for aquatic ecosystems in Australia/New Zealand, the European Union and the United States of America is described.

3.1. Quality classes for ecosystems in existing guidelines

Quality classes for ecosystems in Australia and New Zealand
In the joint Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000a) three levels of protection of ecosystem conditions are recognized and defined:
High conservation/ecological value systems: effectively unmodified or other highly-valued ecosystems, typically (but not always) occurring in national parks, conservation reserves or in remote and/or inaccessible locations.
Slightly to moderately disturbed systems: ecosystems in which aquatic biological diversity may have been adversely affected to a relatively small but measurable degree by human activity. The biological communities remain in a healthy condition and ecosystem integrity is largely retained. Typically, freshwater systems would have slightly to moderately cleared catchments and/or reasonably intact riparian vegetation.
Highly disturbed systems. These are measurably degraded ecosystems of lower ecological value. Examples of highly disturbed systems would be some shipping ports and sections of harbors serving coastal cities, urban streams receiving road and stormwater runoff, or rural streams receiving runoff from intensive horticulture.
It is stated that the three levels should be considered as a practical but arbitrary approach to viewing the continuum of disturbance across ecosystems.
The level of protection is the level of ecosystem quality desired by stakeholders and implied by the selected management goals and water quality objectives for the water resource. The valuation of a water body is part of the first step of the management framework of the guidelines as shown in figure 3.1.
Stakeholders need to be actively involved in the steps. A number of examples of stakeholder involvement are presented in the guidelines.

The guideline provides for each class recommended levels of protection by narrative descriptions of biological, physical & chemical stressors, toxicants and sediments. The guideline recommends that for the high conservation ecosystems the values of the indicators of biodiversity should not change markedly. This means that any decision to relax the physical and chemical guidelines should only be made if it is known such degradation will not compromise biological diversity. For slightly and moderate disturbed systems maintenance of biological diversity condition should be a key management goal, but an increased level of change might be acceptable. The third ecosystem condition recognizes that degraded aquatic ecosystems still retain, or after rehabilitation may have, ecological or conservation values, but for practical reasons it may not be feasible to return them to a slightly–moderately disturbed condition.
For each level of protection numerical trigger values for toxicants are presented in the

guideline. The highest protection level, 99% of the species expected to be protected, has been chosen as the default value for ecosystems with high conservation value. The 95% protection level should apply to slightly- moderately disturbed ecosystems.
For biological indicators, and for physical and chemical stressors where no biological or ecological effects are available, the preferred approach to deriving guideline trigger values is from local reference data. For toxicants in water and sediments the general trigger guideline values can be used, but data about reference sites may be a reason to change the trigger values.

Quality classes for ecosystems in the EU
Concerning ecological classification in the WFD (WFD, 2000) definitions are given for three classes of ecological status of water bodies. The general definitions are:
High Status: there are no, or only very minor, anthropogenic alterations to the values of the physico-chemical 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.
Good status: 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.
Moderate status: 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.

Waters achieving a status below moderate shall be classified as **poor or bad**. No specific definitions are given for these classes. In the presentation of monitoring results , five classes are used for the classification of ecological status. Each class has a color code going form blue, green yellow, orange to red. Presentation of chemical monitoring results is limited to two classes: good (blue) or failing to achieve good (red).
The general definitions for the high, good and moderate status are specified for biological, hydromorphological and physico-chemical quality elements of rivers, lakes, transitional waters and coastal waters.

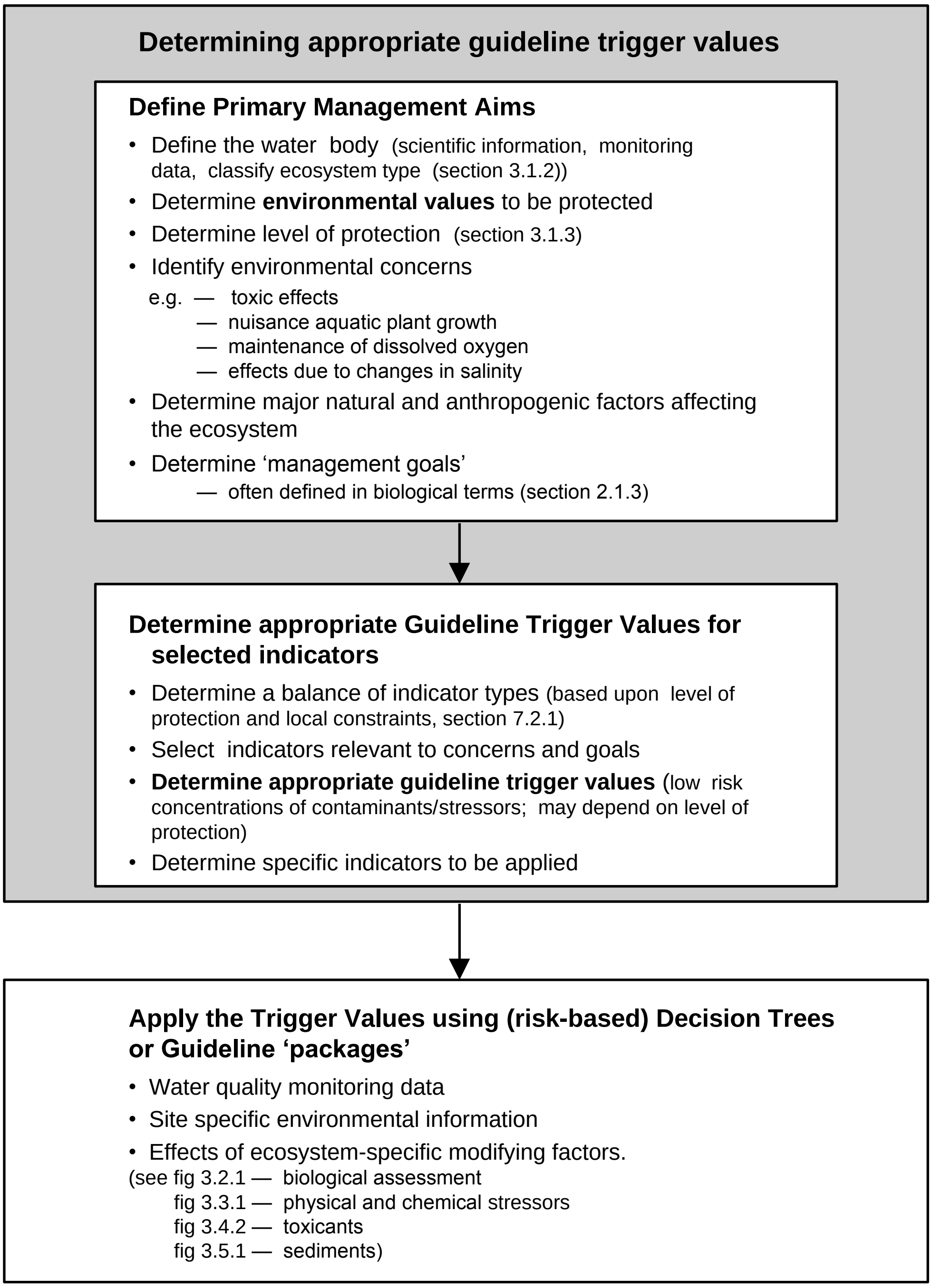

Figure 3.1. Flow chart of the steps involved in applying the ANZECC guidelines for protection of aquatic ecosystems. The references in the flowchart refer to the original document (ANZECC/ARMCANZ, 2000a).

Member states shall protect, enhance and restore all bodies of surface waters with the aim of achieving good surface water status at the latest 15 years after the data of entry of the Directive in the year 2000. For heavy modified and artificial water bodies the good ecological potential shall be achieved. The operational programs of measures for achieving the aims shall be specified in river basin plans. The deadline may be extended for the purpose of phased achievement of the objectives, provided that no further deterioration occurs and some other conditions are met.

Key elements of the monitoring as the selection of monitoring sites and selection of substances, frequency of monitoring and standards for quality monitoring are described in the WFD. In order to ensure comparability of such monitoring systems, the results of the systems operated by each Member State shall be expressed as ecological quality ratios for the purposes of classification of ecological status. These ratios shall represent the relationship between the values of the biological parameters observed for a given body of surface water and the values for these parameters in the reference conditions applicable to that body. The ratio shall be expressed as a numerical value between zero and one, with high ecological status represented by values close to one and bad ecological status by values close to zero. The value for the boundary between the classes of high and good status, and the value for the boundary between good and moderate status shall be established through an intercalibration exercise among the member states . In Chapter 4 more attention will be paid on the intercalibration and boundaries between classes.

Quality classes for ecosystems in the USA

All states in the United States use some form of designated use of classification systems for a long time. In the procedure for initiating narrative biological criteria (USEPA, 1992) was described how biological criteria can be used to help define the level of protection for “aquatic life use” within four hypothetical State-designated use categories going from class A (Highest quality or Special Categories) to class D (Lowest quality water). The use of categories in policy-making and water management is the responsibility of States.
Because all states use different methods and indices to determine biological condition, and therefore it is difficult to determine if conditions vary across states and to develop national assessments, a descriptive model, the Biological Condition Gradient (BCG) has been developed (Davies and Jackson, 2006). The model shows an ecologically based relationship between stressors and the response of the aquatic community. See Figure 3.2.

US EPA adopted this method as one of the three tools for biological assessments (USEPA, 2011). Six levels of biological conditions are described in the BCG (See Figure 3.2). It provides a framework for understanding current conditions relative to natural, undisturbed conditions. The main purposes are to assess aquatic resources more uniformly and to communicate more clearly to the public. States are free in the use of the framework or in the adaption of the framework for their own water policy and water resource management. Nowadays a number of states use the BCG calibration e.g. Pennsylvania.

For chemical pollutants National Recommended Water Quality criteria are available (USEPA, 2014a). The Aquatic Life Criteria Table provides numerical values for more than 150 pollutants for protecting aquatic life in freshwater and saltwater. For both type of waters two values are presented. The Criteria Maximum Concentration (CMC) (acute) is an estimate of the highest concentration of a material in surface water to which an aquatic community can be exposed briefly without resulting in an unacceptable effect and has been based on acute toxicity data. The Criterion Continuous Concentration (CCC) (chronic) is an estimate of the highest concentration of a material in surface water to which an aquatic community can be exposed indefinitely without resulting in an unacceptable effect . Given this values three “classes” of water quality may be distinguished: good quality (concentrations of pollutants in the water below CCC), moderate quality (concentrations between CCC and CMC) and quality at risk (concentrations above CMC). However, EPA hasn’t published a federal system for such a classification. States use different methods in presenting the pollution status.

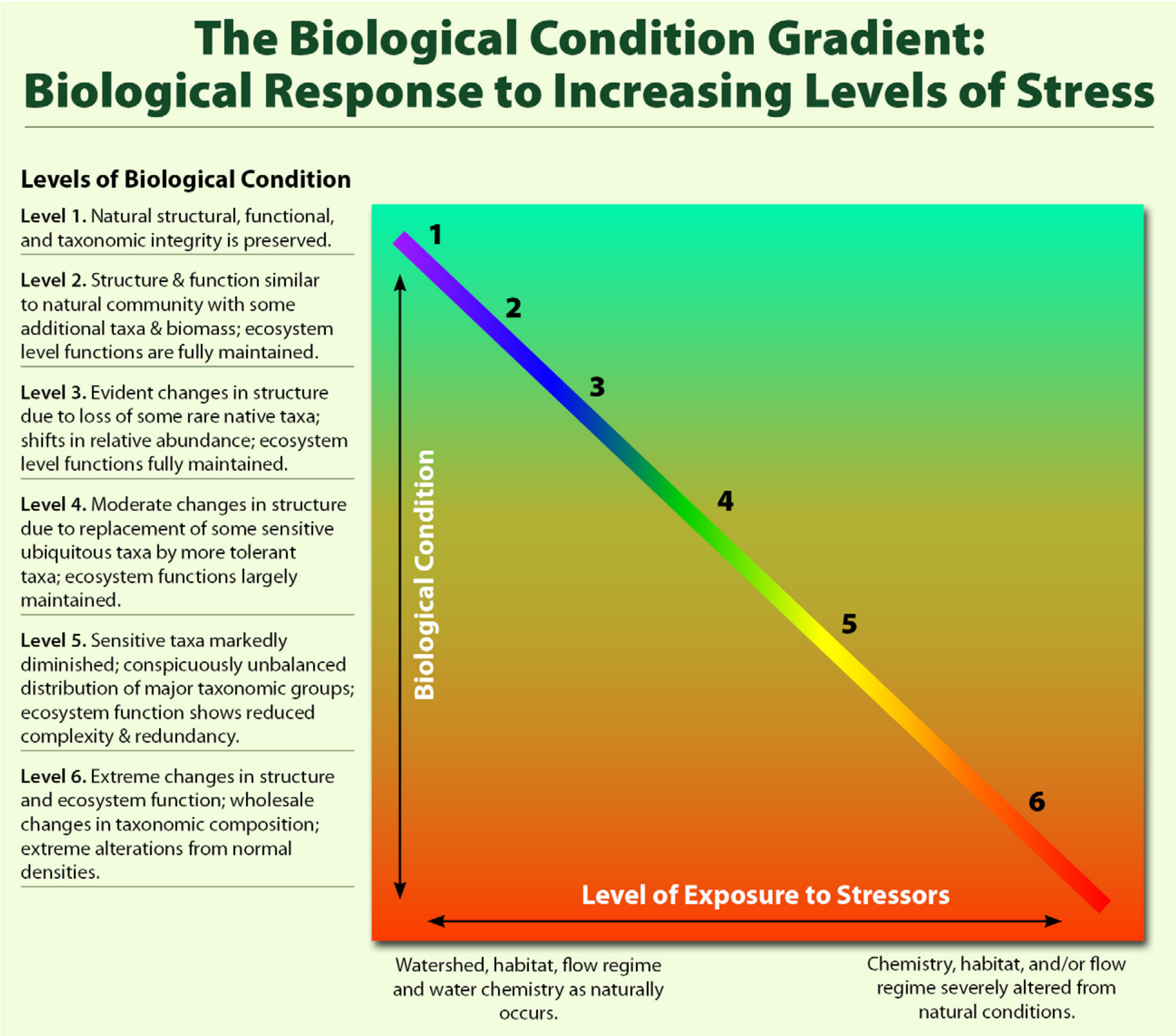

Figure 3.2. Biological Condition Gradient (USEPA 2011, modified from Davies and Jackson, 2006)

3.2. Findings

- Quality classes for ecosystems are used for at least four reasons
  - to formulate present or future objectives concerning the status desired
  - to present the ecosystem quality status in a transparent way ; awareness by authorities and stakeholders
  - to compare the quality status of different waters
  - to report progress of the quality status
- In the considered guidelines of Australia, European Union and USA three to six classes are described for the ecological condition of aquatic ecosystems. The highest class is always related to systems with unmodified and undisturbed systems with a natural biological structure and functioning. The lowest class reflects highly disturbed systems with extreme changes in structure and function of the ecosystem.
- For each class narrative descriptions are given concerning the biological condition and the level of disturbance. Methods and/or toolboxes are available to assess the

ecological condition.

- Toxicants numerical values are derived to give a certain level of protection of the ecosystems. In Australia/New Zealand these levels are directly related to the three classes of ecological condition. In the European Union two classes are distinguished concerning chemical quality: bad or good quality. In the USA two guideline values, chronic and acute toxicity, are available, but they are not related to a defined water quality class.
- The policy formulations concerning the classes distinguished is rather different. In Australia and USA the classes are a framework for states and water management authorities to establish the ecosystem condition and to formulate aims and measures for preventing deterioration or improving of the ecosystem condition. Member states of the European Union shall protect, enhance and restore all bodies of surface waters with the aim of achieving the "good surface water" class at the latest 15 years after the data of entry of the Directive in the year 2000. Under certain condition the death line may be changed.

4. Indicators applied for ecological assessment

This chapter deals with the biological/chemical land hydromorphological indicators for ecological assessment and how these indicators are related to stressors and pressures. The same regions as in Chapter 3 are considered.

4.1. Indicators applied for ecological assessment in Australia and New Zealand

The Australian and New Zealand Guidelines (ANZECC/ARMCANZ, 2000a) distinguish four type of guidelines and sets of indicators for ecosystem assessment:

- Biological assessment
- Physical and chemical stressors
- Water quality guidelines for toxicants
- Sediment quality guidelines

The guidelines for biological assessment are intended to detect important departures from a relatively natural, unpolluted or undisturbed state – reference conditions. The focus is on i) changes in species diversity, community composition and/or structure and ii)changes in abundance and distribution of species of high conservation value or species important to the integrity of ecosystems. It is explained that bioassessment and biological indicators have come into use because the traditional physical and chemical guidelines are too simple to be meaningful for biological communities or processes.
To select the most appropriate biological indicators and protocols three broad assessment objectives are described: i) broad-scale assessment (at catchment, regional or larger scale), ii) early detection of short- or longer-term changes and iii) assessment of biodiversity. For broad-scale assessment and early detection Rapid Biological Assessment (RBA) methods are recommended, because RBA's can be carried out at relative low costs at a large number of sites or over a large geographical area. RBA based on stream macroinvertebrates is part of the Australian River Assessment Scheme (AUSRIVAS).

A broad number of biological indicators may be used. The recommended biological indicators are related to the water quality issue. For example, if nutrients input might be the problem, the structure of phytoplankton or benthic algae communities and changes to vegetation structure are recommended as indicators for streams and wetlands. Other quality issues may require other indicators as fish, macrophytes, zooplankton, frogs and aquatic and semi-aquatic reptiles and water birds (ANZECC, 2000b)

The physical and chemical stressors include a number of naturally occurring physical and chemical parameters which can cause serious degradation aquatic ecosystems when ambient values are too high and/or too low. The following stressors are considered: nutrient, biodegradable organic matter, dissolved oxygen, turbidity, suspended particulate matter, temperature, salinity, pH and changes in flow regime. The effects of abnormal values may be direct or indirect, toxic or non-toxic. See Figure 4.1.

The water quality guidelines for toxicants provides trigger values for toxicants and guidelines for the application of the trigger values. Trigger values are present for metals and metalloids, non- metallic inorganics and a large number of organic toxicants. For the way of deriving see Chapter 5. The selection of indicators depends on the environmental concerns identified and the management aims formulated. See Figure 3.1. in Chapter 3 for the flowchart.

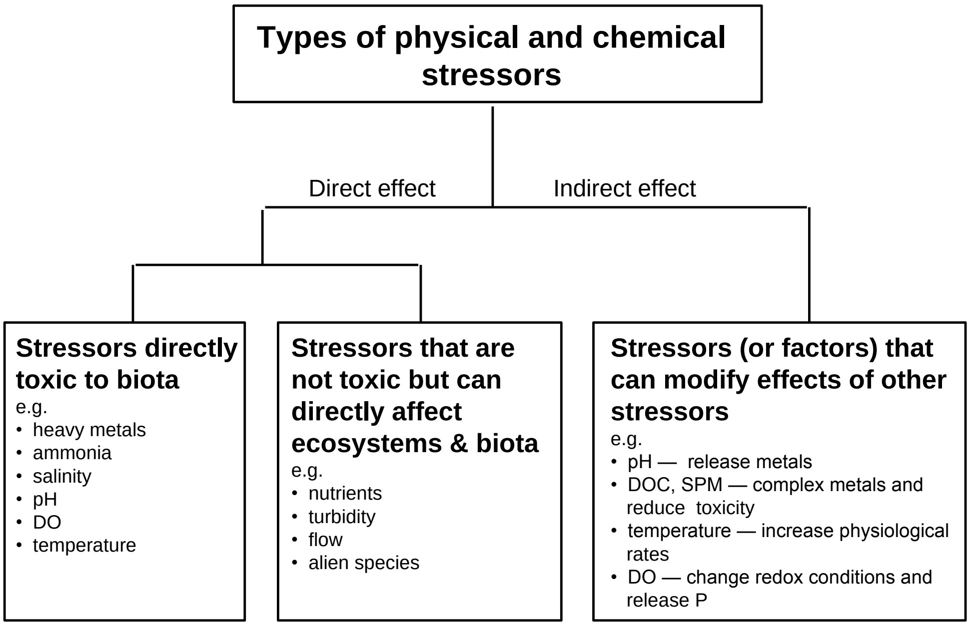

Figure 4.1. Types of physical and chemical stressors (ANZECC/ARMCANZ, 2000a)

The establishment of guidelines for sediments will serve three principal purposes:
- to identify sediments where contaminant concentrations are likely to result in adverse effects on sediment ecological health;
- to facilitate decisions about the potential remobilization of contaminants into the water column and/or into aquatic food chains;
- to identify and enable protection of uncontaminated sediments.

Many urban and harbour sediments fall into the first category, usually being contaminated by heavy metals and hydrophobic organic compounds resulting from both diffuse and point-source inputs. Recommended guideline values for a range of metals, metalloids, organometallic and organic sediment contaminants are listed. The guideline numbers are trigger values that, if exceeded, prompt further action as defined by the decision tree.

Beside the water quality guideline the Aquatic Ecosystems Toolkit provides indicators as already described in Chapter 2. Whilst the toolkit has been developed for high ecological value ecosystems, it is not designed to replace existing tools or systems for identifying and classifying potential aquatic ecological assets, it has been developed to complement and build on other systems, and is flexible in its application. For the development of guidelines for ecosystems it may be valuable to take knowledge of the criteria which are presented for identification of high ecological value aquatic ecosystems.

- Diversity: the aquatic ecosystem exhibits exceptional diversity of species (native/migratory), habitats, and/or geomorphological features/processes.
- Distinctiveness: the aquatic ecosystem is rare/threatened or unusual; and/or the aquatic ecosystem supports rare/threatened/endemic species/communities/genetically unique populations; and/or the aquatic ecosystem exhibits rare or unusual geomorphological features/processes and/or environmental conditions
- Vital habitat: an aquatic ecosystem provides vital habitat for flora and fauna species

if it supports unusually large numbers of a particular native or migratory species, and/or maintenance of populations of specific species at critical life cycle stages, and/or key/significant refugia for aquatic species that are dependent on the habitat, particularly at times of stress.

- Naturalness: the ecological character of the aquatic ecosystem is not adversely affected by modern human activity.
- Representativeness: the aquatic ecosystem is an outstanding example of an aquatic ecosystem class to which it has been assigned, within a drainage division.

Indicators applied for ecological assessment in the EU

The quality elements for the classification of ecological status as specified in the EU WFD (EC 2000) includes three types of indicators

- Biological elements
- Hydromorphological elements supporting the biological elements
- Chemical and physico-chemical elements supporting the biological elements

The biological elements include i) the composition and abundance of aquatic flora (phytoplankton, macrophytes and phytobenthos), ii) composition and abundance of benthic invertebrate fauna and the composition, iii) abundance and age structure of fish fauna.
Hydromorphological elements consist of indicators for the i) hydrological regime (quantity and dynamics of water flow, connection to groundwater bodies) , ii) river continuity (only for rivers) and iii) morphological conditions (depth, structure and substrate of the bed, structure of the riparian zone)
The physico-chemical elements are divided in three groups: i) general elements (thermal conditions, oxygen conditions, salinity, acidification status, nutrient conditions), ii) specific pollutants including all priority substances identified as being discharged into the body of water and iii) pollution by other substances identified as being discharged in significant quantities into the body of water.
In order to assess the magnitude of the pressure to which bodies of surface water are subject Member States shall monitor (surveillance monitoring) for those quality elements which are indicative of the pressures to which the body or bodies are subject. In order to assess the impact of these pressures, Member States shall monitor as relevant:
. parameters indicative of the biological quality element, or elements, most sensitive to the pressures to which the water bodies are subject,
. all priority substances discharged, and other pollutants discharged in significant quantities,
. parameters indicative of the hydromorphological quality element most sensitive to the pressure identified.
Besides the surveillance monitoring, investigative monitoring shall be carried out: where the reason for any exceedances is unknown, where surveillance monitoring indicates that the objectives set out in Article 4 for a body of water are not likely to be achieved and operational monitoring has not already been established, in order to ascertain the causes of a water body or water bodies failing to achieve the environmental objectives, or to ascertain the magnitude and impacts of accidental pollution.

Concerning the identification of pressures Member States shall collect and maintain information on the type and magnitude of the significant anthropogenic pressures to which the surface water bodies in each river basin district are liable to be subject, in particular the following.

- Estimation and identification of significant point source pollution
- Estimation and identification of significant diffuse source pollution
- Estimation and identification of significant water abstraction for urban, industrial, agricultural and other uses
- Estimation and identification of the impact of significant water flow regulation
- Identification of significant morphological alterations to water bodies
- Estimation and identification of other significant anthropogenic impacts on the status of surface waters
- Estimation of land use patterns, including identification of the main urban, industrial and agricultural areas and, where relevant, fisheries and forests.

Member States shall carry out an assessment of the susceptibility of the surface water status of bodies to the pressures identified above. Based on this analysis each Member State shall ensure the establishment for each river basin district, or for the part of an international river basin district within its territory, of a program of measures in order to achieve the objectives established.

Indicators applied for ecological assessment in the USA

Biological assessment is a principal monitoring tool and is used to varying degrees and purposes by all 50 states over the past 20 years (USEPA 2000b).The three major biological assemblages, or groups, monitored in comprehensive biological assessment programs are fish, macro invertebrates and algae. Monitoring of physical and chemical indicators have already done for a much longer time according to the Clean Water Act of 1965, in which water quality standards became a feature of the law (Copeland, 2010). States were required to set standards and that would be used to determine actual pollution levels.

There are no federal lists for mandatory or recommended (assemblages of) indicators, but the last decennia a lot of work has been done on tools for improving the use of biological assessment (USEPA, 2011). Three tools are described in this tool:

1. The Biological Assessment Program Review
2. The Biological Condition Gradient
3. Stressor Identification and Casual Analysis/Diagnoses Decision Information System

Recently a comprehensive report concerning the process of Biological Assessment Program Review has been published (USEPA 2013). With the help of the program review process described in the document, states and tribes can identify the technical capabilities and the limitations of their biological assessment programs and develop a plan to build on the program strengths and address the limitations. The document is intended to be used as a road map for technical development of a biological assessment program. It provides a step-by-step process for evaluating both the technical rigor of a water quality agency's biological assessment program and the extent to which the water quality agency uses the information to support overall water quality management. The technical rigor of a biological assessment program determines the degree of accuracy and precision in assessing biological condition and deriving stressor-response relationships. With increasing technical rigor, a water quality agency gains increased confidence in data analysis and interpretation, as well as more comprehensive support for a variety of water quality management activities, including the following:

- More precisely defining goals for aquatic life use protection.
- Deriving biological criteria.
- Identifying high quality waters and establishing biological condition baselines.
- Identifying waters that fail to support designated aquatic life uses.
- Supporting development of water quality criteria.
- Conducting causal analysis.
- Monitoring biological response to management actions

Four levels of technical program rigor are distinguished. See figure 4.2. A biological assessment program's level of rigor is dependent on the quality and level of resolution of 13 technical elements and divided in three groups:

- Biological Assessment Design with the elements:
  - Index Period
  - Spatial Sampling Design
  - Natural Variability
  - Reference Site Selection
  - Reference Conditions
- Data Collection and Compilation with the elements
  - Taxa and Taxonomic resolution
  - Sample Collection
  - Sample Processing
  - Data Management
- Analysis and Interpretation with the elements:
  - Ecological attributes
  - Discriminatory Capacity
  - Stressor Association
  - Professional Review.

The report describes for all of the 13 elements the level of technical rigor. The report also present 10 biological and other ecological attributes to characterize the Biological Condition Gradient. For example, highly sensitive taxa, intermediate sensitive and common taxa and highly tolerant taxa are types of attributes which are proposed.

The purpose of the Stressor Identification and Causal Analysis/Diagnosis Decision Information System is to identify the cause of biological impairment which is established in the biological assessment . The core of the SI process consists of the following three main steps:

- Listing candidate causes of impairment
- Analyzing new and previously existing data to generate evidence for each candidate cause
- Producing a causal characterization using the evidence generated to draw conclusions about the stressors that are most likely to have caused the impairment

A comprehensive guidance document for stressor identification is available (USEPA, 2000).

In the Primer on Using Biological Assessments to Support Water Quality Management 17 case studies in a different states and/or river basins are described.

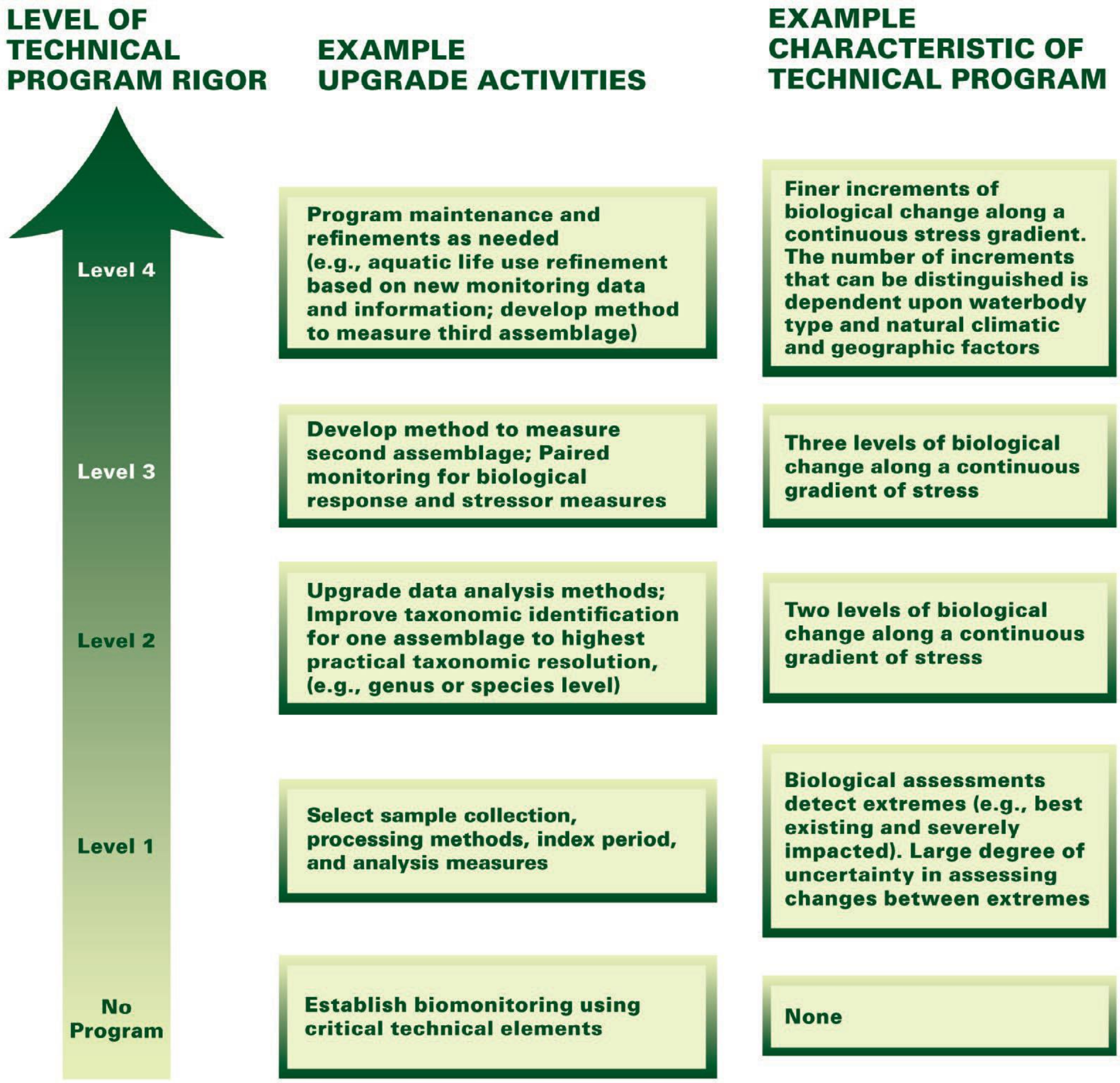

Figure 4.2. Examples of typical upgrade activities state or tribal water quality agencies have taken to incrementally strengthen their technical programs. The example characteristics provided in column three are relevant to a biological assessment program's technical capability to distinguish incremental biological change along a gradient of increasing stress. Improved ability to discriminate biological changes supports more detailed description of designated aquatic life uses and derivation of biological criteria (USEPA,2013).

4.2. Findings

- Comprehensive guidelines and tools for ecological assessment are available and a lot of experiences has already described as well as processes for reviewing ecological assessment programs.
- The biological indicators that are most used are composition and abundance of aquatic fauna, macro invertebrates and fish. In some case also species like frogs and water birds are used.

- The physico-chemical indicators can be divided in three groups :
    - general, naturally occurring elements as nutrients, dissolved oxygen, pH and biodegradable organic matter
    - toxicants
    - other substances
- Beside biological and physico-chemical indicators hydromorphological indicators are relevant for assessing ecosystem quality
- The selection of indicators is a process in which a number of elements are relevant. Most important are the type of water (lakes, rivers, wetlands, etc), the management aims and the identified environmental concerns. In Europe the indicators are to a large extend prescribed to establish whether the aquatic ecosystems has achieved the good quality status, or not. Australia and US focus on guidelines for the states to select indicators as part of ecological assessment programs. For example, the USA recently published a comprehensive biological assessment program including 13 elements and four levels of accuracy.
- Tools for analyzing the results of the ecological assessment and the pressures and stressors which may be the cause of impairment are available. An example is the Stressor Identification guideline in the USA.

5. Water quality criteria applied for ecological assessment

Numerical values or narrative descriptions of indicators are needed to classify the ecological quality status of an aquatic ecosystems and can be used to set water quality objectives and standards. In some countries, water quality standards play the role of regulatory instrument and may be legally binding and/or provide a classification scheme to set water quality objectives.

5.1. Definitions

Several definitions and synonyms are used in water quality guidelines. In "Water Pollution Control. A guide to the use of water quality principles " (Helmer and Hespanol, 1997), published in behalf of UNEP, WSSCC and WHO, the following definitions are presented in chapter 3 by Enderlein et al (1997):

- **Water quality criterion** (synonym: water quality guideline): numerical concentration or narrative statement recommended to support and maintain a designated water use
- **Water quality objective** (synonyms: water quality goal or target): A numerical or narrative statement established to support and to protect the designated water uses of water at a specific site, river basin or parts(s) thereof
- **Water quality standard**: an objective that is recognized in enforceable environmental control of a level of Government

New definition and synonyms have been introduced in water quality guidelines. In the Canadian Water Quality Guidelines (CCME, 1999) criteria and guidelines are differentiated. Criteria are defined as scientific data evaluated to derive the recommended limits and guidelines as recommended numerical concentrations or narrative statements. In Australia and New Zealand (ANZECC/ARMCANZ , 2000a) the terms "Water quality guidelines" and "Water quality objectives" are used according to the given definitions of Enderlein. The term "Guideline trigger value" (and in the past "default value") is used to indicate that, if exceeded, there is a potential to cause a problem and so trigger a management response. In the USA the term " National recommended water quality criteria" is used for numerical criteria for pollutants. Objectives and standards can be set by states and tribes. The EU WFD (EC, 2000) defines environmental quality standards: the concentration of a particular pollutant or group of pollutants in water, sediment or biota which should not be exceeded in order to protect human health and the environment. These standards are also called chemical water quality standards. Member States shall take measures with the aim to achieve these standards within 15 years.

At present, often the terms "Threshold" or "Threshold value" are used in ecological assessment, but different definitions are used. Firstly, a threshold value is the value of a key variable that will elicit a fundamental and irreversible change in the behavior of the system. Groffman and others (2006) define ecological thresholds as the points at which there is an abrupt change in an ecosystem quality, property or phenomenon, or where small changes in an environmental driver produce large responses in the ecosystem. On a general level, ecological thresholds are the breaking points of ecosystems at which the pressures lead to abrupt changes in the ecosystem. Secondly, a threshold value is a value to delineate different classes of water quality, e.g. the set of ecological standards along ecological status scale (Irvine, 2012).

The definitions as given by Enderlein et al (1997) seems to be still appropriate looking at the use of terms in the guidelines considered. The definition of Enderlein make clear difference between recommended values (criteria or guidelines), established objectives and enforceable standards.

5.2. Criteria for biological indicators

As concluded in Chapter 3, for biological indicators narrative descriptions are given to assess the biological status in a certain quality class in Australia and New Zealand, in the European Union and in the USA. This paragraph will describe more in detail which (numerical) methods are applied to assess the status based on biological indicators and which approaches are applied to improve the comparability of results of biological assessments of categories of ecosystems.

Reference conditions

The value of biological indicators in aquatic ecosystems which are undisturbed, the so-called reference conditions, seems to be a starting point and important base for each assessment of biological quality status. The Australian/New Zealand guidelines (ANZECC/ARMCANZ, 2000a) explicitly recommend that the preferred approach to derive guideline trigger values for biological indicators is from local reference data. Three sources of information are mentioned to define reference conditions i) historical data collected from the site being assessed, ii) spatial data collected from sites or areas nearby that are uninfluenced by disturbance, or iii) data from other sources if there are neither suitable historical data nor comparable reference sites nearby.

Reference conditions in the EU WFD (EC, 2000) are equated with the “high ecological status” of the classification system and are meant to represent the structure and functioning of biological communities under no or very minor anthropogenic disturbances. Member states should establish type-specific biological reference conditions representing the biological quality elements which are prescribed in the guideline. For heavily modified and artificial water bodies the relevant biological elements shall reflect, as far as possible, those associated with the closest comparable water body type. The European Commission published a guidance document concerning typology, reference conditions and classification of rivers and lakes which provide a common understanding of concepts and terms and a stepwise approach for establishing reference conditions and ecological class boundaries (EC, 2003).

In the USA the primer on using biological assessment (USEPA, 2011) recommends the use of information on the composition of a naturally occurring aquatic community to define goals for a waterbody. Many states have used such information to define more precisely their designated aquatic life uses, develop biological criteria, and measure the effectiveness of controls and management actions to achieve those uses. In the Biological Assessment Program review (USEPA, 2013) knowledge about reference conditions is one of the key elements in a review. It is stated that the reference conditions serve as benchmark for judging conditions of the site and as basis for derivation of biological criteria.

Because the concept of “reference conditions” is increasingly used to describe the standard or benchmark against which current condition is compared, there is a need to bring some consistency to the use of the term (Stoddard et al, 2006). Stoddard et al argued the need for a “reference condition” term that is reserved to the “naturalness” of the biota (structure and function) ad that the naturalness implies the absence of significant human disturbance or alteration. They also propose terms for conditions which are different from the reference condition for biological integrity, e.g. minimal disturbed condition (MDC), historical condition

(HC), least disturbed condition (LCD) and best attainable condition (BAC) and present an review of methods used on estimating reference conditions.

Deriving numerical criteria for biological indicators in Australia and New Zealand

In Australian and New Zealand guidelines for Water Quality "Rapid Biological Assessment" (RBA) is recommended for broad-scale assessment of biodiversity (ANZECC/ARMCANZ, 2000a). RBA procedures can be carried out at relatively low costs at a large number of sites or over large geographical areas. AUSRIVAS (AUSstralian RIVer Assessment System) is a RBA method which is often used in Australia (Linke et al, 2002). AUSRIVAS is based largely on RIVPACS (River InVertebrate Prediction And Classification System), which was developed in Britain and has been employed successfully using aquatic invertebrates. In AUSRIVAS site data are compared with regional-relevant reference conditions. Because of the more varied landscape 48 models for individual states and distinct areas are developed in order to achieve better resolution for assessing sites within a particular region (Simpson, 2000). Two complementary indices summarize the outputs from the analysis of AUSRIVAS data: i) the ratio of the number of families of invertebrates at a site to the number of families expected (O/E Family) and ii) the ratio of the observed SIGNAL (Average level of Stream Invertebrate Grade Number) and the expected SIGNAL value (ANZECC/ARMCANZ, 2000a). The values of the indices are related to bands which refer to the relationship of the index value and the reference condition. See Table 5.1.

Table 5.1. Division of AUSRIVAS O/E indices into bands or categories for reporting. The names of the bands refer to the relationship of the index value to the reference condition (band A). For each index, the verbal interpretation of the band is stated first, followed by likely causes (dot-points). (ANZECC/ARMCANZ, 2000a, Table 3.2.4)

<table>
<tr><th rowspan="2">Band label</th><th rowspan="2">Band name</th><th colspan="2">Comments</th></tr>
<tr><th>O/E Families</th><th>O/E SIGNAL</th></tr>
<tr><td>X</td><td>Richer than reference</td><td>More families found than expected.
• Potential biodiversity 'hot-spot'
• Mild organic enrichment</td><td>Greater SIGNAL value than expected.
• Potential biodiversity 'hot-spot'
• Differential loss of pollution-tolerant taxa (potential disturbance unrelated to water quality)</td></tr>
<tr><td>A</td><td>Reference</td><td>Index value within range of central 80% of reference sites</td><td>Index value within range of central 80% of reference sites</td></tr>
<tr><td>B</td><td>Below reference</td><td>Fewer families than expected
• Potential disturbance either to water quality or habitat quality or both resulting in a loss of families</td><td>Lower SIGNAL value than expected
• Differential loss of pollution-sensitive families
• Potential disturbance to water quality</td></tr>
<tr><td>C</td><td>Well below reference</td><td>Many fewer families than expected
• Loss of families due to substantial disturbance to water and/or habitat quality</td><td>Much lower SIGNAL value than expected
• Most expected families that are sensitive to pollution have been lost</td></tr>
</table>

Band label	Band name	Comments	
		O/E **Families**	*O/E* **SIGNAL**
			• Substantial disturbance to water quality
D	Impoverished	Few of the expected families remain • Severe disturbance	Very low SIGNAL value • Only hardy, pollution-tolerant families remain

The more recently published guidelines for identifying high ecological value aquatic ecosystems (Aquatic Ecosystems Task Group, 2012) do not provide numerical criteria. The narrative criteria are presented in Chapter 4 of this report.

Deriving numerical criteria for biological indicators in the EU

The EU WFD recognizes the problem of comparability of biological monitoring results. To ensure comparability, the results of biological monitoring shall be expressed as ecological quality ratios (EQR) for the purposes of classification of ecological status. These ratios shall represent the relationship between the values of the biological parameters observed for a given body of surface water and the values for these parameters in the reference conditions applicable to that body. The ratio shall be expressed as a numerical value between zero and one, with high ecological status represented by values close to one and bad ecological status by values close to zero. Each Member State shall divide the ecological quality ratio for their monitoring system for each surface water category into five classes ranging from high to bad ecological status by assigning a numerical value to each of the boundaries between the classes. The value for the boundary between the classes of high and good status, and the value for the boundary between good and moderate status shall be established through an intercalibration exercise.

The intercalibration process is aimed at ensuring comparability of the classification results of the WFD assessment methods developed by the member states for the quality elements. The European Commission facilitates an exchange of information between members states leading to the identification of a range of sites in each ecoregion in the Community. Geographical Intercalibration Groups have been established and a number of guidelines for the intercalibration are published (EC, 2003, EC, 2010). The process has been more time consuming and methods are more complex than originally expected, but the development of assessment methods has been a transparent process and has resulted in improved and more standardized methods for assessing water bodies in Europe (Hering et al, 2010). For some biological elements (BQE) and water categories, such as benthic invertebrates in coastal waters (Borja et al., 2007, 2009a cited by Hering et al, 2010) and phytoplankton biomass in lakes (as chlorophyll a), the intercalibration results were surprisingly clear: most of the assessment systems give the same pattern. For other BQEs, such as phytoplankton composition in lakes, the first intercalibration results differed so much for certain regions (Central-Baltic GIG). For some BQEs, such as fish, and one water category (transitional waters) the assessment systems had not been sufficiently developed to allow any intercalibration results in the first phase (2004–2008). Due to shortcomings the EC extended the intercalibration process with a second phase (2009-2012) to allow completion of intercalibration of all biological elements in all water categories (EC, 2010).

The following tentative scale of EQR values was established by a group of experts, based on their judgment of what would be appropriate intervals from high to bad in terms of species richness of benthic macroinvertebrates:

High status:	1.00 – 0.80
Good status:	0.80 – 0.60
Moderate status:	0.60 – 0.40
Poor status:	0.40 – 0.20
Bad status:	<0.20

In an extensive overview of 297 biological assessment methods applied in Europe, Birk et al (2012) found that the class boundary setting was mostly based on statistical principles (45%) and 37% of the assessment methods used ecological approaches alone or together with other approaches. In 18 % of cases class boundary setting was limited to expert judgments. They advocate better reflection of the necessary sampling effort and precision, full validation of pressure-impact relationships and an implementation of more ecological components into classification.

Deriving numerical criteria for biological indicators in the USA

In the USA numerical biological criteria have been developed by some states. A few cases are described in the primer on using biological assessment (EPA, 2011). The Pennsylvania Department of Environmental Protection (PA DEP) has developed a new benthic macroinvertebrate index of biotic integrity (IBI) to assess the health of wadeable, freestone streams. Additionally, PA DEP calibrated a benthic macroinvertebrate Biological Condition Gradient (BCG) and is exploring using the BCG to more precisely describe biological characteristics in Pennsylvania streams. Potentially, the BCG can be used in conjunction with the IBI to identify aquatic life impairments and to describe the biological characteristics of waters assigned special protection. The case description gives an example of the relation of the IBI score and the Biological Condition Gradient level assignment.

Arizona has also developed numeric biological criteria to protect aquatic live and has established those values as water quality standards. On the basis of statistical analysis of reference, stressed, and test data sets, an attainment threshold of 25% of the reference site distribution was selected to be protective of the aquatic life use. The nonattainment biological criteria threshold was set at the 10th percentile of reference, the level at which a majority of stressed samples occurs in the Arizona Department of Environmental Quality database. An inconclusive zone falls between the 10% and 25% of reference. The zone of uncertainty encompasses variability in Arizona IBI (index of biological integrity) scores near the 25%. To verify the biological integrity of the inconclusive samples, verification sampling is required before making an attainment decision.

In the USA the need for better comparability of the result of biological assessment is recognized too. A National Wadeable Streams Assessment (WSA) has been carried out to evaluate the biological condition of streams in the USA (USEPA 2006). Macroinvertebrate assemblages in each stream were analyzed with a multimetric index of biotic integrity and observed/expected indices were derived from the River InVertebrate Prediction and Classification System (RIVPACS). Ultimately, 1625 sites were used and reference data were used to help to define nine large eco-regions. It is concluded that the WSA provided an unparalleled opportunity to push the limits of the conceptual and technical understanding how to best apply reference-condition approach to a real world (Herlihy et al, 2008).

5.3. Criteria for general physical and chemical indicators

The common character of the general physical and chemical indicators is that these indicators represent natural-occuring physical and chemical quality elements. The main indicators in this group concern oxygenation conditions, the nutrient condition, thermal conditions, transparency, acidification and salinity. When ambient values are too high or too low in comparison to reference conditions, serious degradation of the aquatic ecosystem may be caused.

Deriving numerical values for general physical and chemical indicators in Australia and New Zealand

For high conservation/ecological sites the Australian and New Zealand guideline (ANZECC/ ARMCANZ, 2000a) recommend that there should be no change from ambient conditions. For slightly or moderately disturbed systems trigger values can be derived in terms of 80th and/or 20th percentile values obtained from a appropriate reference system. For stressors that cause problems at high concentrations (e.g. nutrients, SPM, biochemical oxygen demand (BOD), salinity) is recommended to take the 80th percentile of the reference distribution as the low-risk trigger value. For stressors that cause problems at low levels (e.g. low temperature water releases from reservoirs, low dissolved oxygen in waterbodies), use the 20th percentile of the reference distribution as a low-risk trigger value. For stressors that cause problems at both high and low values (e.g. temperature, salinity, pH), the desired range for the median concentration is defined by the 20th percentile and 80th percentile of the reference distribution. Default trigger values has been derived for five geographical regions across Australia and New Zealand. As an example, in Table 5.2 and 5.3 the results of the derivation for New Zealand are given. Factsheets for the general indicators, including the significance and effects of the indicator change on the aquatic ecosystems have been published. (ANZECC/ARMCANZ, 2000b).

Table 5.2. Default trigger values for physical and chemical stressors in New Zealand for slightly disturbed ecosystems. Trigger values are used to assess risk of adverse effects due to nutrients, biodegradable organic matter and pH in various ecosystem types. Chl *a* = chlorophyll *a*, TP = total phosphorus, FRP = filterable reactive phosphate,d TN = total nitrogen, NO_x = oxides of nitrogen, NH_4^+ = ammoniacal nitrogen, DO = dissolved oxygen. (ANZECC/ ARMCANZ, 2000a, table 3.3.10)

Ecosystem type	**Chl *a***	**TP**	**FRP**	**TN**	**NO_x**	**NH_4^+**	**DO[e] (% saturation)**		**pH[e]**	
	(µg L^{-1})	(µg P L^{-1})	(µg P L^{-1})	(µg N L^{-1})	(µg N L^{-1})	(µg N L^{-1})	Lower limit	Upper limit	Lower limit	Upper limit
Upland river	na[a]	26[b]	9[b]	295[b]	167[b]	10[b]	99	103	7.3	8.0
Lowland river	no data	33[c]	10[c]	614[c]	444[c]	21[c]	98	105	7.2	7.8

na = not applicable

a = monitoring of periphyton and not phytoplankton biomass is recommended in upland rivers — values for periphyton biomass (mg Chl *a* m^{-2}) to be developed. New Zealand is currently making routine observations of periphyton cover.

b = values for glacial and lake-fed sites in upland rivers are lower;

c = values are lower for Haast River which receives waters from alpine regions;

d = commonly referred to as dissolved reactive phosphorus in New Zealand;

e = DO and pH percentiles may not be very useful as trigger values because of diurnal and seasonal variation — values listed are for daytime sampling.

Table 5.3. Default trigger values for water clarity (lower limit) and turbidity (upper limit) indicative of unmodified or slightly disturbed ecosystems in New Zealand (ANCECC/ ARMCANZ, 2000a, table 3.3.11)

Ecosystem types	**Upland rivers**[a b]		**Lowland rivers**	
	Clarity (m^{-1})[c d]	Turbidity (NTU)[c d]	Clarity (m^{-1})	Turbidity (NTU)
	0.6	4.1	0.8	5.6

a = Light availability is generally less of an issue in NZ rivers and streams than is visual clarity because, in contrast to many of Australia's rivers, most NZ rivers are comparatively clear and/or shallow. Davies-Colley et al. (1992) recommend that visual clarity, light penetration and water colour are important optical properties of an ecosystem which need to be protected (see Volume 2). Neither turbidity nor visual clarity provide a useful estimate of light penetration — light penetration should be considered separately to turbidity or visual clarity. Clarity relates to the transmission of light through water and is measured by the visual range of a black disk (see NZ Ministry for the Environment (1994)) or a Secchi disk.
b = Recent work has shown that at least some NZ indigenous fish are sensitive to low levels of turbidity; however, it may also be desirable to protect the naturally high turbidities of alpine glacial lakes to prevent possible ecological impacts, such as change in predator–prey relationships.
c = Note that turbidity and visual water clarity are closely and inversely related, and the 80th percentile for turbidity is consistent with the 20th percentile for visibility and vice versa.
d = Clarity and turbidity values for glacial sites in upland rivers are lower and higher, respectively.

Deriving numerical values for general physical and chemical indicators in the EU

In the EU WFD the ranges and levels established for the general physico-chemical quality elements must support the achievement of the values required for the biological quality elements at good status or good potential, as relevant. Since the values for the biological quality elements at good status will be type-specific, it is assumed that the ranges and levels established for the general physico-chemical quality elements should also be type-specific. All member states shall derive general water quality standards and classify their water bodies in one of the five classes. For example the UK published in the first phase standards (related to certain biological elements indicators) in rivers for BOD, dissolved oxygen (macro invertebrates), ammonia (macroinvertebrates), pH (fish) and phosphorus (diatoms). For lakes standards are given for dissolved oxygen (fish), conductivity (all species), acid neutralizing capacity (diatoms) and total phosphorus (phytoplankton biomass, macrophytes and phytobenthos). A large number of new additional standards are scheduled. Concerning eutrophication assessment an extensive guideline document has been published (EC, 2009). Cardoso et al (2009) published an overview of class boundaries based on average phytoplankton chlorophyll concentrations for different type of lakes. Class boundaries for the oligotrophic, mesotrophic, eutrophic, polytrophic and hyper-trophic lakes are presented as well as for class boundaries of the EU WFD (reference, high/good and good/moderate boundaries).

Looking at the progress as was presented in the River Basin Management Plans by all Member States, it is concluded that standards have been set for some supporting physico-chemical and hydromorphological quality elements. However, most of the physico-chemical standards relate to nutrients and organic matter and are in most cases not clearly linked to the good/moderate class boundaries for the sensitive biological quality elements. If the program of measures is based on nutrient standards that are too relaxed relative to the good/moderate boundaries for the biological quality elements, then good ecological status may not be achievable (EC, 2012b).

Deriving numerical values for general physical and chemical indicators in the USA

The nationally recommended Aquatic Life Criteria of the USA EPA include the following general physical and chemical indicators: nutrients, oxygen, pH, solids suspended and transparency and temperature of water. For solids suspended and transparency only narrative description are available on national level, the criteria for the other indicators are described in documents taking into account ecoregional differences.

To address nitrogen/phosphorus pollution in rivers and streams EPA recommends three types of scientifically defensible empirical approaches for setting numerical criteria (USEPA 2000a) and in lakes and reservoirs (2000b): reference condition approaches, mechanistic modeling, and stressor-response analysis. More recently a four-step process for estimating and interpreting stressor-response relationships for deriving numerical criteria to address nitrogen/phosphorus pollution was developed (USEPA, 2012).

5.4. Criteria for toxic chemicals

The term toxicant is given to chemical contaminants such as metals, aromatic hydrocarbons, pesticides and herbicides. These toxicants are directly or indirectly discharged into aquatic ecosystems. The natural background concentrations are zero, except for metals. So, for the derivation of criteria reference values cannot be used. The common methods for deriving criteria are based on toxicity data from acute and chronic toxicity tests in laboratories and (semi)field experiments and to a lesser extent specific field monitoring studies.

In Australia, US and Europe during the last decades methods to derive criteria for toxic substances have been established and standards are set based on a growing number of toxicity data. Most criteria relate to the concentration of a toxic substance in water, but for a number of toxic substances also the concentration in sediment and biota may be relevant to protect aquatic life. Especially for those substances which have with very low water solubility have a tendency to accumulate in the sediment and/or to bioaccumulate through the food web . If these substances pose a significant risk through indirect toxicity (i.e. secondary poisoning resulting from food-chain transfer) and their analysis is more feasible in other environmental matrices, such as biota and/or sediments, then a sediment or biota criterion may be required alongside, or instead of, the water column quality criterion.

A short overview of the methods applied in the Australia/New Zealand guidelines, in the EU WFD and by the EPA for deriving criteria for toxic substance are described in Annex 2, because these methods have a rather technical character. All the methods are based on ecotoxicology experiments in laboratories and include both acute and chronic toxicity tests for aquatic taxa like algae, zooplankton and fish. If data are available bioaccumulation is taken into account in all guidelines, as well as data from (semi-) field studies. However, the defined protection levels differ and also the approaches to calculated criteria for a defined level of protection are more or less different. Different statistical distribution models and safety factors are applied to take into account the differences in number and reliability of toxicity data.

Numerical values for toxic substances in Australian and New Zealand

In the Australian/New Zealand guideline (ANZECC/ARMCANZ, 2000a,2000b) the trigger values derived using the statistical distribution method were calculated at four different protection levels, 99%, 95%, 90% and 80%. Here, protection level signifies the percentage of species expected to be protected. The decision to apply a certain protection level to a specific ecosystem is the prerogative of each particular state jurisdiction or catchment manager, in consultation with the community and stakeholders. State jurisdictions or catchment managers can choose to apply different levels of protection to different ecosystem conditions if there is confidence that the disturbance is due to an overall physico-chemical disturbance and not just structural alteration.

Numerical values for toxic substances in the EU

The EU WFD (EC, 2000) regulated that Member States shall derive all standards for toxic substances. However, in 2008 the Directive was amended on this subject (EC, 2008). For a more effective regulation of surface water protection, it was decided that it is appropriate to set up Environmental Quality Standards (EQSs) for pollutants classified as priority substances at Community level and to leave it to Member States to lay down, where necessary, rules for remaining pollutants at national level. The EU Directive of 2008 (EC, 2008) provide EQSs for 41 pesticides, biocides (non-agricultural pesticides and heavy metals, as well as other groups of substances such as certain flame retardants. This includes 33 substances which have been designated as priority substances. EQSs are given as annual average concentrations and for some substances as maximum acceptable concentration. With the exception of cadmium, lead, mercury and nickel the EQS set up in this Annex are expressed as total concentrations in the whole water sample. In the case of metals the EQS refers to the dissolved concentration. For mercury and its compounds, an EQS of 20 µg/kg, for hexachlorobenzene an EQS of 10 µg/kg, and/or for hexachlorobutadiene an EQS of 55 µg/kg have been established on community level. These EQSs being for prey tissue (wet weight) were chosen as the most appropriate indicator from among fish, mollusks, crustaceans and other biota.

Numerical values for toxic substances in the USA

The recommended water quality criteria for aquatic life in the USA include a list of approximately 60 substances, most of them are toxic pollutants. The criteria contain two expressions of allowable magnitude: a criterion maximum concentration (CMC) to protect against acute (short-term) effects; and a criterion continuous concentration (CCC). The criteria are derived for the total concentration of a toxicant in the water column. Only for heavy metals EPA recommend the application of dissolved metal concentrations, which more closely approximate the bioavailable fraction.

Comparison of numerical values for toxic substances

In Table 5.3. a small selection of water quality criteria in the guidelines of Australian/New Zealand, EU and USA is presented. The table shows that a few water quality criteria for certain substances are nearly the same, i.e. the 99% protection in Australia/New Zealand and the annual average values of the EU WFD for cadmium, mercury and naphtalene. Comparing the lowest criteria in Australia/New Zealand (99% protection), Europe (annual averages) and USA (CCC-values) a number of criteria differs less than a factor 10: cadmium, lead, mercury, nickel. But especially the criteria for diamizon, endosulfan and simazine differ by a factor between 10 and 100. No far-going conclusions may be drawn from these comparisons, because – among others - the way of deriving are different, the used toxic data may vary, the definition of the protection level and the application of the criteria in water management decision may be different. However, it is clear that deriving water quality criteria is a complex process of integration of high-level scientific knowledge, of taking into account a large number of uncertainties and of policy-definitions of protection levels. Because criteria for toxic substances are in general not site-specific, except for heavy metals, it may be recommended that these criteria would be derived on international level as has been carried out for the WHO drinking water standards. So, the best knowledge in the world may be applied in deriving criteria and world-wide accepted criteria may play an important role in the protection of aquatic ecosystems.

Table 5.4. Water quality criteria for toxic substances in the Australian/New Zealand guidelines (ANZECC/ARMCANZ, 2000a), in the European Water Framework directive (EUWFD, 2008) and as recommended by US EPA (2104). Note: see references for explanatory remarks concerning the values.

	Australian/New Zealand Trigger Values in µg/l[1]		European Environmental Quality standards in µg/l[1]		US EPA National Recommended Water Quality criteria in µg/l[1]	
	90% protection of species	99% protection of species	Annual average	Maximum allowable	CMC (Acute)	CCC (Chronic)
Cadmium[2]	0.4	0.06	0.09	0.6	2.0	0.25
Lead[2]	5.6	1.0	7.2	na	65	2.5
Mercury[2]	1.9	0.06	0.05	0.07	1.4	0.77
Nickel[2]	13	8	20	na	470	52
Naphatalene	37	2.5	2.4	na	na	na
Pentachlorophenol	17	3.6	0.4	na	19	15
Tributyltin compounds			0.0002		0.4	0.007
Diamizon	0.2	0.0003	na	na	0.17	0.17
Endosulfan	0.2	0.03	0.005	0.01	0.22	0.22
Simazine	11	0.2	1	4	na	na
[1] Total concentrations in water, but for metals total dissolved concentrations						
[2] Criteria depend on hardness in the water column and in Europe on natural background and other water quality parameters						

5.5 Criteria for hydromorphological indicators

The hydromorphological condition of an aquatic ecosystem can be characterized by the hydrologic regime (quantity and dynamics of water flow) and morphological conditions (depth, structure and substrate of the bed and riparian zones). The hydromorphological indicators are relevant to analyze the impact of hydromorphological changes on the functioning and structure of the biological community and to develop strategies for recovery of a disturbed system.

Criteria for hydromorphological indicators in Australia and New Zealand

In the Australian/New Zealand guidelines (ANZECC/ARMCANZ, 2000a) the hydromorphological indicator “flow” is mentioned as one of the physical and chemical stressors. The factsheets “Environmental flows” for (ANZECC/ARMCANZ, 2000b) contain guidelines for the establishment of flow requirements needed to sustain the ecological values of rivers. As background a brief summary of the ecological effects that can be caused by changed flow regimes due to changes in the catchment, weirs and dams and abstraction or diversion of water is presented. A review is given of the methods that are currently in use for determining environmental flow requirements. As stated in the factsheet, a generic process for setting flow requirements is needed, since each river system will have different flow requirements and the publication of ‘magic numbers’ or ‘rules of thumb’ is not possible. There are still many unknowns associated with the setting of flow requirements, in particular the detailed relationships between flow and key ecological processes. Concerning future flow guidelines Arthington et al (2006) suggest that a region-by-region and country-by country analysis using hydrological classification methods combined with ecological calibration could fairly rapidly provide global environmental flow guidelines within the coming decade. The development of scientifically credible flow management guidelines in distinctive physiographic and ecological regions of the world would make a major contribution to the resolution of conflicts over shared water resources, and thereby help to ensure that societies continue to benefit from the biodiversity and essential ecological goods and services provided by river ecosystems.

The factsheet “Hydrodynamics” (ANZECC/ARMCANZ, 2000b) deals with the hydrodynamics in impounded waters (i.e. lakes, reservoirs, estuary). Two indicators are mentioned: i) residence time of the water which may influence the growth of cyanobacteria. The recommended guideline is that residence times should be reduced to less than the average cell doubling time of the species of concern so that cells are flushed out of the system to prevent nuisance growths of cyanobacteria in standing water bodies. ii) Thermal stratification which may occur in summer and may lead to dramatic physical, chemical and biological changes both in the upper layer as well as in the lower layer, i.e. anoxic conditions in the lower layer and releases of iron, manganese and nutrients to the upper layer.

Criteria for hydromorphological indicators in the EU

In the EU WFD hydromorphological quality elements are required for determination of high status. The values of the elements should reflect totally, or nearly totally undisturbed conditions. For other status classes the hydromorphological elements are required to have conditions consistent with the achievement of the biological elements. In the guideline typology, reference conditions and classification systems (EC, 2003) the hydromorphological elements supporting the biological elements are listed (See Table 5.5).

Hydromorphological standards are less well developed than nutrient standards. Further developments are clearly needed, using available CEN (European Committee for

Standardization) standards for rivers and lakes habitat surveys, as well as new research results and good examples from practice (EC, 2012). The REFORM project (Restoring rivers FOR catchment Management) is funded by the European Commission with the aim to provide a framework for improving the success of hydromorphological restoration measures to reach, in a cost-effective manner, target ecological status or potential of rivers. A comprehensive review on ecological responses to hydromorphological degradation and restoration, was published in 2013 (Wolter et al, 2013)

Table 5.5 Hydromorphological elements supporting the biological elements (EC, 2003, Table 2)

Hydromorphological elements supporting the biological elements	
• *Quantity and dynamics of water flow* • *Connection to ground water bodies* • *River continuity* • *River depth and width variation* • *Structure and substrate of the river bed* • *Structure of the riparian zone*	• *Quantity and dynamics of water flow* • *Residence time* • *Connection to the ground water body* • *Lake depth variation* • *Quantity, structure and substrate of the lake bed* • *Structure of the lake shore*

In relation to changes in hydromorphological conditions it is important to note that member states may designate a body of surface water as artificial or heavily modified, when the changes to the hydromorphological characteristics of that body which would be necessary for achieving good ecological status would have significant adverse effects on, among others (i) the wider environment; (ii) navigation, including port facilities, or recreation; (iii) activities for the purposes of which water is stored, such as drinking-water supply, power generation or irrigation; (iv) water regulation, flood protection, land drainage, or (v) other equally important sustainable human development. For these artificial and heavily modified waters reference conditions are not applicable. These hydromorphological conditions are considered as a given condition on which the ecological potential should be established.

Criteria for hydromorphological indicators in the USA

The chances of the physical habitat structure such as sedimentation from stormwater runoff and physical habitat alterations from dredging, filling, and channelization, and changes in the flow regime are mentioned as stressor which may be analyzed in biological assessments (USEPA, 2011). On federal level no narrative nor numerical values are presented for these indicators, but a National Rivers and Streams Assessment 2008–2009 (USEPA,2014) was carried out in which – among others - four indicators of physical habitat condition were assessed: excess streambed sediments, riparian vegetative cover (vegetation in the land corridor surrounding the river or stream), riparian disturbance (human activities near the river or stream), and in-stream fish habitat. Also stream conditions were considered in this extensive study. Of these, poor riparian vegetative cover and high levels of riparian disturbance are the most widespread stressors, reported in 24% and 20% of the nation’s river and stream length, respectively. However, excess levels of streambed sediments, reported in 15% of river and stream length, were found to have a somewhat greater impact on biological condition. Poor biological condition is 60% more likely in rivers and streams with excessive levels of streambed sediments (USEPA, 2014).

5.6. Integrated ecological assessment

Integrated ecological assessment in Australia and New Zealand

The Australia/New Zealand guidelines provide decision trees for biological the assessment of biological assessment, and assessing general water quality indicators and toxicants in ambient waters. If trigger values are exceeded further site-specific investigations are recommended to examine whether the water quality is at low or high risk (Figure 5.1). In the case of high risk remedial actions should be initiated. The guidelines don't provide methods for integration of the results of biological, physical, chemical and hydromorphological indicator values. A comprehensive framework and guidance for the monitoring and reporting of fresh and marine waters and groundwater (ANZECC/ARMCANZ, 2000c) provide extensively methods for statistical data analysis and for reporting, but no methods are described how to rank the information to make the results comparable with results of assessments in other aquatic ecosystems.

The Aquatic Ecosystem Toolkit to guide the identification of high ecological value aquatic ecosystems includes an integrated ecological condition assessment framework, but this module is still under development and will probably be published at the end of 2014.

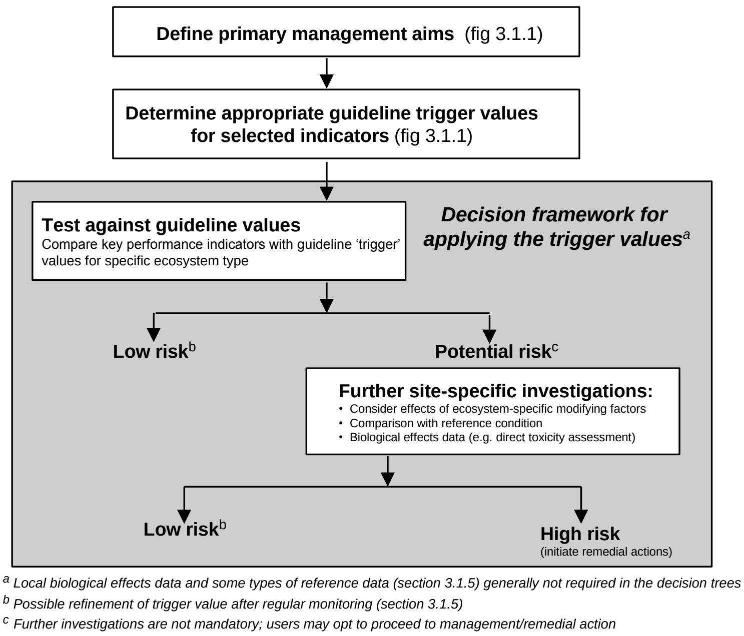

Figure 5.1 Decision tree framework ('guideline packages') for assessing the physico-chemical stressors in ambient waters The references in the flowchart refer to the original document (ANZECC/ARMCANZ, 2000a, Figure. 3.3.1)

Integrated ecological assessment in the EU

In the EU WFD guideline on typology, reference conditions and classification systems (EU WFD, 2003) a scheme is presented concerning the relative roles of biological, hydromorphological and physico-chemical elements in status classification (see Figure 5.2). For highly modified water bodies and artificial water bodies the scheme deviates a little

because reference conditions are not available. The main reason for this guideline is to ensure comparability of the monitoring results of the systems operated by each Member State. In a recent overview of the status of the ecological status, based on the River Basin Management Plans, the results show that only around 44% of rivers and 33% of transitional waters are reported to be in high or good status. 56% of the lakes are reported to be in good or high status, and 51% for coastal waters (EU, 2012).
A recent review of 252 WFD-compliant assessment systems published on http://www.wiser.eu/results/methods-db revealed that a large proportion (46%) of these systems target various forms of water pollution (acidification, eutrophication, heavy metals, pollution by organic compounds, and pollution by organic matter). Other frequently addressed stress types are general degradation (19%), hydromorphological degradation (10%), habitat destruction (8%), riparian habitat alteration (5%), catchment land use (4%), flow modification (4%) and impact of alien species (4%), resulting in a higher diversity of stressors being assessed (Hering et al, 2010).

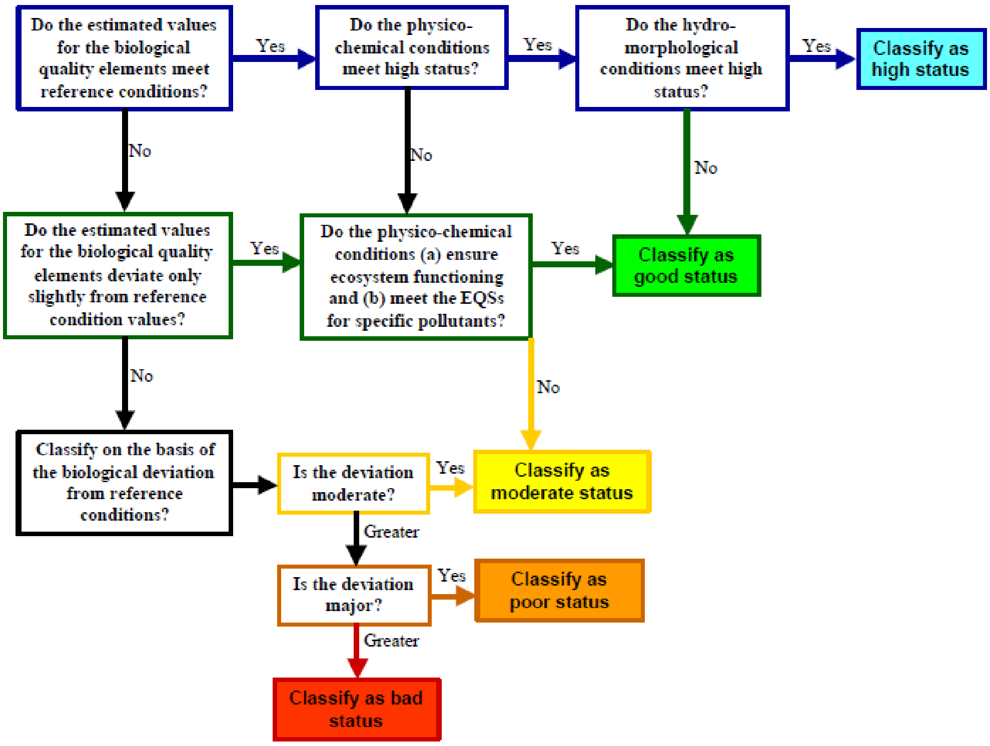

Figure 5.2 Indication of the relative roles of biological, hydromorphological and physicochemical quality elements in ecological status classification according the normative definitions in Annex V,1.2 of the EU WFD (EU WFD, 2003, Figure 3).

Integrated ecological assessment in the USA

In the USA the Biological Condition Gradient (BCG) was designed to provide a means to map different indicators on a common scale of biological condition to facilitate comparisons between programs and across jurisdictional boundaries in context of the Clean Water Act. The US EPA recommend this tool to describe how biological attributes of aquatic ecosystems

change along a gradient of increasing anthropogenic stress (USEPA 2012). It provides a framework for understanding current conditions relative to natural, undisturbed conditions as described in Chapter 3 (Figure 3.2). Some states, such as Maine and Ohio, have used a framework similar to the BCG to more precisely define their designated aquatic life uses.
It is a multistep process to calibrate a BCG to local conditions (Figure 5.3). That process is followed to describe the native aquatic assemblages under natural conditions, identify the predominant regional stressors and describe the BCG, including the theoretical foundation and observed assemblage response to stressors.

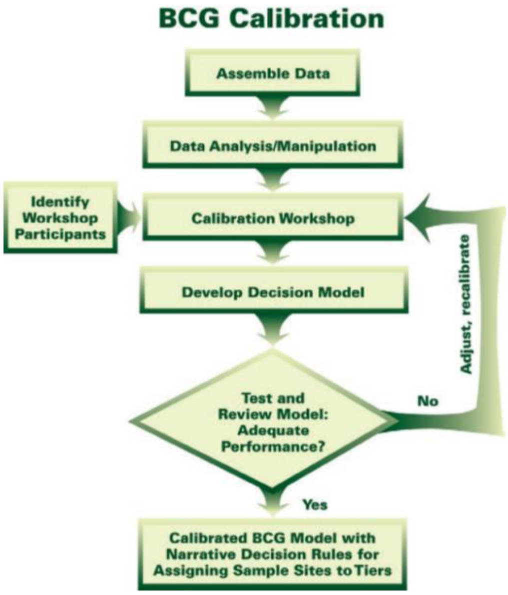

Figure 5.3. Steps in a Biological Condition Gradient calibration (USEPA, 2012, figure 2-3)

5.7. Relations between biological indicators and stressors

In the three guidelines considered a lot of attention is put on the identification of the cause of aquatic life impairments. In a short review some subjects will be highlighted in this report.

Relation between biological indicators and stressors in Australia and New Zealand

In the Australian and New Zealand guidelines two types of physical and chemical stressors that directly affect aquatic ecosystems are distinguished : those that are directly toxic to biota, and those that, while not directly toxic, can result in adverse changes to the ecosystem (e.g. to its biological diversity or its usefulness to humans). See also Figure 4.1. Excessive amounts of direct-effect stressors cause problems, but some of the elements and compounds covered here are essential at low concentrations for the effective functioning of the biota — nutrients such as phosphorus and nitrogen, and heavy metals such as copper and zinc, for example. The guidelines provide a narrative description of the biological effects of unnatural changes in these general physical and chemical indicators, e.g increasing levels of nutrients, lack of dissolved oxygen, excess suspended particulate matter, unnatural change in salinity , in temperature or in pH. For toxicants it is recommended to perform biological effects assessment if trigger values are exceeded and site-specific factors that may modify the guideline trigger value have been considered. The guidelines don’t provide more detailed approaches for identification of stressors. Site-specific problem analyses with help of advanced assessment methods seems to be the way of doing.

Relations between biological indicators and stressors in the EU

In the guideline concerning establishing reference conditions (EC, 2003) it is recommended that the use of both ecological and pressure criteria may be the most efficient way for screening of potential reference sites or values or needed to aid in at least a preliminary assessment of status of waters. Indeed, to establish reference conditions it could be most cost-effective to start with pressure criteria, because the reference community is defined as the biological community expected to occur where there is no or only very minor anthropogenic disturbance. In other words, to avoid circularity (i.e. use of the same variable to delineate and validate reference condition), pressure criteria may be used conveniently to screen for sites or values representing potential reference conditions. Once identified, biological elements should be used to corroborate this ecological high status. See Figure 5.4. Uncertainty is a problematic issue in the first RBMPs (River Basin Management Plans) in the assessment of ecological status (EU, 2012). There is no common understanding across Member States on how uncertainty should be assessed, and the information reported on uncertainty is often insufficient or missing in the RBMPs and associated documents. This lack of information concerns especially the uncertainty in the assessment methods themselves, e.g. uncertainty in relationships between the biological metrics used and the main pressures, as well as uncertainty in the boundary setting.

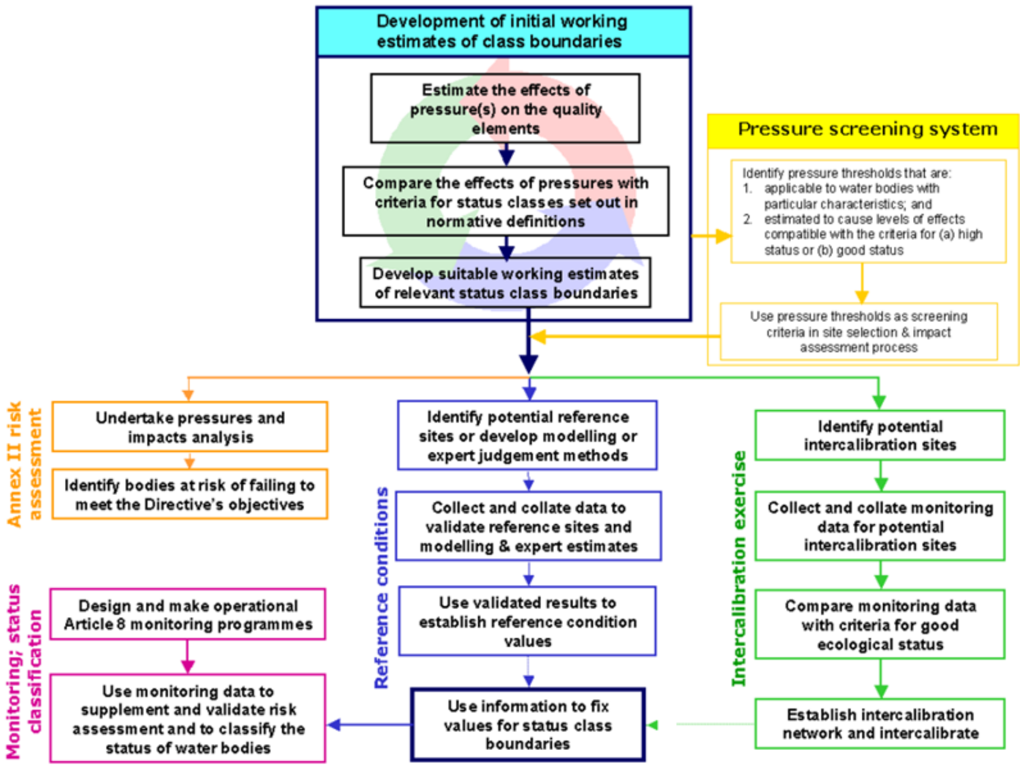

Figure 5.4. The respective roles of pressure criteria and ecological criteria in identifying status classes (EU WFD, 2003)

Relations between biological indicators and stressors in the USA

Besides biological assessment program review and the biological condition gradient a third tool is recommended in the primer on using biological assessments: stressor identification (SI) and casual analysis/diagnosis decision information system: CADDIS (USEPA, 2011). In 2000 the Stressor Identification Guidance Document was published (USEPA, 2000) with the intention to lead water resource managers through a formal and rigorous process that identifies stressors causing biological impairment in aquatic ecosystems and provides a structure for organizing the scientific evidence supporting the conclusions.
The core of the SI process consists of the following three main steps:

- Listing candidate causes of impairment.
- Analyzing new and previously existing data to generate evidence for each candidate cause.
- Producing a causal characterization using the evidence generated to draw conclusions about the stressors that are most likely to have caused the impairment.

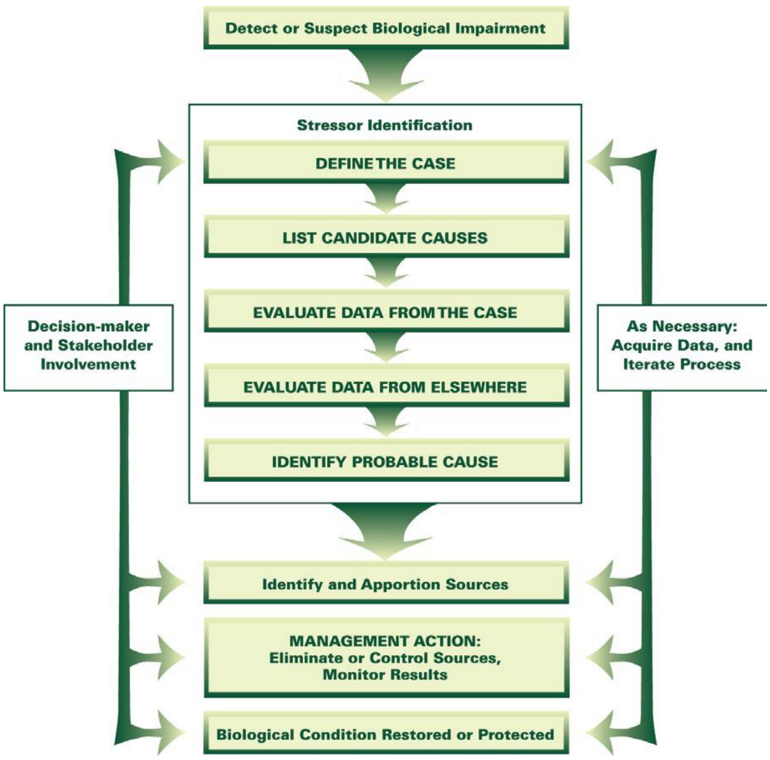

Figure 5.5. Stressor identification process (USEPA, 2011).

The SI process is an iterative process as shown in Figure 5.5. The kind of information needed includes information on the type of impairment, the extent of the impairment, any evidence of the usual causes of impairment (e.g., hydrological alteration, invasive species, habitat loss, toxicants, total nitrogen and phosphorus), and other information from the site. The evidence is considered first and then other, less direct kinds of evidence are gathered and evaluated, if needed. For example, one might consider other situations that are similar and can provide useful insights. CADDIS is an online application of the SI process that uses a step-by-step guide, worksheets, technical information, and examples to help scientists and engineers find, access, organize, share, and use environmental information to evaluate causes of biological effects observed in aquatic systems such as streams, lakes, and estuaries. CADDIS also contains updates, clarifications, and additional material developed since the SI guidance document was published in 2000.

5.8 Findings

- The definitions as given by Enderlein et al (1997) seems to be still appropriate looking at the use of terms at present used in the guidelines considered. The definitions of Enderlein make a clear difference between recommended values (criteria or guidelines), established objectives and enforceable standards.
- Reference conditions play a major and increasing role in deriving biological criteria and in describing a standard or benchmark against the current condition is compared. So, there is a need to bring some consistency to the use of the term. Stoddard et al (2006) argued the need for a “reference condition” term that is reserved to the “naturalness” of the biota (structure and function) ad that the naturalness implies the absence of significant human disturbance or alteration.
- Numerical criteria for biological indicators are nearly always related to reference conditions e.g. the ratio of species observed for the site examined and known form reference sites.
- A large number of biological assessment methods is available and the number of comparisons of these methods is rapidly growing as well as the number of sites were these methods are applied.
- Guidelines for quality assessment of natural-occuring physical and chemical quality elements as oxygenation conditions, the nutrient condition, thermal conditions, transparency, acidification and salinity are available. Numerical criteria can be derived with help of reference conditions. Especially on the impact of discharges of nutrients a huge amount of data are published.
- Comprehensive guidelines are available for deriving criteria for toxic substances. It is clear that deriving water quality criteria is a complex process of integration of high-level scientific knowledge, taking into account a large number of uncertainties and of policy-definitions of protection levels. Because criteria for toxic substances are in general not site-specific, except for heavy metals, it may be recommended that these criteria would be derived on international level as has been carried out for the WHO drinking water standards. So, the best knowledge in the world may be applied in deriving criteria and world-wide accepted criteria may play an important role in the protection of aquatic ecosystems.
- The hydromorphological condition of an aquatic ecosystem characterized by i.e. quantity and dynamics of water flow and morphological conditions as depth, structure, substrate of the bed and riparian zones) are relevant because of the impact of hydromorphological changes on the functioning and structure of the biological community and to develop strategies for recovery of a disturbed system. Hydromorphological reference conditions are needed to develop general and site-specific criteria for hydromorphological assessment and restoration.
- Step-by step approaches and decision trees are developed to support the ecological assessment based on biological, physico-chemical and hydromorphological quality indicators as well as methods for classification of the status of a aquatic ecosystem.
- In the guidelines of Australia/New Zealand, EU and USA a lot of attention is put on methods for the identification of cause of aquatic impairments and to clarify the relations between biological structure and functioning and the stressors which may

influence the biological structure and functioning. However, the presence of sevral stressor at the same time and the complexity of the ecosystem caused that clear impact of certain stressors on aquatic life cannot be proved easily.

6. Application of water quality guidelines at basin level to protect freshwater ecosystems

Water Quality Guidelines (WQGs) need implementation mechanisms to achieve objectives established in the guidelines. This chapter focuses on the role of (river) basin organizations to implement water quality guidelines in order to protect fresh water ecosystems. The concept of the river basin as an unit of water management is widely accepted as an indispensable approach needed for integrated water resources management (IWRM). As the protection of fresh water ecosystems should be considered as part of IWRM, basin organizations can play an important role in supporting the implementation of water quality guidelines for ecosystems. Moreover, a large number of aquatic ecosystems are transboundary systems and consequently protection of these ecosystems should include the whole catchment area.

The role of basin organizations in IWRP and in the application of WQGs will be reviewed. Also attention will be paid on mandates and organizational structures of basin organizations, compliance and enforcement, stakeholder and public participation, the role of knowledge and reporting and evaluation.

6.1. Integrated water resource management and the role of (river) basin organizations

Basin organizations (BOs) are specialized organizations set up by political authorities, and in some cases in response to stakeholder demands. BOs deal with the water resource management issues in a river basin, a lake basin, or across an important aquifer.

Basin organizations provide a mechanism for ensuring that land use and needs are reflected in water management - and vice versa. Experience has varied dramatically in the ability of these organizations to achieve IWRM. Their functions vary from water allocation, resource management and planning, to education of basin communities, to developing natural resources management strategies and programs of remediation of degraded lands and waterways. They may also play a role in consensus building, facilitation and conflict management.

Recent developments has focused on an integrated river basin management (IRBM), a subset of IWRM, and catchment management rather than single sector approaches. Key characteristics of sustainable river basin management are:

- Basin-wide planning to balance all user needs for water resources and to provide protection from water related hazards;
- Wide public and stakeholder participation in decision-making, local empowerment;
- Effective demand management;
- Agreement on objectives within the basin, and mechanisms for monitoring those agreements;
- Adequate human and financial resources.

By Pegram et al (2013) a book concerning river basin planning has been drafted as part of an extended dialogue between a team of international experts led by the World Wild Fund for Nature (WWF) and a Chinese team led by the General Institute of Water resources and Hydropower Planning and Design (GIWP), Ministry of Water resources, China. The book present a comprehensive overview of strategic basin planning and techniques for basin planning. The following characteristics for the strategic approach to basin planning are mentioned:

- trade-offs between economic, social and environmental objectives, and between existing and potential future demands
- a sophisticated approach to recognizing environmental water needs and the importance of aquatic ecosystem functioning in providing goods and services
- understanding basin interactions, including the range of hydrological, ecological, social and economic systems and activities at work at basin
- robust scenario-based analysis to address uncertainty in future development and climate, by assessing alternative hydro-economic development, social justice and environmental protection.

It is stated that modern basin planning is increasingly developing ecological based objectives, for example related to species and ecosystems, rather than more traditional "environmental" objectives, such as water quality objectives.

Varying opinions exist about the most effective scale of application: the success of a river basin organization may depend on such things as, the level of human and institutional capacity of the civil society, the degree to which water resources are developed, and climatic variability (arid versus temperate river basins, for example). The policy and legislative framework will govern the purpose and effectiveness of the RBO. Generally RBOs rarely have strong transnational law-making functions.
A large number of publications concerning about IWRM is available in the Toolbox of the Global Water Partnership. Experience shows that all RBOs evolve with time and see their composition and duties adapted from time to time reflecting the real needs of the moment. GWP (2014) states that successful river basin organizations are supported by:

- An ability to establish trusted technical competencies;
- A focus on serious recurrent problems such as flooding or drought or supply shortages, and the provision of solutions acceptable to all stakeholders;
- A broad stakeholder involvement, catering for grassroots participation at a basin-wide level (e.g. through water forums);
- An ability to generate some form of sustaining revenue;
- The capacity to collect fees, and attract grants and/or loans;
- Clear jurisdictional boundaries and appropriate powers.

An overview of River Basin Organizations, presented by Priscoli (2006) describes the development of RBO's in the USA, Canada, France, Germany, The Netherlands, Portugal, Great Britain, Spain, Russia, The Danube basin, Nigeria, Vietnam, China Indonesia, Brazil, Mexico and Australia. Examples of RBO's are also described, e.g. Columbia River, Danube, Komadugu-Yobe, Mekong, Yellow river. From the overview can be concluded that most of the RBO's are established to solve problems flooding and droughts, to improve navigation and to manage hydropower stations. One became aware that this type of problems only can be solved on a basin scale and cooperation between states and countries is needed to prevent or to solve conflicts of interest. Water quality problems and ecosystem protection

were in most cases not the main trigger for establishing RBO's. From the eighties the role of the river basin approach in tackling water quality problems was increasing.
Jaspers (2003) stated that water resources management on hydrological boundaries is not a new phenomenon, but the inability to manage water quality or to preserve environmental integrity and to sustain environmental flows offered a new dimension. He concluded that at present it is virtually impossible *not* to organize water resources management in a integrated matter and on hydrological boundaries.

6.2. Improving water quality and protecting ecosystems and the role of basin organizations

Australia

The National Water Quality Management Strategy (NWQMS, 1998) to improving water quality outlines a three-tiered approach to water quality management i) the national level for establishment of a vision of achieving sustainable use, ii) state or territory level implementation through state water planning and policy process and iii) regional or catchment for complementary planning e.g. catchment strategies and implementation by relevant stakeholders. It is stated that, ultimately, it is the responsibility of local stakeholders and state or territory or regional government to agree on the level of protection to be applied to water bodies.
An independent evaluation of the national water strategy (KPMG, 2011) based on desktop analysis and stakeholder consultation found a number of shortcomings in the strategy, among others that the strategy does not have any specific vision, policy priorities or targets, the update up technical guidelines occurs on ad hoc basis, the development time for technical guidelines is too lengthy, the technical documents are inconsistent in language and format and there are no performance metrics or reporting processing in place to measure the ongoing effectiveness of the national water quality management effectiveness. It is noted that the implementation primarily occurs through various agencies, local councils, authorities and departments within each jurisdiction. The national guidelines are not mandatory and the policy framework and guideline application differs depending on the relevant structure and interlinked agencies and bodies in place in each state or territory. The evaluation does not give any information about the role of basin organizations.

The best-known river basin organization in Australia is the Murray-Darling Basin Authority (MDBA). It is an independent expertise based government agency responsible for planning and management of both surface water and groundwater. In 2012 the Murray-Darling Basin Plan passed into law and has been a significant milestone in Australian water reform. The Basin Plan balances social, economic and environmental demands on the Basin's resources, to ensure – among others- healthy and divers ecosystems with rivers regularly connected to their creeks, billabongs and floodplains, and ultimately the ocean (MDBA, 2012).
Furthermore, twelve case studies concerning improvement water quality are available with stories of progress and success from across Australia (Booth and Lamble, 2012). However, the study does not provide overall conclusions concerning results and success factors.

European Union

The most innovative aspect of the WFD is its river basin approach whereby water

management is oriented based on hydrological, not political, boundaries (Moss 2012). The River Basin District is the main unit for management of river basins which competent authorities need to be identified that will apply the rules of the Directive. There is a requirement to co-ordinate the actions ((nationally and internationally) to achieve objectives established by the Directive. Member States shall ensure that a river basin management plan (RBMP) is produced for each river basin district. In the case of an international river basin district, Member States shall ensure coordination with the aim of producing a single international river basin plan.
All RBMPs' are assessed in detail by the staff of the EU Commission. The key aspect*s* of the results of the assessment are reported in a so-called Commission's implementation report. The third implementation report was published in 2012 (EC 2012). This comprehensive report provide among other the status and adoption of RBMP's, overview of the status of EU waters and outlook, implementation of governance structures, classification of the ecological status and programs of different kind of measures. Some findings are

- 121 RBMPs (out of a total of 170) have been reported
- more than half (55%) of the total number of classified surface waters in Europe are reported to have less than good ecological status/potential.
- there is a high percentage of surface water bodies for which the reported chemical status is " unknown". See figure 6.1
- there has been some progress in monitoring programmes since reporting to the Commission in 2007. For example, at the EU level there has been a 39% increase in monitoring sites in surface waters and 17% more for groundwater.
- In terms of transparency, it was found that the RBMPs from 11 countries (out of 25) were conserved clear and well structured, whilst in some plans it was difficult to find the relevant information
- International co-operation has been significantly enhanced since the adoption of the WFD, in particular in some of the larger basins. International RBMPs have been adopted in catchments like the larger Dabube, Rhine, Elbe, Scheldt, Odra, Meuse and Ems.

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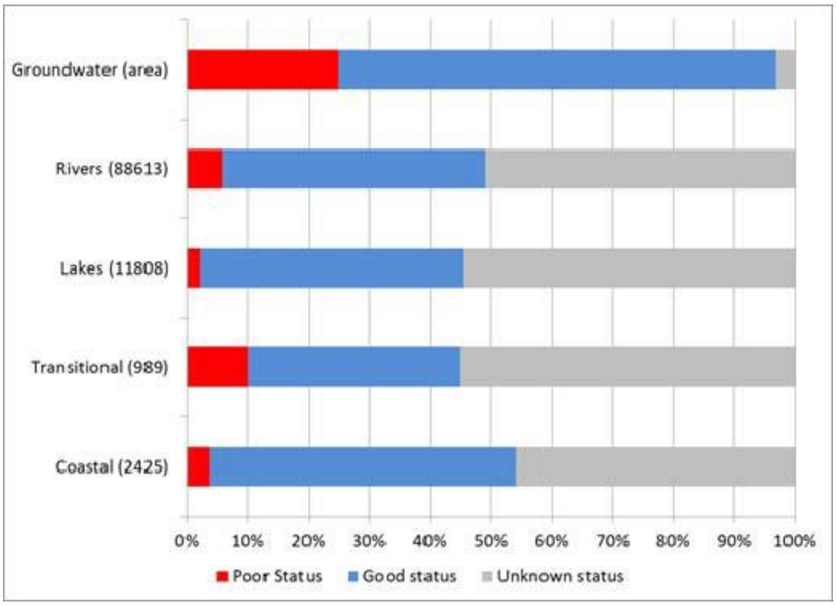

***Figure 6.1.**:* Percentage of rivers, lakes, groundwater, transitional and coastal waters in good, poor and unknown chemical status in the EU (EC,2012, data source: Water Information System for Europe,WISE).

United States of America

As described in a lot of publications, e.g. Priscoli (2006) and Abdalla et al (2010) the river basin approach has a long tradition in the USA. To provide users with a comprehensive resource to develop more effective watershed plans as a means to improve and protect the nation's water quality EPA published the Handbook for Developing Watershed Plans to Restore and Protect our Waters (the Handbook) (USEPA, 2013b). The Handbook also provides guidance on how to incorporate the nine minimum elements from the Clean Water Act section 319 Nonpoint Source Program's funding guidelines into the watershed plan development process. The nine elements from the Clean Water Act include – among others- identification of causes and sources pollution, estimation of pollutant loading, description of management measures and identification and monitoring to measure progress. Since the Handbook was issued, EPA and other entities have stepped up watershed plan implementation, introduced new initiatives, developed new tools, and provided additional funding sources.

The Handbook provide six steps in watershed planning and implementation processes:

1. Build partnerships
2. Characterize the Watershed
3. Finalize goals and identify solutions
4. Design and Implementation plan
5. Implement Watershed Plan
6. Measure progress and make adjustments

Restoration of aquatic ecosystems may be one of the goals of a the watershed planning and implementation process. For example, a preliminary goal developed during the scoping phase, in step 1 of the watershed planning process, might have been to "restore aquatic habitat." Based on the information collected during data analysis, in step 2 of the watershed planning process, you might determine that the causes contributing to poor aquatic habitat include upland sediment erosion and delivery, streambank erosion, and near-stream land

disturbance (e.g., livestock, construction). Linking the preliminary goal to the source and impacts of pollution will help you define your management objectives. In this case, appropriate management objectives could include (1) reducing sediment loads from upland sources and (2) improving riparian vegetation and limiting livestock access to stabilize streambanks (USEPA, 2013b).
Attention for improvement of fresh water ecosystems in BOs may be needed in the future. As concluded in a collaborative survey during 2008-2209 (USEPA, 2014) twenty-one percent of the nation's river and stream length is in good biological condition, 23% is in fair condition, and 55% is in poor condition, based on a robust, commonly used index that combines different measures of the condition of aquatic benthic macroinvertebrates (aquatic insects and other creatures such as crayfish). Of the three major climatic regions (Eastern Highlands, Plains and Lowlands, and West) discussed in this report, the West is in the best biological condition, with 42% of river and stream length in good condition. In the Eastern Highlands, 17% of river and stream length is in good condition; in the Plains and Lowlands, only 16% is rated in good condition.

Other countries

As concluded in chapter 2 in all countries studied water laws and/or water quality guidelines have been established to protect human uses and in most cases also to protect aquatic life. All governmental frameworks include guidelines for physical indicators and chemical substances and provide strategies for pollution preventions, measures and/or regulations to prevent and reduce discharges of pollutants, although the number of pollutants considered are largely varying. However, only a few laws or guidelines focus more explicitly on the protection of the aquatic ecosystems by developing specific guidelines, by using biological and hydromorphological indicators and by taking into account other pressures than chemical pollution.
Within this review study it was not possible to review BOs and basin plans from all over the world and to analyze in what extend those organizations take into account protection and improvement of fresh water ecosystems. Only a few examples will be mentioned.
China worked together with the WWF a comprehensive overview of strategic basin planning and techniques for basin planning, in which developing ecological based objectives and the importance of aquatic ecosystem functioning is acknowledged (Pegram et al, 2013).
The Mekong Delta in Vietnam has been subject of comprehensie studies including the ecosystem charartistics (Renaud and Kuenzer, ed, 2012).
In South Africa Catchment Management Strategy is available. It is a framework that takes into account all matters relevant to protection, use, development, conservation, management and control of resources. Concerning ecosystem protection the focus is on physical-chemical water quality requirements for aquatic ecosystems.

6.3. Mandates and organizational structures of basin organizations

BOs vary considerably in form and function and there are many types of basin organizations in the world. The reasons for this vary and include many enabling environmental factors (laws ,investments and policies), individual and organizational capacities and management factors (Hooper, 2005). He made a classifications of nine types of BO: Advisory Committee, Authority, Association, Commission, Council, Corporation, Tribunal, Trust and Federations. He described the differences between these types. The main difference is the mandate of the BOs, varying from a legal entity as a Basin Authority which is responsible for planning decisions and may set and enact regulations, to a rather non-committal Advisory Board.

Hooper (2006) has also derived general performance indicators for RBO's. Hooper has identified 115 indicators for best practice integrated river basin management, which were grouped in 10 categories.
(1) coordinated decision-making – the use of coordination mechanisms between and within agencies and basin organizations; consensus based decision-making; links between local water institutions and a basin organization; how relevant sectoral interests are engaged
(2) responsive decision-making – decision processes which adapt to new knowledge and new conditions; promote efficiency; value cross-sectoral dialogue; promote best practices
(3) goals, goal shift and goal completion – achievement of goals using an integrated approach
(4) financial sustainability – evidence of ongoing financial support, cost-sharing, transparency, innovative water pricing and demand management
(5) organizational design – the use of democratic processes; evidence of stable international agreements and evidence of national water policy conducive to river basin management; use of organizational structures which fit basin needs and avoid fragmentation
(6) role of law – the existence of laws which support river basin management; laws characterized by strong & flexible arrangements
(7) training and capacity building – the use of ongoing training and capacity building of staff relevant to basin needs
(8) information and research – the existence of a knowledge system to aid decision-making, protocols to share information, and a culture of research-knowledge links
(9) accountability and monitoring – evidence that basin organizations are accountable to constituent governments & citizens; use of transparent reporting mechanisms
(10) private and public sector roles – evidence of stakeholder participation; clear specification of roles of private and public sector

Studies about the cost-effectiveness of Basin Organizations seems to be scarce, and need more attention. Evaluation of the functioning of the RBO's has been presented by Bozkir et al (2010), Veiga and Magrini (2011)and Schmeier (2014).
Bozkir et al (2013) emphasize the importance of cooperation among national and international on hand of the successful Rhine case and recommend that the Rhine case may serve as an example of an alternative approach which leads to a sustamineble river management plan.
In an detailed analysis of fifteen years Brazilian water resource management policy is concluded that the new institutional framework, including among others river basin committees and water agencies, is in line with international trends, and despite the major progress that was made, the implementation process still faces many challenges, especially in the least developed regions of the country (Veiga and Magrini, 2013).
Schmeier (2010) compared several RBO's on their structure, mandate, how they are financed etc. She concluded that that three main points matter for the performance of RBOs in managing the river basin:
1. The RBOs institutional design, that is, the way its organizational bodies are designed and interact with one another,
2. The institution's link to its member states and the distribution of tasks between the

different governance levels, and
3. The financing of the institution.
Her overall findings as shown in Table 6.1 can be summarized demonstrating the differences between implementation- and coordination-oriented RBOs and the respective impacts on the organizational structure, the degree of (de-)centralization and the financing of the institution, noting that there is a broad continuum between the two prototypes.

In conclusion, the role of BOs in the application of WQGs for fresh water ecosystems highly depends on the type of basin organization. There is not a straightforward approach for application of WQGs in basis organization. Basin organizations can play an important role, but a tailor-made approach is needed in which the mandate of a basin organization and organizational structure should be established by the competent federal authorities of the countries involved.

6.4. Compliance and enforcement

For an effective process of application of WQGs compliance and legal mechanisms for enforcement are indispensable. Although basis organizations may play an important role in getting compliance and in enforcement of regulations, it strongly depends on the mandate, capacity and financing of the basin organization whether it will be effective. In this review we were not able to analyze the role of existing basin organization in getting compliance and their role in enforcement, because most of the information needed is not public available. So, only general policies concerning compliance and enforcement will be presented in this paragraph.
Table 6.1 Differences between implementation- and coordination-oriented RBOs (Schmeier (2010).

	Implementation-oriented RBO	Coordination-oriented RBO
Role and Respon-sibilities	- Focus on the implementation of programs and projects in the basin, often beyond pure water resources management (development focus)	- Focus on coordination of member states' activities in water resources management (independent from development needs of members)
Organi-zational Structure	- Rather large, with different organizational bodies in charge of the different tasks and activities - High degree of centralization	- Rather small, with limited number of subsidiary bodies - Strongly decentralized
Secretariat	- Rather large with various subsidiary departments - Fulfills large number of tasks (beyond administrative services) - Maintains large amount of centralized data and information	- Rather small, with limited number of departments and small number of staff - Provides administrative and technical services and facilitates work of member states
Links to Member States	- Needs to be maintained through specific links - Complexity of operation makes ownership difficult - If managed efficiently, strong links can develop due to implementation	- Ensured through decentralized Working and Expert Groups and national implementation - Links are based on personnel exchange and interaction on all governance levels
Financial Require-ments	- High financial needs due to complex structure and many tasks (including implementation - Program/project structure allows for acquisition of external funding	- Relatively low financial needs due to limited number of tasks carried out on the transboundary level
Advanta-ges	- High level of engagement in river basin development - Centralization of knowledge on the basin	- Short decision-making channels - High efficiency in management
Dis-advantages	- Long decision-making channels with many intermediary bodies - High financial needs for programs and projects	- Focus on water resources management only (i.e. no development focus) - Requires high human, financial and technical capacities in member states
Examples	LCBC, NBA, NBI, OMVS, ZRA	ICPDR, ICPER, ICPR, OKACOM

Compliance is defined as the full implementation of established requirements; it occurs when requirements are met and designed changes are achieved. Compliance is conditional on visible and effective surveillance, culminating in enforcement. Enforcement is the set of actions aimed at achieving compliance. This holds out the prospect of a society characterized by mutual respect and tolerance.

Promoting compliance is a matter that equally concerns those who make, implement and enforce policy and legislation. At national governmental level in most countries policy directorates are responsible for developing and assuring the quality of the Ministry's policy. Authorities or Inspectorates are primarily responsible for enforcement and investigation. However it is important, that policies are practicable and enforceable.

Enforceability refers to the suitability of the legislation in terms of the ability of the competent authorities to use legal and administrative means at their disposal under domestic law to encourage or, in the event of willful non-compliance, compel individual addressees to comply with their obligations under the legislation. Together, policy and enforcement must promote compliance by the public, companies and authorities- themselves. Therefore it is essential to agree on which rules must be assigned highest priority, how compliance can most effectively be achieved and where the compliance responsibilities lie. Such agreements require a shared picture of the extent of poor compliance and of the associated risks to society. The ultimate priority setting is obviously a political responsibility and not a civil service one.

Compliance and enforcement in Australia

The Australian National Framework for Compliance and Enforcement Systems for Water Resource Management (COAG,2009) prescribes a risk-based approach to monitoring and enforcing compliance. The Framework defines a 'risk-based compliance strategy' as one that "identifies 'at risk' water resources and targets breaches of water resources legislation most likely to further stress the resource or which undermine the public's confidence in effective water resource management". The pyramid (see Figure 6.2.) is designed with most compliance action at the base involving processes for encouraging and assisting compliance**.** Further up the pyramid actions are more concerned with directing compliance through verbal directions, advisory notices and warning notices. The top, where generally there is the least activity, involves administrative remedies and criminal proceedings.

For the pyramid to work effectively, jurisdictions require each of the elements to be effective and operate efficiently, to allow for the strategy's overall success. Portion of space in each layer represents portion of enforcement activity at that level.
While these pyramids concentrate most resources to the bottom of the pyramid (for example, in educational programs and technical assistance) the framework ensures that the tools and processes at all levels of the pyramid are equally robust. If any of the elements are not robust it allows a weakness or gap in the framework that can be exploited by those seeking to take advantage, which could potentially cause the failure of the whole approach.

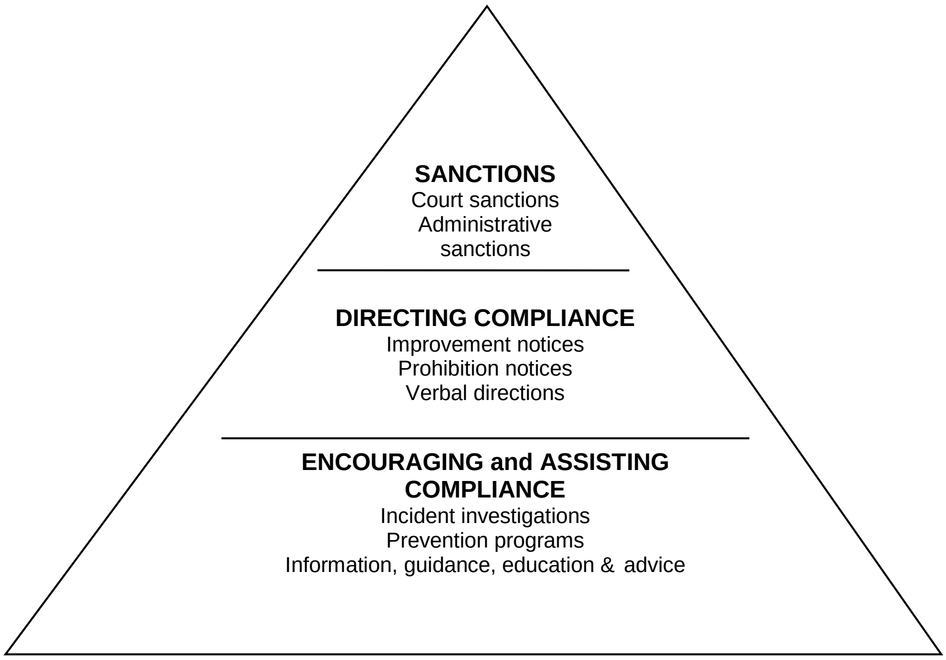

Figure 6.2. Enforcement Pyramid (COAG, 2012, modified from Ayres and Braithwaite (1992)

The National Framework aims to provide a nationally consistent approach by strengthening compliance and enforcement within each jurisdiction and addressing any gaps in their systems. This includes:

- robust compliance standards and enforcement strategies;
- rigorous and appropriate application of compliance standards and enforcement strategies;
- regular and consistent public reporting of monitoring and compliance action;
- raised public awareness; and
- an increase in resources to appropriate levels.

In the States and Territories of Australia State Offices are responsible for managing the state's water sources. A key part of this responsibility is ensuring compliance with water management legislation to enable the secure and sustainable sharing of water between users. While most water users follow the rules and meet requirements, some people carry out illegal water activities. Water theft and harming a water source are serious crimes. These breaches can threaten water supplies for legitimate water users and harm the environment. The Compliance Policy (DSEWPC,2009) explains how to prevent, detect and stop illegal water activities. This includes:

- assisting the community to understand their water rights and how to comply with the rules
- monitoring water related activities to identify potential breaches
- investigating alleged breaches and taking appropriate action when a breach occurs.

The focus of the enforcement efforts is on the use of water, not on the ecological system.

Compliance and enforcement within EU

Striking the right balance between flexibility in local implementation and robust and enforceable standards is essential to promoting adaptive capacity in water governance, yet achieving these goals simultaneously poses unique difficulty. The Water Framework Directive is transposed into national law of each member state. Enforcement therefore is carried out by national institutions.

The decentralized implementation of Water Framework Directive allows member states flexibility in developing scale-specific water management policy, and scale-specific solutions are crucial to adaptive governance (Green et al. 2013). The Directive provides flexibility for developing water policy at the appropriate level, because geophysical circumstances differ per region (Keessen et al. 2010).

The structure of overlapping levels of control vary by member state, as each state implements the WFD through different institutions, but all river basins plans are assessed , at the highest level, by the European Union. See for example the third implementation report (EC, 2012). Below that, a member state may create a new state-wide water management agency, or revise an existing one, to coordinate or oversee the work of river basin districts .

Serving flexibility and regional differentiation is positive, but at the same time, the legal system must have “teeth” at the scale of the European Commission if the Directive is to improve river basin management and be effective in the end. For chemical objectives, the key is to set enforceable standards, i.e., thresholds, for the most hazardous substances at the supranational scale but allow for novelty and innovation in the manner in which member states meet those standards. This raises the question of how enforcement of standards not set at EU level can be made equally effective. The available oversight mechanisms of monitoring and reporting of compliance with chemical standards are expected to achieve compliance with chemical standards set by member states. That leaves the question whether the same approach is effective with novel ecological standards that are set by member states. Guidelines for intercalibration are available to tackle the problems of comparability (EC, 2010).

Compliance and enforcement in USA

The US EPA enforces requirements under the Clean Water Act (CWA). USEPA works with its federal, state and tribal regulatory partners through a comprehensive Clean Water Act compliance monitoring program to protect human health and the environment by ensuring that the regulated community obeys environmental laws/regulations through on-site visits by qualified inspectors, and a review of the information EPA or a state/tribe requires to be submitted.

The web CWA compliance assistance program provides businesses, federal facilities, local governments and tribes with tools to help meet environmental regulatory equirements. Under the CWA's National Pollutant Discharge Elimination System (NPDES) program, EPA regulates discharges of pollutants from municipal and industrial wastewater treatment plants, sewer collection systems, and stormwater discharges from industrial facilities and municipalities. The Clean Water Action Plan targets enforcement to the most important water pollution problems.

Compliance, monitoring and sanctions

Legislation is a fundament for successful application of WQG’s. However, the existing WQG’s and related regulations show large differences in approaches. They may be voluntary, market based or mandatory or combinations of those approaches. On a (inter)national level choices have to be made on which subjects mandatory approaches are preferable. Legal instruments may include rights and licenses, taxes or charges, penalties, but also the duty for monitoring and reporting. Besides the extent to which a rule is observed, the reasons for non-compliance will be examined. It is necessary to know the reasons, because they will form the basis for selecting the appropriate intervention. Furthermore, the compliance behavior of regulates is a central point in all action that an authority takes to reach the policy goals identified (Van der Schaaf, 2005). The "Table of 11" is a methodology of identifying possible reasons for non-compliance. The Table of Eleven was presented as an important part of a compliance strategy, including spontaneous compliance, monitoring and sanctions. Sanctions are any adverse consequences imposed on a violator. Lugwisha et al (2008) described the challenges on compliance and enforcement of the wastewater management legislation in Tanzania based on analysis with the Table of 11.

Table 7.1. “Table of 11” (Van der Schaaf, 2005).

Aspects of spontaneous compliance	1 Knowledge of the regulations 2 Costs/benefit ratio

	3 Degree of acceptance 4 Loyalty and obedience of the target group 5 Informal monitoring
Aspects of monitoring	6 Informal report probability 7 Monitoring probability 8 Detection probability 9 Selectivity
Aspects of sanctions	10 Chance of sanctions 11 Severity of sanctions

6.5 Stakeholder and public participation and the role of basin organizations

Stakeholder participation and public participation is more and more recognized as one of the success factors for improving water quality and protecting ecosystems. It plays a crucial role in raising societal resilience and building adaptive capacity. In a number of WQGs and in basin organizations the participation is strongly advised or even a legal duty. A few examples in water policy may illustrate that stakeholder and public participation is one of the leading principles in the improvement of water quality and the protection of ecosystems.

The National Water Quality Management Strategy (NWQMS, 1998) in Australia stated that the national objectives will be achieved by applying four principles to water quality management, among which community involvement in setting water quality objectives and developing management plans. This policy has been applied in the development of basin Plans. For example, the Murray–Darling Basin Authority have presented a guide to the proposed Basin Plan, in which the Authority is providing an early opportunity for individuals, stakeholders and the community to examine the thinking of the Authority and provide feedback. This feedback will be taken into consideration in finalizing the proposed Basin Plan. The Authority has developed comprehensive consultation and engagement processes. The steps the Authority must follow once the proposed Basin Plan has been released are outlined in the *Water Act 2007 .* These include a minimum 16 weeks of public consultation providing individuals, stakeholders and the community an opportunity to comment on the proposed Basin Plan.

The US guide to developing watershed plans to restore and protect our waters (USEPA, 2013b) provide a six steps of watershed planning. It is important to note that the first step is “Build partnership”, including identify stake holders, identify issues of concern, set primary goals and conduct public outreach. The US EPA has published a Public Participation Guide o internet. They state that there is a great deal of public participation being implemented throughout the world today. Laws and regulations in many countries regularly require public meetings and comment on government actions. Some require even more extensive forms of public engagement and input. However, all of this activity does not automatically translate into good practice. Meaningful public participation requires much more than simply holding public meetings or hearings or collecting public comment. When done in a meaningful way, public participation will result in two significant benefits:

- Sponsor agencies will make better and more easily implementable decisions that reflect public interests and values and are better understood by the public.
- Communities develop long-term capacity to solve and manage challenging social

issues, often overcoming longstanding differences and misunderstandings.

In the joint report of the WWF and Chinese experts (Pegram et al, 2013) ten golden rules of basin planning are given. One of these rules is “Engage stakeholders with a view to strengthening institutional relationships”. Basin planning should be seen as an opportunity to build trust and relationships between these bodies so that action to secure implementation can be achieved. The basin planning process should also recognize and try to incorporate the diverse perspectives of stakeholders at different scales that will have an influence on the implementation of the strategy.

The EU WFD sets out a framework for vertical coordination from the European level to the water-body level, as well as horizontal coordination of all relevant measures, stakeholders and policies requiring at least six months. The purpose is to involve all stakeholders, including the public, with a view to ensuring that the best and most cost-effective measures are identified and selected, and that acceptance of the measures is built into the process. Another key mechanism for sectorial and territorial integration is the stakeholder involvement in the development of River Basin Management Plans (RBMPs) by the requirement to 'encourage the active involvement of interested parties in the implementation' of the RBMPs, in particular in the development of plans, which sets out a three stage process of stakeholder and public consultation requiring at least six months. The purpose is to involve all stakeholders, including the public, with a view to ensuring that the best and most cost-effective measures are identified and selected, and that acceptance of the measures is built into the process.
As public participation is considered as a key mechanism for integration and coordination at the river basin district level, all RPBMs are evaluated regularly by the European Commission (EC,2012). As shown in Figure 6.3. the RBMPs indicated that a wide range of outreach methods and consultation mechanisms were used for reaching out to and consulting with stakeholders (including the public) EC (2012). The most predominant outreach methods were to use the internet for announcing the consultation and for carrying out the consultation by inviting comments via the web. Media was used to a large extent for announcing the consultations, and local authorities played a big role in reaching out. In many cases the interested parties known to the authorities were directly invited to respond.

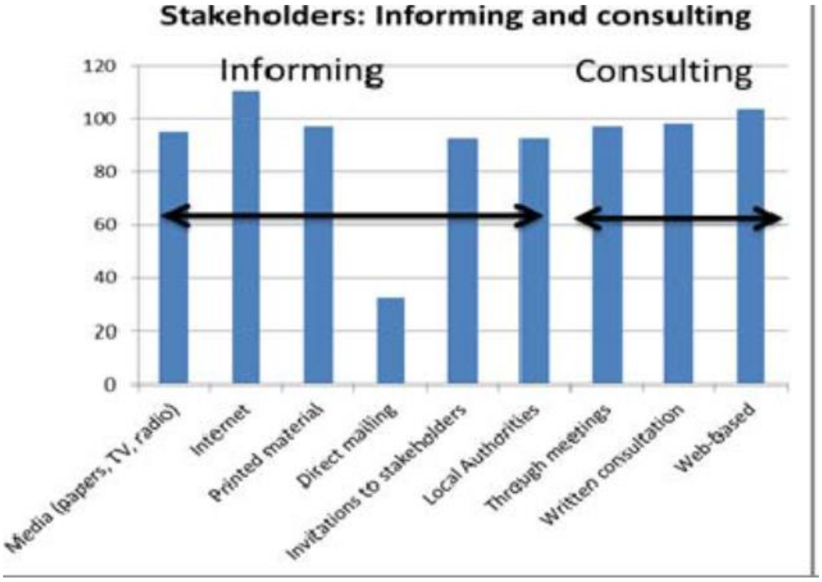

Figure 6.3. Means of informing stakeholders and the public, as well as consulting (EC,2012).

Although it is difficult to assess the real impact of consultations on the RPBMPs due to the many responses by stakeholders, in Figure 6.4 a indication of the impacts on the main subjects of RBMPs are given. It appears that in some cases the consultation led to less stringent measures or objectives
being defined but in some cases an increased level of ambition was reported.
In no other region or country such a detailed analysis on the role of public participation was published.

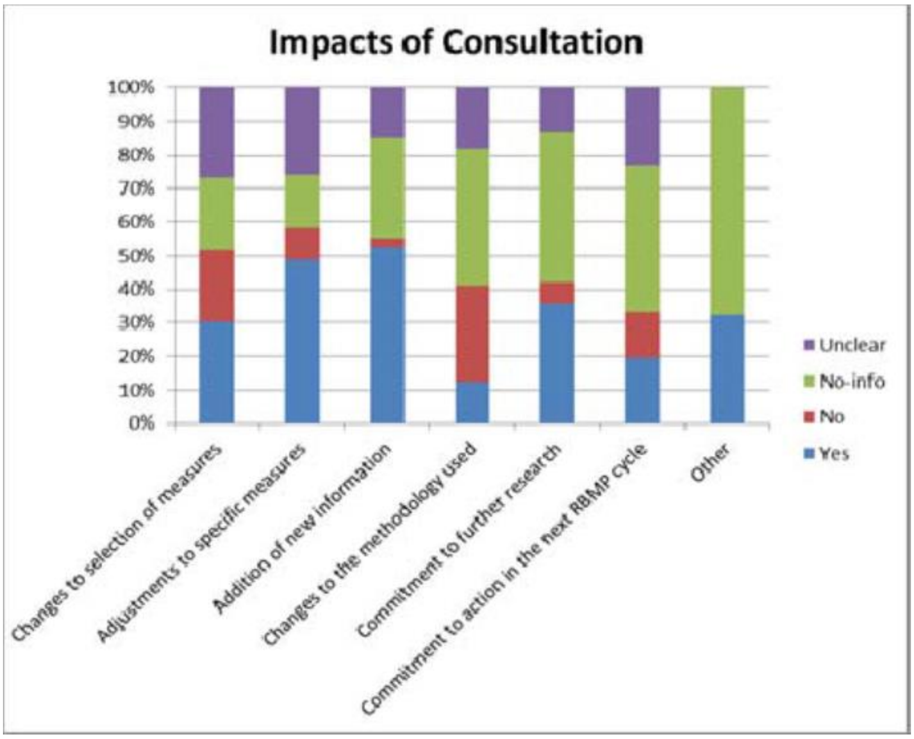

Figure 6.4. Type of impacts of public consultation reported in the RBMPs (EC,2012).

6.6. Knowledge and the role of basin organization

The relevance of knowledge in river basin management is uncontested, but the concrete function of knowledge remains often unclear. First the type of scientific input itself can be expected to matter for whether and to what extent science is translated into policy. The type of scientific input and, in particular, its focus on the issues at stake in the basin varies significantly across RBO's. Schmeier (2014) studied the International Commission for the Protection of the Danube River (ICPDR), The International Commission for the Protection of the Rhine (ICPR), the Lake Victoria Fisheries Organization (LVFO) and the Mekong River Commission (MRC). The targeting of scientific outputs of a RBO, both in terms of addressing the right topics and presenting them in a policy-oriented manner, can be regarded as an important prerequisite for science guiding policy in the process of river basin management. Based on a pilot investigation for the river Rhine, Pfeiffer and Leentvaar (2013) concluded that active stimulation of knowledge-based collaboration can lead to substantial influences on the policy processes.

To support the exchange knowledge the International Network of Basin Organizations (INBO) organizes meetings, publishes papers and participates in projects.

6.7. The role of basin organizations in reporting and evaluation

Many River Basin Organizations or Water Authorities report the state of the waters in their region on an annual basis. However not all reports are open to the public. Monitoring and Evaluation are basic element of these reports. Monitoring and Evaluation is the systematic collection and analysis of information to enable managers and key stakeholders to make informed decisions, uphold existing practices, policies and principles and improve the performance of their projects or management actions. Monitoring is the regular gathering, analyzing and reporting of information that is needed for evaluation and/or effective (project) management. Evaluation is a selective and periodic exercise that attempts to objectively assess the overall progress and worth of management actions. It uses the information gathered through monitoring and other research activities and is carried out at particular points during the lifetime of an activity. Monitoring and Evaluation can help an organization to extract, from past and ongoing activities, relevant information that can be used as the basis for future planning. A structured Monitoring and Evaluation approach makes information available to support the implementation of water management policies and activities and will enhance the sustainability.

In several river basis the publication of reports on the state of water quality in the basin is a stimulus to improve management actions in this field. It also creates awareness among stakeholder groups, thus creating pressure on government authorities to continue with their efforts to improve water quality.

6.8. Findings

The main findings concerning the application of water quality guidelines at basin level to protect fresh water ecosystems are:

- The application of WQGs to protect fresh water ecosystems should be considered as part of Integrated Water Resource Management. Given the fact that the basin approach has been widely accepted as the most proper entity for IWRM, basin organizations may play an important role in the protection of ecosystems

- In Australia, European Union and USA the basin approach has been acknowledges as entity which is important for the application of WQGs, but the role of BO's and the goals and impact of basin plans vary enormously.
- the role of BOs highly depends on the type of basin organization and the mandate for the organization. There is no straightforward approach for application of WQGs in BOs. BOs can surely play an important role, but a tailor-made approach is needed in which the mandate of a basin organization and organizational structure should be established by the competent federal authorities of the countries involved.
- Getting compliance is a key element for implementing guidelines effectively. The need for getting compliance by the public, companies and competent authorities is clearly recognized in programs for implementation of the guidelines in Australia, EU and USA. In addition to achieve compliance, legal and administrative means are indispensable to encourage or compel individual addresses to comply with their obligations under the legislation.
- Basin organizations play an important role in the overall water resource management and in getting compliance e.g. by encouraging stakeholders and public participation, public reporting about the status of water quality.
- Impacts of public consultations are clearly demonstrated, e.g. in river basin management plans in the EU (EC, 2012).
- Active stimulation of knowledge based cooperation can lead to substantial influences on the policy-process.

7. Conclusions and recommendations

A quick review of water quality guidelines in 15 countries or regions show that in all countries and regions water laws and/or water quality guidelines have been established to protect human uses and in most cases also to protect aquatic life. Most of the laws and guidelines date from the eighties and nineties of the past century and some have been adapted partly in recent years. However, only a few guidelines focus more explicitly on the protection of the aquatic ecosystems by developing specific guidelines for that purpose. The Australian/New Zealand Water Guidelines, the European Water Framework Directive and related guidelines and the US EPA guidelines are selected for a more in-depth review, as these guidelines are based on a long-lasting experience and because they also provide most extensively scientific-based approaches and tools for quality assessment of aquatic ecosystems.

Main conclusions based on the three guidelines reviewed:

- The term “Water Quality Guideline” has been used in at least two meanings: i) the overall framework for assessment and ii) narrative or numerical criteria to assess water quality. Also the terms water quality criteria, water quality objective and water quality standards should be defined clearly if water quality guidelines will be developed. The same holds for the terms uses, pressures and stressors.
- The guidelines for aquatic ecosystem are part of in a larger framework of guidelines

for water quality which may include– among others – guidelines for drinking water and other uses, analyses of pressures, pollution prevention measures and monitoring and assessment methods.

- Quality classes for ecosystems are used for at least four reasons
  - to formulate present or future objectives concerning the status desired
  - to present the ecosystem quality status in a transparent way; creating awareness by authorities and stakeholders
  - to compare the quality status of different waters
  - to report progress of the quality status
- Narrative and numerical criteria for biological, natural-occuring physical and chemical quality indicators and hydromorphological indicators are nearly always related to reference conditions e.g. the ratio of species observed for the site examined and known form reference sites.
- Comprehensive guidelines are available for deriving criteria for toxic substances. It is clear that deriving water quality criteria is a complex process of integration of high-level scientific knowledge, taking into account a large number of uncertainties and of policy-definitions of protection levels. The resulting numerical criteria in the guidelines considered show sometimes large differences mainly due to differences in definition of the criteria level, the data used and safety factors applied.
- Frameworks and decision trees are available for the quality assessment of aquatic ecosystems. These frameworks and decision trees provide step by step approaches for the quality assessment. Major elements are the setting of general objectives, typology of waters, methods for deriving quality criteria, biological, physical, chemical and hydromorphological indicators for monitoring and assessment, methods for analyzing and reporting of monitoring data.
- Step by step approaches and decision trees are developed to support the ecological assessment based on biological, physical-chemical and hydromorphological quality indicators as well as methods for classification of the status of an aquatic ecosystem.
- The application of WQGs to protect fresh water ecosystems should be considered as part of Integrated Water Resource Management. The basin approach has been acknowledges as entity for IWRM and are for the application of WQGs for ecosystems. However in the countries and regions considered the role of BO's and the goals and impact of basin plans vary enormously.
- Compliance by stakeholders, companies and competent authorities is the key factor for implementing of guidelines for aquatic ecosystems. However, enforcement mechanisms are indispensable for encouraging or compelling all stakeholders if they don't comply with the obligations under the legislation.

Recommendations for the deriving and application of water quality guidelines for aquatic ecosystems

Provide common terminology for water quality assessment

We recommended to use the term "Water Quality Guidelines for Ecosystems" exclusively for frameworks which support the quality assessment of aquatic ecosystems, and not just for the (numerical) criteria. Concerning narrative or numerical water quality criteria we propose to adopt the definitions given by Enderlein et al (1997).

- **Water quality criterion**: numerical concentration or narrative statement recommended to support and maintain a designated water use
- **Water quality objective** (synonyms: water quality goal or target): A numerical or narrative statement established to support and to protect the designated water uses of water at a specific site, river basin or parts(s) thereof
- **Water quality standard**: an objective that is recognized in enforceable environmental control of a level of Government

Concerning the anthropogenic influence on aquatic ecosystems we note that different terms are used such as drivers, pressures and stressors. It would be helpful if - on international policy level - a general model will be agreed on. For example the DIPSR-model (Driver-Pressure-State-Impact-Response) or a general model which clarifies the difference between pressures and stressors.

Provide a common guideline for protection and restoration of fresh water ecosystems.
This guidelines may offer a framework for the setting of goals and development of quality criteria, analysis of the quality status and stressors, identification of high-value areas, estimation of the category of ecosystem quality, monitoring, setting of future management goals, identification of issues of governance, legal framework, compliance and enforcement and stakeholder participation. The guideline should be applied as part of Integrated Water Resource Management.

Derive numerical water quality criteria for toxic substances on an international level.
Because criteria for toxic substances are in general not site-specific, it may be recommended that these criteria would be derived on international level as has been carried out for the WHO drinking water standards. Putting together all available scientific and indigenous knowledge concerning methods, quality measures and available toxicity data may result in internationally accepted criteria that are easily comparable for assessing the status of global aquatic ecosystems, as well as facilitating the development of sustainable approaches for addressing water- related problems.

Acknowledge that reference values are needed to assess ecological status
Quality criteria for general physico-chemical, biological and hydromorphological indicators for the assessment of ecosystems often should be derived from reference values and cannot be set on international level. Reference values may be derived from historical data, areas nearby that are uninfluenced by disturbance or other comparable areas.

Strengthen the mandate and cooperation between authorities, stakeholders and states in basin organizations to protect and restore aquatic ecosystems.
Basic prerequisites include compatible long-term goals, sufficient technical and financial capacity, stakeholder engagement and cooperation in monitoring, data-analysis and data-presentation to protect ecosystem health and maintain or improve water quality.

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Annex 1. Overview of existing guidelines in 15 countries

Annex 2. Methods for deriving water quality criteria for toxic substances

Australia/New Zealand

Most of the trigger values in the Australian/New Zealand guideline (ANZECC/ARMCANZ, 2000a) have been derived using data from single-species toxicity tests on a range of test species, because these formed the bulk of the concentration–response information. *High reliability* trigger values were calculated from chronic 'no observable effect concentration' (NOEC) data. However the majority of trigger values were *moderate reliability* trigger values, derived from short-term acute toxicity data (from tests ≤96 h duration) by applying acute-to-chronic conversion factors. As described by Warne (2001) two different methods were used to derive the guidelines: a modification of the Canadian assessment factor method and a new statistical distribution method called the Burr III method which was developed by Aldenberg and Slob (1993). The statistical distribution approach of Aldenberg and Slob has been adopted in the Netherlands and is recommended by the OECD (1992, 1995). The approach is based on calculations of a probability distribution of aquatic toxicity end-points. It attempts to protect a pre-determined percentage of species, usually 95%, but enables quantitative alteration of protection levels.

In Volume 2 of the guidelines (ANZECC/ARMCANZ, 2000b) a very comprehensive description of the backgrounds of the approach is given. This includes among others the data used and incorporating bioaccumulation, bioconcentration, secondary poisoning, pH, hardness and other factors in the approach. A decision tree for applying the guideline trigger values is given. The derivation of 21 groups of chemicals are described in detail. In a separate chapter in Volume 2 of the guidelines the derivation of sediment guidelines is presented.

EU

In Annex 1.2.6. of the EU WFD (EC 2000) the procedure of setting chemical water quality standards by the Member States is given for the protection of aquatic biota. Standards may be set for water, sediment or biota. Where possible, both acute and chronic data shall be obtained for the taxa set out below which are relevant for the water body type concerned as well as any other aquatic taxa for which data are available. The base set of taxa are:
. algae and/or macrophytes
. daphnia or representative organisms for saline waters
. fish.
For the setting of a maximum annual average concentration set appropriate safety factors in each case consistent with the nature and quality of the available data should applied. Safety factor may vary:

- 1000 if at least one acute L(E)C50 from each of three trophic levels of the base set is available
- 100 if one chronic NOEC (either fish or daphnia or a representative organism for saline waters)
- 50: if two chronic NOECs from species representing two trophic levels (fish and/or daphnia or a representative organism for saline waters and/or algae)
- 10: if chronic NOECs from at least three species (normally fish, daphnia or are presentative organism for saline waters and algae) representing three trophic levels

Other cases, including field data or model ecosystems, which allow more precise safety factors to be calculated and applied case-by-case assessment. Where data on persistence and bioaccumulation are available, these shall be taken into account in deriving the final value of an environmental quality standard. The standards thus derived should be compared with any evidence from field studies. Where anomalies appear, the derivation shall be reviewed to allow a more precise safety factor to be calculated. The standards shall be subject to peer review and public consultation including allowing a more precise safety factor to be calculated.
A comprehensive technical guidance for the deriving of quality standards for toxic substances is available (EC, 2011). The guidance includes standards to protect water quality, biota standards (levels of toxicants in aquatic organisms) and standards to protect benthic (sediment dwelling) standards. Environmental quality standards in biota shall be derived to protect:
1. Humans from adverse effects resulting from the consumption of chemical-contaminated food (fish, molluscs, crustaceans, etc.).
2. Top predators, such as birds and mammals, from risks of secondary poisoning brought about by consuming toxic chemicals in their prey.
3. Benthic and pelagic predators (e.g. predatory fish) that may also be at risk from secondary poisoning.
Currently, technical guidance for benthic and pelagic predators is not well-developed. At present, biota standards developed for birds and mammals are assumed to be sufficiently protective for benthic and pelagic predators.

USA

In the USA guidelines for deriving numerical national water quality criteria for the protection of aquatic organism and their uses were already established in 1985 (US EPA, 1985). After a decision is made that a national criterion is needed for a particular material, all available information concerning toxicity to, and bioaccumulation by. aquatic organisms is collected and reviewed for acceptability. If enough acceptable data for 48- to 96-hour toxicity tests on aquatic plants and animals are available, they are used to derive the acute criterion. If sufficient data on the ratio of acute to chronic toxicity concentrations are available, they are used to derive the chronic or long-term exposure criteria. If justified, one or both of the criteria may be related to other water quality characteristics, such as pH, temperature, or hardness. Separate criteria are developed for fresh and salt waters. Water quality criteria for aquatic life contain two expressions of allowable magnitude: a criterion maximum concentration (CMC) to protect against acute (short-term) effects; and a criterion continuous concentration (CCC) to protect against chronic (long-term) effects. EPA derives acute criteria from 48- to 96-hour tests of lethality or immobilization. EPA derives chronic criteria from longer term (often greater than 28-day) tests that measure survival, growth, or reproduction. Where appropriate, the calculated water quality criteria may be lowered to be protective of commercially or recreationally important species.

The handbook also provides an approach for deriving sediment criteria. The Equilibrium Partitioning (EqP) Sediment Quality Criteria (SQC) are the USA Environmental Protection Agency's best recommendation of the concentration of a substance in sediment that will not unacceptably affect benthic organisms or their uses.

The Water Quality Standards Regulation (USEPA, 2014) allows States to develop numerical criteria or modify EPA's recommended criteria to account for site-specific or other scientifically defensible factors. States may meet the requirements by choosing one of three scientifically and technically sound options (or some combination thereof):

1. Adopt statewide numeric criteria in State water quality standards for all toxic pollutants for which EPA has developed criteria guidance, regardless of whether the pollutants are known to be present;
2. Adopt specific numeric criteria in State water quality standards for toxic pollutants as necessary to support designated uses where such pollutants are discharged or are present in the affected waters and could reasonably be expected to interfere with designated uses;
3. Adopt a "translator procedure" to be applied to a narrative water quality standard provision that prohibits toxicity in receiving waters. At a minimum, such criteria need to be developed for toxic pollutants, as necessary to support designated uses, where these pollutants are discharged or present in the affected waters and could reasonably be expected to interfere with designated uses,

The three options are discussed in more detail in the Water Quality Standards Handbook. The State needs to demonstrate that its procedures for developing criteria, including translator methods, yield fully protective criteria for human health and for aquatic life. EPA's review process will proceed, which requires that criteria be based on sound scientific rationale and be protective of all designated uses.