European Commission

Common Implementation Strategy for the Water Framework Directive (2000/60/EC)

Guidance document n.° 7

Monitoring under the Water Framework Directive

COMMON IMPLEMENTATION STRATEGY

FOR THE WATER FRAMEWORK DIRECTIVE (2000/60/EC)

Guidance Document No 7

Monitoring under the Water Framework Directive

Produced by Working Group 2.7 - Monitoring

Disclaimer:

This technical document has been developed through a collaborative programme involving the European Commission, all the Member States, the Accession Countries, Norway and other stakeholders and Non-Governmental Organisations. The document should be regarded as presenting an informal consensus position on best practice agreed by all partners. However, the document does not necessarily represent the official, formal position of any of the partners. Hence, the views expressed in the document do not necessarily represent the views of the European Commission.

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Foreword

The EU Member States, Norway and the European Commission have jointly developed a common strategy for supporting the implementation of the Directive 2000/60/EC establishing a framework for Community action in the field of water policy (the Water Framework Directive). The main aim of this strategy is to allow a coherent and harmonious implementation of this Directive. The focus is on methodological questions related to a common understanding of the technical and scientific implications of the Water Framework Directive.

One of the main short-term objectives of the strategy is the development of non-legally binding and practical Guidance Documents on various technical issues of the Directive. These Guidance Documents are targeted to those experts who are directly or indirectly implementing the Water Framework Directive in river basins. The structure, presentation and terminology is therefore adapted to the needs of these experts and formal, legalistic language is avoided wherever possible.

In the context of the above-mentioned strategy, project 2.7 "Development of Guidance on monitoring" was launched in December 2000. An informal working group (working group 2.7) was established to facilitate the production of this Guidance. Project 2.7 was initiated to provide Member States with Guidance on monitoring of inland surface water, transitional waters, coastal waters and groundwater, based on the criteria provided in Annex V of the Water Framework Directive. Italy and the European Environment Agency have the joint responsibility, as co-leaders of Working Group 2.7, for the co-ordination of the working group that is composed of scientists and technical experts from governmental and non-governmental organisations.

The present Guidance Document is the outcome of this working group. It contains the synthesis of the output of the Working Group 2.7 activities and discussions that have taken place since December 2000. It builds on the input and feedback from a wide range of experts and stakeholders that have been involved throughout the procedure of Guidance development through meetings, workshops, conferences and electronic media, without binding them in any way to this content.

"We, the water directors of the European Union, Norway, Switzerland and the countries applying for accession to the European Union, have examined and endorsed this Guidance during our informal meeting under the Danish Presidency in Copenhagen (21/22 November 2002). We would like to thank the participants of the Working Group and, in particular, the leaders, Italy and the European Environment Agency, for preparing this high quality document.

We strongly believe that this and other Guidance Documents developed under the Common Implementation Strategy will play a key role in the process of implementing the Water Framework Directive.

This Guidance Document is a living document that will need continuous input and improvements as application and experience build up in all countries of the European Union and beyond. We agree, however, that this document will be made publicly available in its current form in order to present it to a wider public as a basis for carrying forward ongoing implementation work.

Moreover, we welcome that several volunteers have committed themselves to test and validate this and other documents in the so-called pilot river basins across Europe during 2003 and 2004 in order to ensure that the Guidance is applicable in practice.

We also commit ourselves to assess and decide upon the necessity for reviewing this document following the pilot testing exercises and the first experiences gained in the initial stages of the implementation."

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1 Introduction

A Guidance Document: What For?

1.1 Purpose of this Guidance Document

The 26 articles of the Directive 2000/60/EC – establishing a framework for Community action in the field of water policy (The Water Framework Directive) describe what shall be done to implement the Directive and the annexes have been developed to assist Member States in ensuring that the articles are implemented in accordance with the requirements of the Directive. However, the complex nature of the Directive means that the annexes may not provide sufficient Guidance to provide Member States with the assistance they require.

The purpose of this document, along with the other Guidance Documents published by the Commission, is to provide experts and stakeholders with Guidance in the implementation of the Directive. The focus of the document is on providing Guidance on establishing programmes of measures with specific emphasis on the appropriate selection of quality elements and design of monitoring programmes in accordance with Articles 8 and 11 and Annex V.

1.2 To whom is this Guidance Document addressed?

If this is your task, we believe the Guidance will help you in doing the job, whether you are:

¾ Undertaking the monitoring programmes yourself;

¾ Leading and managing experts undertaking the monitoring;

¾ Using the results of the monitoring for taking part in the policy making process; or,

¾ Reporting on the results of monitoring to the European Union as required by the Directive.

1.3 What you can find in this Guidance document?

1.3.1 Common understanding of concepts and terms

Chapter 2 provides clarification of key concepts and terms of the Directive. This has been developed through an extensive process of review and represents, as far as possible, a common understanding between Member States who have been involved in Working Group 2.7. Clarification is provided on the following terms and concepts:

¾ The term ‘supporting’;

¾ The term ‘water body’;

¾ The concepts of risk, precision and confidence;

¾ Monitoring of wetlands;

¾ Surveillance, operational and investigative monitoring of surface waters;

¾ Surveillance, operational and quantitative status monitoring of groundwater;

¾ Surface water monitoring for protected areas; and,

¾ Other monitoring considerations such as intercalibration exercises and monitoring of heavily modified water bodies.

1.3.2 Guidance on the selection of Quality Elements

Chapter 3 provides a number of tables summarising the key features of each quality element for surface waters and how each of the quality elements are monitored in Member States. In addition Guidance is provided on the appropriate selection of mandatory and recommended quality elements and parameters that are most representative of catchment pressures for each surface water body type.

Guidance on the selection of groundwater parameters is provided in Chapter 4.

1.3.3 Best Practices and Tool Box

Chapter 5 provides Guidance on the design and implementation of monitoring programmes. Guidance is given on the appropriate selection of water bodies and monitoring sites within water bodies and sampling frequencies required for implementation of surveillance, operational, investigative and quantitative status monitoring programmes and for the monitoring of protected areas.

The chapter provides an overview of the process of establishing a monitoring programme based on the identified objectives and required outcomes of the Directive, with particular emphasis on achieving acceptable levels of risk, precision and confidence.

1.3.4 Best practice examples of current national monitoring

Chapter 6 provides an overview of national monitoring contributions received from Member States. A list of monitoring fact sheets, including the title of the programme, Member State who proposes the method and website link is provided in Annex IV.

1.4 Guidance on monitoring – a framework approach

This Guidance document proposes an overall methodological approach to monitoring for the implementation of the WFD. Because of the diversity of catchment pressures, water-body types, biological communities and hydromorphological and physico-chemical characteristics within the Europena Union the appropriate implementation of programmes of measures in accordance with the requirements of the Directive will vary between Member States and river basins. This proposed methodology will need to be tailored to specific circumstances.

It is not the intention of this Guidance to define prescriptive methods for the assessment and classification of ecological status. This is due to the following factors:

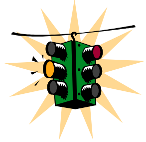
¾ There are a number of existing classification systems already in use throughout the EU that are potentially suitable for adaptation to meet the requirements of the WFD, some of which have been incorporated into National Standards;

¾ Individual Member States generally understand local natural variations in biological communities, hydromorphological conditions and physico-chemical variables;

¾ The level of habitat detail required varies for different indicators depending on their sensitivity to natural variation in habitat conditions; and

¾ There are existing international, European and national standards for a number of the required quality elements.

This Guidance, therefore, provides a framework within which Member States can either use/modify their existing methods, or where no appropriate monitoring and assessment systems exists, develop new systems that will incorporate all the requirements of the WFD.

	***Look Out! The methodology from this Guidance Document must be adapted to regional and national circumstances*** *The Guidance Document proposes an overall methodological approach. Because of the diversity of circumstances within the European Union, the way to apply a logical approach and answer questions will vary from one river basin to the next. This proposed methodology will therefore need to be tailored to specific circumstances.*

While monitoring for surface and groundwater status will require the development/adaptation of specific assessment systems, it is critical that Member States ensure that the following key criteria are incorporated into the programmes of measures:

¾ An assessment on the deviation of observed conditions to those that would normally be found under reference conditions;

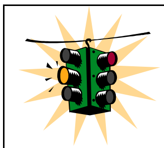
¾ Provides for natural and artificial physical habitat variation;

¾ Accounts for the range of natural variability and variability arising from anthropogenic activities of all quality elements in all water-body types;

¾ Accounts for interactions between surface and groundwaters; and,

¾ Provides for detection of the full range of potential impacts to enable a robust classification of ecological status.

Incorporation of the above key criteria into the assessment systems of each Member State will ensure that ecological quality is reported to the Commission using a unit-less classification scale based on ratios or fractions of reference values. This will enable Member States to continue using existing national assessment systems (where they exist), whilst reporting ecological status to the Commission on a common European scale.

	***Look Out! What you will not find in this Guidance Document*** *The Guidance Document focuses on the monitoring requirements of the Directive. The Guidance does not focus on:* ¾ *Determination of reference conditions;* ¾ *Development of assessment and classification Systems;* ¾ *Monitoring wetlands; or,* ¾ *Data analysis and reporting.*

Implementing the Directive: Setting the Scene

1.5 December 2000: A Milestone for Water Policy

1.5.1 A long negotiation process

December 22, 2000, will remain a milestone in the history of water policies in Europe: on that date, the Water Framework Directive (or the Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy) was published in the Official Journal of the European Communities and thereby entered into force!

This Directive is the result of a process of more than five years of discussions and negotiations between a wide range of experts, stakeholders and policy makers. This process has stressed the widespread agreement on key principles of modern water management that today form the foundation of the Water Framework Directive.

1.6 The water Framework Directive: new challenges in EU water policy

1.6.1 What is the purpose of the Directive?

The Directive establishes a framework for the protection of all waters (including inland surface waters, transitional waters, coastal waters and groundwater) which:

¾ Prevents further deterioration of, protects and enhances the status of water resources;

¾ Promotes sustainable water use based on long-term protection of water resources;

¾ Aims at enhancing protection and improvement of the aquatic environment through specific measures for the progressive reduction of discharges, emissions and losses of priority substances and the cessation or phasing-out of discharges, emissions and losses of the priority hazardous substances;

¾ Ensures the progressive reduction of pollution of groundwater and prevents its further pollution; and

¾ Contributes to mitigating the effects of floods and droughts.

1.6.2 …and what is the key objective?

Overall, the Directive aims at achieving *good water status* for all waters by 2015.

1.7 What are the key actions that Member States need to take?

¾ To identify the individual river basins lying within their national territory and assign them to individual River Basin Districts (RBDs) and identify competent authorities by 2003 (Article 3, Article 24);

¾ To characterise river basin districts in terms of pressures, impacts and economics of water uses, including a register of protected areas lying within the river basin district, by 2004 (Article 5, Article 6, Annex II, Annex III);

¾ To carry out, jointly and together with the European Commission, the intercalibration of the ecological status classification systems by 2006 (Article 2 (22), Annex V);

¾ To make the monitoring networks operational by 2006 (Article 8);

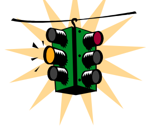
¾ Based on sound monitoring and the analysis of the characteristics of the river basin, to identify by 2009 a programme of measures for achieving the environmental objectives of the Water Framework Directive cost-effectively (Article 11, Annex III);

¾ To produce and publish River Basin Management Plans (RBMPs) for each RBD including the designation of heavily modified water bodies, by 2009 (Article 13, Article 4.3);

¾ To implement water pricing policies that enhance the sustainability of water resources by 2010 (Article 9);

¾ To make the programme of measures operational by 2012 (Article 11); and,

¾ To implement the programmes of measures and achieve the environmental objectives by 2015 (Article 4).



Look Out!

Member States may not always reach good water status for all water bodies of a river basin district by 2015, for reasons of technical feasibility, disproportionate costs or natural conditions. Under such conditions that will be specifically explained in the RBMPs, the Water Framework Directive offers the possibility to Member States to engage into two further six- year cycles of planning and implementation of measures.

1.8 Changing the management process – information, consultation and participation

Article 14 of the Directive specifies that Member States shall encourage the active involvement of all interested parties in the implementation of the Directive and development of river basin management plans. Also, Member States will inform and consult the public, including users, in particular for:

¾ The timetable and work programme for the production of river basin management plans and the role of consultation at the latest by 2006;

¾ The overview of the significant water management issues in the river basin at the latest by 2007; and,

¾ The draft river basin management plan, at the latest by 2008.

Integration: a key concept underlying the Water Framework Directive

The central concept to the Water Framework Directive is the concept of integration that is seen as key to the management of water protection within the river basin district:

¾ **Integration of environmental objectives,** combining quality, ecological and quantity objectives for protecting highly valuable aquatic ecosystems and ensuring a general 'good' status of other waters;

¾ **Integration of all water resources**, combining fresh surface water and groundwater bodies, wetlands, coastal water resources **at the river basin scale**;

¾ **Integration of all water uses, functions and values** into a common policy framework, i.e. investigating water for the environment, water for health and human consumption, water for economic sectors, transport, leisure, water as a social good;

¾ **Integration of disciplines, analyses and expertise,** combining hydrology, hydraulics, ecology, chemistry, soil sciences, technology, engineering and economics to assess current pressures and impacts on water resources and identify measures for achieving the environmental objectives of the Directive in the most cost-effective manner;

¾ **Integration of water legislation into a common and coherent framework.** The requirements of some old water legislation (e.g. the Freshwater Fish Directive) have been reformulated in the Water Framework Directive to meet modern ecological thinking. After a transitional period, these old Directives will be repealed. Other pieces of legislation (e.g. the Nitrates Directive and the Urban Wastewater Treatment Directive) must be co-ordinated in river basin management plans where they form the basis of the programmes of measures;

¾ **Integration of all significant management and ecological aspects** relevant to sustainable river basin planning including those which are beyond the scope of the Water Framework Directive such as flood protection and prevention;

¾ **Integration of a wide range of measures, including pricing and economic and financial instruments, in a common management approach** for achieving the environmental objectives of the Directive. Programmes of measures are defined in **River Basin Management Plans** developed for each river basin district;

¾ **Integration of stakeholders and civil society in decision making,** by promoting transparency and making information accessible to the public, and by offering an unique opportunity for involving stakeholders in the development of river basin management plans;

- ¾ **Integration of different decision-making levels that influence water resources and water status** (these could be at a local, regional or national level), for an effective management of all waters;
- ¾ **Integration of water management by different Member States,** for river basins shared by several countries, existing and/or future Member States of the European Union.

1.9 What is being done to support implementation?

Activities to support the implementation of the Water Framework Directive are under way in both Member States and in countries candidate for accession to the European Union. Examples of activities include consultation of the public, development of national Guidance, pilot activities for testing specific elements of the Directive or the overall planning process, discussions on the institutional framework or launching of research programmes dedicated to the Water Framework Directive.

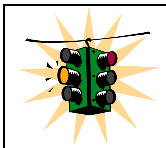
May 2001 – Sweden**: **Member States, Norway and the European Commission agreed a Common Implementation Strategy

The main objective of this strategy is to provide support to the implementation of the Water Framework Directive by developing coherent and common understanding and Guidance on key elements of this Directive. Key principles in this common strategy include sharing information and experiences, developing common methodologies and approaches, and involving experts from candidate countries and involving stakeholders from the water community.

In the context of this common implementation strategy, a series of working groups and joint activities have been launched for the development and testing of non-legally binding Guidance. A strategic co-ordination group oversees these working groups and reports directly to the water directors of the European Union and Commission that play the role of overall decision body for the Common Implementation Strategy.

A working group has been created for dealing specifically with monitoring issues. The main short-term objective of this working group was the development of a non-legally binding and practical Guidance for supporting the implementation of the monitoring requirements of the Water Framework Directive. The members of this working group on monitoring are scientists, technical experts and stakeholders from European Union Member States, from a limited number of candidate countries to the European Union and from focal point organisations involved in water and environmental policy in candidate countries.

The working group on monitoring has organised several discussions and feedback events such as meetings and workshops, to ensure an adequate input and feedback from a wider audience during the Guidance development phase, and to evaluate earlier versions of the Guidance Document,. You will find the synthesis of key discussions and events in Annex VII.



Look Out! You can contact the experts involved in the working group on monitoring

The list of working group 2.7 (monitoring) members with full contact details can be found in Annex V. If you need input into your own activities, contact a member from the working group in your country. If you want more information on specific scoping and testing pilot studies, you can also contact directly the persons in charge of carrying out these studies.

Developing the Guidance Document: an interactive process

Within a very short time period, a large number of experts and stakeholders have been involved at varying degrees in the development of this Guidance Document. The process for their involvement has included the following activities:

¾ Regular meetings of the 40-plus experts and stakeholder members of working group 2.7;

¾ Organisation of four workshops to present and discuss the activities and preliminary output of Working group 2.7:

- Working Group Meeting No. 1 June 2001 - Rome, Italy. Discussion of proposed work schedule and member state contributions;
- Working group co-ordination team meeting November 2001 – Brussels, Belgium. Meeting held with small group of experts from lead countries to discuss progress on the work plan and agree on the next phases;
- Working Group Meeting No. 2 January 2002 - Rome, Italy. Presentation and discussion of the first draft. Identification of areas for comment and Member State contributions;
- Working Group Meeting No. 3 June 2002 - Brussels, Belgium. Revised draft presented and discussed;
- Working Group Meeting No. 4 September 2002 – Copenhagen, Denmark. Presentation of final draft for comment and discussion.

¾ Regular interactions with experts from other working groups of the Common Implementation Strategy, mainly those dealing with the assessment of pressures and impacts, intercalibration, reference conditions, groundwater, coastal waters and river basin planning. Three events for discussing and evaluating the Guidance Document; and,

¾ A final evaluation of the draft Guidance (content and format) was undertaken following the Copenhagen working group meeting. Criteria for evaluating the Guidance were completeness, rigour, practicality, ease of use, ease of understanding and usefulness, and integration with other disciplines and elements of the Directive.

2 Common Understanding of the Monitoring Requirements of the Water Framework Directive

2.1 Monitoring requirements for the Directive

Article 8 of the Directive establishes the requirements for the monitoring of surface water status, groundwater status and protected areas. Monitoring programmes are required to establish a coherent and comprehensive overview of water status within each river basin district. The programmes have to be operational at the latest by 22 December 2006, and must be in accordance with the requirements of Annex V.

Annex V indicates that monitoring information from **surface waters** is required for:

¾ The classification of status. (*Note: Member States must provide a map for each river basin district in their territory illustrating the classification of the ecological and chemical status of each body of water using the colour-coding system specified by the Directive.)*

¾ Supplementing and validating the Annex II risk assessment procedure;

¾ The efficient and effective design of future monitoring programmes;

¾ The assessment of long-term changes in natural conditions;

¾ The assessment of long-term changes resulting from widespread anthropogenic activity;

¾ Estimating pollutants loads transferred across international boundaries or discharging into seas;

¾ Assessing changes in status of those bodies identified as being at risk in response to the application of measures for improvement or prevention of deterioration;

¾ Ascertaining causes of water bodies failing to achieve environmental objectives where the reason for failure has not been identified;

¾ Ascertaining the magnitude and impacts of accidental pollution;

¾ Use in the intercalibration exercise *(Note this is not an Article 8 requirement)*;

¾ Assessing compliance with the standards and objectives of Protected Areas; and,

¾ Quantifying reference conditions (where they exist) for surface water bodies. (*Note that this is an Annex II requirement).*

Annex V also indicates that monitoring information from **groundwater** is required for:

¾ Providing a reliable assessment of quantitative status of all groundwater bodies or groups of bodies; *(Note: Member States must provide maps illustrating the quantitative status of all groundwater bodies or groups of bodies using the colour-coding scheme set out in the Directive);*

¾ Estimating the direction and rate of flow in groundwater bodies that cross Member States boundaries;

¾ Supplementing and validating the impact assessment procedure;

¾ Use in the assessment of long term trends both as a result of changes in natural conditions and through anthropogenic activity;

¾ Establishing the chemical status of all groundwater bodies or groups of bodies determined to be at risk. *(Note: Member States must provide maps illustrating the* *chemical status of all groundwater bodies or groups of bodies using the colour-coding scheme set out in the Directive.)*;

¾ Establishing the presence of significant and sustained upwards trends in the concentrations of pollutants. *(Note: Member States must indicate on the maps of chemical status using a black-dot, those groundwater bodies in which there is a significant upward trend);* and,

¾ Assessing the reversal of such trends in the concentration of pollutants in groundwater *(Note: Member States must indicate on the maps of chemical status using a blue-dot, those groundwater bodies in which a significant upward trend has been reversed).*

2.1.1 Reporting

The following must be reported in the River Basin Management Plans:

¾ Maps of the monitoring networks;

¾ Maps of water status;

¾ An indication on the maps of the bodies of groundwater which are subject to a significant upward trend in concentration of pollutants and an indication of the bodies of groundwater in which such trends have been reversed; and,

¾ Estimates of the confidence and precision attained by the monitoring systems.

Three types of monitoring[1] for surface waters are described in Annex V: surveillance, operational and investigative monitoring. For groundwater a water level monitoring network is required which will provide a reliable assessment of the quantitative status of all groundwater bodies or groups of bodies including an assessment of the available groundwater resource. It should be noted that the water level network alone will not be able to achieve this assessment. In terms of groundwater chemical status, surveillance and operational monitoring are required. An additional objective of groundwater surveillance and operational monitoring is to provide information that can be used in the assessment and in establishing the presence of long term trends in pollutant concentrations. Surveillance monitoring data should also be used to assess long term trends in natural conditions.

These types are to be supplemented by monitoring programmes required for Protected Areas registered under Article 6. Annex V only describes requirements for Drinking Water Protected Areas in surface water and for Protected Areas for habitats and species. Member States may wish to integrate monitoring programmes established for other Protected Areas within the programmes established under the Directive. This is likely to improve the cost-effectiveness of the various programmes.

2.2 What Water bodies should be monitored

The Water Framework Directive covers **all** waters[2] including inland waters (surface water and groundwater) and transitional and coastal waters up to one sea mile (and for the chemical status also territorial waters which may extend to 12 sea miles) from the territorial baseline of a Member State independent of the size and the characteristics[3].

This totality of waters is, for the purpose of the implementation of the directive, attributed to geographical or administrative units, in particular the **river basin**, the **river basin district**,

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[1] In the context of the Directive monitoring means the gathering of data and information on the status of water, and does not include the direct measurement of emissions and discharges to water. The latter is being dealt with by WG 2.1, IMPRESS

[2] Taken from horizontal Guidance on the application of the term "water body", version 7.0
[3] Articles 2 (1), (2) and (3)

and the "**water body**"[4]. In addition, groundwaters and stretches of coastal waters must be associated with a river basin (district).

Whereas the river basin is the geographical area related to the hydrological system, the river basin district must be designated by the Member States in accordance to the directive as the "**main unit for management of river basins**"[5].

One key purpose of the Directive is to prevent further deterioration of, and protect and enhance the status of aquatic ecosystems, and with regard to their water needs, terrestrial ecosystems and wetlands directly depending on the aquatic ecosystems. The success of the Directive in achieving this purpose and its related objectives will be mainly measured by the status of "water bodies". "Water bodies" are therefore the units that will be used for reporting and assessing compliance with the Directive's principal environmental objectives. However, it should be emphasised that the identification of a "water body" is a tool not an objective in itself.

Monitoring is a cross-cutting activity within the Directive and as such there are important interrelationships with other Articles and Annexes of the Directive. A key Article in relation to monitoring and the design of appropriate programmes for surface waters and groundwater is Article 5. Figures 2.1 and 2.2 summarise the relationship between articles 5 and 8 for surface waters and groundwater, respectively. Article 5 requires river basin districts to be characterised and the environmental impact of human activities to be reviewed in accordance with Annex II. The first assessments must be completed by 22 December 2004. Risk assessments will be on-going as they will be required for subsequent River Basin Management Plans. The first assessments must be completed 2 years before monitoring programmes have to be operational.

Annex II describes a process by which surface water bodies are identified, categorised and then typified according to one of two systems A or B given in section 1.2 of the Annex. Type-specific reference conditions have to be identified for each surface water body type. It is the type specific reference conditions from each surface water body type that the monitoring results will be compared with to give an assessment of the status of a water body categorised in the water body type. Information on the type and magnitude of the significant anthropogenic pressures to which the surface water bodies in each river basin district are subject has to be collected and maintained. There must then be an assessment of the susceptibility of the surface water status of bodies to the pressures identified, and of the likelihood that surface water bodies within the river basin district will fail to meet the environmental quality objectives set under Article 4. This assessment will use any available existing monitoring data: the extent of existing data will vary greatly from country to country. Also expert judgement and /or modelling approach (i.e. risk assessment) can be used. For the first assessment there will not be data arising from the Article 8 monitoring programmes as they do not have to be operational until the end of 2006: data should be available for subsequent assessments for future RBMPs. However, many countries already have extensive monitoring programmes.

[4] *Articles 2 (13), (15), (10), and (12) respectively*
[5] *Article 2 (15)*

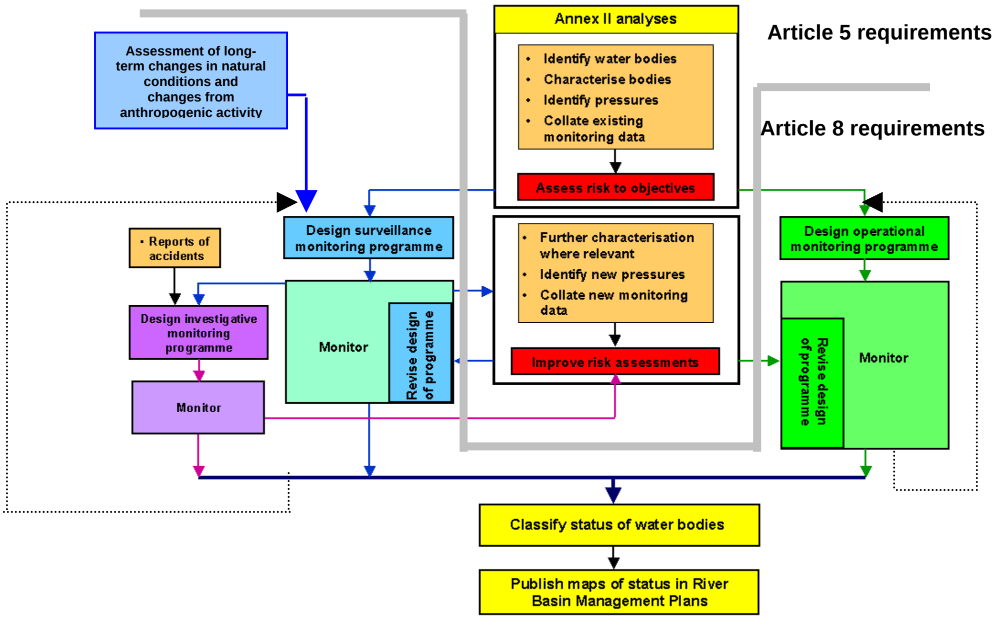


Figure 2.1 **Schematic diagram illustrating the relationship between Article 5 and Article 8 in the design of surface water monitoring programmes**

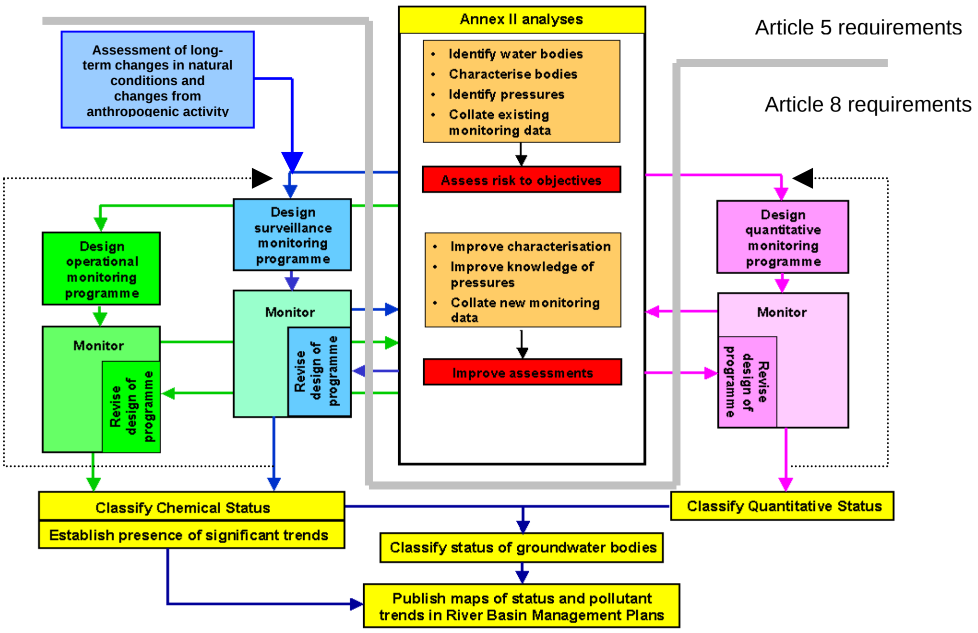
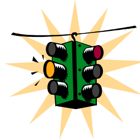


Figure 2.2 **Schematic diagram illustrating the relationship between Article 5 and Article 8 in the design of groundwater monitoring programmes**

Thus the Annex II risk assessments play a key role in the initial design and subsequent revision of the monitoring programmes required by the Directive.

The Directive introduces a flexible hierarchical system for monitoring the very many different types of water body across Europe reflecting the fact that natural physical and geological conditions and anthropogenic pressures vary greatly across Europe. Because of this, a monitoring system designed for one part of Europe may not be entirely applicable in another. The Directive seeks ways of harmonising the results of monitoring systems and ecological assessments rather than imposing a common ecological quality assessment system in each country.

	***Look Out! The methodology from this Guidance Document must be adapted to regional and national circumstances*** *The Guidance Document proposes an overall pragmatic approach. Because of the diversity of circumstances within the European Union, Member States may apply this Guidance in a flexible way in answer to problems that will vary from one river basin to the next. This proposed Guidance will therefore need to be tailored to specific circumstances. However, these adaptations should be justified and should be reported in a transparent way.*

The objective of monitoring is to establish a coherent and comprehensive overview of water status within each River Basin District and must permit the classification of all surface water bodies into one of five classes[6] and groundwater into one of two classes[7]. However, this does not mean that monitoring stations will be needed in each and every water body. Member States will have to ensure that enough individual water bodies of each water body type are monitored. They will also have to determine how many stations are required in each individual water body to determine its ecological and chemical status. This process of selecting water bodies and monitoring stations should entail statistical assessment techniques, and should ensure that the overview of water status has an acceptable level of confidence and precision.

There is flexibility in terms of monitoring frequencies reflecting that some determinands and quality elements (in terms of surface waters) will be more variable than others. Member States can also plan their monitoring programmes and resources so that not all the selected quality elements (for surface waters) and chemical parameters (for groundwater) have to be monitored every year at every station. This should prevent a situation where countries have to monitor for chemical substances even though they are known not to be present in the catchment, except where validation of the risk assessments is required. In short, cost-effective and targeted monitoring programmes can be designed.

An important aspect in the design of monitoring programmes is quantifying the temporal and spatial variability of quality elements and the parameters indicative of the quality elements in the surface water bodies being considered. Those that are very variable may require more sampling (and hence cost) than those that are more stable or predictable. Alternatively, variability might be reduced or managed by an appropriate targeted or stratified sampling programme which collects data in a limited but well-defined sampling window.

For surface water bodies, the Directive requires that sufficient surface water bodies are monitored in surveillance programmes to provide an assessment of the overall surface water status within each catchment and sub-catchment within the river basin district. Operational monitoring is to establish the status of those water bodies identified as being at risk of failing their environmental objectives, and to assess any changes in their status from the programmes of measures. Operational monitoring programmes must use parameters indicative of the quality element or elements most sensitive to the pressure or pressures to which the body or group of bodies is subject. This means that the least number of estimated quality element values may be used in status classification. This will help reduce the errors in the assessment of status. It will therefore be inherently less error prone than surveillance

[6] *Annex V 1.3*
[7] *Annex V 2.2.4 and 2.4.5*

monitoring which uses estimates of all quality elements (i.e. the chance of a water body being wrongly classified will in theory be lower in operational monitoring, everything else being equal).

Indicators must be used in monitoring to estimate the value for the relevant biological quality element. Where the confidence in the estimate provided by one indicator is considered unacceptable, several indicators may be used and a weighting procedure adopted to obtain an acceptable confidence in the estimated value of the quality element. This will also help reduce errors in the assessment of status. Indicators can also be chosen for which reference conditions can be most reliably established and for which errors in monitoring are small and well known.

The purpose of delineating water bodies is to provide for an accurate description of the status of surface water and groundwater and provide a sound basis for management of the water environment. The number of water bodies required in monitoring programmes will, therefore, be strongly dependent on the degree of variation in the status of the water environment as well as on the extent and characteristics of surface waters in a Member State's territory (e.g. number of lakes, whether the State has a coast, etc). Where there are numerous and significant differences in status, water bodies will be equally numerous to reflect those differences. Where status is similar, water bodies will tend to be larger and therefore fewer in number. The scale of monitoring programmes will be dependent to some degree on the numbers of water bodies – or more accurately on the extent of, and variability in, impacts on the water environment. However, the amount of monitoring required will also depend on the degree to which the characteristics of, and range of pressures on, a Member State's water bodies allow them to be grouped for monitoring purposes.

2.3 Clarification of the term "supporting"

The Directive specifies quality elements for the classification of ecological status[8] that include hydromorphological elements supporting the biological elements and chemical and physico-chemical elements supporting the biological elements. For surveillance monitoring, parameters indicative of all the biological, hydromorphological and all general and specific physico-chemical quality elements are required to be monitored. For operational monitoring, the parameters used should be those indicative of the biological and hydromorphological quality elements most sensitive to the pressures to which the body is subject, all priority substances discharged and other substances discharged in significant quantities. The ecological status classification[9] of a body of water is to be represented by the lower of the values for the biological and physico-chemical monitoring results for the relevant quality elements classified in accordance with the normative definitions[10].

Supporting means that the values of the physico-chemical and hydromorphological quality elements are such as to support a biological community of a certain ecological status, as this recognises the fact that biological communities are products of their physical and chemical environment. The latter 2 aspects fundamentally determine the type of water body and habitat, and hence the type-specific biological community. It is not intended that these supporting elements can be used as surrogates for the biological elements in surveillance and operational monitoring. The monitoring or assessment of the physical and physico-chemical quality elements will support the interpretation assessment and classification of the results arising from the monitoring of the biological quality elements.

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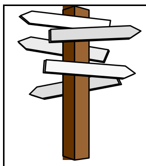
[8] *Annex V.1.1*
[9] *Annex V.1.4.2*
[10] *Annex V.1.2*



The classification of ecological status is being considered by Working Group 2.3 on *"establishing reference conditions and ecological status class boundaries for inland surface waters*", and Working Group 2.4 on *"typology, reference conditions and classification systems for transitional and coastal waters"* .The reader should refer to the Guidance Documents produced by these 2 Working Groups (WFD CIS Guidance Document Nos. 10 and 5). for information on the use of quality elements for the classification of ecological status.

The Directive permits Member States to make estimates of the values of the biological quality elements using monitoring data for parameters indicative of the biological quality elements. The use of indicator parameters should facilitate reliable and cost-effective assessments:

1. Monitoring whole biological quality elements, such as the abundance of all fish species, in each water body could be a very onerous task. The Directive therefore provides that Member States may use species or groups of species representative of the quality element as a whole in their monitoring systems[11].
2. Second, the possibility of using more than one indicator to estimate the value for a biological quality element could provide an important means of avoiding unacceptable risks of misclassification. This is because the results for different indicators can be cross-checked. If the result for one is at odds with the result for another, this may suggest that more data is needed to achieve the required confidence in the estimated value of the quality element.

In some situations, one or more of the indicators used may need to be non-biological. For example, where the pressure to which a water body is subject results in hydromorphological changes, such as a reduction in habitat area, estimates of the values for the abundance of biological elements in the remaining habitat could be made using biological indicators. However, to provide the necessary estimate of the effect of the loss of habitat on the abundance of the quality elements in the water body as a whole, these estimates would need to be combined with a non-biological measure of the reduction in habitat area.

In another situation, a biological indicator is able to provide an estimate of the value of a biological quality element, such as phytoplankton abundance, but the errors in that estimate do not provide for an acceptable level of confidence in status classification. The pressure to which the water body is subject also affects a non-biological parameter; phosphorous concentration. Monitoring information on this parameter could therefore be used to improve confidence in the value of the biological quality element estimated by the biological indicator.

Key Principal

The use of non-biological indicators for estimating the condition of a biological quality element may complement the use of biological indicators but it cannot replace it. Without comprehensive knowledge of all the pressures on a water body and their combined biological effects, direct measures of the condition of the biological quality elements using biological indicators will always be necessary to validate any biological impacts suggested by non-biological indicators.

2.4 Horizontal Guidance on the application of the term "water body"

Article 2.10 of the Directive provides the following definition of a body of surface water: *"Body of surface water" means a* ***discrete and significant element*** *of surface water such as a*

[11] *Annex V 1.4.1(i)*

lake, a reservoir, a stream, river or canal, part of a stream, river or canal, a transitional water or a stretch of coastal water.

Article 2.12 defines a groundwater body as: "*Body of groundwater" means a distinct volume of groundwater within an aquifer or aquifers*.

The Commission, at the request of many of the Working Groups, is developing a horizontal Guidance Document on the identification of water bodies under the Water Framework Directive[12]. Some key aspects with regards to the design and implementation of appropriate monitoring programmes are reproduced below.

Key Principal

The "water body" should be a coherent sub-unit in the river basin (district) to which the environmental objectives of the directive must apply. Hence, the main purpose of identifying "water bodies" is to enable the status to be accurately described and compared to environmental objectives[13].

It should be clear that the identification of water bodies is, first and foremost, based on geographical and hydrological determinants. However, the identification and subsequent classification of water bodies must provide for a sufficiently accurate description of this defined geographic area to enable an unambiguous comparison with the objectives of the Directive. This is because the environmental objectives of the Directive, and the measures needed to achieve them, apply to "water bodies". A key descriptor in this context is the "status" of those bodies. If water bodies are identified that do not permit an accurate description of the status of aquatic ecosystems, Member States will be unable to apply the Directive's objectives correctly. At the same time, an endless sub-division of water bodies should be avoided in order to reduce administrative burden if it does not fulfil any purpose as regards the proper implementation of the Directive. In addition, the aggregation of water bodies may, under certain circumstances, also help to reduce meaningless administrative burden, in particular for smaller water bodies.

However, identifying water bodies that will provide for an accurate description of the status of surface water and groundwater will require information from the Article 5 analyses and reviews, and the Article 8 monitoring programmes. Some of the necessary information will not be available before 2004. The information that is available is likely to be updated and improved in the period prior to the publication of each river basin management plan.

Geographical or hydromorphological features can significantly influence surface water ecosystems and their vulnerability to human activities. These features can also differentiate discrete elements of surface water. For example, the confluence of one part of a river with another could clearly demarcate a geographically and hydromorphologically distinct boundary to a water body.

However, the Directive does not exclude other elements, such as a part of a lake or part of transitional water, from being considered as water bodies. For example, if part of a lake is of a different type to the rest of the lake, the lake must be sub-divided into more than one surface water body.

A requirement that is implicit in the Directive is that the purpose of identifying "water bodies" is to enable the **status** of surface waters and groundwater to be accurately described.

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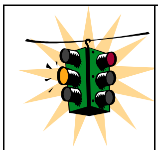
[12] *Version 8.0, 31 October 2002*

[13] *An estimate of the status of water bodies will be required to assess the likelihood that they will fail to meet the environmental quality objectives set for them under Article 4 [Article 5; Annex II 1.5 & 2]. The status of water bodies must be classified using information from the monitoring programmes [Article 8, Annex V 1.3, 2.2 & 2.4]. The status of water bodies must be reported in the river basin management plans [Article 13, Annex VII] and, where necessary, measures must be prepared [Article 11, Annex VI].*

A discrete element of surface water should not contain significant elements of different status. A "water body" must be capable of being assigned to a single ecological status class with sufficient confidence and precision through the Directive's monitoring programmes.

The delineation of bodies of groundwater must ensure that the relevant objectives of the Directive can be achieved. This does not mean that a body of groundwater must be delineated so that it is homogeneous in terms of its natural characteristics, or the concentrations of pollutants or level alterations within it. However, bodies should be delineated in a way that enables an appropriate description of the quantitative and chemical status of groundwater.

It is clearly possible to progressively subdivide waters into smaller and smaller units that would impose significant logistic burdens. However, it is not possible to define the scale below which subdivision is inappropriate. It will be necessary to balance the requirement to adequately describe water status with the need to avoid the fragmentation of surface waters into unmanageable numbers of water bodies. In addition, it may be appropriate to aggregate water bodies under certain circumstances, to reduce meaningless administrative burden. In the end, it is a matter for Members States to decide on the basis of the characteristics of each River Basin District.



Look Out!
The Directive only requires sub-divisions of surface water and groundwater that are necessary for the clear, consistent and effective application of its objectives. Sub-divisions of surface water and groundwater into smaller and smaller water bodies that do not support this purpose should be avoided.

Key Principal
Surface water bodies or bodies of groundwater may each be grouped for the purposes of assessing the risk of failing to achieve the objectives set for them under Article 4 (pressures and impacts). They may also be grouped for monitoring purposes where monitoring sufficient indicative or representative water bodies in the sub-groups of surface water or groundwater bodies provides for an acceptable level of confidence and precision in the results of monitoring, and in particular the classification of water body status.

2.5 Risk, precision and confidence

Risk[14] and confidence[15] are words used in Annex II[16] (in terms of risk of failing environmental objectives, and confidence in the values of reference conditions), and risk, confidence and also precision[17] are words used in Annex V[18] (design of monitoring programmes). Their interpretation will affect the scale and extent of the monitoring required to assess status at any particular time and changes in status with time. What are considered to be "acceptable", "adequate" and "sufficient" levels of precision and confidence, and a "significant" risk, will determine aspects such as the:

¾ number of water bodies included in the various types of monitoring;

¾ number of stations that will be required to assess the status of each water body; and

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[14] *At the simplest level, a risk can be thought of as the chance of an event happening. It has two aspects: the chance, and the event that might happen. These are conventionally called the probability and the consequence.*
[15] *The probability (expressed as a percentage) that the answer obtained (e.g. by the monitoring programme) does in fact lie within calculated and quoted limits, or within the desired or designed precision.*
[16] *Annex II.1.1.5, 2.1 and 1.3*
[17] *The discrepancy between the answer (e.g. a mean) given by the monitoring and sampling programme and the true value.*
[18] *Annex V 1.3, 2.3 and 2.4*

¾ frequency at which parameters indicative of surface water quality elements will have to be monitored.

Choosing levels of precision and confidence would set limits on how much uncertainty (arising from natural and anthropogenic variability) can be tolerated in the results of monitoring programmes. In terms of monitoring for the Directive, it will be necessary to estimate the status of water bodies and in particular to identify those that are not of 'good' status or good ecological potential or are deteriorating in status. Thus status will have to be estimated from the sampled data. This estimate will almost always differ from the true value (i.e. the status which would be calculated if all water bodies were monitored and sampled continuously for all components that define quality).

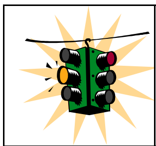
The level of acceptable risk will affect the amount of monitoring required to estimate a water body's status. In general terms, the lower the desired risk of misclassification, the more monitoring (and hence costs) required to assess the status of a water body. It is likely that there will have to be a balance between the costs of monitoring against the risk of a water body being misclassified. Misclassification implies that measures to improve status could be inefficiently and inappropriately targeted. It should also be borne in mind that in general the cost of measures for improvement in water status would be orders of magnitude greater than the costs of monitoring. The extra costs of monitoring to reduce the risk of misclassification might therefore be justified in terms of ensuring that decisions to spend larger sums of money required for improvements are based on reliable information on status. Further, from an economics point of view, stronger criteria should be applied to avoid a situation where water bodies fulfilling the objective are misjudged and new measures applied. Also it should be noted that for surface water surveillance monitoring, and all groundwater monitoring, sufficient monitoring should be done to validate risk assessments and test assumptions made.

The Directive has not specified the levels of precision and confidence required from monitoring programmes and status assessments. This perhaps recognises that achievement of too rigorous precision and confidence requirements would entail a much-increased level of monitoring for some, if not all, Member States.

Key Principal
On the other hand the actual precision and confidence levels achieved should enable meaningful assessments of status in time and space to be made. Member States will have to quote these levels in RBMPs and will thus be open to scrutiny and comment by others. This should serve to highlight any obvious deficiencies or inadequacies in the future.

The starting point for many Member States will probably be an assessment of existing stations and samples to see what level of precision and confidence can be achieved by those resources. It is likely that this will have to be an iterative process with modification and revision of monitoring programmes to achieve levels of precision and confidence that allow meaningful assessments and classification.

It is also likely that Member States will use expert judgement to some extent in assessing the risk of misclassification. For example in the case of a misclassifying bodies "at risk" the persons responsible for making the decision to implement expensive measures will clearly secure their decisions by further assessments before implementing the measures. In the case of misclassifying bodies as "not being at risk" there will be much local experience and expert judgement (by water managers or public persons) to doubt the monitoring results and assessment and look for further clarification.



Look Out!
Guidance on the level of precision required for classification is being discussed by WG 2.3 Reference conditions inland surface water and WG 2.4 Typology, classification of transitional, coastal waters.

2.6 Inclusion of wetlands within the monitoring requirements of the Directive

"Wetland ecosystems are ecologically and functionally significant elements of the water environment, with potentially an important role to play in helping to achieve sustainable river basin management. The Water Framework Directive does not set environmental objectives for wetlands. However, wetlands that are dependent on groundwater bodies, form part of a surface water body, or are Protected Areas, will benefit from WFD obligations to protect and restore the status of water. Relevant definitions are developed in CIS horizontal Guidance Documents water bodies (WFD CIS Guidance Document No. 2) and further considered in the Guidance Document on wetlands (currently under development).

Pressures on wetlands (for example physical modification or pollution) can result in impacts on the ecological status of water bodies. Measures to manage such pressures may therefore need to be considered as part of river basin management plans, where they are necessary to meet the environmental objectives of the Directive.

Wetland creation and enhancement can in appropriate circumstances offer sustainable, cost-effective and socially acceptable mechanisms for helping to achieve the environmental objectives of the Directive. In particular, wetlands can help to abate pollution impacts, contribute to mitigating the effects of droughts and floods, help to achieve sustainable coastal management and to promote groundwater recharge. The relevance of wetlands within programmes of measures is examined further in a separate horizontal Guidance Document on wetlands (currently under development).

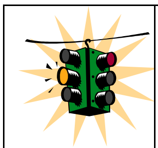
Wetlands are not defined as a separate water category or water body type within the Directive. There are, however, explicit references to wetlands within the Directive[19]. Wetlands could be considered as relevant under the Directive in three contexts:

1. As part of the structure and condition of riparian zones of rivers, shore zones of lakes and intertidal zones of transitional and coastal waters. The structure and condition of these zones is one of the hydromorphological quality elements specified in Annex V 1.1 – 1.2;
2. As directly dependent terrestrial ecosystems in the definition of good groundwater quantitative status and good groundwater chemical status (Annex V 2.1.2 and 2.3.2); and
3. For use in supplementary measures, which MSs may use where cost-effective, to achieve the Directive's objectives (Annex VI B vii).

"Wetlands" are defined by Articles 1.1 and 2.1 of the Ramsar Convention (Ramsar, Iran, 1971) as shown below:

Article 1.1: *".. Wetlands are areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres.*"

Article 2.1, wetlands: *"may incorporate riparian and coastal zones adjacent to the wetlands, and islands or bodies of marine water deeper than six metres at low tide lying within the wetlands".*



Look Out!
The inclusion of wetlands in the monitoring requirements of the Directive is a matter of discussion between Members States, NGOs and other stakeholders. As a result the EEB and WWF prepared a draft paper regarding wetlands and WFD. It was presented at the Strategic Co-ordination Group (SCG) (30.09.0 -01.10.02) meeting in order to determine what actions are required. At this meeting it was agreed that the SCG should take the issue of wetlands under the umbrella of the CIS and to prepare a 'horizontal guidance' within 2003.

[19] *e.g. Article 1(a), Preamble (8), (23)*

2.7 Surveillance monitoring of surface waters

2.7.1 Objectives and timing

The objectives[20] of surveillance monitoring of surface waters are to provide information for:

¾ Supplementing and validating the impact assessment procedure detailed in Annex II;

¾ The efficient and effective design of future monitoring programmes;

¾ The assessment of long term changes in natural conditions; and

¾ The assessment of long term changes resulting from widespread anthropogenic activity.

The results of such monitoring should be reviewed and used, in combination with the impact assessment procedure described in Annex II, to determine requirements for monitoring programmes in the current and subsequent River Basin Management Plans (RBMP).

As has already been described, there will be no information arising from surveillance monitoring for the first risk assessment undertaken under Article 5 – monitoring programmes have to be operational by December 2006, and the first Article 5 characterisation/risk assessment completed by December 2004. However, any existing monitoring data should be used in the assessment. Many countries have already established extensive monitoring programmes.

Surveillance monitoring has to be undertaken for at least a period of one year during the period of a RBMP. The deadline for the first RBMP is 22 December 2009. The monitoring programmes must start by 22 December 2006. The first results will be needed for the first draft RBMP to be published at the end of 2008[21], and then for the finalised RBMPs at the end of 2009. These plans must include status maps.

2.7.2 Selection of monitoring points

The Directive requires that sufficient water bodies should be included in the surveillance monitoring programme to provide an assessment of the overall surface water status within each catchment and sub-catchment of the river basin district. This would imply that more water bodies would have to be monitored in a heterogeneous river basin district in terms of types of water body characteristics and anthropogenic pressures than in a more homogenous catchment. In both cases a statistically representative sub sample would be adequate. A good example of representative sub sampling is in some Nordic lake monitoring programmes where only relatively few of the many thousands of lakes are monitored and directly assessed. The results from the 'few' lakes are then extrapolated to the whole 'population' of lakes being assessed.

If there is low confidence in the Annex II risk assessments (e.g. because of limited existing monitoring data), more surveillance monitoring will be required initially to supplement and validate the assessments than will be the case where existing information is extensive.

Surveillance monitoring may also initially need to be more extensive in terms of the number of water bodies included, monitoring stations within bodies and the range of quality elements. This is because:

¾ of the probable lack of appropriate existing monitoring information and data;

¾ the Directive requires Member States to consider a different range of quality elements and a different range of pressures than have previous Directives.

[20] *Annex V.1.3.1*
[21] *Article 14.1.c*

Member States may also wish or have the need to (depending on the amount of existing information and the confidence in the first Annex II risk assessments) undertake surveillance monitoring each year, at least during the first three years (2006-2008).

For subsequent surveillance monitoring programmes the same principles, outlined above, of validating the risk assessment (which may well have changed) etc, should be used to develop the programme but, depending on the additional information provided from the other monitoring programmes, such as the operational monitoring programmes, the extent of the surveillance monitoring programme will change with time.

Annex II risk assessments are to identify those water bodies at risk of failing EQOs. If confidence in the identification of water bodies at risk is still low after both the Annex II risk assessments and their supplementation and validation using surveillance monitoring data, bodies that are actually not at risk should be assumed to be at risk. Consequently, a larger operational monitoring network will be required than would be the case if water bodies at risk and not at risk were more reliably differentiated by the risk assessments.

Key Question

For risk assessments, and therefore surveillance monitoring what is the acceptable risk of a body being described as not at risk of failing the objectives when it is in fact at risk of such a failure?

The Directive also stipulates that monitoring should be carried out at points where:

¾ The rate of water flow is significant within the river basin district as a whole; including points on large rivers where the catchment is greater than 2 500 km^2;

¾ The volume of water present is significant within the river basin district, including large lakes and reservoirs;

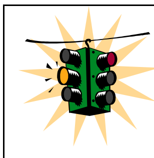
¾ Significant bodies of water cross a Member State boundary;

¾ Sites are identified under the Information Exchange Decision 77/795/EEC; and

¾ At such other sites as are required to estimate the pollutant load which is transferred across Member States boundaries, and which is transferred into the marine environment.

The size typology given in Annex II (System A) implies that rivers with catchment areas greater than 10 km^2 and (b) lakes greater than 0.5 km^2 in surface area are water bodies that fall under the requirements of the Directive and might need to be included within the water status assessment and monitoring. Surface waters below the System A typology size thresholds could be Protected Areas, be important to the ecology of the river basin as a whole (e.g. important spawning and breeding grounds), or be subject to pressures that have significant consequences elsewhere in the river basin district. In the System B typology no such size limits are implied, though the typology used must achieve at least the same degree of differentiation as would be achieved using System A. Member States may thus wish or need to include small water bodies within the monitoring and assessment requirements of the Directive.

In practice Member States will determine the size of water body that needs to be included in monitoring programmes. It will depend on the nature (natural and anthropogenic) of each River Basin District being characterised and the attainment of the objective to obtain a coherent and comprehensive overview of water status within the River Basin District.

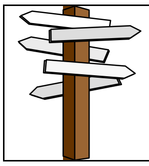


Look Out!

The horizontal guidance on water bodies (see section 3) indicates that Member States have flexibility to decide whether the purposes of the Directive, which apply to all surface waters, can be achieved without the identification of every minor but discrete element of surface water as a water body.

Surveillance monitoring is also required to provide information on long-term natural changes and long-term changes resulting from widespread anthropogenic activity. Information on the first will be important if such changes are likely to affect reference conditions. Monitoring for long-term natural changes is likely to be focused on high and maybe 'good' status water bodies. This is because such changes (possibly relatively small and gradual) are more likely to be detectable in the absence of the impact of anthropogenic activities which may mask natural changes. In terms of changes resulting from widespread anthropogenic activity, monitoring will be important to determine or confirm the impact of, for example, long range transport and deposition of pollutants from the atmosphere. If this is likely to lead to a risk of water bodies deteriorating in status (any status level down to poor) then those water bodies or groups of bodies will have to be included in operational monitoring programmes.

The first surveillance programme should also seek to establish a quantitative baseline for future assessments of long-term natural or anthropogenically induced changes, and also against which reductions in pollution from Priority Substances (PH), and cessation and phasing out of emissions of Priority Hazardous Substances (PHS) will be judged. This will be important in supplementing and validating the assessment of whether water bodies are at risk of failing Article 4 EQOs[22] or not.



The EAF Expert Group on the Analysis and Monitoring of Priority Substances will also be considering the assessment of compliance of PS and PHS in terms of the WFD.

2.7.3 Selection of quality elements

For surveillance monitoring, Member States must monitor at least for a period of a year parameters indicative of all biological, hydromorphological and general physico-chemical quality elements. The relevant quality elements for each type of water are given in Annex V.1.1. Thus for rivers, the biological parameters chosen to be indicative of the status of each biological element such as the aquatic flora, macro-invertebrates and fish must be monitored for. For example, in the case of the aquatic flora, the parameters might be presence or absence of indicator species or the population structure. The Directive indicates that monitoring of the biological quality elements must be at an appropriate taxonomic level to achieve adequate confidence and precision in the classification of the quality elements. This applies equally to the three types of surface water monitoring.

Those priority list substances discharged into the river basin or sub-basins must be monitored. Other pollutants[23] also need to be monitored if they are discharged in significant quantities in the river basin or sub-basin. No definition of 'significance' is given but quantities that could compromise the achievement of one of the Directive's objectives are clearly significant, and as examples, one might assume that a discharge that impacted a Protected Area, or caused exceedence of any national standard set under Annex V 1.2.6 of the Directive or caused a biological or ecotoxicological effect in a water body would be expected to be significant.

A structured approach should be used to inform the process of selecting which chemical should be monitored for in the surveillance monitoring programme. This should be based on a combination of knowledge of use patterns (quantity and locations), pathways for inputs (diffuse and/or point source) and existing information on potential ecological impacts. This is a basis for the risk assessment required under Annex II of the Directive.

Additionally the selection should be informed by information on the ecological status where indications of toxic impacts are found or from ecotoxicological evidence. This will help to

[22] *Article 4.1.a.i and 4.1.a.iv*
[23] *Annex VIII*

identify situations where unknown chemicals are entering the environment which need investigative monitoring.

Further guidance on the selection of chemicals is being provided by the IMPRESS working group (WFD CIS Guidance Document No. 3).

In the case of transboundary river basins, pollution may originate from sources which cannot be identified by the Member State. For example, it may originate from a country not covered by the requirements of the WFD. In these cases there would be no Annex II assessments on which to base the monitoring (unless the effects of the pollution have been detected through existing monitoring programmes). For this reason, a Member State might decide to monitor parameters indicative of all priority substances and all other relevant pollutants at a selection of surveillance sites established to detect possible transboundary pollution problems. In addition, Member States may suitably decide to monitor for all priority substances and other relevant pollutants during the first year of surveillance, especially in the case of transboundary water bodies or pollutants with long-range mobility.

2.8 Operational monitoring of surface waters

2.8.1 Objectives

The objectives of operational monitoring[24] are to:

¾ Establish the status of those bodies identified as being at risk of failing to meet their environmental objectives; and

¾ Assess any changes in the status of such bodies resulting from the programmes of measures.

Operational monitoring (or in some cases investigative monitoring) will be used to establish or confirm the status of bodies thought to be at risk. Therefore, it is operational monitoring that will produce the environmental quality ratios used for status classification for those water bodies included in operational monitoring. It is highly focused on parameters indicative of the quality elements most sensitive to the pressures to which the water body or bodies are subject.

Key Question

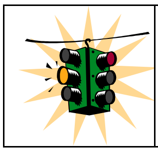
For operational monitoring, what is the acceptable level of risk of a body being wrongly classified?

The answer partly depends on what action is likely to be required if the objective is failed. Expensive measures would require higher certainty of failure to obtain EQOs to justify them than would low cost measures. Because the implications of misclassification could be serious for water users, there should be a high level of confidence in the estimates produced from operational monitoring data. In some cases failing objectives can be serious for water users, but in many cases implementation of unnecessary measures have more serious consequences for the community and therefore it is important to judge whether or not a water body is fulfilling its objectives.

Thus the required confidence in establishing the status of a water body will be highest where the implications of a misclassification to below 'good' status are high with costs potentially being wrongly imposed on a water user. Similarly there needs to be high confidence in ensuring that water bodies of less than 'good' status are not misclassified as good. In short a high level of confidence will be required close to the boundary of good/moderate status.

[24] *Annex V.1.3.2*

The more water bodies identified as being at risk of failing to achieve an environmental objective, the more operational monitoring will be required. Put more accurately: the more significant pressures there are upon the water environment, the more monitoring will be required to provide the information for managing those pressures. Generally it should be easier to achieve high levels of confidence in status classification where the pressure is very high and well identified, than at sites that lie close to the good/moderate status boundary.



Look Out!
Outputs from the Working Group on Pressures and Impacts will influence the monitoring programmes for environmental pressures such as the Priority Substances.

2.8.2 Selection of monitoring sites

Operational monitoring has to be undertaken for all water bodies that have been identified, by the review of the environmental impact of human activities (Annex II) and/or from the results of the surveillance monitoring, as being at risk of failing the relevant environmental objectives under Article 4. Monitoring must also be carried out for all bodies into which priority substances are discharged. This implies that monitoring in all such bodies will not necessarily be required as the Directive allows similar[25] water bodies to be grouped and representatively monitored.

In addition, monitoring sites for those priority list substances with environmental quality standards should be selected according to the requirements of the legislation establishing the standards.

The Directive gives further guidance on the selection of monitoring sites for other water bodies and those receiving discharges of priority list substances without specific guidance in legislation. The guidance differentiates between bodies at risk (of failing EOs) from significant point source, diffuse source and hydromorphological pressures. The number of monitoring stations selected needs to be sufficient to assess the magnitude and impact of the three specified pressures:

- In terms of all significant pressures more than one station per water body may be required to do this;
- In cases where a body of water is subject to more than one point source, stations may be selected to represent the magnitude and impact of the sources as a whole. In theory, it may sometimes be sufficient to have no monitoring points in a body where information from adjacent similar bodies, for example, allows an adequate assessment of the magnitude and impact of the point source. The confidence in any judgement of ‘sufficiency’ must be set out in the RBMP;
- In terms of diffuse sources and hydromorphological pressures, stations may be required in a number of those water bodies at risk;
- For diffuse sources, the selected water bodies need to be representative of the relative risks of the occurrence of the diffuse source pressures, and of the relative risks of the failure to achieve good surface water status. However, in selecting the representative water bodies for operational monitoring it should be taken into account that water bodies can only be grouped, for example, where the ecological conditions are similar or almost similar in terms of the magnitude and type pressure as well as in terms of hydrological and biological conditions such as retention time and food web structure. In all cases grouping must be technically or scientifically justifiable;

[25] *For example, in terms of type, pressures to which they are subject and sensitivity to those pressures.*

ξ For hydromorphological pressures, the selected water bodies should be indicative of the overall impact of the pressure to which all the bodies are subject;

ξ If only one source of pollutant is present in a water body included in the operational monitoring programme, the monitoring station should be selected according to what is judged to be the most sensitive location. If there are several sources of pollution or other pressures, it might be desirable or necessary (from the management perspective) for the operational monitoring system to be able to discriminate between the different pressures and sources. This could, for example, help in the apportionment of reduction measures relative to the impact of the pressures. Thus more than one monitoring station and different quality elements might be considered. It should also be noted that in many cases it will not be possible to measure the impact of each source of pressure, and that the impact of groups of pressures will have to be considered.

2.8.3 Selection of quality elements

For operational monitoring, Member States are required to monitor for those biological and hydromorphological quality elements most sensitive to the pressures to which the body or bodies are subject. For example, if organic pollution is a significant pressure on a river then benthic invertebrates might be the most sensitive and appropriate indicator of that pressure. Thus in the absence of other pressures, aquatic flora and fish populations may not need to be monitored in those bodies of water. However, the monitoring and assessment system must still be based on the concept of ecological status and not just reflect degrees of organic pollution without comparison to the appropriate reference conditions. This is because its ecological status must be defined.

As discussed in section 3, the use of non-biological indicators for estimating the condition of a biological quality element may complement the use of biological indicators but it cannot replace it. This does not exclude the use of non-biological indicators (such as physico-chemical parameters) when it is operationally appropriate, for example when measures to reduce pressures (e.g. discharges from Urban Waste Water Treatment Works) are related to specific physico-chemical parameters (e.g. total organic carbon, BOD or nutrients). In this case it might be appropriate to monitor non-biological indicators and biological indicators (e.g. macrozoobenthos) at different frequencies with the results from the physico-chemical monitoring being periodically validated by the results of the biological monitoring. This would be necessary because non-biological indicators cannot be relied on without checking their inference using biological indicators because we do not have perfect knowledge of cause-effect relationships, pressures, the effects of pressure combinations etc.

If a body is not identified as being at risk because of discharges of priority substances or other pollutants, no operational monitoring for these substances is required. A pollutant is defined[26] as ‘any substance liable to cause pollution in particular those listed in Annex VIII’. As such nutrients and substances that have an unfavourable influence on oxygen balance must also be considered as well as metals and organic micropollutants. Operational monitoring must use parameters relevant to the assessment of the effects of the pressures placing the body at risk.

2.9 Investigative monitoring

Investigative monitoring[27] may also be required in specified cases. These are given as:

¾ where the reason for any exceedences (of Environmental Objectives) is unknown;

[26] *Article 2.31*
[27] *Annex V.1.3.3*

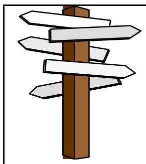
¾ where surveillance monitoring indicates that the objectives set under Article 4 for a body of water are not likely to be achieved and operational monitoring has not already been established, in order to ascertain the causes of a water body or water bodies failing to achieve the environmental objectives; or

¾ to ascertain the magnitude and impacts of accidental pollution.

The results of the monitoring would then be used to inform the establishment of a programme of measures for the achievement of the environmental objectives and specific measures necessary to remedy the effects of accidental pollution.

Investigative monitoring will thus be designed to the specific case or problem being investigated. In some cases it will be more intensive in terms of monitoring frequencies and focused on particular water bodies or parts of water bodies, and on relevant quality elements. Ecotoxicological monitoring and assessment methods would in some cases be appropriate for investigative monitoring.

Investigative monitoring might also include alarm or early warning monitoring, for example, for the protection of drinking water intakes against accidental pollution. This type of monitoring could be considered as part of the programmes of measures required by Article 11.3.1 and could include continuous or semi-continuous measurements of a few chemical (such as dissolved oxygen) and/or biological (such as fish) determinands. Such monitors are used on the River Rhine, for example.

	**Information on the use of bioassays to support implementation of the Directive is provided in the document: "The potential role of bioassays in meeting the monitoring needs of the Water Framework Directive" < http://forum.europa.eu.int/Members/irc/env/wfd/library?l=/working_groups/ wg_2_monitoring/factsheets_monitoring/bioassays >.**

2.10 Frequency of monitoring for surface waters

2.10.1 General aspects

Some determinands and quality elements will be very variable (natural, anthropogenically caused and due to sampling error) in particular water bodies. A lot of monitoring in terms of numbers of sites and frequency of monitoring might thus be required to obtain high or sufficient levels of confidence and precision in a water body's status. There will of course be a cost implication for Member States for the required monitoring. It is likely therefore, that the levels of confidence and precision achievable will be balanced against the costs, i.e. an assessment of the cost-effectiveness of the monitoring programme may be undertaken. In short the provision of reliable information from monitoring programmes will allow measures to be effectively and efficiently targeted.

The actual confidence and precision achieved by monitoring at any particular monitoring site will depend partly on the variability (both natural and resulting from anthropogenic activities) of the determinand being measured, and the frequency of monitoring. Member States are able to target their monitoring to particular times of year to take into account variability due to seasonal factors. An example would be the sampling for nutrients in marine waters in winter when uptake by biota is at its minimum. Seasonal sampling to reflect seasonal human pressures is also permitted.

Thus the Directive allows Member States to tailor their monitoring frequencies according to the conditions and variability within their own waters. These are likely to differ greatly from determinand to determinand, from water body type to water body type, from area to area and from country to country, recognising that a frequency adequate in one country may not be so in another. However, the key is to ensure that a reliable assessment of the status of all water bodies can be achieved, and the reliability of that assessment in terms of confidence and precision must be provided. The latter will have to be published in RBMPs and will therefore, be open to review and scrutiny by other experts, members of the public and the Commission.

As already described, lower monitoring frequencies and on some occasions even no monitoring may be justified when previous monitoring reveals/has revealed that concentrations of substances are below detection limits, declining or stable and there is no obvious risk of increase. An increase will not be likely for instance when the substance is not used in catchment and there is no atmospheric deposition. This corresponds with the thoughts to the principles used by OSPAR/HELCOM in their monitoring and assessment programmes

The minimum monitoring frequencies quoted in the Directive[28] may also not be adequate or realistic for transitional and coastal waters. There will generally be a lower level of confidence in most marine systems because of the much higher natural variability and heterogeneity. Natural variability can be reduced by targeting monitoring to specific seasons such as measuring nutrient concentrations in transitional and coastal waters during winter. Similarly the OSPAR guidelines for the monitoring of biota help programme managers to reduce variability by avoiding the spawning season, sampling pre-spawning for a worst-case scenario etc.

2.10.2 Surveillance monitoring

Surveillance monitoring must be carried out for each monitoring site for a period of one year during the period covered by a RBMP for parameters indicative of all biological quality elements, all hydromorphological quality elements and all general physico-chemical quality elements. Annex V[29] provides tabulated guidelines in terms of the minimum monitoring frequencies for all the quality elements. The suggested minimum frequencies are generally lower than currently applied in some countries. More frequent samples will be necessary to obtain sufficient precision in supplementing and validating Annex II assessments in many cases, for example phytoplankton and nutrients in lakes. Less frequent samples for the general physico-chemical quality elements are permissible if technically justified and based on expert judgement. In addition not all quality elements need to be monitored during the same year, there can be phased monitoring from year to year as long as all are monitored at least once over a year during the lifetime of the RBMP.

There is also an additional clause in Annex V that allows Member States to only undertake surveillance monitoring in specific water bodies once every three river basin management plans (RBMPs) (i.e. once in 18 years) when that body has reached ‘good’ status and when there is no evidence that impacts on that body have changed.

An objective of surveillance monitoring is to assess the long term changes in natural conditions and long term changes resulting from widespread anthropogenic activity. The minimum frequencies given in the Directive may not be adequate to achieve an acceptable level of confidence and precision in this assessment. It may therefore be necessary to increase the frequencies of at least some surveillance monitoring parameters and monitor more than once every sixth year at those surveillance sites designed to detect long-term changes.

2.10.3 Operational monitoring

In terms of operational monitoring Member States are required to determine monitoring frequencies that will provide a reliable assessment of the status of the relevant quality element. The same guidance given on minimum monitoring frequencies for surveillance

[28] *Annex V.1.3.4*
[29] *Annex V.1.3.4*

monitoring is also used for operational monitoring. Again more frequent monitoring will mostly likely be necessary in many cases, but also less frequent monitoring is justified when based on technical knowledge and expert judgement.

The statistical interpretation of results from monitoring is an important topic to ensure a reliable assessment of status etc. Data arising from traditional sampling programmes (e.g. regular monthly sampling) and from more targeted sampling, as might be used in operational monitoring, must be treated in an appropriate manner. These statistical issues are discussed in more detail in the Tool Box, chapter 5.

Member States can also amend their operational monitoring programmes (particularly the monitoring frequency) during the duration of a RBMP where an impact is found not to be significant or the relevant pressure is removed, and the ecological status is no longer less than good.

2.10.4 Summary

In summary, sampling frequencies for surveillance and operational monitoring should be critically assessed in terms of the confidence in the estimates they will provide. For example, Member States may have to undertake additional surveillance monitoring at least during the first 3 years from 2006 to 2008. Also, it may be that data needs to be gathered in every year of subsequent RBMP periods in order to get enough to meet adequate confidence targets in assessing compliance with monitoring objectives and associated Environmental Objectives.

2.11 Monitoring for Protected Areas

There are additional monitoring requirements for protected areas[30]. Protected Areas include bodies of surface water and groundwater used for the abstraction of drinking water and habitat and species protection areas identified under the Birds Directive or the Habitats Directive. Thus for the former areas monitoring sites must be designated in bodies of surface water which provide more than 100 m^3 a day as an average. For groundwater there appears to be no additional monitoring requirements.

In terms of drinking water protected areas, all priority list substances discharged into the water body and all other substances discharged in significant quantities which could affect the status of the body of water and which are included in the requirements of the Drinking Water Directive should be monitored.

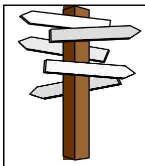
In other words, the monitoring requirements appear to be the same as for other water bodies at risk, except that grouping may not usually be permitted if the body supplies more than 100 m^3 per day. There may be special cases where there is a high number of small mosaic groundwater body types where grouping may be permitted. One of the objectives for Drinking Water Protected Areas is to aim to prevent deterioration in quality in order to reduce the level of purification treatment required. This objective was added to the Directive after the Annex V requirements had been effectively finalised. This means that there are no explicit monitoring requirements designed to provide information for the purposes of assessing and securing achievement of this Protected Area objective. The provisions quoted above do not cover it because they focus on risks to status rather than risks to the relevant quality parameters.

Monitoring frequencies are also given for certain Drinking Water Protected Areas[31] and relate to the size of the population that the Protected Area serves – the greater the population the greater the frequency.

In terms of habitat and species protection areas, bodies of water forming these areas must be included in operational monitoring if they are identified (by the Annex II risk assessment

[30] *Annex V.1.3.5*
[31] *Annex V.1.3.5*

and surveillance monitoring) as being at risk of not meeting their environmental objectives. Monitoring must be carried out to assess the magnitude and impact of all relevant significant pressures on these bodies, and where necessary, to assess changes in the status of such bodies resulting from the programmes of measures. Monitoring should also continue until the areas satisfy the water-related requirements of the legislation under which they are designated and met their objectives under Article 4.



Additional monitoring is required for drinking water abstraction points and habitat and species protection areas. However the register or registers of protected areas also includes areas designated as bathing waters under Directive 76/160/EEC, as vulnerable zones under Directive 91/676/EEC and areas as sensitive under Directive 91/271/EEC. These latter Directives also have monitoring and reporting requirements. The EAF on Reporting is considering not only the reporting required under the WFD but also existing reporting requirements with the aim of 'streamlining' the reporting process. The Working Group on Monitoring also recommends that ways of integrating, rationalising and streamlining the monitoring requirements under the other Directives should also be considered in future work that might revise this draft Guidance Document.

2.12 Other requirements for surface water monitoring

2.12.1 Reference conditions

Member States have the opportunity of establishing reference conditions based on existing high status water bodies where they still exist. In this case monitoring will be required to define the values of the biological quality elements. Type-specific hydromorphological and physico-chemical conditions have also to be established for each type at high ecological status. Reference conditions can also be derived from modelling approaches. These could utilise data from existing water bodies in which the relevant quality element is subject to no more than very minor anthropogenic disturbance. As high status is the anchor point for the classification of ecological status, it would be expected that the results from the monitoring would have a high level of confidence and precision. In particular, the natural variability (e.g. diurnal, monthly, seasonal and inter-annual) of the quality elements needs to be quantified and understood if the impact of anthropogenic pressures on water bodies of lesser status is to be determined. Thus more stations per water body and a higher sampling frequency per station over a number of years may be required.

It should also be noted that the errors in reference conditions and in estimates of the actual conditions will sum. Making sure the errors in the reference conditions are small will be beneficial only if the errors in the estimates of current conditions are not large.

In addition, reference stations, for which there are long time series of data, which indicate stable conditions under the present conditions, may not need high sampling frequencies.

There are linkages here with Working Groups 2.3 on reference conditions for inland surface waters (WFD CIS Guidance Document No. 10) and 2.4 on typology and classification of transitional and coastal water (WFD CIS Guidance Document No. 5). Thus this subsection may be modified to reflect conclusions reached by these other groups.

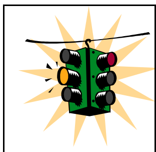
2.12.2 Intercalibration

Annex V.1.4.1 deals with the comparability of biological monitoring results and the intercalibration exercise between countries. Monitoring of the biological quality elements will be undertaken at those sites included in an intercalibration network. The network will consist of sites selected from a range of surface water body types present within each ecoregion. The sites shall be selected by expert judgement based on joint inspections and all other available information. A Member State's monitoring and assessment system will also be applied to the appropriate identified sites and water bodies in one or more other Member States. It would be valuable also to intercalibrate other monitoring results and methodologies.

The results from the monitoring of the biological quality elements will then be formulated as Ecological Quality Ratios (EQRs) for the purpose of classification and comparison with the results from other appropriate Member States.

It has been proposed in the Intercalibration working group 2.5, and supported by different Member States, that monitoring methods of the different Member States sharing the same natural water body should undertake measurements simultaneously, to permit a real comparison of the assessment of 'good' status.

The intercalibration exercise is intended to be a one-off exercise and should be completed within 5.5 years of the entry into force of the Directive (22 June 2006).



Look Out!

However, it has been proposed in the Intercalibration group, and supported by different Member States, that the intercalibration exercise should be repeated. An intercalibration exercise will also be required once the Accession countries have joined the EU. This will by necessity involve at least some of the existing EU Member States.

Its purpose is to define the boundary between high and good and between good and moderate status. The achievement of 'good' status is one of the major Environmental Objectives of the Directive and hence its level will determine how many water bodies require measures to be applied to achieve 'good' status. The definition of this boundary is thus a crucial aspect of the implementation of the Directive.

It is stated that at least two sites corresponding to the boundary between good and high status and two sites corresponding to the boundary between good and moderate status should be selected for an intercalibration network for each water body type within each ecoregion. In practise, because of the natural variability between the same types of water bodies, the number of sites may have to be much larger to be able to define the borderlines between the status groups and the variability of this borderline.

Key issue

The issues surrounding the intercalibration exercise are being discussed with Working Group 2.5 on intercalibration. Thus this subsection may be modified to reflect conclusions reached by this other group.

2.12.3 Heavily Modified and Artificial Water Bodies

According to the WFD, the biological status of surface water is to be assessed using the elements phytoplankton, other aquatic flora, macroinvertebrates and fish fauna. It is suggested that the preliminary assessments of ecological status should be based on the most sensitive quality elements with respect to the existing physical alterations. Effects resulting from other impacts (e.g. toxic effects on macroinvertebrates, eutrophication concerning macrophytes) should be excluded as far as possible. Some suggestions on the suitability of biological elements as indicators for physical alterations can be made:

¾ Benthic invertebrate fauna and fish are the most relevant groups for the assessment of hydropower generation impacts;

¾ Long distance migrating fish species can serve as a criterion for the assessment of disruption in river continuum;

¾ Macrophytes are good indicators of changes in flow downstream of reservoirs as well as for the assessment of regulated lakes because they are sensitive to water level fluctuation; and,

¾ For linear physical alterations such as flood works, benthic invertebrate fauna and macrophytes/phytobenthos are most appropriate indicators.

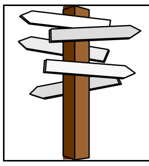
Annex VI of the Guidance Document provides an overview of the key issues for each water body and should be referred to for more details.

Key issue

The issues surrounding the heavily modified water bodies are covered by Working Group 2.2. Thus this subsection may be modified to reflect conclusions reached by this other group.

2.12.4 Standards for monitoring of surface water quality elements

The Directive also indicates that the monitoring of type parameters for surface waters should conform to appropriate international standards (such as those developed by CEN and ISO) which should ensure the provision of data of an equivalent scientific quality and comparability.



It is recommended that appropriate standards are developed as a matter of priority and urgency for those aspects of monitoring for which there are no internationally agreed standards or techniques/methods

The use and development of standards and quality assurance in sampling and laboratory work is further elaborated in Chapter 5.

2.13 Monitoring of groundwater

The Water Framework Directive requires the establishment of monitoring programmes covering groundwater quantitative status, chemical status[32] and the assessment of significant, long-term pollutant trends resulting from human activity[33] by 22 December 2006 at the latest. The programmes must also provide for any additional monitoring requirements relevant to Protected Areas. The programmes must provide the information necessary to validate the Annex II risk assessment procedure and to assess the achievement of the Directive's objectives for groundwater. The relevant objectives are:

¾ To prevent deterioration in the status of all bodies of groundwater [Article 4.1(b)(i)];

¾ To prevent or limit the input of pollutants into groundwater [Article 4.1(b)(i)];

¾ To protect, enhance and restore all bodies of groundwater and ensure a balance between abstraction and recharge with the aim of achieving good groundwater status [Article 4.1(b)(ii)];

¾ To reverse any significant and sustained upward trend in the concentration of any pollutant in groundwater in order to progressively reduce pollution of groundwater [Article 4.1(b)(iii)];

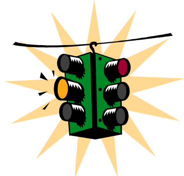
¾ To achieve compliance with any standards and objectives for Protected Areas [Article 4.1(c)]. Relevant Protected Areas include areas designated for the abstraction of water intended for human consumption under Article 7 (Drinking Water Protected Areas),

[32] *Article 8*
[33] *Annex V*

Nitrate Vulnerable Zones established under Directive 91/676/EEC, and areas designated for the protection of habitats and species in which the status of water is an important factor in their protection;

Key principle

The monitoring programmes must provide the information necessary to assess whether the Directive's environmental objectives will be achieved. This means that a clear understanding of the environmental conditions required for the achievement of the objectives, and of how these could be affected by human activities, is essential to the design of effective monitoring programmes.



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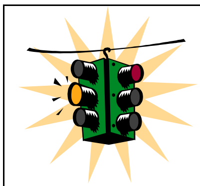
The Article 17 Daughter Directive may establish additional criteria for the assessment of groundwater status. This guidance may need to be updated once such criteria have been established.



Look Out!

The Article 17 Daughter Directive is expected to establish criteria for the identification of significant and sustained upward trends. Until such criteria have been established, Member States must decide whether a trend in pollutant concentrations is significant and sustained according to their own criteria. In developing such criteria, Member States should take into account the objective to progressively reduce pollution of groundwater [Article 4.1(b)(iii)].

The monitoring programmes should be designed on the basis of the results of the Annex II[2] characterisation and risk assessment procedure. Guidance on characterisation and risk assessment for bodies and groups of bodies of groundwater can be found in the WFD CIS Guidance Document No. 3 - IMPRESS. The results of the assessments should provide the necessary information on, and understanding of, the groundwater system and the potential effects of human activities on it with which to design the monitoring programmes. In particular, monitoring programme design will require:

¾ Estimated boundaries of all bodies of groundwater;

¾ Information on the natural characteristics, and a conceptual understanding, of all bodies or groups of bodies of groundwater;

¾ Information on how bodies may be grouped because of similar hydrogeological characteristics and therefore similar responses to the identified pressures;

¾ Identification of those bodies, or groups of bodies, of groundwater at risk of failing to achieve Directive's objectives, including the reasons why those are considered to be at risk;

¾ Information on (a) the level of confidence in the risk assessments (e.g. in the conceptual understanding of the groundwater system, the identification of pressures, etc), and (b) what monitoring data would be required to validate the risk assessments.

To ensure the targeted and cost-effective development of the groundwater monitoring programmes, this information and understanding should serve as the basis for identifying (see Figure 2.3):

¾ The bodies, or groups of bodies relevant to each monitoring programme;

¾ The appropriate monitoring sites in those bodies, or groups of bodies;

¾ The appropriate parameters for monitoring at each site; and

¾ The monitoring frequencies for those parameters at each site.

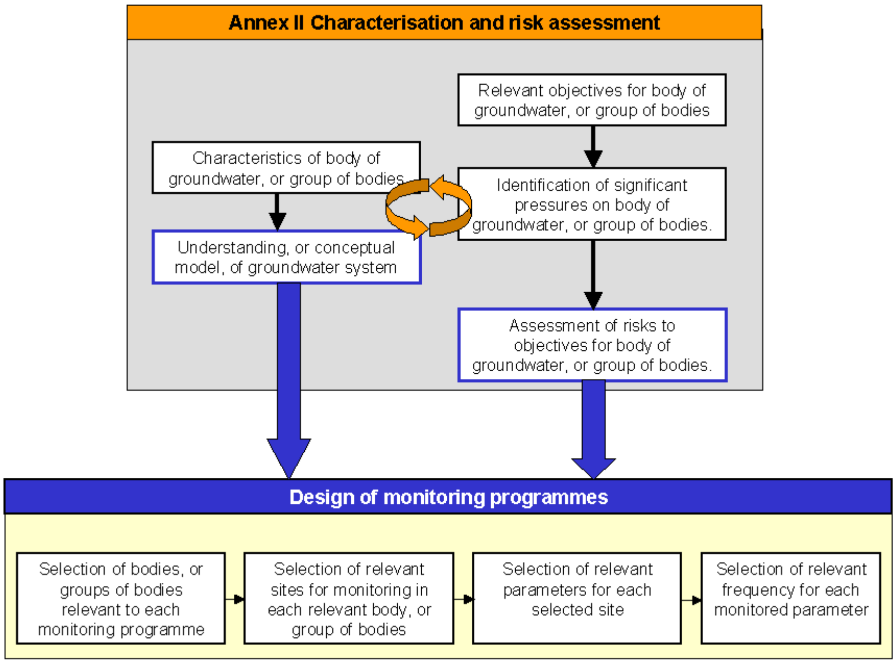
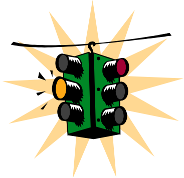


Figure 2.3 The basic information necessary for the design of groundwater monitoring programmes

The Directive sets out its requirements for the different groundwater monitoring programmes in Annex V (2.2 and 2.4). The monitoring programmes must include:

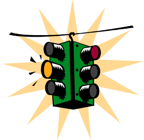
A 'groundwater level monitoring' network to supplement and validate the Annex II characterisation and risk assessment procedure with respect to risks of failing to achieve good groundwater quantitative status in all bodies or groups of bodies of groundwater. Good groundwater quantitative status requires that: (a) the available groundwater resource for the body as a whole is not exceeded by the long-term annual average rate of abstraction; (b) abstractions and other anthropogenic alterations to groundwater levels have not caused, and are not such as will cause, significant diminution in the status of associated surface water bodies or significant damage to directly dependent terrestrial ecosystems; and (c) anthropogenic alterations to flow direction have not caused, and are not likely to cause, saltwater or other intrusions.

A 'surveillance monitoring' network to: (a) supplement and validate the Annex II characterisation and risk assessment procedure with respect to risks of failing to achieve good groundwater chemical status; (b) establish the status of all groundwater bodies, or groups of bodies, determined as not being at risk on the basis of the risk assessments; and (c) provide information for use in the assessment of long term trends in natural conditions and in pollutant concentrations resulting from human activity. Surveillance monitoring should be undertaken in each plan period and to the extent necessary to adequately supplement and validate the risk assessment procedure for each body or group of bodies of groundwater. The programmes should be operational from the beginning of the plan period where necessary to provide information for the design of the operational monitoring programmes, and may operate for the duration of the planning period if required. The programmes should be designed to help ensure that all significant risks to the achievement of the Directive's objectives have been identified. Where confidence in the Annex II risk assessments is inadequate, parameters indicative of pressures from human activities, which may be affecting bodies of groundwater but which have not been identified as causing a risk to the objectives, should be included in the surveillance monitoring programmes in order to supplement and validate the risk assessments.



Look Out!

No minimum duration for the surveillance programme is specified. For the first river basin planning period, Member States that already have extensive groundwater monitoring networks may only need a short period of surveillance monitoring to help design their operational monitoring programmes. However, Member States whose existing networks are more limited may require more information from surveillance programmes before the design of their operational programmes can be completed.

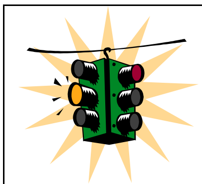


Look Out!

Surveillance monitoring is only specified in the Directive for bodies at risk or which cross a boundary between Member States. However, to adequately supplement and validate the Annex II risk assessment procedure, validation monitoring will also be needed for bodies, or groups of bodies, not identified as being at risk. The amount and frequency of monitoring undertaken for these bodies, or groups of bodies, must be sufficient to enable Member States to be adequately confident that the bodies are at 'good' status and that there are no significant and sustained upward trends.

An 'operational monitoring' network to: (a) establish the status of all groundwater bodies, or groups of bodies, determined as being at risk; and (b) establish the presence of significant and sustained upward trends in the concentration of any pollutant. Operational monitoring has to be carried out for the periods between surveillance monitoring. In contrast to surveillance monitoring, operational monitoring is highly focused on assessing the specific, identified risks to the achievement of the Directive's objectives.

The results of monitoring must be used to estimate the chemical and quantitative status of bodies of groundwater. Colour-coded maps[34] of the status of bodies of groundwater, or groups of bodies, and an indication on the maps of which bodies are subject to a significant and sustained upward trend in pollutant concentrations and in which bodies such trends have been reversed must be included in the draft river basin management plans and in the finalised river basin management plans. The first of these plans must be published by 22 December 2008[35] and 22 December 2009[36] respectively. The results of monitoring should also assist in designing programmes of measures, testing the effectiveness of these measures and informing the setting of objectives. Later on monitoring results should be used in the reviews of the Annex II risk assessment procedure, the first of which must be complete by 22 December 2013.



Look Out!

For many Member States, the estimates of groundwater body status included in the first draft river basin management plans at the end of 2008 will have to be based more on surveillance monitoring results and less on operational monitoring data than will be the case in the finalised plan published at the end of 2009 and in subsequent river basin management plans. Accordingly, the confidence in the status classifications included in the first plan may be lower than will be the case in subsequent plans. Member States must report the confidence and precision achieved in the results of monitoring in each plan.

The detailed purposes of, and requirements for, each of the groundwater monitoring programmes are discussed in Chapter 4. Chapter 5.3 contains a toolbox of good practice examples illustrating how the guidelines could be implemented. The tools developed by CIS

[34] *Annex V 2.5*
[35] *Article 14*
[36] *Article 15*

2.8, Statistical aspects of groundwater trends and aggregation of monitoring results, should also be taken into account when designing the monitoring programmes.

3 What Quality Elements should be monitored for Surface Waters?

The following sections provide guidance on the appropriate selection of quality elements and parameters for rivers, lakes, transitional waters and coastal waters to support the implementation of the WFD. The selection of quality elements has been based primarily on Annex V.1.1 and Annex V.1.2 of the WFD. Guidance on the selection of quality elements and parameters for rivers, lakes, transitional and coastal waters are summarised in Figures 3.1 - 3.4. These figures show the quality elements as specified in Annex V, and additional recommended quality elements which have been identified by Member States for that particular water body type.

Look Out!

The proposed selection of recommended quality elements and parameters is intended as a guide only. Member States should use their own discretion based on local knowledge and expertise as to what specific sub-element or parameter will provide the best representation of catchment pressures for each quality element.

The key features of each quality element, their existing use in classification systems throughout the EU and their relevance to the Directive are summarised in Tables 3.1-3.12.

Quality Element Descriptions

An overview of the key issues for surface waters description of each of the Quality Elements and sub-elements identified in this chapter, and their relevance for each water body type are provided in Annex VI.

For further details on monitoring guidance for surface waters refer to the full contributions received from Member States:

¾ Rivers:
http://forum.europa.eu.int/Members/irc/env/wfd/library?l=/working_groups/wg_2_monitoring/factsheets_monitoring/rivers&vm=detailed&sb=Title

¾ Lakes:
http://forum.europa.eu.int/Members/irc/env/wfd/library?l=/working_groups/wg_2_monitoring/factsheets_monitoring/lakes&vm=detailed&sb=Title

¾ Transitional and coastal waters:
http://forum.europa.eu.int/Members/irc/env/wfd/library?l=/working_groups/wg_2_monitoring/factsheets_monitoring/transitional_coastal&vm=detailed&sb=Title

3.1 Selection of Quality Elements for Rivers

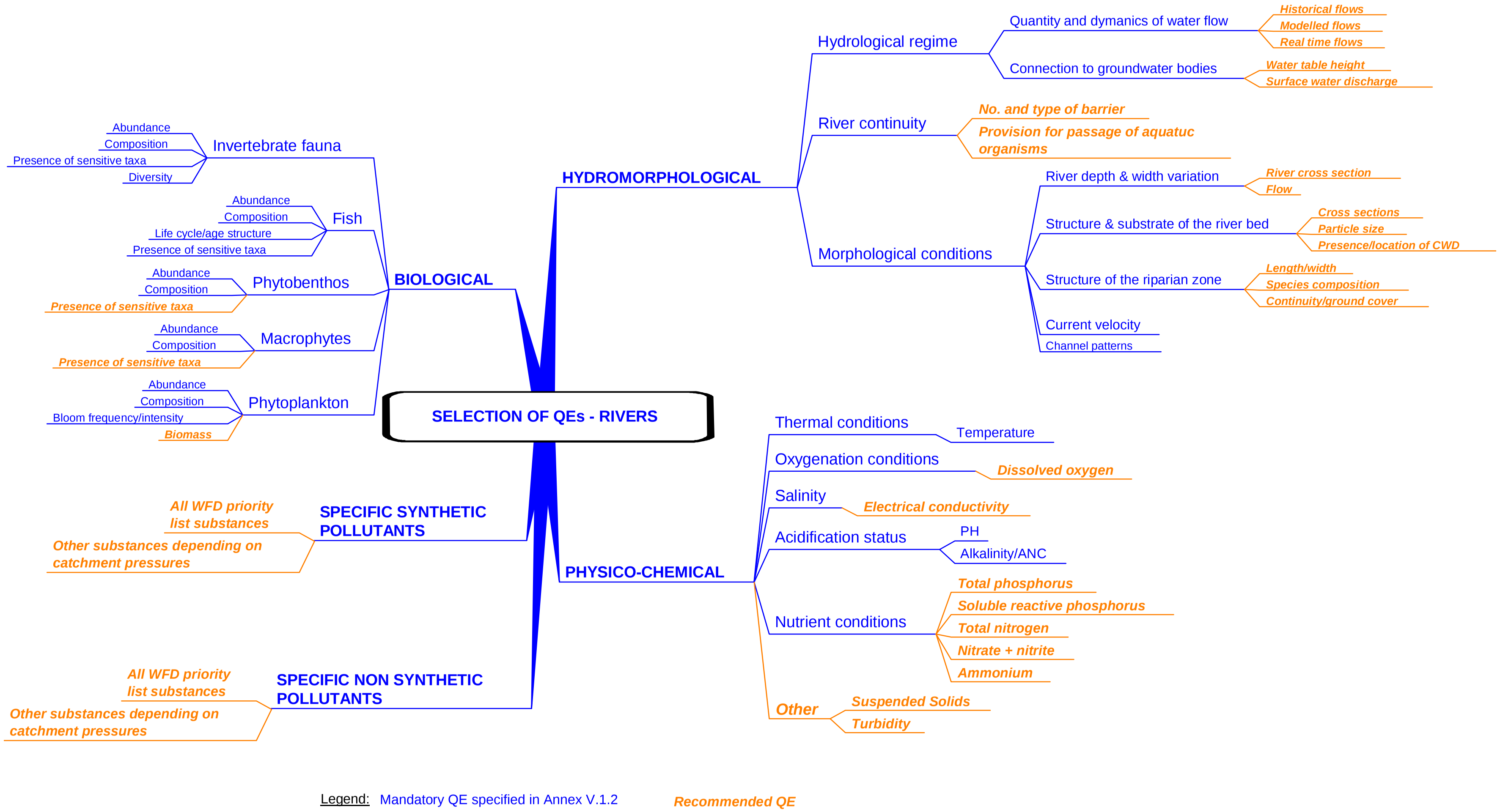


Figure 3.1 Selection of quality elements for rivers

Table 3.1 Key features of each biological quality element (QE) for rivers

Aspect/feature	Benthic invertebrates	Macrophytes	Benthic Algae	Fish	Phytoplankton
Measured parameters indicative of QE	Composition, abundance diversity, and presence of sensitive taxa.	Composition and abundance , and presence of sensitive taxa	Composition and abundance, , and presence of sensitive taxa	Composition and abundance, sensitive species diversity, age structure,	Composition, abundance and planktonic blooms, and presence of sensitive taxa
Supportive/interpretative parameters measured or sampled at the same time	Morphology, physico-chemical parameters (e.g. Temp/DO, nutrients, pH etc), river flow, substrate/habitat sampled	Morphology, river flow, depth, transparency	Substrate/habitat sampled, morphology, nutrients (N, P, Si), TOC, pH, hydrological regime, light conditions	Substrate/habitat sampled, river size (depth/width), river flow, temp, oxygen	Chlorophyll *a,* flow, physico-chemical parameters (e.g. temp, DO, N, P, Si)
Pressures to which QE responds	Mainly developed to detect organic pollution or acidity, can be modified to detect full range of impacts.	Mainly used to detect eutrophication, river dynamics including hydropower effects.	Mainly used as an indicator of productivity. Can be used to detect eutrophication, acidification, river dynamics.	Can be used to detect habitat and morphological changes, acidification and eutrophication.	Used as indicator of productivity/eutrophication.
Mobility of QE	Low, although unfavourable conditions may cause drift	Low. Generally fixed position.	Low	High. Tendency to avoid undesirable conditions (e.g. low oxygen conditions).	High. Drifting with river water
Level and sources of variability of QE	High seasonal variation in community structure. Influenced by climatic events e.g. rainfall/flooding	High seasonal variation in community structure and abundance.	High seasonal variation in community structure. Limited by light and nutrient availability and available substrate for colonisation. Influenced by climatic events	High seasonal variation in community structure (e.g. spawning/migration) and abundance. High interannual variation due to age structure.	High inter and intra-seasonal variation in community structure and biomass. Influenced by climatic events, light, nutrient availability, stability and residence time
Presence in rivers	Abundant	Abundant if suitable habitat. Limited in fast flowing streams.	Abundant if suitable habitat. Limited in large, deep rivers with poor habitat	Abundant	Generally low. May be abundant if conditions conducive to growth
Sampling methodology	ISO 8265, 7828, 9391 (surber sampler, handnet, grab)	CEN –standard under development	CEN –standard under development	Depending on habitats – nets, electrofisher	Integrated sample (3-4m), depth sampler
Habitats sampled	Riffle, pool (rocks/logs), edge (littoral), macrophytes,	Littoral, deposition areas (e.g. pools)	Benthic substrate/artificial substrate	All habitats	Water column
Typical sampling frequency	6 monthly/Annual	Annual/6 monthly	Quarterly/6 monthly	Annual	Monthly/Quarterly
Time of year of sampling	Summer and winter. Spring and autumn in Scandinavia.	Mid to late summer.	All seasons/summer and winter. Summer & autumn in Nordic countries.	Varied	Should cover all seasons. Only during ice free periods in Nordic countries.
Typical sample size	Variable depending on sampling methodology and habitat	Variable, may be standardised	Variable, may be standardised	Variable, may be standardised	Single integrated sample
Ease of sampling	Relatively simple. Difficulties in deep or fast flowing rivers.	Simple due to fixed position and general proximity to banks	Relatively simple. Difficulties in deep or fast flowing rivers. Observations and % cover	Requires specialised sampling equipment (e.g. electrofisher).	Simple using integrated hosepipe (or grab sample in shallow water)
Laboratory or field measurement	Field collection and sorting. Microscopic identification in laboratory	Field collection and identification	Field collection, microscopic identification in laboratory	Field collection, measurement and identification	Field collection, laboratory preparation followed by microscopic identification
Ease and level of Identification	Relatively simple to Genus. Requires expert identification to species level for some (e.g. chironomids). May be damaged during sampling/preservation	Simple to identify to species, except some genera (e.g. potamogeton)	Requires expert identification for majority of species (see phytoplankton)	Simple to identify to species, except some cyprinids which require expert knowledge	Requires expert identification of majority of genera and species. Some small unicellular species (e.g. unicellular greens) difficult to identify unless under high power microscopy

Aspect/feature	Benthic invertebrates	Macrophytes	Benthic Algae	Fish	Phytoplankton
Nature of reference for comparison of quality/samples/stations	Yes: UK, France, Germany, Austria, Denmark, Sweden, Norway	No but underway in some European institutions	No	Yes: UK (HABSCORE) and France.	No
Methodology consistent across EU?	No	No	No	No	No
Current use in biological monitoring or classification in EU	Austria, Belgium, Denmark, Finland, France, Spain, Germany, Italy, Ireland, Luxembourg, Portugal Netherlands, Sweden, Norway and the UK	Austria, Belgium, France, Germany, Ireland, Netherlands and the UK	Austria, Belgium, France, Germany, Ireland, Norway, Sweden, Finland, Spain, Netherlands and the UK	Austria, France, Belgium, Ireland, Norway and the UK	None
Current use of biotic indices/scores	Yes. UK (BMWP), France (IBGN), Germany (Saprobic), Austria (Saprobic), Spain (SBMWP), Belgium (BBI), Netherlands (K-value)	No but some indices under development/calibration (Austria)	Yes. Sweden (developing). Norway and Germany – Index of occurrence of sensitive taxa	Yes. UK (HABSCORE).	No
Existing monitoring system meets requirements of WFD?	No	No	No	No	No
ISO/CEN standards	ISO 7828:1985 ISO 9391:1993 ISO 8265: 1988	CEN-Standard under development	CEN-Standard under development	CEN-Standard under development	
Applicability to rivers	High	Moderate	High	High	Low-Moderate
Main advantages	ξ Currently most common biological indicator used for ecological classification. ξ Existing classification systems in place ξ Possibility of adapting existing systems to incorporate requirements of WFD. ξ Less variable than physico-chemical elements	ξ Easy to sample and identify. ξ Low interannual variability	ξ Easy to sample (in shallow water) ξ Some existing methods developed ξ Less variable than physico-chemical elements ξ Responds quickly to changes in environmental and anthropogenic conditions ξ Possibility of adapting existing systems to incorporate requirements of WFD.	ξ Existing river classification systems in place ξ Possibility of adapting existing classification systems to incorporate requirements of WFD.	ξ Easy to sample ξ May be relevant in rivers where residence times enough to sustain growth (e.g. lowland rivers, upstream of impoundments)

Aspect/feature	Benthic invertebrates	Macrophytes	Benthic Algae	Fish	Phytoplankton
Main disadvantages	ξ Methods require adaptation to meet requirements of WFD ξ Some require specialist expertise to identify to species ξ High substrate-related spatial variability and high temporal variability due to hatching of insects and variation of water flow ξ Time consuming and expensive ξ Presence of exotic species in some EU rivers.	ξ Not commonly used in EU ξ Lack of information for comparison to reference ξ Methodology needs to be adapted to incorporate requirements of WFD	ξ Not commonly used in EU ξ Lack in information for comparison to reference ξ Methodology needs to be adapted to incorporate requirements of WFD. ξ Difficult to sample in deep rivers ξ High substrate related spatial variability ξ High seasonal variation ξ Requires specialist expertise for species identification	ξ Requires specialist sampling equipment ξ High mobility ξ Horizontal and vertical distribution patters (differs between species)	ξ Not routinely used in river quality assessment in EU ξ Not generally present in flowing rivers ξ High variability requires frequent sampling ξ Difficult to establish dose-response relationships due to flow-related variability.
Conclusions/ Recommendations	This QE is best developed in EU and hence it is recommended as one of the key elements for monitoring especially for organic pollution.	Under certain hydrological conditions this QE is not suitable. However, in good conditions it can give a robust assessment.	Recommended, particularly for assessment of trophic status.	It is recommended as one of the key elements for monitoring for habitat and morphological changes. Further work required for assessing the impact of pollution on fish populations.	Only recommended for large, slow flowing rivers.

Table 3.2 Key features of each hydromorphological quality elements for rivers

Aspect/feature	Quantity and dynamics of water flow	Connection to groundwater bodies	River Continuity	River depth and width variation	Structure and substrate of the river bed	Structure of the riparian zone
Measured parameters indicative of QE	Historical flows, modelled flows, real-time flow, current velocity	Water table height, surface water discharge	No and type of barrier and associated provision for fish passage	River cross section, flow	Cross section, particle size, presence and location of CWD	Length, width, species present, continuity, ground cover
Pressures to which QE responds	Used to detect impact of water storage, abstraction and discharge on biota, hydropower regulation	Provides information on surface-groundwater relationship	Used to detect impact on upstream migration of fish	Used to detect impact on biota from changing flows and habitat availability	Determines impact on biota from changing habitat availability	Influences structure of banks, provides habitat and shading for biota, filters diffuse runoff
Level and sources of variability of QE	Highly variable depending on geographical and climatic conditions. Variations reduced as response to barriers	Moderate variability	Low variability. Based on presence/modification of infrastructure	Moderate variability. Influenced by hydropower regulation	Variable depending on particle size and flow (e.g. gravel/sand scour/sedimentation prevalent following high flows)	Variable. Possibility of physical clearing, accessibility from livestock, erosion etc
Sampling methodology	ISO standard for current velocity. No common methodology for dynamics	No common methodology	No common methodology	No common methodology	No common methodology	No common methodology
Typical sampling frequency	In-situ, real time	6 monthly, depending on climatology and geology	Every 5-6 years	Annual	Annual	Annual
Time of year of sampling	All year	Winter and summer	varied	varied	varied	varied
Typical "sample" size or survey area	Common standard for No of monitoring points in cross sections developed	Not defined	Entire reach	No common agreement	No common agreement	50m in headwaters 100m in middle and lower reaches
Ease of sampling /measurements	Simple using in-situ flow gauging stations in small rivers. Greater effort required for large rivers.	Simple. Measurement of groundwater height (boreholes) and river flow	Simple. Survey to determine location and type of structures and abstraction sites/volumes	Can be simple using observation and measurement or detailed using laser survey equipment	Simple following minimal training	Simple following minimal training. Collection and laboratory identification of species may be required
Basis of any comparison of results/quality/stations e.g. reference conditions/best quality	No	No	No	No	No	No
Methodology consistent across EU?	No	No	No	No	No	No
Current use in monitoring programmes or for classification in EU	Yes. Belgium, France, Sweden, UK, Finland and Norway	Yes. Belgium, UK	Yes. Belgium, Germany, France	Yes. Belgium, Germany, France, UK and Norway	Yes. Belgium, Germany, France, UK and Norway	Yes. Belgium, Germany, France, Italy , UK
Existing monitoring systems meet requirements of WFD?						

Aspect/feature	Quantity and dynamics of water flow	Connection to groundwater bodies	River Continuity	River depth and width variation	Structure and substrate of the river bed	Structure of the riparian zone
Existing classification systems meet requirements of WFD?	No	No	No	No	No	No
ISO/CEN standards	ISO/TC 113 CEN?TC 318 under development	No	No	No	No	No
Applicability to rivers	High	High	High	High	High	High
Main Advantages	ξ Possibility of adapting existing systems to incorporate requirements of WFD.	ξ	ξ Methodology needs to be developed to incorporate requirements of WFD.	ξ Methodology needs to be developed to incorporate requirements of WFD.	ξ	ξ
Main disadvantages	ξ Not commonly used	ξ Not commonly used	ξ Not commonly used	ξ Not commonly used	ξ Not commonly used	ξ Not commonly used
Conclusions/ recommendations	Simple to monitor. Key supporting parameter for interpretation	Can not be commonly used. Only relevant under certain conditions when groundwater plays a major role in water balance. Methodology must be elaborated.	Very relevant for some species. One extensive survey is sufficient – supplied when necessary	Not applicable for all rivers such as rivers with high natural variation. Methodology needs further elaboration	Essential for interpreting the biological quality elements and possibility of sediment accumulation	Applicability depends on the shape, size etc. of the riparian zone. Methodology must be further elaborated

Table 3.3 Key features of each chemical and physico-chemical quality element for rivers

Aspect/feature	Thermal Conditions	Oxygenation Conditions	Salinity	Acidification Status	Nutrients
Measured parameters indicative of QE	Temperature	Dissolved oxygen (mg/L and % sat)	Conductivity, ca concentration	pH, ANC, Alkalinity	TP, TN, SRP, NO_3 + NO_2, NH_4
Pressures to which QE responds	Inflows, water releases, industrial discharges	Organic pollution, industrial discharges	Agricultural runoff, industrial discharges	Industrial discharges, acid rain	Agricultural, domestic and industrial discharges
Level and sources of variability of QE	Variable. Influence d by climatic conditions	Moderate. Diel changes due to respiration. Lower variation in fast flowing rivers.	Low variability although influenced by water flow	Variable depending on buffer capacity, water flow etc	Variable depending on landuse, buffer capacity, temp/DO, presence of binding metals etc
Monitoring considerations	Seasonal stratification and mixing (in deep water), cold water releases	Diel/diurnal variations	Seasonal stratification and mixing in deep waters	Seasonal variations	Sources (diffuse/point), sufficient speciation to enable source discrimination
Sampling methodology	In-situ using submersible probe	In-situ using submersible probe, or sample collection and Winklers titration	In-situ using submersible probe	In-situ using submersible probe, sample collection	Sample collection in field followed by laboratory analysis
Typical sampling frequency	Fortnightly-monthly	Fortnightly-monthly	Fortnightly-monthly	Fortnightly-monthly	Fortnightly-monthly. More frequently during flooding.
Time of year of sampling	All seasons.	All seasons	All seasons	All seasons. Special attention when sea salt or snow melt episodes.	All seasons. Particularly following inflow events. Not during ice cover.
Typical "sample" size	Single measurement or water column profile	Single measurement or water column profile	Single measurement	Single measurement	Single sample, or profile in deep waters
Ease of sampling /measurements	Simple using in-situ submersible probe	Simple using in-situ submersible probe, or sample collection followed by Winklers titration	Simple using in-situ submersible probe	Simple using in-situ submersible probe. Sample collection followed by laboratory analysis	Simple. Surface water sample or profile using depth sampler (e.g. van dorn)
Methodology consistent across EU?	No	No	No	No	No
Current use in monitoring programmes or for classification in EU	All	All	All	All	All
Existing monitoring systems meet requirements of WFD?	Yes	Yes	Yes	Yes	Yes
Existing classification system meets requirements of WFD?	No	No	No	No	No
ISO/CEN standards	Yes	Yes	Yes	Yes	Yes
Applicability to rivers	Moderate. Stratification may be present in deep, slow flowing rivers. Can help detect thermal pollution.	Moderate. Oxygen depletion may be present in deep, slow flowing rivers or upstream of impoundments	High	Low. Problem in stagnant waters.	High

Aspect/feature	Thermal Conditions	Oxygenation Conditions	Salinity	Acidification Status	Nutrients
Main advantages	ξ Simple to sample in-situ ξ Able to implement standard methodology	ξ Simple to sample in-situ ξ Able to implement standard methodology	ξ Simple to sample in-situ ξ Able to implement standard methodology	ξ Simple to sample in-situ ξ Able to implement standard methodology	ξ Can provide information as to pollutant sources ξ Simple to sample in-situ ξ Able to implement standard methodology
Main disadvantages	ξ Does not provide long-term indication	ξ Diel variations may require frequent monitoring ξ Does not provide long-term indication	ξ Does not provide long-term indication	ξ Does not provide long-term indication ξ May require intensive monitoring following rainfall events	ξ Does not provide long-term indication ξ May require intensive monitoring following rainfall events
Recommendations	Basic determinand for assessment of biocenosis.	Basic determinand for assessment of biocenosis.	Recommended in rivers in semi-arid climate and/or with high salinity.	Recommended in rivers with risk of acidification	Very important indicator for human activity/ eutrophication. Total N and P, nitrate and orthophosphate should be monitored as a minimum. Ammonia monitored where concentrations are expected to be problematic e.g. exceedences of limit values over a specific limit.

3.2 Selection of Quality Elements for Lakes

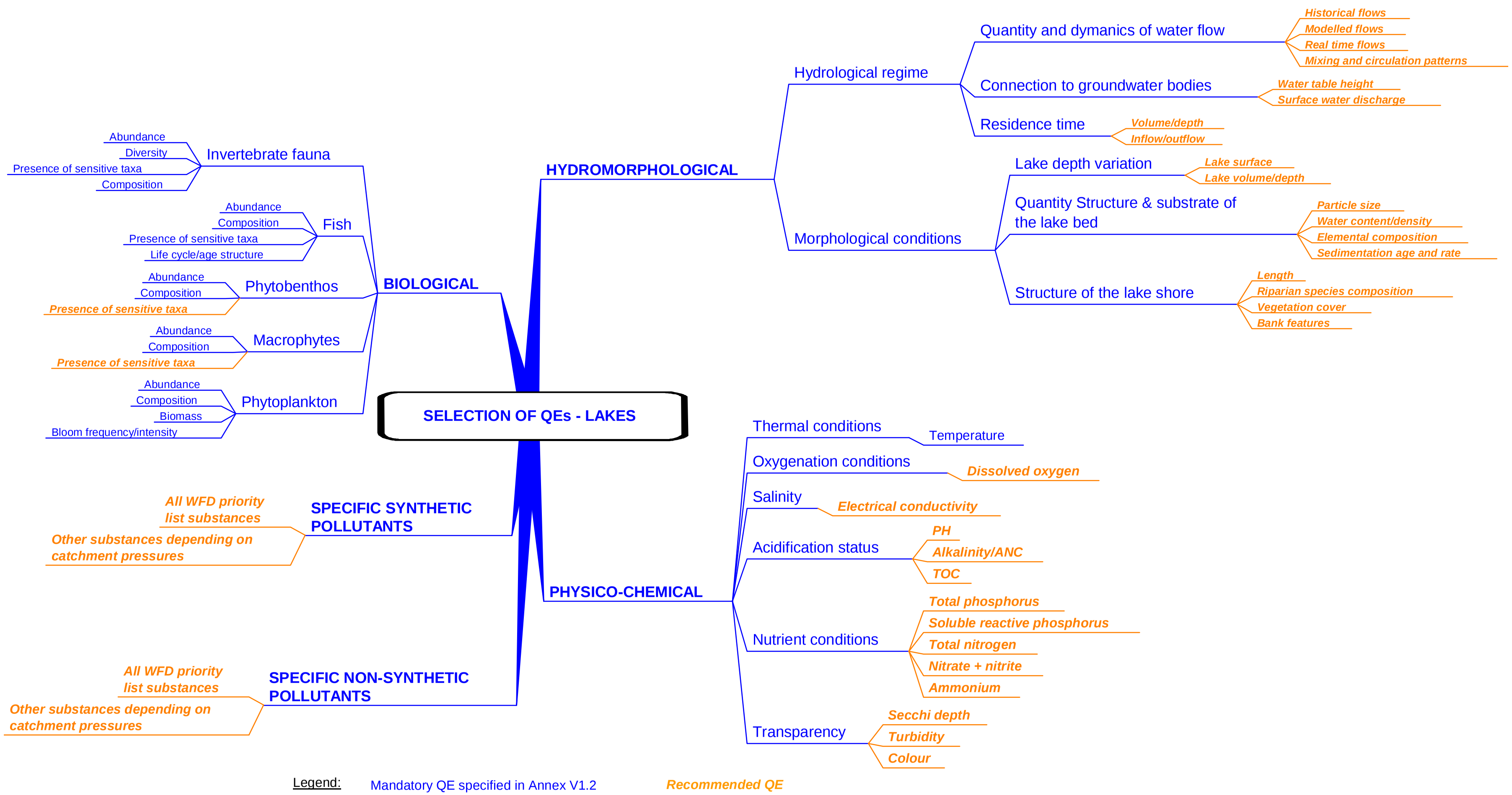


Figure 3.2 Selection of quality elements for lakes

Table 3.4 Key features of each biological quality element (QE) for lakes

Aspect/feature	Phytoplankton	Macrophytes	Phytobenthos	Benthic invertebrates	Fish
Measured parameters indicative of QE	Composition, abundance biomass (Chla), blooms	Composition and abundance	Composition and abundance	Composition, abundance, diversity and sensitive taxa	Composition, abundance, sensitive species and age structure
Supportive/interpretative parameters often/typically measured or sampled at the same time	Nutrient concentrations (total/soluble), chlorophyll, DO, POC, TOC, pH, alkalinity, temperature, transparency, Fluorometric in-situ monitoring	Nutrient concentrations (total/soluble) in lake water, sediment and pore water, substrate type, pH, alkalinity, conductivity, transparency, Secchi disc, ca concentration	Nutrient concentrations (total/soluble) in lake water, sediment and pore water, substrate type, pH, alkalinity, conductivity, transparency, Secchi disc, ca concentration	Nutrient concentrations (total/soluble), DO, pH, alkalinity, sediment analysis, toxicity bioassays	Nutrient concentrations (total/soluble), DO, pH, alkalinity, temperature, toxicity bioassays, trophic condition, Zooplankton dynamics, ANC, TOC
Pressures to which QE responds	Eutrophication, organic pollution, acidification, toxic contamination	Eutrophication, acidification, toxic contamination, siltation, river regulation, lake water level, introduction of exotic species	Eutrophication, acidification, toxic contamination, siltation, river regulation, lake water level, introduction of exotic species	Eutrophication, organic pollution, acidification, toxic contamination, siltation, river regulation, hydro-morphological alteration (littoral)	Eutrophication, acidification, toxic contamination, fisheries, hydro-morphological alteration, Introduction of exotic species
Mobility of QE	Medium	non-mobile	non-mobile	Low to Medium, high when hatching	High
Level and sources of variability of QE	High inter and intra seasonal variation in community structure and biomass Medium to high spatial variability	Medium-high seasonal variability in community structure and biomass High spatial variability	Medium-high seasonal variability in community structure and biomass, Low interannual variability High spatial variability	Medium-high seasonal variability in community structure and biomass High spatial variability	High spatial and seasonal variability Populations clumped in respect to habitat variables
Presence in lakes	Abundant	Abundant, rare in reservoirs	Abundant, rare in reservoirs	Abundant	Abundant
Sampling methodology	Integrated or discrete samples in the water column 1-5 sites per lake A number of sampling gears are commonly used such as hand-held bottles or flexible hose	Aerial photography or/and transect sampling perpendicular to the shore line	In-situ observations of occurrence of natural substrate in littoral zone and/or among macrophyte beds and scraping of sub-strata	Qualitative or semi-quantitative hand net or kick-sampling; Ekman grab or core sampling Gear type depends on type of substrate, e.g. submerged aquatic vegetation – dip net; sand and clay - Peterson, Van Veen grabs; mud – Ponar, Ekman grabs	Electrofishing Net captures, several types (e.g. gill nets, trammel net) Trawls Acoustic
Habitats sampled	Water column (i.e. epilimnion, euphotic zone, metalimnion)	Macrophytes: littoral zone	benthic substrata/ artificial substrata	Littoral, sub-littoral and profundal	Littoral, open waters
Typical sampling frequency	Monthly/ quarterly In Nordic countries 6 times/summer	Yearly (late summer in Nordic countries), in natural lakes every 3-6 years	Varied from several times during the growing season to once a year	Yearly, in natural lakes every 3-6 years Twice yearly in littoral	Depend upon water body physical characteristics and objective, yearly
Time of year of sampling	All seasons, at least twice a year during spring overturn and summer stratification In Nordic countries no sampling during ice coverage. More stations required if high spatial variation.	Late summer, decided through expert judgement	Quarterly/ 6 monthly/ several times during the growing season In Nordic countries no sampling during ice coverage	Early spring and late summer	Late Spring through to early Autumn

Aspect/feature	Phytoplankton	Macrophytes	Phytobenthos	Benthic invertebrates	Fish
Typical sample effort	Often 1 station located in the centre of the lake	3-10 transects per lake with 2-3 quadrats on each transect should be sufficient for the majority of the lakes	Lake wide, 3-10 transects, littoral to sub-littoral	Lakewide composite samples of 2/ 3 grabs at each of 3-5 sub-littoral sites (7-15 grabs total	Dependent on type of sampling gear: For electrofishing multiple habitats are selected in littoral areas based on the substrate and cover. CEN-standard in preparation In shallow lakes fish can be sampled with multimesh gillnets and random sampling. Sampling time 10-12 h overnight. Time less in small lakes and those where fish densities are high. In deeper lakes stratification related to depth zones is recommended. CEN standard under development
Ease of sampling	Relatively simple	Variable, requires specialised sampling equipment and relatively specialised personal with diving qualifications Alternative methods can be used such as drop cameras/ROV/Rakes.	Relatively simple, some difficulty in deep lakes, boat required and expert knowledge of potential hazards in specific lakes	Relatively simple, some difficulty in deep lakes, boat required and expert knowledge of potential hazards in specific lakes	Difficult, requires specialised sampling equipment
Laboratory or field measurement	Laboratory sample preparation followed by identification, counting and biomass determination under microscopy. Algal toxin determinations in laboratory, chla.	Field measurements through aerial photography; samples from transects, laboratory identification to species; analysis of chl-a content, fresh, dry and ash free dry biomass (AFDM), organic content		Sample processing in the laboratory, at least 100 organisms per sub-sample (if possible) are identified to the appropriated taxonomic level frequently to species	Sampling duration and area or distance sampled are recorded in order to determine the level of effort. In the laboratory the specimens are identified to species, enumerated, measured, weighted and examined for the incidence of external abnormalities
Ease and level of Identification	Relatively simple for measures based on high taxonomic levels (e.g. family), difficult for identification to lower taxonomic levels (i.e. genus and species) Biomass evaluation is difficult	Identification to species relatively easy with exception of vegetative stages of certain genera (e.g. Potamogeton)	Identification to species relatively easy for high taxonomic groups (e.g. family), difficult for genus or species. Biomass evaluation difficult.	Relatively simple for measures based on high taxonomic levels, difficult for identification to lower taxonomic levels (i.e. species)	Relatively easy, some difficulties may appear with rare specimens and early fry
Nature of reference for comparison of quality/samples/stations	Estimates of phytoplankton indicators/ indices (e.g. cell density, biovolume) to be expected in the absence of significant anthropogenic pressures	Reference values refer to typical indicator values (TRS) and species diversity of flora in lakes not significantly affected by human activities	Little knowledge of reference conditions for phytobenthos in lakes. No established methodology	Reference values for the diversity, abundance and distribution indices indicate expected conditions if the lakes are not significantly affected by human activities. References set using the 25 percentile of sites considered unimpaired-Sweden.	Difficult to determine because only impacts of the physico-chemical and hydromorphological pressures are to be addressed not fisheries/ stocking/ species introductions

Aspect/feature	Phytoplankton	Macrophytes	Phytobenthos	Benthic invertebrates	Fish
Methodology consistent across EU?	No	No	No	No	No
Current use in biological monitoring or classification in EU	Denmark, Finland, Ireland, Netherlands, Sweden, UK and Norway	Denmark, Netherlands, Sweden, UK for conservation and Norway	No	Finland, Netherlands, Sweden and Norway	Finland, Netherlands, Sweden and Norway
Current use of biotic indicators and indices/scores	Taxonomic analyses (e.g. diversity indices, taxa richness, indicators species) Phytoplankton total volume, presence of spring diatom blooms, occurrence of harmful algae, number and proportion of toxin- producing cyanobacteria (blue-greens)	Trophic Ranking Score (TRS), species with low TRS values occur primarily in waters poor in nutrients, while high values are associated with eutrophic waters); level of diversity. Relative occurrence of functional groups. Macrophyte Trophic Index (TIM)	No	Shannon's diversity index (measure of variation and dominance within animal communities); ASPT index (Average Score Per Taxa, related to the occurrence of sensitive (high index value) and tolerant (low value) species); Danish fauna index (evaluation of the effects of eutrophication and organic pollution in the exposed littoral zone of lakes); Benthic Quality Index (BQI, to evaluate eutrophication and organic pollution in the deep bottom areas); O/C Index (complementary or alternative to BQI); acidity index (reflects the presence of species with varying pH tolerances)	Index of Biotic Integrity (IBI) incorporates measurements of fish assemblage composition and relative abundance; % of piscivore/ zooplanktivore (a surrogate for age structure of fish community); % of invertevore/ omnivore
Existing monitoring system meets requirements of WFD?	No	No	No	No	No
ISO/CEN standards	Under development	Under development	Under development	Under development	Under development
Applicability to lakes	High	High (very low in reservoirs)	High (moderate in reservoirs, depending on water management)	Moderate	High (moderate to low in reservoirs).
Main advantages	ξ Easy to sample ξ Relevant for water quality and trophic state ξ Used in many countries to evaluate eutrophication ξ Easy to standardise	ξ Easy to sample and identify (especially in shallow water) ξ Good indicator of a broad range of impacts, especially eutrophication and siltation	ξ Easy to identify to family level ξ Good indicator of eutrophication	ξ Easy to sample (particularly in shallow waters) ξ Relatively simple to analyse ξ Some existing methods developed ξ Combines chemical and biological features	ξ Possibility of adapting classification systems to incorporate requirements of WFD

Aspect/feature	Phytoplankton	Macrophytes	Phytobenthos	Benthic invertebrates	Fish
Main disadvantages	ξ Requires taxonomic expertise for species identification; ξ High temporal variability requires frequent sampling ξ Vertical and horizontal sample profiles required due to spatial heterogeneity	ξ Difficult to sample in deep waters ξ Not commonly used in EU ξ Lack of information for comparison to reference ξ Methodology needs to be developed to incorporate requirements of WFD	ξ No standard methods ξ Lack of information for comparison to reference conditions ξ Not commonly used in EU ξ Methodology needs to be developed to incorporate requirements of WFD	ξ Not commonly used in EU ξ Lack of information for comparison to reference ξ Methodology needs to be developed to incorporate requirements of WFD ξ Time consuming and expensive to analyse	ξ Requires specialised sampling equipment ξ Methodology needs to be developed to incorporate requirements of WFD
Conclusions/ recommendations	Responds rapidly to changes in phosphorus concentration levels. Identification to order or genus are suitable/ recommended levels for monitoring phytoplankton taxonomic composition. While at present it is not clear that identification to species represents a substantial improvement of the information value of the data. More work required in this area.	Key parameter for evaluating other biological components in lakes. Macrophytes hold an important role in the metabolism of lakes. However their monitoring is not frequently used in the assessment of ecological quality.	The phytobenthos holds an important role in the metabolism of lakes. However there is very little experience and information on the use of phytobenthos. Further work is required in this area.	Important parameter for evaluating other biological components. Their use is at an early stage of development. It is required to develop meaningful methodologies. The drafting of a suitable guideline is the part of method development of CEN. The CEN group recommends that the identification of benthic invertebrate fauna should be carried out to the species level.	Key biological quality element. Can be difficult to interpret (fishery, biomanipulation etc.) Integrate all anthropogenic and natural impacts. The composition, abundance and structure of fish communities can be very useful indicators of ecological quality. Fish are only included in monitoring systems of very few EU member states

Table 3.5 Key features of each hydromorphological quality element for lakes

Aspect/feature	Quantity and dynamics of water flow	Residence time	Connection to the groundwater body	Lake depth variation (water level variation)	Quantity, structure and substrate of lake bed	Structure of lake shore
Measured parameters indicative of QE	Inflow and outflow rates. Water level, spillway and bottom outlets discharges (reservoirs), mixing and circulation patterns	volume, depth, inflow and outflow	Lake surface, lake volume	Lake surface, lake volume, lake depth	Grain size, water content, density, LOI, elemental composition, sedimentation rate, sediment age (Cs 137), microfossils in paleolimnological studies	Length, riparian vegetation cover, species present, bank features and composition
Pressures to which QE responds	Climate variability, flood control, man made activities	Climate variability, man made activities	Climate variability, man made activities	Climate variability, siltation, water use, flow discharges	Siltation	Man-made modifications, erosion, run-off Water level fluctuations in reservoirs
Level and sources of variability of QE	Med variability	Low but may vary under extreme climatic conditions	High variability	Generally low variability, high variability in reservoirs (epilimnetic/ hypolimnetic discharges)	Highly variable, dependent on spread patterns and pollution by historical development	Variable
Sampling methodology	Water level gauge, flow meters, and current meters. In situ using scales or submersible probes associated or not to teletransmission	Echo sounding necessary for depth-volume curves, hypsographic curves	Depth-volume curves, hypsographic curves. Water level gauge.	Sonar device (echosounder), phathometer, Transect methodology with metered sounding poles	Core and grab samplers depending on study objectives 3 main sampling types may be distinguished: deterministic, stochastic and regular grid systems	Transects, aerial photography, planimetry
Typical sampling frequency	Weekly/monthly. Hourly/daily (reservoirs)	Every 5/ 10 year, or less frequently if no changes are suspected. Once per year for reservoirs.	variable	Natural lakes: every 15 yr. Reservoirs: variable	Mostly once a year, or less frequently if no changes expected (reference conditions), in polluted lakes every 3rd to 5th year	Every 6 years
Time of year of sampling	All seasons	All seasons, not during ice cover	All seasons	Reservoirs: generally during operational functioning, spring/ begin fall	Usually winter (from ice in Nordic countries)/ summer	Varied. Spring/summer during growing period
Typical "sample" size or survey area	Inflowing/outflowing waters; gauging stations	Entire lake	Entire lake	Entire lake	Varied depending on study objective	Entire lake shore habitat
Ease of sampling /measurements	Simple following minimal practical training	Easy for theoretical residence time estimation Difficult for the evaluation of effective residence time	difficult	Relatively easy following minimal training	Relatively easy following minimal practical training	
Basis of any comparison of results/quality/stations e.g. reference conditions/best quality	Historical data	Historical data	Historical data	Historical data	Paleolimnology/ sediment core studies	Historical data
Methodology consistent across EU?	Yes, according to other countries practices	No	No	No	No	No

Aspect/feature	Quantity and dynamics of water flow	Residence time	Connection to the groundwater body	Lake depth variation (water level variation)	Quantity, structure and substrate of lake bed	Structure of lake shore
Current use in monitoring programmes or for classification in EU	No/yes (reservoirs)	No	No	No, France, UK, Spain	No	No
Existing monitoring systems meet requirements of WFD?	no	No	No	No	No	No
Existing classification systems meet requirements of WFD?	no	No	No	No	No	No
ISO/CEN standards	Yes, refer to ISO/TC 113, CEN/TC 318	No	No	No	No	No
Applicability to lakes	high	High	High	High	High	High
Main Advantages	ξ Hydrological measurements are essential for the interpretation of water quality data and for water resource management	ξ Lake hydrology forms the basis for water quality assessment; ξ Water residence time influences nutrient retention and development of anoxia in deep, stratified water bodies	ξ Lake hydrology forms the basis for water quality assessment.	ξ Water level fluctuation has a direct impact on littoral aquatic life ξ Lake basin morphology influences lake hydrodynamics and sensitivity to nutrient loading	ξ Can be regarded as environmental tachometers. The paleolimnological study is often the only tool to gather knowledge of past reference conditions. ξ The contaminants accumulate often in sediments, the contents are high and the sampling frequency may be quite low.	ξ Indicators in protection of biological integrity
Main disadvantages	Time consuming and costly	Time consuming and costly	Time consuming and costly	Accurate Hydrographic maps of lakes are rarely available in sufficient detail for ecological analysis even if bathymetric maps are available their accuracy should be checked carefully *	Paleolimnological examinations are often relative expensive and the result depends on the undisturbed state of the sedimental archive. The preservation of microfossils may vary.	Methodology needs to be developed to incorporate requirements of the WFD

Aspect/feature	**Quantity and dynamics of water flow**	**Residence time**	**Connection to the groundwater body**	**Lake depth variation (water level variation)**	**Quantity, structure and substrate of lake bed**	**Structure of lake shore**
Conclusions/ recommendations	Important for calculating mass balances etc. A basic element for use with other relevant parameters	Important for characterising and assessing lake quality data.	Only relevant where groundwater constitutes a major part of the lake water balance. Methodology needs further development	Only relevant where it is of ecological significance. Important consideration in the design of monitoring programmes. Very important in reservoirs. As a supporting elements the measurement of depth over time and space are both important. Thus recommended that both are used.	Not generally used in monitoring programmes. Exchange processes between sediment and water are important in determining the quality of many lakes.	Necessary for interpretation of biological parameters (e.g. macrophytes, some fish species) especially for shallow lakes or lakes with an extensive shallow littoral zone.

Only limited monitoring of hydrological features is currently included in existing classification systems in Europe
With the exception of lake depth variation, monitoring for morphological features is not included in any existing classification system in the EU

Table 3.6 Key features of each chemical and physico-chemical quality element for lakes

Aspect/feature	Transparency	Thermal Conditions	Oxygenation Conditions	Salinity	Acidification	Nutrients
Measured parameters indicative of QE	Secchi depth, turbidity, colour, TSS	Temperature	DO, TOC, BOD, COD DOC	Conductivity	Alkalinity, pH, ANC	Total P, SRP, Total N, N-NO3, N-NO2, N-NH4
Relevance of quality element	Eutrophication, acidification	Hydrological cycle, biological activity	Production, respiration, mineralisation		Buffering capacity, sensitivity to acidification	Eutrophication
Pressures to which QE responds	Agricultural, domestic and industrial discharges	Thermal discharges. Water management in reservoirs.	Eutrophication, organic pollution, industrial discharges	Industrial discharges, run-off	Acid rain, industrial discharges	Agricultural, domestic and industrial discharges
Level and sources of variability of QE	High, influenced by allocthonous and autocthonous material	High, influenced by climate conditions, topography, morphology and waterbody dimensions	Variable, diel changes due to respiration/ photosynthesis	Low-medium, influenced by climatic events	Low-medium, influenced by climatic events	Low-medium, influenced by climatic events
Monitoring considerations	Seasonal variation	Seasonal variation (mixing and stratification)	Diel variation High gradient in stratified lakes	Seasonal variation	Seasonal variation	Sufficient speciation to enable discrimination (point and diffuse)
Sampling methodology	*In situ* using Secchi disc TSS: field sample collection followed by laboratory analysis Turbidity: *in situ* turbidimeters, nephelometers Colour: *in situ* comparison to Forel-Ule scale or in lab.	*In situ* using thermistor probes or reversing type Hg thermometer	On-line data acquisition; *in situ* submersible probes; field sample collection followed by laboratory Winkler titration	*In situ* using submersible probes	*In situ* measurement of pH with probe. Sample collection followed by laboratory analysis	Sample collection in the field followed by laboratory analysis
Typical sampling frequency	Monthly/ quarterly related to the biological elements sampling periodicity. Fortnightly of monthly during growth season in Nordic countries.	Monthly/ quarterly	Depends on morphological characteristics of lake: daily/monthly, or at the end of stratification periods (late winter if ice cover or late summer.	Monthly/ quarterly. Should be measured during snow melt or heavy rainfall events	Monthly/ quarterly. Should be measured during snow melt or heavy rainfall events	Monthly/ quarterly Fortnightly of monthly during growth season in Nordic countries.
Time of year of sampling	All seasons.	All seasons	All seasons	All seasons	All seasons	All seasons, or mainly during growth season, SRP also measured during late winter in bottom waters
Typical "sample" size	In-situ observations. Sample collections for chemical analyses (turb, TSS)	Water column profile	Single measurements, water column profiles. 100mL for Winkler titration	In-situ water column profile, integrated epilimnion or single sample from outlet (depending on monitoring purpose)	Single sample from outlet of lake or water column profile	integrated epilimnion, single samples or water column profile (100-500mL)
Ease of sampling /measurements	Simple , using *in situ* probes or surface water sample	Simple, using *in situ* probes or water samplers	Simple, using *in situ* submersible probes or sample collection followed by titration	Simple, using *in situ* probe	Simple	Relatively easy, depth sampler need for deep lakes

Aspect/feature	Transparency	Thermal Conditions	Oxygenation Conditions	Salinity	Acidification	Nutrients
Basis of any comparison of results/quality/stations e.g. reference conditions/best quality	Historical data or data from comparable pristine lakes	Historical data or data from comparable pristine lakes	Historical data or data from comparable pristine lakes	Historical data or data from comparable pristine lakes	Historical data or data from comparable pristine lakes	Statistical methods: MEI index for total phosphorus Historical data or data from comparable pristine lakes
Methodology consistent across EU?	No	No	No	No	No	No
Current use in monitoring programmes or for classification in EU	Yes	Finland, France, Italy, Norway	Finland, France, Italy, Norway Sweden	Finland, Belgium, France, Italy	Belgium, Finland, France, Italy, Norway, Sweden, UK	Germany, Spain, Finland, France, Italy, Ireland, Netherlands, Norway, Sweden, UK
Existing monitoring systems meet requirements of WFD?	No	No	No	No	No	No
Existing classification system meets requirements of WFD?	No	No	No	No	No	No
ISO/CEN standards	No	No	ISO 5813:1983 DO ISO 5815:1989 BOD_5	Yes	Yes, no standard for ANC	Yes, several ISO standards exist
Applicability to lakes	high	High	High	Moderate	High	High
Main advantages	ξ Simple to sample ξ It is possible the most universally used parameter in limnology: it is a simple and powerful tool for tracking long-term trends	ξ Simple to measure ξ Fundamental to understand the hydrological cycle and lake ecology	ξ Simple to sample and to measure ξ Extremely useful because it can act as an integrator of the lake health	ξ Simple to measure ξ Conductivity is little influenced by anthropogenic inputs. A good correlation was found with the MEI cond and P concentration allowing the determination of natural background (reference) concentrations for P	ξ Simple to measure ξ Provides long term trends in acidification ξ Alkalinity is little influenced by anthropogenic inputs(except in acidified and limed lakes). A good correlation was found with the MEI alk and P concentration allowing the determination of natural background (reference) concentrations for P	ξ Provide information and long-term information on the trophic state
Main disadvantages	ξ No disadvantages	ξ May require intensive monitoring for appropriate description of thermal conditions	ξ May require intensive monitoring following depletion events in stratified lakes	ξ Does not provide long term information on trends	ξ None	ξ Need for standardisation of analytical techniques

Aspect/feature	Transparency	Thermal Conditions	Oxygenation Conditions	Salinity	Acidification	Nutrients
Conclusions/ recommendations	Easy to monitor. Secchi disc is widely used in limnology for assessing the biological condition of lakes. However, in humic lakes Secchi disc is not useful for assessment of eutrophication..	Important supporting parameter for interpreting ecological conditions. Seasonal variation, variation with depth and in large lakes horizontal variation should be monitored.	Recommended, and particularly important in deep/stratified lakes and lakes with ice cover.	Important for at characterisation of a lake. For example, it gives an indication of lake mixing processes and of metabolic activity of the lake.	Important for lake characterisation. Acidity is important because it governs the chemical form which metals occur in water body. Alkalinity and Its related variables, pH and conductivity are important classification parameters	Very important indicator for human activity/eutrophication. Total N and P, nitrate and orthophosphate should be monitored as a minimum. Ammonia monitored where concentrations are expected to be problematic e.g. exceedences of limit values over a specific limit. Phosphorus is most often considered to be the nutrient that determines algal production in lakes Thus the focus is mainly on P with regards to lake eutrophication. Nutrients should be monitored not only in water but also in sediments where sediment water interchange processes are expected to be important

3.3 Selection of Quality Elements for Transitional Waters

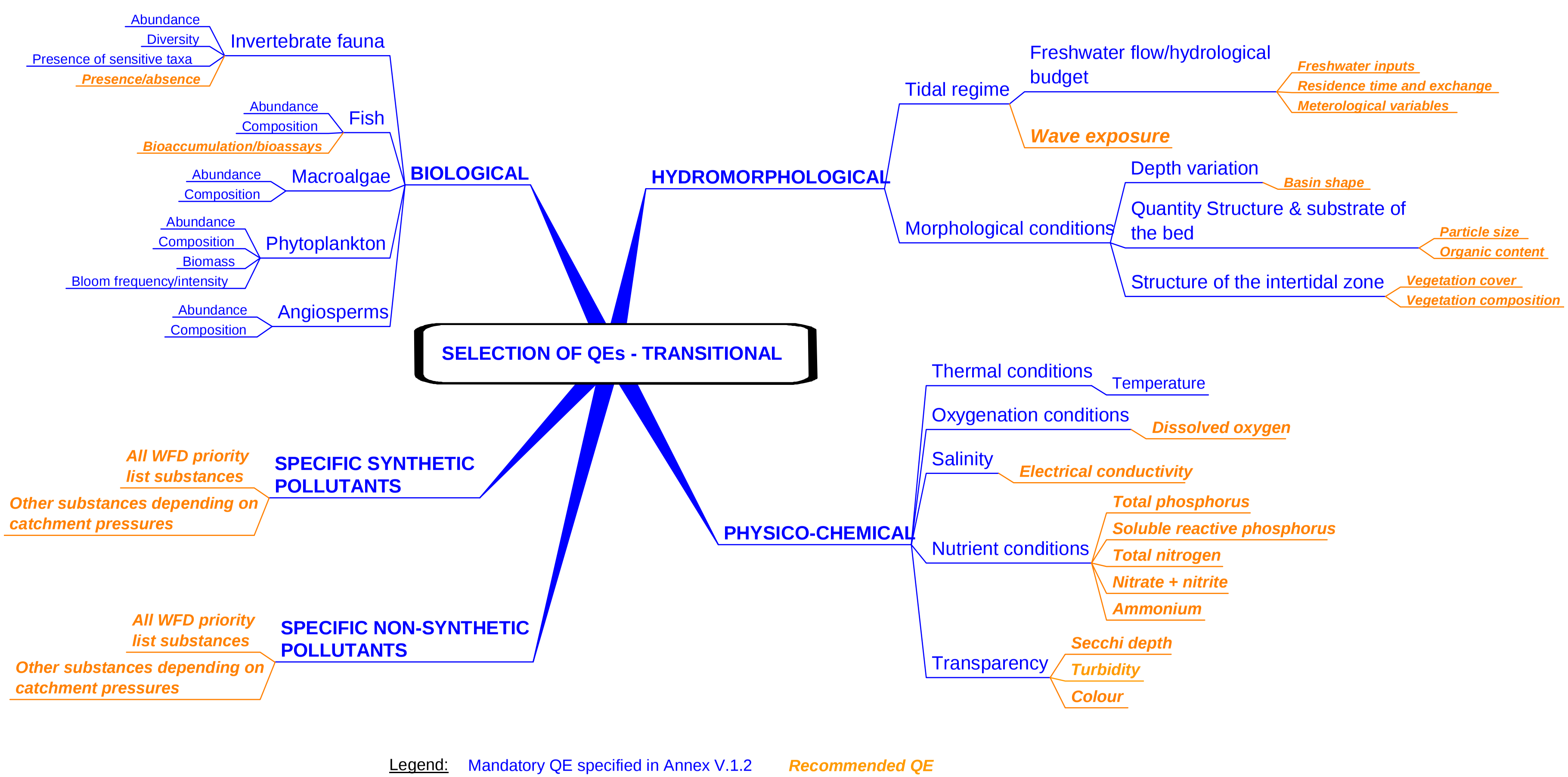


Figure 3.3 Selection of quality elements for transitional waters

Table 3.7. Key features of each biological quality element for transitional waters

Aspect/feature	Phytoplankton	Macroalgae	Angiosperms	Benthic invertebrate fauna	Fish fauna
Measured parameters indicative of QE	Composition, abundance, biomass (biomass as Chl. a), blooms.	Composition, abundance and cover	Composition and abundance	Diversity, abundance and sensitive taxa	Composition, abundance [37], sensitive species.
Supportive/interpretative parameters measured or sampled at the same time (optional parameters)	Transparency, currents, clorophyll "a", Physics-chemical parameters (e.g. temperature, salinity, oxygen, nutrients) Metereological factors Seston	Biomass, density, depth distribu-tion. Physic-chemical (temperature, salinity, nutrients, light/transpa-rency, waves, tides) Sediment and nature of substratum Metereological factors Seston	Biomass, density, depth distribution Physic-chemical (temperature, salinity, nutrients, light/transparency, waves, tides) Sediment and nature of substratum Meteoreological factors Seston	Biomass Characteristics of the habitat (topographic complexity, nature of the substratum, redox, organic matter, etc.) Physico-chemical parameters	Dissolved oxygen, salinity, temperature, pH, tide. Fish biometry and body condition.
Pressures to which QE responds	Environmental pressures such as water temperature, salinity and others have strong influence on phytoplankton composition and abundance; eutrophication; Other impacts affecting nutrient loading	Nitrogen and phosphorus loadings Human exploitation from fishery, aquaculture, tourism, power plants River/land use changes	Nitrogen and phosphorus loadings Human exploitation from fishery, aquaculture, tourism, power plants River/land use changes	Many types of anthropogenic disturbances (i.e. eutrophication, organic pollution and mechanical pollution or sediment disturbance)	Can be used to detect impacts like dams, water regulation measures, lack of natural habitats like rubble beds for spawning etc.
Mobility of QE	Moderate-high at the small scale at which the dynamic processes mainly occur	Low	Low	Low (sessile/semisessile species) to moderate/high (meroplanctic larvae, migratory gammarid species)	Very high (also, transitional waters are transient habitats of migrating species)
Level and sources of variability of QE	Highly variable on a short term temporal scale (i.e., hours-days) affected by : - trophic conditions - phisico-chemical features - hydrodynamics	High to intermediate variability due to: - chemical-physical and biological variables - hydrodynamics and meteo conditions - anthropogenic impacts	Intermediate to low variability due to: - chemical-physical and biological variables - hydrodynamics and meteo conditions - anthropogenic impacts	Highly variable on spatial and temporal scales caused by both natural and anthropogenic processes (i.e., seasonality, trophic conditions, chemical stress, land use, substrate features)	High seasonal variation. Anthropogenic and natural impacts determine changes/absences of species
Presence in transitional waters	Yes	Yes	Yes	Yes	Yes

[37] *Contaminant bioaccumulation and bioassays are not required for monitoring of ecological quality, only composition and abundance of fish fauna required; only relevant for chemical status if Quality Standards are set for transitional water fish*

Aspect/feature	Phytoplankton	Macroalgae	Angiosperms	Benthic invertebrate fauna	Fish fauna
Sampling methodology	Water sampling	Destructive: bottom sampler(hand corer , benthic grabs, etc.) Non-destructive (counts in quadrats or photographic/video methods, including aerial photography for larger species)	Destructive: bottom sampler(hand corer, benthic grabs, etc.) Non-destructive (counts in quadrats or photographic/video methods, including aerial photography)	Destructive: bottom sampler(hand corer, Van Veen grabs, etc.); use 500 micron sieve instead of or together with 1 mm sieve Non-destructive (counts in quadrats or photographic method) Litter bag or leaf pack techniques (in brackish transitional waters?), artificial substrates Use expert knowledge and pilot studies to determine best regional/type-specific sampling design Remote video techniques (ROV, towed sledge) where appropriate Acoustic methods for biogenic structures from a small boat	Fish-Net sampling (stationary: stake net fishery covering full tidal cycle; supported by trap/fixed net fishing and bottom trawls; mesh 8 mm at cod end) Use expert knowledge and pilot studies to determine best regional/type-specific sampling design
Habitats sampled	Water column	Hard and soft bottom	Hard and soft bottom	Hard and soft bottom in eulittoral and sublittoral zone	All main habitats in transitional waters
Typical sampling frequency	Seasonal sampling (?stick to minimum frequencies given in WFD because in transitional waters phytoplankton does not say much?) Use expert knowledge and pilot studies to determine best regional/type-specific sampling design	Seasonally preferable At least twice per year (max/min cover) Use expert knowledge and pilot studies to determine best regional/type-specific sampling design	Seasonally preferable Once or twice per year (max/min cover) Use expert knowledge and pilot studies to determine best regional/type-specific sampling design	Preferable every three months At least twice per year Use expert knowledge and pilot studies to determine best regional/type-specific sampling design	Twice per year Use expert knowledge and pilot studies to determine best regional/type-specific sampling design
Time of year of sampling	? At times of minimum flow rate (not during spring melt) + in the same tidal phase?	Seasonally preferable At least twice per year (max/min cover) Use expert knowledge and pilot studies to determine best regional/type-specific sampling design	Seasonally preferable At least once per year at max cover Use expert knowledge and pilot studies to determine best regional/type-specific sampling design	During peak growth period; sampling in spring and autumn with several days of sampling each to find growth peak As recommended in OSPAR/HELCOM/ICES guidelines	. Spring and autumn; cover full tidal cycle

Aspect/feature	Phytoplankton	Macroalgae	Angiosperms	Benthic invertebrate fauna	Fish fauna
Typical sample size	50-250 ml of water	50x50 cm		0.1 m^2 for soft bottom; for hard bottom use standard sampling time of 20-30 minutes	. [38]
Ease of sampling	Easy	Intermediate to low	Intermediate to low	Intermediate	Intermediate
Laboratory or field measurement	Field collection, laboratory preparation followed by microscopic identification and photo/video documentation	Field collection, laboratory preparation and identification, photo/video documentation, and storage of type material	Field collection, laboratory preparation and identification, photo/video documentation and storage of type material	Field collection, laboratory preparation and identification, photo/video documentation; storage of type material	Field collection, identification and documentation Optional, not mandatory:: assessment of biometry parameters and body weight
Ease and level of Identification	Difficult at the species level. Usually simple to identify to genus	Simple after adequate training, but requires taxonomic experts, particularly for some groups of macroalgae.	Simple after adequate training but requires taxonomic experts, particularly for some groups of macroalgae.	Requires expert identification to species level and for some groups	Easy for experts
Nature of reference for comparison of quality/samples/stations and quality assurance	No. BEQUALM (???) Reference type material partly available at universities and research institutions; quality assurance acc. to national and international programmes	No Reference type material partly available at universities and research institutions; quality assurance acc. to national and international programmes	No Reference type material partly available at universities and research institutions; quality assurance acc. to national and international programmes	Reference type material partly available at universities and research institutions; quality assurance acc. to national and international programmes (OSPAR/HELCOM/ICES, BEQUALM)	No. usually not necessary. If needed, reference type material partly available at universities and research institutions. Quality assurance acc. to national and international programmes (HELCOM Guidelines for coastal fish monitoring might be adapted)
Methodology consistent across EU?	No, but consistent among HELCOM and OSPAR countries for Baltic Sea and North East Atlantic BEQUALM scheme under development (??? we have no actual information – phytoplankton ringtests were carried out in the past, however, they do not cover regional specialities and thus cannot replace national ringtests; chlorophyll ringtests are carried out by QUASIMEME)	No, but consistent in Baltic countries (HELCOM Guidelines for phytobenthos monitoring)	No, but consistent in Baltic countries (HELCOM Guidelines for phytobenthos monitoring)	HELCOM/OSPAR Guidelines for macrozoobenthos, to be adapted to transitional waters if necessary; BEQUALM scheme under development	. Use expert knowledge and pilot studies to determine best regional/type-specific methodology

[38] *OSPAR Guidelines for fish are for contaminant analysis, not relevant for abundance and composition*

Aspect/feature	Phytoplankton	Macroalgae	Angiosperms	Benthic invertebrate fauna	Fish fauna
Current use in biological monitoring or classification in EU	Part of national monitoring in different EU countries	Part of national monitoring in different EU countries	Part of national monitoring in different EU countries	Part of national monitoring in different EU countries	Part of national monitoring in different EU countries
Current use of biotic indices/scores	No	No, but ratio of fast-growing opportunistic versus slowly growing perennial species can be used (shifts due to eutrophication)	No	No	No
Existing monitoring system meets requirements of WFD?	No	No	No	No	No
ISO/CEN standards **Other standards**	OSPAR JAMP Eutrophication Monitoring Guidelines: Phytoplankton Species Composition; HELCOM COMBINE Monitoring Guidelines *i)* for phytoplankton species composition, abundance and biomass and *ii*) for phytoplankton Chlorophyll a ISO 10260 (1992) for the determination of chlorophyll a	ISO/CEN: No HELCOM COMBINE Guidelines on Phytobenthos Monitoring	ISO/CEN: No HELCOM COMBINE Guidelines on Phytobenthos Monitoring	ISO 7828:1985 (Guidance on handnet sampling of aquatic benthic macro-invertebrates) ISO 9391:1993 (Sampling in deep waters for macro-invertebrates – Guidance on the use of colonization, qualitative and quantitative samplers) ISO 16665 (marine soft-bottom macrofauna; in preparation) HELCOM/OSPAR Guidelines for macrozoobenthos, to be adapted to transitional waters if necessary;	No
Applicability to Transitional waters	low	High	High	High	with restrictions

Aspect/feature	Phytoplankton	Macroalgae	Angiosperms	Benthic invertebrate fauna	Fish fauna
Main advantages	Ease of sampling	Identify potential disturbance phenomena Evaluation of community evolution Cost-effective (???), objective and amenable to optimisation through statistical procedures	Identify potential disturbance phenomena Evaluation of community evolution Cost-effective (???), objective and amenable to optimisation through statistical procedures	Identify potential disturbance phenomena Evaluation of community evolution Cost-effective, objective and amenable to optimisation through statistical procedures	Relatively easy to compare fish fauna at "pristine state" by use of historical list of fish species with list in actual condition. Identifies natural and anthropogenic impacts from a wide range of sources. [Passage of migratory fish is an excellent indicator of good water quality in freshwater part of river only; in trans. water indicative of good hydromorphological conditions – no dams/constructions or sufficient number of fish passages]
Main disadvantages	High spatial-temporal variability, occurrence of freshwater, marine and brackish species in varying physiological state (brackish water zone as "graveyard" of freshwater and marine species), high influence of temperature and salinity fluctuations on phytoplankton composition Taxonomic identification can be difficult and time-consuming. Lack of quality assurance protocols	No standardized method except in HELCOM countries Lack of taxonomic detail (looping of tiny species into morphological groups). Lack of quality assurance protocols	No standardized method except in HELCOM countries Lack of taxonomic detail (looping of tiny species into morphological groups). Lack of quality assurance protocols	High spatial-temporal variability Lack of taxonomic detail (looping of tiny species into morphological groups). Lack of quality assurance protocols High taxonomic expertise required. High sampling frequency and high number of samples required due to variability in time and space	The high mobility, occurrence of eurytolerant marine and freshwater fish and of migrating fish species makes it difficult to relate to impacts occurring at the local scale Long life cycles Large sample sizes requirements Long time series needed for reliable accounts on composition and abundance

Table 3.8 Key features of each hydromorphological quality element for transitional waters

Aspect/feature	Morphological conditions			Tidal regime Hydrological budget
	Depth variation	**Quantity, structure and substrate of the bed**	**Structure of the transitional zone**	
Measured parameters indicative of QE	Shape of the basin	Grain size Organic content	Vegetation cover Vegetation type	Freshwater inputs Exchange with the ocean Water residence time Metereological variables
Pressures to which QE responds	Hydrological modification Suspended solids Dredging	Mechanical and organic pollution Hydrological modification Suspended solids. Dredging	Land use and modification of hydrology	Modifications of land use Modifications of the marine sandy coasts Outlet modification
Level and sources of variability of QE	Slow changes due to impaired decomposition, Solid transport through the ecotone from the terrestrial environment, freshwater transport High variability for some typology due to sand transport and accumulation.	Low natural variability Moderate variability due to human impact	Low natural variability Moderate variability due to human impact	High temporal variability due to hydrological and meteo-conditions Low temporal variability due to groundwater uses and land use
Sampling methodology	Echo soundings Remote sensing	Corers	Remote sensing images and field surveys	In situ measurements of water flows
Typical sampling frequency	Once every 5 years	Once every 3 years	Once every 3 years	A complete annual cycle with quarterly samplings, every 3 years
Time of year of sampling	Indifferent	Indifferent	Spring-summer	Seasonal
Typical "sample" size or survey area	Grid from 1 X 1 m up to 10 m X 10 m	Undisturbed bottom sample from 10 cm X 10 cm up to 200 cm X 200 cm	Entire ecotone	All water inputs and outputs
Ease of sampling /measurements	Rapid electronic measurements	Rapid sampling, time consuming laboratory analysis	Easy Rapid using remote sensing technology, if possible.	Easy and rapid sampling when supported by expensive field equipment
Basis of any comparison of results/quality/stations e.g. reference conditions/best quality	Maps of the National Hydrographical services	No	Corine habitat maps	No
Methodology consistent across EU?	No	FOLC method	No	No
Current use in monitoring programmes or for classification in EU	No	No	No	No
Existing monitoring systems meet requirements of WFD?	No	No	No	No

Aspect/feature	**Morphological conditions**			**Tidal regime Hydrological budget**
	Depth variation	**Quantity, structure and substrate of the bed**	**Structure of the transitional zone**	
Existing classification systems meet requirements of WFD?	No	No	N0	No
ISO/CEN standards				
waters	Yes	Yes	Yes	Yes
Main Advantages	Rapidity of sampling and map making	Rapid sampling	Rapid sampling and map making	Rapid sampling and map making
Main disadvantages	None	Time consuming laboratory analysis		Expensive instrumentation

Table 3.9 Key features of each chemical and physico-chemical quality element for transitional waters

Aspect/feature	Transparency	Thermal conditions	Oxygenation	Salinity	Nutrients
Measured parameters indicative of QE	Light penetration & quality	Thermal Profiles along water column	Oxygen profiles	ppt psu	Reactive species and total budgets (N,P,Si)
Relevance of quality element	High	High	High	High	High
Pressure to which the QE responds	Resuspension Solids transport by rivers Aquaculture Eutrophication	Climate variables Thermal pollution Provides information on mixing conditions	Organic matter loading Eutrophication Aquaculture	Freshwater and marine water inflows Water hydrodynamics	Nitrogen and phosphorus loading from river discharge, local point and non-point pollution, aquaculture
Level and sources of variability of QE	High natural variability due to seasonal plankton blooms, freshwater runoff and meteorological factors	Predictable high natural variability due to seasonal and mixing condition Some variability due to human impact	High natural variability due to daily changes in temperature and production/respiration.	Predictable high natural variability due to the thermohaline circulation and freshwater inputs Anthropogenic inputs	High natural variability due to seasonal variation (meteo and biological) Anthropogenic inputs
Monitoring considerations	Dependence from daylight and salinity	Special attention to water column profile Dependence on salinity	Dependence from hydrodynamics, physical characteristics and day time of measurement Due to fast dynamics characterising lagoons and coastal lakes, repeated 24-72 hours continuous samplings are strongly recommended at least twice per year (winter-summer)	Dependence from hydrodynamics (and salinity)	Dependence from hydrodynamics and biological factors Special attention to sediments exchange for total budget consideration
Sampling methodology	Secchi disc, autographic photometers	Portable electronic equipment Automated on site buoy	Portable electronic equipment Automated on site buoy	Portable electronic equipment Automated on site buoy	Water sampling, followed by laboratory analysis
Typical sampling frequency	Monthly	Daily measurements with on site buoy Monthly controls	Daily measurements with on site buoy Monthly controls	Daily measurements with on site buoy Monthly controls	Monthly
Time of year of sampling	Every month	Daily + Every month	Daily + Every month	Daily + Every month	Every month
Typical sample size	none	none	None/100 ml	None/100 ml	1-2 litres
Ease of sampling/measurements	High	High	High	High	High
Basis of any comparison of results/quality/stations e.g. reference conditions/best quality quality/samples/stations					Spatial comparisons and site-based trend assessment
Methodology consistent across EU			OSPAR JAMP Eutrophication Monitoring Guidelines: Oxygen		OSPAR Nutrient Monitoring Guidelines
Current use in monitoring or classification programme in EU					OSPAR Nutrient Monitoring Guidelines

Aspect/feature	Transparency	Thermal conditions	Oxygenation		Nutrients
Existing monitoring system meets requirements of WFD					
ISO/CEN standards	No	No	No	No	No
Applicability to transitional waters	High	High	High	High	High
Main advantages	Ease of measurement	Ease of measurement	Ease of measurement if autographical	Ease of measurement.	Rapid sampling
Main disadvantages	Extreme temporal variability.	Account must be taken of diurnal and seasonal variability.	Account must be taken of diurnal and seasonal variability. Time consuming if not autographical	Account must be taken of the tidal state at the time of sampling.	Time consuming High spatial and temporal variation Antagonistic with phytoplankton and seaweeds biomass

3.4 Selection of Quality Elements for Coastal Waters

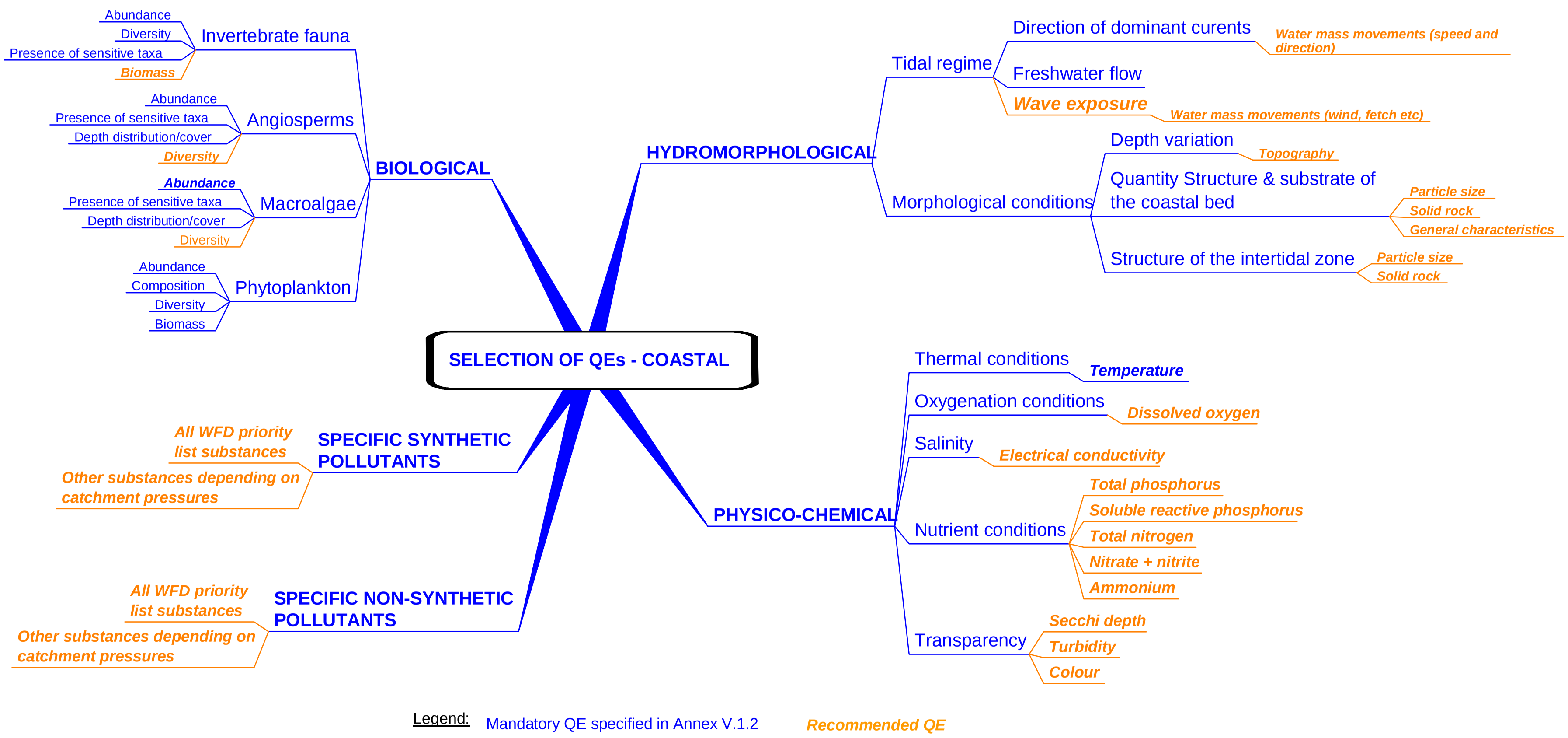


Figure 3.4 Selection of quality elements for coastal waters

Table 3.10 Key features of each biological quality element for coastal waters

Aspect/feature	AQUATIC FLORA		AQUATIC FAUNA
	Phytoplankton	**Macroalgae/Angiosperms (Phytobenthos)**	**Benthic invertebrate fauna**
Measured parameters indicative of QE As reported in Annex V (1.1.4 and 1.2.4)	Composition, abundance, biomass, blooms	Composition, abundance, sensitive taxa, cover	Composition, abundance, diversity, sensitive taxa
Supportive/interpretative parameters measured or sampled at the same time	Physico-chemical parameters: transparency, , temperature, salinity, oxygen, nutrients chlorophyll "a" Hydromorphological parameters: currents Key species	Very important supporting parameter :distribution (Horizontally and vertically) Biomass, density Physico-chemical (transparency , temperature, salinity, nutrients) Hydromorphological parameters: tides, wave exposure, bearing, slope, Sediment and nature of substratum Height above/below tidal datum	Very important supporting parameter: biomass Characteristics of the habitat (morphology, wave exposure, bearing, slope texture, topographic complexity, nature of the substratum etc.) Physico-chemical parameters (temperature, salinity, oxygen, nutrients) Presence and distribution/extent of particular biogenic aggregations (i.e. molluscs beds, polychaete "reefs")
Pressures to which QE responds	Eutrophication Nutrients discharges, suspended matters, toxic substances	Many types of anthropogenic disturbances (i.e. nutrient loading, fishing, modification of shore and bed structure suspended matter input)	Many types of anthropogenic disturbances (i.e. :eutrophication, organic pollution, mechanical disturbance, physical modification of seabed , sediments dynamics and fishing)
Mobility of QE	High	Low	Low
Level and sources of variability of QE	High inter and intra-seasonal variation in community structure and biomass. Spatial patchiness Influenced by: irradiance, nutrient availability, water column stability and residence time.	Small-scale spatial patchiness and temporal variation, seasonal trends for some taxa Influenced by climatic seasonality (i.e. events, irradiance, nutrient availability)	Small-scale spatial patchiness and temporal variation, seasonal trends for some taxa Influenced by seasonal growth patterns Influenced by substrate variability and physical environmental parameters variations
Presence in coastal waters	Abundant	Abundant to rare: Regional differences: (e.g. seagrass beds are rare in the North Sea)	Abundant
Sampling methodology	Water sampling (plankton net, water samples)	Direct by SCUBA diving or walking in the intertidal: non-destructive (quantitative counts in quadrats or photographic method, semi-quantitative abundance estimation according to defined scale) , destructive (suction or bottom sampler) Indirect: Shipboard sampling using box samplers (grab, corer) Remote sensing surveys (satellite, airborne multispectral or aerial photography) (e.g. density on mudflats) Remote video techniques (ROV, towed sledge) where appropriate	Direct by SCUBA diving or walking in the intertidal: non-destructive (quantitative counts in quadrats or photographic method, semi-quantitative abundance estimation according to defined scale) destructive (suction or bottom sampler) Indirect: Shipboard sampling using box corers, grabs, dredges Remote video techniques (ROV, towed sledge)where appropriate Echo sounding technique (ROXANN) which can be used to measure the extent of biological habitats

Aspect/feature	**AQUATIC FLORA**		**AQUATIC FAUNA**
	Phytoplankton	**Macroalgae/Angiosperms (Phytobenthos)**	**Benthic invertebrate fauna**
Habitats sampled	Water column.	Hard and soft bottom	Hard and soft bottom
Typical sampling frequency	Best: 15 days At least: monthly sampling at standard depths Determine best regional/type-specific sampling design (i.e. maximum and minimum levels)	Seasonally preferable (4 times for year) At least twice per year (max/min cover); regionally different (HELCOM: once per year) Frequency may be less for seagrasses and/or other long-lived species	Seasonally preferable at least during peak growth period As recommended in OSPAR/HELCOM/ICES guidelines once per year (same season) At least twice per year for Mediterranean Ecoregion
Time of year of sampling	Should cover all seasons, with emphasis on bloom seasons. And particular events related (exceptional blooms)	Seasonally preferable (4 times for year) At least twice per year (max/min cover) with timing depending on ecoregion As recommended in OSPAR/HELCOM/ICES guidelines(once per year, June-September)	Seasonally preferable at least during peak growth period
Typical sample size	Variable: usually 50-250 ml, /1 litre As recommended in OSPAR/HELCOM/ICES guidelines	Variable dependent on methodology and phytobenthos group types Quadrats of different sizes (from 15x15cm to several m2 depending on the size of the group) As recommended in OSPAR/HELCOM/ICES guidelines or SCUBA Diving transects (ISO std under development)	Variable dependent on methodology Quadrats of different sizes (20÷50 cm) for hard bottom Combination of nets and corers for soft bottom As recommended in OSPAR/HELCOM/ICES guidelines SCUBA Diving transects (ISO std under development)
Ease of sampling	Simple water sampling.	In situ techniques: simple after training of skilled personnel (SCUBA-diving) for species identification and methodology; but variable due to meteo-marine conditions and methodology Shipboard sampling: easy on soft bottom, difficult on hard bottom. Aerial photography is technically demanding	In situ techniques :simple after minimum training but variable due to meteo-marine conditions and methodology Relatively easy shipboard sampling
Laboratory or field measurement	Field collection, laboratory preparation followed by microscopic identification.	Field collection, laboratory preparation, sorting and identification	Field collection, laboratory sorting and identification
Ease and level of Identification	Taxonomy expert work. Difficult at the species level. Usually simple to identify to genus	Simple after adequate training but requires taxonomic experts, particularly for some groups of macroalgae.	Taxonomy expert work. Simple after adequate training.
Nature of reference for comparison of quality/samples/stations	Ref. type material at Universities & research Institutions; quality assurance according to national and international programmes and recommendation (OSPAR/HELCOM/ICES) BEQUALM, under development QUASIMEMME (chlorophyll a)	Ref. type material at Universities & research Institutions; quality assurance according to national and international programmes and recommendation (/HELCOM COMBINE guidelines)	Ref. type material at Universities & research Institutions; quality assurance according to national and international programmes and recommendation (OSPAR/HELCOM/ICES;) BEQUALM (UK and NL)
Methodology consistent across EU?	No but consistent across NE Atlantic and across Baltic Sea (OSPAR and HELCOM Countries)	No but consistent across NE Atlantic and across Baltic Sea (OSPAR and HELCOM Countries)	No but consistent across NE Atlantic and across Baltic Sea (OSPAR and HELCOM Countries)

Aspect/feature	**AQUATIC FLORA**		**AQUATIC FAUNA**
	Phytoplankton	**Macroalgae/Angiosperms (Phytobenthos)**	**Benthic invertebrate fauna**
Current use in biological monitoring or classification in EU	Italy, Norway (partly) , Netherlands, Germany, Sweden (monit), Spain	Norway (partly) Germany (tentative),Denmark, Sweden(monit & class), UK, Spain	Norway (partly), Netherlands, Germany, Spain, , Sweden(monit & class)
Current use of biotic indices/scores	Norway	No Spain (Catalonia)	Norway, Sweden UK, Spain
Existing monitoring system meets requirements of WFD?	Generally No Partially in: Italy, Germany, Norway, Sweden	Partially in Germany, Norway, UK, Sweden	Norway, Partially in Germany, Sweden
ISO/CEN standards	No CEN/TC 230 N 0423 in preparation	No Rocky shore ISO standard in preparation (Norway standard 9424):	National Norwegian soft bottom standards (ISO in preparation: TC 230/SC 5: ISO/TC 147/SC5 N350) In preparation ISO16665
Applicability to Coastal waters	High	High	High
Main advantages	Good indicator of changes in trophic status Ease of sampling Indicators of short-term impact due to rapid turn-over times Important monitoring of harmful algae (DSP/PSP)	Good integrating indicator of general state of environment Identify potential disturbance phenomena Evaluation of community evolution: provides information on ecosystem stability Key element in coastal ecosystems Good integrating indicator of broad range of impacts Cost-effective, consistent and amenable to optimisation through statistical procedures	Good integrating indicator of general state of environment Identify potential disturbance phenomena Evaluation of community evolution Cost-effective, consistent and amenable to optimisation through statistical procedures
Main disadvantages	High spatial-temporal variability requires frequent sampling and good spatial coverage Consistent identification requires consistent training and quality assurance procedures as well as intercalibration Taxonomic identification can be difficult and time-consuming	Require certified and skilled divers Not standardised method Lack of taxonomic detail (looping of tiny species into morphological groups) Consistent identification requires consistent training and quality assurance protocols	Lack of taxonomic detail (looping of tiny species into morphological groups) Consistent identification requires consistent training and quality assurance protocols Require certified and skilled divers
Recommendation/ Conclusion	Good indicator of changes in trophic status and of short-term impact, due to rapid turnover times. Identification of nuisance or potential toxic species is a particularly important assessment parameter. Bloom frequency and intensity are indicative parameters for classification of ecological status. WFD minimum frequency (every 6 months) can be inadequate for many regions: pilot studies and local expert knowledge could help in establishing the most appropriate frequencies.	Key elements in coastal ecosystems. Good integrating indicators of the status of the environment, responding to a broad range of impacts. Provide important information on the ecosystem stability, as variations may indicate long-term changes in the physical conditions at the site. For angiosperms, the most important parameter is distribution (extension and variation in time and space).	Good integrating indicators of the status of the environment. Important variables to be considered together with the required parameters (composition and abundance) are diversity of species and presence of sensitive or higher taxa as well as biomass, the latter being indicative of eutrophication. Several indexes exist and their use is quite spread, although not commonly agreed.

Table 3.11 Key features of each hydromorphological quality element in coastal waters

Aspect/feature	Morphological conditions			Tidal regime	
	Depth variation	**Structure and substrate of the coastal bed**	**Structure of the intertidal zone**	**Direction of dominant currents**	**Wave exposure**
Measured parameters indicative of QE	Topography of the type of water body	- Grain size - Solid rock - Other general characteristics: coarse description (mud, sand, gravel, hard soils or rocks sedimentological structures (ripples, sand reefs, under water dunes etc.) - bioturbation, lamination in sediment cover, oxigenation conditions in sediments	- Rock type , form and exposure to waves, - Grain size - Distribution of biological communities - H/L tide levels - erosion/deposition	Water mass movements (speed and direction)	Water mass movements (wave, wind, Fetch-index) frequency of storms directions H/L tide/surge levels
Pressures to which QE responds	Landfill, dredging, dumping, and natural large scale bottom dynamics	Mechanical disturbance and variation in structure and substrate composition due to anthropogenic input	- Mechanical disturbance and variation in structure and substrate composition due to anthropogenic input - Change in macroalgal composition due to chemical inputs. - diking - beach nourish	Natural modification (mechanical and climatic) of coastline Anthropogenic modifications (constructions)	Natural modification (mechanical) of coastline climate constructions
Level and sources of variability of QE	Very low variability due to natural erosion and sedimentation. Moderate variability due to human impact Seasonal variations are important in nearshore areas	Low natural variability Moderate variability due to human impact Seasonal variations are important in nearshore areas	High natural variability (regularly: tidal flooding and drought periods. irregularly: storms, etc.). High variability due to human impact	High natural variability depending on winds, tides and climatic changes low frequency climatic changes (e.g. NAO) (Germany)	Seasonal variability Low frequency climatic changes
Sampling methodology	Echo soundings ROV	Corers Scanning acoustic techniques Diving Video	- Skindiving , photo, corer (intertidal soft bottom) - Remote imaging (satellite airborne systems); - Viewpoint photography; In-situ measurements along transects[39]s	Drifters, in situ measurements, autographic instruments, Doppler Historical flows data , modelled flows (mainly large scale)	In situ measurements, autographic instruments, Fetch calculations Calculations (mainly large scale) from maps and meteorological data modelling gauging

Aspect/feature	**Morphological conditions**			**Tidal regime**	
	Depth variation	**Structure and substrate of the coastal bed**	**Structure of the intertidal zone**	**Direction of dominant currents**	**Wave exposure**
Typical sampling frequency	Once every 5/6 years Before and after significant pressure applied	Once every 5/ 6 years Sampling "ad hoc" for specific reasons (i.e. construction, benthic studies support)	Once /twice every 5/ 6 years Sampling for specific reasons (i.e. construction, mapping)	Annual cycle.	Annual cycle.
Time of year of sampling	Indifferent Important if seasonal variations in nearshore areas	Indifferent	Summer (to avoid winter with possible ice cover) and if using biological communities	Annual cycle	Annual cycle
Typical "sample" size or survey area	Hydromorphological grids vary according to desired scales. Suggestion: grid from 100 m X 100 m up to 500 m X 500 m	Undisturbed bottom sample from 10 cm X 10 cm up to 200 cm X 200 cm box grab samples (50cm x 50 cm, where appropriate) (Germany) Larger areas covered by ROV/divers Side Scan Sonar	Whole intertidal zone using imaging techniques Sediment samples collected by 5cm diameter corer, 15cm depth.(UK) Undisturbed bottom sample from 10 cm X 10 cm up to 200 cm X 500 cm (Norway)	Instruments integrate information from large spatial and temporal areas Importance of instrument's location operational modelling	Instruments integrates information from large spatial and temporal areas Importance of instrument's location
Ease of sampling /measurements	Rapid electronic measurements	Rapid sampling, time consuming laboratory analysis	Rapid sampling, time consuming laboratory analysis depending on substrate type or sampling technique	Rapid sampling and map making with autographic instruments	Rapid sampling and map making with autographic instruments
Basis of any comparison of results/quality/stations e.g. reference conditions/best quality	Maps of National Hydrographical /Geological services,	Seabed sediment maps from National Geological Surveys (i.e. British Geological Survey)	Biological maps should use a standard classification such as EUNIS (e.g. UK has the Marine Biotope classification) Maps from National Geological Surveys (e.g. British Geological Survey)	No	No
Methodology consistent across EU?	No	No	No	No	No
Current use in monitoring programmes or for classification in EU	Used in operational monitoring, but not continuously in most of the countries	Italy Sweden (in connection with benthic studies)	UK – SAC monitoring programme		
Existing monitoring systems meet requirements of WFD?			Partially for UK?		
Existing classification systems meet requirements of WFD?					

Aspect/feature	**Morphological conditions**			**Tidal regime**	
	Depth variation	**Structure and substrate of the coastal bed**	**Structure of the intertidal zone**	**Direction of dominant currents**	**Wave exposure**
ISO/CEN standards					
waters	Yes	Yes	Yes	Yes	Yes
Main Advantages	Rapidity of sampling and map making	Rapid sampling Provides information about hydrodynamism and different community distribution	Rapidity of sampling and map making Provides an overview of a whole system to identify extent of localised effects Provides link with biological QE	Continuous measurement, ease of mapping. Information on dispersion of pollution (i.e. oil spill) and loads dilution	Continuous measurement, ease of mapping. Information on dispersion of pollution (i.e. oil spill) and loads dilution
Main disadvantages	None	Time consuming laboratory analysis	Time consuming laboratory analysis for sediment characterisation Mapping can be expensive	Expensive instrumentation.	Expensive instrumentation
Recommendation/ Conclusion	Depth variations could be important elements to be monitored in areas where disturbances are expected: anthropogenic changes will have relevance for the status classification of the water body.	Indicator of hydrodynamism and supporting element for community distribution; Changes in morphological conditions and/or nature of the substratum may exert severe detrimental effects on benthic organisms.	Note relevant for the Mediterranean and the Baltic ecoregions, given their low tidal range. Thus it is suggested to use the "intertidal/ *mediolittoral"* term for meaningful ecological relevance (see Annex VI).	Direction and intensity (speed) of dominant currents are important parameters, especially in ecoregions or part of ecoregions with low tidal range (Baltic, Mediterranea, Skagerrak) where tidal currents play a very minor role, if any. Can be particularly relevant in areas where anthropogenic disturbance occur (see Annex VI). It can be necessary to take into account short term effects.	To be monitored in areas submitted to anthropogenic disturbances. Suggested parameters are frequencies of storm, direction, high/low tide surge levels.

Table 3.12 Key features of each chemical and physico-chemical quality element for coastal waters

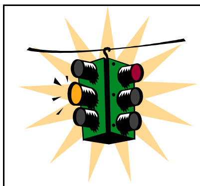
Aspect/feature	Transparency	Thermal Conditions	Oxygenation Conditions	Salinity	Nutrient conditions
Measured parameters indicative of QE	Light penetration & quality	Temperature Water column structure (in stratified waters)	D.O. concentration O2 % saturation	ppt psu	NO3, NO2, NH4, P04, Si concentration, total N, total P
Relevance of quality element	High	High	High	High	High
Pressures to which QE responds	Nutrient surplus (plankton enrichment). Organic matter pollution (sewage, sludge) Particulate load Land runoff Riverine discharges	Thermal point source pollution Thermal alteration due to reduced water exchange and modified dynamics by coastal constructions Climatic changes	Organic pollution, anthropog. enhanced productivity Reduced water exchange by human impacts .	Freshwater runoff. Mixing condition and origin of the water masses Reduced water exchange by human impacts	nutrient surplus, organic pollution (sewage, sludge) Land runoff Local point and diffuse source inputs Atmospheric input (especially N)
Level and sources of variability of QE	High natural variability due to seasonal plankton blooms freshwater runoff, wind and tidal currents action	High natural variability due to seasonal and mixing condition	High natural variability due to daily changes in temperature and production/respiration. and water exchange conditions. Supply of organic matter Wind activity	High natural variability due to the thermohaline circulation (wind, precipitation, riverine inputs…)	High natural variability due to seasonal variation (meteo and biological) Riverine inputs Water mass movements Remineralisation
Monitoring considerations	Dependence from daylight	Special attention to water column profile when necessary	Dependence from hydrodynamism physical characteristics and day time of measurement; Relate sampling time to tidal cycle	Dependence from hydrodynamism	Dependence from hydrodynamism
Sampling methodology	Secchi disc, autographic photometers	Autographic instruments CTD	Autographic instruments, or water sampling deployed automatic systems	Autographic instruments CTD	Water sampling, followed by laboratory analysis. Autographic instruments (experimental)
Typical sampling frequency	Best: every 15-30 days At least seasonal	Best: every 15-30 days At least seasonal	Best: every 15-30 days At least seasonal	Best: every 15-30 days At least seasonal	Best: every 15-30 days At least seasonal
Time of year of sampling	All year round	All year round	All year round	All year round	All year round
Typical "sample" size	Single measurement or water column profile.	Water column profile. deployed automatic systems	Water column profile. deployed automatic systems	Water column profile. deployed automatic systems	Single sample, or water column profile. deployed automatic systems
Ease of sampling /measurements	Simple.	Simple.	Simple using autographic instruments.	Simple.	Simple. Surface water sample or profile using depth sampler.
Basis of any comparison of results/quality/stations e.g. reference conditions/best quality		No	No	Norway UK	Denmark: Quasimemme + national inter comparisons Sweden. Quasimemme Norway (ring tests/ Quasimemme)

Aspect/feature	Transparency	Thermal Conditions	Oxygenation Conditions	Salinity	Nutrient conditions
Methodology consistent across EU?	No	No	No but consistent across NE Atlantic and across Baltic Sea (OSPAR and HELCOM Countries)	No	No but consistent across NE Atlantic and across Baltic Sea (OSPAR and HELCOM Countries)
Current use in monitoring programmes or for classification in EU	Italy, Sweden, UK, Denmark, Spain (Basque Country)	Italy, Sweden, Norway Germany, UK, Denmark, Spain (Basque Country)	Italy, Sweden, Norway Germany, UK, Denmark, Spain (Basque Country)	Italy, Sweden, Norway Germany, UK, Denmark, Spain (Basque Country)	Italy, Sweden, Norway Germany, UK, Denmark, Spain (Basque Country)
Existing monitoring systems meet requirements of WFD?	No Spain (Basque Country)	No Partially for UK and Norway Spain (Basque Country)	No Partially for UK and Norway Spain (Basque Country)	No Partially for UK and Norway Spain (Basque Country)	No Partially for UK and Norway Spain (Basque Country)
Existing classification system meets requirements of WFD?	No	No	No Norway	No	No Norway
ISO/CEN standards	No	No	Norway	No	Norway
Applicability to Coastal waters Information in this row is redundant because parameters are mandatory according to WFD	High	High	High	High	High
Main advantages	Ease of measurement.	Ease of measurement.	Ease of measurement if autographical.	Ease of measurement.	Rapid sampling
Main disadvantages	High temporal variability	None	Time consuming if not autographical	None	Time consuming
Recommendation/ Conclusion	Easy measure. Routinely used in most national monitoring programmes. Measurement is difficult in "troubled waters", e.g. the NE Atlantic Wadden Sea with high loads of resuspended sediments.	Easy measure. Routinely used in most national monitoring programmes. Temperature profiles along the water column easily obtained by in *situ* autographic instruments. The thermal structure of the water column is a very important information (see Annex VI).	Easy measure. Routinely used in most national monitoring programmes. Important parameter. % of saturation is particularly relevant (see Annex VI).	Easy measure. Routinely used in most national monitoring programmes. Important parameter (see Annex VI).	The concentration of nutrients, together with the concentration of chlorophyll 'a', indicator of actual production, provide information on the general trophic conditions. Important parameter (see Annex VI).

4 Design of groundwater monitoring programmes

4.1 Introduction

This Section of the guidance provides specific advice on the design of groundwater monitoring programmes. It also describes the general principles applicable to all of the groundwater monitoring programmes, as well as the specific requirements for each of the groundwater monitoring programmes.



Look Out!

This guidance uses the term conceptual model as shorthand for the understanding, or working description, of the real hydrogeological system that is needed to design effective groundwater monitoring programmes. The term should NOT be taken to imply that a mathematical model is required for all bodies of groundwater. On the contrary, complex mathematical models are only likely to be required to properly design and justify very expensive restoration measures for bodies that are failing to achieve the Directive's objectives.

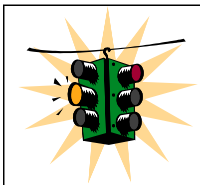
4.2 Principles for the design and operation of groundwater monitoring programmes

4.2.1 Identify the purposes for which monitoring information is required

The design of monitoring programmes involves deciding what to monitor, where and when. The answers to these questions depend first and foremost on the purpose which monitoring will serve. The first step before designing a network is therefore to clearly identify the purpose, or purposes, for which the monitoring information is needed.

The monitoring required by the Directive is intended to provide information to help assess the achievement of the Directive's environmental objectives. Monitoring programmes should therefore be designed to provide the information needed to establish whether the particular environmental conditions specified by these objectives are being achieved. Among other things, this will involve monitoring to test the understanding of the groundwater system on which assessments are based and the effectiveness of any measures applied.

The relevant environmental objectives for groundwater are listed in Section 2.13 of the common understanding.



Look Out!

The requirements of the Directive's 'prevent or limit inputs of pollutants' objective [Article 4.1(b)(i)] are unclear. The Directive does not specify which pollutants[40] should be prevented from entry, and to what extent the entry of others on the list should be limited nor does it describe any relevant monitoring requirements in Annex V. It is therefore not possible to provide guidance on what, if any, monitoring should be implemented to assess the achievement of this objective.

Additional criteria for assessing good groundwater chemical status, including the application of quality standards, may be established by the

[40] *Annex VIII provides an indicative list of the main pollutants*

new groundwater directive envisaged by Article 17. It is assumed that the daughter directive will indicate how compliance with any quality standards it establishes should be assessed. This document only provides monitoring guidance for the good chemical status criteria that are not dependent on the daughter directive.

Annex V of the Directive describes the purposes of the different groundwater monitoring programmes. It also specifies certain criteria for determining what, where and when to monitor in respect of these purposes. Figure 4.1 below summarises these requirements.

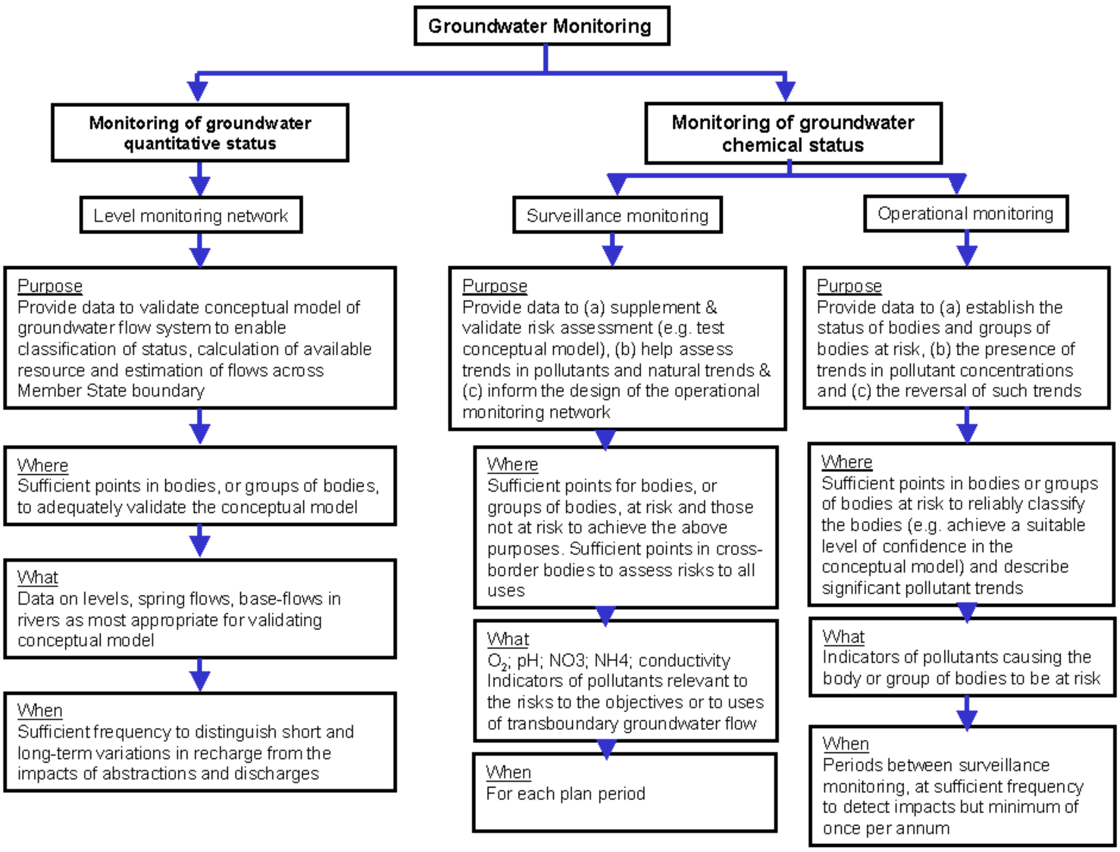
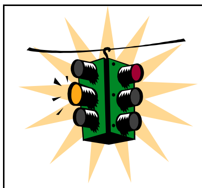


Figure 4.1 Summary of the purposes of, and requirements for, the groundwater monitoring programmes specified in Annex V of the Directive.



Look Out!

Monitoring of spring flows (e.g. flow rate, chemical composition;) and/or river base-flows will often be an important, and sometimes the principal, means of obtaining reliable information for use in assessing quantitative and chemical status.

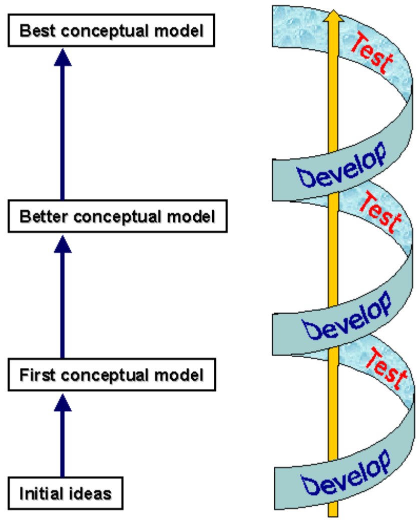
4.2.2 Monitoring should be designed on the basis of an understanding of the groundwater system

The Annex II risk assessment procedure is intended to help target and prioritise monitoring effort to where there are likely to be environmental problems. The monitoring programmes should be designed to provide the information needed to validate the risk assessment procedure and establish the magnitude, and spatial and temporal distribution, of any impacts. Risks assessments for groundwater should be based on a conceptual model/understanding of the groundwater system and how pressures interact with that system. A conceptual model/understanding is not only necessary to design monitoring programmes. It is also needed to interpret the data provided by those programmes, and hence assess the achievement of the Directive's objectives (Figure 4.2).

<u>Definition of conceptual modelling/ understanding</u>

A conceptual model/understanding is a simplified representation, or working description, of how the real hydrogeological system is believed to behave. It describes how hydrogeologists believe a groundwater system behaves.

- It is a set of working hypotheses and assumptions
- It concentrates on features of the system that are relevant in relation to the predictions or assessments required
- It is based on evidence
- It is an approximation of reality
- It should be written down so that it can be tested using existing and/or new data.
- The level of refinement needed in a model is proportionate to (i) the difficulty in making the assessments or predictions required, and (ii) the potential consequences of errors in those assessments.



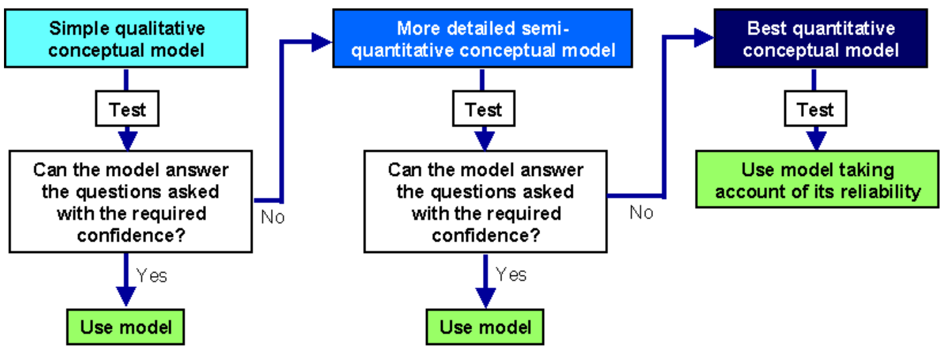
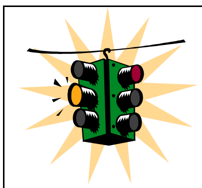


Figure 4.2 Definition of conceptual modelling/understanding



Look Out!

The testing of conceptual models/understandings is important to ensure they provide for acceptable levels of confidence in the assessments they enable. The Directive requires the confidence in the results of monitoring to be reported in the River Basin Management Plans. Guidance on testing conceptual models/understandings using water balances is provided in the toolbox. It is important to note that although the guidance recommends testing models numerically this does not mean that the models themselves have to be mathematical. On the contrary, complex mathematical models are only likely to be required to properly design and justify very expensive restoration measures for bodies that are failing to achieve the Directive's objectives.

The level of detail in any conceptual model/understanding needs to be proportional to the difficulty in judging the effects of pressures on the objectives for groundwater. The first model will be a simple, generalised sketch of the groundwater system. Where necessary, the spatial specificity of this first conceptual model/understanding can be gradually improved (Figure 4.3). Monitoring data is required to test or validate the conceptual model/understanding. Such testing will require some monitoring data for all bodies, or groups of bodies, identified as being at risk as well as a selection of those identified as not being at risk of failing to meet their objectives.

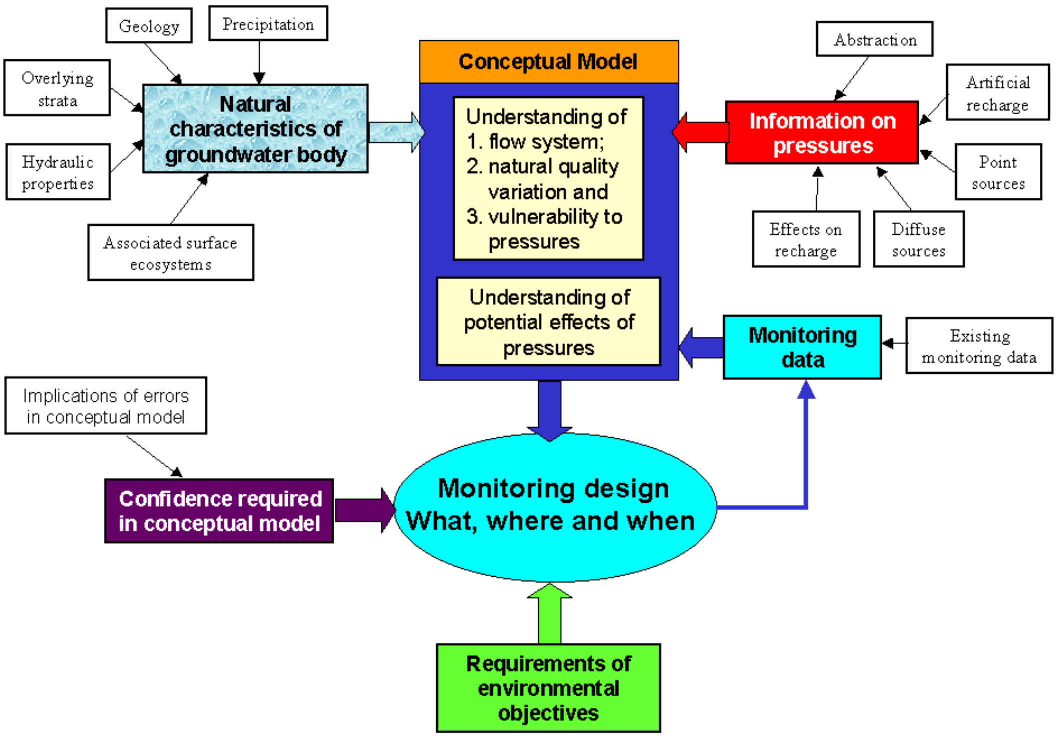


Figure 4.3 **Monitoring programmes should be designed on the basis of a conceptual model/understanding of the groundwater system. The model will represent the current understanding of the groundwater system based on information on its natural characteristics and the pressures on it. Monitoring should provide the information needed to test the model and, where necessary, improve it so that an appropriate level of confidence can be achieved in the prediction and assessment of groundwater problems.**

The amount of monitoring information needed to validate the Annex II risk assessments will depend in part on the level of confidence in, and complexity of, the conceptual model/understanding. The greater the difficulty in judging the risks to the objectives, the more monitoring information is likely to be required. The greatest amount of monitoring will be necessary where the implications of misjudging the risks to the objectives would be very serious (e.g. lead to substantial costs being unnecessarily imposed on water users or fail to identify risks of significant damage that could be averted).

During the course of each planning cycle, and between one planning cycle and the next, new monitoring data will contribute to improved understanding of groundwater systems and their vulnerability to pressures. This will increase confidence in the conceptual model/understanding and the risk assessments it enables.

Key principle

The amount of monitoring that is required will be proportional to the difficulty in judging (a) the status of a body, or group of bodies, of groundwater and (b) the presence of adverse trends, and (c) to the implications of errors in such judgements.

Designing the monitoring programmes on the basis of conceptual models/understandings ensures that the programmes will be appropriate to the hydrogeological characteristics of the body, or group of bodies, of groundwater and, where relevant, to the behaviour of pollutants in the groundwater system. For example, monitoring quantitative or chemical status in a low permeability fractured medium will require a different strategy (in terms of what to measure, where and when) than would monitoring quantitative or chemical status in a high permeability inter-granular flow medium.

Key principle

The design and operation of monitoring programmes should be informed by:

(a) the objectives applying to the body;
(b) the characteristics of the groundwater body, or group of bodies;
(c) the existing level of understanding (i.e. the confidence in the conceptual model/understanding) of the particular groundwater system;
(d) the type, extent and range of the pressures on the body, or group of bodies;
(e) the confidence in the assessment of risk from pressures on the body, or group of bodies; and
(f) the level of confidence required in the assessment of risk.

Groundwater systems are 3-dimensional. In some circumstances, where a body is at risk of failing to achieve its objectives and potentially costly restoration and improvement measures may be needed, monitoring information from different layers in a body of groundwater may be required to enable appropriate measures to be designed and targeted. The need for this sort of monitoring should be indicated by the risk assessments required under Annex II. However, most pressures are likely to have significant effects in the upper layers of aquifers.

Different types of objectives demand different environmental outcomes. They may therefore require different monitoring strategies to provide the information needed to assess their achievement. However, the design of the monitoring programme should always be based on an appropriate conceptual model/understanding. For example, objectives requiring the protection of associated surface water bodies, directly dependent terrestrial ecosystems, drinking water abstraction points or other legitimate uses from point sources of pollution might require monitoring in the predicted flow path between the source and one of the receptors listed above. However, monitoring data to assess objectives for general groundwater quality could be provided by more dispersed monitoring depending on the conceptual model/understanding of the distribution of pollutants in the groundwater.

4.2.3 Ensuring the cost-effective development of groundwater monitoring networks

Reliable monitoring data are essential for the cost-effective achievement of objectives for groundwater. However, installing groundwater monitoring networks is expensive. Member States may have networks comprising a variety of site types ranging from infrequently used private wells to large yielding public water supply boreholes. The use of conceptual models/understanding as the basis for developing and reviewing monitoring networks should help ensure that each selected monitoring point provides relevant and reliable data for use in assessing the achievement of the Directive's objectives. It will also enable Member States with limited existing networks to iteratively build up their networks to the extent needed to test or develop their conceptual models/understandings. The alternative of installing a very extensive network and reducing this overtime would be far less effective and much more costly.

The Directive permits bodies of groundwater to be grouped for monitoring purposes. This is also important to ensure the most cost-effective design of monitoring networks. For example, in areas of high rainfall and only low levels of groundwater abstraction, existing data and monitoring information from a representative selection of bodies should provide sufficient information to confirm that the bodies achieve good quantitative status. However, such grouping must be undertaken on a scientific basis so that monitoring information obtained for the group provides for a suitably reliable assessment that is valid for each body in the group. This means that either:

- The conceptual models/understandings for the bodies in the group should be similar such that the testing of the models and the predictions made on the basis of those models, for a selection of the bodies in the group will also provide sufficient confidence in the models and predictions for the other bodies in the group; or

- Monitoring information from a selection of the most sensitive bodies in a group demonstrates that those sensitive bodies, and hence the group as a whole, are not failing to achieve 'good' status because of the effects of a pressure, or pressures, to which all the bodies in the group are subject (e.g. diffuse pollution). Monitoring information may be needed initially from a range of bodies in the group to determine which are the most sensitive bodies.

The adequate testing of a conceptual model/understanding may require new, targeted monitoring data. However, particularly where pressures are low, adequate validation of a model may be achieved using existing data or data from a surface water monitoring programme.

Key principle

Groundwater bodies may be grouped for monitoring purposes provided that the monitoring information obtained provides for a reliable assessment of the status of each body in the group and the confirmation of any significant upward trends in pollutant concentrations.

Monitoring data from surface water bodies may be important in assessing the condition of bodies of groundwater. Surface waters with a large base flow can be used to indicate the quality of groundwater. The effects of human alterations to groundwater quality and levels on the status of large base flow surface waters are also likely to be larger than the effects of the same alterations on the status of low base flow surface waters.

Key principle

Designing and operating integrated groundwater and surface water monitoring networks will produce cost-effective monitoring information for assessing the achievement of the objectives for both surface and groundwater bodies.

4.2.4 Quality assurance of monitoring design and data analysis

The confidence in any assessment of groundwater will depend on the confidence in the conceptual model/understanding of how pressures are interacting with the groundwater system. The confidence in any model needs to be evaluated by testing its predictions with monitoring data. However, errors in the monitoring data could lead to errors in the evaluation of the reliability of the conceptual model/understanding. It is important that the probability and magnitude of errors in the monitoring data are estimated so that the confidence in the conceptual model/understanding can be properly understood. For the surveillance and operational monitoring programmes, estimates of the level of confidence and precision in the results of monitoring must be given in the river basin management plans[41].

An appropriate quality assurance procedure should reduce errors in monitoring data. Such a procedure should review the location and design of monitoring points to ensure that the data they provide are relevant to the aspects of the conceptual model/understanding being tested. Errors can also occur in sampling and in the analysis of water samples. Quality assurance procedures may take the form of standardisation of sampling and analytical methods (e.g. ISO standards); replicate analyses; ionic balance checks on samples; and laboratory accreditation schemes.

4.3 Characterisation of groundwater bodies

The Annex II initial and further characterisation should provide the basic information for designing targeted and cost-effective monitoring programmes. To do this, the Annex II procedure must produce a conceptual model/understanding for each body of groundwater, or group of bodies, that is (a) relevant to assessing how the identified pressures could affect the objectives for the body, or group of bodies, and (b) proportionate in terms of its detail and complexity to the likely risks to the objectives for that body, or group of bodies. Monitoring information may be used to iteratively improve the conceptual model/understanding so that it provides for appropriately reliable assessments.

The initial results of the Annex II assessments must be reported at the end of 2004. However, the assessments may need further development to help design the monitoring programmes for implementation at the end of 2006. The monitoring data provided by the monitoring programmes will then be available to validate and refine the assessments and the conceptual models/understandings on which they were based.

4.4 Monitoring of quantitative status

4.4.1 Purpose of monitoring

The Directive's requirements for good groundwater quantitative status are three-fold. Firstly, there is a requirement to ensure that the available groundwater resource[42] for the body as a whole is not exceeded by the long-term annual average rate of abstraction[43]. Secondly, abstractions and other anthropogenic alterations to groundwater levels should not adversely affect associated surface water bodies and terrestrial ecosystems that depend directly for their water needs on the body of groundwater. Thirdly, anthropogenic alterations to flow direction must not have caused, or be likely to cause, saltwater or other intrusion.

In assessing quantitative status, the water needs of associated surface water bodies and directly dependent terrestrial ecosystems must be taken into account. For the latter, good groundwater status requires that human alterations to groundwater flows and levels have not caused, and, taking account of lag times, will not cause, significant damage. However, the Directive does not provide an explanation of what constitutes 'significant damage'. Existing data held by Member States about the ecological, cultural and socio-economic significance of dependent terrestrial systems should be used as the basis of a 'significance test' in this context.

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[41] *Annex V 2.4.1*
[42] *Article 2.27*
[43] *Annex V 2.1.2*

Even if long-term level monitoring data are available, the measurements of groundwater levels may not be sufficient on their own to assess the available groundwater resource (see Table 4.1). For example, there may have been an impact prior to the start of the monitoring or a new abstraction may be proposed. The prediction of adverse impacts on associated surface water bodies or terrestrial ecosystems using level monitoring will normally need to be supported by an estimate of recharge, a conceptual model/understanding of the flow system and a water balance estimate to test the conceptual model/understanding (see Section 1 of the toolbox).

Table 4.1 The role of water level and spring flow data, conceptual modelling and water balance estimation in assessing quantitative status. In scenarios 2, 3 and 4 monitoring data may be required to test the conceptual model/understanding.

Scenario 1	Scenario 2	Scenario 3	Scenario 4
(a) Long-term level monitoring data is available (b) No trends in data indicating falling water levels noted (c) No impacts thought to be present on the water needs of surface ecosystems (d) No increase in the level of abstraction is proposed	(a) Long-term level monitoring data is not available	(a) Long-term level data may or may not be available (b) A new abstraction is proposed	(a) Long-term level data may or may not be available (b) Impacts are thought to be present on the water needs of surface ecosystems
The available level data is sufficient to indicate that the water balance is satisfactory	**Conceptual model/ understanding and water balance calculation will be necessary**	**Conceptual model/ understanding and water balance calculation will be necessary**	**Conceptual model/ understanding and water balance calculation will be necessary**

Key principle

Information on levels (spring flows etc) should be used in conjunction with estimates of recharge and an appropriate conceptual model/understanding of the groundwater flow system when assessing the quantitative status of bodies of groundwater, or groups of bodies.

The estimation of recharge and the development of a suitable conceptual model/understanding should be part of the characterisation of bodies of groundwater, or groups of bodies.

4.4.2 Water Level Monitoring Network Design

The water level monitoring network should be designed so that it supports and aids the development and testing of the conceptual model/understanding. The development of the network will be an iterative process, evolving over time where necessary. The amount of monitoring required also depends on the extent of existing information on water levels and the groundwater flow system. Where this is adequate and reliable, it may not be necessary to extend monitoring programmes.

What to monitor

The most appropriate parameters to monitor quantitative status will depend on the conceptual model/understanding of the groundwater system. For example, spring flows or even base-flows in rivers may be more appropriate than the use of boreholes in low permeability fractured media or where the risks of failing to achieve good quantitative status are low and information from the surface water monitoring network can adequately validate this assessment.

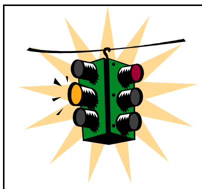
Where to monitor

The choice of where to monitor will depend on what is needed to test the conceptual model/understanding and the predictions it provides. In principle, the more spatially variable the groundwater flow system or the pressures on it, the greater the density of monitoring points that will be required to provide the data needed to make suitably confident assessments of the status of a groundwater body, or group of bodies.

When to monitor

The most appropriate monitoring frequency will depend on the conceptual model/understanding of the groundwater system and the nature of the pressures on the system. The frequency chosen should allow short-term and long-term level variations within the groundwater body to be detected. For example, for formations in which the natural temporal variability of groundwater level is high or in which the response to pressures is rapid, more frequent monitoring will be required than will be the case for bodies of groundwater that are relatively unresponsive to short-term variations in precipitation or pressures. Where monitoring is designed to pick up seasonal or annual variations, the timing of monitoring should be standardised from year to year.

4.5 Monitoring of chemical status and pollutant trends



Look Out!

Article 17 requires the Commission to come forward with a proposal for a daughter directive on groundwater by the end of 2002. Among other things, this proposal may include further criteria for assessing good groundwater chemical status and for the identification of trends. This may have implications for the design of the monitoring programmes described in this section.

4.5.1 Purpose of monitoring

Groundwater quality monitoring carried out in accordance with the WFD should be designed to answer specific questions and support the achievement of the environmental objectives. The principal purposes of groundwater quality monitoring are to:

(a) Provide information for use in classifying the chemical status of groundwater bodies or groups of bodies;

(b) Establish the presence of any **significant** upward trend in pollutant concentrations in groundwater bodies and the reversal of such trends.

Look Out!

Article 4.1.b.iii requires the reversal of any significant upward trend in pollutant concentrations in groundwater. However, the monitoring requirements set out in Annex V only refer to monitoring in bodies of groundwater. Since all groundwater that could adversely affect surface ecosystems or is capable of providing more than 10 m^3 a day for abstraction will be part of an aquifer (see Horizontal Guidance on Water Bodies), nearly all groundwater will be included within bodies of groundwater. By definition, pollutant trends in groundwater that is not part of a body of groundwater should not be able to significantly affect any surface water bodies, terrestrial ecosystems or uses of groundwater requiring significant abstraction. Therefore, trends in pollutants in any groundwater that is not part of a body of groundwater would not normally be expected to constitute pollution as defined in Article 2.33.

The requirements of good groundwater chemical status are threefold:

1. The concentrations of pollutants should not exhibit the effects of saline or other intrusions as measured by changes in conductivity;
2. The concentration of pollutants should not exceed the quality standards applicable under other relevant Community legislation in accordance with Article 17. The daughter directive will clarify this criterion; and
3. The concentration of pollutants should not be such as would result in failure to achieve the environmental objectives specified under Article 4 for associated surface waters nor any significant diminution of the ecological or chemical quality of such bodies nor in any significant damage to terrestrial ecosystems which depend directly on the groundwater body.

All three criteria must be satisfied for a body to achieve ‘good’ groundwater chemical status. If not, the body should be classified as ‘poor’ groundwater chemical status. The classification of groundwater chemical status is only concerned with the concentrations of substances introduced into groundwater as a result of human activities. The concentration of substances in an undisturbed body of groundwater (e.g. naturally high concentrations of arsenic) will not affect the body’s status. However, naturally occurring substances released by human activities, such as mining, will be relevant to the assessment of status.

Additional criteria for starting points for trend reversal may be specified in the daughter directive under Article 17. However, it is already clear that the purpose of trend reversal is to reduce pollution of groundwater, where pollution is defined in terms of risks of harm to the quality of aquatic and terrestrial ecosystems, human health, damage to material property and interference with legitimate uses of the environment[44]. A conceptual model/understanding of the groundwater system and the fate and behaviour of pollutants should therefore be used to predict those trends that have resulted, or would result, in pollution.

Look Out!

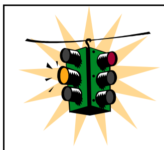
The Directive says surveillance monitoring must be undertaken during each planning cycle, and operational monitoring must be carried out during periods not covered by surveillance monitoring. No minimum duration or frequency is specified for the surveillance programme. Operational monitoring must be carried out at least once a year during periods between surveillance monitoring. Member States should undertake sufficient surveillance monitoring during each plan period to allow adequate validation of the Annex II risk assessments and obtain information for use in trend assessment, and sufficient operational monitoring to establish the status of bodies at risk and the presence of significant and sustained upward trend in pollutant concentrations.

[44] *Article 2.33*

4.5.2 Surveillance monitoring

The confidence in the Annex II risk assessments will be variable depending on the confidence in the conceptual model/understanding of the groundwater system. Surveillance monitoring is intended to provide information to:

- **supplement and validate the assessments** of risks of failing to achieve (1) good groundwater status [Article 4.1(b)(i) and Article 4.1(b)(ii)]; (2) any relevant Protected Area objectives [Article 4.1(c)]; or (3) the trend reversal objective [Article 4.1(b)(iii)]; and
- **contribute to the assessment of significant long-term trends** resulting from changes in natural conditions and anthropogenic activity.



Look Out!

Surveillance monitoring is only specified in the Directive for bodies at risk or which cross a boundary between Member States. However, to adequately supplement and validate the Annex II risk assessment procedure, validation monitoring will also be needed for bodies, or groups of bodies, not identified as being at risk. The amount and frequency of monitoring undertaken for these bodies, or groups of bodies, must be sufficient to enable Member States to be adequately confident that the bodies are at 'good' status and that there are no significant and sustained upward trends. Colour-coded maps of the status of all bodies must be published in the river basin management plans.

Validation will involve testing the conceptual models/understanding to the extent necessary to confidently differentiate bodies at risk from those not at risk and thus classify as 'good' status those bodies considered not to be at risk. Surveillance monitoring may also provide sufficient information to reliably classify, as 'poor' status, some bodies thought to be at risk.

4.5.3 Operational monitoring

Operational monitoring must provide the monitoring data needed to achieve an appropriate level of confidence to classify bodies at risk as either poor or 'good' status or to establish the presence of significant upward trends in pollutants (see Figure 4.4).

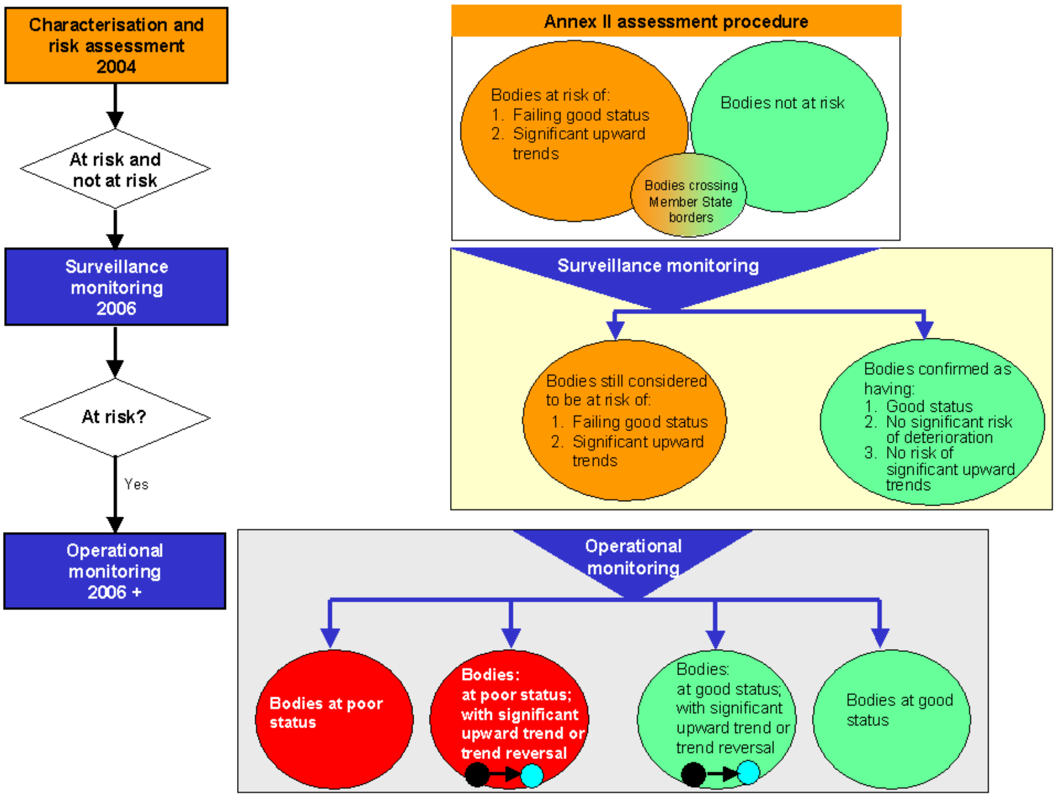


Figure 4.4 The outputs of risk assessment, surveillance and operational monitoring.

The surveillance monitoring programmes must be designed on the basis of the results of Annex II characterisation and risk assessment procedure. Operational monitoring programmes must be designed on the basis of the characterisation and risk assessment as refined by the data from the surveillance monitoring programmes. To supplement and validate the Annex II risk assessments, surveillance monitoring will be necessary in bodies, or groups of bodies, identified as being at risk and a selection of those identified as not being at risk. Operational monitoring is focused exclusively on bodies, or groups of bodies, at risk. Note the information provided by operational monitoring may establish that some bodies, or groups of bodies, considered likely to fail to achieve environmental objectives on the basis of the Annex II risk assessment and the surveillance monitoring programme are at 'good' status.

4.5.4 Where to monitor

Information on pressures, the conceptual model/understanding of the groundwater system, the fate and behaviour of pollutants in it and the consequent risks to the objectives should be used to determine the most appropriate locations for monitoring points. For example, where a surface water body or a directly dependent terrestrial ecosystem is at risk from a significant point source, the monitoring locations to test the prediction provided by the conceptual model/understanding (see Figure 4.5) would be different from those needed to test a conceptual model/understanding suggesting a risk to the objectives from diffuse pollution distributed uniformly across a groundwater body.

Where the conceptual models/understandings of a group of groundwater bodies and the pressures on each of the bodies in the group is similar, the validation of the model may be achieved using monitoring information from a selection of water bodies rather than using monitoring data for each body. In some cases, existing monitoring data or monitoring data collected by the surface water monitoring programmes may be sufficient to adequately test a conceptual model/understanding.

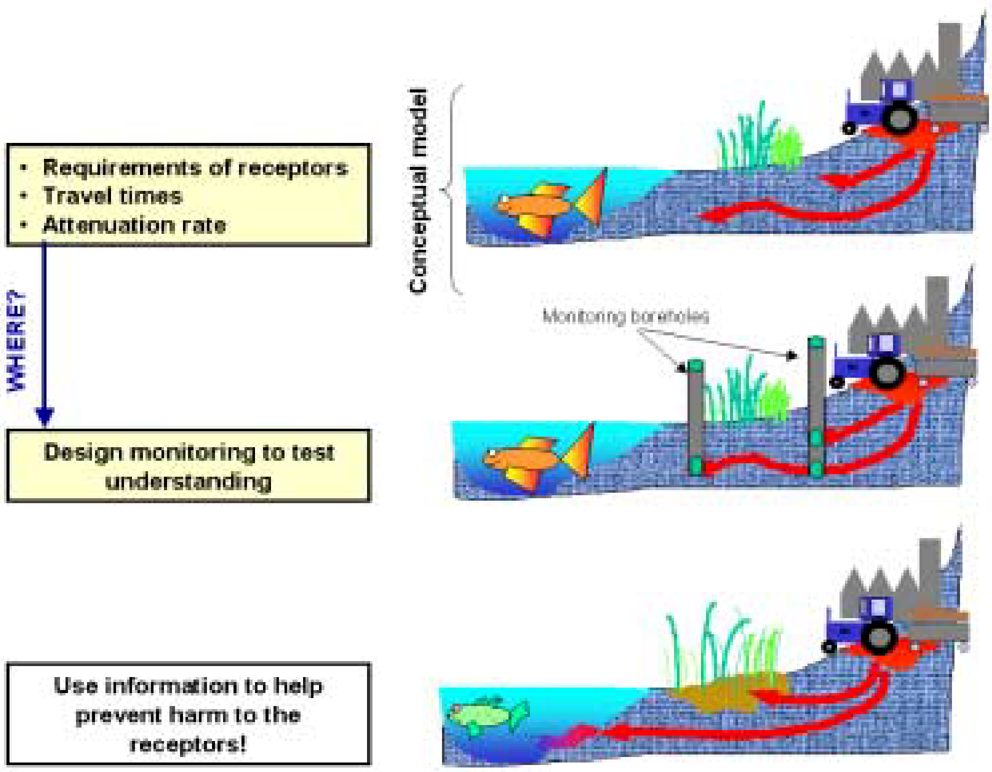


Figure 4.5 **The selection of monitoring locations will depend on the development of a conceptual model/understanding of how the objectives for the body of groundwater may be at risk (see Section 1 of the Toolbox). For example, a pollutant plume from a point source discharge that may be adversely affect an associated surface water body may require the use of targeted monitoring compared to that needed to assess risks from pollutants distributed uniformly across a body of groundwater.**

4.5.5 What to monitor

Where surveillance monitoring is required, the Directive requires that a core set of parameters be monitored. These parameters are oxygen content, pH value, conductivity, nitrate and ammonium. Other monitored parameters for both surveillance and operational monitoring must be selected on the basis of (a) the purpose of the monitoring programme, (b) the identified pressures and (c) the risk assessments made using a suitable conceptual model/understanding of the groundwater system and the fate and behaviour of pollutants in it. For example, the principal purpose of surveillance monitoring is to supplement and validate the Annex II risk assessments. To do this, the predictions of risk made during the Annex II assessments must be tested. Such testing should involve consideration of:

(a) the predicted effects of pressures identified during the Annex II risk assessment procedure; and

(b) whether there are any significant effects due to pressures not identified during the Annex II assessment procedure.

In the case of point (b) above, the guidance recommends that Member States select monitoring parameters that, if present, would indicate effects associated with different types of human activity. Some examples of indicators relevant to different activities that may be present in the recharge area of bodies, or groups of bodies, of groundwater are suggested in Table 5.2 (Chapter 5).

Table 5.3 (Chapter 5) provides examples of pollutants typically associated with different human activities, and which may therefore be appropriate to consider in monitoring programmes depending on the conceptual model/understanding and the likely risks to the objectives. For example, suites of parameters commonly associated with certain types of pressures have been identified (e.g. gas works: PAH, Phenol, hydrocarbons, etc). Parameters indicative of the pollutants that are liable to be present can be used to ensure cost-effective monitoring. The toolbox outlines some of the indicators used by Member States.

Other chemical parameters may need to be sampled for quality assurance purposes. For example, measuring the concentrations of major ions in a water sample so that an ion balance can be used as a check that the water analysis results are representative of the sampled groundwater should be considered as a routine quality assurance procedure.

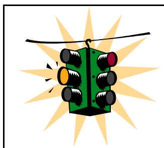
4.5.6 When to monitor

The conceptual model/understanding of the groundwater system and the understanding of the fate and behaviour of pollutants within it, and the aspect of the model being tested should also determine the appropriate frequency of monitoring. The toolbox provides examples of frequencies that Member States have found appropriate in a number of hydrogeological circumstances and in relation to different pollutant behaviours.

4.6 Monitoring of Protected Areas

The Water Framework Directive establishes a planning framework to, among other things, support the achievement of the standards and objectives for Protected Areas established under Community legislation. In the context of groundwater, these areas may include Natura 2000 sites established under the Habitats Directive (92/43/EEC) or the Birds Directive (79/409/EEC), Nitrate Vulnerable Zones established under the Nitrates Directive (91/676/EEC) and Drinking Water Protected Areas established under Article 7 of the Water Framework Directive.

To ensure monitoring programmes are as efficient and as effective as possible, it would be appropriate to ensure that the quantitative status and the chemical status monitoring programmes described above complement, and are integrated with, the programmes established for Protected Areas so that the groundwater monitoring networks are as far as possible multi-purpose



Look Out!

For Drinking Water Protected Areas, Article 7.1 requires Member States to make sure they monitor, in accordance with Annex V, bodies of groundwater providing more than 100 m^3 a day as an average. Annex V does not define any specific additional monitoring requirements for such bodies. In contrast, Annex V does define specific monitoring requirements for surface water bodies used to provide more than 100 m^3 a day as an average.

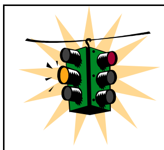
No specific monitoring requirements are described in relation to the Drinking Water Protected Area objective of preventing deterioration in quality in order to reduce the level of purification treatment required in the production of drinking water [Article 4.1(c), Article 7.3]

The achievement of the Drinking Water Protected Area objective requires that the quality of the abstracted groundwater prior to treatment does not change as a result of human activities in a way that would require an increased level of purification treatment to meet the standards required at the point of consumption under Directive 80/778/EEC, as amended by Directive 98/83/EC. Assessing compliance with, and providing the necessary information to achieve, this objective requires:

¾ Establishing the chemical composition of the abstracted water prior to any purification treatment. This analysis should take account of any parameters that could affect the level of treatment required to produce drinking water. Member States are required under Annex II 2.3(c) to collect and maintain information on the chemical composition of water abstracted from (i) any points providing an average of 10 m^3 or more per day, whether or not that water is intended for human consumption, and (ii) points serving 50 or more persons;

¾ During each planning period, collecting information, where relevant, on the composition of water abstracted in a way that is proportionate to the risks to the quality of that water identified in the Annex II risk assessment procedure. This should enable the detection of any deterioration in the abstracted water's quality that could affect the level of purification treatment required to produce drinking water – and hence indicate a failure to achieve the Protected Area objective;

¾ Establishing a conceptual model/understanding of the groundwater system from which the abstracted water is drawn. The model should be proportionate to the likely risks to the objective and should enable measures to be designed, where necessary, to protect the recharge area from any inputs of pollutants that would result in a failure to achieve the Protected Area objective (see Section 6 of the groundwater toolbox).



Look Out!

Revisions are currently being proposed to the draft guidelines for the monitoring required under the Nitrates Directive (91/676/EEC).

4.7 Reporting Requirements

A summary report of the network must be submitted to the Commission by 22 March 2007[45], and a map showing the network must be included in the river basin management plan.

4.7.1 Chemical and quantitative status assessment

The results of monitoring should be used to assess whether any of the criteria defining 'good' status have been failed. If so the body should be classed as 'poor' status. The Directive specifies that in assessing chemical status for a groundwater body, the results of individual monitoring points within a groundwater body should be aggregated for the body as a whole. Figure 4.5 describes the tests involved in assessing the status of a body of groundwater.

[45] *Article 15*

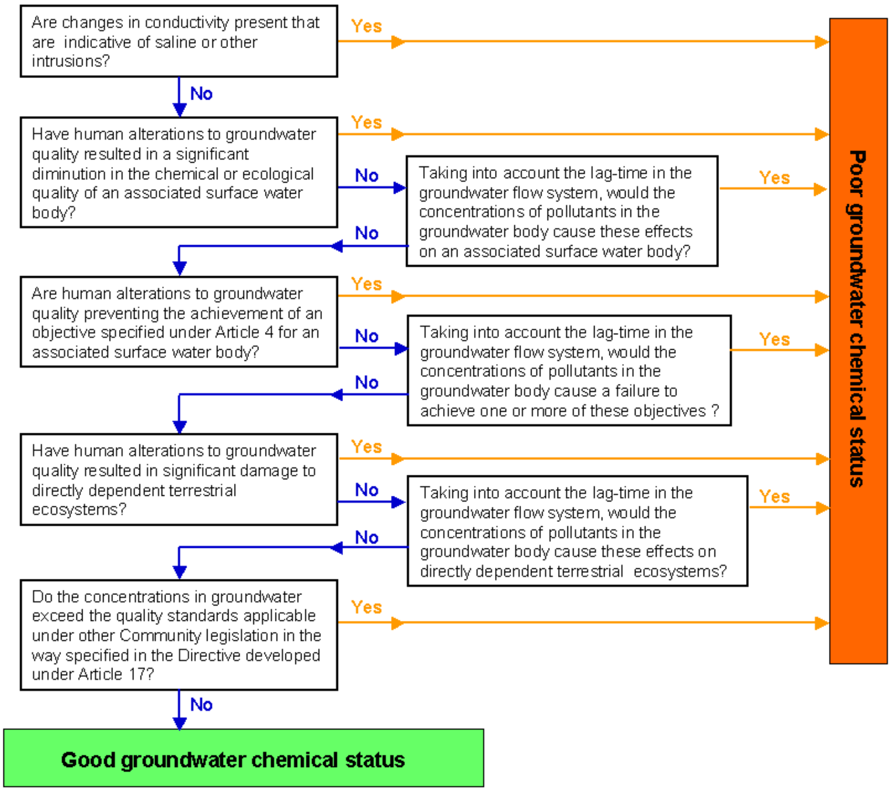


Figure 4.6 **Tests involved in determining the chemical status of a body of groundwater. In conjunction with a suitable conceptual model/understanding of the groundwater system, information from monitoring points in the body of groundwater, or group of bodies should be used to make an assessment of the chemical status of the body, or bodies. Such an assessment requires consideration of each of the tests shown in the Figure.**

4.8 Schedule of Monitoring

Table 4.2 Critical Path Analysis for Work Needed on Monitoring for WFD

FORMAL WFD REQUIREMENT	Monitoring Work needed to aid decisions	Related work from other CIS WGs, EAF	Time needed	When start to hit critical path	To be completed
Initial delineation of water bodies		Water body paper is being prepared by the Commission	1 yr	2002	Beginning 2003
Characterisation of water bodies according to Annex II		Guidance is being developed by CIS 2.1: IMPRESS	2 yrs	2002/3	End 2004
Defining information needs	Translate information from characterisation into monitoring strategy		0.5 yrs	2004	2005
Design and installation of monitoring network	Implement strategy for quantitative monitoring and chemical monitoring		1 yr	2005	2006
	Compare existing monitoring stations/networks with the strategy		0.5 yrs	2005	End 2005
	Installation of new monitoring stations, modification of existing ones, if required		1 yr	2005	2006
	Make monitoring network operational				End 2006
Performing monitoring, data collection	Monitoring of groundwater quantitative status		1 yr	2006	2007
	Monitoring of groundwater chemical status surveillance monitoring operational monitoring	Scope of monitoring is defined by Annex V and may be supplemented by a new Groundwater Directive under Article 17	1 yr	2006	2007
Assessing monitoring results, interpretation and presentation of groundwater status	Quality assurance and quality control	Additional criteria for defining good groundwater status and defining significant trends may be introduced by a daughter directive under Article 17	0.5 yrs	2008	2008
Detail work programme for RBMPs		Guidance will be developed by BESTPRACT	0.5 yrs		2003-5
Identify significant water management issues	Could not be based on monitoring results because they are not available in time	Guidance will be developed by BESTPRACT	0.5 yrs	2005	2007
Publish and consult on draft RBMPs	Could be based on preliminary monitoring results, if available on time	Guidance will be developed by BESTPRACT	1yr	2007	2008
Publish RBMPs and establish programme of measures in each basin for each RBMP	Based on status assessment according to monitoring results	Guidance will be developed by BESTPRACT	0.5 yrs	2008	2009 end
Implement measures			3 yrs (?)		2012
Continuation of first monitoring cycle			7 yrs	2008	2015
Second cycle of monitoring	Aim: inter alia validation of effects of measures		6 yrs	2016	2021

5 Best Practices and Tool Box

5.1 General Guidance for Optimisation of Monitoring Programmes

5.1.1 Issues for Consideration

The key processes involved in designing an environmental monitoring programme are to determine what to monitor, where, when and how often. The answers to these questions depend on:

¾ The objective(s) of the monitoring (e.g. to determine the chemical status of a water body, or to test for a trend);

¾ The desired precision and confidence with which the required statistic (e.g. a percentile, or the slope of a linear trend) is to be estimated; and

¾ The types and magnitudes of variability exhibited by the water body or bodies to be monitored.

It is therefore imperative to clearly identify the key objectives that the monitoring needs to address. This will govern the approach to programme design and enable identification of:

¾ The hypotheses to be tested;

¾ Realistic and measurable goals/targets; and

¾ The acceptable level of risk, precision and confidence.

The information obtained can then be used to formulate an understanding of the system to be studied and develop the appropriate questions to be asked, based on the identified hypotheses. This can be formalised using a conceptual process model, which links the driving forces, pressures and current state of the system. The assumptions underlying the model can be reviewed and validated throughout the study, as more information becomes available.

Temporal and spatial heterogeneity, both natural and anthropogenic, should be considered, as this will influence the location and number of water bodies monitored, the location and number of monitoring stations within each water body, and the frequency of sample collection.

Selecting acceptable levels of risk, precision and confidence would set limits on how much uncertainty (arising from natural and anthropogenic variability) can be tolerated in the conclusions obtained from monitoring programmes.

Once the acceptable levels of risk, precision and confidence associated with the identified objectives have been defined, an optimal monitoring programme can be developed using a range of statistical tools. These tools will ensure that the programme:

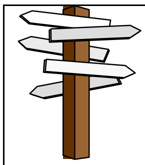
¾ Meets the required objectives of the programme;

¾ Monitors a sufficient number of sites and at a frequency that provides the required precision and confidence in the results; and

¾ Is implemented in a cost effective and scientifically robust manner.

Statistical planning tools covering a comprehensive range of common monitoring objectives are provided by the ‘Manual of Best Practice for the Design of Water Quality Monitoring Programmes’. This manual presents the results of a collaborative study between the UK and Italy to assist organisations charged with monitoring activities. The manual provides step-by-step guidance on the choice of an appropriate monitoring strategy, the quality elements to be monitored, the sample numbers needed to achieve the desired precision and confidence, and appropriate data analysis methods. The manual emphasises the importance of ensuring that the method of data analysis is specified at the programme planning stage, as this forms an integral part of the calculation of required sample numbers. For example, if the required number of samples to achieve a specified precision and confidence were calculated on the assumption that linear regression would be the method of trend analysis, that precision would not subsequently be achieved if it were later decided to switch to the use of Sen's test for trend.

The guidance covers the use of both chemical and biological monitoring methods, for rivers, estuaries and coastal waters.



Information to assist with the Statistical Design of Monitoring Programmes can be found in:

¾ *Manual of Best Practice in the Design of Water Quality Monitoring Programmes*

¾ *Vos, P., E. Meelis and W.J. ter Keurs, 2000, A framework for the design of ecological monitoring programs as a tool for environmental and nature management. In: Environmental Monitoring and Assessment 61: 317-344.*

¾ *Nagelkerke, L.A.J. and W.L.T. van Densen, The utility of multivariate techniques for the analysis of fish community structures and the design of monitoring programmes, 2000. In: Proceedings Monitoring Tailor-Made III (eds J.G. Timmerman, W.P. Cofino, R.E. Enderlein, W. Jülich, P. Literathy, J.M. Martin, P. Ross, N. Thyssen, R. Kerry Turner, R.C. Ward), p. 323-332.*

5.1.2 Development of a Conceptual Understanding

Conceptual models[46] play a key role in the guidance and should be used as a basis for the development and review of monitoring programmes in accordance with the Directive.

The level of detail required in the model is proportional to the difficulty in judging the effects of pressures on the objectives. Monitoring data is required to test or validate the conceptual model/understanding. Such testing will require some monitoring data for all bodies, or groups of bodies, identified as being at risk as well as a selection of those identified as not being at risk of failing their objectives.

The amount of monitoring information needed to validate the Annex II risk assessments will depend in part on the level of assurance in the conceptual model/understanding. The greater the difficulty in judging the risks to the objectives, the more monitoring information is likely to be required. The greatest amount of monitoring will be necessary where the implications of misjudging the risks to the objectives would be very serious - where, for example, it could lead to substantial costs being unnecessarily imposed on water users (the Type I error), or fail to identify risks of significant damage that could be averted (the Type II error).

The amount of monitoring that is required will be related to:

¾ **the difficulty in judging (a) the status of a water body, or group of water bodies and (b) the presence of adverse trends, and the implications of errors in such judgements.**

[46] *A conceptual model in this context does not refer to a quantitative mathematical model, rather a 'qualitative conceptual understanding' of the interrelationships occurring within the system.*

During the course of each planning cycle, and between one planning cycle and the next, new monitoring data will contribute to improved understanding of the water bodies concerned and their vulnerability to pressures. This will increase confidence in the conceptual model/understanding and the risk assessments it enables.

Key Principle

The conceptual model/understanding represents the current understanding of the system based on information on its natural characteristics and the pressures on it. Monitoring should provide the information needed to test the model and, where necessary, improve it so that it produces an appropriate level of assurance in the assessment pressures and impacts.

5.1.3 Quality assurance/Quality control

ISO 5667-14 describes a variety of quality control techniques for monitoring all types of water samples.

Where available, methods standardised by ISO, CEN or national standardisation bodies should be used. In any case, the laboratory using a method should be responsible for ensuring that the method is adequately validated. If the method has been validated by a standards approving organisation, the user will normally need only to establish performance data for their own use of the method.

In the case of methods that have not been validated by a standardisation body, the documentation describing the method should be clear and unambiguous in order to allow easy implementation. ISO 78-2 advises on methods documentation for general chemical methods.

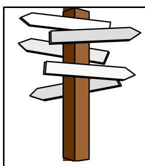
In order to assure comparability across Europe, laboratories must document a programme of quality assurance/quality control (EN ISO 17025) and participate regularly in proficiency testing programmes.

A requirement of the WFD is that all monitoring shall conform to the relevant standards on the national, European or international scale to ensure the provision of data of an equivalent scientific quality and comparability. Therefore, all biological and physico-chemical assessment systems must comply with the relevant international and national standards where they exist.

At present there are a number of standards covering the sampling of macroinvertebrates. Equivalent standards are currently lacking for phytoplankton, macrophyte, benthic algae, and fish sampling, but they all are under development in CEN, and will probably be ready before 2006. Though there are appropriate standard methods for many of the physico-chemical quality elements, for many of the priority substances there are no standard analytical techniques. The expert working group on the analysis and monitoring of priority substances will deal with standard analytical methods for priority substances.

Key Issue

It is recommended that appropriate standards are developed as a matter of priority and urgency for those aspects of monitoring for which there are no internationally agreed standards or techniques/methods.



You can obtain ISO/CEN Standards

For details of the available ISO/CEN standards, refer to the following sites:

¾ *CEN www.cenorm.be/catweb*

¾ *ISO www.iso.ch*

For rivers, lakes and ground water there are monitoring guidelines prepared by UN/ECE Working Group on Monitoring and Assessment.

For coastal and transitional waters, there are also monitoring guidelines of OSPAR (Joint Monitoring and Assessment Programme) and HELCOM (COMBINE-Programme). Ongoing work of the ICES/OSPAR and ICES/HELCOM Steering Groups on Quality Assurance in the North East Atlantic (SGQAE) and in the Baltic (SGQAB), and the work of quality assurance groups like QUASIMEME and BEQUALM should also help to ensure that comparable and quality monitoring data are produced for the Water Framework Directive.

Implementation of QA programmes

Errors inevitably occur both in the process of sampling and in the analysis of water samples. The aim of an appropriate quality assurance procedure is to quantify and control these errors. Quality assurance procedures may take the form of standardisation of sampling and analytical methods, replicate analyses, ionic balance checks on samples and laboratory accreditation schemes.

Notwithstanding the benefits of the one-off intercalibration exercise for the purpose of classification and comparison with the results from other appropriate Member States, a continuous quality assurance system should be developed to ensure that all monitoring results meet assured target levels of precision and bias. Therefore, QA measures should be implemented for each monitoring institution as well as in data collection centres, and encompass all operational facets of a monitoring programme, including:

¾ Field sampling and sample receipt;

¾ Sample storage and preservation; and

¾ Laboratory analysis;

These measures are based on:

¾ Developing comprehensive and understandable Standard Operating Procedures (SOPs);

¾ Using validated monitoring methods (sampling, chemical or biological analysis, reporting), that means experimental proof and related documentation confirms that each method is fit for its intended purpose;

¾ Establishing routine internal quality control measures (control charts, reference materials, internal QA audits); and

¾ Participation in external QA schemes (laboratory proficiency testing schemes, taxonomical workshops, external QA audits, QA accreditation).

It is generally accepted that approximately 25% of a laboratory's effort is required to establish and maintain an effective quality assurance system.

Experimental evidence must be supplied and documented in SOPs such that:

¾ All methods possess sufficient sensitivity, selectivity and specificity;

¾ Method accuracy and precision meet the requirements (still to be established) for each programme of measures developed for implementation of the Water Framework Directive; and

¾ Analytical detection limits (i.e. the smallest concentrations that are quantitatively detectable with a defined uncertainty) do not jeopardise the assessment of compliance with quality limits/targets or decisions made between good and moderate status.

In routine monitoring, quality assurance should ensure at any time that the methods used are strictly controlled and monitored. For that purpose, all monitoring institutions should have implemented an internal QA system according to ISO 17 025 (2000). To obtain long-term control of the performance of monitoring methods, results of internal QA measures (e.g. analysis of certified reference materials) must be recorded in control charts.

To evaluate the comparability of monitoring data throughout the Member States, participation in external quality audits and in external quality assessment schemes like international laboratory proficiency testing or taxonomical workshops is highly recommended.

An acceptable level of quality must be achieved for all monitoring data generated within the WFD Monitoring. It is possible to evaluate if monitoring data is fit for the intended purpose using the following QA criteria:

¾ Monitoring data are reported with an uncertainty estimate calculated from method validation or from inter-comparison exercises;

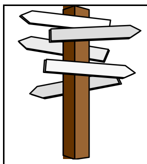
¾ Limits of detection are well below the principal levels of interest and allow the control of quality objectives;

¾ Satisfactory results can be obtained in analysing independent reference materials/samples, and this is demonstrated by appropriate control charts (or electronic equivalent) for the determinands of interest; and,

¾ Participation in relevant proficiency testing schemes at least once per year (with the proportion of results identified as outside limits of error being below 20% for all parameters) Quality Assurance

Expression of results

The results of measurements must indicate any rounding of numbers, final units, ± combined uncertainty, confidence interval. The detection limit (limit of quantification) of the method should be reported. The procedure of calculation of the detection limit (limit of quantification) should also be clearly reported.



Key sources of information on sampling protocols and quality assurance

¾ *The UN/ECE Task Force on Monitoring and Assessment provides practical guidance on methods and quality assurance for monitoring transboundary waters (www.iwac-riza.org).*

¾ *The European Environment Agency provides technical guidance on design and operation of monitoring networks through its EUROWATERNET initiative (www.eea.eu.int).*

5.2 Best Practice and Tool Box for Monitoring Surface Waters

5.2.1 Objectives of monitoring

While the overall objectives of monitoring for the Directive are clearly defined, the specific monitoring objectives cannot be specified in any detail, as they will change depending on the purpose i.e. surveillance, operational or investigative monitoring, or monitoring for protected areas. In this respect, monitoring programme objectives will be different when assessing ecological status, as opposed to monitoring seasonal or long-term trends. Similarly, investigative monitoring may involve different determinands, sites and frequencies than general operational or surveillance monitoring, as the programme will be designed to assess a specific stress or impact.

Key Principle

The monitoring programmes must provide the information necessary to assess whether the Directive's environmental objectives will be achieved. This means that, to design monitoring programmes in accordance with the requirements of the Directive, a clear understanding of the environmental conditions required for the achievement of the objectives, and how these could be affected by human activities, is essential.

5.2.2 Holistic Assessment of Ecological Quality

Most ecological assessment systems used to date have been restricted to the assessment of a single impact element, such as organic pollution or acidification, and are not applicable to a broad range of waterbody types or geographical regions. As identified by Nixon *et al* (1996), the WFD (then the Ecological Directive) requires that a classification system be capable of incorporating the full range of impacts. However, the system should also be capable of detecting specific impacts, such as organic pollution, where this has been identified as a key stressor during the surveillance monitoring period.

Numerous predictive systems have been developed, which compare the observed communities to those expected under reference conditions. The outputs of such systems give rise to unitless ratios of observed to expected values that are ideally suited to the WFD.

It has been agreed that the results of the systems operated by each Member State will be expressed as EQRs for the purposes of classification of ecological status. These ratios will represent the relationship between observed values and the values expected under the reference conditions applicable to that particular site. Member States will be required to express the ratio as a numerical value between zero and one, with 'good' ecological status represented by values close to one and 'bad' ecological status by values close to zero.

5.2.3 Incorporation of Natural and Artificial Habitat Variation

While a number of different assessment systems for rivers have attempted to incorporate natural habitat variation, the majority of biological classification systems do not account for variations in physical habitat. As a result, the observed diversity at many sites (e.g. lowland rivers, naturally silted) will not meet the expected diversity of the prescribed reference conditions, even if the site has pristine water quality.

Examples of systems which have attempted to include artificial habitat variation are the UK's RIVPACS (macroinvertebrates) and HABSCORE (salmonid fish abundance) systems. In these cases the reference condition is defined in terms of pristine water quality and existing physical habitat. Therefore, if the community is as would be expected for the existing physical habitat, and the water quality is pristine, it will receive that same EQI score as a pristine site that is not physically impacted.

5.2.4 Locations of water bodies to be monitored

It is not economically feasible to monitor all water bodies for all conditions. Therefore, it is necessary to group 'similar' water bodies (as discussed below) and to select appropriate representative sites for the determination of ecological status for that particular group of sites. As discussed in Chapter 2, while the Directive requires that monitoring is undertaken for all surface and groundwater bodies, grouping is permitted as long as sufficient water bodies are monitored within a group to provide an accurate assessment of status for that group.

Member States should firstly determine which water bodies are required to be monitored in accordance with the Directive. The water bodies selected will vary depending on the objectives of the programme. For example, Annex V of the Directive provides different criteria for the selection of water bodies, depending on whether the objectives of the programme are established to satisfy the requirements for surveillance, operational or investigative monitoring, or for protected areas. Therefore each Member State must first discriminate according to the specific requirements of the Directive (e.g. size/population boundaries) and eliminate those water bodies in which monitoring is not required.

Once the relevant water bodies have been identified, further grouping may be required due to economic constraints. Water bodies may be grouped based on similar hydrological, geomorphological, geographical or trophic conditions. Alternatively water bodies could be grouped based on similar catchment impacts or land-uses. However, the latter may only be possible in catchments that are dominated by a single land-use. Another possibility is to use multivariate classification procedures for identifying groups of sites that form relatively homogenous areas (although this 'black box' approach should be used with caution as there is no guarantee that the composition of the resulting groups will have a recognisable or obvious rationale). Whatever the method by which the water bodies are grouped, it is essential that sufficient water bodies are selected from each group to enable the specific objectives of the monitoring programme to be met with the required levels of precision and confidence.

The characterisation required by Annex II makes possible a characterisation of water bodies based on environmental variables. Water body characterisation as a function of pressures would be made possible through an assessment of pressures and impacts, in which optimisation of the monitoring programme could be achieved by a grouping of pressures.

A relationship may exist between the defined typologies and human pressures due to the fact that the human race tends to adapt to environmental conditions. This theory is supported by the results of a regionalisation study based on the geomorphology, physiography, climate and macroinvertebrate communities undertaken in the Ebro River Basin. The study found that almost 50% of the control stations investigated were considered as non-or less perturbed by human activity. However, substantial regional variation was reported. For instance, in mountain and high mountain regions, the percentage rose to between 70 and 90%, whereas in the southern mountain area the percentage decreased to 60%. In the central zone and in the hollow area, where there is the greatest concentration of human activity, the area assessed as "natural state" decreased to 20%.

5.2.5 Risk, Precision and confidence in the assessment of surface water and groundwater status

The concepts of risk, precision and confidence and how they relate to the Directive are discussed in Chapter 2. For convenience the definitions are repeated here:

Risk At the simplest level, a risk can be thought of as the chance of an undesirable event happening. It has two aspects: the chance, and the event that might happen. These are conventionally called the probability and the consequence.

Confidence The long-run probability (expressed as a percentage) that the true value of a statistical parameter (e.g. the population mean) does in fact lie within calculated and quoted limits placed around the answer actually obtained from the monitoring programme (e.g. the sample mean).

Precision Most simply, precision is a measure of statistical uncertainty equal to the half-width of the C% confidence interval. For any one monitoring exercise, the estimation error is the discrepancy between the answer obtained from the samples and the true value. The precision is then the level of estimation error that is achieved or bettered on a specified (high) proportion C% of occasions.

Where the monitoring objective relates to quality characterisation (e.g. to determine the status of a water body) the statistical objective is specified by stating:

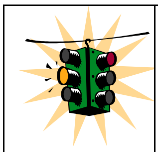
¾ the parameter to be estimated (e.g. the mean or the 90-percentile);

¾ the desired precision (e.g. 0.5 mg/l; 20%); and

¾ the desired confidence (e.g. 90%, 99%).

Then, given an estimate of the variability of the determinand of interest in the water body, the required number of samples can be calculated. As a simple example, if s is the standard deviation, d is the desired precision, and u is the standard Normal deviate corresponding to the desired confidence level (e.g. u = 1.65 for 90% confidence), then the required number of samples is given approximately by:

$$\mathbf{n = (us/d)^2}$$



Look Out!
Further information on methodology for the calculation of sample numbers to achieve desired levels of precision and confidence, or desired Type I and II errors, can be found in:

¾ ***Manual of Best Practice in the Design of Water Quality Monitoring.***
¾ ***Ellis 1989. Handbook on the Design and implementation of monitoring programmes;***
¾ ***Strien, A.J. van, R. van de Pavert, D. Moss, T.J. Yates, C.A.M. van Swaay and P. Vos, 1997, The statistical power of two butterfly monitoring schemes to detect trends. In: Journal of Applied Ecology, 34: 817-828.***
¾ ***Strien,. A.J. van, W. Hagemeijer and T.J. Verstrael, 1994, Estimating the probability of detecting trends in breeding birds: often overlooked but necessary. In: Bird Numbers 1992. Distribution, Monitoring and Ecological***
¾ ***Aspects (eds E.J. M. Hagemeijer and T.J. Verstrael), pp 525-531. Proceedings of the 12th International Conference of IBCC and EOAC. Statistics Netherlands/ SOVON, Voorburg/ Beek-Ubbergen***
¾ ***Matheron G., Traite de geostatistique appliquee. Tome 1(1962). Tome 2(1963), Editions Technip, Paris.***
¾ ***Matheron G., la theorie des variables regionalisees, et ses applications. Les cahiers du centre de morphologie mathematique, fascicule 5. Ecole des Mines de Paris, 1970.***

Other monitoring objectives will relate to the detection of trends or differences. The statistical objective is then expressed slightly differently, because there are two types of error to consider. It is now necessary to specify:

¾ the parameter to be estimated (e.g. the before-after mean difference, or the slope of a trend line);

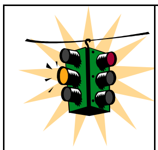
¾ the desired confidence (C%) associated with any assertion that a change has been detected (e.g. 90%, 99%). The 'Type I error' - the risk of a false positive - is then given by (100 - C)%.

¾ the Type II error - the risk that a difference which is truly present fails to be detected by the monitoring programme.

As before, the required number of samples can be calculated given chosen values for the above items together with an estimate of the variability of the determinand of interest in the water body. As a simple example, if s is the standard deviation, D is the before-after mean difference that it is desired to detect, and u_1 and u_2 are the standard Normal deviates corresponding to the desired Type I and II errors, then the required total number of samples (split equally between the two periods of comparison) is given approximately by:

$$n = 2(\{u_1+u_2\}s/D)^2$$

Although a confidence level of 95% is commonly used, scope is available to trade off precision against confidence to produce a more congenial statistical specification for a given amount of sampling effort. However, Ellis (1989) points out that reducing the confidence level much below 90% represents a spurious saving. There is nothing to be gained by having a high degree of precision if there is only a poor level of confidence that it will actually be achieved. As a possible starting point Member States may wish to set the required confidence level at 90% and compare the achievable precision obtained for the different water body types, quality elements and summary statistics. Similarly the Type II error (the risk of failing to detect a change that has truly occurred) could be set at 10% when determining the amount of change or differences that can practically be detected by existing monitoring programmes.



Look Out!

Guidance on the level of precision required for classification should arise from WG 2.3 Reference conditions inland surface water and WG 2.4 Typology, classification of transitional, coastal waters, particularly for the different monitoring types – Surveillance, operational and investigative. This will influence advice on sampling frequencies and spatial distribution of sites.

The appropriate level of confidence and precision will, in part, relate to the implications of getting the assessments wrong (e.g. misclassifying a water body and thus imposing costs on water users). In a sub-catchment with no pressures upon it, relatively little monitoring information would be required to enable reliable classification. In a sub-catchment in which severe and obvious environmental damage is extensive, high confidence in status classification could also be achieved with limited monitoring. In contrast, considerable monitoring effort may need to be directed at sub-catchments subjected to a range of different pressures and with a range of sensitivities to those pressures.

Note that the number of water bodies in these sub-catchments has only a slight bearing on the required monitoring effort. Monitoring effort is dictated by the difficulty of determining the effects of significant pressures upon the water environment.

Figure 5.1 provides a practical example of how the number of stations required changes with different levels of precision for the same level of confidence. It concerns the estimation of mean phosphate concentration for different types of rivers (grouped as river types not as individual water bodies) in England and Wales. To achieve 50% precision with 90% confidence, the number of samples varies from 13 in small upland rivers to 39 in small lowland rivers. This indicates that the variability of phosphate is greater in the latter compared to the former and hence more stations are required to achieve the same precision. The numbers of stations to achieve 10% precision are much higher, namely 214 for small upland rivers and 675 in small lowland rivers. However, it should be pointed out that the Directive would only require such monitoring information if it were relevant to the assessment of significant effects upon the status of water bodies in the basin district.

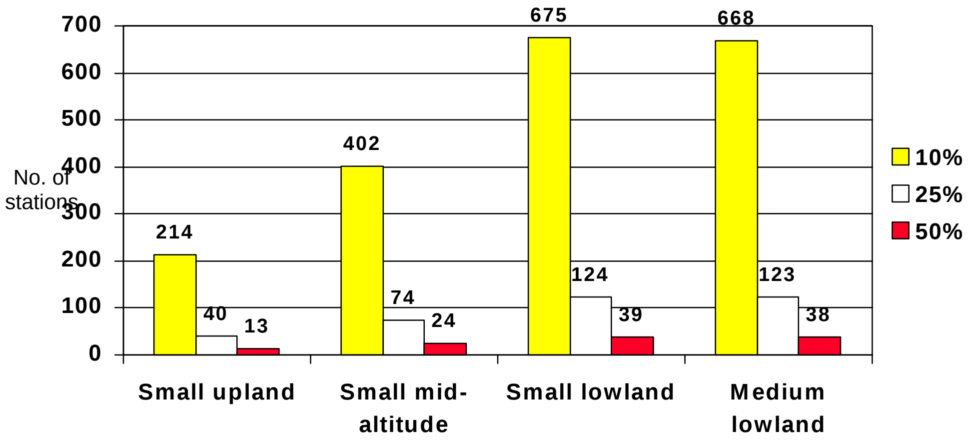


Figure 5.1 Number of river stations required to estimate phosphate mean concentrations to 10%, 25% and 50% precision with 90% confidence*

**Note there were 103 stations on small upland rivers, 653 on small mid-altitude rivers, 3769 stations on small lowland rivers and 425 stations on medium lowland rivers*

Risk of failing environmental quality objectives

The Directive refers to the identification of water bodies at risk of failing environmental quality objectives as defined in Article 4. This identification will be partially based on existing monitoring data (initially) and then on data arising from surveillance monitoring for subsequent periods of RBMPs. Those water bodies identified as being at risk will then be subject to operational monitoring which will confirm or reject their status in terms of failure to meet the relevant objectives. By implication this means that operational monitoring may need to provide a more precise assessment of the status of those water bodies identified at-risk than that originally obtained from surveillance monitoring.

Not all the Environmental Objectives given in Article 4 will be applicable to all water bodies: they can be summarised as follows:

¾ To achieve good groundwater status, good ecological status, good ecological potential or good chemical status;

¾ To comply with any standards and objectives associated with Protected Areas;

¾ To prevent deterioration in the status of a body of surface water or groundwater;

¾ To progressively reduce pollution from priority substances, and cease or phase out emissions, discharges and losses of priority hazardous substances; and,

¾ To reverse any significant and sustained upward trend in the concentration of any pollutant in groundwater.

Objectives 1 and 2 imply that assessments will have to be made as to whether status is better or worse than that which defines the threshold value between good and moderate status (or potential), or is in compliance with defined standards. Objectives 3 to 5 relate to assessing whether status is deteriorating with time or pollution is decreasing with time. In the latter cases, threshold levels or concentrations of substances against which risk of failure is judged will be specific to the water body of interest and will relate to levels or concentrations specified at a particular time.

As indicated above, the assessment of the risk of failure of a water body will make use (when possible) of data from monitoring stations within the body. The discrimination between good and moderate and hence the risk of failure could be determined based on comparison of the calculated 'confidence of compliance' with the appropriate standard or threshold value.

As noted earlier, the assessment of failure would have to consider what would be acceptable Type I and Type II errors. A Type I error would occur when a water body that was truly satisfactory was failed on the evidence of the monitoring programme. Conversely, a Type II error would occur when a water body that was truly unsatisfactory was passed by the monitoring programme.

In the figure below (Figure 5.2), where the parameter of interest might for example be the 90%ile, the judgement will be easy to make when the sample 90%ile and the entire confidence interval better than the threshold or standard (case A, or when they are worse than the threshold or standard (case D. However, there will be many cases where there is an overlap between the confidence limits and the thresholds (cases B and C). There are three possible approaches to assess failure in these cases. In a benefit-of-the-doubt approach, a monitoring station/water body is deemed to have passed, even when the estimate P has marginally failed, as long as part of the confidence interval falls into the 'good' status range. In a fail-safe approach, conversely, the monitoring station/water body fails, even when the estimate P has marginally passed, as long as part of the confidence interval falls into the less than 'good' status. Finally, in a face-value judgement sampling error is ignored and the pass/fail rule depends solely on the observed value of the summary statistic P.

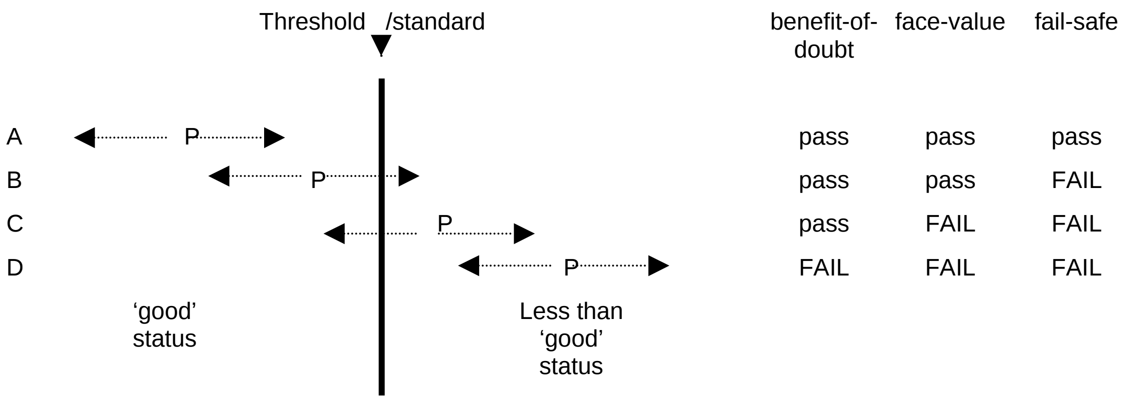
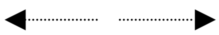


Figure 5.2 Methods of classification for groundwater bodies

NB: P denotes the parameter of interest (e.g. 90%ile) calculated from the sample data



represents the confidence interval for the unknown true value of P

The agreed or desired level of precision required in the estimate of the parameter P of interest and the desired level of confidence will determine how easy the above judgement of success or failure is going to be. For a given level of confidence, an increasingly precise estimate of P (obtained by increasing the number of samples) will reduce the width of the confidence interval, thus making the judgement of success or failure easier.

Risk of misclassification of status

The design of surveillance and operational monitoring should aim to control to acceptable levels the risk of a water body's status being wrongly assessed and hence misclassified.

Many water bodies and stations will lie close to class/status boundaries, and this, coupled with the uncertainty produced by infrequent/discrete monitoring, means that there is a substantial risk that such water bodies will be misclassified. This issue was examined by the Environment Agency of England and Wales. For their chemical general quality assessment ('GQA') scheme, it was demonstrated that, for any particular stretch of river, there was an average misclassification risk of 19%. The equivalent risk of misclassification based on sampling river invertebrates was calculated to be 22%.

The issue of misclassification was discussed at the REFCOND workshop held in Uppsala in May 2001. Two presentation slides from the workshop are reproduced below (Figure 5.3). They illustrate how the statistical uncertainty in the estimate of a water quality parameter (in this case 90%ile BOD) may cross a number of class boundaries. In this instance, the 'statistical confidence' curve spans three different classes. With 70% of the area of the curve lying within the moderate class, on a face value assessment the station would be classified as moderate.

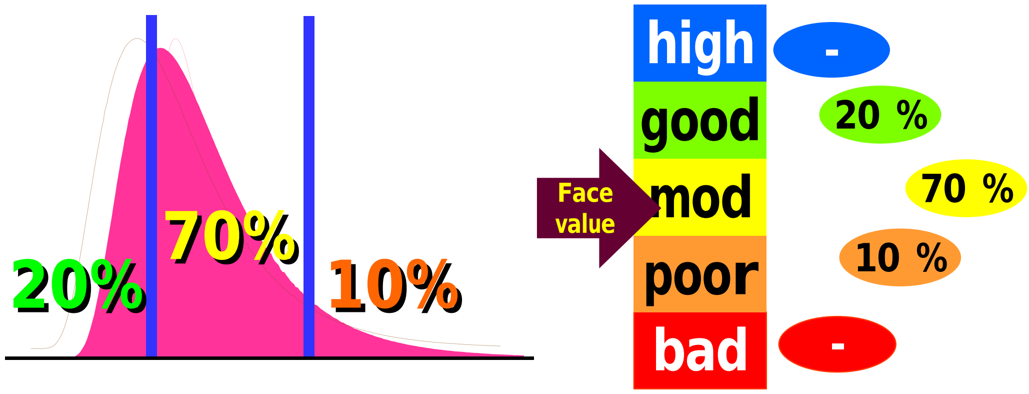


Figure 5.3 Classification of a monitoring station based on 'face value' assessment of quality (from presentation by Tony Warn the EA (England and Wales) at the REFCOND workshop, May 2001).

5.2.6 Surveillance monitoring of surface waters

Number and location of monitoring stations

Surveillance monitoring is required in a sufficient number of surface water bodies to provide an assessment of the overall surface water status within each catchment or sub-catchment within the river basin district. The location of monitoring stations within a water body should provide information that is representative of the general conditions of the water body, and which specifically addresses the objectives of the surveillance monitoring programme (as defined in Section 2.7.1). Therefore, it must enable the assessment of long term changes resulting from natural or anthropogenic activity and provide sufficient information to both supplement the Annex II risk assessments and assist with design of future monitoring programmes.

It is often assumed that a waterbody is well mixed and that a mid-water or mid-stream sample will be sufficiently representative. However, this is often not the case. For example, in thermally stratified waters the depth of sampling is critical because the concentrations of many measured parameters can vary greatly between the thermal layers. Ideally, therefore, monitoring should be undertaken at sufficient stations to provide an adequate description of the key spatial effects. However, it is worth noting the considerable resource implications of such investigations, any one of which would need at least 20 or 30 samples. This is in marked contrast with the minimum frequencies specified in Annex V of the WFD - typically four per year.

It was noted earlier that although the Directive requires assessments of status to be made for each individual water bodies, it does nevertheless permit water bodies to be grouped, provided they are sufficiently similar in all critical characteristics, and a group assessment made using just a representative sample of water bodies selected from the group. This is an instance of the well-established statistical principle of stratified random sampling[47]. Here, however, the aim is not to produce the most precise overall estimate of average status across all groups. Each group of water bodies is individually of interest, and the aim is to produce acceptably precise estimates of the relevant water quality measures for each of those groups. Thus the optimal allocation of samples across groups is not a relevant issue here. What is critical, however, is the requirement for the groups to be relatively homogeneous.

The grouping of water bodies has been discussed in some detail earlier in the document. How this would be done in practice depends very much on the statistical definitions of the boundaries determining whether the quality status is 'high', 'good' or 'moderate'. For chemical quality, for example, it would be possible for the assessment to be based on (a) mean concentrations, (b) extreme percentiles (such as the 10%ile for dissolved oxygen or the 90%ile for ammoniacal nitrogen), or (c) the proportion of samples falling below a given concentration limit. Thus it is not possible to go into detail here. Some general points can nevertheless be made.

The validity of the approach depends critically on the within-group variation shown by the water bodies in a selected group being **small in relation to the difference between the 'High'/'Good' and the 'Good'/'Moderate' limits**. For example, suppose these two status boundaries were defined by mean BOD values of 1.0 mg/l and 2.0 mg/l. On the one hand, if it were the case that the mean BODs for the various water bodies in the group all fell within 0.2 mg/l of each other, then given a sampled group mean of, say, 1.3 mg/l, this would provide sound evidence that all the water bodies in the group could be classified as 'good'. But if, on the other hand, the group had been formed less tightly and within-group mean BODs spanned a range of 1.2 mg/l, it would no longer be valid to assume that, because a sample of water bodies had a mean of 1.3 mg/l, all water bodies fell into the 'good' category. (In that example, we might expect about 10% of water bodies to have mean BODs below 1.0 mg/l - and hence be misclassified by the group sampling approach.)

Any consideration of the water body grouping option should therefore include a thorough assessment of (a) the degree of homogeneity of the group, and (b) the likely size of misclassification risks introduced by applying the estimated average group class to all individual water bodies in the group.

Frequency of monitoring

Minimum monitoring frequencies for surveillance monitoring are outlined in Annex V of the WFD. The Directive states that the frequencies identified should be applied unless "greater intervals would be justified on the basis of technical knowledge or expert judgement". Furthermore, it is the requirement of the directive that "frequencies shall be chosen so as to achieve an acceptable level of confidence and precision" and that "monitoring frequencies shall be selected which take account of variability in parameters resulting from both natural and anthropogenic pressures. The times at which monitoring is undertaken shall be selected so as to minimise the impact of seasonal variation on the results".

A number of important questions are prompted by these extracts from the Directive - especially in relation to the proposed 'minimum frequencies', which are typically 4 per year. Assuming that the confidence level is set at 90%, it is worth noting what can be achieved with just 4 samples in a year. If the aim were to estimate annual mean concentration, the

[47] *With stratified sampling, the population is divided into a number of strata (in this case, groups of water bodies) in such a way that the within-stratum variations are small in relation to differences between strata. Then, for any given total number of samples, statistical theory shows how samples can best be allocated across strata so as to produce the most precise overall estimate of the mean.*

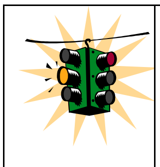
90% confidence interval for this would be “sample mean ρ1.18s” (where s is the standard deviation). For many common determinands, the relative standard deviation (i.e. s/mean) is at least 50%. Thus the annual means would be estimated to no better than ρ60%, which for many purposes might be thought unacceptably wide. Confidence intervals for percentiles would generally be a lot wider - and furthermore dependent on the assumed statistical distribution (which there would be no way of testing with so little data). This means that in practice it would be unrealistic to address any percentile-based objective:

The position is substantially worse when considering the magnitude of change that could be detected between any two years - the procedure envisaged under surveillance monitoring. The 90% confidence interval for the true mean difference would be sample mean difference ρ1.37s. Thus, assuming the same relative standard deviation as before, the two sample means would need to differ by at least 70% before it could be claimed with 90% confidence that there was a genuine difference between the two years. This, again, will be unhelpfully wide for many purposes.

Given this background, the suggestion that greater sampling intervals (i.e. lower frequencies than 4 per year) could be justified on the basis of expert judgement needs to be treated with some caution.

The recommendation made in the Directive to target sampling times so as to minimise the impact of seasonal variation is sound in principle. This will reduce the standard deviation, and so, for a given level of confidence, improve the precision (i.e. narrow the width of the confidence interval). However, it is important that the basis on which the targeting is justified is made clear, as the very act of targeting causes the samples to be drawn from a sub-population whose characteristics will usually be different from those of the overall population. For example, sampling a river only in summer will commonly generate much lower dissolved oxygen values (and hence a lower mean and 10%ile) than if sampling spans the full year. It is critical, therefore, to check that the process of targeting does not introduce bias in relation to the original purpose of the monitoring. For example, if High status is defined in terms of an annual 10%ile dissolved oxygen value, summer-only sampling could produce a very biased assessment of the water body.

In view of the above comments about sampling frequency, and as discussed in Section 2.7.2, monitoring may initially need to be more extensive to account for the expected lack of background data and information and the more comprehensive requirements of the Directive as compared to previous Directives. It is especially important to ensure that an adequate amount of data has been collected to characterise the ‘before’ or baseline conditions, as any shortcomings at this stage clearly cannot be corrected retrospectively. Nor can they be compensated for simply by increasing the ‘after’ frequency. For example, a comparison based on 12 samples in each of two time periods has a greater power to detect a change in mean than does a comparison with 6 samples before and 100 afterwards. It should be noted that the greater the analytical error in relation to environmental variability, the poorer the precision will be for a given number of samples and confidence level.



Look Out!

Specific guidance on statistical design for individual monitoring programmes cannot be provided at this stage. Monitoring program design will be influenced by:

¾ *The levels of confidence and precision identified in individual River Basin Management Plans;*

¾ *Outcomes of working group 2.3 REFCOND (levels of confidence and precision);*

¾ *How the physico-chemical status boundaries will be classified; and,*

¾ *The outcomes of the pilot testing exercises*

Further guidance on statistical analysis for the design of surveillance and operational monitoring programs will be required following the pilot testing exercises and subsequent development of River Basin Management Plans.

5.2.7 Operational monitoring of surface waters

The number and locations of monitoring stations required for operational monitoring are, in part, governed by the outcomes of the Annex II risk assessments and surveillance monitoring. Therefore, specific guidance on the number and location of water bodies and sites cannot be provided until those bodies at risk of failing the environmental objectives of the Directive are determined. However, random or stratified random sampling will be needed for bodies at risk from diffuse sources or hydromorphological pressures.

In any case, the same principals mentioned in the preceding discussions on sampling frequency in the context of surveillance monitoring should equally be applied to the design of an operational monitoring programme.

5.3 Best Practice and Tool Box for Groundwater

5.3.1 Introduction

5.3.2 Description of conceptual model/understanding approach

Conceptual models/understandings are simplified representations, or working descriptions, of how real hydrogeological systems are believed to behave. Their development under the Annex II characterisation procedure will be necessary to allow assessments of the risks of failing to meet the Directive's environmental objectives to be made. Conceptual models/understandings will also be required for designing effective monitoring programmes, classifying the status of water bodies and designing suitable programmes of measures. Because of their importance in the planning process, conceptual models/understandings should be tested numerically to ensure that they are adequately reliable and sufficiently precise for the purposes for which they will be used. The testing of the models should be based on water balance calculations. If a model accurately reflects the real hydrological system, over the long-term groundwater recharge would be expected to equal groundwater discharges to surface ecosystems and to adjacent bodies of groundwater. As well as validating conceptual models/understandings, water balance calculations will also be involved in assessing quantitative status (see Section 7 of the toolbox).

The level of complexity involved in any model will depend on the difficulty in judging the status of the body of groundwater and the implications of that status assessment. For example, where a body of groundwater is subject to no or only minor pressures, a very basic conceptual model/understanding will be adequate. However, to justify, and properly target, very costly restoration or enhancement measures for bodies failing to achieve 'good' status, relatively complex models are likely to be required. Different sorts of data, and different levels of confidence and precision in data, will be relevant to the development and subsequent testing of conceptual models/understandings in these different circumstances (Figure 5.4). This Section describes the development and testing of basic conceptual models/ understandings, and provides examples of under what circumstances and in what ways such models may need to be improved (Figure 5.6 to Figure 5.10).

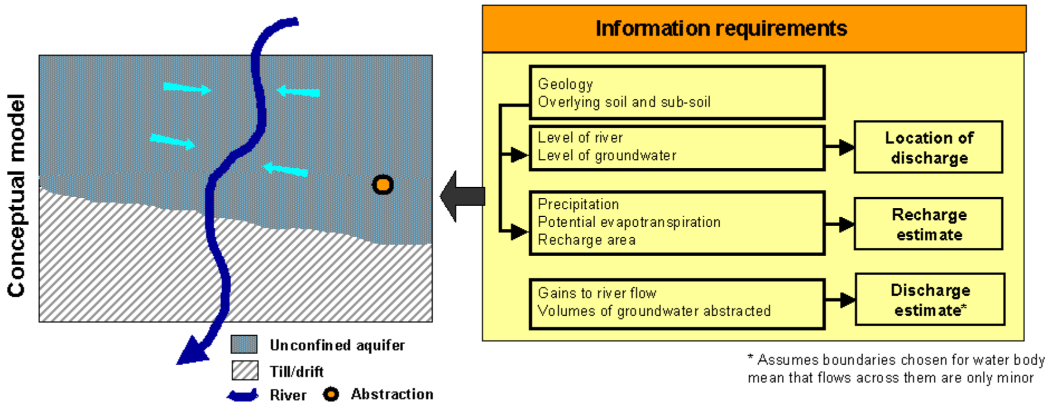


Figure 5.4 **Schematic illustration of a simple conceptual model/understanding of a body of groundwater in which the only significant groundwater discharge is to a river [i.e. the groundwater body has been delineated in such a way that any flows across its boundaries are negligible - See WFD CIS Guidance Document No. 2 on Water Bodies].**

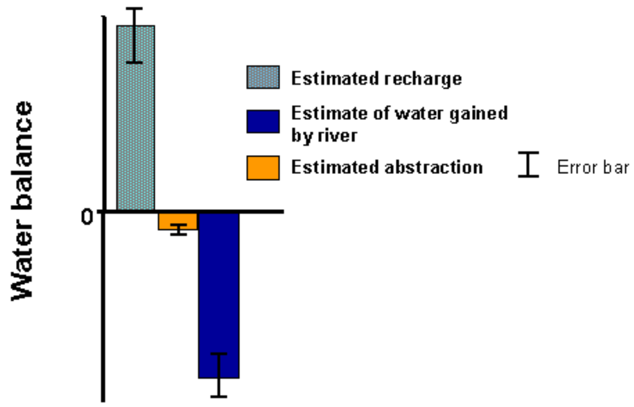


Figure 5.5 **Water balance used to test the conceptual model/understanding illustrated in Figure 5.4.**

The simple conceptual model/understanding illustrated in Figure 5.4 can be tested by lumped estimates of recharge, discharge and abstraction to see if it explains the bulk flows of water in the hydrogeological system (see Figure 5.5). If the water balance calculation balanced, and the model was adequate for use in assessing the status of the body of groundwater, no further development of the model would be necessary (see Figure 5.6). Where there is an apparent long-term water balance deficit, this could indicate over-abstraction but it could also result from errors in the conceptual model/understanding or the estimation of one or more of the components of the water balance (e.g. error in the recharge estimate). An improved, more detailed conceptual model/understanding would be required to enable a reliable assessment of status.

The level of precision required in the water balance will vary with the complexity, and likely significance, of the pressures to which a water body is subject (see Figure 5.7). For example, if a water body were subject to only minor pressures, provided there were no orders of magnitude imbalances in the water balance calculation, the model would be adequate. Where pressures were greater, in terms of numbers, distribution and/or significance, improvements to the conceptual model/understanding would be necessary in order to adequately assess status and design appropriate measures. Improving on a basic conceptual model/understanding involves reducing the errors in the estimates of recharge, groundwater discharge and abstraction, and appropriately refining its spatial and temporal resolution.

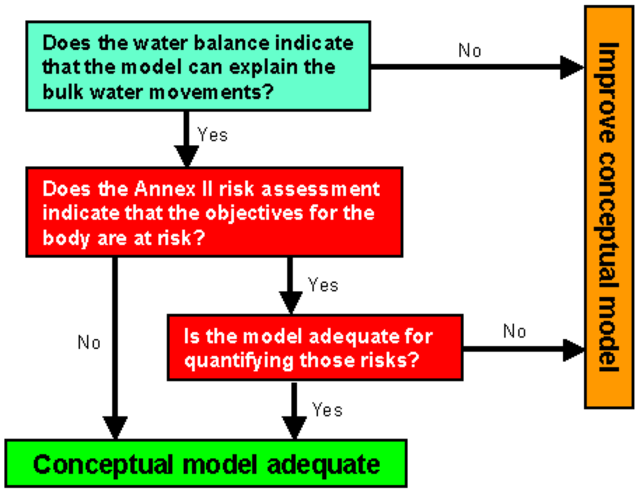


Figure 5.6 Considerations involved in determining the adequacy of a conceptual model/understanding.

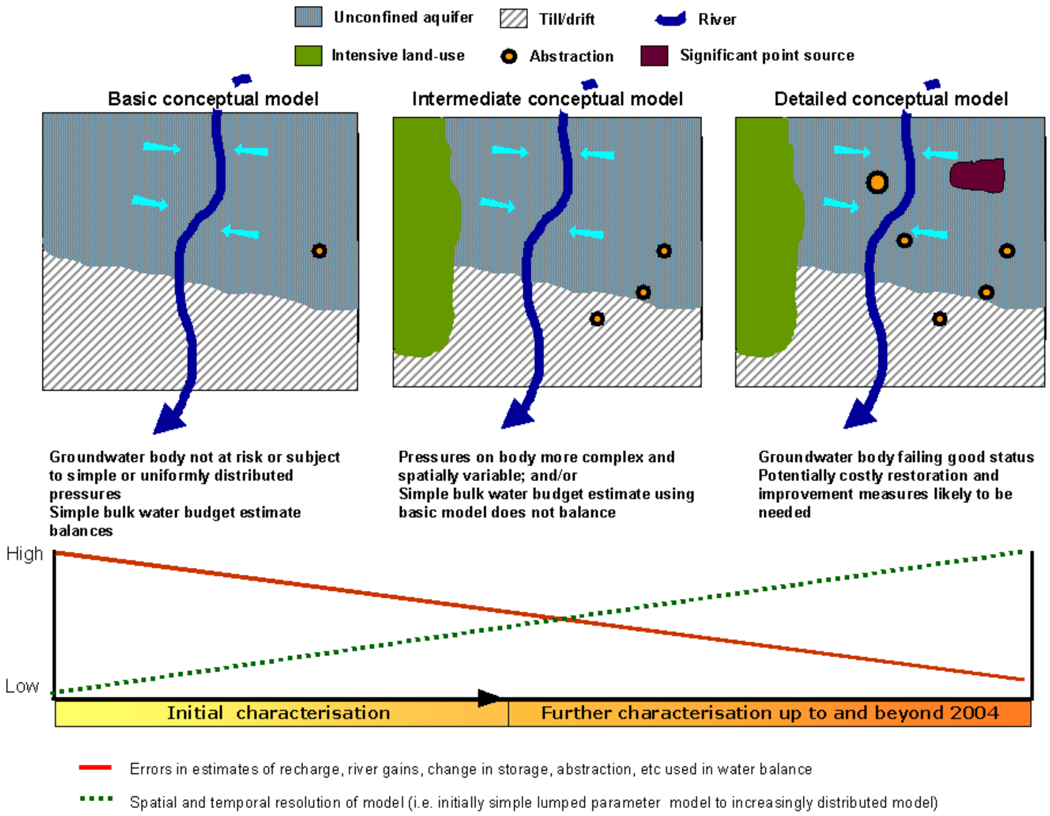


Figure 5.7 Development of a conceptual model/understanding in relation to the increasing complexity of pressures on the body and the cost of restoration and improvement measures.

For example, a complex quantitative model would tend to be based on (and tested), using estimates of the properties of different parts of the body of groundwater rather than relying on lumped estimates for the groundwater body's catchment. This produces a better understanding of spatial and temporal variability in the hydrogeological system and reduces the errors in the estimates of recharge and discharge used to test the model.

Table 5.1 Illustration of potential differences in data requirements for simple and best quantitative conceptual model/understandings.

	Basic conceptual model/understanding	Best quantitative model
Recharge	¾ Precipitation	¾ Precipitation
	-	¾ Estimate of artificial sources of recharge (e.g. leaking drinking water supply pipes etc)
	¾ Lumped estimate of potential evapotranspiration	¾ Estimate of actual evapotranspiration based on properties of land cover (e.g. types of crops).
	¾ Recharge area based on simple assumption of unconfined/confined	¾ Detailed properties of overlying soils and sub-soils; land-sealing (sub-balances to test properties)
River Gain	¾ Use of river flow data if available ¾ Standard length/gain coefficients for different geological settings ¾ Expert judgement	¾ Naturalisation estimates of river flows (e.g. estimated hydrograph with all river abstractions and discharges (other than groundwater) removed. Hydrograph separation to determine groundwater contribution. ¾ Estimate of change in storage.

Monitoring programmes should be designed to provide the data needed to appropriately test conceptual models/understandings (Table 5.1). The monitoring data needed to test any particular model will depend on the extent and quality of existing data and on the difficulty in assessing the status of the body, or group of bodies, and the implications of that assessment for the programmes of measures. Different types of monitoring data may be used in validating a conceptual model/understanding. For example, information on the physico-chemical properties of the groundwater and the surface water body at low river flows may improve confidence in the estimates of the extent of groundwater – surface water connectivity.

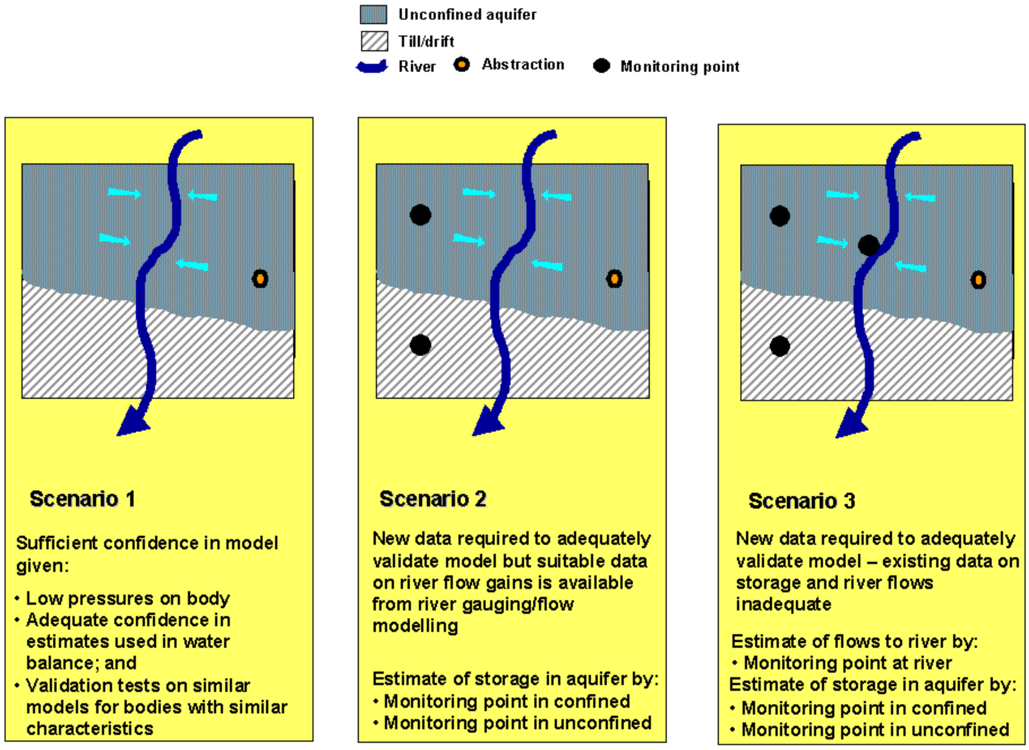


Figure 5.8 **Monitoring design in relation to conceptual model/understanding validation. Groundwater monitoring requirements will depend on the confidence required in the model and the extent and quality of existing data.**

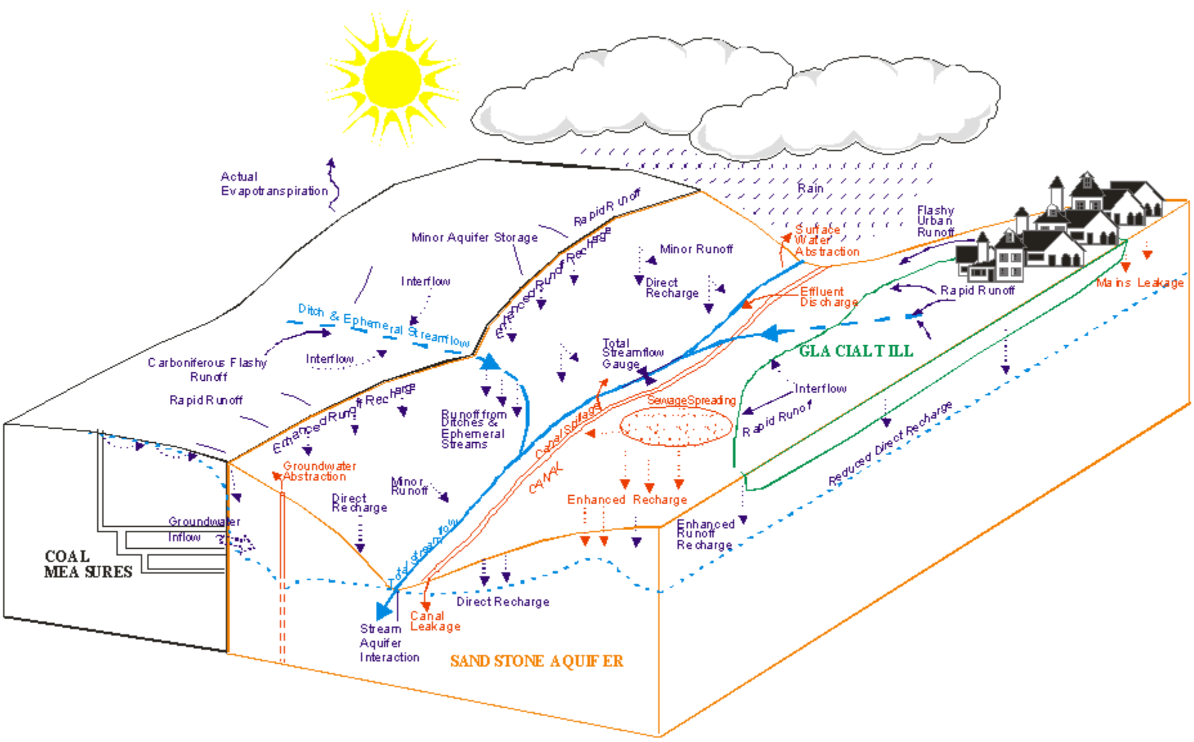


Figure 5.9 **Illustration of an intermediate conceptual model/understanding**

Further information on water balances is available from:

¾ ***Rushton, K. R. and Redshaw, S. C. (1979). Seepage and groundwater flow. John Wiley & Son Chichester pp 133***

¾ ***Freeze, R. A. & Cherry, J. A. (1979). Groundwater. Prentice Hall New Jersey***

5.3.3 Chemical Status Monitoring

Approaches to selecting pollutant suites in relation to particular human activities

Table 5.2 Examples of analytical suites that have been used in monitoring programmes in the UK to provide data on the risks to groundwater objectives from particular types of land use.

	Land use					
	Arable	Managed grassland	Managed woodlands	Urban	Sheep	Amenity
Field parameters						
Major ions	9	9	9	9	9	9
Trace metals				9		
Special inorganics				9		
Organonitrogen pesticides	9		9		9	
Organochlorine pesticides	9					9
Acid herbicides	9	9		9		9
Uron/urocarb pesticides	9			9		9
Phenols				9		
VOCs				9		
PAHs				9		
Special Organics	9				9	

Useful indicators for monitoring in relation to different types of human activity

Table 5.3 Examples of parameters that may be used in monitoring programmes to indicate that a particular human activity may be affecting groundwater quality.

Parameter(s)	Source
Nitrate	Agriculture
Ammonia	Urban areas, agriculture, land-fill
Phosphorous	Agriculture
Pesticides	Agriculture, traffic areas (rail tracks)
Sulphate	Agriculture, atmospheric depositions (acid rain), urban areas
pH-value	Atmospheric deposition (acid rain)
Chloride	Traffic (de-icing salt, road salt), agriculture, urban areas
Tetrachloroethene and Trichloroethene	Housing area, small trade (e.g. dry cleaner), industry
Micro-biological parameters	Animal or human waste disposal

The UN-ECE's guidelines also identify indicator parameters related to different problems, functions and uses. These are summarised in Table 5.4.

Table 5.4 Parameter suites for groundwater quality assessment related to some problems and functions/uses. (After Chilton *et al*, 1994)

Problems	Functions and Uses	Suite/groups	Parameters
Acidification, salinization	Ecosystems, agriculture	1. Field parameters	Temperature, pH, Dissolved Oxygen (DO), Electrical Conductivity (EC)
Salinization, excess nutrients	Drinking water, agriculture, ecosystems	2. Major ions	Ca, Mg, Na, K, HCO_3, Cl, SO_4, PO_4, NH_4, NO_3, NO_2, TOC, EC, ionic balance.
Pollution with hazardous substances	Drinking water, ecosystems	3. Minor ions and trace elements	Choice depends partly on local pollution sources as indicated by land-use approach.
Pollution with hazardous	Drinking water, ecosystems substances	4. Organic compounds	Aromatic hydrocarbons, halogenated hydrocarbons, phenols, chlorophenols. Choice depends partly on local pollution sources as indicated by land-use approach.
Pollution with hazardous substances	Drinking water, ecosystems	5. Pesticides	Choice depends in part on local usage, land-use approach and existing observed occurrences in groundwater.
Pollution with hazardous substances	Drinking water, agriculture	6. Bacteria	Total coliforms, faecal coliforms.

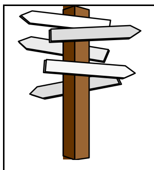
List II substances are Fe, Mn, Sr, Cu, Pb, Cr, Zn, Ni, As, Hg, Cd, B, F, Br and Cyanide.
(Drinking Water and Nitrate Directive)

Assessing background chemistry

An understanding of the natural chemical composition of a body of groundwater is important where:

¾ it is not clear whether concentrations of non-synthetic substances detected in the groundwater (e.g. As, Cd) are: (i) part of the natural chemical composition of the body of groundwater; (ii) occur as a result of human activities and should therefore be regarded as pollutants; or (iii) are a combination of (i) and (ii); or

¾ estimates of the background (i.e. reference condition) values for the physico-chemical quality elements are required for an associated surface water body. Where groundwater contributions to river base flows are high, the base flow chemistry of the river will be significantly influenced by groundwater chemistry.



Further information on assessing background chemistry is available from:

¾ **The EU Framework V funded Baseline project (EVK1 – CT1999-0006) (E-mail: hydro@bgs.ac.uk; Website: www.bgs.ac.uk/hydro/baseline)**

Designing chemical status monitoring networks; General principles

Definition of the objectives of groundwater monitoring is an essential prerequisite before identifying monitoring strategies and methods. Monitoring design includes: selection and design of monitoring sites, frequency and duration of monitoring, monitoring procedures, treatment of samples and analytical requirements. ISO 5667-1 and EN 25667-1 give the principles on the design of sampling programmes in aquatic environments.

Selecting monitoring sites and density in relation to risk

The assessment of chemical status and the identification of pollutant trends require a flexible, risk-based approach to selecting sites for monitoring. The conceptual model/understanding and the risk assessment it enables should be used to identify locations for, and the density of, monitoring points in relation to different land use pressures. The actual density of monitoring sites and location of individual sites will depend on the difficulty of reliably assessing the effects of pressures on the status of the body and the likelihood of costly measures being required. Such decisions must be made locally and be iteratively based on an appropriately detailed conceptual model/understanding of the groundwater system coupled with the assessment of risks to the Directive's objectives.

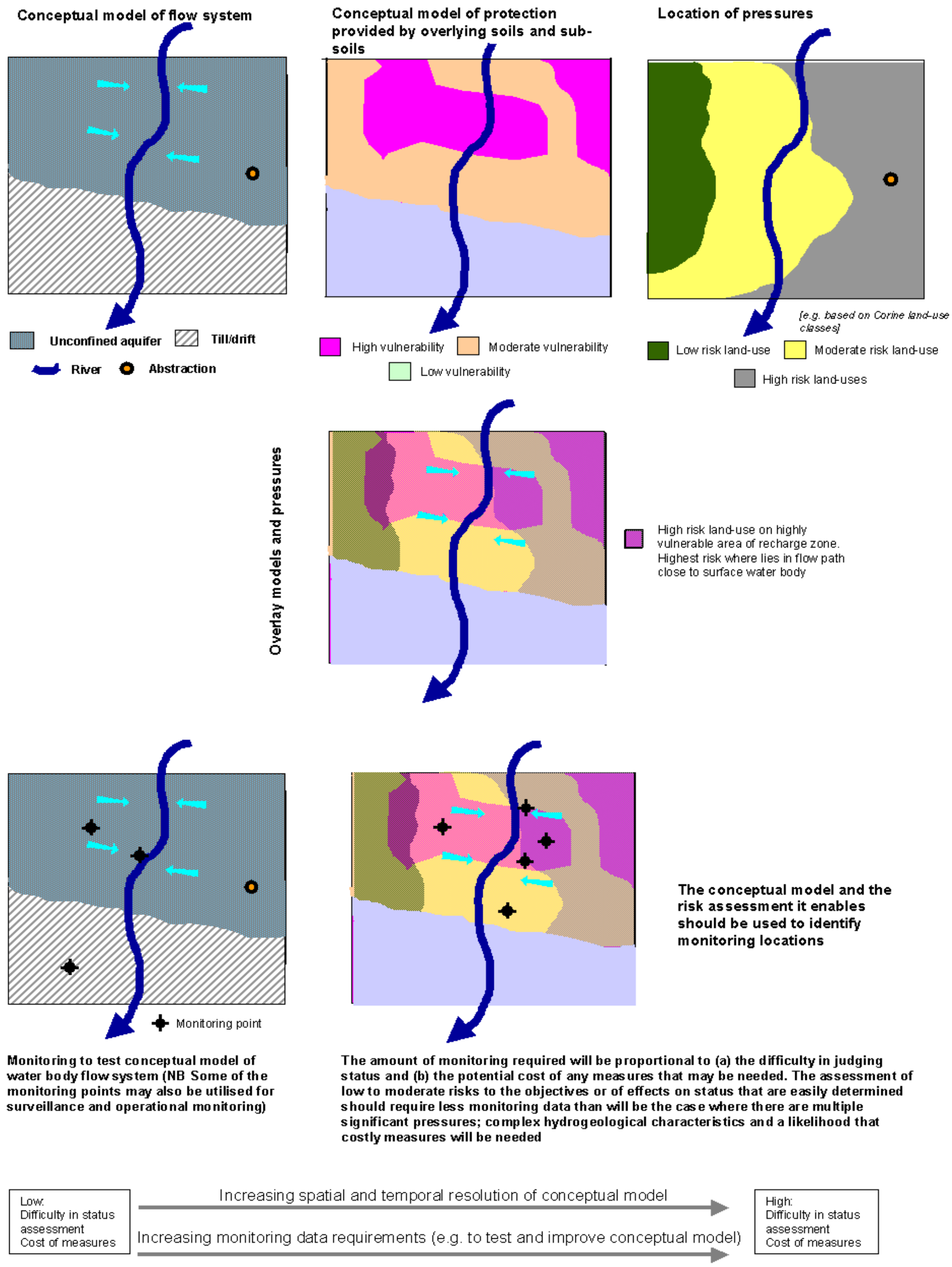


Figure 5.10 Monitoring locations for assessing chemical status should be selected on the basis of the Annex II risk assessments.

Where a body is at risk (illustrated in **Figure 5.10**) its status is difficult to determine because of its complex hydrogeological characteristics and/or the complex range of pressures to which it is subject; and costly measures may be required, improved conceptual models/ understandings and greater monitoring density will be necessary.

Approaches to determining monitoring frequencies in relation to groundwater body characteristics and the behaviour of pollutants

The sampling frequency for pollutants should be based on:

¾ the conceptual model/understanding of the groundwater system and the fate and behaviour of pollutants in it; and

¾ the aspect of the conceptual model/understanding being tested.

In the UK, a sampling frequency for groundwater quality is used that combines the requirements of the Directive with the main hydrogeological factors that influence groundwater flow. The framework ensures more frequent sampling in aquifers in which groundwater flow is rapid and less frequent in aquifers with slower movement (Table 5.5). It also builds in a less frequent requirement for sampling in confined aquifers than in unconfined aquifers, reflecting the greater degree of protection from pollution provided by the confining layers. The schedule is consistent with the Directive's requirements for operational monitoring to be undertaken at least annually between surveillance monitoring periods and for surveillance monitoring to be undertaken during each planning cycle. These frequencies may not be relevant for trend assessment. Guidance on monitoring frequencies for trend assessment are provided in CIS 2.8.

Table 5.5 Sampling frequency for groundwater hydrogeology

			SURVEILLANCE	*OPERATIONAL*
Hydrogeology	SLOW	Unconfined	3 years	6 monthly
		Confined	6 years	Annual
	FAST	Unconfined	Annual	Quarterly
		Confined	3 years	6 monthly

In Germany, the following table (Table 5.6) provides guidance on monitoring frequencies in relation to aquifer properties. The table does not address monitoring frequencies in relation to point sources, especially infiltrating dense liquid phases.

Table 5.6 German guidance on monitoring frequencies in relation to aquifer properties

Scenarios	Frequencies					
	Monthly	Quarterly	Half yearly	Yearly	Every two Years	Every five Years
shallow ground-water (depth to table δ 3 m), unconfined porous aquifer	x	X	X	x		
deep ground-water (depth to table τ 10 m), unconfined porous aquifer				x	X	X
shallow ground-water (depth to table δ 3 m), unconfined fractured aquifer	x	X	X	x		
deep groundwater (depth to table τ 10 m), unconfined fractured aquifer		x	X	X		
karst aquifer (without more or less impermeable cover)	X	X	X			
karst aquifer (with more or less impermeable cover)	x	X	X	x		
confined groundwater (with more or less impermeable cover with thickness < 2 m)				X	X	x
confined groundwater (with more or less impermeable cover with thickness > 2 m)				x	X	X
high rate of recharge		x	X	X		
Trend assessment			X	X		
season-dependent human activities		x	X	x		

Notes on Table: Large X indicates the most likely frequency. Small x indicates the range of frequencies depending on the particular circumstances. The frequencies suggested may not be relevant for trend assessment. Guidance on monitoring frequencies for trend assessment are provided in CIS 2.8.

Intrusions

One of the criteria required to achieve both good groundwater quantitative status and good groundwater chemical status is that a body of groundwater is not subject to saline or other intrusions resulting from human induced changes in flow direction. Some alterations to flow direction, however localised, would be expected to accompany any abstraction. Sometimes these will induce movements of water into a body of groundwater from an adjacent groundwater body or an associated surface water body. This water may well have a different chemical composition to that of the body of groundwater, either because of the pollutant concentrations it contains or because of its natural chemistry. The Directive does not regard temporary or continuous changes in flow direction and their associated effects on chemical composition as intrusions so long as they are limited spatially and do not compromise the achievement of any of the Directive's other environmental objectives for the body of groundwater (see Figure 5.11).

An assessment of whether an intrusion is present requires:

¾ the development of a conceptual model/understanding of the groundwater system;

¾ the use of that model to predict whether the pressures on the water body may have caused an intrusion; and

¾ the testing of that prediction to the extent necessary to develop the required confidence in the model and in the classification decisions it enables.

The testing of the conceptual models/understandings and the validation of their predictions will require the use of monitoring data.

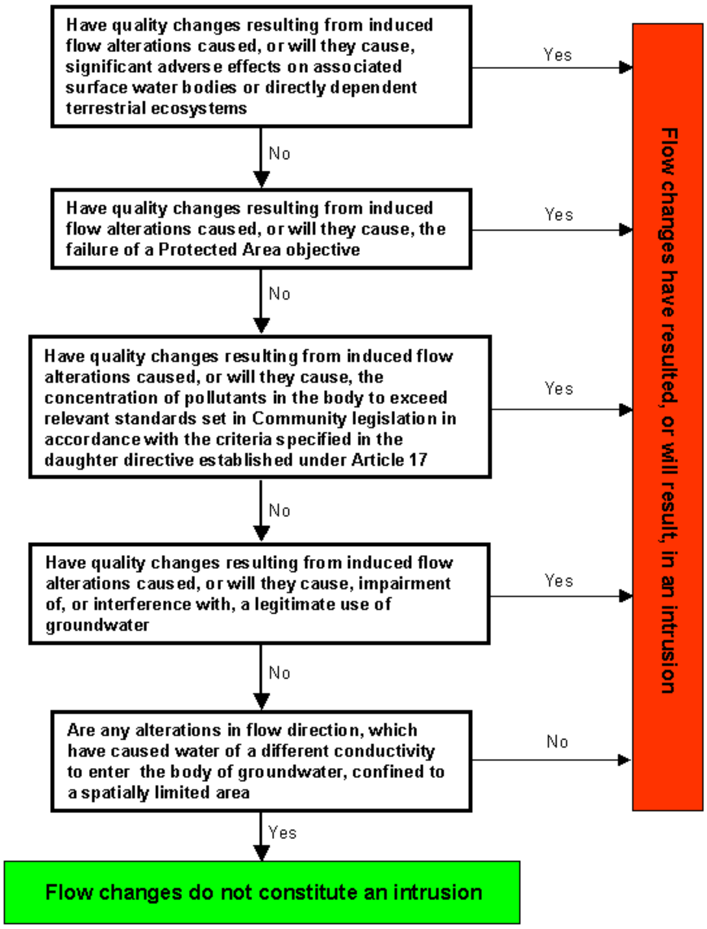


Figure 5.11 **Criteria for defining a saline or other intrusions into groundwater bodies. Where one of the intrusions defined in the figure occurs, a body of groundwater will fail to achieve good quantitative status and good chemical status.**

5.3.4 Sampling protocols

General principles

Care should be taken in the construction and operation of sampling points and in the analysis of samples collected so that they do not inadvertently affect the data provided.

Sampling design

A definition of the purpose of groundwater sampling is an essential prerequisite before identifying the sampling strategies and methods. Sampling design includes: selection and design of sampling sites, frequency and duration of sampling, sampling procedures, treatment of samples and analytical requirements. ISO 5667-1 and EN 25667-1 give the principles on the design of sampling programmes in aquatic environments.

Sampling methods

ISO 5667-11 (1993) gives the principles for groundwater sampling methods focused to survey the quality of groundwater supplies, to detect and assess groundwater pollution and to assist in groundwater resource management. ISO 5667-18 (2001) gives the principles of groundwater sampling methods at contaminated sites.

ISO 5667-2 gives the general information on the choice of material for sampling equipment. Generally polyethylene, polypropylene, polycarbonate and glass containers are recommended for most sampling situations. Opaque sample containers should be used if the sampled parameter degrades in light (e.g. some pesticides). Contamination or modification to the chemistry of groundwater samples should be minimised by selecting suitable materials for sampling equipment and borehole construction.

Sample storage, conditioning and transportation

Groundwater samples storage, conditioning and transportation from the sampling sites to the laboratory are extremely important, because the results of the analysis should be representative of the conditions at the time of sampling. General guidance on these aspects is given in ISO 5667-2 and ISO 5667-3. Specific indications for groundwater samples are given in ISO 5667-11.

Sample identification and records

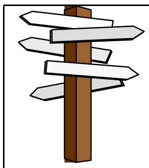
An identification system that provides an unambiguous method for sample tracking should be adopted. It is crucial that a clear and unambiguous labelling system be used for samples to enable effective management of samples, accurate presentation of results and interpretation. ISO 5667-11 gives guidance on sample identification and record procedures. In addition, other relevant environmental data should be reported and recorded in order that any repeat sampling can be carried out and any variability in results examined.

Monitoring points

The influence of the construction of a monitoring point and its condition and maintenance on the data obtained should be evaluated. For example, could the condition of the casing of the borehole be affecting the results? Are the intended geological strata exposed in the borehole? Is water entering the borehole from the surface?

Key sources of information on sampling protocols and quality assurance

- **The UN/ECE Task Force on Monitoring and Assessment provides practical Guidance on methods and quality assurance for monitoring transboundary groundwaters (www.iwac-riza.org).**
- **The European Environment Agency provides technical Guidance on design and operation of groundwater monitoring networks through its EUROWATERNET initiative (www.eea.eu.int).**
- **The AMPS working group under the EAF Priority Substances aims to ensure "the availability of good quality data..." and could deliver useful input on quality assurance requirements. http://forum.europa.eu.int/Members/irc/env/wfd/library?l=/experts_advisory/advisory_substances/monitoring_substances&vm=detailed&sb=Title**



List of standards for Groundwater Monitoring and Sampling used in Germany

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¾ **DVGW-Merkblatt W 112 (2001-07): Entnahme von Wasserproben bei der Erschließung, Gewinnung und Überwachung von Grundwasser *(Water sampling in recovery, capture and observation of groundwater)*.**

¾ **DVGW-Merkblatt W 121 (2002-07): Bau und Ausbau von Grundwassermessstellen *(Construction and design of groundwater monitoring wells).***

¾ **DVGW-Hinweis W 254 (1988-04): Grundsätze für Rohwasseruntersuchungen *(Principles of raw water analysis)*.**

¾ **DVWK-Regel 128 (1992): Entnahme und Untersuchungsumfang von Grundwasserproben *(Withdrawal and analysis of groundwater samples).***

¾ **DVWK-Merkblatt 245 (1997): Tiefenorientierte Probennahme aus Grundwassermessstellen *(Depth oriented sampling of groundwater).***

¾ **E EN ISO 5667-1:1995-03, Wasserbeschaffenheit Probenahme - Teil 1: Anleitung zur Aufstellung von Probenahmeprogrammen *(Water quality, sampling – Part 1: Guidance for setting up sampling programmes)*.**

¾ **E EN ISO 5667-2:1995-03, Wasserbeschaffenheit - Probenahme - Teil 2: Anleitung zur Probenahmetechnik *(Water quality, sampling – Part 2: Guidance on sampling techniques)*.**

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¾ **DIN EN ISO 5667-3, Wasserbeschaffenheit – Probenahme - Teil 3: Anleitung zur Konservierung und Handhabung von Proben *(Water quality, sampling – Part 3: Guidance for conservation and handling of samples)*.**

¾ **DIN 38402-13, Deutsche Einheitsverfahren zur Wasser-, Abwasser- und Schlammuntersuchung - Teil 13: Allgemeine Angaben (Gruppe A), Probenahme**

¾ **aus Grundwasserleitern (A 13) *(German standards for analysis of water, wastewater and sludge – part 13: General Remarks (Group A), Sampling of groundwater (A 13).***

¾ **LAWA AQS-Merkblatt P8/2, Probennahme von *Grundwasser (LAWA Guidance on quality assurance P8/2, Sampling of groundwater).***

¾ **LAWA (1987): Grundwasser - Richtlinien für Beobachtung und Auswertung - Teil 2: Grundwassertemperatur *(Groundwater – Guidance for monitoring and assessment – part 2: groundwater temperature).***

¾ **LAWA (1993): Grundwasser - Richtlinien für Beobachtung und Auswertung, Teil 3: Grundwasserbeschaffenheit *(Groundwater – Guidance for monitoring and assessment – part 3: groundwater quality).***

¾ **LAWA (2000): Grundwasser – Empfehlungen zur Konfiguration von Meßnetzen sowie zu Bau und Betrieb von Grundwassermeßstellen (qualitativ) *(Groundwater – recommendations on the design of monitoring networks and on the construction and operation of monitoring stations (qualitative))*.**

¾ **LAWA (2000: Empfehlungen zur Optimierung des Grundwasserdienstes (quantitative) (*Recommendations on the optimisation of quantitative groundwater monitoring)*.**

5.3.5 Quantitative status monitoring

Guidance on how to estimate the interaction of groundwater with surface waters and terrestrial ecosystems

An understanding of groundwater connections to surface waters and terrestrial ecosystems is necessary for:

¾ the development of a conceptual model/understanding of the hydrogeological system;

¾ the determination of the available groundwater resource;

¾ the assessment of quantitative status; and

¾ the assessment of groundwater chemical status.

The degree of precision and confidence needed in this understanding will depend on the risks of failing to meet the objectives for the body of groundwater and the implications of errors in an assessment of groundwater status.

Figure 5.12 outlines a series of steps that may be used to develop an initial understanding of where and how groundwater may interact with surface waters, and in particular river water bodies. This initial understanding should be tested and improved to the extent needed to provide an appropriate level of confidence in the assessments that depend on it. For example, where abstraction and pollution pressures are low, a generalised estimate of the extent of interaction is likely to be sufficient to enable a conceptual model/understanding of the interaction of groundwater and surface water to be developed and then tested using a water balance (see Section 1).

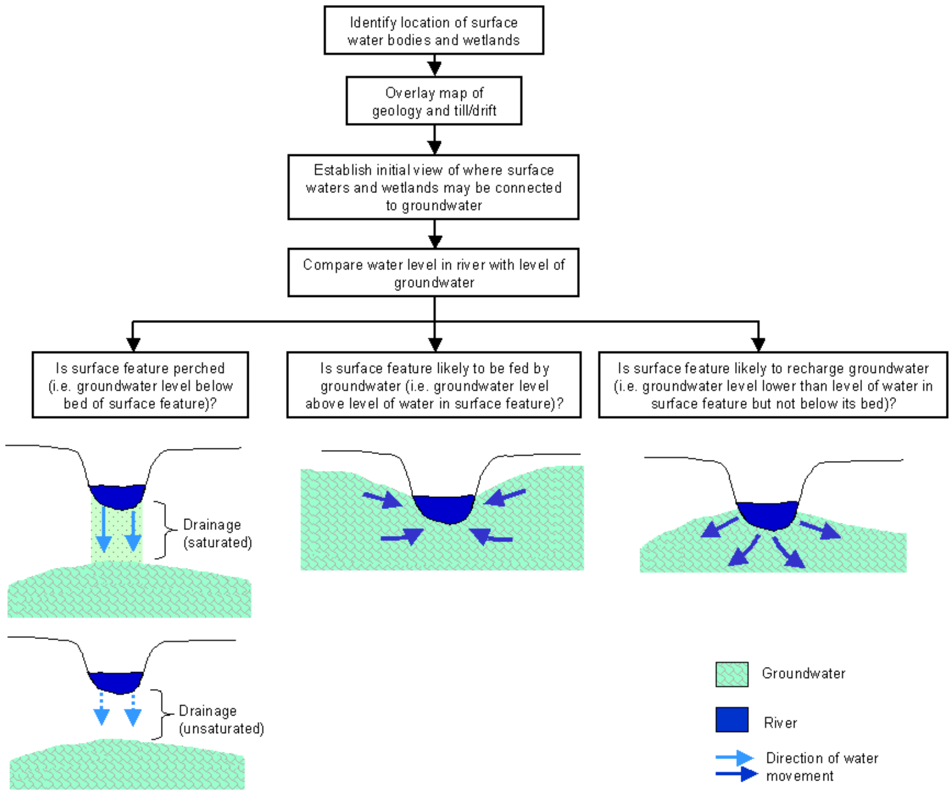


Figure 5.12 Suggested steps in the development of an understanding of the locations and types of interaction between groundwater and surface ecosystems.

Different approaches to testing the understanding of groundwater interactions with surface waters will be appropriate in different geological settings and for bodies subject to different pressures and associated risks of failing to achieve their objectives. Figure 5.13 lists some general approaches and the circumstances in which they may be appropriate.

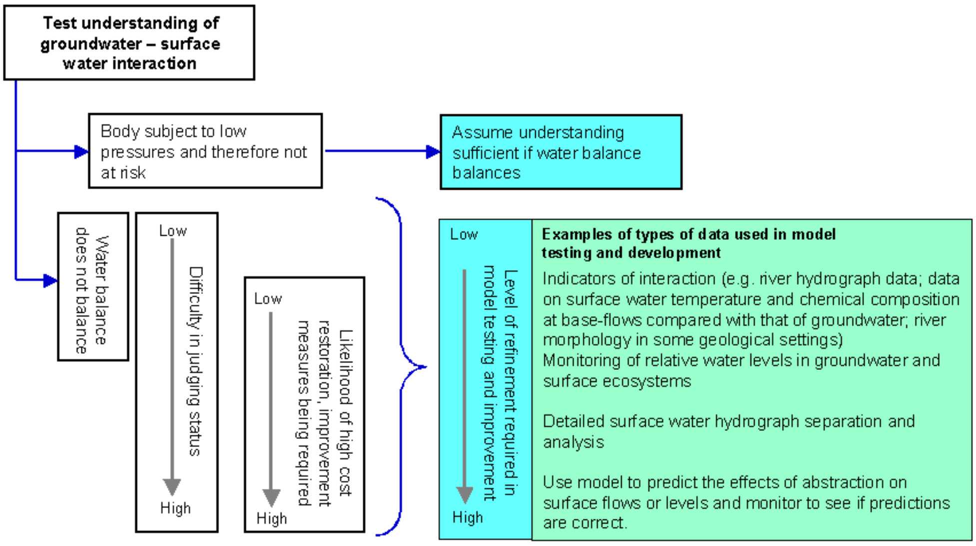


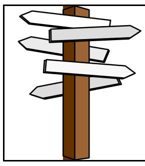
Figure 5.13 Approaches to testing and developing initial assessment of groundwater interactions with surface waters

5.3.6 Where to get further information

Interactions with rivers

To achieve 'good' status, the Directive requires the control of abstractions that could cause a significant diminution in the ecological or chemical quality of a surface water or significant damage to a directly dependent terrestrial ecosystem. An important means of testing a conceptual model/understanding of how groundwater interacts with surface water and terrestrial ecosystems is to use it to predict the effects of an abstraction on water flows and levels in the surface ecosystems, and then use monitoring (e.g. in conjunction with a pump test) to see if the predictions made by the model were correct.

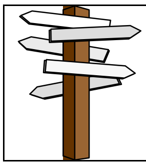
A system has been developed in the UK called 'Interaction of Groundwater Abstraction and River Flows' for providing a consistent means of using a conceptual model/understanding to predict the effects of an abstraction on river flows (e.g. design of pump tests etc). Monitoring to see if the predicted effects have occurred provides information for assessing the accuracy and precision of the conceptual model/understanding and for helping to improve the model if required.



Interaction of Groundwater Abstraction and River Flows (IGARF)] Environment Agency, Bristol England. [Will be available from web site: www.environment-agency.gov.uk in early 2003].

Interactions with terrestrial ecosystems

An assessment of groundwater body status also requires an understanding of how groundwater interacts with terrestrial ecosystems. As with surface water interactions, this requires the development and testing of a suitable conceptual model/understanding. It also requires information on the dependence of those ecosystems on the quality and the levels and flows of groundwater. The level of detail required in an estimate of the water needs of terrestrial ecosystems will depend on the likelihood of (a) those water needs being significantly affected, given the pressures on the body of groundwater, and (b) potentially costly improvement and restoration measures being required. Generic, orders of magnitude estimates of water needs may be adequate where risks are low. Where risks are high, specific research to establish the water needs of the terrestrial ecosystems may be required.

	A guide to monitoring water levels and flows at wetland sites (2000). Environment Agency, Bristol, England (Website: www.environment-agency.gov.uk)

How to measure available groundwater resource

Good quantitative status requires that the available groundwater resource is not exceeded by the long term annual average rate of abstraction and that any alterations to groundwater levels resulting from human activities have not resulted, and will not result, in (i) a failure to achieve any of the environmental objectives for associated surface water bodies; (ii) any significant diminution in the status of those bodies; nor significant damage to terrestrial ecosystems directly depending on groundwater.

The estimation of the available groundwater resource requires:

¾ an appropriate conceptual model/understanding of the groundwater body tested using a water balance; and;

¾ an estimate of the groundwater flow/levels needed by associated surface water bodies and directly dependent terrestrial ecosystems to achieve the criteria described above.

The steps involved in the estimation are illustrated in Figure 5.14. The accuracy and precision needed in the conceptual model/understanding and in particular the estimates of groundwater recharge and surface water - groundwater interaction it provides, will depend on the difficulty in judging whether the recharge to the body of groundwater, less the water needs of surface ecosystems, exceeds the rate of abstraction (see Figure 5.15). For example, for groundwater bodies, or groups of bodies, subject to only small groundwater abstractions (e.g. the recharge and river base-flow greatly exceed the rate of abstraction), orders of magnitude estimates of recharge and river flow needs are likely to be sufficient for testing the water balance, determining the available groundwater resource and assessing quantitative status.

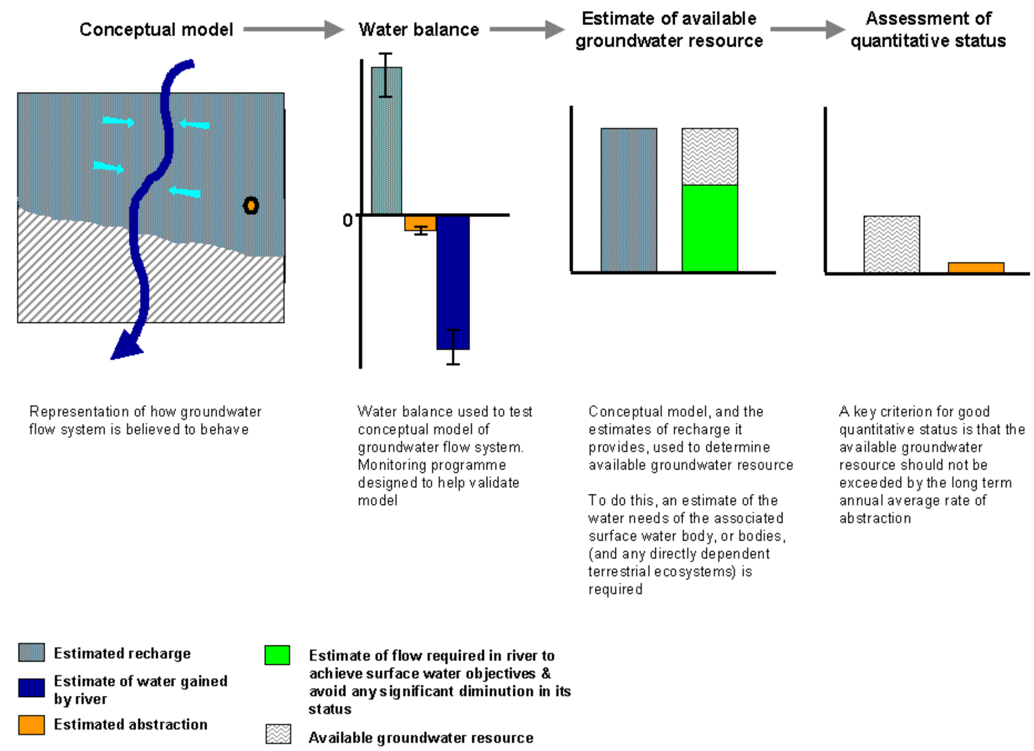


Figure 5.14 Illustration of the steps involved in estimating the available groundwater resource for a body of groundwater

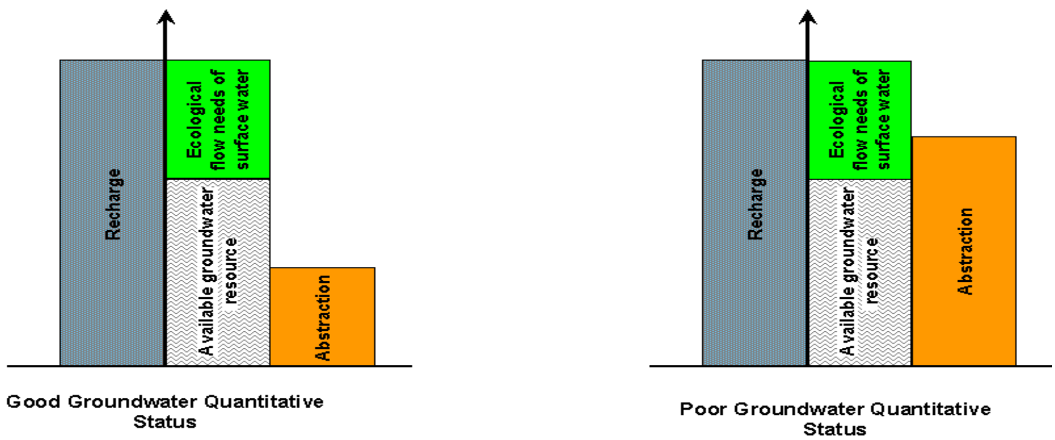
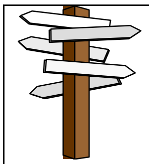


Figure 5.15 Illustration of bodies at poor and 'good' status in terms of the requirement to have a positive available groundwater resource once abstractions have been taken into account.



Where to get further information

¾ *Theis, C.V., (1941). The effect of a well on the flow of a nearby stream. American Geophysical Union Transactions 22 pp 734 – 738*

¾ *Hantush, M. S., (1965). Wells near streams with semi-pervious beds.*

	Journal of Geophysical Research 70 pp 2829 2838. ¾ *Stang, O., (1980). Stream depletion by wells near a superficial, rectilinear stream. Seminar No. 5, Nordiske Hydrologiske konference, Vemladen, presented in Bullock, A., A. Gustard, K. Irving, A. Sekuli and A. Young, (1994). Low flow estimation in artificially influenced catchments, Institute of Hydrology, Environment Agency R & D Note 274, WRc, Swindon, UK.*

Approaches to estimating flow across Member State boundaries

The Directive requires Member States to estimate groundwater flows across their boundaries. This is a separate requirement from the assessment of the status of bodies of groundwater. It will provide management information to Member States on how groundwater and its associated surface ecosystems may be affected by pressures in neighbouring States, and therefore how the measures needed to achieve the Directive's objectives should be apportioned between those States.

To provide estimates of flows across a national border, conceptual models/understandings tested using water balances will be needed for the groundwater systems on both sides of the border. The degree of accuracy and precision needed in such models will be proportionate to the difficulty in reliably judging the status of water bodies on either side of the border and in assessing the achievement of other relevant objectives, and should be such as to enable effective measures to be designed.

5.3.7 Application of CIS 2.8 Guidance in trend analysis

Summary of the results of CIS WG 2.8

One of the focuses of the Guidance prepared by CIS WG 2.8 was the development of particular statistical methods for the identification of upward trends in pollutants and the reversal of trends in accordance with Annex V 2.4.4 of the Directive. The Guidance also outlines the monitoring design considerations needed to provide suitable time series data for trend analysis.

The main results of CIS WG 2.8 (www.wfdgw.net) consist of the:

¾ Development of an appropriate data aggregation method for the assessment of groundwater quality at the groundwater body level respectively for groups of groundwater bodies including the determination of minimum requirements for calculation; and,

¾ Development of an appropriate statistical method for trend assessment and trend reversal including the determination of the minimum requirements for calculation.

The following general requirements are met by the proposed statistical procedures:

¾ Statistical correctness;

¾ Development of a pragmatic way;

¾ One data aggregation method suitable for small, large and groups of GW-bodies as well as for small GW-bodies with few sampling sites; and

¾ Applicability for all types of parameters.

The Guidance also outlines the monitoring design considerations for providing suitable data for chemical status assessment and time series data for trend analysis. All results are expressed at a certain level of confidence.

Application of CIS WG 2.8 Guidance

Figure 5.16 below illustrates the role of CIS 2.8 Guidance in the assessment of trends in pollutant concentrations in groundwater.

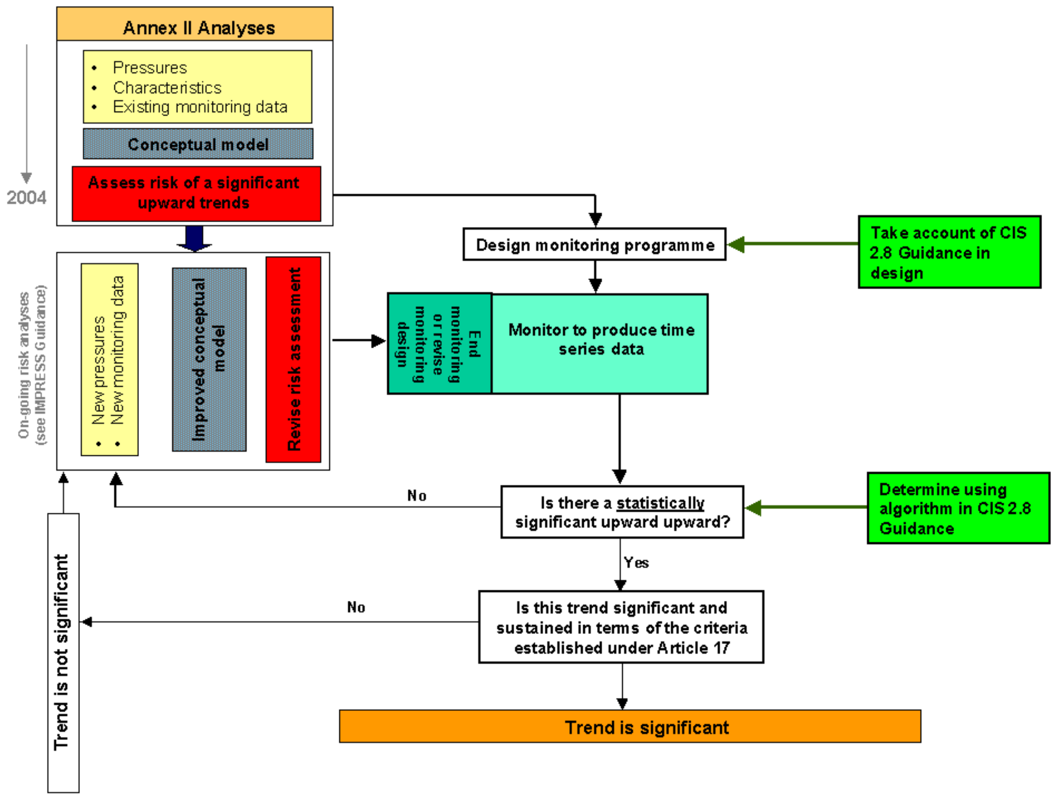


Figure 5.16 Use of CIS 2.8 Guidance in trend analysis

The Article 17 Daughter Directive is expected to establish criteria for the identification of significant and sustained upward trends. Until these criteria have been established, Member States must decide whether a trend is significant and sustained according to their own criteria. In developing such criteria, Member States should take into account the purpose of the trend reversal objective, which is to progressively reduce pollution of groundwater [Article 4.1(b)(iii)].

5.3.8 Drinking Water Protected Area Monitoring

One of the objectives for drinking water Protected Areas is to avoid deterioration in groundwater quality in order to reduce the level of purification treatment. Compliance with this objective can be simply monitored by assessing changes in the quality of abstracted water prior to any purification treatment. However, the design of the protection measures needed to ensure that the objective is achieved will require a means of predicting which pressures could cause a deterioration in the quality of the abstracted water. An appropriate conceptual model/understanding for the Protected Area will be necessary to enable such predictions. The complexity of any such model should be proportionate to the likely risks to the achievement of the objective. Where risks are minor (e.g. because pressures are low or the soil and sub-soils are impermeable) a simple conceptual model/understanding will be sufficient (Figure 5.17). Where the risks of quality deterioration are high, a more accurate and precise conceptual model/understanding, which includes more detailed consideration to groundwater flow characteristics, will be required, and monitoring data will be needed for its validation.

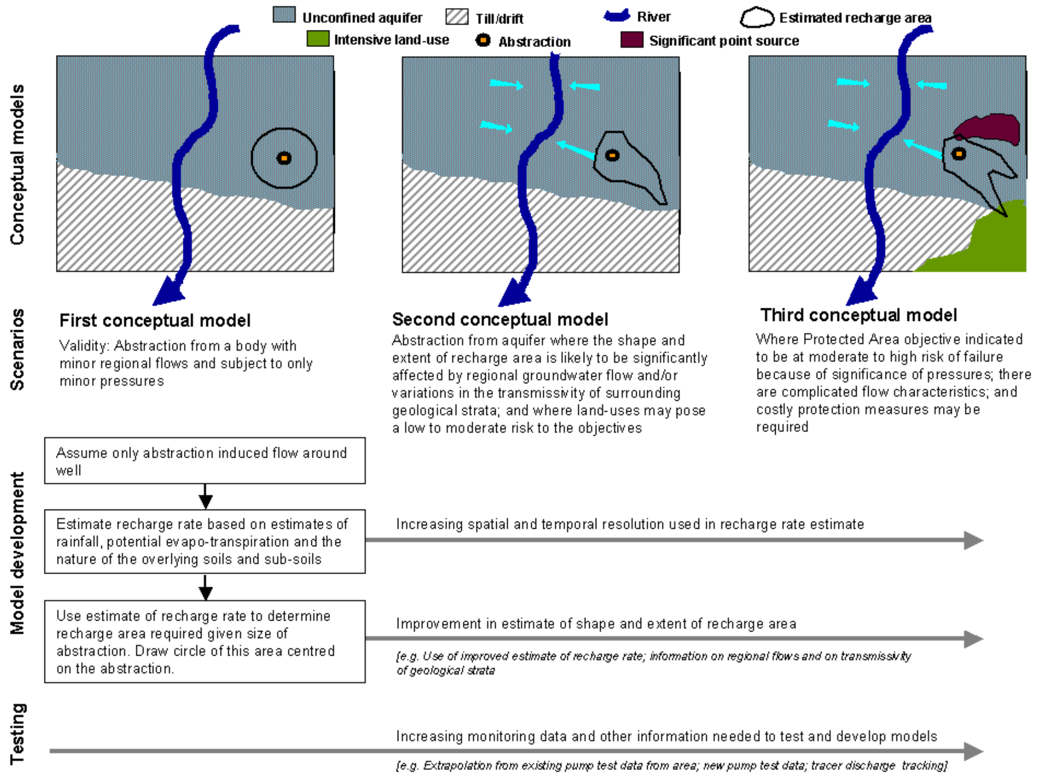


Figure 5.17 Development of conceptual models/understandings for drinking water protected areas.

6 Best Practice Examples for Using the Guidance

6.1 Contributions from Member States on Monitoring Methods -Fact Sheets

As a result of the third workshop in Brussels, Member States were requested to provide fact sheets on current monitoring methods undertaken in their country, which could be used or developed for the implementation of monitoring programmes in accordance with Annex V of the Directive.

Due to the overwhelming response from a number of countries, it was decided that, rather than include only a selection of fact sheets in the Guidance Document, all fact sheets would be uploaded directly to Circa. These fact sheets are available for Member States to review and use at their discretion.

Each fact sheet provides the following information:

- Details of the water category and quality element;
- Name and brief description of the method;
- Which country proposes the method, and where the method is currently being used;
- If the method provides a comparison to reference conditions/communities, and whether or not this is compliant with the requirements of the Directive;
- If there are existing national or international standards for the method;
- If the method is currently published in scientific literature;
- Applicability of the proposed method for use in implementation of the Directive;
- Relevant references; and
- Contact details to obtain additional information about the method.

Annex IV provides a list of fact sheet contributions, including the fact sheet title, country that has proposed the method and weblinks to the fact sheet.

7 Summary and Conclusions

A common strategy for the implementation WFD was developed in May 2001. The strategy aims provide support to Member States to ensure a coherent and harmonious implementation of this Directive.

An informal working group Working Group 2.7 was established within the CIS to facilitate the production of a practical and non-legally binding Guidance Document to assist Member States with developing surface and groundwater monitoring programmes in accordance with Article 8 and Annex V of the Directive.

The Guidance document provides a common understanding on the monitoring requirements of the Water Framework Directive. Guidance and principles generic to all water categories are provided as well as more specific Guidance on groundwater, rivers, lakes, transitional waters and coastal waters. This is largely based on current best practice in Member States and Norway. In addition, details of current monitoring practices in Member States and Norway are also given with details of national experts that could provide additional assistance.

The Guidance Document proposes an overall pragmatic approach. Because of the diversity of circumstances within the European Union, Member States may apply this Guidance in a flexible way in answer to problems that will vary from one river basin to the next. This proposed Guidance will therefore need to be tailored to specific circumstances. However, these adaptations should be justified and should be reported in a transparent way.

It is recommended that the Commission considers establishing a drafting group to further develop horizontal Guidance on the classification of ecological status of surface waters particularly in relation to Annex V.1.4.2 and Annex V.1.2. This is to do with the interpretation of the normative definition of good ecological status in terms of the physico-chemical quality elements, and the role of physico-chemical and hydromorphological quality elements as supporting the biological quality elements. This issue is also of relevance to Working Groups 2.3 on reference conditions for inland surface waters and 2.4 on typology and classification of transitional and coastal waters.

The Article 17 Groundwater Directive may establish additional criteria for the assessment of groundwater status. This Guidance may need to be updated once such criteria have been established.

Additional monitoring is required for drinking water abstraction points and habitat and species protection areas. However the register or registers of protected areas also includes areas designated as bathing waters under Directive 76/160/EEC, as vulnerable zones under Directive 91/676/EEC and areas as sensitive under Directive 91/271/EEC. These latter Directives also have monitoring and reporting requirements. The EAF on Reporting is considering not only the reporting required under the WFD but also existing reporting requirements with the aim of 'streamlining' the reporting process. The Working Group on Monitoring also recommends that ways of integrating, rationalising and streamlining the monitoring requirements under the other Directives should also be considered in future work that might revise this draft Guidance Document.

It is recommended that appropriate standards are developed as a matter of priority and urgency for those aspects of monitoring for which there are no internationally agreed standards or techniques/methods.

It is anticipated that the Guidance can be further developed by work undertaken in the next phase of the Common Implementation Strategy, for example, by the development of further horizontal Guidance on some aspects, and in the light of experience gained during the pilot basin testing phase.

ANNEX I GLOSSARY

Glossary of terms (excluding terms already defined in Article II of the Directive).

Term	Definition
Common Implementation Strategy	The Common Implementation Strategy for the Water Framework Directive (known as the CIS) was agreed by the European Commission, Member States and Norway in May 2001. The main aim of the CIS is to provide support in the implementation of the WFD, by developing a common understanding and Guidance on key elements of this Directive. Experts from the above countries and candidate countries as well as stakeholders from the water community are all involved in the CIS to: ξ Raise awareness an exchange information; ξ Develop Guidance Documents on various technical issues; ξ Carry out integrated testing in pilot river basins; and A series of working groups and joint activities has been developed to help carry out the activities listed above. A Strategic Co-ordination Group (or SCG) oversees these working groups and reports directly to the Water Directors of the European Union, Norway, Switzerland, the Candidate Countries and Commission, the engine of the CIS. For more information refer to the following website: http://europa.eu.int/comm/environment/water/water-framework/index_en.html.
Conceptual Model	A conceptual understanding of the interrelationships occurring within a system. The conceptual model graphically describes how experts believe the system behaves. Once developed the model is continuously refined as scientists obtain an improved understanding of the water bodies concerned and their vulnerability to pressures.
Confidence	The long-run probability (expressed as a percentage) that the true value of a statistical parameter (e.g. the population mean) does in fact lie within calculated and quoted limits placed around the answer actually obtained from the monitoring programme (e.g. the sample mean).
Ecological Quality Ratio	Ratio representing the relationship between the values of the biological parameters observed for a given body of surface water and values for these parameters in the reference conditions applicable to that body. The ratio shall be represented as a numerical value between zero and one, with high ecological status represented by values close to one and bad ecological status by values close to zero (Annex V 1.4(ii)).
Impact	The environmental effect of a pressure (e.g. fish killed, ecosystem modified).
Intercalibration	An exercise facilitated by the Commission to ensure that the high/good and good/moderate class boundaries are consistent with the normative definitions in Annex V Section 1.2 of the Directive and are comparable between Member States (see Guidance produced by WG 2.5) (Annex V 1.4. (iv)).

Term	Definition
Monitoring Standards	International or national standards developed to ensure provision of data or an equivalent scientific quality and comparability (e.g. those developed by CEN and ISO).
Parameter	Parameters indicative of the quality elements listed in Annex V, Table 1.1 in the Directive that will be used in monitoring and classification of ecological status. Examples on parameters relevant for the biological quality element composition and abundance of benthic invertebrate fauna are.: number of species or groups of species, presence of sensitive species or groups of species and proportion of tolerant/intolerant species.
Precision	A measure of the statistical uncertainty equal to the half width of the C% confidence interval. For any one monitoring exercise, the estimation error is the discrepancy between the answer obtained from the samples and the true value. The precision is then the level of estimation error that is achieved or bettered on a specified (high) proportion C% of occasions.
Pressure	The direct effect of the driver (for example, an effect that causes a change in flow or a change in the water chemistry of surface and groundwater.
Quality Assurance	Procedures implemented to ensure results of monitoring programmes meet the required target levels of precision and confidence. Can take the form of standardised sampling and analytical methods, replicate analyses, ionic balance checks and laboratory accreditation schemes.
Quality Element	Annex V, Table 1.1 in the Directive, explicitly defines the quality elements that must be used for the assessment of ecological status (eg. composition and abundance of benthic invertebrate fauna). Quality elements include biological elements and elements supporting the biological elements. These supporting elements are in two categories: 'hydromorphological' and 'chemical and physicochemical'.
Risk	2.7 Monitoring: Chance of an undesirable event happening. It has to aspects: the chance and the event that it might happen. These are conventionally called the probability and the confidence.
WFD, The Directive	Directive 2000/60/EC establishing a framework for Community action in the field of water policy.

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The European Environment Agency provides technical Guidance on design and operation of groundwater monitoring networks through its EUROWATERNET initiative (www.eea.eu.int).

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Links to Other Work

Table III.1 Completed and current research relevant to the WFD.

Article	Directive Requirements	Research: Completed / Current/ Recommended	Start/End
4	Reverse any significant upward trend in pollutants	**DG Environment Ad hoc – (Austria) statistical aspects of the identification of groundwater pollution trends, and aggregation of monitoring results**. After initial characterisation, bodies at risk require detailed characterisation of human impacts. Surveillance to verify if those identified at risk actually are is then required using indicative parameters. Plus operation monitoring of those confirmed at risk. This research clarifies statistical aspects. Status: current. Now part of the water group 2.8 under the Commissions Common Strategy	?
4	Environmental objectives	**Finnish Environment Institute.** Ecological basis for the discrimination, classification and monitoring of Finnish water bodies (krister.karttunen@vyh.fi , anas.pilke@vyh.fi). Status: current.	?
4	Environmental objectives	**Finnish Environment Institute.** Ecological basis for the discrimination and classification of regulated lakes in Finland (Mika.marttunen@vyh.fi). Status: current.	?
4	Environmental objectives	**Finnish Environment Institute.** Analysis of existing monitoring data for ecological classification of coastal waters (saara.back@vyh.fi). Status: current.	?
4	Environmental objectives	**Finnish Regional Environment Centre.** Use of macrozoobenthos in assessing the ecological state in the coastal waters of the Quark region (hans-goran.lax@vyh.fi). Status: current.	?
4	Environmental objectives	**Finnish Regional Environment Centre (Finland).** Ecological status of streams in Vuoksi River basin (kari-matti.vuori@vyh.fi). Status: current.	?
4	Environmental objectives	**Finnish Regional Environment Centre.** Applicability of periphyton methods for biomonitoring and classifying ecological status in the Vuoksi watercourse in littoral and pelagical zone (pekka.sojakka@vyh.fi, pertti.manninen@vyh.fi). Status: current.	?
4	Environmental objectives	**Finnish Regional Environment Centre.** Development of aquatic macrophyte monitoring for the national implementation of the WFD (olavi.sandman@vyh.fi). Status: current.	?
4	Environmental objectives	**Finnish Game and Fisheries Research Unit.** The analysis of fish community structure as a basis for the development of ecological classification and monitoring of surface waters (martti.rask@rktl.fi). Status: current.	?
4	Environmental objectives	**Helsinki University (Finland).** The control mechanisms required by the WFD and its Finnish implementation (jukka.matinvesi@vyh.fi, kai.kaatra@mmm.fi**).** Status: current.	?
4	Environmental objectives	**LIFE (Ian Codling, WRc, UK) Efficiency of Applied Policies regarding the Prevention and Control of Diffuse Pollution in Surface Waters: Inventory and comparison of approaches in seven countries, Germany, Denmark, France, The Netherlands, Sweden and the UK.** Project highlights those practices relevant to the aims of the proposed WFD, which seek to achieve good water quality status within river catchments through control of both point and diffuse sources of pollution. Status: current.	Nov 1999-April 2000
4	Environmental objectives	**Finnish Regional Environment Centre. Typology and restoration of the lakes of lowered water level (**heikki.tanskanen@vyh.fi **).** Status: current.	?
5	Characterise water body types	**FP5. TARGET. Functional assessments of surface water body ecological status.** Status: current.	?

Article	Directive Requirements	Research: Completed / Current/ Recommended	Start/End
5	Analysis of characteristics	**Finnish Environment Institute. The application of the WFD in heavily modified water bodies in Europe –** The Lake Kemijarvi case study (mika.marttunen@vyh.fi). Status: current.	?
5	Analysis of characteristics	**FP5 An operational system of Groundwater Recharge at European scale.** Contact persons: Professor M.A.Mimikou, Dr. E.A.Baltas. To develop a simple consistent and reliable system to estimate groundwater recharge at the catchment and regional scale. Status: recommended.	?
5	Analysis of characteristics	**FP5 River basin modelling for holistic catchment management.** Contact persons: M. A. Mimikou, Dr E. A. Baltas. The aim of this project is to establish current state of the art in river basin scale modelling and catchment management to identify issues for research to underpin the implementation of the WFD.	?
5	Analysis of characteristics	**FP5 Decision Support System for Integrated Water Resources Management.** Contact persons: Professor M.A.Mimikou, E.L.Varanou. Managing water resources on the river basin scale as the proper physical unit to account for the interaction between surface water and ground water as well as water quantity and quality. Status: recommended.	?
5	Analysis of characteristics	**FP5 Hydrological and Hydrometeorological Systems for Europe – HYDROMET (FP 4)** Contact persons: Professor M.A.Mimikou, Dr. E.A.Baltas. This project aimed to develop weather radar system for hydrological applications. Status: completed.	?
5	Analysis of characteristics	**FP5 Impact of Climate Change on Hydrological and Water Resource Systems in the European Community (FP 4).** Contact persons: Professor M.A.Mimikou, Dr. E.L.Varanou. This project aims to assess the impacts of climate change on water resources in Northern Greece on a regional basis (catchment scale). Status: completed.	?
5	Analysis of characteristics	**FP5 European River Flood Occurrence & Total Risk Assessment System – EUROTAS (FP 4).** Contact persons: Professor M.A.Mimikou, E.L.Varanou. To develop and demonstrate an integrated catchment model for the assessment and mitigation of flood risk. Status: current.	?
5	Analysis of characteristics	**FP5 Climate Hydrochemistry and Economics of Surface – Water Systems – CHESS (FP 4).** Contact persons: Professor M. A. Mimikou, E. C. Gkouvatsou. This project aims to investigate how expected changes in climate and land cover will affect the quality of freshwater resources in Europe. Status: current.	?
5	Integrated Catchment Management	**FP5 (EVK1) Data assimilation within a unifying modelling framework for improved river basin water resources management (contact Cees Veerman).** The aim of this project is to develop, implement and test a model that incorporates stream channel, land surface and soil components.	2000 - 2001
5	Integrated Catchment Management	**FP5 (EVK1) Integrated evaluation for sustainable river basin governance (contact Leopoldo Guimaraes).** This project aims to develop a set of guidelines for river basin authorities describing an integrated evaluation process, establishing criteria for assessing the sustainability of an evaluation process and providing practical tools to make the guidelines operational.	2001 - 2004
5	Integrated Catchment Management	**FP5 (EVK1) Freshwater integrated resource management (contact Peter Brooks, University of Surrey).** The aim of this project is to improve water resource planning through the use of multi-agent models that integrate hydrological, social and economic aspects of water resource management through the representation of stakeholder decision making.	
8	Determine ecological status .	**EA (E1-S01). Use of macrophytes for environmental monitoring of rivers.** This project aimed to develop a macrophyte-based methodology for monitoring the ecological health of river environments, and assessing their rehabilitation requirements. Status: completed.	?
8	Determine ecological status	**EA (E1D(01)15. Assessment of LIFE scores to link freshwater invertebrate communities to flow conditions.** Status: current.	?
8	Determine ecological status	**EA (E1A (01)02. Implementation of the PYSM system for the ecological assessment of ponds.** The aim is develop a co-ordinated monitoring programme for ponds and small water bodies in England and Wales. Status: current.	?
8	Determine ecological status	**EA (PR W1/017/1). PLANTPACS – A Study into the Feasibility of Producing a Predictive System to Assess River Quality and Ecological Status using Macrophytes.** This project was designed to develop a predictive system for macrophytes in rivers to determine overall environmental quality. Status: completed.	Published January 2000
8	Determine ecological status	**EA (E1-091). Still water ecological classification systems.** This project aims to review ecologically based classification systems that would be applicable to temperate standing freshwaters over 0.5km^2 surface area. Status: current.	04/05/99-31/03/01
8	Determine ecological status	**FP5 TARGET - Integrated assessment tools to gauge local functional status within freshwater ecosystems.** Develop a suite of generic tools for assessing functional status of running water ecosystems, based on modified versions of existing limnological and ecotoxicological tests. Has created	2000-2002

Article	Directive Requirements	Research: Completed / Current/ Recommended	Start/End
		Ecological Quality Manual containing procedures for the selection of tools and interpretation of results within ecoregion studied. Status: current.	
8	Determine ecological status	**FP5. EMERGE European Mountain Lake Ecosystem Regionalisation Diagnostic and Socio-economic Evaluation (contact: Simon Patrick Environmental Change Research Centre UCL).** Assessing the status of remote mountain lake ecosystems following the requirements of the WFD. Provides an evaluation of findings in ecological, environmental and socio-economic terms. Status: current.	2000-2002
8	Determine ecological status	**FP5 (contact: Dr Daniel Hering Institute of Ecology, Department of Hydrobiology University of Essen DE). AQEM, assessment method for defining ecological quality of surface water using benthic macroinvertebrates.** To develop an assessment procedure for rivers that meets the demands of the WFD using benthic macroinvertebrates. System based on fauna of near natural reference streams, new data sets to be comparable. Status: current.	2000-2002
8	Determine ecological status	**FP5 (contact: Prof. Brian Moss, school of Biological Sciences, University of Liverpool). ECOFRAME - Ecological quality and functioning of shallow lake ecosystems with respect to the needs of the WFD.** Shallow lakes are complex systems due to importance of higher plants, and thus pose particular problems for the implementation of WFD. Aims to test robustness of proposed sampling frequencies, to decide best criteria for determination of ecological status (high, good, moderate and worse). Status: current.	2000-2002
8	Determine ecological status	**FP5 (contact: Prof. Edwin Taylor; School of Biological Sciences, University of Birmingham, UK). CITYFISH.** This is a project that is modelling ecological quality of urban rivers: ecotoxicological factors limiting restoration of fish populations. Status: current.	2000 - 2002
8	Determine ecological status	**EPA (contact: Larry Stapleton, Environmental Monitoring and Laboratory Services Division, Ireland). Remote sensing of lakes: improved chlorophyll calibration and data processing.** Project developed aerial remote sensing facility to produce routine chlorophyll estimations for Irish lakes, as well as information on lake macrophytes and catchment land-use. Led to creation of a GIS suitable for lake management purposes. Status: completed.	1995-98
8	Determine ecological status	**EPA (contact: Larry Stapleton, Environmental Monitoring and Laboratory Services Division, Ireland). Ecological assessment of Irish lakes.** Developed field based assessment technique similar to that developed for rivers, to allow lakes to be graded using a range of ecological characteristics – flora, fauna, catchment type, and trophic status. Provided a data set of biological and chemical characteristics and catchment data (land use, rainfall) to investigate associations between patterns of land use and lake nutrient concentrations. Status: completed.	1995-99
8	Determine ecological status	**FP5 Predicting aquatic ecosystem quality using artificial neural networks: impact of environmental characteristics on the structure of aquatic communities (contact Raymond Bastide Universite Paul Sabatier de Toulouse III).** This project aims to develop the methodology for linking environmental characteristics and community structure and at a functional level the sensitivity of organisms and their response to disturbance.	2003
8	Determine ecological status	**FP5 Integrated assessment tools to gauge local functional status within freshwater ecosystems (contact Amadeu Mortagua, Universidade de Coimbra).** The aims of this study, which is based in Portugal, The Netherlands and the UK, are to develop an integrated set of tools for assessing ecological processes that maintain ecosystem services. The bioassays include energy supply, energy consumption and transfer.	2000 - 2003
8	Determine ecological status	**FP5 (EKV1) Towards harmonised procedures for quantification of catchment scale nutrient losses from European Catchments.** The aim of this project is to evaluate 10 tools that are currently used to support policy reporting at national and international level for estimating diffuse losses of N and P across a range of catchment types.	?

NOTE: FEI = Finnish Environmental Institute; FREC = Finnish Regional Centre; FF&G = Finnish Fish and Game, NERC = National Environment Research Council

ANNEX III SUMMARY OF FACTSHEETS ON CURRENT MONITORING UNDERTAKEN BY MEMBER STATES

Fact Sheet Title	Quality Element	Proposed by
Rivers		
Biological http://forum.europa.eu.int/Members/irc/env/wfd/library?l=/working_groups/wg_2_monitoring/factsheets_monitoring/rivers&vm=detailed&sb=Title		
Determination of the acute lethal toxicity of substances to a freshwater fish (*Brachydanio rerio* Hamilton-Buchanan (*Teleostei, Cyprinidae*))	Fish	Finland
IBGN Expert System	Benthic invertebrate fauna	France
Acidification index	Benthic invertebrate fauna	UK
Fresh water algal growth inhibition test with *Scenedesmus subspicatus* and *Selenastrum capricornutum*	Setting EQS -chronic toxicity data	Finland
HBMWP (Hellenic BMWP) +HASPT+Hindex	Benthic invertebrate fauna	Greece
IBE Extended Biotic Index modified for Italian rivers	Benthic invertebrate fauna	Italy
Environmental Quality Criteria – Benthic fauna - rivers	Benthic invertebrate fauna	Sweden
Determination of the inhibition of the mobility of *Daphnia magna* Straus (*Cladocera, Crustacea*)- Acute toxicity test	Setting EQS -chronic toxicity data	Finland
Protocol for monitoring epilithic diatoms at ECN river sites	Aquatic flora	UK
Protocol for monitoring aquatic macrophytes at ECN rivers sites	Aquatic flora	UK
Electric Fishing	Fish	UK
Swedish fish index	Fish	Sweden
IP (Indice poissons)	Fish	France
Quantitative sampling of fish with electricity	Fish	Sweden
Determination of toxicity to embryos and larvae of freshwater fish – semi-static method	Setting EQS -chronic toxicity data	Finland
IBD (Indice biologique diatomées)	Aquatic flora	France
Biological GQA (General Quality Assessment) classification	Benthic invertebrate fauna	UK
Acidification index based on invertebrates	Benthic invertebrate fauna	Norway
Lotic-invertebrate Index for Flow Evaluation (LIFE) Index	Benthic invertebrate fauna	UK
River Ecosystem Survey	General biological QEs	France
FBI monitoring method – Fish based index, indice poissons	Fish fauna	France
Determination of the inhibitory effect of water samples on the light emission of *Vibrio fischeri* (Luminescent bacteria test)	Setting EQS -chronic toxicity data	Finland
Mean Trophic Ranking (MTR)	Aquatic flora	UK
IBMR (Indice biologique macrophytes en rivière)	Aquatic flora	France
Occurrence of river macrophytes	Aquatic flora	Sweden
Periphyton method in running waters	Aquatic flora	Finland
Guidance standard for routine sampling of benthic algae in swift running water	Aquatic flora	Norway
Diatoms in running waters	Aquatic flora	Sweden

Fact Sheet Title	Quality Element	Proposed by
Rivers ***Biological*** ***continued..***		
The Trophic Diatom Index (TDI) and Diatom Quality Index (DQI)	Aquatic flora	UK
Composition, abundance and age structure of fish fauna	Fish	UK
Hydromorphological http://forum.europa.eu.int/Members/irc/env/wfd/library?l=/working_groups/wg_2_monitoring/factsheets_monitoring/rivers&vm=detailed&sb=Title		
River Habitat Survey (RHS) classification	Aquatic habitat/River structure	UK
REH (habitat assessment network)	Fish habitat/River structure	France
River Habitat Survey	Aquatic habitat	Greece
Physical SEQ (Quality Evaluation System)	Aquatic habitat	France
IFF – Indice di Funzionalità Fluviale (River Functionality Index)	Hydromorphology	Italy
QBR Index	Structure of riparian zone	Spain
Physico-chemical http://forum.europa.eu.int/Members/irc/env/wfd/library?l=/working_groups/wg_2_monitoring/factsheets_monitoring/rivers&vm=detailed&sb=Title		
Determination of alkalinity	Acidification	Sweden
Determination of ammonia nitrogen of water	Nutrients	Finland
ANC (Acid neutralizing Capacity)	Acidification	Norway
Determination of dissolved oxygen content in water	Oxygenation conditions	Finland
Determination of total-P after digestion with peroxidisulphate	Nutrients	Sweden
Determination of the sum of nitrite and nitrate nitrogen, nitrate nitrogen and total nitrogen in water by automated analytical equipment	Nutrients	Finland
Determination of phosphate in water	Nutrients	Finland
Determination of pH-value of water	Acidity	Finland
Determination of total phosphorus in water. Digestion with peroxidesulphate	Nutrients	Finland
Water -SEQ	General phys-chem	France
Guidance on Input Trend Assessment and the Adjustment of Loads	Identify and quantify pollution sources	The Netherlands
Lakes		
Biological http://forum.europa.eu.int/Members/irc/env/wfd/library?l=/working_groups/wg_2_monitoring/factsheets_monitoring/lakes&vm=detailed&sb=Title		
Chironomid Pupal Exuviae Technique (CPET) for assessing canal water quality	Benthic invertebrate fauna	UK
Predictive System for Multimetrics (PSYM)	Benthic invertebrate fauna	UK
Determination of the acute lethal toxicity of substances to a freshwater fish (*Brachydanio rerio* Hamilton-Buchanan (*Teleostei, Cyprinidae*))	EQS for acute toxicity data	Finland
Fresh water algal growth inhibition test with Scenedesmus subspicatus and Selenastrum capricornutum	Setting EQS for chronic toxicity data	Finland

Fact Sheet Title	Quality Element	Proposed by
Lakes ***Biological continued..***		
Environmental Quality Criteria – Benthic fauna - lakes	Benthic Invertebrate fauna	Sweden
Chironomid Pupal Exuviae Technique (CPET) for assessing lake status	Benthic invertebrate fauna	UK
Determination of chlorophyll-a, spectrophotometric determination in methanol extract	Aquatic flora	Norway
Determination of the inhibition of the mobility of *Daphnia magna* Straus (*Cladocera, Crustacea*)- Acute toxicity test	EQS for acute toxicity data	Finland
Protocol for monitoring aquatic macrophytes at ECN lake sites	Aquatic flora	UK
Electric Fishing	Fish	UK
Sampling of fish with gillnets	Fish	Sweden
Swedish fish index	Fish	Sweden
Determination of toxicity to embryos and larvae of freshwater fish – semi-static method	Setting EQS for chronic toxicity data	Finland
Composition, abundance and age structure of fish fauna	Fish	UK
Acidification index based on invertebrates	Benthic invertebrate fauna	Norway
Predictive System for Multimetrics (PSYM)	Aquatic flora	UK
Determination of the inhibitory effect of water samples on the light emission of *Vibrio fischeri* (Luminescent bacteria test)	EQS for acute toxicity data	Finland
Aquatic plant monitoring method	Aquatic flora	Finland
Submerged macrophytes in lakes	Aquatic flora	Sweden
Phytoplankton sampling in lakes for ECN sites	Aquatic flora	UK
Inverted microscope analysis	Aquatic flora	Sweden
Methods for quantitative assessment of phytoplankton in freshwaters	Aquatic flora	Finland
Physiochemical		
Determination of alkalinity	Acidification	Sweden
Determination of ammonia nitrogen of water	Nutrients	Finland
ANC (Acid neutralising Capacity)	Acidification	Norway
Determination of dissolved oxygen content in water	Oxygenation conditions	Finland
Determination of the sum of nitrite and nitrate nitrogen, nitrate nitrogen and total nitrogen in water by automated analytical equipment	Nutrients	Finland
Determination of phosphate in water	Nutrients	Finland
Determination of pH-value of water	Acidity	Finland
Determination of total phosphorus in water. Digestion with peroxidesulphate.	Nutrients	Finland
Toxicity and ecotoxicity		
Determination of toxicity to embryos and larvae of freshwater fish – semi-static method	Setting EQS for chronic toxicity data	Finland
Determination of the inhibition of the mobility of *Daphnia magna* Straus (*Cladocera, Crustacea*)- Acute toxicity test	Setting EQS for chronic toxicity data	Finland
Determination of the acute lethal toxicity of substances to a freshwater fish (*Brachydanio rerio* Hamilton-Buchanan (*Teleostei, Cyprinidae*	Setting EQS for acute toxicity data	Finland
Fresh water algal growth inhibition test with *Scenedesmus subspicatus* and *Selenastrum capricornutum*	Setting EQS for chronic toxicity data	Finland

Fact Sheet Title	Quality Element	Proposed by
Coastal –transitional		
Biological http://forum.europa.eu.int/Members/irc/env/wfd/library?l=/working_groups/wg_2_monitoring/factsheets_monitoring/transitional_coastal&vm=detailed&sb=Title		
Guidelines for marine biological investigations of littoral and sublittoral hard bottom	Aquatic flora Benthic invertebrate fauna	Norway
Guidelines for quantitative investigation of marine softbottom macrofauna	Benthic invertebrate fauna	Norway
Effect-directed identification procedures	Contaminants	The Netherlands
Seine Netting	Fish fauna	UK
Benthic invertebrate fauna	Benthic invertebrate fauna	UK
Soft bottom macrozoobenthos	Benthic invertebrate fauna	HELCOM
Soft bottom macrozoobenthos	Benthic invertebrate fauna	Sweden
Composition and cover of macroalgae	Aquatic flora	Denmark
Cartography of littoral benthic communities	Aquatic flora Benthic invertebrate fauna	Spain
Phytobenthic plant and animal communities	Aquatic flora	HELCOM
Sampling of Littoral benthic communities	Aquatic flora Benthic invertebrate fauna	Spain
Phytobenthic plant and animal communities	Aquatic flora	Sweden
Power Station Intake Screens - fish abundance/competition	Fish	UK
Beam Trawling - fish abundance/competition	Fish	UK
Kick Sampling - fish abundance/competition	Fish	UK
Otter Trawling – fish abundance/competition	Fish	UK
Fish fauna abundance/competition	Fish	UK
REPHY – Composition, abundance and biomass of phytoplankton	Phytoplankton	France
REBENT –Composition and abundance of phytobenthos and benthic invertebrate fauna	Aquatic flora, benthic invertebrate fauna	France
RSP – Distribution, abundance and vitality of angiosperms (P*osidonia oceanica*) - Mediterranean	Aquatic flora	France
RSG –Distribution, abundance and vitality of gorgons (*Paramuricea clavata*) - Mediterranean	Benthic invertebrate fauna	France
RINBIO – Biological integrators: inorganic and organic contaminants in mussels - Mediterranean	Contaminants	France
Catography of littoral benthic communities in Mediterranean	Aquatic flora, benthic invertebrate fauna	France
Physiochemical http://forum.europa.eu.int/Members/irc/env/wfd/library?l=/working_groups/wg_2_monitoring/factsheets_monitoring/transitional_coastal&vm=detailed&sb=Title		
Determination of alkalinity	Acidification	Sweden
Determination of ammonia nitrogen of water	Nutrients	Finland
Co-ordinated environmental monitoring programme	Physiochemical	Belgium Netherlands
Determination of dissolved oxygen content in water	Oxygenation conditions	Finland
Determination of the sum of nitrite and nitrate nitrogen, nitrate nitrogen and total nitrogen in water by automated analytical equipment.	Nutrients	Finland
Organotin determination in sediments	Contaminants	Netherlands
Determination of phosphate in water	Nutrients	Finland

Fact Sheet Title	Quality Element	Proposed by
Determination of pH-value of water	Acidity	Finland
Determination of total phosphorus in water. Digestion with peroxidesulphate.	Nutrients	Finland
Guidance on Input Trend Assessment and the Adjustment of Loads	Physico-chemical	Netherlands
Phytoplankton chlorophyll a	Aquatic flora	HELCOM Sweden
Method for monitoring littoral waters	Nutrients	Spain
Nutrient determination	Nutrients	HELCOM Sweden
Determination of oxygen concentrations in coastal waters and the Baltic Sea	Oxygenation conditions	HELCOM Sweden
Determination of salinity in coastal waters and the Baltic Sea	Salinity	HELCOM
Light attenuation	Transparency	HELCOM Sweden
Determination of temperature in coastal waters and the Baltic Sea	Thermal conditions	HELCOM
Groundwater		
Monitoring of groundwater: criteria to set the monitoring network of groundwater according to socio-economic and hydrogeological conditions of the regional district	Hydrogeological	Italy

ANNEX IV WORKING GROUP CONTACTS

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ANNEX V KEY CONSIDERATIONS FOR MONITORING QUALITY ELEMENTS

V1.1 Rivers

V1.1.1 Key considerations for rivers

River systems across Europe are extremely variable in size and structure and, although they have a long and very intense history of study in relation to their responses to an equally varied range of pressures, monitoring the effects of the impacts on biological communities is complex. The choice of the quality elements to be used in the monitoring programmes will improve over time but, in the first instance, choosing the quality elements most relevant to specific pressures will depend on the size of the river system, availability of existing monitoring methods and data-sets, and local knowledge of the significant pressures.

V1.1.2 Key Biological Quality elements

The use of macroinvertebrates to assess the effects of organic pollution of rivers has a long history throughout Europe and, although the details in methodologies might vary from country to country, their use for this purpose is well understood. Currently, this is the most commonly used element for biological classification of rivers in Europe.

More recently methods for using macroinvertebrates as indicators of other pressures including toxic chemicals and alterations in river flows and channel morphology, have or are being developed. The sensitivity of macroinvertebrates to a wide range of impacts makes them a very useful tool for assessing river quality. They are less useful in deep rivers where they may be difficult to sample.

Monitoring macrophyte community structure and biomass is most relevant for assessing the impacts of eutrophication in small to medium-sized rivers. They can be used for assessing the impacts of high flows and flow variation associated with hydropower effects and of stream maintenance. As with macroinvertebrates, they are not widely used in large, deep river systems or in more shallow rivers subject to wide flow variations, such as those subject to the impact of melting snow. Further macrophytes can absent in streams in dense forested areas.

Methods are available and several countries use macrophytes for river quality assessment. A CEN sampling method is currently nearing completion but further work will be needed on the use of macrophytes for the Directive.

Benthic algae currently have limited use in European countries but are valuable under some circumstances, particularly for describing the impacts of eutrophication. Diatoms and filamentous algae have been used most effectively for this purpose.

River phytoplankton species and abundance are important indicators of eutrophication but are limited in their use to large, slow flowing rivers.

The use of fish as indicators of impacts on river systems is relatively uncommon across Europe. Although it is clearly recognised that fish are important indicators of river condition, they are difficult to sample without specialist equipment and the results are difficult to interpret because of their mobility within the river systems, barriers in the river systems, effects of fishery and stocking etc. Care must be taken in choosing the most appropriate indicators of local conditions and impacts, particularly in the case of migratory Salmonids.

The use of fish as indicators of accidental pollution is an important consideration in setting up monitoring schemes.

V1.1.3 Key hydromorphological elements

The physical structure and flow dynamics of river systems are very important elements for determining ecological quality. All the biological quality elements vary in accordance with their habitat requirements and the processes associated with the hydromorphological quality elements and flow dynamics are highly influential in determining the basic floral and faunal community composition. Of particular importance are the influences of these elements on substrate, the decomposition of organic matter and the extent of interaction with the riparian zone.

Further work is needed to provide better methods to describe the relationships between the biological quality elements and the morphology, river continuity and hydrological regime.

The influence of groundwater inputs to river systems (or loss to groundwater systems and/or irrigation) is also an important issue to be considered under the Directive, both in terms of maintaining the river system and the potential to cause pollution.

V1.1.4 Key physico-chemical elements

Many of the basic physico-chemical quality elements in Annex V of the Directive are basic measures of river condition and like the physico-chemical elements are important influences on natural river systems. These includes temperature, nutrients, salinity and the pH balance. It is important therefore to include measurements of these elements in relation to their natural as well as potential polluting influences. For example, nutrient concentrations outside the expected range of concentrations are likely to cause eutrophication.

The other main quality elements, which need to be taken account of, are the specific pollutants identified as being likely to cause a failure of the biological quality status. These will vary locally and will need to be determined during the analysis of pressures.

V1.2 Lakes

V1.2.1 Influence of eutrophication on ecosystem structure and function

The key element influencing ecosystem structure and function in lakes and reservoirs is anthropogenic eutrophication. Eutrophication, which in principle is a natural, but very slow phenomenon of lakes, contributes to a number of water quality problems such as phytoplankton blooms, reduced recreational aesthetics, hypolimnetic oxygen depletion, reduced transparency and fish kills. It is important to note that the fundamental processes, such as stratification and internal nutrient loading, occurring in natural lakes and artificial reservoirs are similar. However, differences in morphology, hydrology and water residence times need to be recognised before comparisons can be made.

The figure below Figure 7.1 illustrates the major physico-chemical and biological processed occurring in lakes during stratified and mixed conditions.

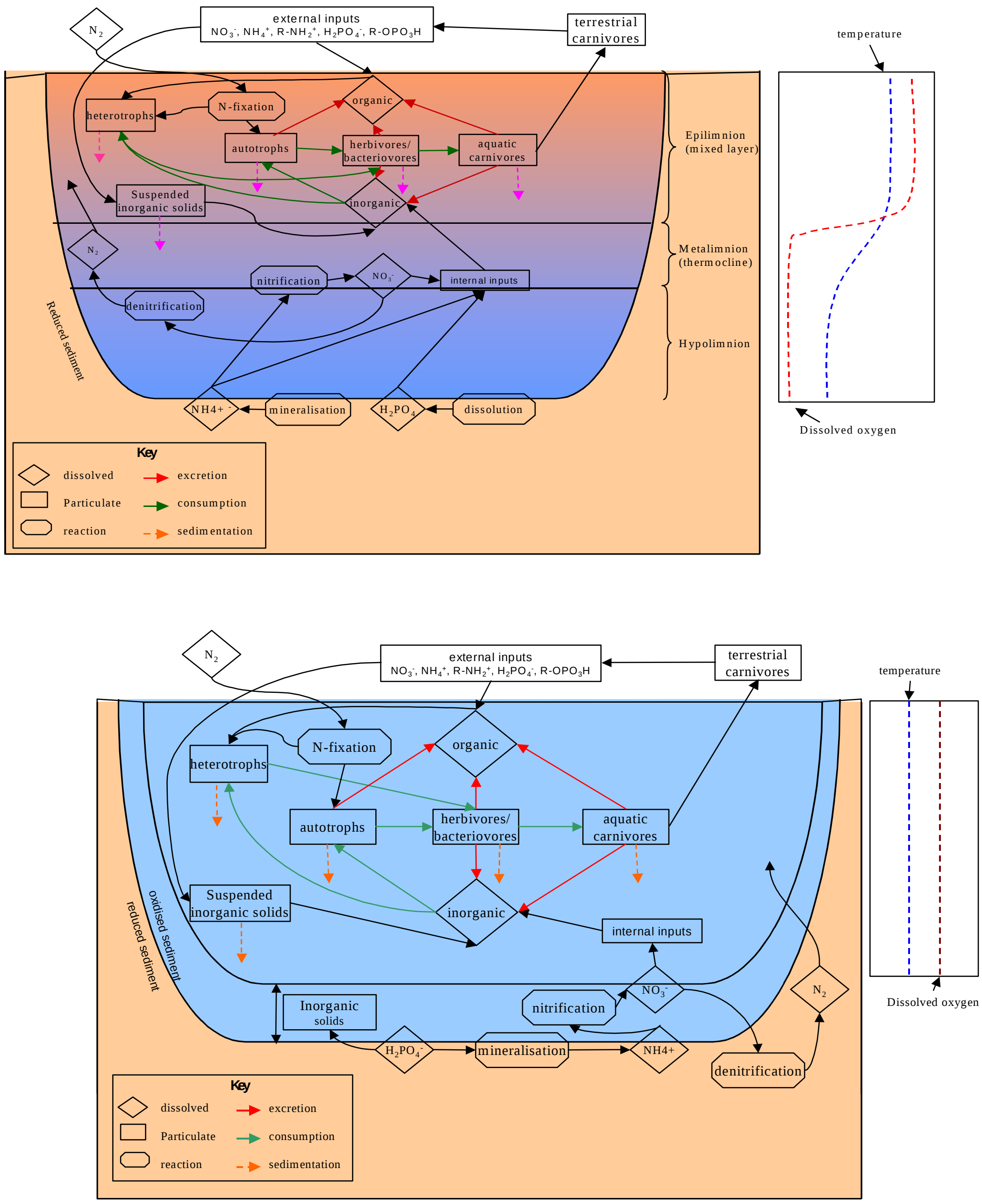

Figure 7.1 **Conceptual model/understanding illustrating the key physico-chemical and biological processes occurring in lakes under stratified and mixed conditions (from Littlejohn 2002).**

V1.2.2 Key biological quality elements

The assessment of phytoplankton diversity, abundance and biomass is of fundamental importance in lakes and reservoirs (Willén, 2000). Phytoplankton growth and distribution is influenced rapidly by physico-chemical changes and excessive blooms of phytoplankton are considered evidence of eutrophication. Chlorophyll-a concentrations can provide a good indicator of phytoplankton biomass and is often a major component of trophic state indices. Attention should, however, be paid to the methods used in analyses. However, due to the number of different methods which can produce variable results as indicated by the findings of the SALMON Project (cf. Premazzi et al., 1999), an important consideration is the standardisation of methodology

Littoral vegetation plays an important role in the regulation of metabolism in lakes and reservoirs. Although the response of macrophytes to pollution have not been previously well documented determination of their composition and abundance are important in defining flow and habitat structure for other biotic elements. Macrophyte communities and associated epiphytic microflora can function as sieves for inorganic nutrients and dissolved organic matter. Large water level fluctuations water level can restrict the development of productive and stabilising littoral flora (Kimmel *et al.* 1990). Therefore, reservoirs (which are the most abundant of lacustrine environments in non-alpine countries like Spain) do not support abundant macrophyte life due to water level fluctuations. This results in a reduction in the nutrient sieving capacity, enabling pelagic processes to assume a greater importance.

Fish have not been frequently used in classification systems due to their behavioral characteristics (e.g. mobility, seasonal upstream or downstream migration and avoidance to pollution). Furthermore, a clear relationship between community structure and ecological quality is not always obvious. For example, stocking programmes can greatly obscure the effects of environmental degradation in that high observed species diversity might be due to the introduction of new fish species. Nevertheless, the composition, abundance and structure of fish communities are useful indicators of long-term ecological impacts as they have long life cycles, are composed of several trophic levels and are relatively simple to identify. Some fish species (as well as mussels) can also be used in monitoring harmful organic substances and heavy metals because they have a high bioaccumulation capacity.

V1.2.3 Key hydromorphological quality elements

Each water body has a unique hydrology that depends on the pluviometric regime and on the morphometry of the river basin. The quantity and temporal patterns of water flow, and hence the residence time, influence the ecology of a water body through nutrient loading, growth of aquatic flora, the maintenance of marginal fish spawning habitat etc. However, natural variability also results from natural and anthropogenic climatic changes.

The quantity and dynamics of flow is greatly influenced by water abstraction and diversion. Furthermore, the addition of water to a lake or river in water supply transfer schemes may be ecologically damaging due to the introduction of water with different chemical and biological characteristics.

Lake morphology, particularly the surface area to depth ratio, is important in the development of littoral zones, to ensure there is adequate sediment substrata available for the establishment of littoral flora. Most European lakes and reservoirs are relatively shallow (mean depth <10m), resulting in a large proportion of the lake or reservoir basin potentially suitable for colonisation by littoral flora. This along with higher sediment deposition rates means that shallow lakes can theoretically support greater numbers of aquatic macrophytes. Wetzel (1990) suggests that based on the evidence of the shallow nature of most of the world’s lakes, the global conclusion is that the littoral zone dominates over the pelagic zone.

Increased water residence time leads to greater stability and increased sedimentation of nitrogen and phosphorus and influences the accumulation of sediments and organic matter (Petrere, 1996). Additionally, water residence time governs the time available for biological interactions to occur and influences such factors as sedimentation, resuspension, dilution, diffusion, turbidity and nutrient supply (Soballe and Kimmell, 1987). Small impoundments, such as weirs, generally have low water residence times and the phytoplankton growth and species composition may be influenced by the flushing rate of the system.

Reservoir construction interferes with ecosystems, by creating a physical barrier for fish migration, increasing mean water depth, altering residence times and flushing rates and ultimately impacting on community structure and function (Petrere 1996). Therefore few autochthonous river fishes are found in reservoirs and generally most of the fish fauna has been recently introduced. The introduction of exotic fish species significantly contributes to the destabilisation of fish populations in reservoirs.

V1.2.4 Key physico-chemical quality elements

Different trophic levels create different conditions for lake metabolism, therefore influencing internal nitrogen and phosphorus cycling through altering the redox state of the sediment-water interface. Low primary production in oligotrophic lakes means that oxygen demand is not sufficient to cause complete deoxygenation of the hypolimnion during the stratification period. Alternatively, the flux of organic matter to the sediments may be significant in eutrophic waters increasing the sediment oxygen demand, leading to complete hypolimnetic anoxia.

Anaerobic conditions limit the diversity of hypolimnetic organisms, and can have a detrimental affect on the quality of fisheries. Low levels of dissolved oxygen at critical times of the year hinder the movements of migratory fish, which in turn may affect breeding success. Therefore monitoring temperature and oxygen are key elements for the determination of stratification/mixing regimes, and the level of biological productivity and respiration rates. Oxygen conditions have been used to characterise lake trophy and can be related to nutrient loading (OECD,1982).

Phosphorus, and to a lesser extent nitrogen, are the nutrients limiting algal growth in lakes and hence monitoring is essential to support the assessment of ecological status. Nutrient monitoring should provide an indication of general trophic conditions and enable discrimination of pollution sources (e.g. point and diffuse). Therefore, in order to provide adequate discrimination, monitoring should include the major forms of nitrogen and phosphorus, including dissolved and particulate and organic and inorganic forms. Additionally, the measurement of silicate ($Si\text{-}SiO_3$, Πg/L^{-1}) may be a useful indicator of potential growth of diatoms.

V1.3 Transitional Waters

Aspects and features of the different quality elements to be monitored are summarised in the Tables 3.7-9.

V1.3.1 Biological Quality Elements

NOTE: see section V1.4.1 (coastal waters) of Annex V

Phytoplankton

Particularly relevant is the identification of nuisance or potentially toxic species, if they are typical for the transitional water studied. The main difficulties in using phytoplankton as a quality element for transitional waters with pronounced tides are represented by the extremely high natural spatial and temporal variability of the planktonic communities which may make phytoplankton monitoring a useless exercise in some transitional waters. The use of size fraction and size spectra may overcome the problems of taxonomic identification and intercalibration, but still require a standardisation of methods In shallow environments, the structure of phytoplankton community can be influenced by the resuspension of benthic microalgae, mostly due to wave and wind.

Seasonal monitoring is suited representing the phytoplankton community variability when seasonal patterns are predictable. However, the seasonal frequency applies only for taxonomic analyses. At least monthly samplings for phytoplankton chlorophyll-a should be considered during the vegetation period, weekly sampling would be optimal, fortnightly sampling recommended. Chlorophyll-a analyses give a coarse assessment of the phytoplankton biomass (expressed as µg L^{-}), therefore parallel sampling for cell identification and counting should be collected and stored. In case of significant month-by-month changes of chlorophyll-a the stored samples might be used for taxonomical analyses. In addition to the chlorophyll-a analysis, the direct water colour can also give important information, namely the coloured waters are symptoms of typical blooms (e.g., red waters for dinoflagellates, etc.).

Macroalgae (seaweeds)

The main difficulties in using macroalgae as a quality element are represented by the ephemeral behaviour of these quality elements undergoing some spatial and temporal variability which bias monitoring, however, to a much lesser extent than in case of phytoplankton. Therefore in some transitional waters, macroalgae and other macrophytes such as angiosperms may be better suited for monitoring the ecological quality than phytoplankton.

The sampling frequency should be suited for representing changes in seaweed communities thus be selected on a region- and type-specific level. During the vegetation period, sampling should be carried out fortnightly to monthly.

Changes in community structure and specific biomasses may be rapid and unpredictable due to the ephemeral characteristics of some of the macroalgae, therefore seasonal samplings are not well suited.

The coverage (as a % of the total system area), changes of this area, the frequency of macroalgal blooms, their size together with the community variability are a good indicator of the state the macroalgae and their environment, and can be used as an early warning systems. Qualitative analyses of new species (new forms) can be also performed by site-trained personnel as an additional warning detection.

Angiosperms (seagrasses)

Optional parameters that countries may wish to use in addition are species abundance (as number of individuals per m^2) and biomass (as g dry weight m^{-2}) as well as depth distribution (lower limit of occurrence). Changes in coverage and composition as well as the occurrence of rare or sensitive species may be used as indicators of human, but also natural impact (e.g. storms, ice winters).

The sampling frequency suited for representing changes in seagrass communities in shallow transitional waters is monthly during the vegetation period. Depending on region and assemblage, it may be sufficient to sample twice during the vegetation period (extensive mapping at a time when species identification is most easy, e.g. during the bloom period, followed by a second survey at the end of the vegetation period).

Benthic invertebrate fauna

Optional parameters that countries may use in addition are biomass (usually expressed as g ashfree dry weight m^{-2}) as well as fractionated biomass (size fractions or body size spectra). However, the reliable determination of macrozoobenthic biomass at a representative station requires a very large number of samples (e.g. 200 replicates per station). Apart from natural small-scale variability, the methodological bias is fairly high due to several steps involved (fresh/wet weight, dry weight, ash-free dry weight). A solution could be to use conversion factors derived from reliable time-series taken in the region/type concerned.

A standardisation of methods is still required and there is a lack of quality assurance protocols. On a temporal scale, the sampling frequency suited for representing changes in benthic invertebrate communities in shallow transitional waters should be selected on a regional/type-specific basis. Sampling should take place at least twice per year (spring and autumn) A recommendable approach for transitional waters in temperate areas (e.g. river Elbe) is fortnightly sampling during spring/early summer (April–June) followed by 2-3 samplings in August/September. In other areas (e.g. Mediterranean), seasonal sampling might be preferable. Recent attempts to apply statistical analyses to the higher taxonomic levels or on species pooled into ecological or trophic guilds have been successful.

Fish fauna

For classifying the ecological status, the limnological classification scheme based on indicator fish species could be used. Sound abundance estimates require long time series due to high variability. In general, the species composition (do typical and specially sensitive species including migrating species and spawning schools[48] occur as to be expected) of transitional waters seems to be most appropriate for WFD purposes; abundance or biomass are not good in these waters because of high variability.

It should be noted that sampling for fish faunal composition and abundance should preferably be carried out at least 2 times per year (spring/autumn) and that for reliable estimates of fish abundance, long time series of at least 10 years are inevitable because of natural variability.

V1.3.2 Hydromorphological Quality Elements

Expertise's suggestion is to consider the hydrological budget a quality element more general than the freshwater flow, which is actually a component of the hydrological budget. Hydrological budget responds to variation of the freshwater flow but also to variation in the sand accumulation vs. sand erosion processes.

Morphological conditions

Refer to same paragraph of Section 1.4.2 (coastal waters).

Depth variations

Refer to same paragraph of Section 1.4.2 (coastal waters).

Structure and substrate of the transitional water bed

Refer to same paragraph of Section 1.4.2 (coastal waters).

Structure of the transitional zone

The structure of the transitional zone can be monitored in terms of structure of the vegetation occurring at the land-water interfaces, as affected by features of the substrate (mud, sand, rock, etc.), of the climatic and hydrologic regimes and of the anthropogenic pressures.

Vegetation coverage, vegetation type and floristic composition are the parameters that can be monitored.

A major problem is that the structure of vegetation is only an indirect indicator of the activity of the transitional zone as a buffering zone for the pressures of the anthropogenic activities in the watershed.

The structure of vegetation can be monitored every three years.

Hydrological budget

The hydrological budget characterizes the different transitional waters, i.e. estuaries, deltas, lagoons, coastal lakes, ports or gulfs, determines the sediment distribution and affects the sensitivity and resilience of transitional water ecosystems. Consequently, the hydrological budget has a major influence on all the quality elements in transitional waters.

Hydrological relevant parameters for an estuary are the volumes entering the estuary during high and low tide (tidal volume). The waterflow (volume and velocity) varies very locally. Subsequently erosion and sedimentation processes are sensitive to anthropogenic measures (LT-process) and extreme events like storm (ST-process). Special attention has to be given to the fish breeding areas between 0 to 5 m water depth and currents below 0.5 m. Monitoring these area's should be included in the program.

Changes in the components of the hydrological budget, due to human activities, are expected to be relatively slow. Therefore, monitoring is recommended every three years.

[48] e.g. of the stickleback (*Gasterosteus aculeatus*)

Monitoring should be performed with data collection on all the freshwater inputs and outputs arranged on a seasonal scale.

V1.3.3 Chemical and Physico-chemical Quality Elements

For all the chemical and physico-chemical quality elements refer to the same paragraphs of section 1.4.3 (coastal waters).

A specific consideration for transitional waters is:

Salinity

It is fundamental to measure the salinity gradient horizontally as well as vertically, especially for the physical delimitation of the transitional zone.

V1.4 Coastal Waters

V1.4.1 Biological Quality Elements

A very important issue when using biological elements as QE is the need of expertise required for taxonomic identification at the species level and the *in-situ* taxonomic resolution limitation.

Appropriately scientifically qualified personnel should carry out the surveys. They should be able to document competence within their specialist field, and participate in ring-testing, when the appropriate routines are available. For investigations spanning several years, priority should be given to continuity in personnel carrying out the recordings.

Phytoplankton

Particularly relevant is the identification of nuisance or potentially toxic species as important assessment parameters. Bloom frequency and intensity is considered an indicative parameter for classification of ecological status.

High natural spatial and temporal variability of the planktonic communities requires frequent sampling to ensure meaningful data for classification or detection of events (blooms). Sampling frequency is determined by the variability, and it is recommended a minimum of monthly sampling with optional increased sampling frequency in seasons with main bloom events. Sampling should be performed together with measurements of chemical and physico-chemical parameters. Seasonal sampling is a minimum frequency.

The minimum sampling frequency required by the Directive is every 6 months; however, available expert knowledge and pilot studies on sampling frequencies could be helpful to set up the most appropriate sampling frequency, number and location of stations on a regional or type-specific level. A selection of region/area-specific phytoplankton indicator species could be useful.

New monitoring programmes for the WFD could build on the existing phytoplankton monitoring programmes for other purposes, as, for example the Shellfish Hygiene Directive (Council Directive 91/492/EEC of 15 July 1991), to ensure best ‘value for money’ in monitoring.

Macroalgae / Angiosperms (Phytobenthos)

It is important to monitor not only their composition and abundance (as requested in the Directive) but also their distributions, extension and variation in time and space (mapping at different needed scales), as it provides important information not only on the health status of the plants’ habitats, but also on the ecosystem stability, as variations may indicate long-term changes in the physical conditions at the site.

Macroalgae are an important region-specific parameter. Macroalgal communities often include a wide range of species/functional groups that may change upon eutrophication e.g. highly diverse algal species can be replaced by opportunistic and stress-resistant seaweeds.

For angiosperms, distribution is the most important parameter because changes are not occurring from month to month. It may therefore be sufficient to monitor angiosperms every 6 months (spring/autumn), once a year or even only once every 3 years, depending on the species.

Supplementary variables essential for interpretation of macrophytobenthos results include: substrate type, depth in relation to sea level or standard datum, slope and bearing, presence of loose sediment, degree of wave exposure, tidal range, Secchi disk depth, and salinity.

Benthic invertebrate fauna

The required parameters to be measured are composition and abundance. Important variables to be considered are also diversity of species and presence of sensitive or higher taxa as well as biomass, the latter being indicative of eutrophication phenomena.

Recent studies in taxonomic classification have shown that looping species into higher taxa (including morphological categories) does not necessarily limit the sensitivity of animal assemblages to detect impacts.

It should be noted that sometimes it is difficult to show a clear correlation between possible changes found in the benthos (e.g. long-term changes in zoobenthos species composition) and eutrophication. Biomass may be a better parameter though not mandatory for WFD monitoring. Therefore it is recommended to include biomass as optional monitoring parameter. Furthermore it should be noted that other factors, e. g. fisheries, may have an overriding effect compared with eutrophication effects. A distinction should be made between acute, direct effects on the benthos (e. g. directly related to dredging or oxygen deficiency and/or toxic blooms) and long-term changes. Both may need different sampling frequencies and spatial coverage.

V1.4.2 Hydromorphological Quality Elements

Morphological conditions

The morphological characteristics of coastal areas are generally subjected to low variability due to natural large-scale bottom dynamics processes or changes in tidal regime and weather patterns.

Relevant for ecological status is the time scale of the changes resulting from human impact in the past. A time scale of 10 to 25 years means that relevant changes in hydro morphological conditions have an impact on ecology. In addition sea level rise makes it necessary to adapt the monitoring frequency and spatial scale to analyse the processes and to find the sand budgets in coastal zone, sheltered seas and estuaries.

Monitoring the trends in depth gradients has to take into account water management measures like dredging and dumping activities and naturally induced variability, under particular weather conditions such as storm events and ice winters/ice coverage, as well as natural coastal erosion and elevation of the land e.g. Baltic.

Depth variations

The topography of the area (shape, bathymetry, slope) influences the biological communities living in it. Depth variations could be important elements to be monitored in areas where disturbances are expected, anthropogenic changes will have relevance for the status classification of the water body.

Structure and substrate of the coastal bed

Changes in morphological conditions and/or nature of the substratum may exert severe detrimental effects on benthic organisms. Differences between communities in coastal zones and estuaries are linked to a coastal typology (see link with CIS WG 2.4):

Possible causes of anthropogenic alterations in structure, substrate and shape of the coastal bed are:

¾ coastal constructions (dredging, dumping, dams, artificial reefs, etc.); and

¾ variations in riverine sediment inputs (solid transport regime) due to human impact.

For depth variation and structure and substrate of the coastal bed it may be sufficient to collect the required information once (e.g. a map of the coastal bed) and to record:

¾ at each sampling carried out after first thorough survey: typical parameters (e.g. nature of substratum) and obvious changes (e.g. visible changes after big storm events); and

¾ changes due to anthropogenic impact (e.g. dam construction).

A thorough survey should be repeated in regular, but longer intervals (e.g. once per management period or longer, depending on parameter).

Structure of the intertidal zone

As for the structure of the intertidal zone, it cannot be used as a quality element in the Mediterranean and the Baltic ecoregions, given the low amplitude of tides in the Mediterranean basin and in the Baltic Sea.

Thus it has been proposed to introduce the intertidal***/mediolittoral*** term as its ecological relevance is due to the fact that it comprises living assemblages that require or tolerate immersion but cannot survive permanent or semi-permanent immersion (same definition for the intertidal). Thus mediolittoral zone supports diverse and very productive assemblages of algae and invertebrates that can be considered analogues to those of intertidal habitats.

Possible causes of anthropogenic alterations in structure, substrate and shape of the intertidal are:

¾ coastal constructions (dredging, dumping, dams, artificial reefs, etc.);

¾ chemical inputs (nutrients) leading to a change in the composition of macroalgal communities; and

¾ variations in coastal or riverine sediment movements (sediment transport regime) due to human impact.

Mediterranean experts' judgements suggest to focus particular attention on the structure and condition of the mediolittoral and upper infralittoral zones in tideless seas, at least in the Mediterranean, since several species and communities thriving in this area are very good biological indicators, as exposed to a wide range of anthropogenic impact due to their critical position at the interface between the sea and the land.

Tidal regime

Tidal regime in terms of direction of dominant currents and level of wave exposure can be seasonally predictable and are available from most of the National Hydrographic Services. Deviations from the natural pattern in tidal regime derive from direct anthropogenic intervention on the profile of the coastline and may have severe bearings on the stability of the biological assemblages, thus they need to be taken into consideration. Asymmetry in the tidal waves results in positive or negative yearly budgets of sediments.

Due to the low tidal range in the Mediterranean and Baltic Seas, tidal currents play a very minor role, if any. It is the case also in part of North Sea e.g. Skagerrak.

Direction of dominant currents

The direction and intensity (speed) of currents represent the main hydromorphological quality elements influencing the biological elements. They could be important elements to be monitored in areas where anthropogenic disturbance could be relevant for the status classification of the water body.

These parameters assume quite a relevant importance in those ecoregions and specific areas where the tidal range being very low poorly influences the coastal processes.

Mainly changes in hydrodynamics induced by morphological changes will result in relevant ecological effects. Temporal changes (storms, anthropogenic activities) could be balanced in the time scale of 5-6 years. On local scales this could not be the case. Monitoring should take into account these short term-effects.

Wave exposure

Wave exposure (wave height, wind, Fetch-index) varies considerably according to coastal typology (from highly exposed to very sheltered) and meteorological conditions, in the different ecoregions. Parameters to be monitored in case of anthropogenic disturbances are e.g. frequencies of storms, directions, high/low tide surge levels.

V1.4.3 Chemical and physico-chemical Quality Elements

In most of the EC countries, all these parameters (with the exception of specific pollutants) are routinely measured as part of their national monitoring programmes, with a variable frequency (weekly to monthly), using national guidelines or OSPAR/HELCOM standards.

Transparency

Transparency is mainly affected by mineral turbidity, organic pollution (e.g. urban discharges) and eutrophication; it can naturally vary due to local hydrodynamics, river discharge and seasonal plankton blooms.

The transparency parameter is necessary for the determination of the depth of the euphotic layer, where primary production exceeds respiration. Measurement is difficult in “troubled waters”, e.g. the NE Atlantic Wadden Sea with high loads of resuspended sediments.

Thermal conditions

Temperature profiles along the water column can be easily obtained by means of *in situ* autographic instruments. The thermal structure of the water column is a relevant information for assessing mixing/stratification conditions, which strongly influence primary production as well as possibly the development of oxygen deficiency.

Oxygenation conditions

Dissolved oxygen concentration is subjected to high natural variability since its solubility depends on temperature and salinity. Deviation, in absolute value, of % saturation from 100% is indicative of intense primary production and/or organic pollution.

Salinity

Salinity in coastal waters can be subjected to high natural variability due to freshwater inputs and mixing of water masses, and due to tidal currents.

Salinity measures in coastal waters can be used to detect freshwater ingressions from the continent; the dilution rate of nearshore waters varies considerably in different areas and can be used, together with other quality elements to indicate potential pollution.

Nutrient conditions

The concentration of nutrients, together with the concentration of chlorophyll ‘a’, indicator of actual production, provide information on the general trophic conditions.

Natural variability of nutrient concentrations can be relevant on a seasonal basis; in coastal waters, high nutrients concentration, mainly related to riverine inputs, are indicative of eutrophication and/or organic pollution.

In order to enable discrimination of pollution sources, the following parameters should be analysed:

¾ Total Phosphorous (TP, Πg L^{-1})

¾ Soluble Reactive Orthophosphate (P-PO4, Πg L^{-1})

¾ Total Nitrogen (TN, Πg L^{-1})

¾ Nitrate+Nitrite (N-NO3 + N-NO2, Πg L^{-1})

¾ Ammonia (N-NH4, Πg L^{-1})

¾ An additional parameter is silicate (Si-SiO3, Πg L^{-1}), which is a growth requirement for Diatoms.

¾ For a better understanding of nutrient cycling in coastal waters, the following supplementary parameters are recommended:

  ¾ Particulate Organic Carbon (POC-C, Πg L^{-1})

  ¾ Particulate Organic Nitrogen (PON-N, Πg L^{-1})

  ¾ Particulate Organic Phosphorous (POP-P, Πg L^{-1})

Nutrient ratios (N/P/Si) are useful for the interpretation of results and eutrophication status.

Existing guidelines and international standards

Quality Element	Object	Guideline / International standard
BIOLOGICAL Q.E.		
Phytoplankton	Sampling procedure; Abundance	OSPAR and HELCOM Conventions: HELCOM COMBINE Manual, Part C., Annex C-6, OSPAR JAMP Eutrophication Monitoring Guidelines: Phytoplankton).
	Abundance ; Composition	Standard in preparation: CEN/TC 230 NO423 "Water quality - Guidance standard for the routine analysis of phytoplankton abundance and composition using inverted microscopy (Utermöhl technique)" - The first working document shall be available in December 2003.
	Chlorophyll a	HELCOM COMBINE Manual (Part C, Annex C-4), OSPAR JAMP Eutrophication Guidelines: Chlorophyll-a. ISO guideline (ISO 10260), only for the spectrophotometric determination of chlorophyll- a.
Macroalgae / Angiosperms	Phytobenthos	HELCOM COMBINE Manual (Part C, Annex C-9) OSPAR JAMP Eutrophication Guidelines: Benthos. ISO standards are being developed (see Annex IV) See also Marine Monitoring Handbook, JNCC (downloadable from http://www.jnvv.gov.uk/marine)
Benthic Invertebrate Fauna		HELCOM COMBINE Manual (Part C, Annexes C-8 and C-9): Guidelines for Macrozoobenthos Monitoring OSPAR JAMP Eutrophication Monitoring Guidelines: Benthos. In preparation: ISO TC 147/SC5 N350: ISO/CD 16665 - 'Water quality - Guidelines for quantitative investigations of marine soft-bottom benthic fauna in the marine environment'. See also Marine Monitoring Handbook, JNCC (downloadable from http://www.jnvv.gov.uk/marine)
MORPHOLOGICAL Q.E.		
		No reference
CHEMICAL AND PHYSICO-CHEMICAL Q.E.		
	Most parameters, incl. nutrients, oxygen	OSPAR JAMP Eutrophication Monitoring Guidelines: Nutrients, Oxygen, HELCOM COMBINE Manual Part B, Annex B-11 and B-14 and Part C, Annex C-2.

For **OSPAR** see: http://www.ospar.org web site, under the sub-heading Measures and sub-heading Agreements

For **HELCOM** see: http://www.helcom.fi/Monas/CombineManual2/CombineHome.ht

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