Marine Resource Conservation Working Group
Asia Pacific Economic Cooperation

Water Quality Criteria / Standards Adopted in the Asia Pacific Region

Phase 2 Report
May 2005

Environmental Protection Department
The Government of Hong Kong Special Administrative Region
of The People's Republic of China

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1 Introduction

1.1 BACKGROUND AND OBJECTIVES

Hong Kong, China submitted a project proposal (in Appendix A) to the Marine Resource Conservation Working Group (MRCWG) of the APEC forum during its 15th meeting with a view to carrying out a literature review on :

- the Water Quality Criteria /Water Quality Standards (WQC/WQS) adopted by the member economies for the protection of the aquatic resources and uses;
- the approach/methodology and the scientific rationales for deriving the WQC/WQS by the member economies.

This project is carried out in phases, with the first phase started in September 2002. In the first phase, two questionnaires were sent out to the involved economies to collect initial information relating to four key issues : (i) the classification of beneficial uses, (ii) the values of the WQC/WQS, (iii) the approach and scientific rationales for deriving these values, and (iv) their application. In the second phase, the focus is on close examination of the key issues.

Report of the first phase was presented at the 16th MRCWG meeting in Hanoi, Vietnam (11 –13 October 2003). The report presents the initial findings of the questionnaire-based survey involving 15 economies, with focus on the general framework of the individual WQC/WQS systems, the classification of beneficial uses and the values of the WQC/WQS.

Derivation of the nation-wide or generic WQC/WQS is a complex process. It requires extensive information on the chemical, physical and biological properties of the parameters of concern as well as the water body. The social and economic characteristics of the local areas need to be taken into account when using these WQC/WQS as management goals. There are more than 100 parameters for which WQC/WQS have been specified. Two parameters : dissolved oxygen and nutrients, chosen because of their wide application in environmental management relating to harmful algal bloom, are suggested for in-depth review to have a good illustration of the designation rationale and derivation process.

There has been a global trend in using the term “ecological integrity” to report the health of a water body. Ecological integrity represents a natural or undisturbed state that comprises three components: chemical integrity, physical integrity and biological integrity. When one or more of these components is degraded or departed from the target levels, the health of the water body will be affected. This report compiled information on the three types of WQS/WQS revolving around this ecology integrity triangle. The microbiological WQC/WQS for recreation purpose and those for the protection of human health and wildlife consumers of aquatic biota will not be covered in this report.

This report, the second of the series, serves to report the project progress, and in greater details the framework, philosophy and methodologies of the water quality management systems of four economies, namely, Australia, Canada, New Zealand and the USA.

1.2 STRUCTURE

This report contains the following sections and appendices :

Section 1	contains the introduction.
Section 2	summarizes the methodology and the reporting method in the second phase.
Section 3	compiles the information collected from the third questionnaire sent to the member economies.
Section 4	summarizes the findings on WQS/WQS system adopted in Australia and New Zealand.
Section 5	summarizes the findings on WQS/WQS system adopted in the USA.
Section 6	summarizes the findings on WQS/WQS system adopted in Canada.
Section 7	concludes the findings and sets out the way forward for the next phase of the project.
Appendix A	contains the project proposal, the third questionnaire sent to member economies and a summary table of the responses received.
Appendix B	contains the list of contacts of the responsible departments/ agencies for acquiring information in this project.
Appendix C	contains the links for on-line access to WQC/WQS in different economies.
Appendix D	contains the list of reference documents used in this project.

2 Methodology and Reporting

Questionnaire-based survey, internet search and contacting with relevant officials were the main methods used in this phase to acquire information pertaining to the objectives of the project. There were a few occasions where officials were contacted for clarification and acquisition of shelved documents. A letter attached with a copy of the Phase 1 Report and a questionnaire was sent to the 14 concerned economies in January 2004. The recipients were asked for information covering the following aspects :

- comment on the Phase 1 Report and clarification on any misinterpretation of the facts found;
- the most recent set of WQC/WQS/WQO values;
- the derivation method and the rationale in developing WQC/WQS/WQO for dissolved oxygen and nutrients;
- an English version of water quality-related documents.

Concurrently, information search continued with browsing the internet following the advice given in the questionnaire replies in the first phase. Thanks to the Water Quality Standards Academy of the USEPA, the author of this report was given an opportunity to attend a training course in May 2004, which introduced the general aspects of the water quality standards programme being implemented in the USA. Relevant course materials are incorporated in this report to supplement information that could not be acquired by the basic research methods.

During information compilation, it is noted that Australia, Canada, New Zealand and the USA have put in substantive effort in WQC/WQS development and have developed a large amount of information in this field, which is readily available for public access via the internet. These four economies are selected for reviewing of the key issues relating to the derivation and application of WQC/WQS because of availability of information for practical conduct of a research. In this report, the information of these economies will be covered in three separation sections, grouped into (i) Australia and New Zealand, (ii) the USA, and (iii) Canada. The grouping is based on the fact that Australia and New Zealand water management systems have been built on the same foundation and they adopt the same water quality criteria and other related policies.

The general approach to the scientific derivation of the criteria and the supporting rationale for their designation will be discussed in greater details for different types of criteria, which include physical and chemical, biological, sediment quality and nutrient criteria.

3 Findings in Phase 2

3.1 COLLECTION AND COLLATION OF INFORMATION

A third questionnaire was sent in January 2004 to the following 14 economies which have been included as target economies for review. *(Text in italic shows the abbreviation of the economy used throughout this report.)*

Australia
Brunei Darussalam, ***Brunei***
Canada
Chile
People's Republic of China, ***China***
Malaysia
New Zealand
Papua New Guinea
Peru
Republic of the Philippines, ***Philippines***
Singapore
Chinese Taipei
Thailand
United States of America, ***USA***

Four economies, namely, Australia, Chile, the Philippines and Chinese Taipei, provided responses to the questionnaire. A copy of the questionnaire and a summary table of the responses are provided in Appendix A. So as not to stray from the main theme of this inter-session report, comments on the Phase 1 report will be incorporated in the final report comprising all the findings in different phases rather than compiling the information at this intermediate stage.

To gain better understanding of the water quality standards program implemented in the USA and to facilitate the preparation of this report, the author attended a training course organized by the Water Quality Standards Academy, USEPA. The course presented an interpretation and application of the water quality standards regulation in the USA, including water body designated uses, the development of water quality criteria, implementation and review. Further guidance and experience shared by the course instructors constitute a significant portion of the materials presented in section 5 of this report.

Guidance documents acquired from the internet or provided by the concerned economies were reviewed. This report includes extensive use of flow charts to illustrate the complex WQC/WQS development processes. The flow charts are either excerpted from the guidance documents or drawn in accordance with the information given therein.

3.2 SUMMARY OF FINDINGS

National guidelines as the basic framework

From the literature review in this phase of the project, it can be easily noted that among the three target groups of economies, the federal governments take a leading role in the formulation of policies and strategies in water quality management. National framework and various programs are in place to achieve ecological sustainable development and to deliver a nation-wide consistent approach to water quality management.

Common features among the water quality management systems of the reviewed economies are found to be :

- national consistency in methods for setting goals, objectives and standards;
- a designated and clearly stated set of beneficial uses or environmental values;
- extensive use of scientific information to derive generic WQC/WQS through research and development;
- clear and explicit administrative processes;
- transparent decision making;
- emphasized federal-provincial rapport and co-operation;
- involvement of stakeholders in definition of goals, development of plans and designation of WQC/WQS;
- mechanisms responsive to change and development, site-specific characteristics regarding ambient environmental conditions, socio-economical needs;
- tactical implementation, monitoring and assessment plans.

Stakeholder involvement

Having wider concern on the environment from the public, stakeholder involvement has become important and requisite in the WQC/WQS development. Maintaining healthy aquatic environment and finding an appropriate balance between protection and other uses of the aquatic environment are the two key elements of stakeholder input that are used to plan and manage water quality. The use of task group in WQC/WQS development is commonly adopted in the water quality systems of the three economy groups. Task groups are often established to firstly formulate WQC/WQS proposal primarily based on scientific information, secondly refine the proposal taking on board public views, and lastly see to the designation of the WQC/WQS. The task groups constitute officers from federal, provincial, state and tribal governments, experts from a diversity of disciplines and interest groups. Such membership is to ensure a breadth of experience and opinions from different perspectives.

The intent of WQC/WQS is to provide the scientific information necessary to define conditions that will protect and maintain the marine environment, including estuarine and marine ecosystems. The WQC/WQS will contain recommendations for physical, chemical, biological variables for this purpose. Most of the recommended values are not to be used as mandatory standards for implementation at the provincial/territorial government level. Rather, they are to be used as reference points for identifying and assessing the potential impacts of environmental quality variables on the uses of the marine environment. Flexibility has been built in the system to enable provincial/territorial governments to modify the recommended WQC/WQS for incorporation into their water quality management goals, taking into account environmental characteristics and other stakeholder inputs such as social, cultural, economic or political constraints. Some of the inputs may be intangible and hard to quantify, however, they are valid to the development process. The relative weighting placed on the scientifically derived WQC/WQS and other considerations will then be case-specific. The process of modifying / developing WQC/WQS as management goals will be carried out through cost-benefit analysis programs involving input from stakeholders and local jurisdiction.

Identification of beneficial uses

The identification of beneficial uses or environmental values is an essential element of the criteria derivation process. WQC/WQS are typically formulated for different types of water uses, which are important for a healthy ecosystem or for public benefit, welfare, safety or health; and which require protection from the effects of pollution, waste discharges and deposits. Common beneficial uses include raw water for drinking water supply, recreation, aquatic life, agricultural water and others. All water resources are subject to at least one of the identified beneficial uses while in the USA all water resources are constitutionally designated to support two basic uses : the protection of aquatic life and recreation purposes.

Sound management of water resources requires a thorough understanding of the environmental conditions and the anthropogenic activities that influence water quality. It also requires integration of the interests of resource user groups with detailed scientific information on the components of ecosystems related to physical, chemical and biological aspects.

Approach to develop physical and chemical WQC/WQS

While a wide array of procedures have been used to derive numerical values for physical and chemical WQC/WQS, the majority of these have been developed using some variations of the theoretical toxicological approach, which is an effects-based approach that relies on published toxicity data from scientific literature. In Canada, Australia and New Zealand, WQC/WQS are developed from a suite of chronic studies, in accordance to the dataset requirements, by multiplying NOEL or NOEC by a safety factor of 0.1 to account for differences in sensitivity to a chemical due to differences in species, in laboratory against field conditions and in test endpoint. When available, acute to chronic ratios (ACRs) may be used to estimate a chronic value from acute toxicity test. In case where no ARCs are available, application factor depending on the environmental fate of the substance are used (e.g. 0.01, 0.05, 0.001).

The USA's approach relies on scientific information of the concerned substance on its effect to aquatic plants and animals, on its bioaccumulation in aquatic organisms and on its potential effects on consumers of aquatic biota. Final acute value (FAV), final chronic value (FCV), final plant value (FPV) and final residue value (FRV) are calculated. The criterion maximum concentration (CMC, short-term criterion) is defined as half of the FAV. The lowest of the FCV, FPV and FRV is used directly to establish the criterion continuous concentration (CCC, long-term criterion). Step-by-step guidance is also provided in the derivation protocol for deriving site-specific WQC/WQS, i.e. recalculation procedure; indicator species procedures, residence species procedures.

Approach to develop biological WQC/WQS

The derivation of biological WQC/WQS in the USA, Australia and New Zealand adopt the reference condition approach, which involves integrated measures of the composition, diversity and functional organization of a reference aquatic community. Canada has yet to develop WQC/WQS in this aspect. The main objective of biological WQC/WQS is to detect important changes of ecosystem in concern from reference conditions. Such departure constitutes impairment of the beneficial use of the water body. Method used to detect such departure is either by (i) statistical analysis for significant differences in two sets of data obtained from the reference site and the concerned site; or (ii) comparing to established biotic indices.

Two types of biological WQC/WQS are used in the USA : narrative and numerical. Statistical approach (hypothesis testing) is mainly used in assessing narrative WQC/WQS while biotic index approach is used in numerical WQC/WQS. The multimetric index is more commonly applied compared to other two biotic indices, namely, discriminant model index and index derived from multivariate ordination. Box and whisker plot is a powerful tool in evaluating the ability of metrics to detect impairment. Metric values beyond the lower or upper quartile of reference conditions are judged impaired to some degree. The actual percentile (25, 10 or 5) adopted is subject to policy decision of each provincial/territorial government.

In Australia and New Zealand, default decision criteria for three types of sites are provided for assessing departure in biodiversity from the reference conditions based on the effect size (i.e. tolerance), the probability of making a Type I error (α) and Type II error (β). For sites of high conservation value, effect size, α, β are recommended to be 10%, 0.1 and 0.2 respectively. These values could be prescribed also for sites of moderately and highly disturbed systems but the effect size could be relaxed, the decision of which should be based on sound ecological principles of sustainability.

Approach to develop nutrient WQC/WQS

Nutrient WQC/WQS in the USA, Australia and New Zealand adopt the same philosophy : for detection of important change from pristine condition or impairment of the beneficial use. Canada has yet to determine a protocol for deriving nutrient WQC/WQS. Nutrients management and effective control of over-enrichment is a complex issue and requires continuous effort to tackle the associated eutrophication problem due to the great variability in inherent nutrient levels and nutrient responses throughout the concerned country. The variability arises from differences in geology climate, water body type and anthropogenic activities. The USA adopts the regional and water-body type approach to derive "ecoregional" nutrient WQC/WQS for application at regional level. The numerical values are derived based on historical data, reference site data, evaluation from a panel of specialists with due consideration on the properties of five important variables, namely, nitrogen, phosphorus, silica, chlorophyll a, water clarity and dissolved oxygen. Four approaches are available for criteria development, which are mainly for establishment of reference conditions. The median or the upper quartile of the frequency of distribution of indicator endpoint is often taken as the reference point of the target condition. Analysis of historical ambient nutrient and sediment data, hind casting modelling, areal load approach and an index site approach are recommended.

In Australia and New Zealand, nutrient WQS/WQC follow the protocol for physical and chemical stressor. Default trigger values are derived from statistical calculation of ecosystem data collected from unmodified or slightly modified ecosystems within five geographical regions across the two nations. The 20^{th} or 80^{th} percentile values of the reference site data are taken to be the default trigger values for slightly to moderately disturbed ecosystem. A less conservative percentile value (i.e. 10^{th}or 90^{th} percentile) is taken if it is aimed to maintain the water quality of highly disturbed ecosystems. No trigger values are applied for pristine water bodies.

Approach to develop sediment QC/QS

Sediment quality has become an important component in water quality management as sediment provides a source of contaminants for benthic biota and hence potentially to the aquatic food chain. In this area, Canada, Australia and New Zealand have developed protocols for derivation of sediment QC/QS. The USA, in principle, uses the partition equilibrium approach to derive sediment quality criteria for non-ionic contaminants. Further refinement in the derivation concerning uncertainty around the assumptions inherent in the approach needs to be addressed before the criteria are established. Formal derivation protocol and water quality criteria have not been established currently.

The Canadian Council of Ministers of the Environment (CCME) approach, also known as the weight-of-evidence approach, matches sediment chemistry and biological effects data. These data are then collected, evaluated, and incorporated into a common database (termed the Biological Effects Database for Sediments, BEDS). Acceptable data are sorted in ascending chemical concentrations and then sub-sorted according to toxicity endpoints. A threshold effects level (TEL) is calculated as the square root of the product of the lower 15th percentile concentration associated with observations of biological effects and the 50th percentile concentration of the no-observed effects data. A safety factor of 0.5 is applied to the TEL to define a no-observable–effects level (NOEL), which is used as the interim sediment quality guideline. The interim guideline will be modified to full guideline when information on specific sediment type or the overlying water column characteristics are known.

In view of few reliable sediment toxicity data available, Australia and New Zealand's approach to deriving sediment quality WQC/WQS is adopting the best available overseas data and refining them based on the current condition and local effects data. The National Oceanic and Atmospheric Administration (NOAA) values form the basis of the default trigger values and they are regarded as interim sediment quality guidelines.

In the following three sections, the philosophy and derivation method for WQC/WQS in each of the target groups of economies are discussed in detail.

4 WQC/WQS of Australia and New Zealand

4.1 PHILOSOPHY OF WQC/WQS APPLICATION

Environmental regulation and management in Australia and New Zealand have recently undergone a major change, adopting a more holistic and integrated pollution-prevention approach to environmental protection. The objective adopted for the protection of aquatic ecosystem is :

> *to maintain and enhance the 'ecological integrity' of freshwater and marine ecosystems, including biological diversity, relative abundance and ecological process;*

and where, ecological integrity is defined as :

> *the ability of aquatic ecosystem to support and maintain key ecological processes and a community of organisms with a species composition, diversity and functional organization as comparable as possible to that of natural habitats within a region.*

Depending on the condition of the ecosystem in concern, whether it is non-degraded or has a history of degradation, the management focus may vary from simple maintenance of the present water quality to improvement in water quality so that the condition of the ecosystem would be more natural and the ecological integrity could be enhanced.

The new approach is issue-oriented, in contrast to the previous approaches that are more often focused on simple management of individual water quality parameters, e.g. toxicant concentration, to meet respective water quality objectives. Substantial emphasis has been put on the biological aspect of aquatic ecosystems, i.e. biodiversity and community metabolism in which the use of biological indicators to accompany physical and chemical indicators is widely promoted in the impact assessment of ecosystem integrity.

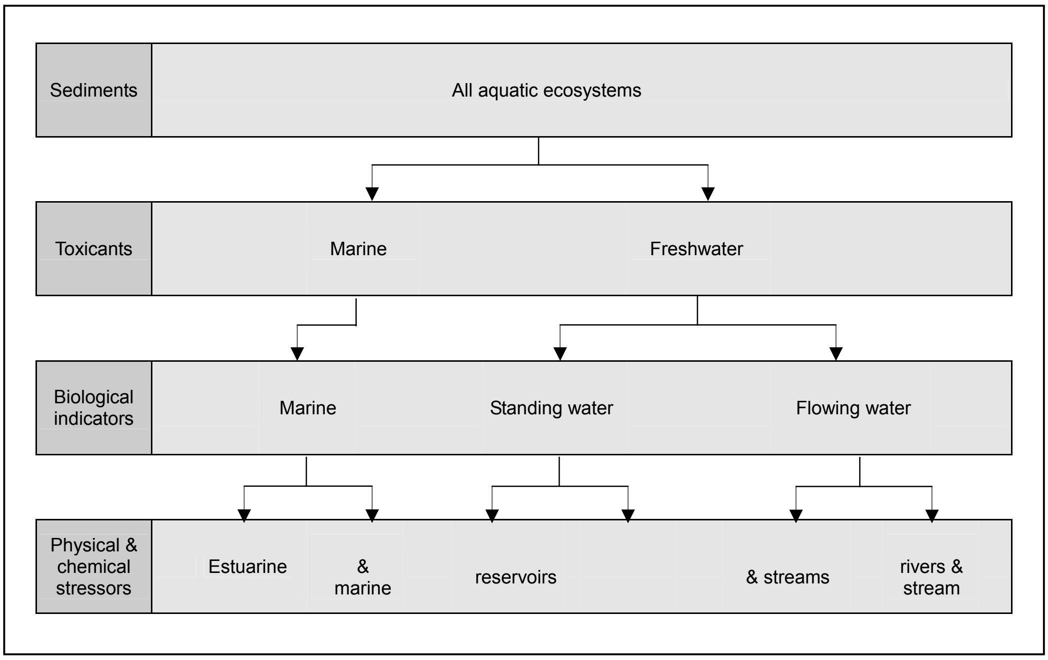
Overall, the approach has moved away from relying solely on chemical indicators for managing water quality to the use of integrated approaches, comprising :

- chemical-specific guidelines coupled with water quality monitoring;
- direct toxicity assessment;
- biological monitoring.

4.2 FRAMEWORK FOR DEVELOPING AND APPLYING THE WQC/WQS

The Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZEECC/ARMCANZ 2000, hereafter referred as 'the Guidelines' in this report) provide a framework for applying numerical guidelines for the protection of aquatic ecosystems. This framework considers protection of up to six types of aquatic ecosystem with application of different categories of indicators. The classification of ecosystem type for each of the broad categories of indicators is given in Figure 4.2.1.

Figure 4.2.1 Classification of ecosystem type for each of the broad categories of indicators



The framework also features three categories of ecosystem conditions, with a level of protection ascribed to each :

- High conservation/ecological value systems (*Condition 1 ecosystem*) are defined as effectively unmodified, highly valued ecosystem, typically occurring in national parks, conservation reserves or remote/inaccessible location. There should be no change in biodiversity and background characteristics beyond natural variability.

- Slightly to moderately disturbed systems (*Condition 2 ecosystem*) are ecosystems in which diversity may have been adversely affected to a relatively small but measurable degree by human activity. Examples include rural streams and marine areas adjacent to metropolitan areas. Departures from reference conditions based on statistical decision criteria are allowed.

- Highly disturbed systems (*Condition 3 ecosystem*) are defined measurably degraded ecosystems of lower ecological value. Examples include shipping ports and urban streams. Departures form reference conditions are more lenient then the other two ecosystems.

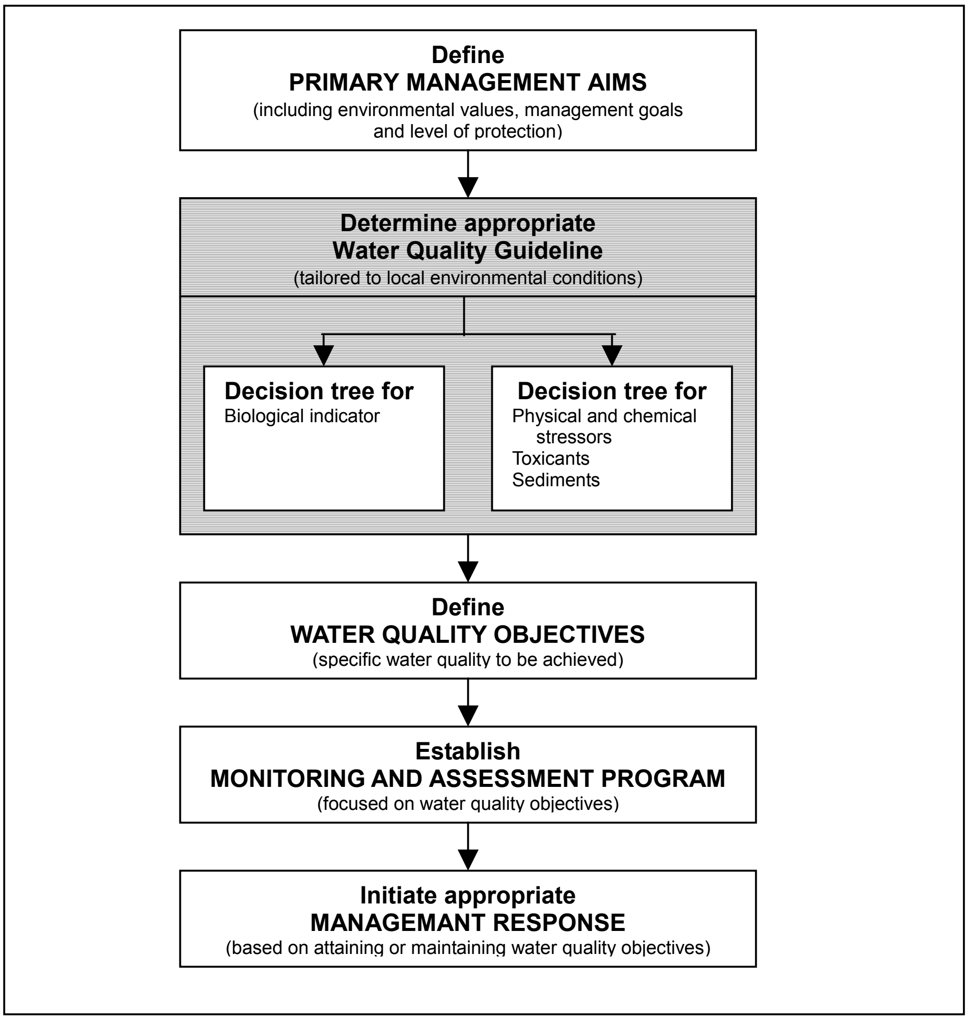
Derivation of WQC/WQS based on risk-based approach is applied to slightly to moderately disturbed (condition 2) and highly disturbed aquatic ecosystems (condition 3) with a focus on identifying the environmental issues and the protection to manage them. Precautionary approach is recommended for aquatic ecosystems considered of high conservation/ecological value (condition 1). This approach should only be relaxed when there are considerable biological assessment data showing that such a change would not disturb the biological diversity of the ecosystem.

Figure 4.2.2 shows the framework of the WQC/WQS system for the protection of aquatic ecosystems. The first stage and the last three stages are common to the application of all the indicator types (biological, physical-chemical, chemical and sediment). The second stage applies different risk-based decision-making processes to the different indicator types.

The initial stage of the framework involves defining the water body by ecosystem classification, determining the environmental values (i.e. beneficial uses), understanding the environmental processes that affect the water quality concerned, deciding the level of protection, and lastly setting the management goals. The philosophy behind selecting a level of protection is either to maintain the existing ecosystem condition, or to enhance a modified ecosystem. Table 4.2.1 summaries a general framework for considering levels of protection across each of the indicator types for each of the ecosystem conditions.

The next stage is to apply the decision tree scheme for the selected indicators. The approach for biological indicator is different from that for the others. It works on the principle of detecting changes in the ecosystem based on statistical criteria while the others work on the application of trigger values. Details on the application of the decision trees for different indicators are provided in the following sections. In this stage, assessment of data and, where possible, refinement of the recommended trigger values are based on local data using (i) the general framework for biological indicators (Section 4.4), or (ii) the decision framework for other indicators (Section 4.5 to 4.7).

Figure 4.2.2 Management framework for developing the water quality WQC/WQS



The third stage is to determine water quality objectives which are the water quality targets, expressed in numerical concentration limit or descriptive statement, agreed between stakeholders or set by the local jurisdiction for the support and maintenance of a designated water use. These objectives also serve as the indicators of management performance. In considering the water quality objectives, besides the general scientific advice provided in the Guidelines, other factors, such as those of a socio-economic nature, management strategies or policies, might need to be included in the decision making process.

The fourth and the last stage of the framework involve the development of tactical monitoring programmes and statistical performance criteria to evaluate compliance with the water quality objectives; and to determine appropriate management responses to attain or maintain water quality objectives.

Table 4.2.1 Recommended levels of protection defined for each indicator type

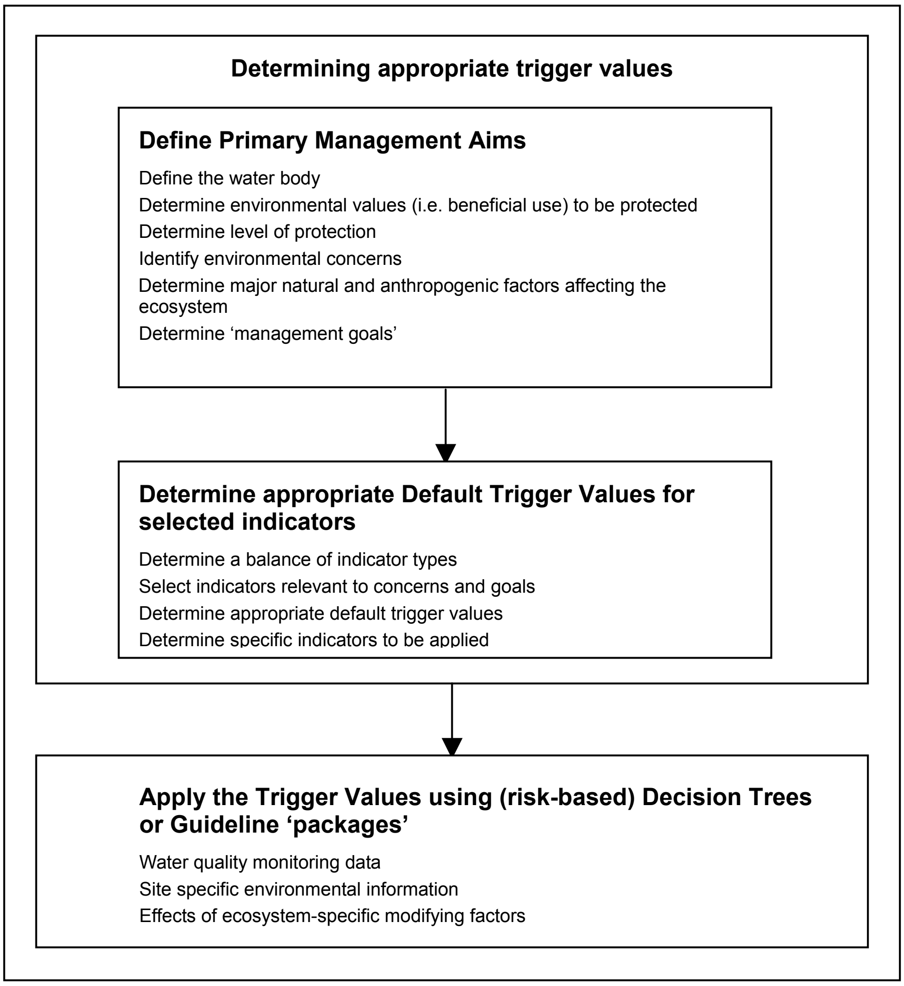
Ecosystem condition	Level of protection			
	Biological Indicators	*Physical & chemical stressors*	Toxicants	Sediments
1 High conservation/ ecological value	• No change in biodiversity beyond natural variability. Recommend ecologically conservative decision criteria for level of detection. • Where reference condition Is poorly characterized, actions to increase the power of detecting a change recommended. • Precautionary approach recommended for assessment of post-baseline data through trend analysis or feedback triggers.	• No change beyond natural variability recommended, using ecologically conservative decision criteria for detecting change. Any relaxation of this objective should only occur where comprehensive biological effects and monitoring data clearly show that biodiversity would not be altered. • Where reference condition is poorly characterized, actions to increase the power of detecting a change recommended. • Precautionary approach taken for assessment of post-baseline data through trend analysis or feedback triggers.	• For toxicants generated by human activities, detection at any concentration could be grounds for investigating their source and for management intervention[1]; for naturally-occurring toxicants, background concentrations should not be exceeded. *Where local biological or chemical data have not yet been gathered,* apply the default values. Any relaxation of these objectives should only occur where comprehensive biological effects and monitoring data clearly show that biodiversity would not be altered. • In the case of effluent discharges, direct toxicity assessment (DTA) should also be required. • Precautionary approach taken for assessment of post-baseline data through trend analysis or feedback triggers.	• No change from background variability characterized by the reference condition. Any relaxation of this objective should only occur where comprehensive biological effects and monitoring data clearly show that biodiversity would not be altered. • Precautionary approach taken for assessment of post-baseline data through trend analysis or feedback triggers.
2 Slightly to moderately disturbed systems	• Negotiated statistical decision criteria for detecting departure from reference condition. Maintenance of biodiversity still a key management goal. • Where reference condition is poorly characterized, actions to increase the inferential strength of the monitoring program suggested. • Precautionary approach may be required for assessment of post-baseline data through trend analysis or feedback triggers.	• Always preferable to use data on local biological effects to derive guidelines. *If local biological effects data unavailable*, use local or regional reference site data to derive trigger value values. Alternatives to the default decision criteria for detecting departure from reference condition may be negotiated by stakeholders but should be ecologically conservative and not compromise biodiversity. *Where local reference site data not yet gathered, apply default, regional low-risk trigger values* • Precautionary approach may be required for assessment of post-baseline data through trend analysis or feedback triggers.	• Always preferable to use data on local biological effects (including DTA) to derive guidelines. If local biological effects data unavailable, apply default, low-risk trigger values . Precautionary approach may be required for assessment of post-baseline data through trend analysis or feedback triggers. • In the case of effluent discharges DTA may be required.	• Apply the sediment quality guidelines. • Precautionary approach taken for assessment of post-baseline data through trend analysis or feedback triggers.
3 Highly disturbed systems	• Selection of reference condition within this category based on community desires. Negotiated statistical decision criteria for detecting departure from reference condition may be more lenient than the previous two condition categories.	• Local or regional reference site data used to derive guideline values using suggested approach in sec 3.3.2.3. Selection of reference condition within this category based on community desires. Negotiated statistical decision criteria may be more lenient than the previous two condition categories. *Where local reference site data not yet gathered*, apply default, regional low-risk trigger value; or use biological effects data from the literature to derive guidelines.	• Apply the same guidelines as for 'slightly-moderately' disturbed systems. However, the lower protection levels provided in the Guidelines may be accepted by stakeholders. • DTA could be used as an alternative approach for deriving site-specific guidelines.	• Relaxation of the trigger values where appropriate, taking into account both upper and lower guideline values. • Precautionary approach may be required for assessment of post-baseline data through trend analysis or feedback triggers.

[1] For globally distributed chemicals such as DDT residues, It may be necessary to apply background concentration, as for naturally occurring toxicants.

4.3 DETERMINATION OF TRIGGER VALUES

Trigger values represent bioavailable concentrations or unacceptable levels of contamination, which when exceeded trigger investigations to check whether a real risk to the ecosystem exists. The general steps to derive trigger values involve determining a balance of indicator types, selecting indicators relevant to concerns and goals, and lastly determining appropriate trigger values. The preferred approach for local jurisdictions to derive trigger values follows this order: use of biological effects data, then local reference data (mainly physical and chemical stressors), and finally the default values provided in the Guidelines. The default approach is applying the default trigger values and refining them based on locally available data. Figure 4.3.1 shows the flow chart of applying the guidelines for protection of aquatic ecosystems involving trigger values.

Figure 4.3.1 Flow chart of applying the guidelines for protection of aquatic



4.4 BIOLOGICAL INDICATORS

4.4.1 Philosophy and approach

Pertaining to the objective of maintaining and enhancing ecological integrity, biological indicator is to provide information on biological or ecological outcomes, which may result either from changes in water quality, changes in the physical habitat or changes in biological interactions. The guidelines for biological assessment are intended to detect important departure of the ecosystem in concern from a reference condition, i.e. relatively natural, unpolluted or undisturbed state. An important departure is defined as one in which the ecosystem shows substantial effects, including :

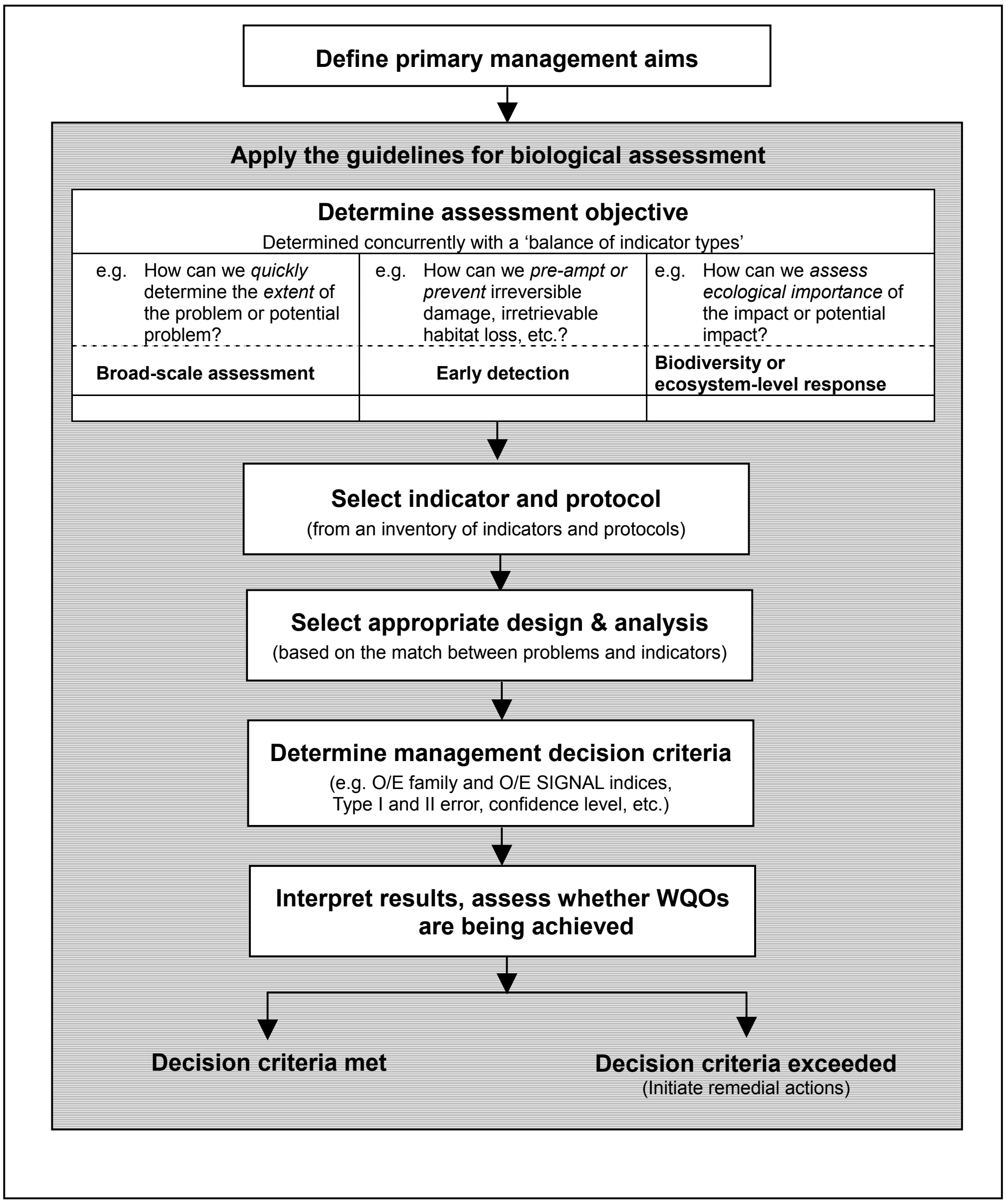
- changes to species richness, community composition and/or structure;
- changes in abundance and distribution of species of high conservation value or species important to the integrity of ecosystems;
- physical, chemical or biological changes to ecosystem processes.

Assessment of departure makes use of statistical design to determine whether a change significantly deviates from a reference condition. Given the vast variability in the biological systems and the vital need for high quality and comprehensive sampling design, the Guidelines provide a suite of protocols with improved design and rigour in reference site selection, sampling approaches and analysis.

4.4.2 Framework for biological assessment of water quality

The steps involved for implementing a biological monitoring and assessment program are presented in a flow chart shown in Figure 4.4.1.

Figure 4.4.1 Decision tree for biological assessment of water quality



4.4.3 Biological assessment objectives

The initial step of the decision tree is to determine the level of protection required for an ecosystem followed by the next step to decide the objective of the assessment from three available choices. This step enables water quality managers to select the most appropriate indicators and protocols that match the objective.

The first of the three assessment objectives is broad-scale assessment for ecosystem health. Tools for rapid biological assessment (RBA) have been developed for rapid, cost effective and adequate first-pass determination of the extent of a problem. The most developed RBA method is AUSRIVAS, which is a method using macroinvertebrate communities in rivers and streams as indicators.

The second assessment objective is early detection of acute and chronic changes in the ecosystem. The detection enables water quality managers to implement responses before serious environmental harm occurs. An indicator used for early detection of changes should be : sensitive to the type of stressor, correlated with environmental effects, time- and cost-effective, highly constant over time and space, regionally and socially relevant, and broadly applicable. Methods for detection fall into two categories, which are classified based on the different combination of the attributes above :

- sub-lethal organism responses (e.g. growth, reproduction)
- rapid biological assessment (RBA, e.g. AUSRIVAS)

The third objective, i.e. assessment of biodiversity, measures the effects upon the ecosystem as a whole, complementary to the data gathered for early detection indicators. The data gathered for this objective are comparatively more detailed and accurate than those for broad-scale assessment. It is widely used in the following scenarios :

- sites of special interest;
- assessment for ecological importance of disturbance at sites and over a broader geographical region;
- in any situation where a management objective has been strongly linked to the Ecologically Sustainable Development tenet of the 'Maintenance of biodiversity and ecological systems'.

To achieve a consistent and defensive approach in the application of WQC/WQS across the nation, viable protocols using diatoms and algae, macrophytes, macroinvertebrates and fish have been developed. The Guidelines provide guidance for matching water quality issues and indicators so that water quality managers can select the most appropriate ones from an inventory of established indicators and protocols. The list of indicators and protocols recommended for various environmental issues is reproduced in Table 4.4.1.

4.4.4 Inventory of indicators and protocols

Indicators

The Guidelines provide a rationale for the use of each indicator recommended for monitoring and assessment of water quality in various aquatic ecosystems of Australia and New Zealand. There are 4 categories of indicators for freshwater systems and 5 for estuaries and coastal marine ecosystems. Summary descriptions of these protocols with reference to important source documents are provided in Appendix 3 of the Guidelines (Vol. 2). Below is a brief account of the indicators established.

For streams, lakes and wetlands

(i) Algae

Algae assumes a fundamental role in food chains and they are particularly suitable for investigations involving organic matters and nutrients. Phytoplankton biomass is routinely used to assess the degree of eutrophication in lakes, estuaries and slow moving or impound rivers. The Autotrophic Index[A] and other biotic and diversity indices based on species abundance (e.g. diatom) are used for biomonitoring. Diversity indices that do not rely on known habitat ranges for data interpretation are alternatives to the Autotrophic Index when a flora is dominated by local algal taxa.

Predictive modeling and paleolimnological approaches are also applicable in the water quality assessment. Three generic early detection-type protocols have been developed for streams and wetlands.

[A] The Autotrophic Index is the ratio of total organic matter (measured as ash-free dry mass) to autotrophic biomass (measures as chlorophyll *a*) in periphyton.

Table 4.4.1 Water quality issues and recommended biological indicators for different ecosystem types.

Code	Issue	Suitable biological indicator or assessment approach	Protocol[1]	Ecosystem type
1A, B	General inorganic (including metals) and organic contaminants: Early detection of short- or longer-term changes from substances in solution/water column	1A Instream/riverside assays measuring sublethal 'whole-body' responses of invertebrate and/or fish species; 1B Biomarkers (chemical/biochemical changes in an organism) Direct toxicity assessment	1A (i), (ii) 1B (i), (ii) sec8.3.6 (Vol2)	S S, W, L, M S, W, L, M
2A,B	General inorganic (including metals) and organic contaminants: Early detection of short- or longer-term changes from substances deposited (sediments)	2A 'Whole-sediment' laboratory toxicity assessment (where sediment tests are available) 2B Bioaccumulation/biomarkers (for organisms that feed through ingestion of sediment); other sublethal incl. behavioral responses where protocols developed	2A, sec 8.3.6 2B(i)-(ii)	S, W, L, M S, W, L, M
3	General inorganic (including metals) and organic contaminants: Changes to biodiversity and/or ecosystem processes	Structure of macroinvertebrate and/or fish populations[2, 3]/communities[3] using rapid, broad-scale (RBA[4]) or quantitative (Q) methods Stream community metabolism	3A(i)-(v) 3B	S, W S
4	Suspended solids in the water column	Structure of macroinvertebrate and/or fish populations[2]/communities using RBA[4] or Q methods Seagrass depth distribution	3A(i)-(v) 6	S M
5	Sedimentation of river bed	As for 4 as well as stream community metabolism	3A(i)-(v), 3B	S
6	Effects of organotins	Imposex in marine gastropods	9	M
7	Salinity: Changes to biodiversity	Structure of macroinvertebrate and/or fish populations[2, 3]/ communities[3] (RBA[4] or Q methods); remote sensing (changes to vegetation structure);	3A(i)-(v) 5	W, S?
8	Herbicide Input: Changes to biodiversity	Structure to phytoplankton or benthic algal communities; remote sensing (changes to vegetation structure).	4(i)-(v), 5	W, S
9	Nutrient inputs: Early detection of short- or longer-term changes from substances deposited or in solution/water column	Structure and/or biomass of benthic algal or phytoplankton communities Stream community metabolism	4(i)-(iii) 3B	S, W S
10	Nutrient inputs: Changes to biodiversity and/or ecosystem processes	Structure and or biomass of phytoplankton, benthic algal and/or macroinvertebrate populations[2]/communities (Q or RBA[4]) Stream community metabolism	3A (i)-(v), 4(i)-(ii) 3B	S, W S
11	Nutrient inputs	11a Seagrass depth distribution 11b Frequency of algal blooms 11c Density of capitellids 11d In-water light climate 11e Filter feeder densities 11f Sediment nutrient status 11g Coral reef trophic status	6 7 8	M M M
12	General effluents (non-specific) and effects of hypoxia	Structure of macroinvertebrate communities (Q or RBA[4])	3A (i)-(iii)	S, W
13	Broad-scale assessment of ecosystem 'health' (non-specific degradation)	13A Composition of macroinvertebrate communities using RBA methods 13B Habitat distributions 13C Assemblage distributions	3A (i)-(ii)	S,W M M

Ecosystem types: S = streams and rivers, W = wetlands, L = lakes and M = estuarine/marine. Letters or indicator in italics denote that while the indicator is not presently available, it could be developed relatively quickly with additional resourcing.

1. The codes listed in this column refer to protocols that are listed by title in Section 8.1.3 of Volume 2 of the Guidelines Summary descriptions of these protocols, with references to important source documents, are provided in Appendix 3, Volume 2.
2. Populations could serve as biodiversity surrogates if a 'keystone' role could be established for a species.
3. For pesticides, study of non-target organisms.
4. Cautionary notes given in the Guidelines on use of RBA methods for site-specific assessments should be consulted.

(ii) Macroinvertebrates

Benthic invertebrates inhabit abundantly in the marine environment and they are important components of ecosystems. They possess various attributes which make them the key indicator group for bioassessment. They graze periphyton, assist in the breakdown of organic matter and cycling of nutrients and in turn, may become food for predators; they have generally limited mobility; they are easy to collect for analysis and they have a diversity of species. A number of invertebrate species live in sediment for a sufficiently long time, rendering them to be of particular value as bioaccumulating indicators.

Analysis of invertebrate data is often expressed using one or more indices, e.g. Macroinvertebrate Community Index (MCI) is used to detect and monitor water quality degradation in New Zealand; the Stream Invertebrate Grade Number – Average Level (SIGNAL) to identify family level in south-eastern Australia. Functional groups measures, which reflect dominance of a particular feeding groups at a site and in turn indicate particular types of chemical contamination, is less commonly employed in Australia than in North America. Four generic biodiversity-type protocols and three early detection-type protocols have been developed for streams and wetlands using this group of indicators.

(iii) Freshwater fish

The use of fish as indicator varies across the two nations. Australia has a high diversity of fish fauna in the northern part of the continent but of low diversity in the southern and inland regions. Exotic species tend to dominate the native fish fauna in both abundance and biomass in southern inland water. In New Zealand, about 75% of the native fish fauna is diadromous. Thus, the use of natural freshwater communities for field bioassessment of water and habitat quality is not recommended in New Zealand.

Bioassessment methods using fish include assessment on the following parameters :

- changes in abundance, population structure, recruitment or distribution of single species;
- changes in community composition;
- physiological or biochemical changes in fish tissues;
- toxicity of ambient waters or effluent.

However, few of these methods have been widely employed due to the lack of understanding of fish population dynamics and ecology. A standardized assessment method has yet to be established at the national level or applied routinely for bioassessment for water quality impacts. Guidance on the use of fish assemblages for measurement of biodiversity response has been prepared and one early detection-type protocol developed using a freshwater fish species for streams and wetlands of Australia.

(iv) Other taxa

Very few viable protocols using microorganisms (other than algae and zooplankton), macrophytes, zooplankton, frogs, aquatic and semi-aquatic reptiles, and water birds, have been developed for as indicators.

There are problems with the use of bacteria, protozoa, fungi macrophytes and zooplankton in bioassessment : rapid generation time, considerable amount of variation in community structure and inadequate taxonomic knowledge. Frogs show high sensitivity to a wide range of environmental insults and the semi-permeable nature of the skin places all life-stage at risk from uptake of contaminants present in the ambient environment. Over the past two decades, frogs are commonly used as bioindicators but several factors have limited further development, which include : semi-aquatic nature of the frog cycle, highly seasonal and transient nature of the larval phase of the life cycle, selective breeding sites, unidentified cause of global decline in population of many frog species.

Gill-breathing, aquatic organisms are at risk from water-borne contaminants because of their metabolism in the water while the link of water-borne contaminants to air-breathing animals is through dietary uptake. Food poisoning of aquatic and semi-aquatic reptiles and water birds has indirect and adverse effect on their population. Monitoring of organisms at the low end of a food chain provides advance warning of potential effects on organisms at the other end. Given the habitual migration between wetlands, breeding success rate of water birds is a more suitable indicator than population or community structure.

For marine and estuarine systems

(i) Biomarkers

Organisms respond to environmental stress by invoking molecular responses, which can be physiological or other changes. Though molecular changes may not necessarily reduce the organism’s ecological fitness, many molecular changes show linkage to pollutants in the ecosystems. A number of site- or host-specific responses have been detected in biomarkers based on the activity of specific enzymes in the liver, kidney and blood of organisms. At this stage in Australia, only biomarkers for estuarine and marine systems have been developed, e.g. biomarkers in flathead have been used to detect pollution.

(ii) Frequency of algal blooms

Algal blooms have undesirable environmental consequences which are often in association with production of large amount of biomass, deoxygenation in bottom waters due to the decay of the biomass, elimination of benthic organisms, emission of noxious and offensive odours affecting local recreational amenity and in some case release of toxic substances affecting human and wildlife. Occurrence of algal blooms is related to a complexity of seasonal factors, like light availability, temperature, nutrients, river runoff, weather conditions, stratification or ocean currents. Because algal blooms are an integrated biological response to various forms of nutrient input, the frequency and intensity of algal blooms are used as a measure of the quality of a water body.

(iii) Seagrass depth distribution

Seagrass are flowering plants that grow in marine or brackish water. There are over 30 species of seagrasses and they are widely distributed in both tropical and temperate coastal waters. Light is a limiting factor for the growth of seagrass at various water depth. Available light is influenced by sediment particles in the water column, by colour from natural or industrial process, by high concentrations of plankton, and by the growth of fouling algae on the seagrass leaves. These are in turn related to various land-based pollution. Thus, the depth distribution of seagrasses is a useful integrated indicator for long-term water quality (light) conditions.

(iv) Imposex in marine gastropods

Imposex is the term given to the development of male genitalia or other form of physical abnormality, in female marine gastropod mollusks. Increased frequencies of imposex are known to be caused by organotin compounds, e.g. butyl and phenyl tins used in antifouling agents. This unique cause-effect relationship has initiated several studies in Australia and New Zealand to use imposex in gastropods to detect the magnitude and distribution of biological effects of organotins near vessels-related premises, e.g. shipyards. A global protocol has been developed which is applicable to a number of taxa, despite the variations in morphology in various gastropod species.

(v) Density of capitellid worms

In Australia there are 36 known species of marine polychaete worms belonging to the Capitellidae family. Because of their wide distribution, their role in sediment process and food webs, and easy identification, they are commonly used as indicators of environmental quality. In particular, capitellids have been identified as responding to organic enrichment of sediments, typically, in response to inputs of sewage.

Protocols

A suite of protocols have been developed for bioassessment in Australia, and in many cases New Zealand. These protocols set out the experimental design for data collection, laboratory testing and statistical analysis for derivation of the indicators. The titles of the protocols are given below for easy reference while summary descriptions of these protocols are provided in Appendix 3 of the Guidelines (Vol. 2). These protocols are generic and are broadly applicable to most regions of Australia and possibly New Zealand. Water quality managers should follow the decision tree (Section 4.4.2) and guidance notes on matching indicators to environment issues (Section 4.4.3).

For marine and estuarine ecosystems

- Direct Toxicity Assessment
- Method 1A (i), (ii) : Instream/riverside assays measuring sub lethal ‘whole-body’ response of invertebrate and/or fish species
- Method 1B (i), (ii) : Measurement of chemical/biochemical markers in aquatic organisms
- Method 2A : ‘Whole-sediment’ laboratory toxicity assessment (where sediment tests are available)
- Method 2B : Bioaccumulation/biomarker for (organisms that feed through ingestion of sediment); other sub lethal responses (incl. behavioural) where protocols developed
- Method 3A(i), (ii) : Monitoring and assessment of streams using macroinvertebrate communities
- Method 3A (iii), (iv) : Monitoring and assessment of wetlands and lakes using macroinvertebrate communities
- Method 3A(v) : Structure of freshwater fish communities
- Method 3B : Stream metabolism
- Method 4(i) : Periphytic algae
- Method 4(ii) : Phytoplankton
- Method 4(iii) : Macroalgae

- Method 5 : Changes to wetland vegetation structure as measured through remote sensing

For marine and estuarine ecosystems

- Method 6 : Seagrass depth distribution
- Method 7 : Frequency of algal blooms
- Method 8 : Density of capitellids
- Method 9 : Imposex in marine gastropods

4.4.5 Determination of decision criteria for biological assessment

When appropriate indicators and protocols for assessment have been selected following the decision tree as shown in Figure 4.4.1, decision criteria should then be set to detect the departure in biodiversity from reference condition, based on the effect size (tolerance from a reference condition), the probability of making a Type I error (α) and Type II error (β).

For situations where there is a paucity of baseline information and/or adequate spatial control, the "weight-of-evidence" approach[B] is recommended for inference. The process is based on risk assessment principle which draws on epidemiological precepts in interpreting test results. For situations when monitoring data are analyzed using predictive models, e.g. AUSRIVAS, two indices derived from the field data using the model can be used for assessment :

- O/E family – the ratio of the number of families of macroinvertebrates at a site to the number of families expected at that site;

- O/E signal – the ratio of the observed signal value for a site to the expected signal value. The signal indicates sensitivity of the biological communities to pollution.

A banding system based on the values of the two indices is used to indicate the state of the macroinvertebrate communities when compared with the reference condition.

[B] The approach is organized around the weight assigned to each 'measurement end-point', the magnitude of its response and concurrence among different end-points. It enables multiple ecological risk measurements to be integrated to evaluate whether significant risk of harm is posed to the environment.

Table 4.4.2 shows the division of AUSRIVAS O/E indices into bands. Water quality managers and stakeholders should take the results into consideration when drawing up site-specific guidelines. A software package of the AUSRIVAS could be downloaded from http://ausrivas.Canberra.edu/auausrivas for performing all the calculations required for the bioassessment.

Table 4.4.2 Banding system of the AUSRIVAS O/E indices

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

Notes: 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, following by likely causes (dot-points).

The setting of the decision criteria depends on the level of protection for each of the three ecosystem conditions. In any case, local jurisdictions could adopt alternative guidelines to the recommended ones after considering site-specific conditions, e.g. having different effect sizes for tests in summer and winter when the ecosystem has a seasonal variability. In the absence of clear information, the default criteria for ecologically conservative decisions should be taken. The criteria are summarized below :

For sites of high conservation value (condition 1 ecosystem)

- $\alpha = 0.1$
- $\beta = 0.2$
- effect size = 10% of or 1 standard deviation about the baseline mean, whichever is smaller
- no. of reference sites = 3-5
- sampling period = at least 3 years for all indicators where possible

For slight to moderately disturbed systems (condition 2 ecosystem)

- prescribe the default values for condition 1
- the effect size could be relaxed, the decision for which is based on principles of sustainability

For highly disturbed systems (condition 3 ecosystem)

- prescribe the default values for condition 1
- the effect size could be arbitrary relaxed, though the decision should still be based on principles of sustainability

It should be noted that the default values for α, β and effect size, are not to be seen as dogma. Flexibility and discretion should be exercised for each case based on the merits and the prevailing conditions. When there is difficulty in gathering sufficient baseline data, the Guidelines recommend that addition monitoring be carried out, including a greater number of indicators and/or sites for 'early detection' and biodiversity measurement.

4.5 PHYSICAL AND CHEMICAL STRESSORS

4.5.1 Philosophy and approach

The objective of applying the WQC/WQS is to ensure that (i) no detectable change in the level of the stressors for condition 1 ecosystems; and (ii) the ecosystems are adequately protected for condition 2 and 3 ecosystems.

Site-specific trigger value for each of the selected indicator is to be determined using either (in order of preference) biological and biological effects data, reference data (data from a reference condition) or the default value given in the Guidelines. Two approaches are recommended for derivation of the trigger values at local jurisdiction level : (i) derivation from reference data, and (ii) applying the default trigger values.

Trigger values are not applied to pristine water bodies (i.e. condition 1 ecosystems). Only monitoring programmes are needed to demonstrate that the values of the stressors are not changing, using conservative decision criteria as the basis for evaluation. When using reference data for deriving the trigger values for slightly to moderately disturbed ecosystems (condition 2), the 20^{th} or 80^{th} percentile values of the collected data are taken to be the target trigger values. A less conservative percentile value (i.e. 10^{th} or 90^{th} percentile) is taken if it is aimed to maintain the water quality of highly disturbed ecosystems (condition 3).

The default trigger values are derived from statistical calculation of ecosystem data collected from unmodified or slightly modified ecosystems within five geographical regions across Australia and New Zealand. Due to the lack of specificity in the data which reflect the local conditions, the Guidelines recommend that the default trigger values should only be regarded as interim until site-or ecosystem-specific values are derived.

Guideline packages, based on risk-based decision approaches and ecosystem-specific factors, are provided for water quality mangers to derive the site-specific trigger values. Throughout the process, statistical decision criteria are used for detecting changes in the ecosystem. These criteria should be conservative and based on sound ecological principles. They could only be relaxed when there are considerable biological assessment data showing that such changes will not affect biological diversity in the system.

4.5.2 Framework for developing the trigger values

Physical and chemical stressors are broadly classified into two types (Figure 4.5.1) depending on whether they have direct or indirect effects on the ecosystem. The following stressors are considered under this category of indicators : nutrients, biodegradable organic matter, dissolved oxygen, turbidity, suspended particulate matter (SPM), temperature, salinity, pH and changes in flow regime. The other stressors are separately dealt with under the category of toxicants and sediments.

Figure 4.5.1 Types of physical and chemical stressors

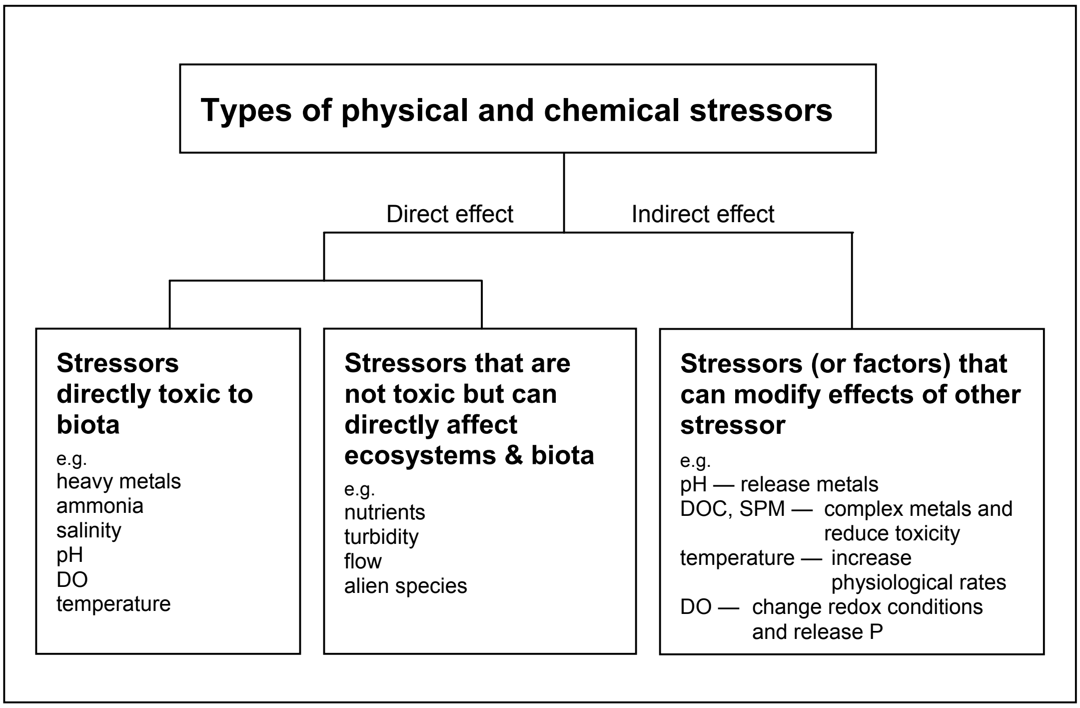


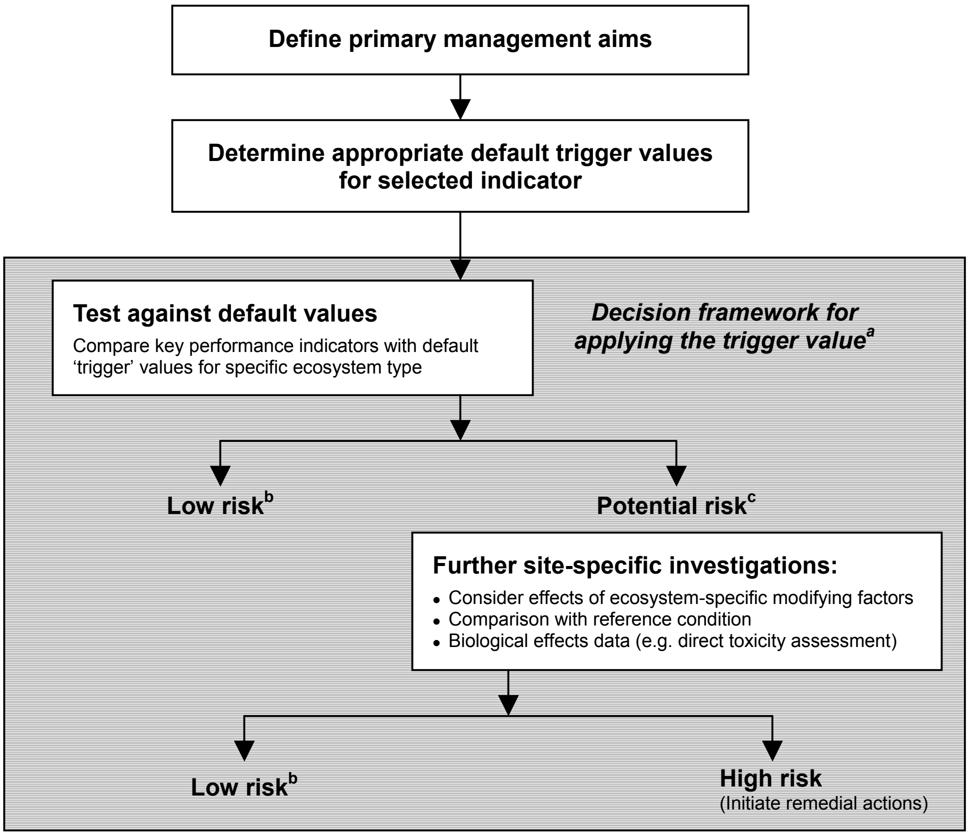
Figure 4.5.2 shows the decision tree framework using default trigger values for determining the physical-chemical stressors. The shaded areas in the figure denote the steps in the guideline packages to help water quality managers to derive the low-risk, site-specific trigger values. Each package consists of two components : (i) a method to derive the low-risk trigger values; and (ii) a protocol for further investigation which involves a decision tree or predictive modeling approach to assess the risk when local data exceed the established trigger values.

Eight guideline packages are available :

- Nuisance growth of aquatic plants (eutrophication);
- Lack of dissolved oxygen (DO; asphyxiation of respiring organism);
- Excess suspended particulate matter (SMP; smothering of benthic organisms, inhibition of primary production);
- Unnatural change in salinity (change in biological diversity);
- Unnatural change in temperature (change in biological diversity);
- Unnatural change in pH (change in biological diversity);
- Poor optical properties of water bodies (reduction in photosynthesis; change in predator-prey relationships);
- Unnatural flow (inhibition of migration; associated temperature modification of spawning; changes in estuarine productivity).

Background information supplementing the underlying relationship of the concerned stressors with ecosystem-specific modifying factors is also provided in the form of fact sheets in the Guidelines. Water quality managers are recommended to consult the provided information when considering effects of ecosystem-specific modifying factors.

Figure 4.5.2 Decision tree ('guideline packages') for assessing the physical-chemical stressors in ambient waters.



[a] Local biological effects data and some types of reference data generally not required in the decision trees
[b] Possible refinement of trigger value after regular monitoting
[c] Further investigations are not mandatory; users may opt to proceed to management/remedial action

4.6 TOXICANTS

4.6.1 Philosophy and approach

Toxicants are defined as the chemical contaminants that have the potential to exert toxic effects at concentrations existed in the environment. The default trigger values of toxicants have been derived using data from single-species toxicity tests on a range of test species using a risk-based statistical distribution approach. The single-species toxicity data are converted to ecosystem-based data by applying an arbitrary assessment factor. Three grades of trigger values are derived based on the confidence level of the collected data : high, moderate or low.

- High reliability trigger values are derived from multiple-species data or chronic NOEC using the risk-based statistical distribution method;

- Moderate reliability trigger values are derived from acute toxicity data (e.g. LC_{50}, 96 hour for fish and 48 hours for some invertebrates) and apply an assessment factor;

- Low reliability trigger values are derived from a set of insufficient quantity using larger assessment factors. These values should be treated as interim or indicative working values and should not be used as default guidelines though it is reasonable to use them in the risk-based decision scheme to determine if conditions at the site increase or decrease the potential risk.

The default trigger values given in the Guidelines are high grade reliable values derived using a statistical distribution approach that aims at protecting 95% of species population. The use of the statistically based 95% protection provides a more defensible basis for decision than use of assessment factors.

Four levels of protection are classified, i.e. to protect 99%, 95%, 90% and 80% of the target species in the ecosystems. 99% protection level is the default protection level for ecosystems with high conservation value (condition 1); 95% protection level for both slightly-moderately disturbed ecosystem (condition 2) and highly disturbed ecosystem (condition 3). However, 90% or 80% protection level could be applied for highly disturbed ecosystem, subject to the management goal and approval. Conservative approach should be applied when there is lack of sufficient local data.

The default trigger values are not to be applied as blanket values to all situations. Following a risk-based decision tree, local jurisdictions should take into account the physical, chemical and biological characteristics of the particular water body to derive the site-specific trigger values. Guidance is also provided to water quality managers to integrate multiple ecological risk measurements into the assessment, which is based on a logical 'weight-of-evidence' approach.

4.6.2 Derivation of default trigger values

Three elements are involved in the derivation process (**F**igure 4.6.1): toxicity test, use of statistical extrapolation method to convert single species-based data to ecosystem-based data and the use of assessment factors.

Multispecies bioassay tests are preferred for the derivation. The practical difficulties with the testing methods have limited the amount of field data available for input into the derivation process. As a result, single-species tests are used and form the basis of the derivation. LC_{50} is taken as the end-point of acute toxicity tests whereas the biological survival, growth and reproduction are preferred for chronic tests.

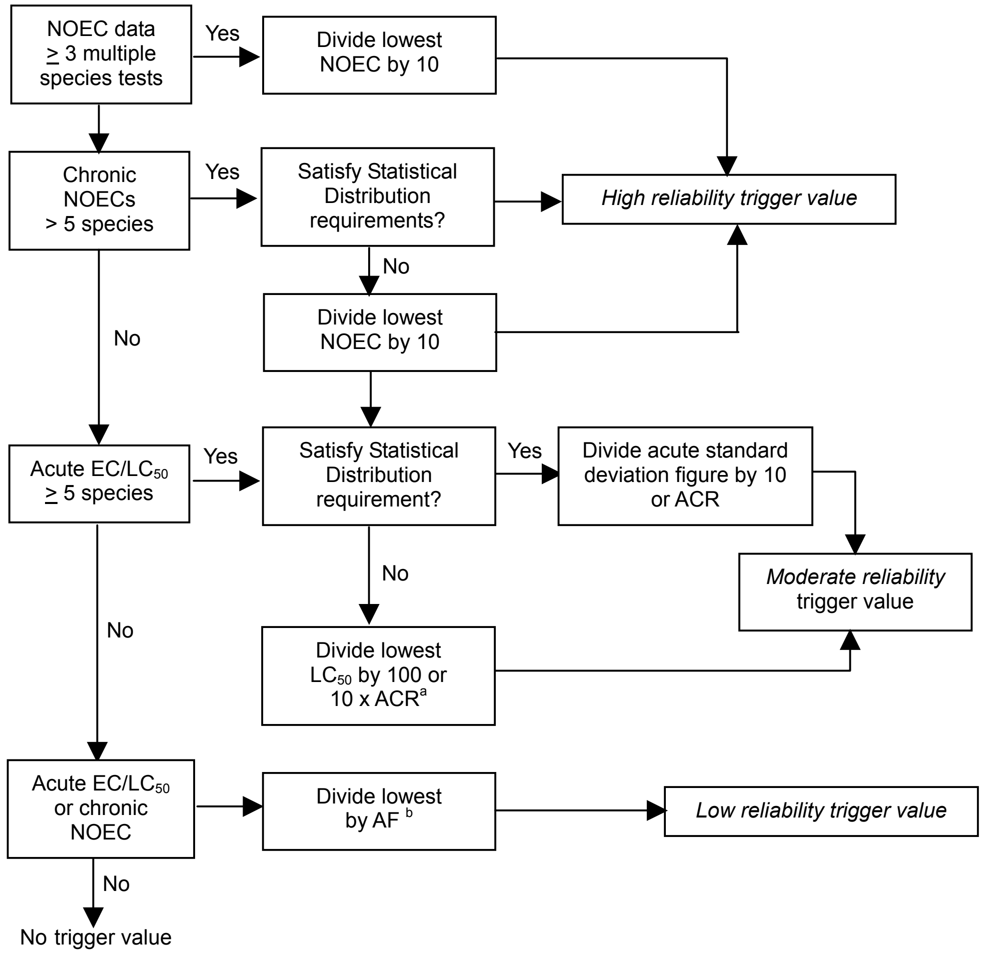
The adopted extrapolation method is based on that of Aldenberg and Slob with modifications. The method is to calculate a value at 95% level of protection based on logistical distribution of the chronic NOEC data for at least 5 species. For slightly-moderately disturbed ecosystems, 50% confidence is used to derive high reliability trigger values and acute LC_{50} is used to derive moderate reliability trigger values.

The magnitude of an assessment factor depends on the type of data (i.e. whether acute or chronic) and the degree of confidence. In general, a factor of 10 is applied to an adequate set of chronic NOEC data. Additional factors are applied in the different scenarios : to convert acute data to chronic, insufficient data on a very limited range of species tested. A factor of 2 should be applied for essential elements.

4.6.3 Framework for applying the default trigger values

The decision tree is outlined in Figure 4.6.2. It should be noted that the decision tree is not mandatory, local jurisdiction may directly apply the default trigger values at any time. The Guidelines provide step-by-step guidance on the consideration of site-specific factors and also some useful information on a compendium of chemicals on their interactions with various parameters in the environment. Some major points about the site-specific factors (the shaded box in the decision tree) are briefly described in the following paragraphs.

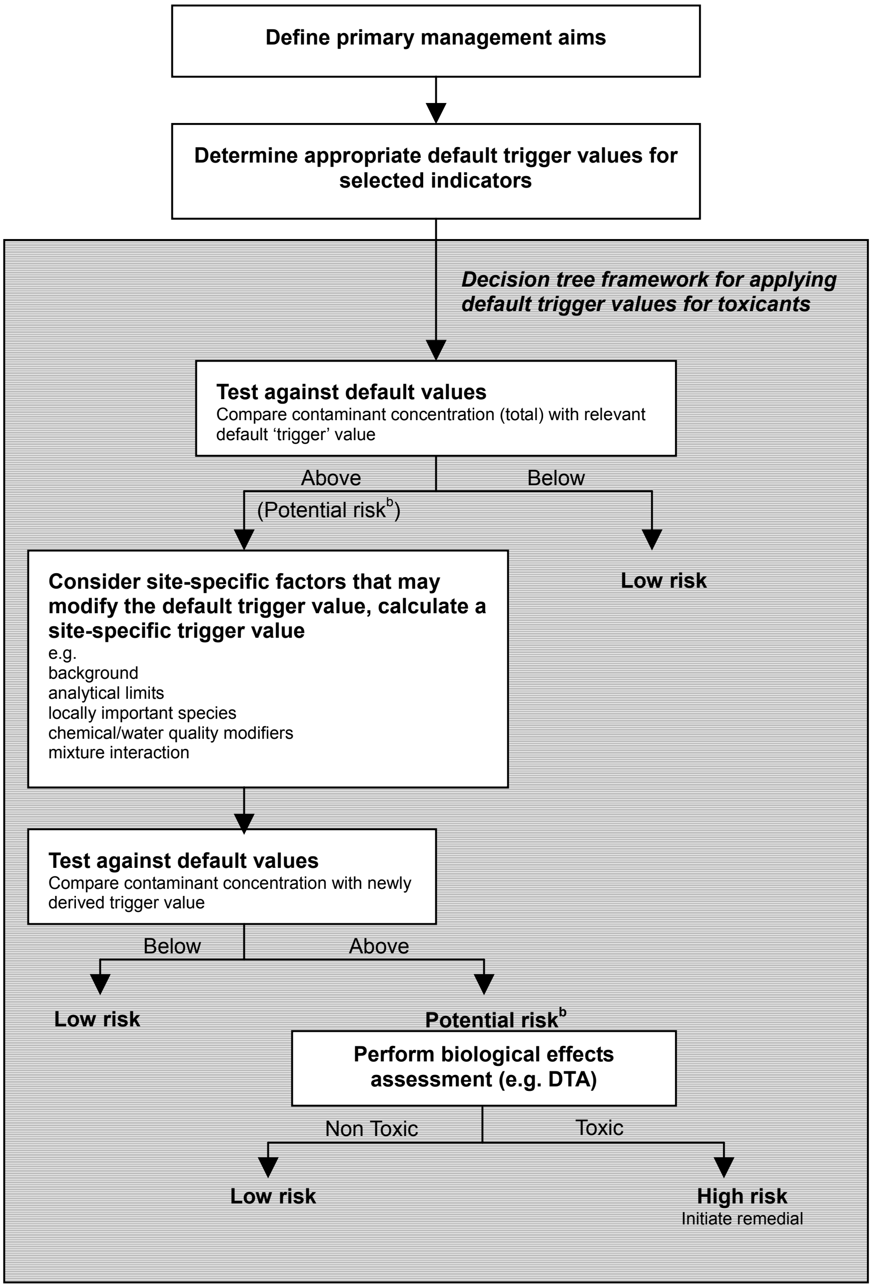
Figure 4.6.1 Schematic diagram of the general procedures for deriving trigger values for toxicants



a ACR = Acute to Chronic Ratio based on 3 methods
(1) experientially derived
(2) a model to calculate LC_0
(3) a default assessment factor of 10 or larger

b AF = Assessment Factor
10 for NOEC; 100 or 1000 for LC_{50}; or other AF as appropriate.

Figure 4.6.2 Decision tree for assessing toxicants in ambient waters



[a] Local biological effects data not required in the decision trees
[b] Further investigations are not mandatory; users may opt to proceed to management/remedial action

Incorporating background concentration

Natural background concentrations of some chemicals, particularly metals, may exceed the default trigger values due to mineralization from the catchment substrate. It is unreasonable to insist on a trigger value below the background concentration. In this case, the 80^{th} percentile of the background concentration is generally taken to be the target trigger value.

Incorporating transient exposure and rapid degradation of the chemical

Most of the background acute data are from 24-96 hour toxicity tests. There has been little international guidance to account for the degradation of chemicals in the site-specific scheme. The Guidelines recommend application of the default trigger values after confirming that acute effects would not occur at the established lowest concentration.

Incorporating bioaccumulation, bioconcentration and secondary poisoning

Bioaccumulation of chemicals in aquatic organisms has become a significant indicator to reveal the potential of the chemicals to cause secondary poisoning of both aquatic and terrestrial predators. Despite recent progress in the development of derivation method for protecting water-associated wildlife from the effects of bioaccumulating chemicals, the lack of Australian and New Zealand data makes it impossible, at this stage, to take secondary poisoning into consideration when deriving the default trigger values for organic toxicants. Until better methods can be developed for application in Australia and New Zealand, secondary poisoning from toxicants are considered in the site-specific decision tree.

The octanol-water partition coefficient[C] (K_{ow} or K_p) and bioconcentration factor [D] (BCF) are used to define chemicals having the potential to bioaccumulate :

- $\log_{10} K_{ow} > 4$ (for organic toxicants);
- BCF>10,000 (for both organic and metallic toxicants).

[C] Octanol-water partition coefficient is the ratio of the concentration of a chemical in n-octanol to the concentration in water, at equilibrium and at a constant temperature. Chemicals with $\log_{10} K_{ow}$ values below 3 are not considered to bioaccumulate.

[D] Bioconcentration factor is the ratio of concentration in test organisms to concentration in water, at equilibrium under specified conditions. Chemicals with BCF values > 1,000 are assumed to have some potential for bioconcentration.

In the absence of local data for site-specific assessment, the Guidelines recommend the 99% protection level as the default for slightly-moderately disturbed ecosystem.

Incorporating local ecotoxicology data

Most of the ecotoxicology data used for the development of default trigger values are largely derived using overseas testing results. Many studies, which attempt to directly assess the relative sensitivity of Australian species to metals and organic chemicals, have been undertaken. Though it does not mean that the toxicity of Australia and New Zealand species could be accurately predicted using the overseas data, yet at least these relative data give some initial confidence to derive trigger values from overseas data. Australian and New Zealand data are available for around 33 chemicals. In case of absence of local data, the default trigger values could be recalculated using only species native to the country or region of concern, or else substituting data from the equivalent representative taxa with data from similar native species.

Incorporating effects of chemical formulations

Chemicals may exhibit various degrees of toxicity when exist in different formulations. The toxicity of chemical formulations can be significantly more toxic than the technical grade chemicals. Since the default trigger values are calculated on technical grade materials, appropriate assessment factors should be applied to account for changes in the toxicity with formulations. It should be noted that changes in toxicity of 2- or 3-fold are considered to be within the range of variations of toxicity tests.

Incorporating adsorption/desorption on suspended matter

Many chemicals may adsorb to suspended materials and become unavailable. The use of an unfiltered sample may lead to overestimation of the bioavailable concentration of a toxicant in the decision scheme. The interactions of toxicants with suspended materials are complex, and vary with chemical concentrations and properties. The Guidelines recommend using soluble metal concentration (passing a sample first through 0.45 μm filter or further through 0.15 μm filter, as necessary) for comparison in the derivation process. As for other non-metallic toxicants, the Guidelines recommend evaluation of the toxic effects and direct toxicity assessment.

Incorporating dissolved organic matter

The inter-relationships between chemicals and suspended materials are also applicable to dissolved organic matter (DOM).

Incorporating effects of salinity

Default values have been derived for both fresh and marine waters. However, there are few toxicity data for estuarine organisms and in which case best estimation of the likely toxicity changes should be exercised. Other factors, e.g. the effect of sulphate ions in the marine water, potential increase in toxicity of toxicants, should also be taken into consideration.

Incorporating pH

The toxicity of metals change with pH of the water. These changes are often associated with changes in bioavailability and speciation of metals. The trigger values for metals have been derived using data from tests at narrow pH ranges, usually 6.5-8.5. For organic chemicals, changes in pH can alter the degradation rate of the chemicals. Water quality managers are recommended to consult literature on effects of pH on the chemicals or consider direct toxicity assessment.

Incorporating temperature

Temperature can have a pivotal effect on the toxicity of chemicals. Many chemicals exhibit between a 2- and 4-fold variations in toxicity for each 10°C rise. Information on firm temperature toxicity relationships is only available for limited number of chemicals. Water quality managers are recommended to refer to the developed relationships for ammonia, phenol, pentachlorophenol, endosulfan and chlorpyrifos for information.

Incorporating water hardness

Increase in water hardness is usually associated with increase in alkalinity, which in turn, affects metal speciation. The relationship between hardness and toxicant uptake is empirically described using an exponential algorithm of the form :

Trigger Value = exp [a ($\log_e$ water hardness $\pm$ b),
where a and b are constants.

Hardness algorithms have been established for six metals : cadmium, chromium (III), copper, lead, nickel and zinc. Two approaches are suggested to calculate hardness-modified trigger values for the six metals in freshwater ecosystems : (i) using the established algorithm, and (ii) applying a factor as designated in the Guidelines. For other metals, metal speciation determination or direct toxicity assessment are recommended.

Incorporating metal speciation

Adsorption to suspended matters, complexation by dissolved organic matters, pH, redox potential can influence metal bioavailability. With the exception of lipid-soluble metal forms, the most toxic metal species are generally the free metals ions. Decrease in pH may increase the free metal ion activity, result in metal desorption from suspended matters and dissociate some complexes. Changes in redox potential can lead to changes in valency states and hence metal availability. Chemical measurement and geochemical speciation modeling are used to determine the form and amount of the bioavailable metal species. Figure 4.6.3 shows the decision tree for applying the default trigger values taking into account metal speciation.

Incorporating simple toxicant mixtures

Interactions between chemical components in a mixture can affect the overall toxicity. If the mixture is complex, water quality managers may opt to proceed to direct toxicity assessment. If the mixture interactions are simple and predictable, the mixture toxicity can be modeled using the equation below :

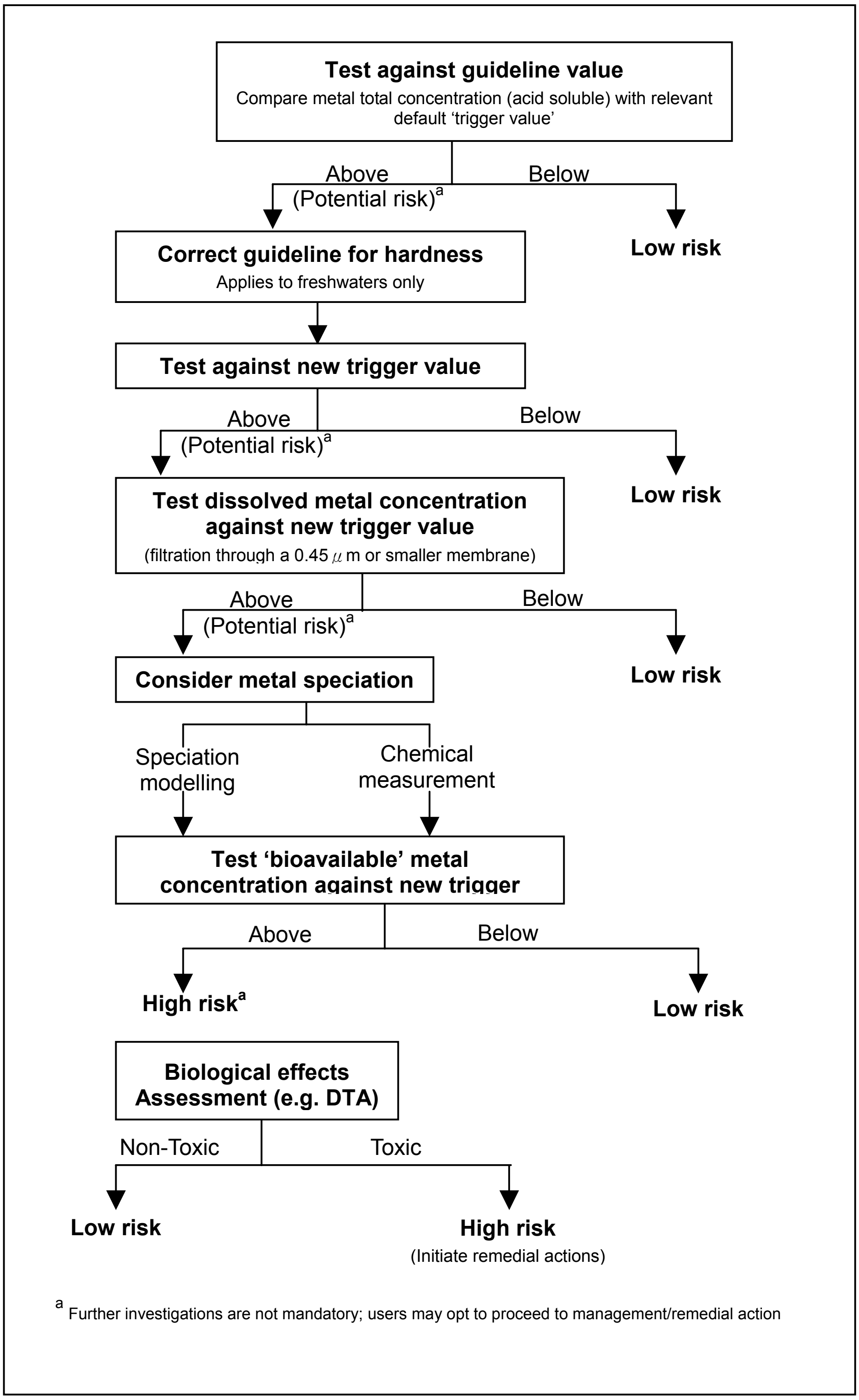
$$TTM = \sum (C_i / WQG_i)$$

where TTM = total toxicity of the mixture

C_i = concentration of the “i” component in the mixture

WQG_i = trigger value for that component

Figure 4.6.3 Decision tree for metal speciation



Incorporating direct toxicity assessment

Direct toxicity assessment (DTA) directly measures the biological effects of chemicals or complex mixtures. It is most commonly used when there is a complex mixture of chemicals entering the specific water body and where either the resultant toxicity cannot be easily estimated or the prediction of toxicity needs to be checked. DTA can also be used in situations when trigger value is below the chemical detection limit, when background levels are high, when it needs to examine toxicity to locally-important species, and to validate the derived site-specific trigger values. The Guidelines give a detailed account of factors that need to be considered for the development of DTA protocols, guidance and recommendations for DTA programmes.

The decision tree allows for toxicity testing as the ultimate means of assessing sediment quality. This arrangement is mainly attributed to the greater cost compared to chemical analysis. Toxicity testing can be applied at any stage of the tree.

4.7 SEDIMENT QUALITY

4.7.1 Philosophy and approach

Sediments both serve as a source and a sink of dissolved contaminants. They provide sources of bioavailable contaminants to benthic biota and hence potentially to the aquatic food chain. Therefore, it is desirable to define situations in which contaminants associated with sediments represent a likely threat to ecosystem health. Sediment guidelines can also serve to identify uncontaminated sites that are worthy of protection.

The objectives of establishing guidelines for sediment quality are 3-folded :

- 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.

Driven by the above objectives, the Guidelines have outlined a procedure for the development of sediment quality guidelines. The decision tree approach is applicable to slightly to moderately disturbed (condition 2) and highly disturbed aquatic ecosystems (condition 3) while the precautionary approach is recommended for aquatic ecosystems considered of high conservation/ecological value (condition 1).

There are many approaches adopted internationally to derive sediment quality guidelines, namely, effects database guidelines, equilibrium partitioning approach and background level method. At present, few reliable sediment toxicity data are available for derivation of sediment quality guidelines and financial constraints have limited further data collection. Because of this, the current guidelines are adopted from the best available overseas data and refined based on the conditions of the existing baseline concentration and local effects data. The NOAA values form the basis of the default trigger values. They should be regarded as interim sediment quality guideline (ISQG) values.

4.7.2 Derivation of default trigger values

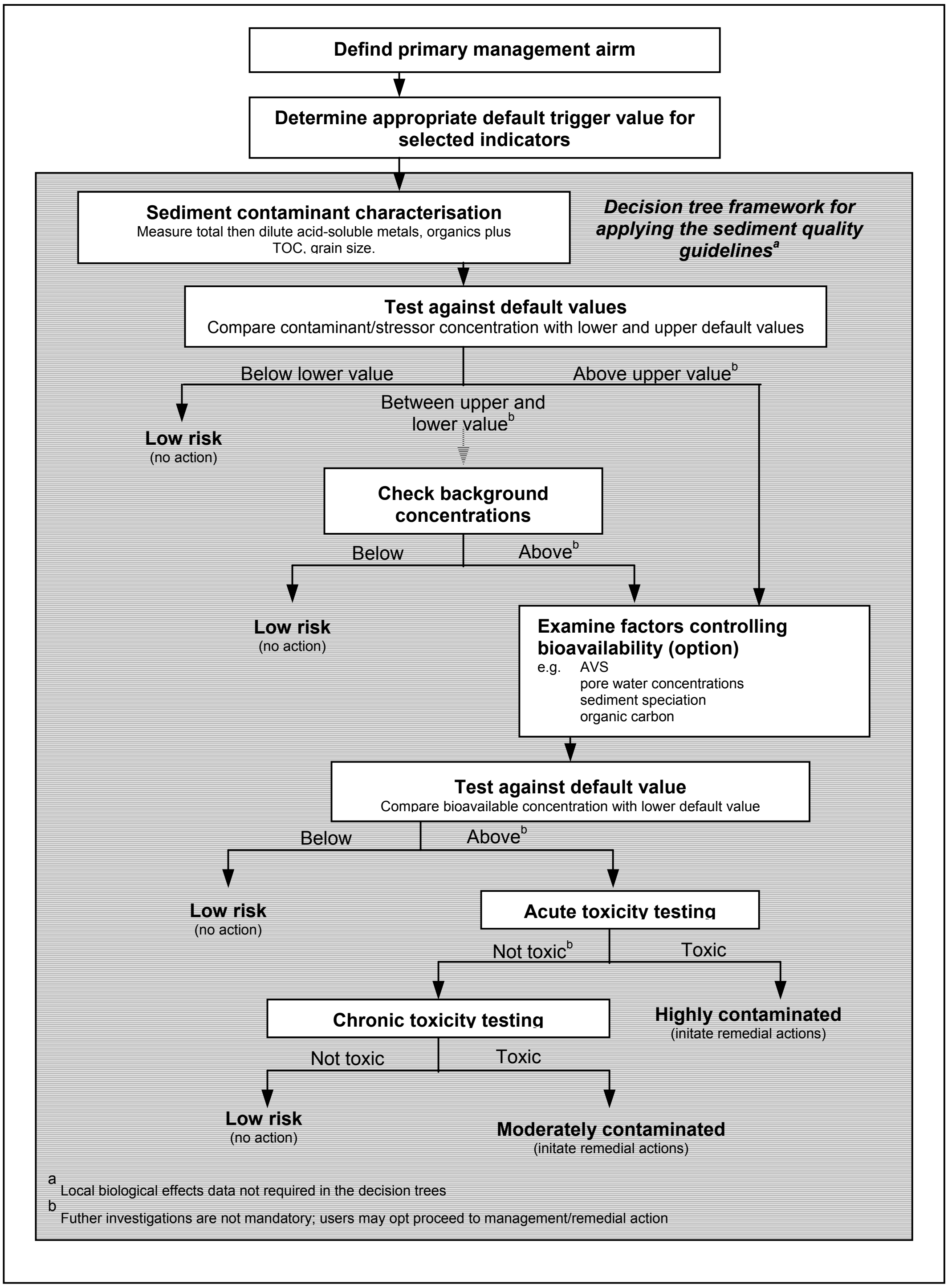
Default trigger values have been determined for 34 chemicals ranging from metals, metalloids, organometallic to organics. Two sets of values (i.e. the low and high ISQG) are tabulated in the Guidelines, corresponding to the effects range–low and –median used in the NOAA listing. No specific trigger values are provided for nutrients as the development of nutrient guidelines are considered to be too difficult at the present stage in light of the complexity in the nutrients metabolism in the sediment pore water, the water column and the benthic organisms.

In the absence of guidelines for a contaminant of interest, an interim approach is adopted to ensure adequate protection for the ecosystems. The approach is to derive a value on the basis of natural background (reference) concentration multiplied by an appropriate factor. A factor of 2 is recommended for general cases, and up to 3 for some highly disturbed ecosystems. An alternative approach is to apply the water quality guidelines values to sediment pore water.

4.7.3 Framework for applying the default trigger values

The general approach to use of the decision scheme is presented in Figure 4.7.1. The methods and steps for deriving sediment trigger values are similar to those for the non-biological types of indicators.

Figure 4.7.1 Decision tree for the assessment of contaminated sediments



Major concerns in the derivation process lie with the comparison with background concentration and consideration of factors controlling bioavailability. For the comparison to be meaningful, the choice of background (i.e. reference sites) is important such that sites with sediments of comparable grain size are used and they are distant from known pollution sources.

Three factors should be taken note of when considering modifying factors for metal : speciation, acid volatile sulphides and pore water. A considerable fraction of the total metal concentration in sediments may exist in forms that are not bioavailable. However, the field data used to derive the default trigger values are likely to be based on total concentration that does not truly reflect the risk of the metal to biota in the ecosystems. Therefore, further analysis on the bioavailable portion or applying assessment factor is recommended. Available sulphide will regulate the solubility of metals such as cadmium, copper, mercury, nickel, lead, silver and zinc, which form relative insoluble sulphides and hence lower the toxicity. Pore water, in most circumstances, represents the dominant phase in which a contaminant is found. If pore water concentration for any metal is below the trigger value, there is unlikely to be an adverse biological disturbance. In the absence of guidelines, the trigger value is determined by application of the default trigger values to sediment pore water, taking a precautionary approach. Temporal variations should be given serious consideration in designing the sampling protocol.

Mobility of sediment particles is a significant factor that needs to be taken into consideration. The most mobile fraction of sediments contains fine, contaminants-rich particles. Sediment mobilization has led to two concerns : enhanced contaminant release and stratification. Release of contaminants may be resulted from disturbance of surface sediment and pore water and chemical transformations (e.g. oxidation of anoxic sediment). Elutriate tests are used to demonstrate a worst-case release scenario. Sediment deposition and stratification results in a greater concentration of fine particular site. There is a higher chance that the trigger value, which is derived, based on whole sediment, will be exceeded. In such case, assessment should then be made on the analysis on the <63μm size fraction only.

Normally, toxicity testing is used to demonstrate the absence of toxicity when the guideline value for a particular contaminant is exceeded. When toxicity is observed, the cause of toxicity is often not necessary attributed to the contaminant of interest because of presence of other toxicity-contributing contaminants. In such case, the Toxicity Identification and Evaluation (TIE)[E] process should be applied.

[E] Toxicity characterization procedures involve the use of selective chemical manipulations or separations and analyses coupled with toxicity testing to identify specific classes of chemicals and ultimately individual chemicals that are responsible for the toxicity observed in a particular sample.

5 WQC/WQS of United States of America

5.1 PHILOSOPHY OF WQC/WQS APPLICATION

The water quality goal stipulated in the Clean Water Act (CWA), states :

> *…to restore and maintain the chemical, physical, and biological integrity of the US nation's waters via various management programs to attain a water quality that can support the protection and propagation of fish, shellfish, and wildlife and recreation in and on the water.*

The CWA requires USEPA to develop pollution control programs for achieving the water quality goal. Basically, two approaches are used: Technology-Based Approach and Water Quality-Based Approach. In the Technology-Based Approach, effluent limits are set based on performance of treatment, and control technologies for industrial discharges and publicly owned treatment works. In the Water Quality-Based Approach, effluent limits are assessed via Total Maximum Daily Load (TMDL) Program or other waste allocation control scheme and set in accordance with the established water quality standards (see Figure 5.1.1).

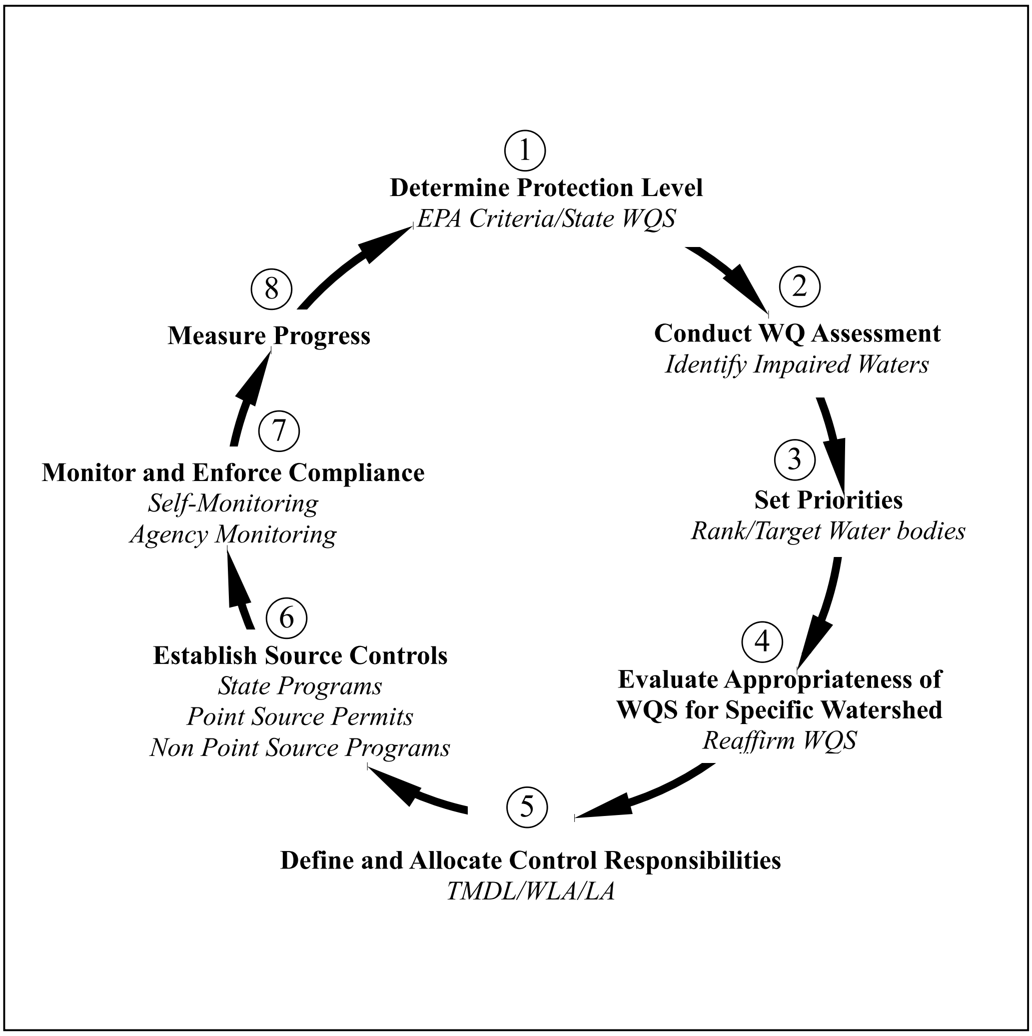
Water quality standards are the foundation of the water quality-based control program mandated by the Clean Water Act. A water quality standard consists of three basic elements:

- water quality criteria to protect designated uses (numeric pollutant concentrations and narrative requirements),
- designated uses of the water body (e.g. recreation, water supply, aquatic life, agriculture),
- general policies addressing implementation issues (e.g. low flows, variances, mixing zones).

Section 304(a)(1) of the CWA requires USEPA to develop generic criteria for water quality that accurately reflect the latest scientific knowledge. These criteria are based solely on data and scientific judgment on pollutant concentrations and environmental or human health effects. Depending on the type of criteria, toxicity-based approach, risk-based approach and reference site approach are used in the criteria development. States and tribes are required to derive water quality standards to reflect the characteristics of the local conditions. The states water quality standards are subject to review once every 3 years.

The water quality criteria published in late 1960's and 1970's were primarily based on the use of literature reviews and the collective scientific judgment of the Agency and advisory panels. USEPA found that continued reliance solely on scientific literature was deemed inadequate because essential information was not available for many pollutants. New methodologies for establishing scientifically defensible criteria would continue to be developed and subject to review by the Agency's Science Advisory Board of outside experts and the public.

Figure 5.1.1 Schematic diagram of applying of water quality-based approach to pollution control



There are six types of water quality criteria: aquatic life, biological, nutrient, sediment, human health and bacteriological. Brief accounts of the first four criteria are given in section 5.3 to 5.5. The last two are not directly related to the protection of aquatic ecosystems and they are not discussed in this report.

5.2 FRAMEWORK FOR DEVELOPING AND APPLYING THE WQC/WQS

Section 303(c) of the CWA establishes the basis for the current Water Quality Standards Program, which involves the following steps :

- Define water quality standards;
- Identify beneficial uses;
- Require states and tribes to adopt standards;
- Require states and tribes to review their standards at least every 3 years;
- Establish the process for USEPA to review states and tribal standards.

5.2.1 Setting of water quality standards and beneficial uses

Water quality standards define the water quality goals of a water body by designating the use(s), by setting criteria necessary to protect the uses, and by establishing antidegradation policies and implementation procedures that serve to maintain and protect water quality. The CWA has introduced some flexibility in the water quality management that allows states and tribes to define uses according to the local environmental conditions while maintaining a consistent approach in the derivation. The CWA allows:

- designating only the uses that are believed to be attainable;
- removing a designated use;
- designating "seasonal" uses.

There may be circumstances rendering attainment of the CWA's two goals of "fishable" use and "swimmable" use infeasible, which may be due to site constraints or other socio-economical considerations. States and tribes are required to conduct Use Attainability Analysis (UAA) for a water body to demonstrate thatthe "fishable/swimmable" uses or other designated uses are not attainable. The procedure of removing a designated use is illustrated in Figure 5.2.1.

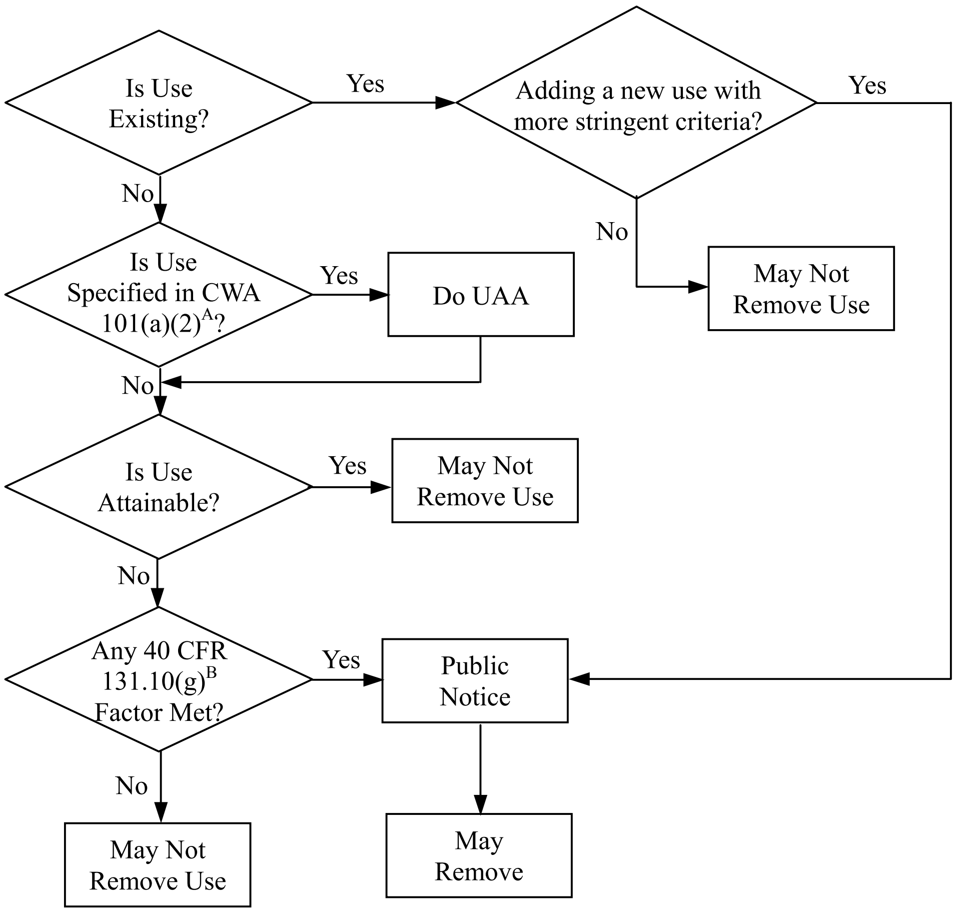
5.2.2 Deriving state and tribal water quality standards

To establish site-specific water quality criteria that reflect the environmental conditions at the site, states and tribe could follow the procedures prescribed in the CWA. Four options are available to derive the state or tribal water quality criteria :

- adopt the recommended section 304(a) criteria;

- modify the section 304(a) criteria to reflect site-specific conditions;
- derive criteria using other scientifically defensible methods;
- establish narrative criteria where numeric criteria cannot be determined.

Figure 5.2.1 Schematic diagram of the process to remove a designated use



[A] Two primary uses are specified: (i) protection and propagation of fish, shellfish and wildlife; (ii) recreation in and on the water.

[B] Specified six factors relating to naturally occurred pollutants, natural conditions and human caused conditions precluding the attainment of uses.

Certain policies could be adopted in the implementation of the water quality standards to allow for flexibility, i.e. water quality variances, anitdegradation, mixing zones and critical flows for water quality-based permit limits.

Variance is a provision for states and tribes to temporarily relax a water quality standard and specify an interim one. Unlike removal of a designated use, variance is both discharger- and pollutant-specific, time-limited and does not forego the currently designated use. It involves the same substantive and procedural requirements as removing a designated use and subject to review every 3 years. Once approved by USEPA, the variance is included as part of the water quality standard and forms the basis of an effluent discharge, i.e. National Pollution D (NPDES) permit. The discharger must meet this "interim" water quality standard within the variance valid period or must make a new demonstration of "unattainability".

Anitdegradation is a policy to protect existing uses and to provide a means for assessing activities that may lower water quality in high quality water. The anitdegradation policy involves classification of US waters into a three-tiered system : "water with existing use", "high quality waters" and "outstanding national resource water waters". Figure 5.2.2 illustrates the pyramid of the three tiers and the associated water quality requirements. States and tribes are required to conduct an antidegradation policy analysis to justify the decisions made in relation to the implementation of the water quality program. The analysis may include water quality standards review, establishment of new or revised load allocations/waste load allocations/total maximum daily loads, NPDES permits review, demonstration of need for advanced treatment, etc.

Independent mixing zones are specified for acute and chronic aquatic life criteria (see Figure 5.2.3). The acute mixing zone is sized to prevent lethality to passing organisms, the chronic mixing zone sized to protect the ecology of the water body as a whole. In case of low flow situations, states and tribes could designate a critical low-flow value below which numerical water quality criteria do not apply. USEPA has recommended two methods to calculate acceptable low-flows : (i) hydrologically-based method and (ii) biologically-based method. DFLOW is a Windows based tool developed to help states and tribes calculate low-flows, harmonic mean flows and percentile flows. The tool and other technical guidance publications are available at http://www.epa.gov/waterscience/dflow.

Figure 5.2.2 The three-tiered system in the antidegradation policy

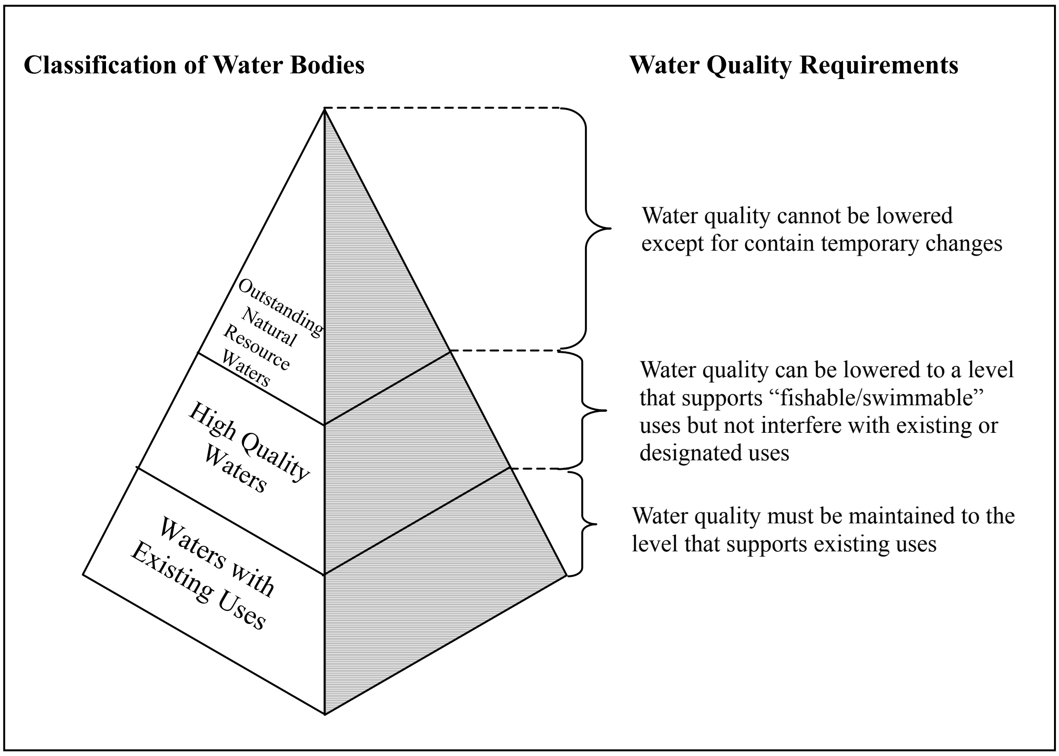
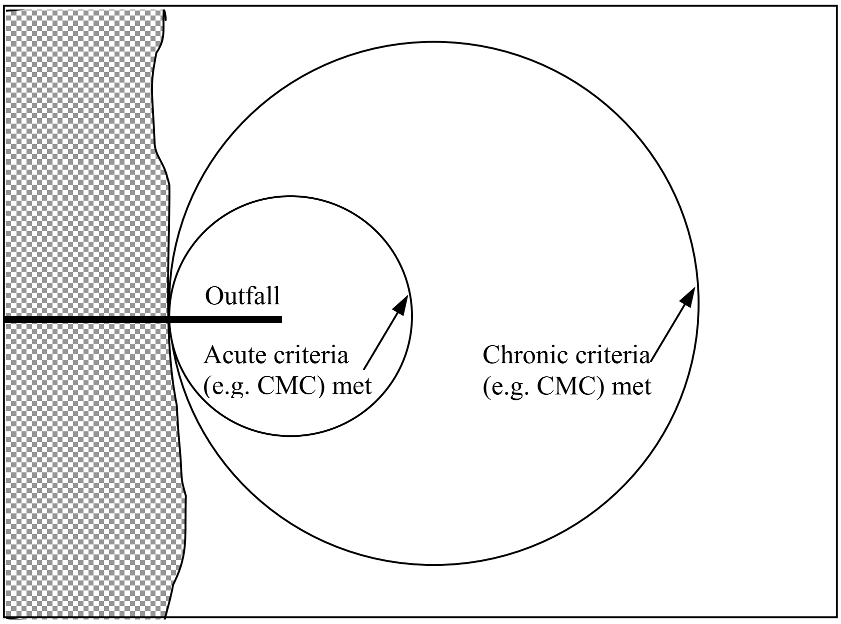


Figure 5.2.3 Schematic diagram of the two parts of the aquatic life mixing zone



5.2.3 Approval on adoption and revision of water quality standards

Primary responsibility for adopting Water Quality Standards rests with the states and tribes that have received authorization to administer the water quality standards regulation. States must review their standards once every three years and revise them if necessary. The review must include a public hearing to take comment on the standards and suggest changes. States may revise their water quality standards at any time. The primary reasons for water quality standards changes should be due to suggestions from the public and the availability of new scientific or toxicity data.

USEPA reviews water quality standards to ensure compliance with the CWA and USEPA's water quality standards regulation. USEPA will approve state water quality standards if the standards meet the requirements of the Act and its supporting regulations. If the standards are inconsistent with the CWA and regulatory requirements, USEPA will disapprove the standards and promulgate federal standards if the state does not adopt revisions to address USEPA's disapproval.

5.3 AQUATIC LIFE CRITERIA

5.3.1 Philosophy and approach

The aquatic life criteria are aimed to protect 95% of the taxonomic and functional groups in the aquatic medium and to prevent unacceptable long-term and short-term effects on:

- commercially, recreationally, and other important species;
- fish and benthic invertebrate assemblages in rivers and streams; and
- fish, benthic invertebrate, and zooplankton assemblages in lakes, reservoirs, estuaries and oceans.

There are three possible forms of WQC : the numerical form is the most common, but the narrative and operational (e.g. concentration of pollutants must not exceed one-tenth of the 96-hour LC_{50}) forms can be used if numerical criteria are not possible or desirable. Numerical WQC are basically composed of three elements : magnitude, duration and frequency. Each criterion generally contains a 4-day average concentration, i.e. criterion continuous concentration (CCC) designed to protect against unacceptable effects from chronic exposures to lower concentrations and a 1-hour average concentration, i.e. criterion maximum concentration (CMC) designed to protect against unacceptable effects from acute exposures to higher concentrations. USEPA considers that the criteria taking the form of a combination of a maximum concentration and a continuous concentration, could more accurately reflect toxicological and practical realities.

The rationale for developing a CCC is to address the unacceptable effect that is caused by fluctuations of the pollutant concentration over a time period. For any threshold material, continuous exposure to any combination of concentrations below the threshold will not cause an unacceptable effect on aquatic organisms and their uses, except that the concentration of a required trace nutrient is too low. Any concentration above the CCC is expected to cause an unacceptable effect. However, the concentration of a pollution in a water body can be above the CCC without causing an unacceptable effect if :

(i) the magnitudes and duration of the excursions above the CCC are appropriately limited;

(ii) there are compensating periods of time during which the concentration is below the CCC.

As it is technically not feasible to integrate the concentration over time, another approximate approach is to require the average concentration not to exceed the CCC. The average concentration is calculated as arithmetic average rather than the geometric mean. The averaging period to allow concentration above CCC should be determined if the allowing fluctuating concentration do not cause more adverse effect than would be caused by a continuous exposure to CCC.

A 4-days averaging period is used in the CCC for two reasons, firstly, it is substantially shorter than the common 20- to 30-days life-cycle tests. An averaging period that is equal to the length of the life-cycle test will allow the worst possible fluctuations and will very likely allow increased adverse effect. Secondly, shorter chronic test will be more focused on the lethal effects on the tested organism at its sensitive life stage at some time during the test. Same consideration is also given to the 1-hour period for CMC because high concentrations of some materials can cause death in 1 to 3 hours.

In addition to concentrations and averaging period, aquatic life criteria from pollutants are further qualified with an exceedance frequency or "allowable frequency". An allowable frequency is established under the assumption that ecosystems will recover after they have been subjected to chemical stressors. Documented studies reveal that it takes six weeks to ten years for ecosystems to recover, depending on the pollutant, the magnitude and duration of the exceedance, and the features of the ecosystems. USEPA has selected a 3-year return interval or allowable frequency based on the most probable rates of ecological recovery from a variety of substantial stresses. This means that an acceptable exceedance rate would be once every 3 years.

Derivation of aquatic life criteria adopts a toxicity-based approach that uses information from many areas of aquatic toxicology. The majority of the WQC has been derived from two methodologies : the 1980 Guidelines for Deriving Water Quality Criteria for the Protection of Aquatic Life and Its Uses, and the 1985 Guidelines for Deriving Numerical National Aquatic Life Criteria for Protection Aquatic Organisms and Their Uses. USEPA has planned a strategy review of the Guideline methodology to ensure that WQC are derived using the best available risk-based scientific methods and procedures. Areas of consideration in the review include : bioaccumulation, dietary route of exposure, endangered species, kinetic-based modeling of toxicity, impact of toxic event, non-traditional endpoints, Final Acute Value, Final Chronic Value, Final Plant Value, Final Residue Value, averaging periods and frequency of exceedances; physiochemical factors and level of risk assessment.

Toxicity tests are used in the derivation of WQC for both freshwater and saltwater species. As toxicity data for saltwater species are far available than for freshwater species, USEPA recommends that the aquatic life criteria in the 2002 compilation apply as follows:

(i) for water where the salinity < 1 ppt in 95% or more of the time, the applicable criteria are the freshwater criteria;

(ii) for water where the salinity > 10 ppt in 95% or more of the time, the applicable criteria are the saltwater criteria;

(iii) for water where the salinity >1 and <10 ppt, the applicable criteria are the more stringent of the freshwater or saltwater criteria, as described in items (i) and (ii) of this section. However, an alternative freshwater or saltwater criterion may be used, if it is supported by scientifically defensible information and data.

5.3.2 Framework for derivation of numerical national WQC

The process of deviation of numerical national WQC is illustrated in a schematic diagram in Figure 5.3.1. After a decision is made that a national criterion is needed for a particular material, all available information concerning toxicity and bioaccumulation will be collected following the USEPA minimum dataset requirements (see Table 5.3.1).

Figure 5.3.1 Schematic diagram of aquatic life criteria derivation process

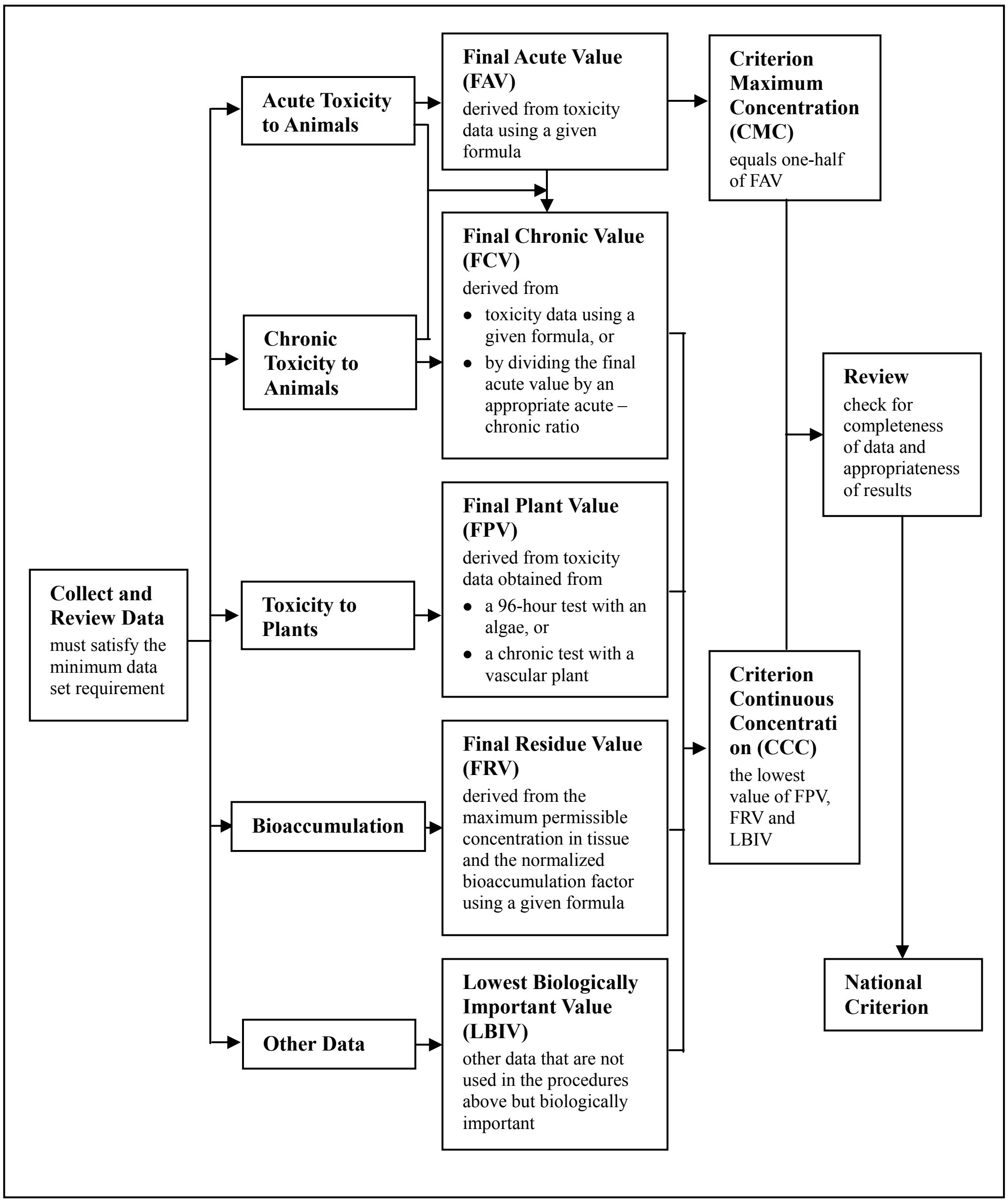


Table 5.3.1 Aquatic life minimum dataset

	Freshwater Life	**Marine Life**
Acute test	≥ 1 species of freshwater animal in > 8 different taxonomic groups • the family Salmonidae in the class Osteichthes • a second family in the class Osteichthyes • a third family in the phylum Chordata • a planktonic crustacean • a benthic crustaecean • an insect • a family in a phylum other than Arthropoda or Chordata • a family in any order of insect or any phylum not already represented.	≥ 1 species of saltwater animal in ≥ 8 different taxonomic groups • two families in the phylum Chordata • a family in a phylum other than Arthropoda or Chordata • either the Mysidae or Penaeidae family • three other families not in the phylum Chordata (may include Mysidae or Penaeidae, whichever was not used above) • any other family
Acute-chronic ratios	≥ 1 species of aquatic animal in ≥ 3 different taxonomic groups • fish • invertebrate • an acutely sensitive freshwater species (the other two may be saltwater species)	≥ 1 species of aquatic animal in ≥ 3 different taxonomic groups • fish • invertebrate • an acutely sensitive saltwater species (the other two may be freshwater species)
Test on Plants	≥ 1 test on a freshwater alga or vascular plant	≥ 1 test on a saltwater alga or vascular plant
Bioconcentration factor	≥ 1 determination with a freshwater species	≥ 1 determination with a saltwater species

Guidance notes on the detail of the derivation are given in the USEPA publication titled "Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses (PB85-227049) - Jan 1985" and on their web site :

http://epa.gov/waterscience/criteria/qalife.html.

Final Acute Value

The Final Acute Value (FAV) is an estimation of the concentration of the pollutant corresponding to a cumulative probability of 0.05 in the acceptable acute toxicity values.

In general, 96-hour EC_{50} flow-through tests are used to determine the acute values at the endpoints where the tested organisms exhibit loss of equilibrium, immobilized or death. If such an EC_{50} is not available from a test, the 96-hr LC_{50} would be used.

The geometric mean of the acceptable data for each species and genus will be calculated. The FAV is calculated using the four GMAVs with the lowest probability and the equations in group 1. If toxicity is related to a water quality characteristic, the FAV is calculated using the Final Acute Equation as illustrated in Group 2 equation.

Group 1 equations :

$$P = R/(N+1)$$

$$S^2 = \frac{\sum((\ln\ GMAV)^2) - ((\sum(\ln\ GMAV))^2)/4)}{\sum(P) - (\sum\sqrt{(P)})^2/4)}$$

$$L = (\sum(\ln\ GMAV) - S(\sum(\sqrt{P})))/4$$

$$A = S(\sqrt{0.05}) + L$$

$$FAV = e^{A}$$

where

GMAV =	Genus Mean Acute Value, i.e. the geometric mean of Species Mean Acute Values (SMAV) for a genus
R =	Ranking of GMAVs, i.e. "1" for the lowest to "N" for the highest
P =	Cumulative Probability at 0.005
Ln =	Natural logarithms. Consistent use of Natural logarithms or common logarithms (base 10) will produce the same result

Group 2 equation :

$$e^{\{V[\ln(FAV_W)] + \ln A - V[\ln Z]\}}$$

where

FAV_w =	Water quality characteristic adjusted Final Acute Value
V =	Slope of acute toxicity values
A =	Final Acute Value at a selected value Z of water characteristic

Final Chronic Value

The Final Chronic Value (FCV) is calculated in the same manner as the FAV or by dividing the FAV by the Final Acute-Chronic Ratio.

Special requirements for conducting life-cycle test, partial life-cycle test and early life-stage are summarized in Table 5.3.2.

Table 5.3.2 Chronic toxicity tests for deriving aquatic life criteria

	Test					
	Life-cycle (embryonic through maturation and reproduction)		Partial life-cycle (juvenile through maturation and reproduction)		Early life-stage (post-fertilization through embryonic, larval and early juvenile development)	
	Start point	End point	Start point	End point	Start point	End point
General Fish	embryos or newly hatched young <48 hours old	$\geq$ 24 days after hatching of the next generation	2-month juvenile prior to active gonad development	$\geq$ 24 days after hatching of the next generation	shortly after fertilization	20- day to 32- day through the test
Salmonids	embryos or newly hatched young <48 hours old	$\geq$ 90 days after hatching of the next generation	embryos or newly hatched young <48 hours old	$\geq$ 90 days after hatching of the next generation	shortly after fertilization	60 days post hatch
Daphnids	embryos or newly hatched young <24 hours old	$\geq$ 21 after test commissioning	--	--	--	--
Mysids	embryos or newly hatched young <24 hours old	7 days past the median time of first brood release in the control	--	--	--	--
Analysis	(i) For fish - survival and growth of adults and young, maturation of males and females, eggs spawned per female, embryo viability (salmonids only) and hatchability. (ii) For daphnids – survival and young per female. (iii) For mysids – survival, growth and young per female		survival and growth of adults and young, maturation of males and females, eggs spawned per female, embryo viability (salmonids only) and hatchability		survival and growth	

Final Plant Value

The Final Plant Value (FPV) is the lowest result of a 96-hour toxicity test with an alga or a chronic test conducted with an aquatic vascular plant. Detailed procedures for conducting and interpreting the results of toxicity tests with plants are not well developed.

Final Residue Value

The Final Residue Value (FRV) is intended to (i) prevent commercially or recreationally important aquatic species from being banned from the market because of exceedance of applicable FDA action levels, and (ii) protect wildlife that consume aquatic organisms. It is arithmetically defined as lowest of the residue values that are obtained by dividing maximum permissible tissue concentrations (adjusted to 1% lipid basis) by appropriate normalized bioconcentration or bioaccumulation factors.

A maximum permissible tissue concentration refers to (i) an FDA action level for fish oil or for the edible portion of fish or shellfish, or (ii) a maximum acceptable dietary intake based on observation on survival, growth, or reproduction in a chronic wildlife feeding study or a long-term wildlife field study.

$$\text{FRV} = \frac{\text{(max permissible tissue conc)}}{\text{appropriate percent lipids}} \times \frac{1}{\text{mean normalized BCF}}$$

where the percent lipid = 100 for fish oil, 11 for fish for freshwater criteria and 10 for fish for saltwater criteria.

Aquatic Life Criterion

A criterion consists of two concentrations : the Criterion Maximum Concentration (CMC) and the Criterion Continuous Concentration (CCC). The CMC = FAV / 2 and CCC = the lowest of the FAC, FPV, FRV, other available data.

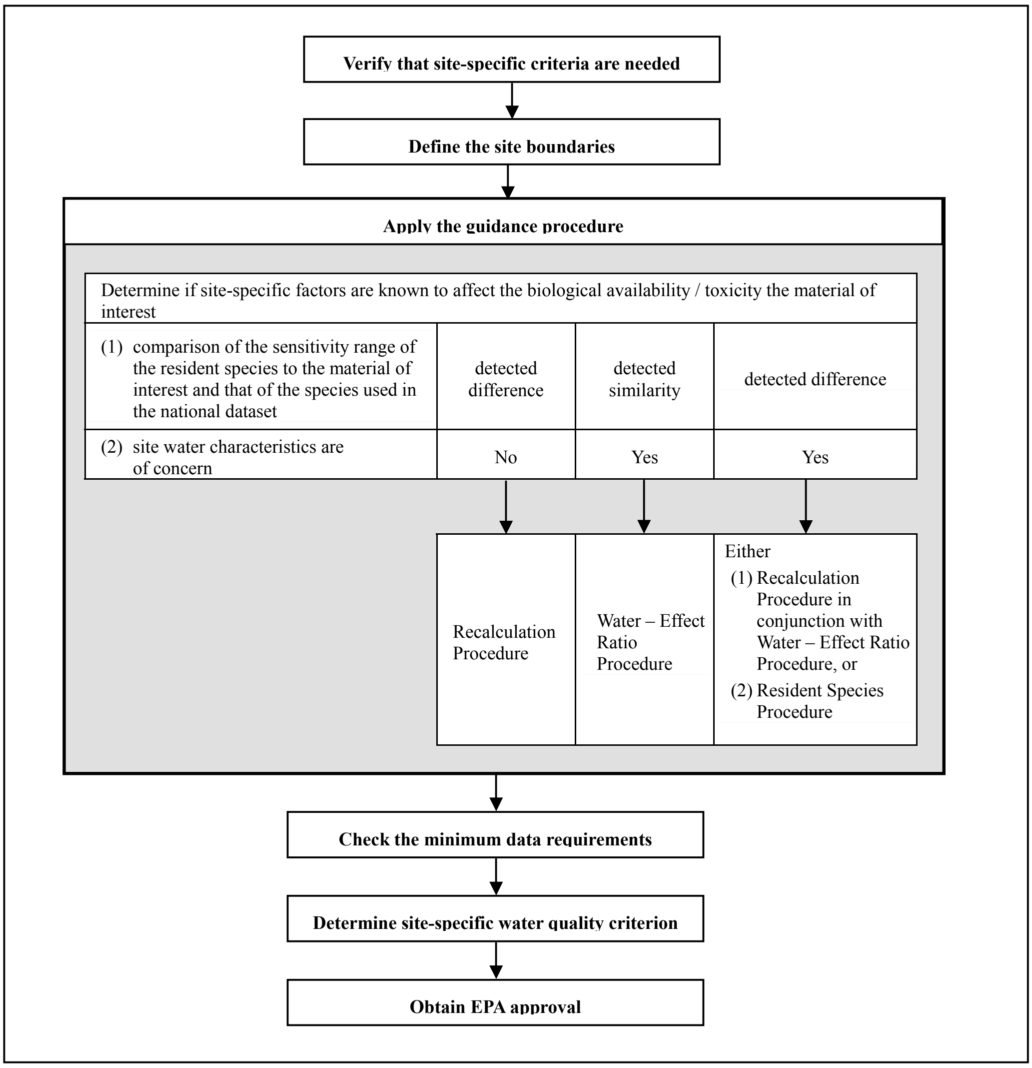
If toxicity is related to a water quality characteristics, the CCC is obtained from the Final Chronic Equation, the FPV, FRV by selecting the one that results in the lowest concentration in the usual range of the water quality characteristic, unless other data show that a lower value should be used.

5.3.3 Determining site-specific water quality criteria

USEPA recognized that the laboratory-derived national water quality criteria may not accurately reflect site-specific conditions concerning sensitivities of aquatic species and toxicities of chemicals in water. Schematic diagram showing the steps in the derivation is shown in Figure 5.3.2. Three approaches are provided for states and tribes to derive site-specific criteria :

- recalculation procedures, which was intended to account for differences in resident species sensitivities;
- water-effect ratio procedures, which was intended to account for differences in biological availability and/or toxicity caused by the physical or chemical characteristics of a site-water;
- resident species procedures, which was intended to account for both types of differences (i.e. species sensitivity and site water characteristics).

Figure 5.3.2 Deriving site-specific aquatic life criteria



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The Recalculation Procedure

This procedure accounts for the toxicological difference between the aquatic species that occur at site and those that were used in the derivation of the national criterion. Its concept is to create a dataset that is appropriate for deriving a site-specific criterion by modifying the national dataset in some or all of three ways :

- Correction of data (to be approved by EPA);
- Addition of data (to be approved by EPA);
- Deletion of data (optional).

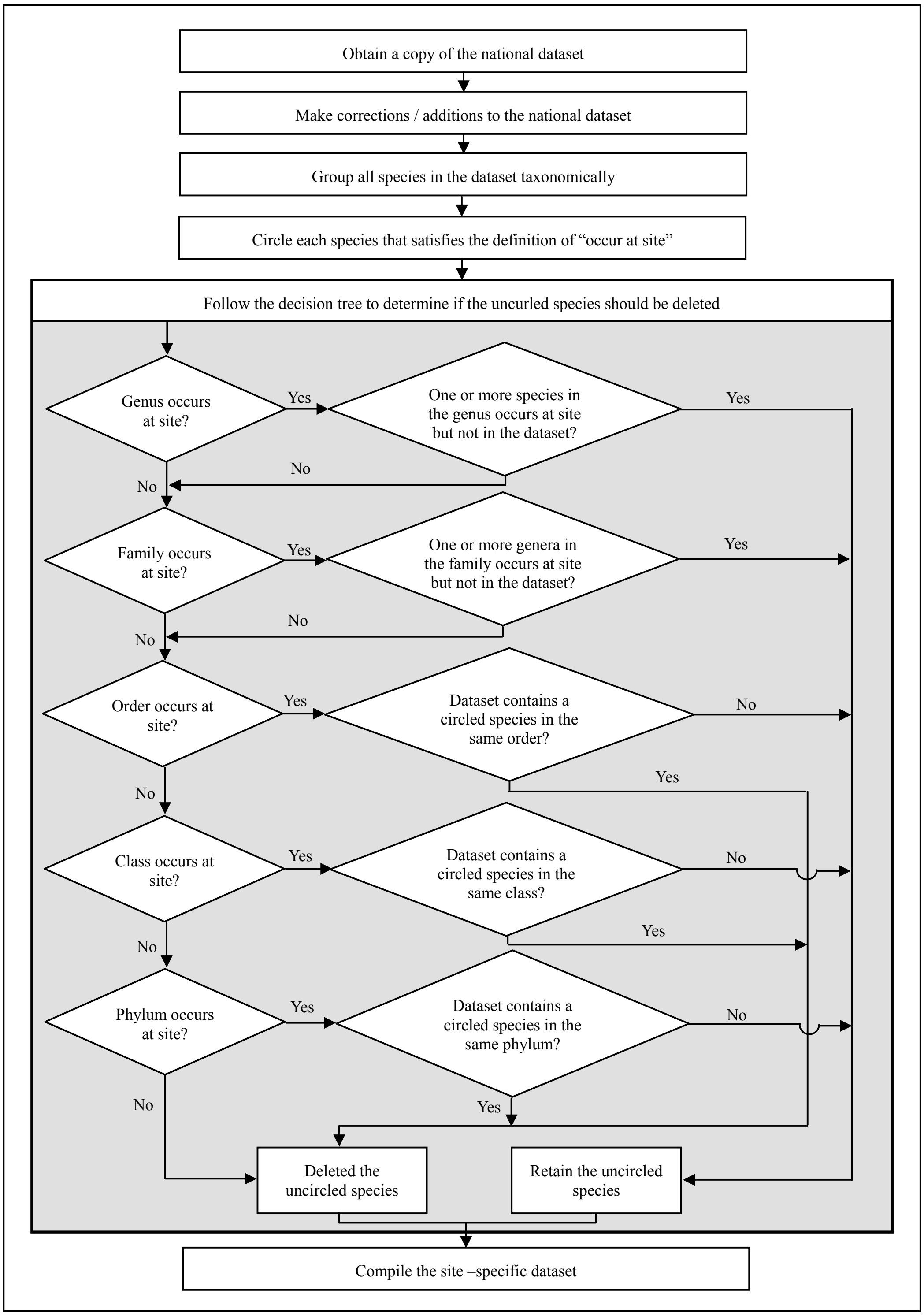
Correction and addition of data are restricted to those that have been previously been approved by EPA and those pending for EPA approval. The deletion process involves a series of decisions to ensure a well balance of representation of species in each taxonomic group in the site-specific dataset. Schematic diagram of the steps of the recalculation procedure is illustrated in Figure 5.3.3.

The dataset must meet the requirements as for the derivation of a national criterion. If a specific requirement cannot be satisfied after deletion due to the lacking of that species at the site, a taxonomically equivalent substitution must be made in order to meet the 8-family minimum dataset requirement. Deriving of the CMC and CCC follows the same procedures as those for the national criterion.

The Water-Effect Ratio Procedure

The Water-Effect Ratio (WER) is a ratio of simultaneous toxicity test results where one test is one in laboratory water and the other test is done in samples of site water. The site water is either a simulated downstream water that is prepared by mixing upstream water and effluent in an appropriate ratio or a sample of the actual site water to which the site-specific criterion is to apply. The WER is calculated by dividing the endpoint obtained in the site water by the endpoint obtained in the laboratory dilution water. After a WER is determined, a site-specific aquatic life criterion can be calculated by multiplying an appropriate national, state, or recalculated criterion by the WER.

Figure 5.3.3 Schematic diagram of the Recalculation Procedure



The WER procedure was first intended for adjusting WQC for metals but later extended to other parameters of concern. The WER is not applicable to WQC that were otherwise derived from laboratory toxicity data. As these WQC may be derived from accidental impairments or health effects in the environment, the effects cannot be reproduced in a laboratory with different waters to assess whether the effects vary.

The procedure involves experimental design and laboratory measurement to address factors that contribute to changes in the WER, which include variations in the forms and concentrations of a pollutant, hardness, alkalinity, pH, suspended solids, organic carbon or other toxic substances, spatial effect and temporal effect. Two methods are recommended for determining a WER :

Method One
- to determine a WER that applies in the vicinities of plumes.
- to determine either cmcWERs (acute) or cccWERs(chronic) or both.
- mostly for single metals, in flowing freshwater situations for large sites.

Method Two
- to determine a WER that applies outside the area of plumes in large bodies of water.
- to determine cccWERs.
- ideally for sites with more than one discharge.

Major experimental design requirements common to the two methods are :

- The primary toxicity test should use a sensitive species with a toxicity response that is close to the nation numerical WQC;
- The WER derived from the primary toxicity tests must be confirmed with a second, sensitive species from a different taxon;
- A minimum of 3 WER tests with a minimum of three weeks apart and preferably in different seasons to account for differences in time and space;
- 2 laboratory dilution water toxicity tests must be confirmed by another laboratory;
- WERs should be determined individually for each metal or “pollutant” at each site and the results could not be extrapolated from one metal/pollutant, or effluent or site to another;
- Both total recoverable and dissolved metal measurements are required for all WER-metal tests to provide additional information on bioavailability, solubility and metal interactions.

The WER depends very much on the characteristics of the site water which vary over time and space, making it difficult to apply a single modifying ratio to the existing numerical WQC. Extensive laboratory analysis is required to incorporate the factors of bioavailability, solubility and chemical interactions into the modification. USEPA provides detailed guidance on the requirement of WER testing, which can be found in Appendix L of the Water Quality Standards Handbook. An interactive program to help readers better understand the steps involved could be found on the USEPA webpage http://www.epa.gov/seahome/wer.html. A schematic diagram to show the implementation of WER is given in Figure 5.3.4.

The Resident Species Procedure

The Resident Species Procedure accounts for differences in resident species sensitivity and differences in biological availability and/or toxicity of a material due to variability in physical and chemical characteristics of a site water. Derivation procedures follow the same as those for the national criterion by conducting tests with resident species in site water.

Figure 5.3.4 Schematic diagram of Water Effect Ratio implementation

Preliminary Analysis

Site definition

- discharges
- water body type
- site boundary

Study plan development

- WER method 1 or method 2
- sampling locations
- temporal samples collection
- simulated site water or downstream water
- chemical testing protocol

↓

Sampling Design

Effluent considerations

- flow to determine the average
- 24h-hour composite samples

Receiving water considerations

- flow to determine dilution with effluent
- 24-hour composite samples

↓

Laboratory Procedures

- selecting appropriate primary and secondary tests
- determining appropriate cmcWER and/or cccWER
- performing chemical testing
- calculating final WER (FWER)

↓

Implementation

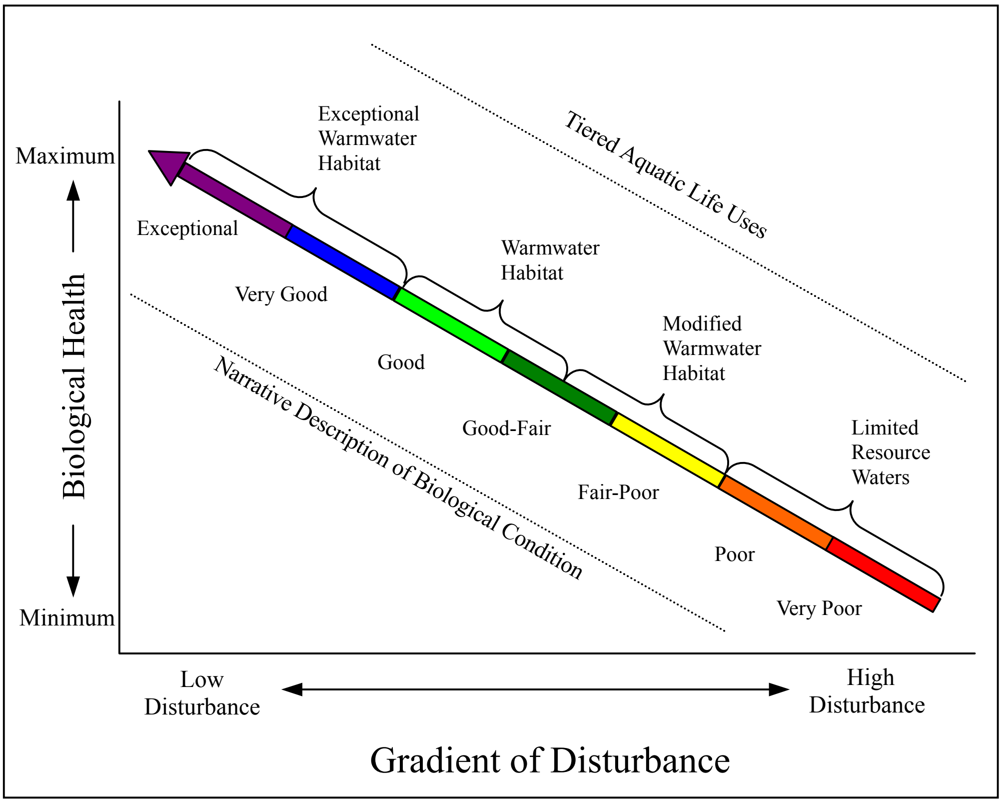
- assigning FWERs and the site specific criteria for each metal/pollutant to each discharger
- performing a waste load allocation and TMDL for each discharge
- establishing monitoring protocol
- establishing a permit condition for periodic testing of WER to verify site-specific criterion

5.4 BIOLOGICAL CRITERIA

5.4.1 Philosophy and approach

Pursuant to the primary goal of Clean Water Act to "restore and maintain the chemical, physical and biological integrity of the nation's water", biological criteria or biocriteria has gained recognition along with the chemical and physical aspect in water quality criteria. The concept of application of biocriteria is based on the premise that the structure and function of an aquatic community within a specific habitat provide critical information about the quality of the water body. Conditions of aquatic ecosystems in pristine waters or minimally unimpaired waters are taken as the reference point for the development of biocriteria. Deviation from the reference condition constitutes impairment of the beneficial use of the water body. A tiered aquatic life use classification characterized by the preferred biological conditions is shown in Figure 5.4.1.

Figure 5.4.1 The framework of biological integrity and aquatic life uses



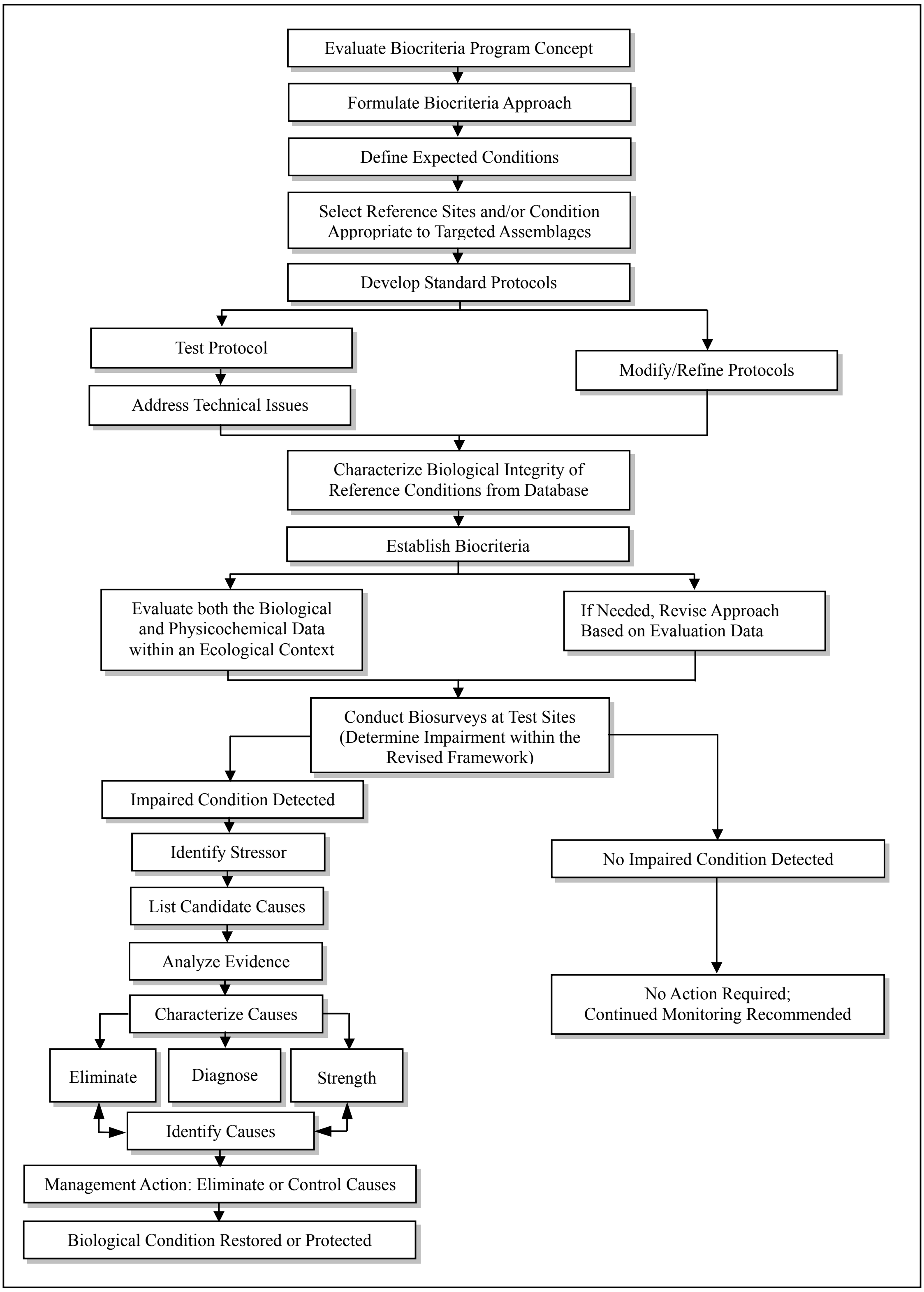
Assessment of biological integrity of a water body is based on the information on resident biological assemblages, such as species distribution, abundance trends and reproduction rate, etc. The information will be assessed using standard methods and compared to the reference condition in terms of criteria. Two approaches are used for the assessment : “Clusters” (statistical approach) is mainly used in assessing narrative biocriteria while “Scores” (multimetric approach) in assessing numeric biocriteria, e.g. the Indices of Biotic Integrity (IBI) for fish and the Rapid Bioassessment Protocols (RBPs) for benthos.

5.4.2 Framework for developing and implementing biocriteria

Biocriteria development and implementation requires an understanding, selection and evaluation of reference sites, measurement of aquatic community structure and hypothesis testing using standard protocols. A conceptual model for biocriteria development and implementation is given in Figure 5.4.2. The five primary steps to develop biocriteria are :

- planning the biocriteria development process;
- designating reference condition for biosurvey sites;
- performing the biosurveys;
- characterizing reference conditions;
- establishing biocriteria.

Figure 5.4.2 Schematic diagram of the process for developing and implementing biocriteria



Planning includes classification of water body types, designation of beneficial uses and determination of water management program objectives. The next step is designating reference condition to establish the basis for making comparisons and for detecting beneficial use impairment. The third step involves developing study designs that select aquatic communities best representative of the biological integrity of the waters and, collect data best representative of the aquatic communities. Issues requiring consideration at this stage of the process include defining the database of biological attributes to be formed, geographical scale and temporal scale for study, parameters and methods of measurement and assessment. The fourth step involves converting raw data to metric values and aggregating metrics to form biological integrity indices using the methods described in Section 5.4.4. Once biological integrity has been characterized and the geographic area regionalized, biological information can be equated to the water quality expectations and biocriteria can be established finally. The subsequent steps in the implementation of biocriteria include conducting biosurveys, comparing the data to the biocriteria and determining impairment and management actions.

5.4.3 Establishing the reference condition

Reference conditions can be established using a combination of methods – reference sites, historical data, simulation models and expert consensus.

Reference sites - reference conditions must be representative of the resource at risk and must be of the same or similar ecological realm or biogeographic region;

Historical data - can provide insights about the communities that once existed and / or those that may be reestablished;

Models - mathematical or statistical models to predict reference condition;

Expert consensus - applicable when no candidate reference sites are acceptable and models are deemed unreliable.

The above four methods can be used mutually to support reference condition decisions, however, the use of actual reference sites to establish reference condition is always important. The most appropriate approach is to conduct a preliminary resource assessment to determine the feasibility of using reference sites (see Figure 5.4.3). If reference sites are not acceptable, then greater reliance need to be placed on the other elements.

If reference sites are considered acceptable, reference conditions could be selected by identifying site-specific reference sites for each evaluation of impact, or selecting ecologically similar regional reference sites for comparison with impacted sites within the same region. Basically, four reference conditions are defined :

Site-specific – best for evaluating the impacts from a point discharge;

Upstream-downstream – best for streams and rivers where the habitat characteristics of the water body above the point of discharge are similar to the habitat characteristics of the stream below the point of discharge;

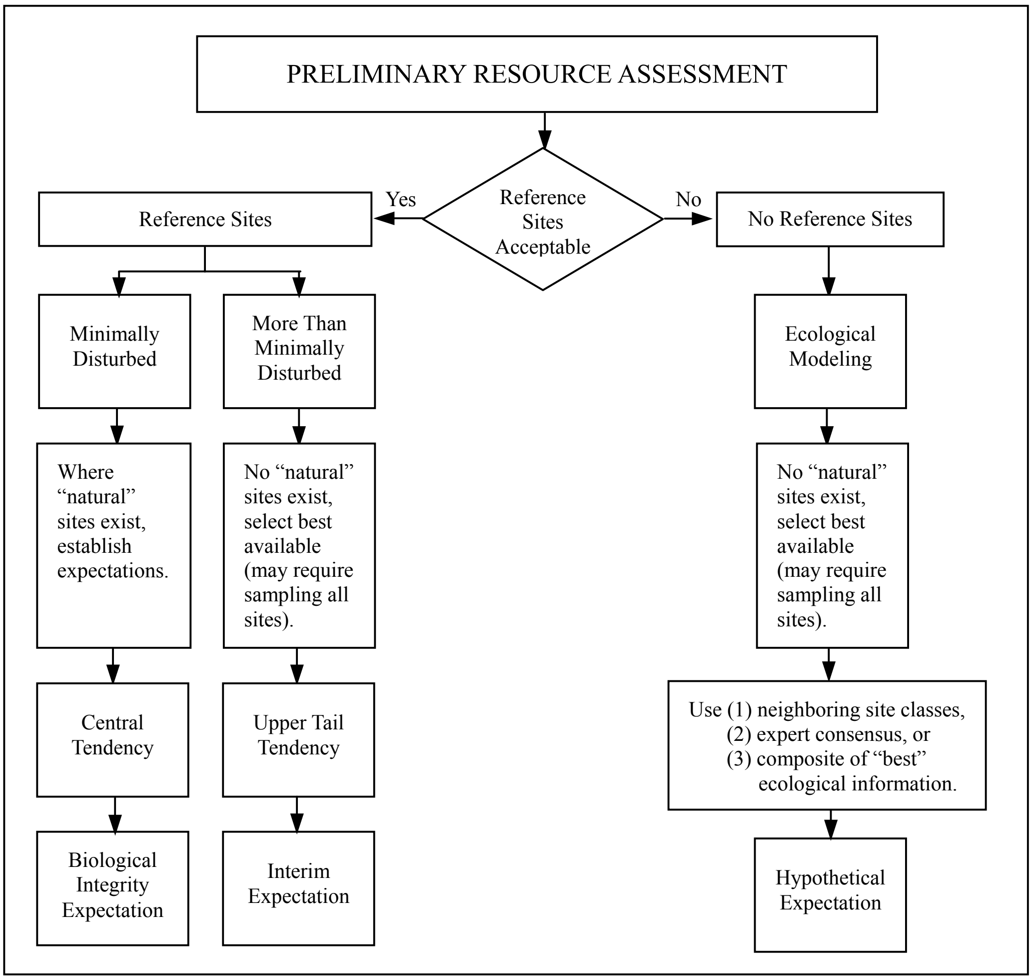
Near field - Far field – best for estuaries, large lakes or wetlands. A gradient of impairment of habitat characteristics will be established to determine areas of least impairment.

Regional – best for aquatic regions within a particular water body type having ecological features similar water quality characteristics, such as soil type, vegetation, land-surface form, climate, and land use.

5.4.4 Approach to develop narrative biocriteria

Narrative biocriteria rely on the use of standard measures and data analyses to make qualitative determinations of the resident communities. The basic steps in criteria development described in Section 5.4.2 still apply only that the statistical analysis is used to identify the presence of impairment and establish the probability of being certain in that judgment. Biological data are used to quantify the attributes of the reference conditions to provide a responsible rationale for decision making and assure a degree of confidence in management decision. Hypothesis testing is used to test whether a site significantly deviates from the reference condition.

Figure 5.4.3 Approach to establishing reference conditions



Narrative criteria can take a number of forms but they must contain several attributes to protect the most natural community possible for the designated use of the water body. Thus, they should include specific language about aquatic community characteristics that (i) must exist in a water body to meet a particular designated aquatic life use, and (ii) are quantifiable. For example, Maine, in additional to the use of a general descriptive statement, i.e. "as naturally occurs", has also incorporated into the criteria ecological attributes such as measures of taxonomic equality, numerical equality and the presence of specific pollution tolerant or intolerant species (see Table 5.4.1).

Table 5.4.1 Narrative criteria within the aquatic life classification scheme for Maine

RIVERS AND STREAMS	MANAGEMENT PERSPECTIVE	NARRATIVE CRITERIA
Class AA	High-quality water for preservation of recreational and ecological interests. No discharges of any kind permitted. No impoundment permitted.	Aquatic life shall be as naturally occurs.
Class A	High-quality water with limited human interference. Discharges restricted to noncontact process water or highly treated wastewater of quality equal to or better than the receiving water. Impoundment allowed.	Aquatic life shall be as naturally occurs.
Class B	Good-quality water. Discharges of well-treated effluents with ample dilution permitted.	Ambient water quality sufficient to support life stages of all indigenous aquatic species. Only nondetrimental changes in community composition may occur.
Class C	Good-quality water. Requirements consistent with interim goals of the Federal Water Quality Law (fishable/ swimmable).	Ambient water quality sufficient to support the life stages of all indigenous fish species. Changes in species composition may occur but structure and function of the aquatic community must be maintained.

5.4.5 Approaches used in developing numerical biocriteria

Three approaches are commonly used in the development of biocriteria, namely, multimetric index, discriminant model index and index derived from multivariate ordination.

<u>Multimetric index</u>

Multimetric index is the most commonly used among the three approaches. This is the basis of many indexes used in fresh waters, for example, the Index of Biotic Integrity (IBI), the Invertebrate Community Index (ICI), the Rapid Bioassessment Protocols. Metrics allows the use of meaningful indicator attributes in assessing the status of assemblages and communities in response to perturbation. Figure 5.4.4 shows the attributes of the biological characteristics that can help build a meaningful metric to reflect influence of human activities on resident biota. Comprehensive assessments of these attributes ensure that all the components of biotic integrity are protected.

Representative metrics should be selected from each of the four primary categories. Candidate metrics are first determined. The candidates should include all potential metrics which have ecological relevance based on the biological data collected from reference sites and the preliminary targeted “stressed” sites. These candidate metrics are then evaluated for their ability in differentiating between impaired and non-impaired sites. Table 5.4.2 and Table 5.4.3 show two examples of suite of attributes used in index development.

Figure 5.4.4 Organization structure of the attributes that should be incorporated into biological assessment

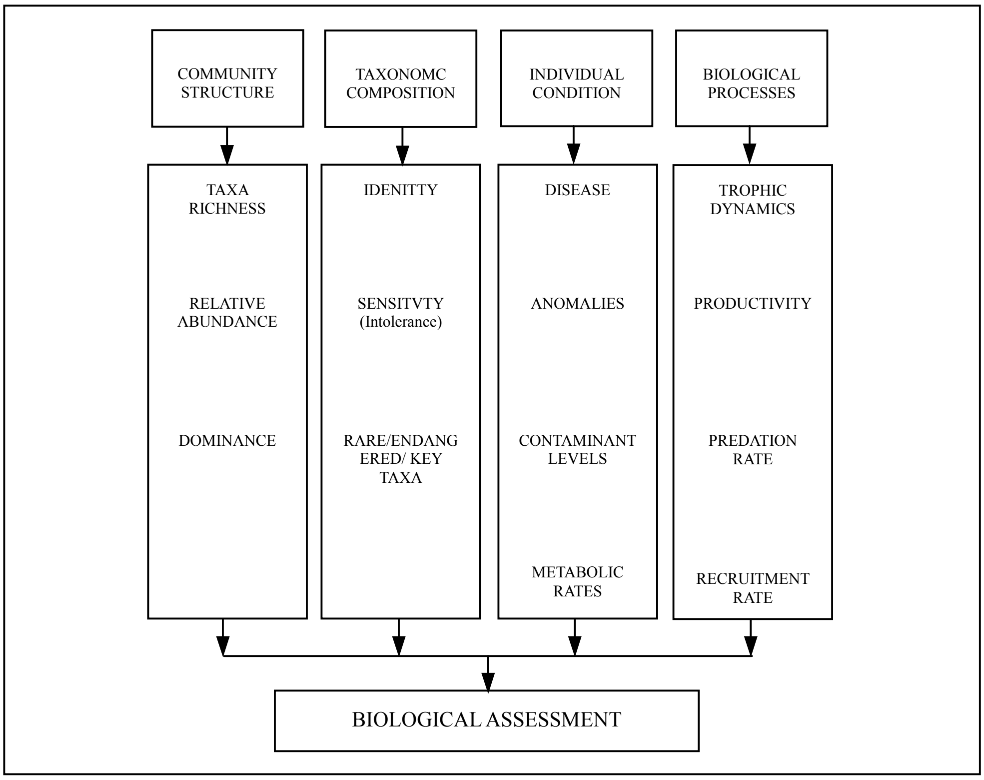


Table 5.4.2 Index of Biotic Integrity metrics used in North America

	ALTERNATIVE IBI METRICS
1.	Total number of species # native fish species # salmonid age classes [a]
2.	Number of darter species # sculpin species # benthicinsectivore species # darter and sculpin species # salmonid yearlings (individuals)[a] % round-bodied suckers # sculpins (individuals)
3.	Number of sunfish species # cyprinid species # water column species # sunfish and trout species # salmonid species # headwater species
4.	Number of sucker species # adult trout species [a] # minnow species # sucker and catfish species
5.	Number of intolerant species # sensitive species # amphibian species Presence of brook trout
6.	Percent green sunfish % common carp % white sucker % tolerant species % creek chub % dace species
7.	Percent omnivores % yearling salmonids [a]
8.	Percent insectivorous cyprinids % insectivores % specialized insectivores # juvenile trout % insectivorous species
9.	Percent top carnivores % catchable salmonids % catchable trout % pioneering species Density catchable trout
10.	Number of individuals Density of individuals
11.	Percent hybrids % introduced species % simple lithophills % simple lithophills species % native species % native wild individuals
12.	Percent diseased individuals

[a] Metric suggested by Moyle or Hughes as a provisional replacement metric in small western salmonid streams.
Taken from Karr et al. (1986). Hughes and Gammon (1987), Miller et at. (1988), Ohio EPA (1987), Streedham (1988), Lyons (1992).

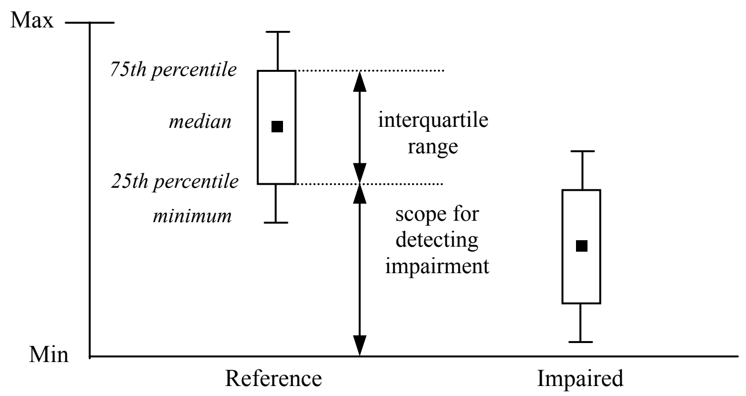
Table 5.4.3 Metric suites used for analysis of macroinvertebrate assemblages

	ALTERNATIVE BENTHIC METRICS	ICI[a]	RBP[b]	RBP[c]	BIBI[d]
1.	Total number taxa	X	X	X	X
	% change in total taxa richness				
2.	Number EPT taxa	X	X		
	# mayfly taxa	X			X
	# caddisfly taxa	X			X
	# stonefly taxa				X
	Missing taxa (EPT)			X	
3.	Number diptera taxa	X			
	# chironomidae taxa				
4.	Number intolerant snail and mussel species				X
5.	Ration EPT/chironomidae abundance				
	Indicator assemblage index			X	
	% EPT taxa				
	% mayfly composition	X			
	% caddisfly composition	X			
6.	Percent Tribe Tanytarsini	X			
7.	Percent other diptera and noninsect composition	X			
8.	Percent tolerant organisms	X			
	% corbicula composition				X
	% oligochaete composition				X
	Ration hydropsychidae/tricoptera		X		
9.	Percent individual dominant taxa		X		
	% individual two dominant taxa				X
	Five dominant taxa in common		X	X	
	Common taxa index			X	
10.	Indicator groups				
11.	Percent individual omnivores and scavengers				X
12.	Percent individual collector getherers and filterers				X
	% individual filterers				
13.	Percent individual grazers and scrapers				X
	Ratio scrapers/filterer collectors				
	Ratio scrapes/(scrapers + % shredders collectors)		X		
14.	Percent individual strict predators				X
15.	Ration shredder/total ind. (+ % shredders)		X		
16.	Percent similarity functional feeding groups (QSI)		X	X	
17.	Total abundance				X
18.	Pinkham-Pearson Community Similarity Index		X		
	Community Loss Index				
	Jaccard Similarity Index				
19.	Quantitative Similarity Index (taxa)		X	X	
20.	Hilsenhoff Biotic Index		X		
	Chandler Biotic Index				
21.	Shannon-Weiner Diversity Index				
	Equitability				
	Index of Community Integrity				

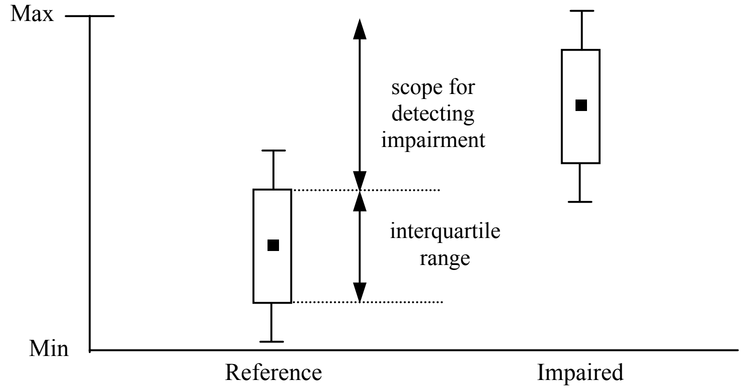
[a] Ohio EPA (1987)
[b] Barour et al. (1192) revised from Plafkin et al. (1989)
[c] Shackelford (1988)
[d] Kerans and Karr (in press)

A key analytical method for evaluating the ability of metrics to detect impairment is using box-and-whisker plots. The interquartile ranges are used to evaluate real differences between two areas and to determine whether a particular metric is a good candidate for use in the assessment. Metric values beyond the lower or upper quartile of reference conditions are judged impaired to some degree. The actual percentile chosen (25, 10 or 5) is subject to policy decision and reflects the amount of uncertainty a water quality management program.

Figure 5.4.5 Generalized box-and-whisker plots illustrating percentiles and the detection coefficient of metrics



a. Metrics that have high values under reference (unimpaired) conditions



b. Metrics that have low values under reference conditions

Each metric will be normalized and aggregated to develop expectations for the values of each of the metrics from the reference data set and to score metrics according to whether they are within the range of reference expectations. Metrics within the range receive a high score; those outside receive a low score. The scores of the metrics will be summed to give the multimetric index value. Table 5.4.4 and Table 5.4.5 show examples of the scoring criteria based on fish community data and index values representing different narrative descriptions of fish assemblage condition. The final step is to validate the index using independent data set that has not been used to develop the index.

Table 5.4.4 Index of Biotic Integrity metrics and scoring criteria based on fish community data from more than 3000 reference sites throughout Ohio applicable only to boat sites.

	SCORING DIVISIONS		
	5	3	1
IBI Metric	METRIC VALUE RANGES		
Total no. species	> 20	10 – 20	< 10
% round-bodied suckers	> 38	19 – 38	< 19
No. sunfish species	> 3	2 – 3	< 2
No. sucker species	> 5	3 – 5	< 3
No. intolerant species	> 3	2 – 3	< 2
% tolerant species	< 15	15 – 27	> 27
% omnivores	< 16	16 – 28	> 28
% insectivores	> 54	27 – 54	< 27
% top carnivores	> 10	5 – 10	< 5
% simple lithophils *	> 50	25 – 50	< 25
% DELT anomalies	< 0.5	0.5 – 3.0	> 3
Fish numbers	<200	200 – 450	>450

* For sites of a drainage area ≤ 600 miles^2, for sites of an area > 600 miles^2, scoring categories vary with drainage area

Table 5.4.5 Ranges for index of Biological integrity values representing different narrative descriptions of fish assemblage condition in Ohio streams.

SITE CATEGORY	EXCEPTIONAL	GOOD	FAIR	POOR	VERY POOR
Wading	50 – 60	36 – 48	28 – 34	18 – 26	< 18
Boat	50 – 60	36 – 48	26 – 34	16 – 24	< 16
Headwaters	50 – 60	40 – 48	26 – 38	16 – 24	< 16

Discriminant Model Index

This approach involves the use of model employing multivariate tests to develop condition indexes. Data of reference sites and impaired sites are collected and fitted into the computation model. The two site types represent the ends of a continuum with intermediate sites not used for modeling building. The model attempts to find a combination of input variables that best predicts biological response to habitat variables. Limitations on this approach still need addressing to resolve the problem of misclassification.

Index derived from Multivariate Ordination

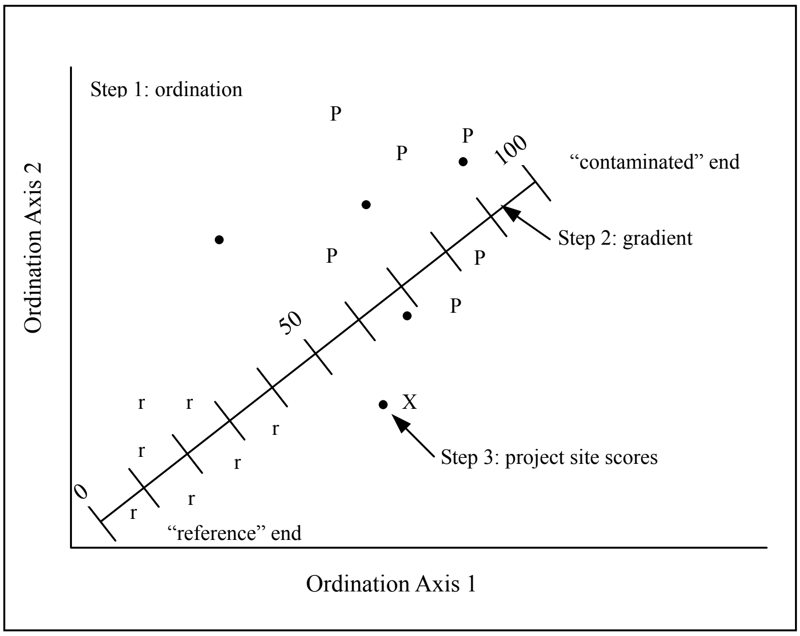
This approach uses multivariate ordination to derive a pollution gradient, which in turn is used to develop an index. The approach is computationally intensive and complex. An index which was derived for benthic macroinvertebrates in Southern California Bright in 2000 is being applied to demersal fish in the same area. The approach works on the assumption that each species has a tolerance for pollution and that if the pollution tolerance is known for sufficiently large set of species, it is possible to infer the degree of degradation from species composition and the tolerances. The index is a weighted average tolerance value of all species found in a sample, weighted by abundance of the species as shown in the equation below :

$$I_s = \frac{\sum_{i=1}^{n} a_{si}^{f} p_i}{\sum_{i=1}^{n} a_{si}^{f}}$$

where I_s is the index value for sample *s, n* is the number of species in sample *s,* a_{si} is the abundance of species *i* in sample *s*, p_i is the tolerance value of species *i*, and the exponent f is used to downweight extreme abundances. If f is zero, than the index is not weighted by abundance

Development of the index first involves an ordination analysis to produce a plot of sites in ordination space in association with a specific pollution type (see Figure 5.4.6). A gradient line is drawn with two ends representing the position of the least unpolluted and most polluted sites. The position of each site in the ordination space is projected on the gradient line. The gradient is then scaled from 0 ("least polluted") to 100 ("most polluted"). The points on the gradient line denote score of a site commensurate with the abundance of a species, which in turn correspond to the tolerance values (p_i) of the above equation. The species tolerance scores are used to predict the Benthic Response Index (BRI) according to the equation. The BRI has a range of 0 to 100 and biocriteria can be set at selected values for specific aquatic uses. The BRI score can be calculated for any new site from species abundance data at the site.

Figure 5.4.6 A plot of sites using multivariate ordination analysis



Steps 1-3. Establishing site scores on a contamination gradient. The gradient is established between reference ("r") and contaminated ("P") sites as plotted in ordination space. Dots are sites not designated as either reference or contaminated. The projection of site "x" on the gradient (dotted line) yields its site score. Adapted from Smith et. al. 2000

The USEPA has published a suite of guidance document to help states develop their own biocriteria. Guidance on bioassessment and biocriteria for lakes, estuaries, wetland, lake and rivers can be found on their web sites : http://www.epa.gov/waterscience/biocriteria/ http://www.epa.gov/bioindicators/html/publications.html.

5.5 NUTRIENT CRITERIA

5.5.1 Philosophy and approach

The nutrient criteria are intended to protect against the adverse effects of over-enrichment of nutrient levels associated with human activities. This nutrient pollution affects not only the biotic integrity of the waters and the decline of valuable fish and shellfish, it has the potential to cause harm to the public health through hazardous algal blooms and the propagation of water borne diseases.

Nutrient criteria development could not follow what has been traditionally done for toxic pollutants. The adverse effects of nutrients are strongly affected by regional and seasonal conditions and their effects are ultimately expressed on ecosystems as a whole. Whereas a toxic pollutant may cause similar toxic effects on algal, invertebrate and vertebrate species, excessive nutrients may first promote algal growth followed by a cascade of ecological impacts that ultimately impair benthic invertebrates and fish species. The problems vary from one region to another because of factors such as geographical variation in geology, vegetation, climate and soil types. For these reasons, USEPA develops nutrient water quality criteria on an ecoregional (water body-type and region) basis using a reference condition approach.

As a starting point, USEPA has delineated the nation into 14 nutrient ecoregions and developed equivalent sets of ecoregional nutrient criteria for two groups of water bodies : lakes & reservoirs and rivers & streams. A summary of the core elements of the ecoregional criteria, namely, Total Phosphorus, Total Nitrogen, Chlorophyll *a* and some measures of water clarity, could be found at http://www.epa.gov/waterscience/criteria/nutrient/ecoregions.

In deriving the ecoregional criteria, USEPA has used available data from water bodies in each ecoregion to determine a best estimate of minimally impacted conditions. USEPA recommends to uses the 75th percentile of a distribution of reference condition values as the target condition of a minimally impacted site. Reference condition waters that would exceed criteria based on the 75th percentile are good candidates for site-specific criteria. As information about “minimally impacted sites” are unavailable on a national scale, alternatively, USEPA recommends to use the 25th percentile of a distribution of samples form the entire population of water bodies within a given physical classification (e.g. an ecoregion).

To account for site-specific conditions, USEPA has made several options available to states and tribes. The following options are in order of preference :

- develop criteria by following the USEPA guidance;
- adopt USEPA’s section 304(a) water quality criteria for nutrients;
- develop criteria use other scientifically defensible methods and appropriate water quality data.

5.5.2 Framework for developing region-specific nutrient criteria

Under the water body-type approach, USEPA has defined 14 ecoregions and classified water body types into 4 categories: estuarine and coastal marine waters, lakes and reservoirs, rivers and streams, and wetlands. The nutrient criteria development processes are basically the same for the four water body types. Guidance manuals for developing nutrient criteria are available at

http://www.epa.gov/waterscience/criteria/nutrient/guidance for general use according to water body-type; and at

http://www.epa.gov/waterscience/criteria/nutrient/ecoregions/lakes/index.html for nutrient criteria for lakes and reservoirs in some ecoregions.

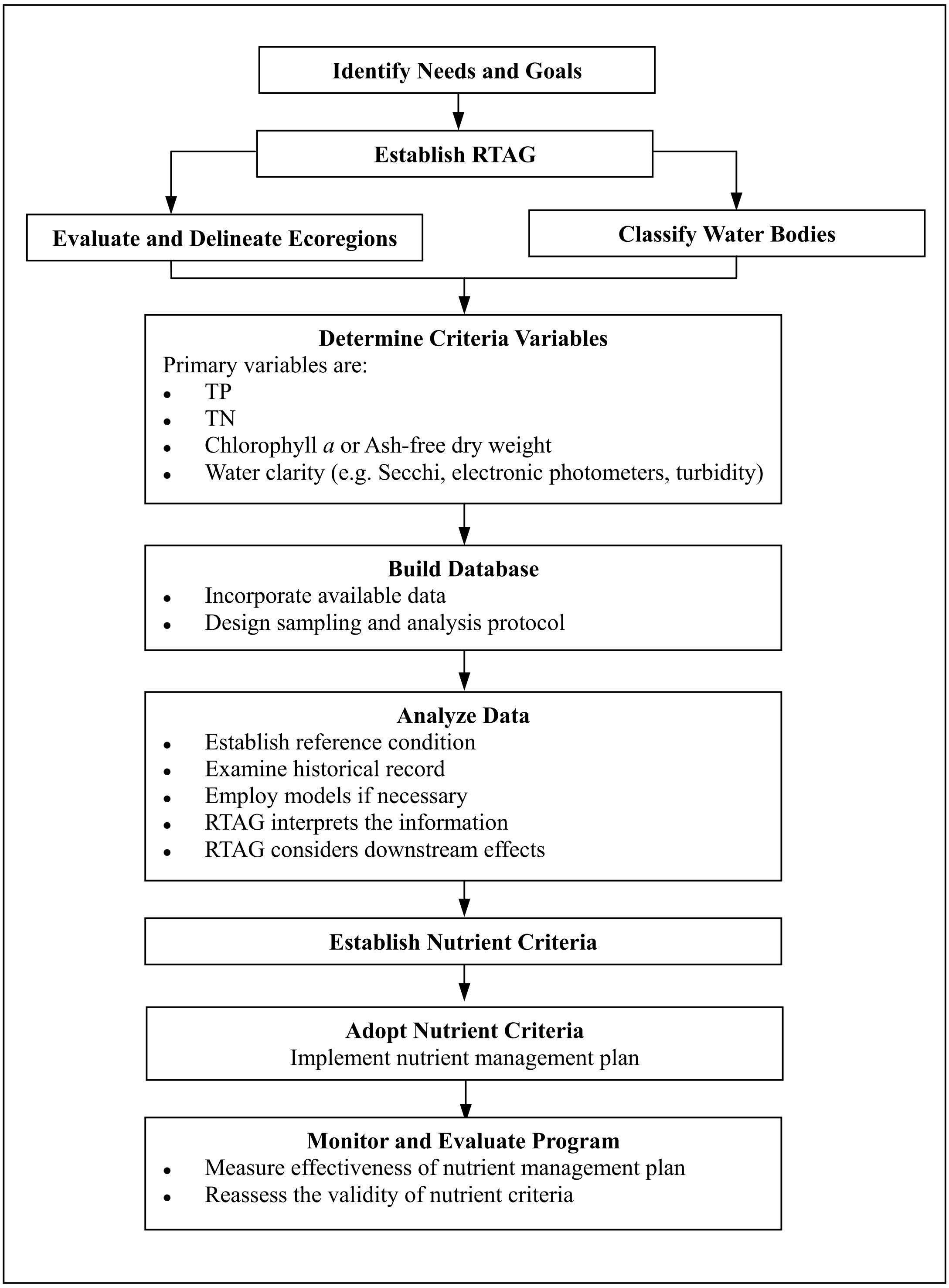
Figure 5.5.1 presents a schematic illustration of the key steps in the criteria development process. For the purpose of this project which primary focuses on management of coastal water, the discussion on criteria development is largely related to estuarine and coastal marine waters.

Once the needs and goals of the nutrient criteria program have been identified, the next step is to establish a Region Technical Assistance Group (RTAG) in each region. The composition of the RTAG is diverse, consisting of a viable subset of scientists and states resource managers so as to have the necessary breadth of experience and expertise to effectively debate and resolve serious scientific and management issues. Each of the RTAGs also serves as the link between regions and USEPA headquarters to help develop and implement the criteria program on a national scale.

The initial task of each RTAG is to delineate nutrient ecoregions or coastal provinces appropriate to the development of site- or region-specific criteria based on the ecoregional map developed by USEPA, taking into account detailed observations and data available from the states and tribes concerned. The next step is to devise a classification scheme for rationally subdividing the water bodies in the state or tribal territory based on physical characteristics, e.g. residence time, salinity, general water chemistry characteristics, depth and grain size or bottom type.

The subsequent steps in the development process involve the collection and evaluation of data. A wide variety of indicator variables may be possible for use to combat nutrient problems. To start off, USEPA has designated four primary variables and dissolved oxygen as the essential indicators, they are (i) total phosphorus (TP) and (ii) total nitrogen (TN) as primary nutrient causal variables of eutrophication; (iii) a measure of algal biomass and (iv) a measure of water clarity as primary variables of eutrophic response. In systems that have hypoxia or anoxia problems, dissolved oxygen is added as a primary response variable. Other optional variables that can be used are loss of seagrass/submerged aquatic vegetation (SAV), benthic macroinfauna, iron and silica as well as other indicators of primary and secondary productivity.

Figure 5.5.1 Schematic diagram of the nutrient criteria development process



When data are available, the nutrient data are then analyzed following steps which involve a sequence of five interrelated elements:

- examination of the historical record or paleoecological evidence for evidence of a trend;
- determination of a reference condition using one of several alternative approaches;
- use of empirical modeling or surrogate datasets;
- objective and comprehensive interpretation of all information by a panel of specialists;
- development of criterion for each variable, which must provide for attainment and maintenance of water quality standards in downstream waters.

An action plan is then established to implement and assess attainment with the developed criteria. The initial criteria list will basically contain two causal variables (TN and TP) and three primary response variables, failure to meet either of the causal criteria is sufficient to indicate "excursion". However, if the causal criteria are met but some combination of response criteria are not met, then USEPA suggests two approaches to determine if the waters in question meet the nutrient criteria :

- decision-making protocol;
- multivariable enrichment index.

5.5.3 Classification of estuarine and coastal water

As a first step in classification, water quality managers must decide which water bodies to include in the population to which criteria will be applicable. In doing so, a short list of factors is provided to characterize the susceptibility of estuaries to nutrient loading :

- system dilution and water residence time or flushing rate,
- ratio of nutrient load per unit area of estuary,
- vertical mixing and stratification,
- algal biomass,
- wave exposure,
- depth distribution,
- ratio of side embayment(s) volume to open estuary volume or other measures of embayment influence on flushing.

For Estuarine waters

Various approaches are used and they are (i) geomorphic classification, (ii) man-made estuaries and (iii) physical/hydrodynamic factor-based classifications.

Estuaries can be geomorphically divided into four main groups :

- coastal plain estuaries,
- lagoonal or bar-built estuaries,
- fjords,
- tectonically caused estuaries.

Man-made estuaries are characterized by dredged bayous, canals and salt water impoundments with weirs function as estuaries.

Physical/Hydrodynamic factor-based classification is based on :

- stratification, mixing and circulation parameters -

  (i) based on the ratio of the volume of freshwater entering the estuary during a tidal cycle to its tidal prism :

ratio	mixing type
>1.0	highly stratified
0.25	partially mixed
<0.1	well mixed

  (ii) based on two-parameter schemes involving factors like circulation, stratification, ratio of tidal amplitude to mean depth, along-estuary and vertical density differences and vertical tidal excursion of isopycnals, etc.

- water residence time – the residence time of water directly affects the residence time of nutrients in estuaries, and therefore the nutrient concentration for a given loading rate, the amount of nutrient that is lost to internal process (e.g. burial in sediments and denitrification) and the amount exported to downstream receiving waters. Residence time and volume together may be used to scale nitrogen loading to estuaries to permit calculation of nitrogen concentrations and perform cross-system comparisons.

- water exchange process (e.g. river flow, tides, and waves) - this classification suggests that river flow in partially mixed estuaries is essentially neutral, but its variation relative to hydrodynamic residence time can be important in interpreting property-salinity diagrams (Table 5.5.1).

- tidal amplitude – provides a means to broadly classify estuaries relative to their sensitivity to nutrient supplies.

mean tidal range	sensitivity
$\geq$ 2 m	tolerant to high nutrient loading
< 2 m	more sensitive to dissolved nitrogen

Table 5.5.1 Classification of coastal system based on relative importance of river flow, tides, and waves to mixing

Type	River flow	Tide	Waves	Description
I		-	-	River delta
II		-		River delta (plus barriers)
III			-	Tidal river delta
IV	0		-	Coastal plain estuary
V	-			Tidal lagoon
VI	-		-	Bay
VII	-	-		Coastal lagoon

Plus and minus designations indicate relative impacts; e.g., - means that river discharge is very small relative to tidal and wave energy
Source: Adapted from Dronkers 1988

- NOAA Scheme of classification of estuarine nutrient export potential using a susceptibility matrix. The low, moderate, and high susceptibility indices are combined with low, moderate, and high human levels of nutrient input, resulting in a final matrix of overall human influence.

- comparative systems empirical modeling approach. The approach uses an empirical regression method to determine the response of estuarine systems to nutrient loading based on the assumption that the grading of systems is due to nutrient disturbance.

- habitat type – according to the presence and extent of different habitats / communities, e.g. seagrasses, mangroves, mudflats, deep channels, oyster reefs, dominance of sand versus mud bottoms, extensive emergent marches and the presence of unconsolidated verses rocky shorelines, etc.

- other theoretical considerations – several schemes have been put up for consideration, e.g. a scheme based on the idea that an ecosystem is a balance between energies that build structure and order; another scheme based on the idea that an ecosystem can be characterized in terms of growth and organization, however, these presented schemes have potential future value but are not widely used currently.

<u>For coastal waters</u>

Several approaches are available which are in order of importance: (i) geomorphic classification; (ii) hydrographic consideration and (iii) habitat and community features.

The conditions of coastal waters differ greatly among continental shelves. Factors leading to the vast differences are interrelated, e.g. the flow of energy and nutrients is driven by differences in form and amount of vegetation, which in turn determined by differences in local and ocean-scale patterns of climate; the steepness of coastal slopes may influence bottom sediment stability and upwelling; the degree of bottom roughness or sculpture may influence vertical mixing and in turn affect water column stability and depth of the euphotic zone versus mixing depth.

Coastal waters contain a variety of biotic communities, including a diverse assemblage of macroepifauna and –infauna, kelp forest, coral reefs, bottom and pelagic fishes, marine mammals and seabirds. The relation of these communities to hydrographic factors can assist in classification.

Distinctive ecosystems of mangroves, seagrass and coral also offer a basis for coastal waters classification.

5.5.4 Inventory of causal and response indicator variables

The guide book on nutrient criteria development for estuarine and coastal marine waters provides an overview of several measurable trophic state variables that can be used. Following paragraphs present some primary variables, which include causal nutrients variables (TN, TP and silica) and two response variables (a measure of algal biomass and water clarity), and dissolved oxygen. These variables are relevant at the national scale to practically all estuaries and are potentially relevant to near shore coastal waters.

Nitrogen

Nitrogen is one of the most important limiting nutrients of autotrophic assemblages incorporated into estuarine and near shore coastal marine bioassessment. Inorganic N has been the mainstay as the primary stimulant to algal biomass production. However, majority of dissolved N transported by river systems is in organic form, i.e. dissolved organic nitrogen (DON). DON and its particulate organic forms participate in algal biomass production through recycling processes. It has been reported that the source of DON can influence the degree of DON utilization by the microbial community. Varying proportions of organic N may be relatively refractive and contribute very little to N over-enrichment problems, however, the readily recyclable component may contribute to N enrichment problems locally and further seaward.

The inorganic N consists of ammonia, nitrite and nitrate-N. Ammonia-N is a primary product of microbial degradation of organic N and it may be oxidized through nitrification to nitrite and nitrate. Denitrification may remove from a few to approximately 50% the TN load entering temperate estuaries annually depending largely on residence time of the water, sediment biogeochemical conditions and water column depth. This process helps to modulate extreme DIN concentrations.

In open coastal waters of the North Atlantic Ocean and at temperate latitudes, there is a typical seasonal progression in DIN and DIP concentrations associated with phytoplankton blooms. The spring bloom reduces these inorganic forms while phytoplankton biomass accumulates. This progression begins at lower latitudes and moves to higher latitudes. The spring bloom subsides in late spring and summer biomass levels often are nutrient limited. In fall, mixing and replenishment of nutrients from deeper waters into the upper surface layers will occur when the thermocline breaks. This induces a short burst of biomass production before light becomes limiting. Seasonal nutrient patterns in estuaries are quite variable due to point source contribution of nutrients and low flow.

Recent studies have found that particularly at the interface between fresh and marine waters, ionized ammonia adsorption to particles was decreased, especially in the 0 to 10% salinity range, as were the nitrification and denitrification process. Further evaluation showed that the reduction in nitrification and denitrification process was due not only to the displacement of bacteria and ionized ammonia from particles but also to decreased bacterial activity. These changes in N dynamics that affect adsorption of suspended solids may need to be considered when evaluating acceptable levels in fresh water systems.

Phosphorus

Phosphorus is an important plant nutrient that may limit algal biomass production. The natural source of P is from slightly soluble minerals in the geosphere. The P entering the sea is mostly orthophosphate from human activities. In estuarine and near shore coastal waters, P is present in dissolved inorganic form as well as dissolved and particulate organic form. Some fraction of P may be strongly embedded in a mineral matrix and this renders the fraction relatively inert to biological utilization. Plants directly take up the phosphates in photosynthesis while some algae are capable of breaking down dissolved organic P (DOP) and utilizing the phosphate as inorganic phosphate. When plants die or are eaten, the organic phosphorus is rapidly converted to orthophosphorus through the action of phosphorylases.

P plays a pivotal role in nutrient management. In instances where phosphate is limiting, the discharge of raw or untreated wastewater, agricultural drainage or certain industrial wastes may stimulate the growth of algae.

Silica

Silica is an important nutrient to diatoms, for their production. Si is often connected to estuarine eutrophication and Si limitation of diatom production is often a measure of N or P over-enrichment. Si limitation can be deduced from ambient ratios relative to the nutrient-sufficient N:Si:P biomass ratios of 16:16:1 (Redfield et al. 1963; Conley et al. 1993).

The decay of Si-rich organisms alters the N:Si and P:Si ratios which in turn alters phytoplankton populations to reduce the relative abundance of diatoms and enhance the relative abundance of flagellates. Eggs and Aksnes (1992) showed that diatoms in excess of 2.2 μM will lead to domination of the phytoplankton community by diatoms. Data on N:P:Si ratios on coastal Louisiana and Texas now suggests the possibility of a joint nutrient limitation of phytoplankton production. The role of Si in estuarine and near shore coastal productivity and food web dynamics and as a basis for controlling co-limiting N and /or P need further investigation.

Chlorophyll a

Rapid proliferation or blooming of phytoplankton, as reflected in chlorophyll a measurements, occurs throughout the ocean but it is most often associated with temperate coastal and estuarine waters and at higher latitudes. In winter months, growth of phytoplankton populations is generally minimal because of insufficient light and also because of a turbulent and unstable upper water column, which carries the phytoplankton cells below the euphotic zone (where light is insufficient) before they can divide.

Chlorophyll a concentrations vary widely as a function of nutrient supply, water column stability, light availability, sinking, grazing, disease organisms and flushing/mixing. Concentrations can vary from the range of 20-40 μg/L in summer to the range of 1- 5 μg/L in the winter.

Water Clarity

Light influences the feeding behavior of many planktonic animal forms, especially crustaeean filter feeders, which have relevance to algal grazing. Water clarity is commonly measured by secchi disc and light attenuation. The simple and inexpensive secchi disc method is more widely used, however, it is not able to distinguish the light attenuation effects of living phytoplankton pigments from other factors (e.g. inorganic suspended sediments, organic nonchlorophyll-based detritus and humic-like materials) that reduce water clarity.

Attenuation of light in the sea in nonalgal bloom areas is determined primarily by the amount of suspended matter, but in estuarine and near shore coastal waters, colour from humic-like materials may interfere the light reduction. A strong seasonal variability in water clarity in temperate estuaries and coastal waters is reported. In open coastal areas and with the coming of spring, the thermocline tends to confine algal cells to the euphotic zone, which becomes rich with nutrients as a result of winter mixing. In partially mixed estuaries where light is adequate at depth, diatoms may grow below the pycnocline.

Dissolved Oxygen

Dissolved oxygen (DO) is an integrative measure of ecosystem health and habitat function. The percent saturation of surface and bottom waters is an index of the production/respiration ratio. DO in bottom waters serves as a measure of habitat availability for benthic animals and pelagic animals that feed on the bottom. Lack of oxygen in bottom waters causes sediment to release dissolved nutrients including orthophosphorus, ammonia and also toxic hydrogen sulphide.

5.5.5 Approaches to nutrient criteria development

Numerical nutrient criteria are developed based on the reference condition approach. The approaches to nutrient criteria development presented here are largely the approaches to establish reference conditions. Four approaches are available for estuaries with one focuses on nutrient loading from the watershed. The fifth one is for coastal marine waters. Downstream effects, salinity gradients and seasonal and inter-annual variability should be taken into consideration when defining reference conditions. Table 5.5.2 summarizes the five approaches to establishing reference conditions in estuaries and coastal waters.

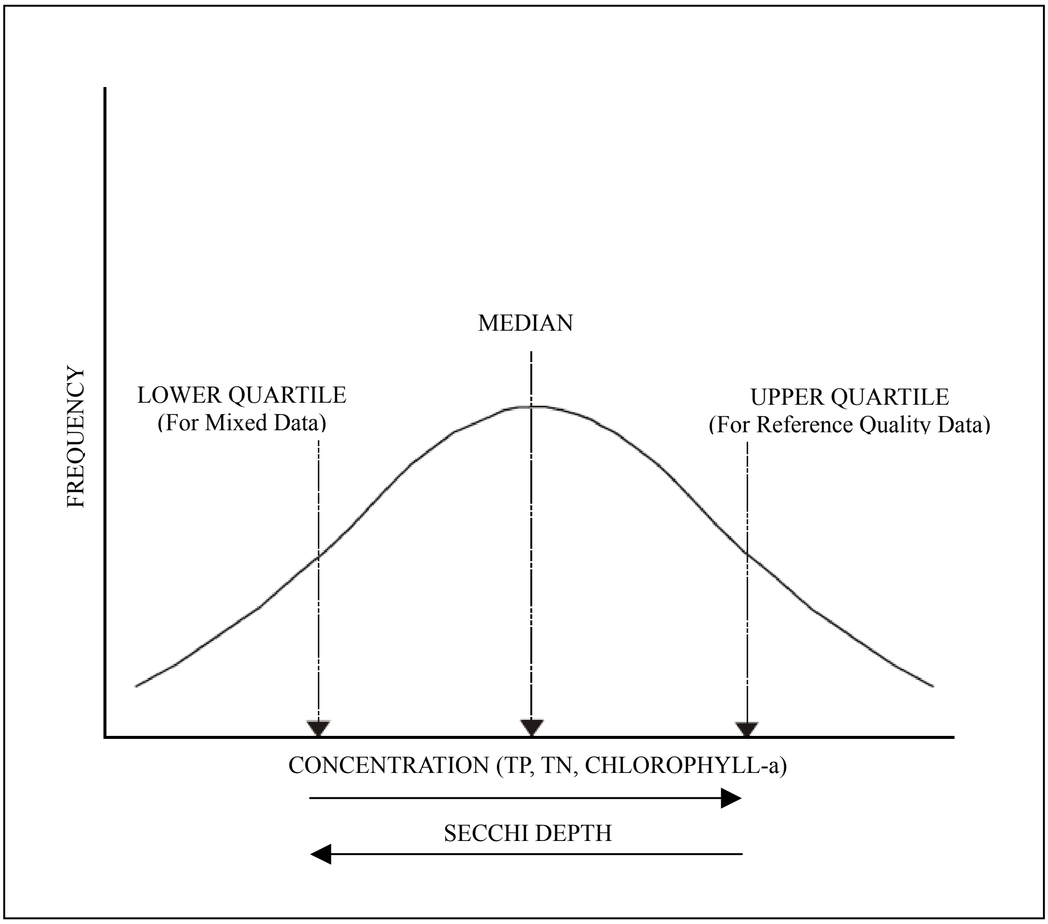
Table 5.5.2 Summary of estuarine and coastal nutrient reference conditions determination

Degree of apparent estuarine degradation	Method recommended	Criterion measure
A. In Situ Observations as the Basis for Estuarine Reference Condition		
1. Recognized unique excellent condition.	Median ambient concentration. Figure 5.5.2.	Concentration of TP, TN, chlorophyll a, Secchi depth (m)
2. Some degradation, but reference sites exist.	Upper quartile. Figure 5.5.2.	Same as above
3. Significantly degraded, including all potential reference sites.	Intercept value on a regression or distribution curve as illustrated in Figure 5.5.3 and Figure 5.5.4 or by use of a comparable comparative regression model.	Same as above
B. Watershed-Based Approaches for Estuarine Reference Condition		
4. Same as approach 3 above, but insufficient historical data	Ref. sites along each trib. And calculate delivery. Summation is reference condition. Figure 5.5.5. Model required to back-calculate load where all tribs. are degraded	Load of TP and TN; model is required to covert load to estuarine concentration.
C. Coastal Reference Condition		
5. Applicable to all coastal reaches - Estuarine plumes - Coastal areas	Index site approach; models may help distinguish anthropogenic contribution. More details could be found in Appendix H of the technical guidebook for estuarine and coastal waters.	Concentrations

In situ observations as the basis for estuarine reference condition

The first three approaches work on spatial and temporal scientific database, depending on the scale of available “minimally unimpaired” conditions. The estuaries are segmented by salinity zones and comparisons are made among zones with similar physical characteristics. The median or the upper quartile of the frequency distribution of indicator endpoints is taken as the reference points of the target conditions (Figure 5.5.2). When reference condition is derived from a set of estuaries or coastal waters within a class of system, it is preferable to have data collected from at least 15 estuaries or embayment.

Figure 5.5.2 Hypothetical frequency distribution of nutrient-related variables showing quantities for reference or high-quality data and mixed data (all data included)

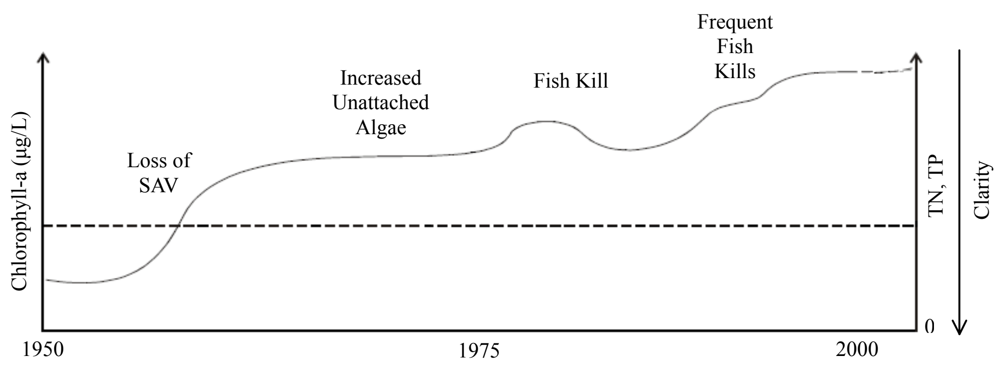


The third approach is applicable to the condition when significant degradation exists and reference sites cannot be identified from current monitoring. Under these circumstances, the reference conditions are established from historical records. Three approaches are available:

- analysis of historical ambient nutrient and hydrographic data;
- analysis of sediment cores;
- model hind casting.

In analyzing historical data, a suite of factors that water quality managers need to take into consideration includes selection of reference period, co-linear effect of freshwater input, seasonal and inter-annual variability. A progression analysis of past measurements can be used as a basis for comparison to present condition (Figure 5.5.3).

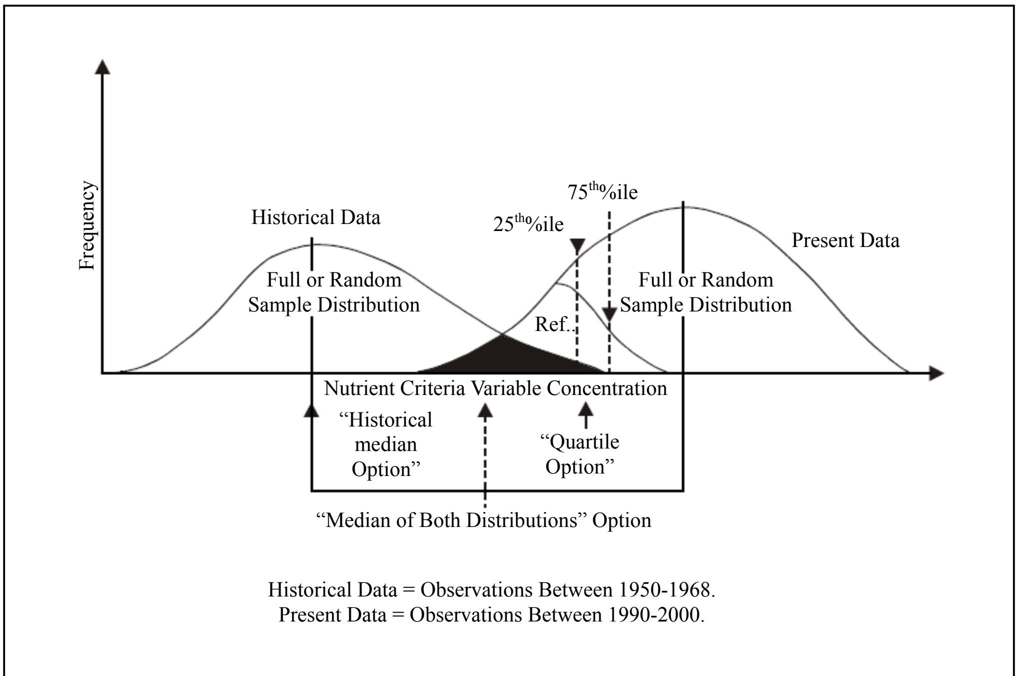
Figure 5.5.3 Hypothetical example of load/concentration response of estuarine biota to increased enrichment. Dashed line represents the selected reference condition level.



In data rich cases, the median of both the historical median and the present median could be used as the reference point (Figure 5.5.4). This simple procedure reflects the magnitude of the departure from minimally impacted waters and is, in part, a function of the length of the historical database, addresses inherent variability, and is realistic approximation of a reference condition over the time span.

Sediment core analysis and hind-casting modeling are two other approaches available for establishing reference conditions based on historical data. Hind casting with sediment cores provides a means to infer reference conditions at a time when nutrient concentrations were much lower than present. Yet, sediment cores analysis have limited applicability in shallow areas with no deposition. Despite inherent problems of data verification and calibration, hind-casting modeling is still considered to be a useful tool when ambient data are inadequate and sediment cores are not applicable. Water quality managers may refer to Chapter 9 of the technical guide book for an account of special features, shortfalls, strong points of a suite of mathematical and empirical models suitable for nutrient criteria development.

Figure 5.5.4 An illustration of the comparison of past and present nutrient data to establish a reference condition of intensively degraded estuaries. The option of selecting the distributions from both time periods is compared to an expected frequency distribution if the observations were available.



Watershed-based approaches for estuarine reference condition

The areal load approach assumes that in an undisturbed estuary and its watershed, the nutrient load historically represent the most natural condition. The nutrient load is measured for the minimally disturbed sub tributary or segment. Reference conditions are then deduced by extrapolating the tributary values in a simple proportional manner to the entire watershed. Figure 5.5.5 illustrates the extrapolation method and the keys steps involved are :

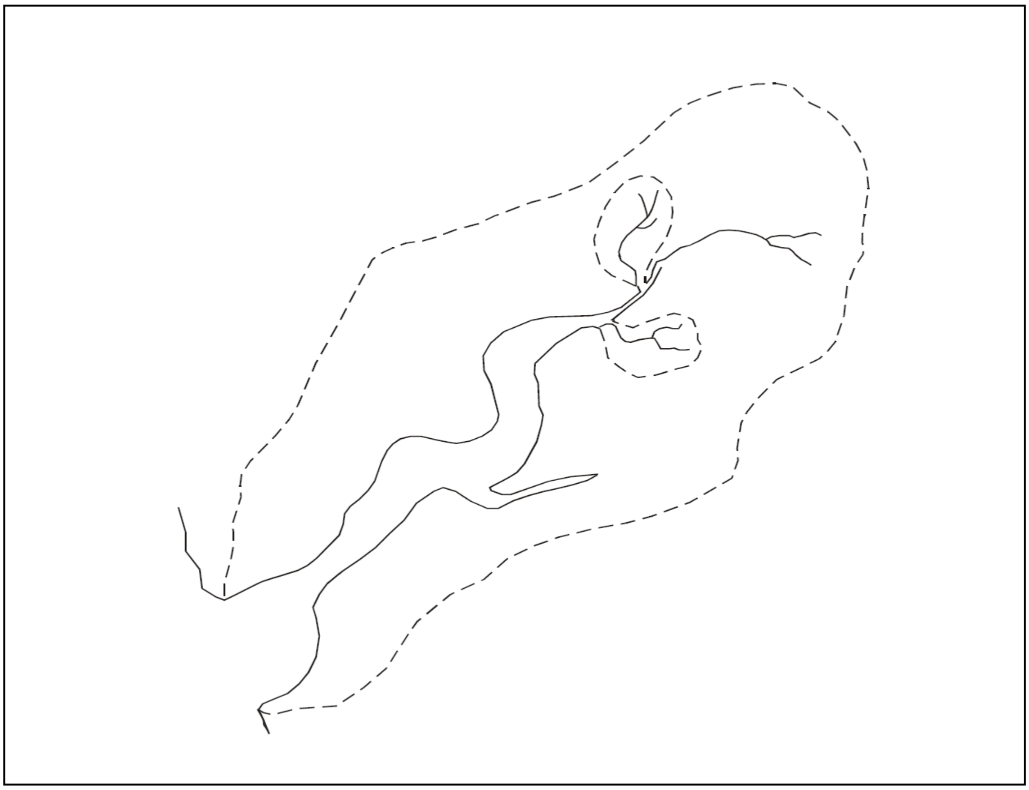
- identify and classify major tributaries to the estuary by physical size, freshwater delivery, geology;
- find the tributary(ies) with the least impaired status and minimal disturbed lands contributing to nutrient loads;
- estimate the annual areal nutrient yield for TN and TP;
- extrapolate the nutrient yield to the entire watershed land area within the region;
- repeat for other regions if the estuary watershed covers more than one major geological landform;
- sum the nutrient yield for all tributaries within the estuarine watershed.

Coastal reference condition

The approach used for establishing coastal reference conditions is an analogue of the approach applicable for a watershed. For assessing coastal estuarine plumes, hydrodynamic model with coupled nutrient-phytoplankton growth kinetics for a large-scale plume or a well-designed research and monitoring plan for a smaller plume is required. For open coastal water, an index site approach is recommended. When the continental shelf is very extensive and too large to conduct comprehensive studies of all sites potentially affected by nutrient enrichment, the index site has the merit of prioritizing coastal waters relative to their susceptibility to nutrient enrichment. More details on the index site approach can be found in Chapter 6 of the National Research Council 2000 publication titled “Clean Coastal Waters: Understanding and Reducing the Effects of Nutrient Pollution”. However, this method likely is relatively crude and therefore needs to subject to deliberations and debates by some mix of policymakers, scientists and water quality managers.

Figure 5.5.5 Areal load estimate approach to nutrient reference condition determination

The watershed is estimated to be approximately 368 square miles; the reference tributary streams representative of above head of tide systems in the watershed are approximately 20 square miles combined. The median load estimate at the mouths of the tributaries could therefore be multiplied by 18.4 to approximate a reference condition load for the river.



5.6 CRITERIA FOR SEDIMENT

USEPA has not published any criteria guidance for sediment. Given suspended solids and sediment transport nutrients, detritus, and other organic matters in natural amounts are critical to the health of a water body, USEPA has started to identify and discuss issues relevant to the establishment of a strategy for development of water quality criteria to protect designated uses from adverse impacts of sediment.

The National Clean Sediment Workgroup was formed in 1998 and a meeting was convened to start off the strategy development process. A consultation paper has been prepared to seek advice from the Science Advisory Board on the best scientific approach for developing water quality criteria for sediment. The later part of this section gives a brief summary of the approaches put forward to the Science Advisory Board for consideration.

5.6.1 Philosophy and approach

“Sediment” is specifically referred as “Suspended and Bedded Sediment” (SABS) under the EPA system. In addition to the commonly used terms of clean sediment, suspended sediment, total suspended solids, bedload, turbidity, SABS also include algal material, particulate leaf detritus and other organic material. USEPS recognized that managing SABS in the aquatic environment will have either direct or indirect consequences on the amount of contaminated sediments and may need to further examine these relationships in future.

While there may be several ways to develop SABS criteria for aquatic life protection, and each method has strengths and limitations, USEPA’s current thinking is that the best approaches should be based on a correlation of SABS with effects on biota or aquatic life sues.

The steps are considered useful when developing a method for setting SABS criteria :

- Decide the level of protection which could be set at 100%, 95% or the most sensitive or important biota;
- develop a conceptual model outlining the ecological processes effected by SABS for a particular water body;
- choose the ecological processes, species or groups of species, and beneficial uses deemed desirable for protection; and

- develop numerical targets for protecting the ecological processes, species or groups of species, and beneficial uses deemed desirable for protection based on the correlation between SABS and the biota.

Eight potential approaches are short-listed and they need to be evaluated before recommending for use by the States and Tribes to derive their own criteria. First five of the eight approaches listed below focus on aquatic life.

- toxicological dose-response approach;
- relative bed stability and sedimentation approach;
- conditional probability approach to establishing thresholds;
- state-by-state reference condition approach;
- fluvial geomorphic approach;
- water body use functional approach;
- successful new state approach;
- combinations of 1-7 or a synthesis of components of each.

These approaches are described in more detail in the draft copy of the consultation paper available for download from USEPA website http://www.epa.gov/waterscience/criteria/sediment/

With the advice of the Science Advisory Board, USEPA has planned to issue a strategy suggesting the best approaches, processes and schedules for EPA, states and tribes to pursue for developing and adopting SABS criteria.

6 WQC/WQS of Canada

6.1 PHILOSOPHY OF WQC/WQS APPLICATION

Canadian Environmental Quality Guidelines (EQGs) are defined as numerical concentrations or narrative statements that are recommended as levels that should result in negligible risk to biota and their functions, or any interactions that are integral to sustaining the health of ecosystems and the designated resource uses they support.

The EQGs are nationally endorsed and they are the science-based goals for the quality of the environments. Recognizing the need to protect components of the ecosystem in a more holistic manner, the Canadian government has improved the EQGs to address also the protection of other resources, including air quality, marine water quality, marine and freshwater sediment quality, tissue quality for the protection of wildlife consumers of aquatic life, and soil quality for agricultural, residential/parkland, commercial and industrial land uses. Within the context of this report, the following discussions will mainly focus on the marine water quality and sediment quality for protection of aquatic life.

The development and implementation of EQGs follow three guiding principles :

- EQCs embody a national goal for environmental quality of no observable adverse effects on atmospheric, aquatic, and terrestrial ecosystems over the long term;
- EQGs are developed for major atmospheric, terrestrial, and aquatic resources uses in Canada;
- EQGs are generic recommendations that are based on the most current scientific information, i.e. they do not directly consider site-specific or management factors that may influence their implementation.

The Canadian Council of Ministers of the Environment (CCME) has released a compendium of all the current EQGs together with the derivation protocols and guideline fact sheets in the "Canadian Environmental Quality Guidelines (1999)". A summary of the EQGs for water, soil, sediment and tissue media is available on the Environment Canada (EC) or the CCME website:

EC: http://www.ec.gc.ca/CEQG-RCQE/English/default.cfm

CCME: http://www.ccme.ca/publications/can_guidelines.html#top

Protocols for the derivation of the following guidelines could also be downloaded from the EC website :

- water quality guidelines for the protection of aquatic life;
- water quality guidelines for the protection of agricultural water uses (irrigation and livestock water);
- environmental and human health soil quality guidelines;
- site-specific quality remediation objectives for contaminated sites in Canada;
- sediment quality guidelines for the protection of aquatic life;
- tissue residue guidelines for the protection of wildlife that consume aquatic biota.

Under the Canada-wide Accord on Environmental Harmonization, the EQGs are released as the Canada-wide ambient standards for national environmental quality. Taking note of the variations in conditions across Canada, the provincial and territorial governments may use the EQGs directly in developing point-source licenses and permits for discharges or modify the national EQGs into environmental quality objectives (EQOs) following the derivation protocol provided and their own legal procedures.

6.2 WATER QUALITY GUIDELINES FOR PROTECTION OF AQUATIC LIFE

6.2.1 Philosophy and approach

The water quality guidelines (WQGs) provide basic scientific information about the effects of water quality variables on water uses. They are used to assess water quality issues and to establish water quality objectives for specific sites (Figure 6.2.1).

The derivation of the WQGs is guided by the following principles :

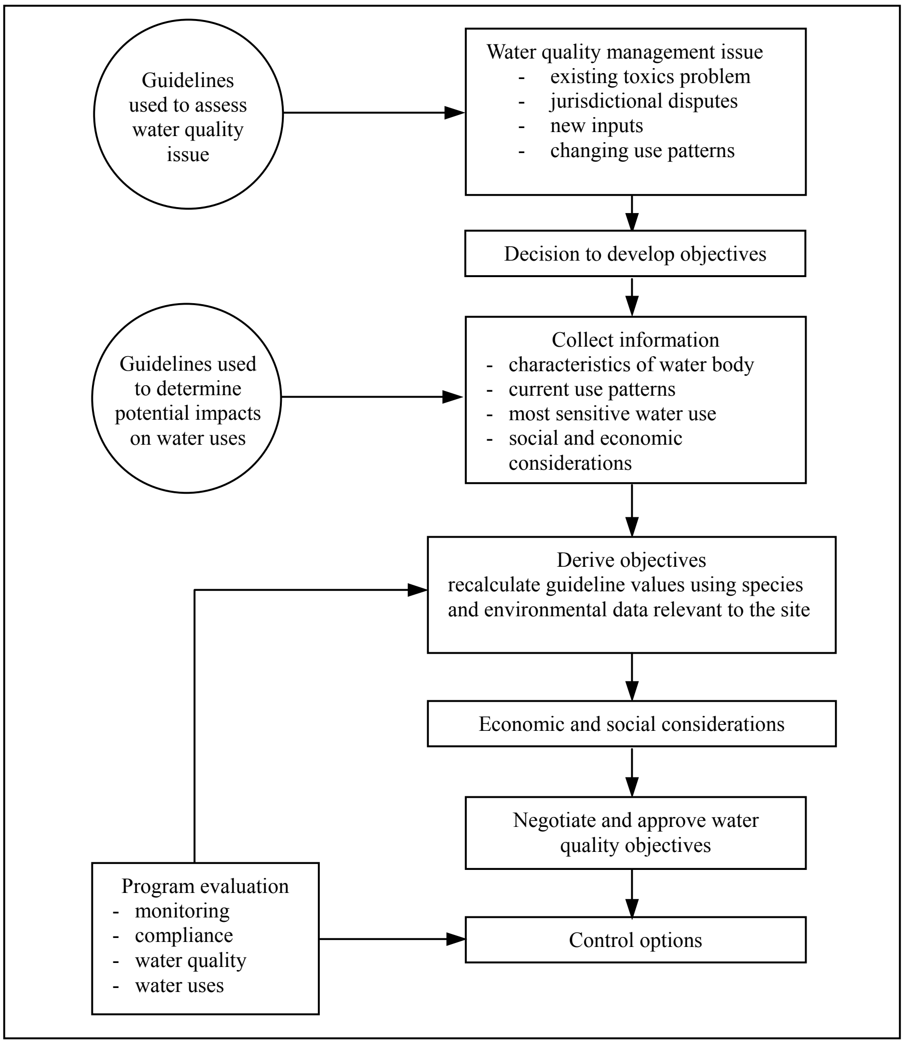
- all components of the aquatic ecosystem are considered if data are available. When data are limited, interim guidelines are derived. These guidelines will be modified when more data become available;

- the guidelines are set at such values as to protect all forms of aquatic life and all aspects of the aquatic life cycles, including the most sensitive life stage of the most sensitive species over the long term (i.e. provide protection of 100% of the aquatic life species in Canada at all times);

- derivation based on a long-term no-effect concentration;

- the guideline is numerically referred as the total concentration in an unfiltered sample unless it is demonstrated that (i) the relationship between variable fractions and their toxicity is firmly established, or (ii) analytical techniques have been developed that unequivocally identify the toxic fraction of a variable in a consistent manner using routine field-verified measurement.

Figure 6.2.1 The role of water quality guidelines and objectives in water quality management



6.2.2 Framework for developing and applying the WQC/WQS

The intended goal of the WQGs is to protect and maintain all forms of aquatic life and all aquatic life stages in the environment. Therefore, the derivation is based on toxicity data collected from fish, invertebrates and plants (Table 6.2.1). The data are then evaluated and classified into three categories, namely, primary, secondary and unacceptable (Table 6.2.2). All data included in the minimum dataset must be primary in order for full guideline derivation. Primary or secondary data may be used for interim guidelines derivation but unacceptable data could not be used.

Table 6.2.1 Aquatic life minimum dataset requirements

	Freshwater Life		**Marine Life**	
	Full Guidelines	**Interim Guidelines**	**Full Guidelines**	**Interim Guidelines**
Fish	≥ 3 studies on 3 or more freshwater species resident in North America • including ≥ 1 coldwater species and ≥ 1 warmwater species • including ≥ 2 chronic studies (partial or full life cycle)	≥ 2 acute and/or chronic studies on 2 or more freshwater species • including 1 coldwater species resident in North America.	≥ 3 studies on 3 or more temperate marine species [1] • including ≥ chronic studies (partial or full life cycle)	≥ 2 acute and/or chronic studies on 2 or more marine species. • including 1 temperate species
Invertebrates	≥ 2 chronic studies on 2 or more species from different classes • including 1 planktonic species resident in North America.	≥ 2 acute and/or chronic studies on 2 or more species from different classes • including 1 planktonic species resident in North America	≥ 2 chronic studies (partial or full life cycle) on 2 or more temperate marine species from different classes.	≥ 2 acute and/or chronic studies on 2 or more species from different classes • including 1 temperate species
Plants	≥ 1 study freshwater vascular plant or algal species resident in North America. • for highly phytotoxic variables, 4 acute and/or chronic studies on non-target freshwater plant or algal species.	• if data are available, use the toxicity study that indicates a plant species is the most sensitive species in the data set • if data are unavailable, further study is not mandatory but the data gap should be denoted in the derivation	≥ 1 study on temperate marine vascular plant or algal species	• if data are available, use the toxicity study that indicates a plant species is the most sensitive species in the data set • if data are unavailable, further study is not mandatory but the data gap should be denoted in the derivation
Data type	primary data	primary or secondary data	primary data	primary or secondary data

[A] Marine species include those found in estuarine, coastal, and open ocean habitats, any of which may be used to derive full guideline or an interim guideline.

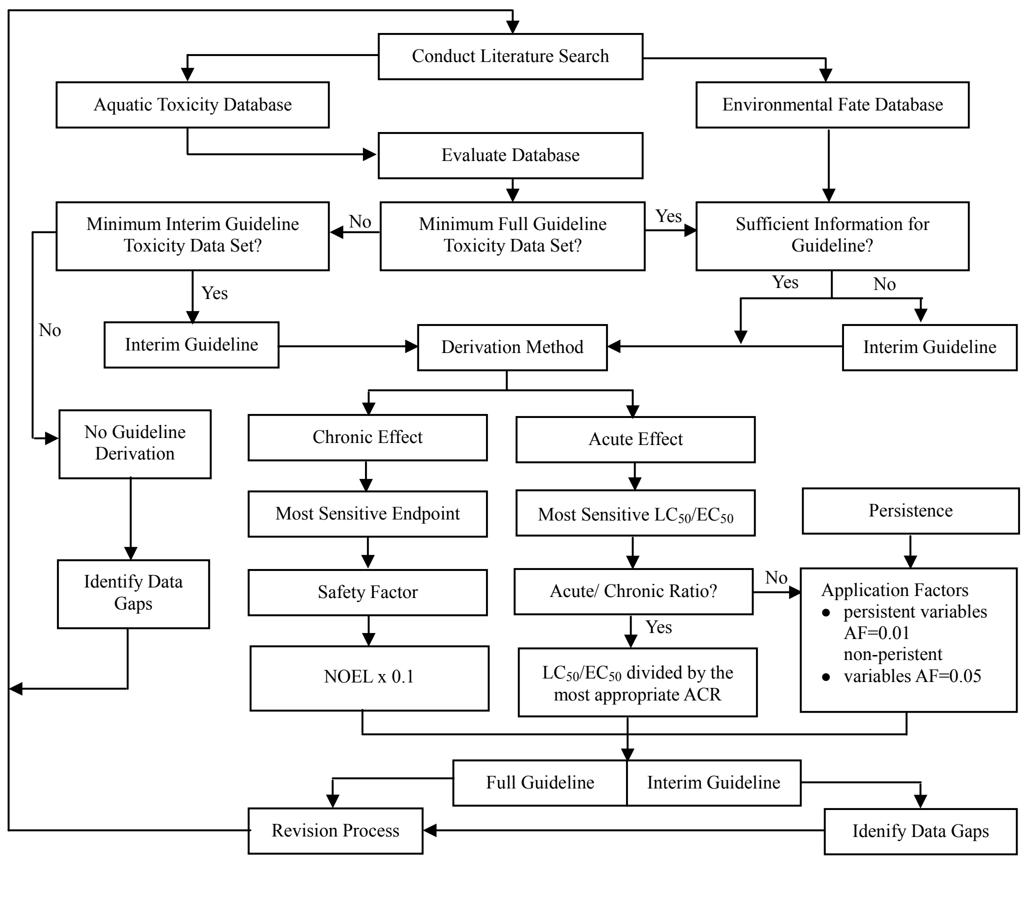
Table 6.2.2 Classification of toxicity data

Primary	Secondary	Unacceptable
● Toxicity tests must employ currently acceptable laboratory practices of exposure and environmental controls. Other types of tests using more novel approaches will be evaluated on a case-by case basis. ● As a minimum requirement, variable concentrations must be measured at the beginning and the end of the exposure period. Calculated concentrations or measurements taken in stock solutions are unacceptable. ● Generally, static tests are unacceptable unless it can be shown that variable concentrations did not change during the test and that adequate environmental conditions for the test species were maintained. ● Preferred endpoints from a partial or full life-cycle test include a determination of effects on embryonic development, hatching, or germination success, survival of juvenile stages, growth, reproduction and survival of adults. ● Responses and survival of controls must be measured and should be appropriate for the life stage of the test species used. ● Measurements of abiotic variables such as temperature, pH, dissolved oxygen and water hardness should be reported so that factors that may affect toxicity can be included in the evaluation process.	● Toxicity tests may employ a wide array of methodologies (e.g. measuring toxicity while test species is exposed to additional stresses such as low temperature, lack of food, or high salinity). ● Static tests are acceptable. ● Preferred test endpoints include those listed for primary data as well as pathological, behavioral, and physiological effects. ● Calculated variable concentrations are acceptable. ● All relevant environmental variables should be measured and reported. The survival of controls must be measured and reported.	● Toxicity data that do not meet the criteria of primary or secondary data are not acceptable.

A protocol is provided to guide the derivation process (Figure 6.2.2) which is applicable for both freshwater and marine life guidelines. The final guideline concentration is arrived at by following either one of the following methods :

(i) multiplying the most sensitive lowest-observable effects level (LOEL) from a chronic exposures study on a native Canadian species by a safety factor of 0.1;
(ii) multiplying the most sensitive EC_{50} or EC_{50} from an acute exposure study by an acute/chronic ratio (ACR) or an application factor. When an ACR is not available, universal application factors (AF) are used, i.e. 0.05 for non-persistent variables and 0.01 for persistent variables.

Figure 6.2.2 The protocol of deriving water quality guidelines for the protection of aquatic life



*non-persistent variables are defined as variables having $t_{1/2}$ in water < 8 weeks

6.2.3 Determining site-specific water quality objectives

Many of the national WQGs will be modified, when used to formulate water quality objectives, to account for site-specific variations in conditions. The CCME recognizes the importance of providing most up-to-date scientific information and guidance on implementing national EQGs to provinces. For this reason, the CCME Task Force is revising the guidance paper titled "Scientific and Technical Guidance on Canadian Water Quality Guideline Implementation" found in Appendix IV of the CCREM (1987). The appendix presents a discussion on the factors affecting the application of the guidelines. The factors include :

- the general characteristics of lakes, rivers and groundwater;
- the effect of local environmental conditions on water quality;
- processes affecting the concentration of parameters in water;
- factors that modify toxicity to aquatic organisms.

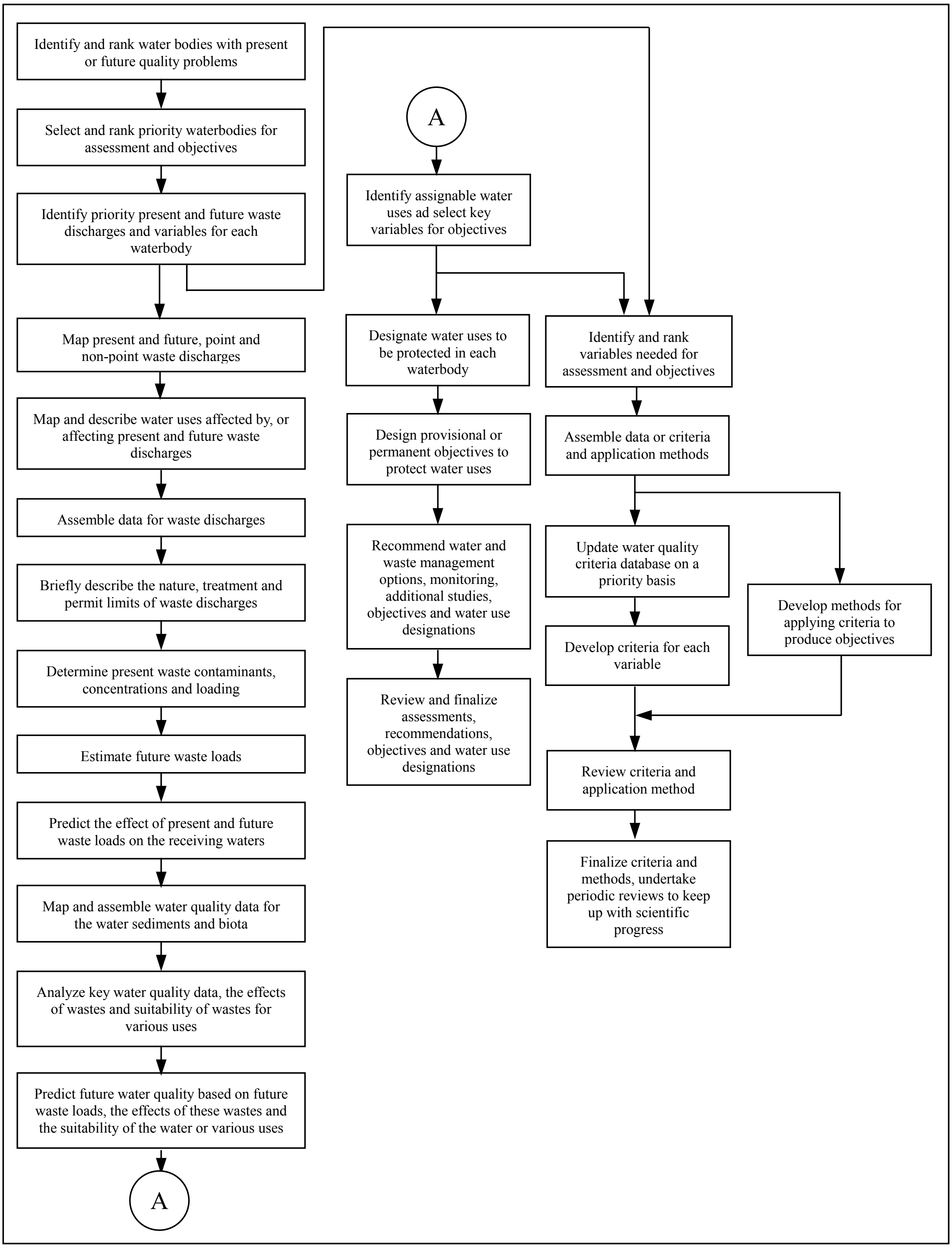
The development of water quality guidelines in each Canadian province is fielded by the local jurisdiction according to their own environmental protection laws and administration procedures. Whilst there are similarities in the WQGs derivation by following the CCME protocol to derive their own WQGs, there are also many differences in the philosophy and application. Given the limitation in locating relevant information, this report only presents a brief review on the development system of the four regions, i.e. British Columbia and Yukon, Alberta, and Manitoba.

<u>British Columbia and Yukon</u>

British Columbia and Yukon (BCY) prepares objectives for water bodies and for water quality characteristics that may be affected by man's activity. Due to the geographical location of the two regions, water types under concern include freshwater and marine water. The process for water quality assessment, and development of criteria and objectives is illustrated in Figure 6.2.3. BCY mainly uses the use-protection strategy in the water quality management, following two principles for WQOs establishment:

- the antidegradation principle for water bodies with aquatic resources of national or regional significance;
- WQOs are to protect the designated uses of the aquatic ecosystem.

Figure 6.2.3 Framework of the development of water quality objectives in British Columbia and Yukon



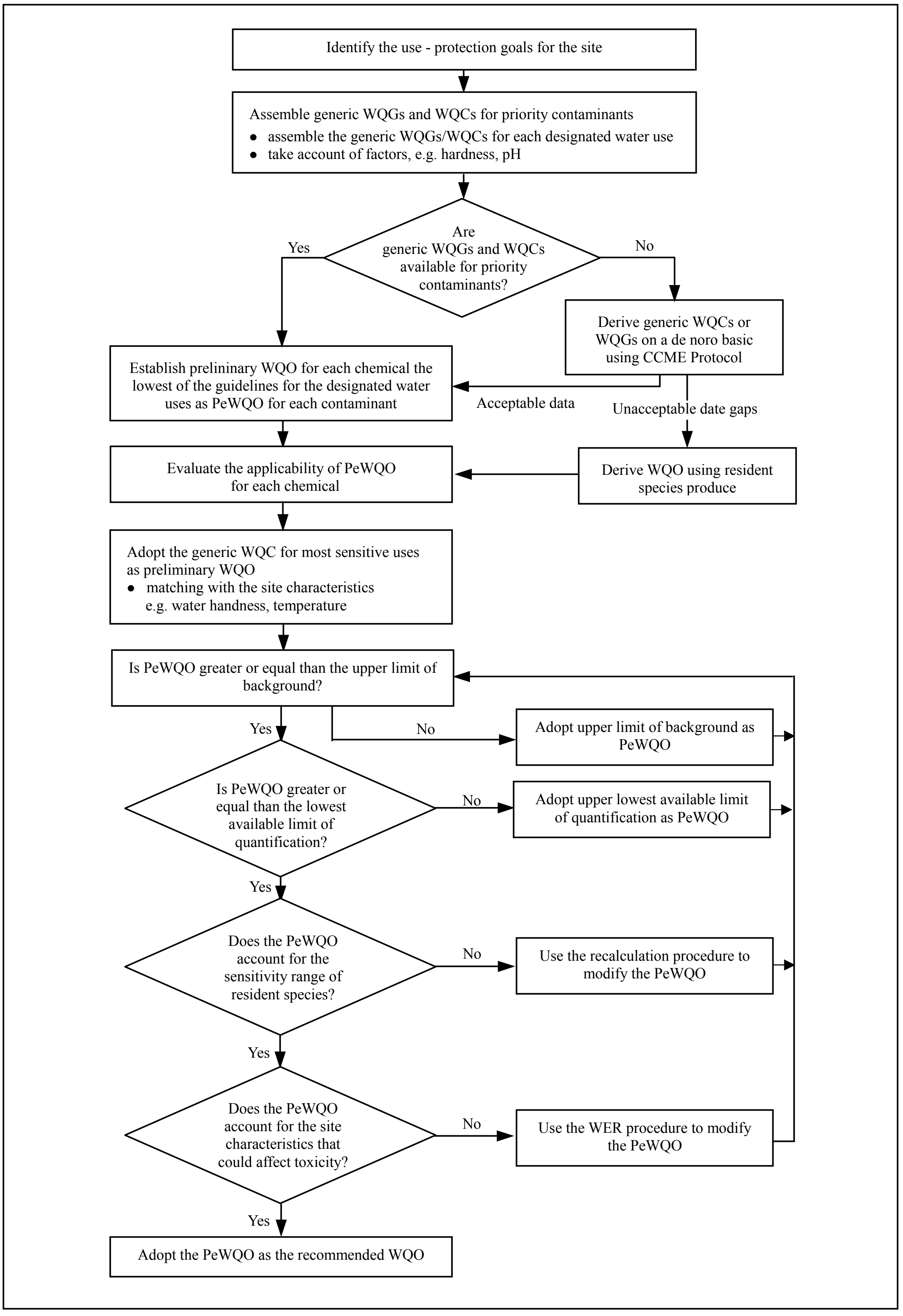
Derivation of numerical WQOs (Figure 6.2.4) could follow either one of the three toxicity-based approaches, which are :

- direct adoption of generic WQGs that have been developed by BCMOELP (British Columbia Ministry of Environment, Lands and Parks, now called Ministry of Water, Land and Air Protection) or the CCME;
- modification of generic WQG to site-specific guidelines when site characteristics have influences on the contaminants' toxicity (e.g. using the recalculation or water effect ratio procedures);
- development of *de novo* WQOs when there is no generic WQGs are available (e.g. using the resident species procedure).

The generic WQGs are developed to be broadly applicable to surface water and groundwater systems in Canada while the provincial WQGs developed by BCMOELP followed similar procedures and are intended to be broadly applicable in British Columbia. Direct adoption of generic WQOs is simple but a crucial step is included to evaluate the applicability of the generic values in the region. The evaluation includes at least four factors and they are:

- the background levels of the contaminant;
- the limit of quantification (i.e. analytical detection limit) for the substance;
- the applicability to the site under consideration of the toxicological information that was used to derive the generic WQGs;
- the processes and levels of substances that could affect the bioavailability of the contaminant.

Figure 6.2.4 Schematic diagram showing the process for deriving numerical water quality objectives in British Columbia and Yukon



Similar to the USA system, recalculation procedure, water effect ratio procedure and resident species procedure are used to modify the provincial WQGs to suit the site-specific conditions. Some specific guidelines are given to help local jurisdictions modify the preliminary WQO. For example, in cases where the ambient background ambient level of a certain metal is higher than the criterion value, the BCMOLP considers that a change of less than 20% going from upstream to downstream should exhibit no harmful effect. The rationale behind is that the precision for measure of low concentration metals in replicates is not usually better than 20% in ideal situation in a laboratory and the natural variability is often greater than 20%. Safety factors used in deriving provincial WQGs from acute toxicity data are slightly different from the recommendations of CCME, i.e. a factor of 0.1 to 0.05 with non-persistent or noncumulative toxicants; a factor of 0.05 to 0.01 with persistent or cumulative toxicants. However, the application of such safety factors is a short-cut method only and chronic data should be used as far as possible.

The protocol for deriving site-specific WQO, a compendium of WQGs for use in the BCY and other water quality relation information can be found at the web site of the ministry of Water, Land, Air Protection, British Columbia

http://wlapwww.gov.bc.ca/wat/wq/

Alberta

The general philosophy of CCME generic WQGs for freshwater aquatic life is to protect all components of the aquatic environment. In recognition of the practical limitation to determine the effects on all forms of aquatic life and all aspects of aquatic life cycles for each guidelines, the Alberta approach which essentially follows the USEPA 1985 method, uses the extrapolation method to derive a guideline value that provides a high level of protection. Several adjustments to the CCME protocol were made:

- the calculation of a final residue value is omitted in the Alberta protocol. It is considered that the protection to consumers of aquatic life from dietary exposure of contaminated aquatic biota might be provided by the CCME tissue residue guideline. The CCME protocol is now under reviewed and the best approach for Alberta would be determined later;

- marine and estuarine toxicological information is not used in Alberta protocol as there is a lack of this water type in the region;

- based on expert judgment, alternation in the taxonomic representation required for guideline derivation is allowed. However, the requirement of eight different families has to be met.

The format of Alberta's full WQGs largely follows that of the USEPA, i.e. they comprise two values, namely, the acute and chronic. The main differences of the CCME and USEPA/Alberta approach are summarized in Table 6.2.3

Table 6.2.3 Comparison of the CCME and USEPA/Alberta approach in deriving full water quality guidelines for the protection of aquatic life

	Alberta Approach	CCME Approach
Data Quality	Primary	Primary
Data Quantity	Acute guideline : 8 acute values from 8 different families	—
	Chronic guideline : 1 plant species, and either 8 chronic values from 8 different families, or data for acute guideline with 3 ACR values (fish, invertebrate, sensitive species)	Chronic guideline : 3 values (2 chronic) from 3 different fish species, 2 chronic invertebrate values from different classes, 1 plant species
Uncertainty Factor	Implicit (statistical approach)	Explicit
Derivation Guideline	Statistical approach using all data & expert judgment	Lowest value multiplied by uncertainty factor
Full Guideline	Acute and Chronic	Chronic

Information source : Protocol to develop Alberta Water Quality Guidelines for Protection of Freshwater Aquatic Life

When information is insufficient to derive full Alberta guidelines, other procedures are used to develop interim guidelines. These procedures basically follow the CCME protocol (1991) with some alternations and the highlights are summarized below :

- the minimum data requirement is the same as that for an interim CCME guideline (chronic value);
- use of secondary data from flow-through tests is allowed;
- results from static tests, in which concentrations were measured and did not change significantly, may be used;
- results from static tests with nominal concentration cannot be used;
- three options are available to derive an acute WQG :

- multiply the interim chronic guideline with a measured acute-to-chronic ratio to calculate an interim FAV value, and divide this value by 2 for an interim acute guideline;
- multiply the interim chronic guideline with a default ACR value of 10, which represents the upper 90th percentile of ACR data, and divide this value by 2 for an interim acute guideline;
- use published acute guidelines from other jurisdictions.

Similarly, the procedures to modify the provincial guidelines to cater for site-specific conditions generally follow USEPA approach, i.e. recalculation procedure and water effect ratio procedure. However, the procedures can only be used when either full Alberta guidelines or USEPA acute or chromic guidelines are available.

Document compiling surface water quality guidelines for use in Alberta and information providing a more comprehensive understanding of the purpose, context and derivation of the respective guidelines could be found at the web site of the Government of Alberta :

http://www3.gov.ab.ca/env/protenf/publications/SurfWtrQual-Nov99.pdf

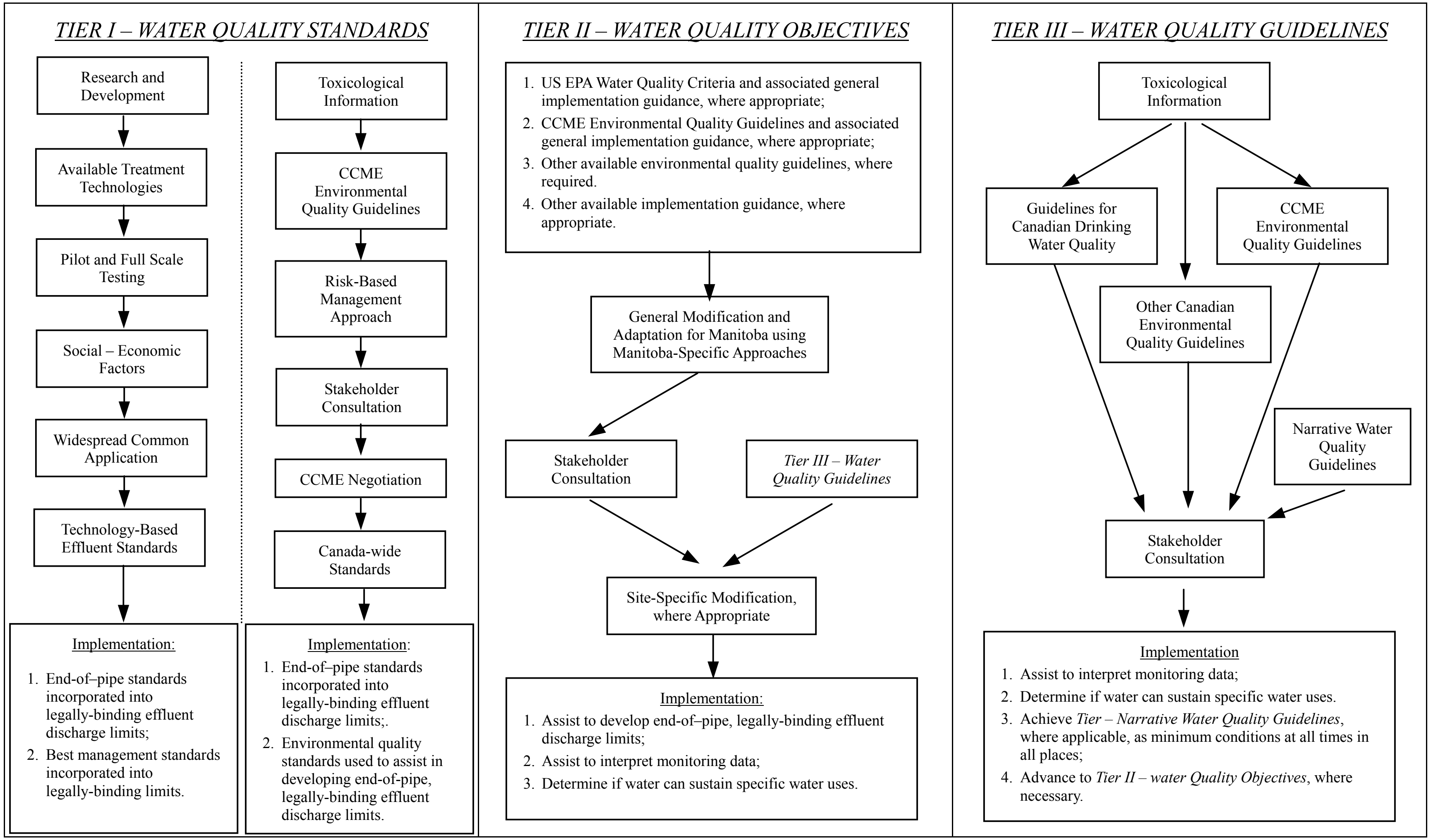
Manitoba

The Manitoba's approach to develop provincial WQGs is mainly a direct adoption of the guidelines from other jurisdictions. The adopted guidelines are first thoroughly evaluated for their applicability to Manitoba and sometimes modified to better suit the unique conditions within the province. Manitoba is undertaking a review on the provincial water quality objectives. It is now at the final stage of consolidating comments from the initial two phases of public consultation. Once the document is finalized, it will supersede the previous 1988 and 1990 publications. A draft of the proposed revisions to the WQGs and an associated Excel spreadsheet to assist with the calculations required for a number of water quality objectives can be downloaded at :

http://www.gov.mb.ca/conservation/watres/mwqsog_2002.pdf
http://www.gov.mb.ca/conservation/watres/mwqsog_2002_calculations.xls

A three-tiered system is proposed to consolidate and harmonize Manitoba's use of standards, objectives and guidelines (Figure 6.2.5).

Figure 6.2.5 General derivation and intended application of the three-tiered system of Manitoba's water quality standards, objectives and guidelines.



Tier I – Water Quality Standards contain technology based standards for common classes of discharges Canada-wide standards developed by CCME.

Tier II – Water Quality Objectives contain objectives for a short list of materials that are common pollutants in Manitoba. These objectives were adopted from the USEPA. They are used directly to assist in developing discharge limitations.

Tier III – Water Quality Guidelines are derived by CCME. They are used to assist in interpreting ambient water quality monitoring data to identify emergency or potential water quality problems.

6.3 SEDIMENT QUALITY

6.3.1 Philosophy and approach

The derivation of the sediment quality guidelines (SQGs) is guided by the following principles :

- the SQGs are intended for protection of all forms of aquatic life and all aspects of their aquatic life cycles during an indefinite period of exposure to substances associated with bed sediments;
- all components of the aquatic ecosystem should be considered, and if data are available, evaluation should focus on ecologically relevant species;
- interim SQGs (ISQGs) are derived when data are available but limited;
- SQGs usually refer to the total concentration of the substance in surficial sediments (i.e. top 5 cm) on a dry weight basis;
- SQGs will be refined as new and relevant scientific data become available.

The derivation is based on toxicological information from field-collected sediments, which is deemed to have accounted for factors that influence the bioavailability of sediment-associated chemicals. The information has been collected from numerous geographic locations throughout North America and the data have been generated using many different species and biological end points. The collected data are entered into tables, collectively known as the Biological Effects Database for Sediments (BEDS). BEDS will be updated periodically as new information becomes available. Therefore, SOGs thus derived are applicable to all classes of chemical and mixtures of chemicals that are likely to occur in Canadian sediments. Derivation approaches used primarily are the National Status and Trends Program (NSTP) approach and the Spiked-sediment Toxicity Test (SSTT) approach.

A formal protocol has been established by the CCME to derive SQGs which relies on both a modification of the NSTP approach and the SSTT approach. The protocol is applicable to the protection of both freshwater and marine (including estuarine) aquatic life associated with bed sediments. When the minimum data set requirements are met for the NSTP approach, ISQGs are derived using weight of evidence of available toxicological information. The ISQGs will be modified to full SQGs when information on specific sediment type or the overlaying water column characteristics are known. Alternatively, SQGs can be developed using the SSTT approach when methodological concerns have been resolved and a formal protocol is established.

Currently, the SSTT data are limited and so only ISQGs can be developed. When more information becomes available, some of these data gaps could be filled and support the derivation using the SSTT approach. To date, ISQGs are recommended for 31 chemicals or substances. Though interim in nature, these guidelines are applied as if there were full SQGs.

6.3.2 Framework for developing and applying the SQGs

The process for developing Canadian SQGs follows the general framework that has been established for the derivation of water quality guidelines. Figure 6.3.1 shows the schematic diagram of the derivation process. The process starts off by collation of toxicological information and evaluation of the information for its overall acceptability to ensure that high quality data are used. Table 6.3.1 shows the dataset requirements of the NSTP and the SSTT approach.

Under the NSTP approach, for each sediment-associated chemical, the acceptable data are sorted according to ascending chemical concentrations, and then sub-sorted according to test endpoint and trend analysis, i.e. effect, no effect, no gradient, small gradient and no concordance. A functional threshold effect level (TEL) is calculated for each chemical as the geometric mean of the 15^{th} percentile concentration of the effect data set (the E_{15}) and the 50^{th} percentile concentration of the no-effect data set (NE_{50}). The TEL sets the upper limit of the range of sediment chemical concentrations within which chemicals are not considered to represent significant hazards to aquatic organisms.

A probable effect level (PEL) is calculated for each chemical as the geometric mean of the 50^{th} percentile concentration of the effect data set (the E_{50}) and the 85^{th} percentile concentration of the no-effect data set (NE_{85}). The PEL represents the lower limit of the range of chemical concentrations that is usually or always associated with adverse biological effects. Figure 6.3.2 illustrates the effect ranges for a sediment-associated chemical.

The primarily basis for this approach is that the potential for toxicity increases with increasing concentrations. Given the extremely wide spectrum of toxicity data, functional levels, i.e. TEL and PEL, are determined to assign ranges of chemical concentrations that are either dominated by no-effect data or probable effect data. The 15^{th}, 50^{th} and 85^{th} percentiles are arbitrarily set to achieve consistency in the derivation while the geometric mean is used to account for the uncertainty in the distribution of the data sets. The definition of the TEL is consistent with the definition of a Canadian sediment quality guideline, i.e. "numerical limits or narrative statements recommended to support and maintain designated uses of the aquatic environment". The PEL is recommended as an additional sediment quality assessment tool that can be useful in identifying sediments in which adverse biological effects are more likely to occur.

The SSTT approach involves an independent evaluation of information from spiked-sediment toxicity tests for estimating the concentration of a chemical below which adverse effects are not expected to occur. In this approach, an SSTT value is derived using data from controlled laboratory tests in which organisms are exposed to sediment spiked with known concentrations of a chemical of specific mixture of chemicals. Such studies provide quantifiable cause-and-effect relationships between the concentration of a chemical in sediments and the observed biological response. The SSTT approach is complementary to the derivation process to confirm and strengthen guidelines developed using the NSTP approach. When sufficient information is available to define the relation of the factor to the toxicity of a specific substance, full guidelines can be developed to reflect this.

Figure 6.3.1 Derivation of Canadian sediment quality guidelines

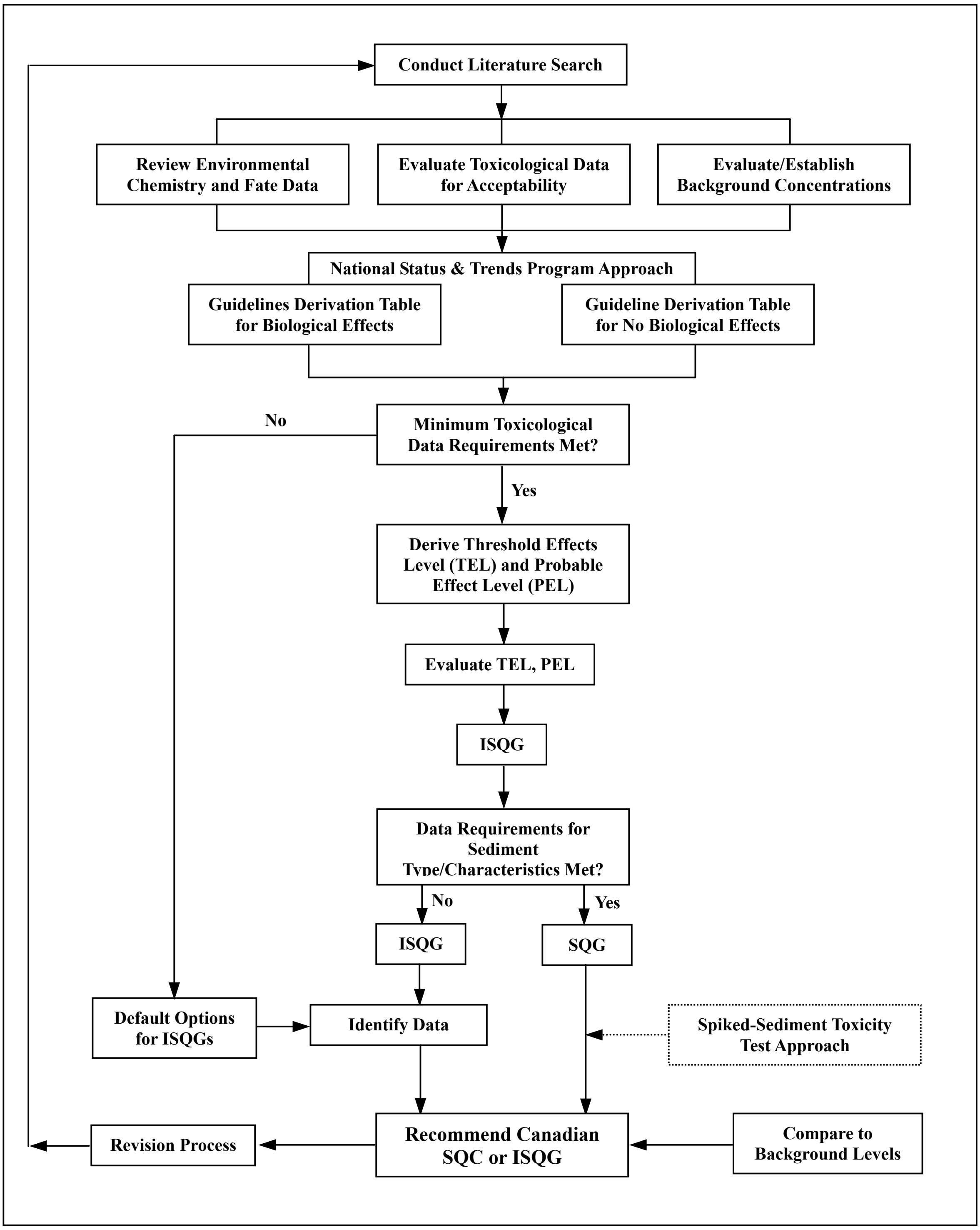
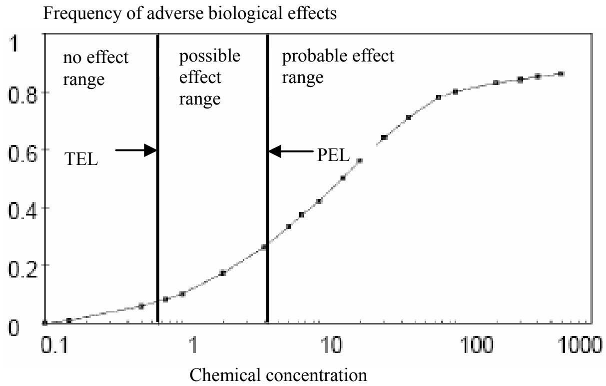


Table 6.3.1 Minimum toxicological data set requirements for sediment quality guidelines

Sediment Quality Guidelines	Requirements
Interim SQGs **(using the NSTP approach)**	● The effect data set for the chemical under consideration must contain at least 20 entries in the guideline derivation table prepared from Biological Effects Database for Sediments (BEDS). ● The no-effect data set for the chemical under consideration must contain at least 20 entries in the guideline derivation table prepared from BEDS.
Full Marine SQGs **(STTT approach)**	● At least 4 studies are required on 2 or more sediment-resident invertebrate species that occur in North America waters. At least 1 of these must be a benthic amphipod species. ● At least 2 of these studies must be partial or full life-cycle tests that consider ecologically relevant end points (e.g. growth, reproduction, developmental effects).
Full Freshwater SQGs **(SSTT approach)**	● At least 4 studies are required on 2 or more sediment-resident invertebrate species that occur in North America waters. These must include at least 1 benthic crustacean species and 1 benthic arthropod species (other than a crustacean). ● At least 2 of these studies must be partial or full life-cycle tests that consider ecologically relevant end points (e.g. growth, reproduction, developmental effects).

Figure 6.3.2 A conceptual example of effect ranges for a sediment-associated chemical



If information exists to support both the modified NSTP and the SSTT approaches, generally, the lower of the two values so derived using either approach is recommended as the Canadian SQGs. Environment Canada and other agencies are providing guidance on determining an acceptable protocol for conducting SSTTs.

The information of naturally occurred chemicals is very important during the SOGs implementation. When it is found that the measured concentrations are higher than the SOGs, background concentrations may serve to determine the extent to which human activities have contributed to the concentrations of chemicals at a site. Referring to background concentrations is particularly important for metals and certain organic substances that may be enriched through natural process. The ratio of metal concentrations to those of a reference site provides an effective means to distinguish the origin of chemicals. Because such ratios are relatively constant in the earth's crust, they can be used to interpret the degree of anthropogenic enrichment. Lithium is commonly used in eastern Canada.

6.3.3 Determining site-specific sediment quality objectives

SQGs are developed with the intention to be conservative since they are to be used on a national basis. For implementation of the SQGs at local jurisdiction level, the SQGs and the sediment toxicity information provide a basis for the establishment of sediment quality objectives (SQOs). The objectives are to be applied directly to a particular site taking into consideration chemical, physical and biological characteristics of that site. The objectives are intended to provide the same level of protection as the SQGs but taken into account such site-specific characteristics. A document is currently under development to provide interpretive guidance on the use of national SQGs.

Three methods are available for determining SQGs in local jurisdictions: (i) deriving numerical values following the CCME protocol, (ii) adopting CCME national SQGs with modification to suit local conditions, if necessary, and (iii) adopting sediment quality assessment values from other jurisdictions.

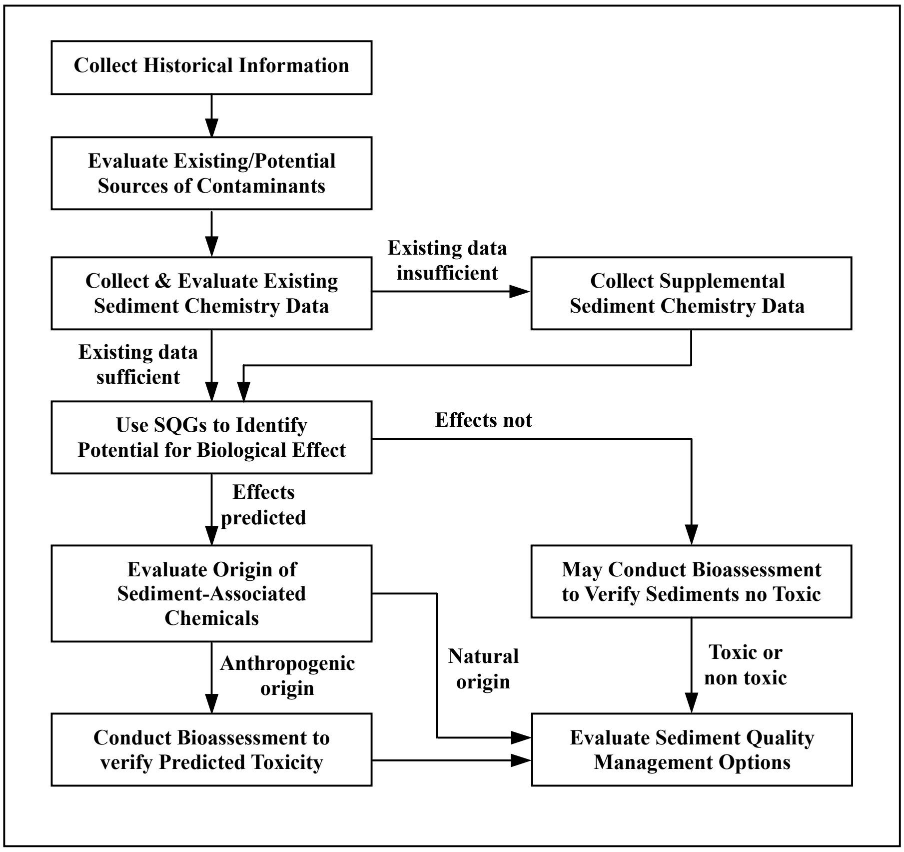
On (i) and (ii), the process depicted in Figure 6.3.1 will be followed. On (iii), sediment quality assessment values from other jurisdictions could only be adopted as ISQGs and subject to critical evaluation of their applicability to Canadian conditions and CCME guiding principles. A three-tiered system is available to give preference to biological-effect based values. The rationale for this system is that the biological effects of sediment-associated chemicals are thought to be most ecologically relevant and scientifically defensible. Guidelines derived by using the partitioning methods are based only indirectly on biological effect and so further data should be gathered to develop the full SQGs using the formal protocol. The steps in the tiered system are:

(i) select the lowest of the guidelines that incorporates data on effects of sediment-associated chemicals on sediment-dwelling organisms;

(ii) for organic contaminants, select the lower value obtained using the equilibrium partitioning and the water quality guideline approaches if no effect-based guidelines are available;

(iii) with respect to site-specific sediment quality objectives, select the upper background limit of a trace element if an interim guideline cannot be developed using tire (i) or (ii) above or if it is below the upper background concentration for trace elements.

Figure 6.3.3 A framework for the assessment of sediment quality



SQGs can be used for evaluating sediment chemical information to identify situations that may be harmful to aquatic organisms associated with bed sediments. They can also be used to help set targets for sediment quality which will sustain aquatic ecosystem health for the long term. Along with the information obtained through a sediment quality assessment, management options are evaluated against the SQOs. Figure 6.3.3 above shows the conceptual framework for conducting sediment quality assessment.

7 Conclusion

Irrespective of the different terminologies used, i.e. water quality criteria, standards, objectives or guidelines, WQC/WQS are the basis of water quality protection programs. Derivation and implementation of these WQC/WQS are increasingly complex, meeting the demand for incorporating changes in public preferences for water quality and resource management, and new scientific and technological advancements.

Each of the reviewed economies sees the vital need to preserve the aquatic environment to meet sustainable use and, as far as possible, to restore the impaired water bodies to an acceptable level of quality. Notwithstanding the various instruments and approaches used, they are functionally similar for the purposes of protecting the water resources.

Derivation of WQC/WQS relies heavily on scientific information on the physical-chemical reaction of the substances of concern in the aquatic environment, and on improved methodologies that address important toxicological endpoints and exposure routes. It can be seen that the economies have rendered much effort in building up a scientific foundation via research work, information sharing and strengthened rapport between policy-makers and academics. Often as a result of a strategy to achieve national consistency and foster broad participation in the setting of WQC/WQS, information papers and guidance documents are placed on the world-wide-web for easy access, which has also helped capacity building among other economies.

Stakeholder involvement, including the broader community, has become an integral part of the process of designation of WQC/WQS in recognition of the value added to the environmental decision-making. The most tangible benefit of adequate and appropriate stakeholder involvement is that informed policy decisions are more likely to avoid constant review and revision. Projects that are understood and accepted by the community are less likely to face pressure for their revision or removal. Among the reviewed economies, stakeholders are involved in various ways and at different levels, depending on the interest and expertise of the stakeholders and the mechanisms available for their involvement. Stakeholders could be engaged in advisory committee in the early stage of formulating WQC/WQS based on scientific information whilst community members could be involved in public consultation where they can voice out their preference towards the environment. Through stakeholder involvement, the elicitation of WQC/WQS are based on a social process of deliberation which modifies the technically derived WQC/WQS into management goals by taking into account other factors such as social, cultural, economic or political constraints.

Dissolved oxygen and nutrients have been selected for in-depth review on the rationale for their designation as WQC/WQS and derivation of the numerical values. The next step of this project, i.e. the third phase, is to compile the relevant information in accordance to the advice given in the return of the third questionnaire. The 14 economies that are covered in this project will be contacted again to ask for comments on this report and recommendations for the forthcoming work pertaining to the completion of this project.

NEW PROJECT PROPOSAL

Name of Committee / Working Group:

Marine Resource Conservation Working Group (MRC WG)

Title of Project:

Water quality criteria or standards adopted in the Asia Pacific region

Proposing APEC Member:

Hong Kong, China

Project Overseer:

Dr. Malcolm Broom

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Water Policy and Planning Group
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Financial Information:

TOTAL COST (US$): Undetermined

Amount being sought from APEC Central Fund

No fund will be sought from the APEC Central Fund for executing the project.

Proposed Project Start Date: 7/2002 – 6/2003

Project Purpose:

The objectives of the project are to collect and compile the water quality criteria (WQC) or standards (WQS) adopted in the APEC economies, and identify the ways these WQC/WQS are derived.

Amongst the APEC economies, most members have established their own WQC/WQS for the protection of aquatic resources and uses. The values of these criteria or standards may vary among different economies because of the need to protect different resources or beneficial uses or because of the different ways these criteria or standards are derived. However, information on these WQC/WQS and the ways they are derived is usually not readily available or accessible.

The APEC economies are united by the oceans and seas. The health of the marine environment is therefore critical to their continuing economic well-being and sustainable development. To enhance cooperation and collaborative effort amongst the member economies to achieve sustainability of the marine environment in the region, it would be beneficial to have accessible information on the WQC/WQS adopted in individual member economies.

The APEC's Strategy to Address Sustainability of the Marine Environment has identified three key objectives, namely, (a) integrated approaches to coastal management; (b) prevention, reduction and control of marine pollution; and (c) sustainable management of marine resources. To achieve these objectives, the Strategy also identifies three central tools: (a) research, exchange of information, technology and expertise; (b) prevention, reduction and control of marine pollution; and (c) sustainable management of marine resources. The proposed project, which is conducted through the identified tools, will help achieve the objectives of the Sustainability of the Marine Environment in the APEC region. Specifically, it will facilitate the attainment of an integrated approach to coastal management by use of the tool of research, exchange of information, technology and expertise. By establishing the water quality requirements needed to protect specific resources or uses, and by identifying the underlying rationales for the setting of those requirements in different economies, the project will provide coastal zone managers with a better information base for making water quality management decision.

A questionnaire-based survey will be carried out to collect the information from the member economies. Information required will be of technical nature and relating to the values of the WQC/WQS and the approach and scientific rationales for deriving these values. Follow-up with individual economies may be needed for clarification purposes or for additional information. The collected data will be assimilated and compiled. Findings will be presented in the format of report with tables summarizing the WQC/WQS used in different member economies.

Hong Kong, China will be responsible for implementing the project, from preparation of questionnaire, through compilation of collected data, to preparation of a report. Findings, in electronic format, will be given to APEC for placing on the APEC Website to facilitate public access.

Strategic Objective:

The objectives of the project are to collect and compile the WQC/WQS adopted in the APEC economies and identify the ways they are derived. The findings of the project will provide the APEC economies with a better understanding of the WQC/WQS adopted in other member economies and thus enhance better cooperation and collaborative work in the region. This will better allow member economies the opportunity to develop clear water quality targets aimed at protecting specific marine resource functions, in circumstances which allow those targets to be tailored to the particular needs of individual economies.

Specific Objectives:

- collect information from member economies concerning the WQC/WQS and how they are derived;

- review the collected information particularly the approach / methodology and the scientific rationales for deriving the WQC/WQS;

- summarize and compare the WQC/WQS adopted in different member economies and outline the approach and rationales for their derivation.

Suggested Review Outcomes:

- identify the WQC/WQS adopted in the member economies for the protection of the aquatic resources and uses;

- identify the approach / methodology and the scientific rationales for deriving the WQC/WQS in the member economies;

- summarize the review findings in the form of report.

Linkages:

The proposed project is to collect information on the WQC/WQS adopted in the APEC economies. A questionnaire-based survey will be conducted to collect the required information and individual member economies will be approached. Support from the APEC economies is essential for completion of this project. Since the required information will be of technical nature, it is suggested that a contact point be identified in each member economies to facilitate the collection of information and liaison.

Dissemination of Project Output:

The project output will be documented in the form of a report in paper format. Copies of the report will be disseminated to all APEC economies for their reference.

The report, in electronic format, will be given to APEC for placing on the APEC Website to facilitate access to the findings by the public and private/business sector.

Meeting APEC Project Criteria:

This proposal has been prepared in accordance with APEC Guidelines.

______________________________ **Malcolm Broom**

Signature of Project Overseer

Date: 17/6/02

____

Signature of Committee / WG Lead Shepherd

Date: 18/6/02

APEC Marine Resources Conservation Working Group (MRC WG) Project (Phase 2)
Water quality criteria adopted in the Asia Pacific region

3rd Questionnaire on Water Quality Criteria

APEC Member : **«Economy»**
Contact person / Organization : ____

Part A : Introduction

Thank you for providing information for our completion of phase 1 of the project. With your assistance given, the findings are summarized in a report attached with this questionnaire for your reference and comment. In phase 2, we will concentrate our effort on reviewing the derivation and application of WQC/WQS/WQO. Two parameters, i.e. dissolved oxygen and nutrients, have been selected for in-depth review for their association with harmful algal bloom. This questionnaire focuses on the identification of specific information pertinent to the designation of the two parameters as WQC/WQS/WQO for the protection of aquatic life and the derivation methods. I should be grateful if you could help by filling in this questionnaire.

Part B: Information relating to WQC/WQS/WQO

Comments on the Phase 1 Report

Q1. The Phase 1 Report gives a summary of findings and an overview of the WQC/WQS/ WQO systems of different economies. The report briefly describes the situations in your economy in the following page(s). Would you please give your comments on the report and clarify any misinterpretation of the facts found.

Concerned pages : «Page_no»

Our comment(s) is/are : *(please use separate sheet if necessary)*

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Updates of the WQC/WQS/WQO values

Q2. We have compiled a database of WQC/WQS/WQO based on your return to the last two questionnaires. There may be new releases of WQC/WQS/WQO since our last information request in December 2002. Are you able to provide us with the new information, if any?

- ☐ Yes, new values of WQC/WQS/WQO for the following parameters are released/updated.

  ____

- ☐ Please visit our following website for the required information.

  ____

- ☐ The most recent set of WQC/WQS/WQO values is attached.
- ☐ No new release.
- ☐ Others (please specify) ______________________________

Derivation of the WQC/WQS/WQO for Dissolved Oxygen

Q3. ***(For those economies that have designated WQC/WQS/WQO for dissolved oxygen for the protection of aquatic life)***

What is the basis or rationale for including dissolved oxygen in the list of the WQC/WQS/WQO? (please ✓ the appropriate box below, more than one choice is allowed)

- ☐ It is the critical parameter affecting the uses or resources of the local aquatic environment.
- ☐ It is a parameter of international concern.
- ☐ It is a parameter of local concern.
- ☐ Others (please specify) ______________________________

Q4. (***For those economies that have made reference to other's WQC/WQS/WQO)***

You have mentioned in your last return that experiences from other places and/or international organizations have been referred to in the development of the existing WQC/WQS/WQO.

(a) Would you please list out the key references or source documents that you have made reference to in developing the WQC/WQS/WQO for dissolved oxygen?

Organization	Ref. No.	Name of Document

(b) Are you able to provide us with a copy of the references?

☐ Yes, a copy of the references is attached.

☐ Please visit our following website for the required information.

____

☐ Others (please specify) ______________________________

Q5. (***For those economies that have made reference to local studies)***

You have mentioned in your last return that local studies (e.g. acute tests, chronic test, bioassay, percentile distribution analysis, etc.) have been made reference to in the development of WQC/WQS/WQO.

(a) Would you please list out the key study reports or source documents (e.g. guidance notes, handbook, manual, etc.) that you have made reference to in developing the WQC/WQS/WQO for dissolved oxygen?

Organization	Ref. No.	Name of Document

(b) Would you please list out the key discussion / working / policy papers which set out why and how the WQC/WQS/WQO for dissolved oxygen is developed?

Organization	Ref. No.	Name of Document

(c) Are you able to provide us with a copy of the study reports or references?

☐ Yes, a copy of the study reports / references is attached.

☐ Please visit our following website for the required information.

____

☐ Others (please specify) ____________________________

Derivation of the WQC/WQS/WQO for Nutrients

Q6. ***(For those economies that have designated WQC/WQS/WQO for nutrients for the protection of aquatic life)***

What is the basis or rationale for including nutrients (i.e. total inorganic nitrogen, nitrite, nitrate, ammonia) in the list of the WQC/WQS/WQO? (please ✓ the appropriate box below, more than one choice is allowed)

☐ They are the critical parameters / substances affecting the uses or resources of the local aquatic environment.

☐ They are substances of international concern.

☐ They are substances of local concern.

☐ They are commonly found in local discharges.

☐ Others (please specify) ____________________________

Q7. (For those economies that have made reference to other's WQC/WQS/WQO)

You have mentioned in your last return that experiences from other places and/or international organizations have been referred to in the development of the existing WQC/WQS/WQO.

(a) Would you please list out the key references or source documents that you have made reference to in developing the WQC/WQS/WQO for nutrients (i.e. total inorganic nitrogen, nitrite, nitrate, ammonia)?

Organization	Ref. No.	Name of Document

(b) Are you able to provide us with a copy of the references?

- ☐ Yes, a copy of the references is attached.
- ☐ Please visit our following website for the required information.

  ____
- ☐ Others (please specify) ____________________

Q8. (For those economies that have made reference to local studies)

You have mentioned in your last return that local studies (e.g. bioassay, percentile distribution analysis, etc.) have been made reference to in the development of WQC/WQS/WQO for nutrients (i.e. total inorganic nitrogen, nitrite, nitrate, ammonia).

(a) Would you please list out the key study reports or source documents (e.g. guidance notes, handbook, manual, etc.) that you have made reference to in developing the WQC/WQS/WQO for nutrients?

Organization	Ref. No.	Name of Document

(b) Would you please list out the key discussion / working / policy papers which set out why and how the WQC/WQS/WQO for nutrients is developed?

Organization	Ref. No.	Name of Document

(c) Are you able to provide us with a copy of the study reports or references?

☐ Yes, a copy of the study reports / references is attached.

☐ Please visit our following website for the required information.

____

☐ Others (please specify) ____________________

Other sources of information

Q9. Has your economy commissioned any studies on the review of international or national protocols/guidelines for the development of WQC/WQS/WQO for the protection of aquatic life?

☐ Yes

☐ No (Go to Q.11)

Q10. Are you able to provide us with a copy of the study reports?

☐ Yes, a copy of the study reports is attached.

☐ Please visit our following website for the required information.

____

☐ Others (please specify) ____________________

Q11. In your return to the last questionnaire, you have provided the name of the appropriate government department or organization to approach for information on the application or interpretation of the WQC/WQS/WQO. For more specific enquiry on the derivation of the WQC/WQS/WQO of dissolved oxygen and nutrients, who would be the appropriate contact person(s) to approach for detailed information?

The contact person(s) is/are : ____

The organizations is/are : ____

End of questionnaire

Thank you !

Please return this questionnaire to us on or before **1 Februry 2004** by either one of the following ways :

(a) by fax to **(852) 2834 9960**;

(b) by e-mail to gretam@edp.gov.hk

(c) by mail to the following address:

Water Policy and Planning Group
Environmental Protection Department
HKSAR Government
24/F., Southorn Centre
130 Hennessy Road, Wanchai
Hong Kong, China
Attn: Ms Greta TAM, E(WP)4

Appendix A : Summary of Responses to the Third Questionnaire

Questions \ APEC Economy		Australia	Chile	Philippines	Chinese Taipei
1. What are your comments on the Phase 1 Report?		Beneficial uses are known as environmental values.	● Chile has similar and implicit criteria for protection of wildlife consumers of aquatic biota by saying one of the uses protected by WQC/WQS/ WQO is aquatic life. ● WQC/WQS/WQO for drinking water is a national standard established by Health Ministry. ● Chile will have standards, not criteria, in water. The document sent at the first questionnaire is a proposal for the standards, but the values must be used in setting standards for water bodies in every region. ● Primary standards are legally bound but not officially yet. ● When a control parameter is above 80% of the standard, then a prevention plan is established, and when a controlled parameter is above 100% of the standard value, then a restoration plan be established. ● Primary standards are oriented to protect human health. ● In page 29, Chile has official effluent standards.		● Chinese Taipei has 4 major categories of beneficial uses, i.e. public use, aquacultural use, industrial use, and drinking water resource. ● Further differentiate public use into 3 classes, and aquacultural and industrials use each into 2 classes. ● 5 criteria for different usage for fresh water and 3 criteria for marine water. ● Water quality standards are given to protect human health and environmental amenity. ● Supplementary information on the Taiwan River Basin and Ocean Management Program to improve the quality of different water bodies; the goal of protecting the quality of drinking water sources and rivers via provision of wastewater sewers and disposal facilities; streamlining of water quality monitoring program and strengthened groundwater monitoring.
2. Are there any updates of the WQC/WQS/ WQO values?	● Yes, new values attached				
	● No new release	✓	✓	✓	
	● Others (please specify)		There is no official complied database of WQC/WQS/WQO.	● Additional information on selected items is marked on Appended A of the Phase 1 Report.	● Internet link to the following references are provided : (i) revised effluent standards - http://www.epa.gov.tw/english/EPM/issue0312.thm (ii) revised regulations facilitating efficient use of water resources – http://www.epa.gov.tw/english/EPM/issue0308.thm.

Questions / APEC Economy		Australia	Chile	Philippines	Chinese Taipei
Derivation of the WQC/WQS/WQO for Dissolved Oxygen					
3. What is the basis or rationale for including dissolved oxygen in the list of the WQC/WQS/WQO?	● Critical parameter affecting uses or resources of the local aquatic life		✓	✓	✓
	● Parameter of international concern				✓
	● Parameter of local concern	✓		✓	
	● Others (please specify)	DO measurements are used to indicate whether there is a disturbance to many ecosystem processes (photosynthesis, respiration, etc.) and to define the living conditions for aerobic (oxygen requiring) organisms. See fact sheet 8.2.1.2 of Volume 2 of the Water Quality Guidelines.	It is one of the listed parameters of concern.		Information on criteria for pH, DO, BOD, SS, NH3-N could be found at http://www.epa.gov.tw/wq/ewmain.htm. References include : ***USEPA*** ● Drinking Water Standards ● Ground Water Rule ***RAIS*** ● Federal and/or State Guideline Values ***Ministry of Environment, Japan*** ● Environmental and Emission Standards ***WHO*** ● WHO Guidelines for Drinking Water Quality
4. What are the key international organization's references or source documents for developing the WQC/WQS/WQO?				● USEPA ● WHO	***USEPA*** ● The Quality of Our Nation's Water, 2000 ● Environmental Indicators of Water Quality in the U.S., 1996
5a. What are the key local references or source documents for developing the WQC/WQS/WQO?		Information available at http://www.deh.gov.au/water/quality/nwqms/index.html#quality, which include: ***ANZECC and ARMCANZ*** ● Australian and New Zealand for Fresh and Marine Water Quality. Volumes 1 and 2 and references therein.	● Gross, M.G. (1977). Oceanography: a view of the earth, 2nd ed. Prentice Hall, New Jersey. U.S.A. ● Libes, S.M. (1992). An Introduction to Marine Biogeochemistry. John Wiley & Sons, New York. ● Millero, F.J. (1996). Chemical Oceanography, 2nd de. CRC Press, Boca Raton, New York, U.S.A. 469. ● Riley, J.P. & R. Chester (1971). Introduction to Marine Chemistry. Academic Press, London. 465p.	✓	Information available at http://cemnt.epa.gov.tw/eng/, which include: ***EPA, Chinese Taipei*** ● Auditing of Environmental Water Quality Data ● The Establishment of Guideline for Water Quality Examination ● Genetic Toxicity Testing for polluted water and air samples ● Investigation report for biomarkers and water quality in Feitsui Reservoir (1986) ● Biological indicator assessment report for reservoir eutrophication in important water reservoirs in Taiwan area ● Study on Standard Bioassay of Fish Toxins
5b. What are the key local discussion / working / policy papers for developing the WQC/WQS/WQO?		Information available at http://www.deh.gov.au/water/quality/nwqms/index.html#quality, which include: ***ANZECC and ARMCANZ*** ● Australian and New Zealand for Fresh and Marine Water Quality. Volume 2. See Fact Sheet 8.2.1.2 on dissolved oxygen. ● Australian and New Zealand for Fresh and Marine Water Quality. Volume 1. See Section 3.3.	Supplementary information provided.		Information available at http://cemnt.epa.gov.tw/eng/, which include: ***EPA, Chinese Taipei*** ● Auditing of Environmental Water Quality Data ● The Study of establishing Total Load Control Related Strategy ● A Study of River Water Quality Management: Development of Evaluation Model of Total Mass Daily Load Control

Questions / APEC Economy		Australia	Chile	Philippines	Chinese Taipei
Derivation of WQC/WQS/WQO for Nutrients					
6. What is the basis or rationale for including nutrients in the list of the WQC/WQS/WQO?	● Critical parameters/substances affecting uses or resources of the local aquatic life			✓	✓
	● Parameters/substances of international concern				
	● Parameters/ substances of local concern	✓	✓	✓	
	● Commonly found in local discharges	✓			✓
	● Others (please specify)	Nutrient pollution can affect receiving waters by stimulating excessive plant growth, change light.			The EPA Bureau of Water Quality Protection proposed for public comment on March 1, 2003, new effluent standards for total nitrogen and phosphate. The draft amendment to the Effluent Standards is pending for approval.
7. What are the key international organization's references or source documents for developing the WQC/WQS/WQO?					***USEPA*** ● Water Quality-Based Approach to Pollution Control ● Development and Implementation of the TMDL ● Basin : A powerful tool for management watersheds
8a. What are the key local references or source documents for developing the WQC/WQS/WQO?		Information available at http://www.deh.gov.au/water/quality/nwqms/index.html#quality, which include: ***ANZECC and ARMCANZ*** ● Australian and New Zealand for Fresh and Marine Water Quality. Volume 2.			Same as the response given in Q.5a.
8b What are the key local discussion / working / policy papers for developing the WQC/WQS/WQO?		Information available at http://www.deh.gov.au/water/quality/nwqms/index.html#quality, which include: ***ANZECC and ARMCANZ*** ● Australian and New Zealand for Fresh and Marine Water Quality. Volume 2. See fact Sheet 8.2.1.1 on nutrients. ● Australian and New Zealand for Fresh and Marine Water Quality. Volume 1. See Section 3.	● Ahumada R., A. Rudolph, S. Madariaga & F. Carrasco (1989). Description of the oceanographic conditions of San Vicente Bay and records regarding the effect of pollution. Fish Biology., 18:37-52. ● Supplementary information provided.		Same as the response given in Q.5b.

Questions \ APEC Economy		Australia	Chile	Philippines	Chinese Taipei
Other sources of information					
9. Are there any studies on the review of international or national protocols/guidelines for the development of WQC/WQS/WQO for the protection of aquatic life?		Yes	No	Yes by TWG, geothermal	Yes
10. What are the relevant study reports?		Information available at http://www.deh.gov.au/water/quality/nwqms/index.html#quality		Copy of results, on DAO 34 & 35.	Same as the response given in Q.3.
11. Who is the appropriate person for further information?	Person Organization	Chris Humphrey Environmental Research Institute of the Supervising Scientist	Paulina Abarca C. National Commission for the Environment	Erlinda A. Gonzales, Ella Deocadiz, Renato T. Cruz EMB-DENR	Hone-Ling SUN Environmental Protection Administration, Chinese Taipei

Note:

✓ = the chosen option

blank cell = option not chosen or response not provided

Appendix B

Information on Water Quality Criteria / Water Quality Standards

Contact Person List

	APEC Economy	Contact Person	Email Address	Authority	Phone No.	Fax No.
1.	Australia	Mr. Richard Nott	richard.nott@deh.gov.au	**Department of the Environment and Heritage** Water Quality Section Land Water and Coasts Division GPO Box 787 Canberra ACT Australia, 2601	(61) 2 6274 1636	(61) 2 6274 1006
2.	Brunei Darussalam	Mr. Sabri Hj mohd Taha	sabri_taha@fisheries.gov.bn	**Fisheries Department** PDQC Division Ministry of Industry and Primary Resources	(673) 2 770234	(673) 2 770237
3.	Canada	Mr. J. Roderick Forbes	forbesr@dfo-mpo.gc.ca	**Fisheries and Oceans Canada** International Policy Coordination 200 Kent Street Ottawa, KIA OE6, Canada	(613) 993 2539	(613) 990 9574
4.	Chile	Mr. Pablo Daud Miranda	pabarca@conama.cl pgabarca@terra.cl	**National Commission for the Environment** Jefe Deaprtamento de Operaciones Comisi-n Nacional del Medio Ambiente Teatinos 254 Santiago, Chile	(56) 2 240 5676 (direct) (56) 2 240 5600 (Central)	(56) 2 244 1262 (56) 2 240 5782
5.	P.R. China	Ms. Yue Chen	zzh@soa.gov.cn	**State Oceanic Administration** Department of Cooperation 1 Fuxingmenwai Avenue Beijing, China 100860	(86) 10-68019791	(86) 10-68048051
6.	Hong Kong	Dr. HungYiu Yeung	hyyeung@epd.gov.hk	**Environmental Protection Department** Water Policy Division The Government of the HKSAR 33/F, Revenue Tower, 5 Gloucester Road,Wan Chai Hong Kong, China	(852) 2594 6321	(852) 2827 8040
7.	Malaysia	Dr. Kamaruzaman Bin Hj Salim	kamsal01@dof.moa.my	**Department of Fisheries** Ministry of Agriculture Wisma Tani Jalan Sultan Salahuddin 50624 Kuala Lumpur	(620) 3 295 4620 (620) 3 298 2011 (ext 4620)	(620) 3 291 0305 (620) 3 297 9744 (620) 3 294 2984

APEC Economy		Contact Person	Email Address	Authority	Phone No.	Fax No.
8.	New Zealand	Mr. Brigit Stephenson	brigit.stephenson@mfe.govt.nz	**Ministry for the Environment – Manat-M-Te Taiao** Oceans Policy Secretariat Level 11, Grand Annexe, 84 Boulcott Street PO Box 10-362 Wellington, New Zealand	(64) 4 917 7550 – direct line (64) 4 917 7400 – Ministry of the Environment 0274 535 599 (Mobile)	(64) 4 917 7521
9.	Papua New Guinea	Mr. Luke Tanikrey	odir@daltron.com.pg	**Department of Environment & Conservation** Office of Environment and Conservation Cnr. Sir John Guise Drv. 7^{th} Floor Somare Foundation Building P O Box 6601, Boroko, NCD Papua New Guinea	(675) 325 0194	(675) 325 0182
10.	Peru	Mr. Sulma Carrasco Barrera	dinama@minproduce.gov.pe	**Ministry of Production** National Direction of Environment Calle Uno Oeste N^{o}60, Corpac San Isidro Peru	(51) 1 224 3231	(51) 1 224 3231
11.	Philippines	Mr. Jim Tito B. San Agustin	jbsanagustin@dfa.gov.ph	**Office of the Undersecretary for International Economic Relations** Department of Foreign Affairs 14/F Office of the Undersecretary for International Economic Relations 2330 Roxas Boulevard, Pasay City The Philippiness	(632) 834 3033	(632) 834 1451
12.	Singapore	Mrs. Renee Chou	chew_hong@ava.gov.sg	**Agri-food & Veterinary Authority of Singapore** Food Supply & Technology Department Technology Division 5 Maxwell Road #03-00 Tower Block MND Complex Singapore 069110	(65) 6325 7637	(65) 6325
767 713 .	Chinese Taipei	Ms. Sun Hone Ling	hlsun@sun.epa.gov.tw	**Bureau of Water Quality Protection** **Environmental Protection Administration** 41, Sec.1, Chung-Hwa Road, Taipei Taiwan 100 Chinese Taipei	(886) 2 2311 7722 ext 2842	(886) 2 2387 9860
14.	Thailand	Ms. Nipavan Bussarawit	ta_pmbc@yahoo.com bnipavan@hotmail.com	**Head of the Fishery Oceanography Unit** Phuket Marine Biological Center Department of Fisheries P.O. Box 60 Phuket 83000 Thailand	(66) 76 391128 (66) 76 391438	(66) 76 391127

APEC Economy		Contact Person	Email Address	Authority	Phone No.	Fax No.
15.	USA	Mr. Patrick J. Cotter	cotter.patrick@epa.gov	**U.S. Environmental Protection Agency** International Activities Specialist U.S. Environmental Protection Agency Office of International Affairs (2660R) 1200 Pennsylvania Avenue, N.W. Washington, D.C. 20460-0001	202-564-6414	202-566-2409

Appendix C : On-line Access to WQC/WQS

APEC Economy	Listing of WQC/WQS can be found at :
Australia	Water Quality Guidelines : http://www.ea.gov.au/water/quality/nwqms/index.html#quality Microbiological Water Quality Guidelines : http://www.mfe.govt.nz/publications/water/microbiological-quality-jun03/ Water Quality Targets : http://www.ea.gov.au/water/quality/targets/ Monitoring Guidelines : http://www.ea.gov.au/water/quality/nwqms/index.html#quality
Brunei	Government of Brunei Darussalam: http://www.brunei.gov.bn/government/index.htm
Canada	Water Quality Guidelines : http://www.ec.gc.ca/CEQG-RCQE/English/default.cfm Drinking Water Quality Guidelines : http://www.hc-sc.gc.ca/hecs-sesc/water/index.htm Recreational Water Quality Guidelines : http://www.hc-sc.gc.ca/hecs-sesc/water/factsheets/recreational_water.htm
Chile	Government website : http://www.conama.cl/portal/1255/channel.html
China	Environmental Protection Standards : http://www.zhb.gov.cn/english/standard.php3
Hong Kong	Water Quality Objectives (Water Pollution Control Ordinance, Cap 258) : http://www.justice.gov.hk/home.htm Effluent Standards : http://www.epd.gov.hk/epd/english/environmentinhk/water/guide_ref/guide_wpc_wpco_1.html
Malaysia	Department of Environment : http://www.jas.sains.my/DOE/egfirst.htm
New Zealand	Water Quality Guidelines : http://www.ea.gov.au/water/quality/nwqms/index.html#quality Microbiological Water Quality Guidelines : http://www.mfe.govt.nz/publications/water/microbiological-quality-jun03/ Water Quality Targets : http://www.ea.gov.au/water/quality/targets/ Monitoring Guidelines : http://www.ea.gov.au/water/quality/nwqms/index.html#quality
Papua New Guinea	Government of Papua New Guinea : http://www.pngonline.gov.pg/government/entry.nsf
Peru	Website in Spanish.
Philippines	Water Quality Criteria : http://www.emb.gov.ph/water.html
Singapore	Effluent discharge standards : http://app10.internet.gov.sg/scripts/nea/cms/htdocs/article.asp?pid=963
Chinese Taipei	Effluent discharge standards : http://www.epa.gov.tw/english/offices/g/effluentstd.htm Drinking water standards : http://www.epa.gov.tw/j/drinkwater/index1.html
Thailand	Water Quality Standards : www.pcd.go.th/Information/Regulations/WaterQuality/WaterQualityStandards.cfm
USA	Quality Criteria for Water : www.epa.gov/waterscience/criteria Water Quality Standards : http://www.epa.gov/waterscience/standards/

Appendix D : References

Economy	Title/Description	Available on internet
Australia and New Zealand	ANZECC & ARMCANZ 1994. ***Policies and principles: A reference document.*** National Water Quality Management Strategy Paper No. 2, Australian and New Zealand Environment and Conservation council & Agriculture and Resource Management Council of Australia and New Zealand, Canberra.	Yes
	ANZECC & ARMCANZ 2000a. ***Australian and New Zealand guidelines for fresh and marine water quality***: National Water Quality Management Strategy Paper No. 4, Australian and New Zealand Environment and Conservation Council & Agriculture and Resource Management Council of Australia and New Zealand, Canberra.	Yes
	ANZECC & ARMCANZ 2000b***. Australian guidelines for water quality monitoring and reporting.*** National Water Quality Management Strategy Paper no 7, Australian and New Zealand Environment and Conservation Council & Agriculture and Resource Management Council of Australian and New Zealand, Canberra.	Yes
	ANZECC 1992, ***Australian Water Quality Guidelines for Fresh and Marine Waters***, National Water Quality Management Strategy Paper No. 4, Australian and New Zealand Environment and Conservation Council, Canberra.	Yes
	ARMCANZ & ANZECC 1998. ***Implementation guidelines***. National water Quality Management Strategy Paper No. 3, Agriculture and Resource Management Council of Australia and New Zealand & Australian and New Zealand Environment and Conservation Council, Canberra.	Yes
Canada	Alberta Environment, 1996. ***Protocol to Develop Alberta Water Quality Guidelines for Protection of Freshwater Aquatic Life.*** Environmental Assession Division, Environment Regulatory Service, Alberta Environment	Yes
	Alberta Environment, 1999. ***Surface Water Quality Guidelines for Use in Alberta.*** Environmental Assurance Division, Science and Standards Branch, Alberta Environment	Yes
	Alberta Environment. ***Framework for Water Management Planning.*** Alberta Environment	Yes
	CCME 1995. ***Protocol for the derivation of Canadian sediment quality guidelines for the protection of aquatic life, CCME EPC-98E.*** Environment Canada, Guidelines Division, Technical Secretariat of the CCME Task Force on Water Quality Guidelines, Canadian Council of Ministers of the Environment, Winnipeg.	Yes
	CCME 1999. ***Guidance manual for developing site-specific soil quality remediation objectives for contaminated sites in Canada.*** Canadian Council of Ministers of the Environment, Winnipeg.	Yes
	CCME 1999. ***Protocol for the derivation of water quality guidelines for the protection of aquatic life.*** Task Force on Water Quality Guidelines, Canadian Council of Ministers of the Environment, Winnipeg.	Yes
	CCME 1999. ***Canadian environmental quality guidelines.*** Canadian Council of Ministers of the Environment, Winnipeg.	Updated parts
	CCME 2002. ***Global Overview of Protocols Used in the Development of Water Quality Guidelines for the Protection of Aquatic Life for Metals.*** Report for Canada Council of Ministers of the Environment by EVS Environment Consultants	No

Economy	Title/Description	Available on internet
	CCME 2003. ***Guidance on the site-specific application of water quality guidelines in Canada : Procedures for deriving numerical water quality objectives for the protection of aquatic life.*** Canadian Council of Ministers of the Environment, Winnipeg.	Yes
	CCREM 1987. ***Canadian water quality guidelines.*** Task Force on Water Quality Guidelines, Canadian Council of Resource and Environment Ministers/	No
	EC, 1994. ***A Review of Environmental Quality Criteria and Guidelines for Priority Substances in the Fraser River Basin.*** Report for Environment Canada by MacDonald Environmental Services Limited	Yes
	Manitoba Environment, 1988. ***Rationale Document Supporting Revisions to Manitoba Surface Water Quality Objectives.*** Water Standards and Studies Section, Department of Environment and Workplace Safety and Health.	Yes
	Manitoba Environment, 1988a. ***Manitoba Surface Water Quality Objectives.*** Water Standards and Studies Section, Department of Environment and Workplace Safety and Health.	Yes
	Manitoba Environment, 1988b. ***Surface Water Quality Management Proposal Volume 2 : Watershed Classification.*** Water Standards and Studies Section, Environmental Management Division.	Yes
	Manitoba Environment, 1990. ***The Development and Use of Water Quality Objectives in Manitoba.*** Water Standards Section, Environmental Management Division, Manitoba Department of Environment.	Yes
	Manitoba Environment, 2002. ***Final Draft – Manitoba Water Quality Standards, Objectives, and Guidelines.*** Water Quality Management Section.	Yes
	MEQG and CCME 1992. ***The Development of Canadian Marine Environmental Quality Guidelines.*** Interdeparmental Working Group on Marine Environmental Quality Guidelines and Canadian Council of Ministers of the Environment Task Group on Water Quality Guidelines.	No
	MWLAPBC 1996. ***Developing Water Quality Objectives in British Columbia : A User's Guide*** Ministry of Water, Land and Air Protection, British Columbia.	Yes
	MWLAPBC 1997. ***Methods for Deriving Site-Specific Water Quality Objectives in British Columbia and Yukon.*** Ministry of Water, Land and Air Protection, British Columbia.	Yes
	MWLAPBC 2001. ***Priniciples for Preparing Water Quality Objectives in British Columbia*** Ministry of Water, Land and Air Protection, British Columbia.	Yes
	MWLAPBC 1998. ***British Columbia Approved Water Quality Guidelines (Criteria).*** Ministry of Water, Land and Air Protection, British Columbia.	Yes
USA	US Arizona Department of Environment Quality 1996. ***Implementation guidelines for the narrative nutrient standard.*** The Water Quality Assessment Unit *of the Environmental Quality*, Arizona Department of Environment Quality.	Yes
	USEPA 1985. ***Guidelines for deriving numerical national water quality criteria for the protection of aquatic organisms and their uses.*** EPA-822-R-8510, Jan 1985. USEPA Office of Research and Development, Environmental Research Laboratories Duluth, Minnesota.	No

Economy	Title/Description	Available on internet
	USEPA 1986. ***Quality criteria for water 1986 Update #1.*** EPA-440/5-86-001, May 1986. USEPA Office of Water Regulations and Standards, Washington.	No
	USEPA 1986. ***Quality criteria for water 1986.*** EPA-440/5-86-001, May 1986. USEPA Office of Water Regulations and Standards, Washington.	Yes
	USEPA 1994. ***Water Quality Standards Handbook***. EPA-823-B-94-005a. USEPA Office of Water	No
	USEPA 1996. ***Biological Criteria, Technical Guidance for Streams and Small Rivers.***. USEPA Office of Water	Yes
	USEPA 1998. ***National strategy for the development of regional nutrient criteria.*** EPA-822-R-98-002, June 1998. USEPA Office of Water.	Yes
	USEPA 1999. ***National recommended water quality criteria – correction.*** EPA-822-Z-99-001, April 1999. USEPA Office of Water.	Yes
	USEPA 2000. ***Estuarine and Coastal Marine Waters : Bioassessment and Biocriteria Technical Guidance*** . EPA-822-B-00-024. USEPA Office of Water	Yes
	USEPA 2000. ***Methodology for deriving ambient water quality criteria for the protection of human health (2000).*** EPA-822-B-00-004, Oct 2000. USEPA Office of Water and Office of Science and Technology.	Yes
	USEPA 2000. ***Nutrient criteria technical guidance manual, lakes and reservoirs.*** EPA 822-B00-001, Apr 2000. USEPA Office of Water and Office of Science and Technology.	Yes
	USEPA 2000. ***Nutrient criteria technical guidance manual, rivers and streams.*** EPA 822-B-00-002, Jul 2000. USEPA Office of Water and Office of Science and Technology.	Yes
	USEPA 2001. ***Nutrient criteria technical guidance manual, estuarine and coastal marine waters.*** EPA 822-B-01-003, Oct 2001. USEPA Office of Water.	Yes
	USEPA 2002. ***Draft strategy for water quality standards and criteria : strengthening the foundation of programs to protect and restore and nation's waters.*** EPA-823-R-02-001, May 2002. USEPA Office of Water.	Yes
	USEPA 2002. ***National recommended water quality criteria : 2002.*** EPA-822-R-047, November 2002. USEPA Office of Water and Office of Science and Technology.	Yes
	USEPA 2004. ***Water Quality Standards Academy, Basic Course, Participant Manual***. EPA-823-B-00-005. USEPA Office of Water.	No