Environmental RTDI Programme 2000–2006

Review of monitoring and research to meet the needs of the EU Water Framework Directive (2000-DS-5-M1)

Final Report

Prepared for the Environmental Protection Agency

by

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Executive Summary

1. In response to the decline in water quality and wetland ecosystems throughout Europe, the European Parliament and Council passed into law EC Directive 2000/60/EC establishing a framework for Community action in the field of water policy, commonly known as the Water Framework Directive (WFD). The WFD will supersede and amalgamate a number of existing, and more narrowly focused, directives enacted in response to pressures on aquatic environments that have been recognised widely since the 1970s. The WFD is about preserving and, where necessary, improving the quality of rivers, lakes, estuaries, coastal waters and ground waters. It will do this by the implementation within designated *River Basin Districts* (RBDs), of *River Basin Management Plans* (RBMPs) designed to establish an integrated approach to catchment management. The WFD will set scientifically robust quality standards, relevant to individual European Member States.

2. The Directive has 26 articles and 11 annexes which outline the requirements. The purpose of the Directive (as specified in Article 1) is to establish a framework for the protection of inland surface waters, transitional waters, coastal waters and ground water which:

   (a) prevents further deterioration and protects and enhances the status of aquatic ecosystems and, with regard to their water needs, terrestrial ecosystems and wetlands directly depending on the aquatic ecosystems;

   (b) promotes sustainable water use based on a long-term protection of available water resources;

   (c) aims at enhanced protection and improvement of the aquatic environment, *inter alia*, 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;

   (d) ensures the progressive reduction of pollution of ground water and prevents its further pollution, and

   (e) contributes to mitigating the effects of floods and droughts.

3. The implementation of the WFD has, potentially, far-reaching effects for the management of catchments and their water bodies. The articles of the WFD provide a comprehensive framework of measures required for the safeguard and enhancement of European water resources. The WFD requires that *Competent Authorities* are identified in order to apply the rules of the WFD and that (under Article 3) sufficient co-ordination measures are put in place to enable effective implementation of the Directive. Article 4 requires the setting of *Environmental Objectives* to prevent deterioration (including current and potential drinking water abstraction sites covered in Article 7) or, where required, to enhance and restore water bodies. For each RBD, it is required (Article 5) to have a comprehensive review of its physical and typological characteristics, anthropogenic pressures and impacts, and economics of water use. Article 8 provides for the establishment of detailed monitoring programmes.

4. Protection of water bodies will be achieved both through a register of *Protected Areas* (Article 6) that takes into account other Community legislation plus an extensive *Programme of Measures*, as outlined in Article 9. The implementation of measures to safeguard water resources is to be described in the RBMPs provided for in Article 13. These Plans are to include provision for public consultation (Article 14) and for the development of a combined approach to point and diffuse sources of pollution (Article 10). The later articles (15–26) are mainly concerned with reporting structures, dates for repeals of existing directives deemed to be superseded by the WFD and future Community Measures, such as (under Article 17) specific strategies to control and prevent pollution of ground water.

5. The Directive requires a series of tasks for implementation. These include the establishment of administra-

tive structures and scientific protocols. The timetable for implementation of the Directive is demanding (Table 1).

6. The implementation of the WFD requires an extensive consolidation of existing approaches to water and catchment management and the development of many new ones. Many of the requirements specified in the annexes of the WFD require research and development. The results of a 6-month desk study to review the preparation of Ireland for the implementation of the WFD, with particular reference to the requirements for research and monitoring are reported here. The project encompassed legal, technical and administrative considerations.

7. As the WFD is, in many respects, a consolidation and updating of pre-existing measures, the task of transposing the Directive into Irish law should not be an unduly onerous one. The WFD does, nevertheless, contain new and far-reaching concepts and controls, and some care will need to be taken to transpose these correctly into Irish law. These include concepts such as a truly combined approach to pollution (Article 10) and stringent environmental objectives (Article 4).

8. Transposition of the WFD into Irish law is likely to require more than an amendment to the existing Local Government (Water Pollution) Acts. Such issues as the identification of five RBDs, two probable International River Basin Districts (Foyle and Erne), and the nomination of county councils as *Competent Authorities* are matters of principle or policy, which appear to require the enactment of primary legislation. The case for primary legislation is strengthened by the necessity to provide for cost-recovery of water services, and the obligation to enact "effective, persuasive and proportionate penalties". If the basic policies and principles are implemented by way of primary legislation, there is no reason why the preponderance of the Directive cannot be implemented by way of secondary legislation made under either the new Act or under existing legislation.

9. In order to comply with its obligations of a *combined approach for point and diffuse sources* [of pollution] under Article 10 of the WFD, Ireland will have to amend existing legislation to reflect the duality of the

Table 1: A summary timetable of the milestones for implementation of the Water Framework Directive.

Year	Milestone
2000	Directive enters into force
2003	Transposition into national law Identification, location and boundaries of RBDs Identification of Competent Authorities Establish a framework of co-ordination for the achievement of the environmental objectives for each RBD
2004	Characterisation of river basins and their water bodies Review of pressures and impacts on water bodies Economic analysis of water use Definition of reference conditions for *good* ecological status of water bodies. Review the list of *priority* substances Register of Protected Areas. Register of sites for use in an intercalibration network to test definition of *high*, *good* and *moderate* status
2006	Monitoring programmes operational Production of timetable and work programme of the RBMPs, including consultation measures.
2008	Draft RBMPs to be made public
2009	Production of RBMPs and Programmes of Measures.
2010	Water pricing to provide efficient water use with regard to recovery of water costs.
2012	Implementation of the Programmes of Measures
2015	*Good* water status to be achieved for all surface waters, artificial and heavily modified waters, and ground waters

current approach to environmental quality standards (EQSs) and emission limit values (ELVs). Furthermore, Ireland will have to establish EQSs for bodies of water, a power which it has had for years but which, at least in respect of the dangerous substance regulations, it has been slow to exercise.

10. If the responsibility for drawing up *programmes of measures* is to be decentralised to local authorities comprising the RBDs, it will be necessary for the primary legislation providing for matters of policy and principle to delegate this programme-making power to local authorities. All other matters of detail can be provided for in delegated legislation, including the 2009 and 2015 deadlines in respect of establishing and reviewing *programmes of measures*.

11. Local authorities already possess the power, under Part VI of the Local Government (Water Pollution) Regulations 1978, to make water quality management plans. While the content of RBMPs made pursuant to Article 13 of the WFD will be much more intricate than indigenous water quality management plans, and indeed will cover certain water supply issues, the existence of local authority water planning powers should ease the transposition burden.

12. The monitoring programmes (defined as *surveillance*, *operational* and *investigative*) required under Article 8 of the WFD need to establish a coherent and comprehensive overview of water status within each RBD. Monitoring is required for each of a number of *quality elements* defined in Annex V. For surface waters, a measurement of quality is required for parameters that are indicative of a number of physico–chemical, hydromorphological and biological elements. The Directive places particular emphasis on the assessment of biological elements. The values measured for each surface water element are to be assessed relative to *type-specific reference* conditions. Monitoring is required to assess groundwater quantitative and chemical status in order to assess detrimental anthropogenic effects on the chemical or quantitative status. Environmental targets are to achieve *good status* for all surface and ground waters by 2015.

13. In order to achieve the goal of the WFD, there is a need to develop protocols for a number of technical tasks. These are mainly the *classification* of waters depending on characteristic typologies; the establishment of criteria and *reference conditions* for the determination of quality status for all elements; the assessment of anthropogenic *risk* to waters; an economic and impact analysis of water use; and an effective monitoring programme.

14. Characterisation of water bodies and determination of *typology* and setting of *type-specific reference conditions* are fundamental to the operation of the WFD. These must be developed for each water body *type* and will dictate the design of monitoring. For the *categorisation* of surface waters, it is recommended that the greatest weight be given to factors that are important for regulating biological communities. An essential early initiative needs to be the *characterisation of ground waters*.

15. The establishment of *reference conditions* poses a significant challenge. Further research is urgently required to assess the feasibility of determining *reference conditions* for all water bodies. The use of reference states, regardless of how they are derived, should be statistically reliable.

16. In order to assist with the determination of *reference conditions*, there is an urgent need for the collation of historical data of potential use for the identification of reference states and further basic survey requirements. Large and useful archives exist in the country. These include information on hydromorphology, fisheries and geology.

17. A concerted effort to implement *surveillance* monitoring in order to fill gaps in knowledge is required. This is very much linked with the requirement to research *reference conditions*.

18. Risk assessment is an important component of the WFD. There is a need for a well-defined and generally accepted definition of risk. It is proposed that the terminology of Smith (1993) is appropriate: “To manage a risk or hazard it must be identified, usually by some form of measurement and quantification, and then assessed to estimate the probability of that risk posing an actual threat to society, before a strategy to minimise it can be formulated”.

19. The assessment of anthropogenic impact to waters requires knowledge of the effect of catchment activities

on the *quality elements*. There is extensive information on physical attributes of catchments and dynamics of major pollutants such as phosphorus. Further information needs to be collected, but availability and technical requirements for collection are varied. Land-use data should be incorporated into GIS systems for reporting and analysis of trends in the quality of aquatic environments. There is a potentially useful role for mathematical catchment models, but the application requires further research.

20. An important risk to aquatic ecosystems, but one that has, overall in Ireland, attracted little research is the introduction of species. There is a requirement to address the consequences of species introductions for the interpretation of the WFD and, in particular, the relevance this has for measures of undisturbed conditions.

21. Protocols for economic analysis relevant to the WFD are poorly developed. As the analyses and reviews must be completed by the end of 2004, the task is formidable.

22. The WFD requires an extensive monitoring system. Current monitoring programmes to fulfil the requirements of existing directives (e.g. 76/464/EEC, 91/271/EEC) are often deficient or non-existent. All monitoring required under existing legislation must be brought up to the specified standard without delay with a reappraisal of existing regulations where these appear to be inadequate to meet the monitoring demands of the WFD. It is essential that monitoring programmes are carefully planned, adequately financed and tightly co-ordinated. This will necessitate meaningful liaison among agencies and others involved in monitoring.

23. Monitoring should have clear objectives related to the need to determine quality ratios based on definitions of *reference conditions*.

24. For monitoring, there is a need for agreement within and among RBDs on which elements and parameters are required to be monitored, and the development of protocols for the monitoring of most, if not all, biotic elements. Monitoring in all the RBDs requires consensus on the use of techniques, taking into account accepted international practice and published standards. These should be robust and subject to measures of Quality Assurance. This will require further research and development.

25. The understanding of underlying spatial and temporal distribution is critical for efficient monitoring. All monitoring should take into account natural variability and wherever possible incorporate estimates of precision in reporting of the results.

26. In so far as it is possible *surveillance* and *operational* monitoring programmes should be designed and managed in parallel, with a view to minimising the number of sampling sites and surveys necessary to meet the data requirements of the WFD.

27. Consideration should be given to the development of programmes for training in order to provide an adequate national capacity for quality assured and quantitative measurements of the required elements.

28. There is a need to develop refined information systems with the capacity for efficient data transfer among RBDs and national authorities. This should include the development of GIS interfaces of catchment models in order to incorporate dynamic models. Models used in *River Basin Management Systems* need to have a clearly defined purpose and well-documented methodology.

29. In conclusion, while Ireland has an existing system of monitoring that provides the foundation for an overall monitoring programme, there is need for further research and development to identify and quantify parameters indicative of the quality elements described in Annex V and to establish robust *typologies* and *reference conditions* required under Annex II. There is a need to further identify and quantify pressures on the aquatic environment through verifiable risk analysis and to promote research on the methods of economic analysis, and their relevance to the WFD. There is an essential requirement for the development and use of effective co-ordination and data management systems.

1. Background to the Project and Terms of Reference

1.1 Introduction

In 1977, C. Ó hEocha, Chairman of the National Science Council opened a Conference on eutrophication with "Time is not on our side in a country in which the quality of the water of many of our lakes has disimproved dramatically in a short number of years" (Downey and Ní Uid, 1977). Six years later his words were echoed by the Water Pollution Advisory Council of Ireland: "Water pollution in Ireland constituted an environmental problem of significant and increasing dimensions" (*An Foras Forbartha*, 1983). The echo has resounded ever since, with National Reports of Water Quality, up to and including that covering 1995–1997 (Lucey *et al.*, 1999), showing sequential increments of degradation.

The political and individual response to this incremental decline of water quality has not been effective enough to mitigate pressures on the aquatic environment. The *Millennium Report* (Stapleton *et al.*, 2000) of the Environmental Protection Agency (EPA) highlighted the continuing degradation of many inland waters and significant problems in some estuarine waters**.** The argument has been made that, compared with other European countries, the quality of the aquatic environment in Ireland is high. This argument is a weak one. There has been a 40% decline of high-quality (Class A) river channel between 1971 and 1997 (Lucey *et al.*, 1999) and comparisons with some other Member States which have more acute environmental problems than Ireland is not valid.

1.2 Directive 2000/60/EC establishing a framework for Community action in the field of water policy

In response to the decline in water quality and wetland ecosystems throughout Europe, the European Parliament and Council passed into law EC Directive 2000/60/EC establishing a framework for Community action in the field of water policy, commonly known as the Water Framework Directive (WFD). The WFD will supersede and amalgamate a number of existing, and more narrowly focused, directives enacted in response to the environmental pressures on aquatic environments that have been recognised widely since the 1970s. The WFD is about preserving and, where necessary, improving the quality of rivers, lakes, estuaries, coastal waters and ground waters. It will do this by the implementation of River Basin Management Plans (RBMPs), designed to establish an integrated approach to catchment management. The WFD will set scientifically robust quality standards, relevant to individual European Member States.

An effective strategy to implement the WFD will necessitate participation of a number of State and non-governmental bodies. Directive implementation, as envisaged by the EU, will be inclusive of scientific, economic and social structures. The requirements of the WFD are complicated, and will impact on administrative and enforcement structures as well on the rationale and practice of environmental management.

The WFD places water within the context of the catchment through the implementation of RBMPs. These plans will be developed for each designated River Basin District (RBD). The WFD will be the effective document under which national legislation will address quality issues within rivers, lakes, transitional waters (mainly estuaries), coastal waters and ground waters. It also addresses those pressures within the catchment that lead to the deterioration of, or provide risk to, water and its ecology. As such, the WFD is extensive in its coverage and has major implications for the sustainable management of both terrestrial and aquatic habitats. Hitherto, quality standards of waters have been generally defined by the definition of *fixed boundaries* between successive increments of quality. The WFD departs from this traditional thinking in that it requires quality status to be defined *relative to reference conditions*, with a key defining issue that quality will largely be based around the concept of *ecological quality*. The terminology of the WFD is such that the measurement of *biological elements* appears to merit greater emphasis than *physico–chemical* or *hydromorphological elements* that support the biological ones. In practice, however, all three categories of elements are required to be measured and managed in order to provide an overall assessment of ecological quality.

The use of reference conditions to evaluate quality elements is of fundamental importance to both surface and groundwater assessment protocols. It necessitates the identification of baseline or reference conditions for rivers, lakes, transitional waters and coastal waters in terms of hydromorphology, chemistry and biology. The WFD refers to an *ecological potential* for heavily modified or artificial waters. The approach to definition of good status for ground waters is broadly similar – reliant on a number of chemical parameters but also on the diminution of chemical or ecological quality of associated terrestrial systems. The requirements of the WFD include the setting of quality standards, supported by ecotoxicological testing, for listed priority substances for both ground and surface waters.

The response of Member States to the demands of the WFD is in its infancy; however, the ambitious timetable set by the EU has already prompted concerted discussions on many of the technical and political issues that need to be addressed for effective implementation. The WFD set out a series of seemingly stringent objectives that require transposition into national law. Despite an extensive list of definitions, the WFD does not provide firm guidance on the workable meaning of many of its aspirational policies. Although the WFD appears rather precise, it is by no means rigid, and incorporates flexibility where serious technical and socio–economic considerations dictate. There has been considerable debate throughout Europe concerning the Directive's implementation (e.g. Bloch, 1999; Demmke, 1999; Irvine, 1999; Kahlenborn, 1999; WWF, 2000; Chave, 2001; Sutcliffe, 2001). This debate relates to all types of waters and will lead to important questions about catchment use and its consequence on aquatic environments. There will be a need under the WFD to establish criteria for environmental risk for each category of aquatic habitat and identify the causative pressures on them.

In order to help WFD implementation in Ireland, this 6-month desk study was funded by the *Environmental Protection Agency* (EPA) under the Environmental RTDI programme 2000–2006. This study was designed to review the monitoring and research requirements, and the state of preparation of Ireland, for WFD implementation within the timescale and milestones prescribed. The principal timetables of achievements imposed by the WFD are given in Table 1.1.

1.3 Management, scope and objectives of the study

The desk study was co-ordinated by *Trinity College Dublin* (TCD). The work employed one full-time research assistant based in TCD supported by a freshwater ecologist

Table 1.1. A summary timetable of the milestones for implementation of the Water Framework Directive.

Year	Milestone
2000	Directive enters into force
2003	Transposition into national law
	Identification, location and boundaries of River Basin Districts
	Identification of Competent Authorities
2004	Characterisation of River Basins
	Identification of pressures and impacts
	Economic analysis of water use
	Identification of location and boundaries of water bodies
	Definition of reference conditions for *good* ecological status of water bodies
	Register of Protected Areas
	Register of sites for use in an intercalibration network to test the definition of *high*, *good* and *moderate* status
2006	Monitoring programmes operational
	Production of timetable and work programme of the River Basin Management Plans, including consultation measures
2008	Draft River Basin Management Plans to be made public
2009	Production of River Basin Management Plans and Programme of Measures
2012	Implementation of the Programme of Measures
2015	*Good* water status to be achieved for all surface waters, artificial and heavily modified waters, and ground waters

and a groundwater specialist from the Departments of Zoology and Civil Structural and Environmental Engineering, respectively. Input from a coastal and estuarine ecologist was provided by *Enterprise Ireland* with assessment of relevant legal aspects by an environmental lawyer.

The objectives of the study were the:

1. identification of Irish agencies and organisations and their likely role in the implementation of the proposed WFD. This will include government agencies, non-Governmental Organisations (NGOs), user groups and advisory steering groups;
2. identification of counterpart groups in Northern Ireland, and the discussion with them of integrated approaches to the implementation of the proposed WFD;
3. collation of studies of direct relevance to the implementation of the WFD;
4. identification of authorised groups established in preparation of the WFD in European Member States, to include main contacts and areas of expertise;
5. evaluation of existing monitoring protocols within Ireland and the identification of the need for further work in order to develop an effective monitoring system;
6. evaluation of current mechanisms for establishing reference states across Europe, and elsewhere, in order to assist with this decision in Ireland;
7. identification and detailing of the timescale for implementation of the WFD;
8. assessment of the resource implications of implementation of the WFD;
9. evaluation of national primary and secondary legislation in relation to WFD water quality assessment; and
10. identification of national legislative lacunae, particularly in relation to the Local Government (Water Pollution) Acts 1977–1990 and the relevant statutory instruments made under the European Communities Acts.

1.4 The DELG Water Framework Co-ordination Group

The challenges posed for a co-ordinated approach to implementation of the WFD was recognised by the Department of the Environment and Local Government (DELG) at an early stage. A seminar on the aims and objectives of the WFD was organised by the DELG and held on 16 November 2000. This was followed by energetic developments within the DELG to identify the roles of organisations in WFD implementation (Appendix A) and the setting up of a National Co-ordination Group (Appendix B).

The participants in the group include officials of relevant Government Departments, their related technical agencies and local authorities. These include the:

- Department of the Environment and Local Government;
- Department of the Marine and Natural Resources;
- Department of Agriculture, Food and Rural Development;
- Department of Arts, Heritage, Gaeltacht and the Islands (and its heritage service, Dúchas);
- Department of Enterprise, Trade and Employment;
- Department of Public Enterprise (represented by the Geological Survey of Ireland);
- Office of Public Works;
- Environmental Protection Agency;
- Central Fisheries Board;
- Local Government Computer Services Board;
- City and County Managers Association; and
- Environment and Heritage Services, Northern Ireland (observer)

The first meeting of the Co-ordination Group was on 9 February 2001 and up to the end of July 2001 this group had met four times. In the meanwhile, a number of working groups was set up to address WFD implementation in relation to specific subject areas. These were lakes, riv-

ers, transitional/coastal waters, ground waters, pressures and impacts, economic analysis, fish stock assessment, and register of Protected areas. All of these categories require detailed consideration to understand the requirements of the WFD. This includes the clarification of definitions, the development of co-ordination measures, and technical guidance and protocols. The perception of what is required for implementation continues to develop. At the European level, the establishment and progress of a *European Implementation Strategy Group* provides for continuous refinement of thinking about the WFD and the practicalities needed for implementation. On 2 May 2001, this group published a draft document entitled a *Common Strategy on the Implementation of the Water Framework Directive*. This outlined the activities and the time required for the preliminary tasks for WFD implementation. This desk study has, therefore, coincided with the development of thinking and exchange of ideas among a range of agencies and individuals both in Ireland and abroad. Indeed, the WFD is probably unique in European environmental law to the extent that the early stages towards implementation have drawn on experience throughout Europe, with active involvement of a Central Strategy Group and an array of analogous groups at national levels.

The development of ideas concerning many aspects of WFD implementation, and especially the more technical aspects, will continue to evolve. Major progress required in preparation for WFD implementation has occurred since the start of this project in December 2000. Much of this activity relates to resolving difficulties presented by the need to *inter alia*: define the River Basin Districts and the *Competent Authorities* that will manage them; set appropriate typologies of waters; set reference conditions; co-ordinate activities for monitoring and data management; and respond to complexities that will be placed on administrative structures. In Ireland, the prototype for addressing many of the difficulties posed by the WFD were provided by the three River Basin Projects funded by the DELG with assistance from the European Cohesion Fund. The first of the final reports from these has recently been produced (Kirk McClure Morton, 2001). The Government is now promoting a second generation of projects that develop the catchment approach to management as required by the WFD. These projects cover the proposed River Basin Districts (RBDs) required by the WFD. Five RBDs are proposed so far; boundaries in the north of the country are not yet resolved pending negotiation with the Northern Irish authorities.

2. Methodology of the Project

2.1 Timetable to achieve project objectives

The objectives were divided into four sequential, but overlapping phases:

- the identification of relevant projects and collation of information within Ireland and Europe;
- the identification of, and discussions with, agencies, NGOs and user groups of potential importance in WFD implementation;
- an evaluation of methodological and associated constraints to WFD implementation; and
- recommendations for a national strategy and identification of resource implications for WFD implementation.

2.2 Information sources

2.2.1 Collation of information

Literature searches were done through the libraries of the EPA and TCD and by contact with other bodies from Ireland and abroad. Published and unpublished material was collated. This included obtaining, as far as practicable, Water Quality Management Plans (WQMPs) provided for under the Water Pollution (1977) Act. Currently there are 15 adopted Plans and 10 draft Plans. A letter and an email was sent to each Local Authority requesting a copy of their WQMP, if one existed, and any other reports or publications available on monitoring and risk assessment.

The collation of information at a European level was based mainly on Internet searches. A useful starting point was the European Commission's website (http://www.europa.eu.int/water). Also useful was the European Water Association website (http://www.ewaonline.de), which provided articles, press releases and Internet links. A collation of websites considered useful for understanding the WFD are given in Appendix C.

2.2.2 Meetings with groups with potential importance for WFD implementation

During the project there has been concerted activity within the Department of Environment and Local Government (DELG) and the project has been kept informed of minutes of meetings and other relevant developments regarding the WFD. This has included attendance, as observer, at meetings of the WFD Co-ordination Group. In addition to on-going informal contact with a number of interested parties, throughout 2001 the project had independent discussions with the DELG (15 December and 9 May), *Dúchas* (19 December), *Aquafact* (24 January), the Local Government Computer Services Board (16 January), Marine Institute (14 December and 21 March), The Heritage Council (2 February), The Department of Agriculture, Food and Rural Development (5 February), The Three Rivers Project (6 February) The DOE (NI) Environment Division (20 March), The North/South Technical Implementation Group (10 May), The Central Fisheries Board (7 June), Mr Paddy Mackey, who has had close involvement with NGOs (16 June), and the Geological Survey of Ireland (21 August).

These meetings were intended to ascertain measures that were under consideration with regard to the WFD, and which sections/individuals within the organisations might be involved. In all cases there was high interest in the WFD. It is probably also highly relevant that most of these meetings were held prior to or soon after the Directive was passed into law. The progress of the DELG implementation group has, inevitably, subsequently altered the perceptions and activities among the bodies we spoke to. Later, informal contact with these bodies has demonstrated a development in understanding of the requirements of the WFD.

Initial plans were that the project would have meetings at a European level. Rapid progress within national and international working groups demonstrated that such meetings would soon be overtaken by events. To provide an overview of the thinking and progress within Member States a questionnaire was sent to individuals considered

to be well briefed on the requirements of the WFD and the national developments towards its implementation. These questions and responses are summarised in Appendix D.

2.3 Structure of the report

The report is structured in an attempt to cover the most relevant and immediate issues for implementation of the WFD in Ireland. In order to provide an overview of research and monitoring needs we have thought it necessary to include (a) reviews of current activities and (b) comment on existing and proposed monitoring structures. An evaluation of research and monitoring encompasses a range of diverse subjects and requires a broad outlook. Monitoring systems, for instance, depend on supporting infrastructure and policies. The report, therefore, addresses the legal requirements of the WFD in relation to the existing legal framework in Ireland (Chapter 3), the capabilities for the fulfilment of a number of technical issues required by the Directive prior to or concurrent with the development of monitoring systems (Chapter 4), a review of current monitoring and that required by the WFD (Chapter 5) and an analysis of the implementation strategy in Ireland (Chapter 6). Chapter 7 provides some overall concluding comments on implementation, resource implications and longer-term issues of the WFD. A list of abbreviations and acronyms used in the report is provided at the end of the text. Chapter 8 provides a list of references cited in the text and a bibliography of information sources relevant to the WFD is provided in Chapter 9. Information addressing details of interest but not appropriate for the main text is appended (Appendices A–E).

3. Legislation

3.1 Introduction

Instead of a series of separate and fragmented European Union measures on water uses and on pollutant discharges, henceforth all water types and issues will be dealt with in a single instrument, *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.* It should be noted at the outset, however, that the integration process will not be entirely complete since some water instruments, e.g. the Urban Waste Water Treatment Directive (91/271/EEC) and the Nitrates Directive (91/676/EEC), will remain outside the scope of the Water Framework Directive (WFD).

Pursuant to the Amsterdam Treaty, and indeed to Article 26 of the WFD, the duty of the Member States to take the necessary measures in order to achieve the results prescribed in the directive is legally binding. The effect of this is that a directive is binding as to the result to be achieved but leaves the Member States free to choose the form and methods for achieving that result. Accordingly, the purpose of this chapter of the Implementation Study is to assess, firstly, the *results* that have to be achieved by Ireland under the WFD and, secondly, the *form and methods* which already exist in Irish law and whether or not these are adequate to bring about the results required by the WFD.

3.2 Analysis of the Objectives of Directive 2000/60/EC

3.2.1 Purpose

Article 1 of the WFD provides that the purpose of the WFD is to protect inland surface waters, transitional waters, coastal waters, and groundwater bodies. Specifically, the Directive has the objective of establishing a framework that will:

- prevent further deterioration and protect and enhance the status of aquatic ecosystems;
- promote sustainable water use;
- aim at enhanced protection and improvement of the aquatic environment;
- ensure the progressive reduction of pollution of ground water and prevent its further pollution; and
- contribute to mitigating the effects of floods and droughts.

3.2.2 Co-ordination of administrative arrangements within River Basin Districts

Pursuant to Article 3(1), Ireland must identify the individual river basins lying within its national territory and then assign these river basins to particular River Basin Districts (RBDs). Thus, small river basins may be combined with larger river basins or joined with other small river basins to form individual RBDs. Moreover, ground waters and coastal waters shall be identified and assigned to the nearest or most appropriate RBD. Thus, unlike a management model based on administrative or political boundaries, the WFD establishes a scheme in which all surface and groundwater bodies that are geographically or hydrologically connected are dealt with within specific aquifer management units (Grimeaud, 2001).

Demmke (1999) observed that, in principle, the European Union has no competence to regulate the organisational structures in the Member States. Thus, in fulfilling its obligations under the WFD, Ireland has administrative autonomy. Moreover, although under Article 249(3) of the Treaty, the WFD is addressed to the Member States, the required implementation regulations and measures do not necessarily have to be issued at central administrative level. Ireland is thus free to carry out the implementation of the Directive through administrative units which are below the central level. However, the European Court of Justice (ECJ) has set some preconditions to restrict the use of this freedom.[1] The distribution of responsibilities within a Member State does not release that Member State from the obligation to ensure that the provisions of a directive are implemented accurately into national law,

1. Joined Cases 227 to 230/85 *Commission v. Belgium* [1998] E.C.R. 1. Case 131/88 *Commission v. Germany* [1991] E.C.R. I-825.

and have validity in the entire territory of the Member States. Equally, the quality of the implementation cannot be allowed to be impaired by distribution of responsibilities within a Member State, as the objectives of a directive and its terms must be achieved.

If Ireland designates more than one competent authority in its national legislation implementing the WFD, **appropriate co-ordination structures** will have to be put in place (see also Chapter 6 of this report).

Article 3 of the WFD specifically obliges the Member States to determine the "appropriate competent authorities". Interestingly, Article 2(16) of the WFD states that competent authority means *"an authority or authorities identified under Article 3(2) or 3(3)"*.[2] The ECJ judged the analogous Article 5 of the Drinking Water Directive 75/442/EEC as not setting any restrictive criterion with regard to the "competent authorities" to be employed or determined by the Member States.[3] Demmke (1999) is of the view that it follows from the freedom to empower administrative departments at regional and municipal level to implement EC law, that Member States have the freedom to choose the relevant authorities. Moreover, in a number of cases, the Court of Justice has upheld the national allocation responsibilities under directives (ECJ, 1990, 1994). Nevertheless, the Member States continue to bear the responsibility for proper and effective implementation of a directive. Ireland would, therefore, in the event of designating more than one competent authority, be obliged to issue regulations that take precautions against the non-fulfilment of obligations under the WFD on the part of regional authorities. Indeed, Article 3(4) expressly requires Ireland to ensure that the requirements of the WFD for the achievement of the environmental objectives under Article 4, and in particular all programmes of measures, are co-ordinated for the whole of an RBD.

Finally, it should be noted that current thinking in Irish public authorities would appear to suggest that county councils may be identified as competent authorities under the WFD. To this end, Article 3(6) permits Member States to identify an existing national body as a competent authority for the purposes of the Directive. However, the proposed designation of county councils as competent authorities contrasts with the approach proposed in both England and Wales, and Scotland, where consultation papers suggest that a single competent authority (the Environment Agency and Scottish Environmental Protection Agency, respectively) shall be designated in those jurisdictions (DETR and National Assembly for Wales, 2001). However, the number, location, and structure of competent authorities would appear to be policy matters, with a number of implementation options appearing to be open to Ireland in terms of compliance with EC law.

Conclusion: Subject to the caveat of ensuring co-ordination between multiple competent authorities and the achievement of the objectives of WFD, Ireland is free to determine competent authorities as it wishes, in respect of number, location and structure of the authorities.

Obligations: Ireland must identify the competent authority/authorities by 22 December 2003. Ireland must provide the Commission with its list of competent authorities and of international competent authorities by 22 June 2004. Annex I of the Directive sets out the information to be provided in respect of each authority.

3.2.3 Environmental objectives

All bodies of surface water, ground water and protected areas are included in the environmental objectives of the WFD, stated in Article 4. Pursuant to Articles 4(1)(a)(i) and 4(1)(b)(i), respectively, Ireland must implement the measures necessary to prevent the deterioration of the status of all bodies of surface and ground water. Under Article 4(1)(a)(ii), the aim is to achieve "good surface water status" by 22 December 2015, in accordance with Annex V. Similarly, pursuant to Article 4(1)(b)(ii), Member States must achieve "good groundwater status" within 15 years, subject to Annex V. Finally, Article 4(1)(c) requires Member States to achieve certain objectives in respect of protected areas by 2015.

3.2.3.1 Legal enforceability of Article 4(1)(a)

Insofar as Article 4(1)(a)(i) mandates Ireland to avoid a deterioration in the status of all bodies of surface water, that sub-article contains a legally binding target for water management and must be implemented accordingly.

2. Emphasis added.
3. Joined Cases 372 to 374/85 *Ministere Public v. Traen* [1987] E.C.R. 2141.

However, other provisions of Article 4(1)(a), i.e. those that relate to the achievement of good ecological and chemical status for surface waters and to the realisation of good ecological potential and good chemical status for artificial or heavily modified water bodies, are imprecise. This leads to problems of enforceability. For example, the expression "with the aim of" may indicate that Ireland would be subject only to an obligation to use all reasonable means to achieve the specified objectives, rather than the "absolute" requirement to realise them (Grimeaud, 2001). Thus, whilst Ireland must take all necessary measures to prevent any further deterioration of given surface water areas, Ireland may not be legally censured for failing to actually bring about "good status". The only obligation in respect of "good status" may be to use all reasonable or possible means to achieve it. Notwithstanding this apparent lack of legal enforceability in respect of some of the environmental objectives outlined in Article 4(1)(a), Ireland will still have to comply, as a minimum, with Articles 4(9) and 11(3)(a), on quality requirements and protection measures in existing legislation.

Conclusion: As a result of the lack of precision in drafting certain provisions of Article 4(1)(a), there appears to be considerable doubt as to whether all aspects of that article are enforceable against the Member States. It seems that Ireland is required to, for example, take measures to prevent further deterioration of surface waters, but may not be required to actually achieve the "good status" which is the central objective of this sub-article. Notwithstanding these ambiguities, it is clear that, at an absolute minimum, Ireland is required to conform to quality requirements set under existing EC environmental legislation.

3.2.3.2 Legal enforceability of Article 4(1)(b)

Article 4(1)(b)(i) provides that Ireland *shall* prevent or limit pollutant inputs and *shall* prevent the deterioration of the status of all groundwater bodies, subject to some exceptions. This "non-deterioration" requirement is likely to amount to a standstill obligation. This would mean that Ireland must ensure that, whatever the current status of a given groundwater body, no further deterioration occurs. Moreover, Article 11(3)(j) stipulates that any direct pollutant discharges into ground water must generally be prohibited.

Questions of the legal enforceability of environmental objectives also arise in respect of ground water. The question is whether Article 4(1)(b) imposes on Member States any obligation, in addition to the "baseline obligations" in Articles 4(9) and 11(3)(a), to comply with related free-standing measures and minimum water quality under the Groundwater Directive (80/68/EEC). The provisions on the achievement of good groundwater quality lack clarity, and, therefore, legal enforceability.

Article 4(1)(b)(ii) contains the terms "shall" and "with the aim of". This contrasts with Article 4(1)(b)(i) which only uses the term "shall" in relation to Ireland's obligations. The expression "with the aim of" may indicate that Ireland would be obliged only to use all reasonable means to achieve good groundwater status, as opposed to an unqualified obligation to actually attain that objective. Consequently, whilst Ireland may have to comply with Articles 4(9) and 11(3)(a), prevent or limit any further deterioration of ground waters per Article 4(1)(b)(i), and take appropriate measures to reverse any significant and sustained upward trends of pollutant concentrations per Article 4(1)(b)(ii), Article 4(1)(b) may not require Ireland to actually bring about "good groundwater status", as long as the Irish competent authorities used all reasonable or possible means to do so.

Conclusion: Again, as a result of the lack of precision in drafting certain provisions of Article 4(1)(b), there is doubt as to whether all aspects of that article are enforceable against Ireland. It seems that Ireland is required to take measures to prevent further deterioration of ground waters, to reverse upward trends in pollutant discharges and to prohibit direct pollutant discharges into ground water. However, as with surface water, there may not be an enforceable requirement to actually attain the objective of "good groundwater status", but merely to strive to do so. Yet again, there is a baseline obligation to conform to quality requirements set under existing EC environmental legislation, in particular Directive 80/68/EEC on the protection of ground water against pollution caused by certain dangerous substances.

3.2.3.3 Legal enforceability of Article 4(1)(c)

Along with surface and ground water, Article 4(1) deals specifically with protected areas, which are to be distin-

guished from other water bodies, and by virtue of their vulnerable nature, are to be made subject to more stringent protection measures. Article 4(1)(c) expressly requires that standards and environmental objectives in relation to protected areas *shall* be achieved by 22 December 2015. This wording contrasts with the expression "with the aim of" elsewhere in Article 4(1). Therefore, for protected areas, Ireland has an absolute obligation to achieve good status and to implement relevant quality standards (Grimeaud, 2001).

Conclusion: Article 4(1)(c) contains an absolute obligation that Ireland must achieve compliance with the relevant standards and objectives in relation to protected areas by 2015.

3.2.3.4 Exceptions

In addition to setting out the obligations on Member States to meet environmental objectives, Article 4 of the WFD also makes provision for limited derogations from these objectives. These derogations or exceptions cover the designation of artificial or heavily modified water bodies, the setting of lower objectives, allowing for new development, and temporary deterioration in quality. However, the exercise of such derogations is subject to a number of conditions; for example, Article 4(8) states that in applying the exceptions contained in sub-articles (3), (4), (5), (6) and (7), Member States must ensure that the achievement of the WFD objectives are not permanently compromised in other bodies of water within the same RBD. Moreover, Article 4(9) requires a baseline of "at least the same level of protection as the existing Community legislation" in applying all WFD provisions, including the exceptions under Article 4.

3.2.3.5 Artificial and heavily modified water bodies

Article 4(1)(a)(ii) specifies that "artificial and heavily modified water bodies" are to be considered separately from other surface water bodies. Article 2 defines an "artificial water body" as a body of surface water that has been created by human activity. "Heavily modified water bodies" are defined in Article 2 as surface water bodies whose character is changed substantially owing to physical alterations caused by human activity and which have been designated as such by Member States in accordance with Annex II. Regarding environmental objectives, Article 4(1)(a)(iii) stipulates that Member States will protect and enhance such water areas "with the aim of" achieving "good ecological potential" and "good surface water chemical status" by 22 December 2015.

Article 4(3)(a) provides that Member States may designate a surface water body as artificial or heavily modified when the changes to be made to the hydromorphological features of that body to achieve "good ecological status" would "significantly" and adversely affect, *inter alia*, beneficial objectives such as the wider environment, navigation or recreation, water regulation, flood prevention or other "equally important sustainable human development activities". It would appear, therefore, that Ireland will thus be called upon to conduct a cost/benefit analysis, which will mean calculating the costs of modifying the hydromorphological features of a given surface water body and an assessment of the resulting environmental benefits (Grimeaud, 2001). The Directive does not, however, provide any specifications of what is to be taken into account in such a calculation.

Consequently, it seems as though Ireland will enjoy some latitude in designating "heavily modified surface water bodies" in particular. For example, it would be left to Ireland to set the appropriate criteria to define terms such as "reasonable", "significant" and "disproportionate". However, Article 4(8) may impose limits on Ireland's discretionary power. Firstly, relying on Article 4(3)(a) must not permanently exclude or compromise the achievement of the directive's environmental objectives for other water bodies in the same RBD. Secondly, Article 4(8) provides that the application of Article 4(3) must be consistent with the implementation of other EC environmental legislation.

Conclusion: Ireland would appear to have considerable discretion in the designation of "artificial" and "heavily modified" water bodies. However, if a body of surface water falling under the provisions of existing water quality directives is designated as an artificial or heavily modified water body, the level of protection shall be at least as good as that required under the existing directive, and the attainment of environmental objectives for other water bodies cannot be permanently excluded.

3.2.3.6 Extended deadlines for achieving "good status"

Member States may be able to postpone the 15-year deadline for achieving "good status" for a given surface groundwater body by up to 12 years in certain circumstances. However, in order to avail of such an extension, Ireland must comply with the four pre-conditions set out in Article 4(4). These are that:

- no further deterioration can occur in the status of the affected body;
- the reasons for the inability to achieve the necessary improvements in the status of bodies of water by 2015 must be for technical reasons, disproportionate expense, or natural conditions;
- extension of the deadline and the reasons for it must be specifically set out in the management plan; and
- a summary of measures required and the expected timetable must be set out in the management plan.

Beyond these requirements, Ireland's ability to rely on Article 4(4) is also restricted by the obligation to comply with Articles 4(8), 4(9) and 11(3)(a) (Grimeaud, 2001). Article 4(8) provides, *inter alia*, that applying Article 4(4) must not "permanently exclude or compromise" the achievement of environmental objectives in Article 4(1) for other associated water bodies, while Articles 4(9) and 11(3)(a) have the effect of requiring Ireland to comply with all existing EC environmental legislation, even when validly extending the 2015 deadlines.

Conclusion: Extensions of the 2015 deadlines are only available in certain defined circumstances. Moreover, the maximum limit on time extensions is 2021, except in cases of adverse natural conditions. Finally, Article 4(4) also places obligations on Ireland not to allow any further deterioration in the status of the water bodies concerned, to set out details of the extension and consequent measures in the management plan, and to comply with the requirements and standards set under existing EC environmental legislation.

3.2.3.7 Less stringent environmental objectives

Article 4(5) allows for the "realisation of less stringent environmental objectives", if human activity per Article 5(1), or natural conditions, make an improvement of the status impossible or disproportionately expensive. The criteria that allow the attainment of less stringent environmental objectives are:

- environmental/socio–economic needs served by human activity cannot be achieved by other means;
- the highest possible ecological and chemical status of surface water is achieved;
- the least possible changes to good groundwater status are permitted;
- no further deterioration occurs in the status of the affected body of water; and
- the establishment of less stringent environmental objectives and the reasons for them, are specifically mentioned in the River Basin Management Plan (RBMP).

Article 4(5)(b) requires that, where such less stringent environmental objectives are relied upon, Ireland must achieve a rather subjective minimum level of water protection. Thus, as with Article 4(1), Article 4(5) may give rise to enforcement problems because of the lack of precise criteria. However, the scope of Ireland's discretion in respect of applying less stringent criteria appears to be limited by the fact that such exemption must not lead to further deterioration of the water body concerned. In addition, Article 4(9) provides that relying on Article 4(5) must not result in water protection levels that would be lower than those imposed in existing EC water measures.

Conclusion: The criteria designed to limit the exercise of Member States' discretion in applying less stringent environmental objectives seem to be sufficiently imprecise as to raise doubts as to their enforceability. However, in applying less stringent environmental objectives to a given water body, at the very least, Ireland will have to satisfy a number of procedural steps, and comply with the standards of existing EC environmental legislation.

3.2.3.8 Temporary deterioration in status

Article 4(6) provides that temporary deterioration in status may occur in certain defined circumstances. The concession is only available where such deterioration results

from circumstances or natural causes that are exceptional or which could not have been reasonably foreseen (Grimeaud, 2001).

In order to avail of the exemption under Article 4(6), the relevant RBMP must include a description of the conditions under which exceptional or unforeseeable circumstances may be declared, i.e. before the occurrence of the exceptional/unforeseen circumstance. This will oblige Ireland to identify types of exceptional circumstances in advance.

Moreover, Articles 4(6)(a) and (d) set the obligations applying to Ireland once an exceptional/unforeseeable deterioration in water quality has taken place. First, Ireland has the baseline obligation of preventing any further deterioration of the water body concerned (Article 4(6)(a)). Second, Article 4(6)(d) provides that "all practicable measures are taken with the aim of restoring the body of water to its status prior to the effects of those circumstances as soon as reasonably practicable". The expression "reasonably practicable" is open to varying interpretations. Moreover, the restoration issue is to be read in the light of the conditions in Article 4(4)(a) including technical feasibility, proportionality of cost and natural conditions. Thus, Ireland would have to aim at restoring the water body affected as soon as the factors in Article 4(4)(a) allow. Also, the use of the terms "with the aim of" may result in a qualified commitment to use all "reasonable means" (Grimeaud, 2001).

Conclusion: There is an obligation to anticipate temporary deterioration and provide for it in management plans, a duty to review annually the effects of an event occurring in exceptional or unforeseeable circumstances, and a duty to provide a summary of those impacts and of the measures taken or to be taken. Thus, it seems that both an enforceable obligation (to stop any further deterioration and ensure the achievement of relevant environmental objectives for other water bodies) and a mere commitment (to restore the damaged water bodies) are simultaneously imposed. The ability of Ireland to rely on Article 4(6) may, however, be limited by the application of Articles 4(8), 4(9) and 11(3)(a) which aim at ensuring, *inter alia*, that existing EC water and environmental legislation is fully complied with.

3.2.3.9 Derogation from the environmental objectives

Under Article 4(7), Ireland may be entitled not only to fail to realise the environmental objectives under Article 4(1), but also to fail to prevent deterioration in the *current* quality status of a water body. Article 4(7), provides, *inter alia*, that failure to prevent the deterioration of a surface or groundwater body may be justified where the failure derives from "new modifications to the physical characteristics of a surface water body or alterations to the level of bodies of ground water". It should be noted that only new modifications or alterations may serve as justifying reasons, and that the discharge of contaminants remains prohibited.

Even if deterioration in water status results specifically from one of the justifying factors, further conditions, as laid out in Article 4(7), have to be fulfilled for a derogation to apply:

- all practicable steps must be taken to mitigate the adverse impacts on the status of the water body;
- reasons for the modifications or alterations must be explained in the relevant RBMP;
- modification or deterioration in quality must be for reasons which are of "overriding public interest" or the benefits of achieving the objectives under Article 4(1) must be outweighed by the benefits of the modifications or alterations in terms of human health, safety and sustainable development; and
- benefits resulting from modifications to the physical characteristics of a surface water body or alterations affecting the high water quality status of such a water body must not be capable of being achieved by other means which are technically feasible and not disproportionately costly, and which are a significantly better environmental option.

Conclusion: Ireland appears to be entitled to fail to achieve good water status, and even to fail to prevent deterioration in the status of a water body, in certain defined circumstances. However, Articles 4(8), 4(9) and 11(3) mean that invoking Article 4(7) must not lead to permanent inability to achieve the environmental objectives of Article 4(1) for other water bodies, the same level of pro-

tection as under existing EC water legislation must be guaranteed, and that using Article 4(7) must be consistent with the implementation of other EC law.

3.2.4 Characteristics of the River Basin Districts

Ireland must ensure that for each RBD or portion of International River Basin District (IRBD) within its territory the following are carried out:

- analysis of the RBD's characteristics;
- review of impact of human activity on surface waters and ground waters; and
- economic analysis of water use.

Obligations: These analyses/reviews must be carried out in accordance with Annexes II and III, must be completed by 22 December 2004, and reviewed by 22 December 2013 and every 6 years thereafter**.**

Conclusion: These provisions will lead to specifications to enable Ireland to characterise the features of each surface and groundwater body, and to identify the anthropogenic pressures that may affect their status. The objective of such examination is to enable Ireland to define "high", "good" or "moderate" status for a water body, and to design programmes of measures (Article 11) and monitoring schemes (Article 8).

3.2.5 Register of protected areas

Pursuant to Article 6(1), Ireland must ensure that registers of areas designated as requiring special protection under Community legislation, for the protection of surface or ground water or habitats and species depending on water, are established for each River Basin District by 22 December 2004. The protected area register must include waters used for the abstraction of drinking water. Such protected area registers must be kept under review and up to date.

Conclusion: This article imposes a clear and unequivocal obligation on Ireland in respect of the maintenance and contents of protected area registers.

3.2.6 Water used for the abstraction of drinking water

As Directive 75/440/EEC on the abstraction of drinking water will be repealed by 22 December 2007, but as Member States do not have to achieve "good status" for such bodies until 2015, there will be an 8-year gap between the repeal and the realisation of the objectives under Article 4(1). Article 7, thus obliges Member States to maintain minimum quality levels so that water treatment to provide drinking water in conformity with relevant EC standards may continue. Article 7 may be read in conjunction with Article 4(9) which provides that in applying the WFD, Ireland must realise a level of protection at least equal to that prescribed under existing EC directives.

Article 7(3) provides that Ireland must ensure the necessary protection for relevant bodies of water "with the aim of" avoiding deterioration in their quality. Consequently, Article 7(3) may not impose an express obligation to guarantee the non-deterioration of water bodies used for abstracting drinking water.

Conclusion: Ireland is required only to take necessary protection measures "with the aim of avoiding" further quality deterioration. Moreover, Article 7(3) gives discretion to Ireland as to the establishment of zones to safeguard water supply.

3.2.7 Monitoring

Article 8(1) requires Ireland to establish monitoring programmes in accordance with Annex V, and to conduct a comprehensive overview of water status in each RBD. Article 8(2) requires these programmes to be operational by 22 December 2006. These are considered further in Chapter 5.

Conclusion: On the surveillance of surface waters, Ireland must, firstly, establish *surveillance* monitoring programmes, and secondly, *operational* monitoring programmes are also to be established with the aim of determining the status of those water bodies identified as being at risk of failing to meet their environmental objectives, and of assessing any changes in the status of such

bodies resulting from the implementation of programmes under Article 11.

3.2.8 Recovery of water service costs

Policies on water pricing derive from the polluter pays principle (arising from environmental policies of the Treaty of Rome, specifically Article 174(2)). Article 9(1) of the WFD calls on Ireland to take account of the principle of recovery of the costs of water services, including environmental and resource costs. These latter are in addition to water industry costs. However, this provision does not define environmental and resource costs. Indeed, Ireland is provided with discretionary power to determine cost recovery, which undoubtedly affects potential legal enforceability.

Finally, there appears to be nothing to oblige Ireland to impose full cost recovery on, for example, agricultural activities. For such water use there would be a requirement to pay only an "adequate contribution" with the level at which such a contribution is set being a policy matter. Indeed, Article 9(4) provides scope to exempt altogether a water use activity from the application of Article 9(1) and (2), as long as this does not jeopardise the environmental objectives of the WFD. Such an exemption can only be awarded after a careful assessment of its impact.

Conclusion: Whilst the second sentence of Article 9(1) would appear, *prima facie*, to require Ireland to implement water pricing policies and an adequate contribution from all water uses, Article 9(4) has the potential to permit a complete derogation in respect of any given water use in certain defined circumstances.

3.2.9 Combined approach for point and diffuse sources

Pursuant to Article 10(1), Ireland must ensure that all discharges into surface waters are controlled. Further, by 22 December 2012, Ireland must ensure the establishment or implementation of emission controls based on best available technology (BAT), relevant emission limit values, and in the case of diffuse impacts, controls including best environmental practices (BEP) as set out in defined pieces of EC environmental legislation (Directives 96/61/EC, 91/271/EEC, 91/676/EEC, 82/176/EEC, 83/513/EEC, 84/156/EEC, 84/491/EEC, and 86/280/EEC). Finally, where a quality objective or quality standard requires stricter conditions than under Article 10(2), then more stringent emission controls shall be set.

Conclusion: When Ireland implements environmental quality standards (EQSs) in respect of diffuse sources of pollution in order to achieve "good surface water status", emission controls or limit values will also have to be set. EQSs define the minimum quality requirements of water to limit the cumulative impacts of emissions (i.e. from diffuse sources), while emission limit values (ELVs) focus on the maximum permissible quantities of pollutants that may be discharged from a particular (i.e. point) source.

3.2.10 Programme of measures

Under Article 11(1), Ireland must establish a *Programme of Measures* for each RBD, or part of an IRBD within its territory, in order to achieve the Article 4 objectives. These programmes are to be established by 22 December 2009, and the measures will have to be operational by 22 December 2012. The programme of measures must take account of the results of the Article 5 analyses, and may make reference to legislative provisions. Each programme of measures must include "basic" measures, and may include "supplementary measures" where appropriate. The programmes may contain specific measures for individual RBDs (e.g. quality bye-laws set by the local authorities comprising a particular RBD) and measures applying to all RBDs in Ireland (such as general legislation on the licensing of discharges).

3.2.10.1 Basic measures

Article 11(3)(a) provides that the obligatory basic measures must include, firstly, those necessary to ensure full implementation of the EC environmental directives which will not be repealed or integrated into the new water management scheme, i.e. Directives 91/271/EEC, 91/676/EEC, and 96/61/EC. Article 11(3)(a) also calls for measures to ensure full compliance with the EC legislation mentioned in Article 10(2), which includes the daughter directives listed in Annex IX and the forthcom-

ing directives to be adopted pursuant to Article 16 on the discharge of priority and dangerous substances.[4]

Article 11(3)(b) stipulates that the programmes of measures are to include the measures which will be adopted under Article 9 on the recovery of costs for water services, while Article 11(3)(c) focuses on measures to promote efficient and sustainable patterns of water use. Further, Article 11(3)(d) insists that the requirements under Article 7, on the protection of water used for drinking water abstraction, are met in accordance with the Drinking Water Directive.

On controls of point-source pollutant discharges, Article 11(3)(g) provides that the programmes of measures are to impose, *inter alia*, a requirement for prior regulation. Article 11(3)(g) provides that point-source pollution controls are to include pollutant emission controls in accordance with Article 10. Article 11(3)(h) deals with controls on diffuse sources of pollution. Like Article 11(3)(g), this provision requires Ireland to set controls in the form of prior regulation, authorisation or registration based on general legally binding rules.

Article 11(3)(j) stipulates, in its first sentence, that any direct pollutant discharges into ground water must generally be prohibited. Article 11(3)(l) calls for programmes of measures to address the prevention of "significant" pollutant losses from technical installations. This provision requires Ireland to ensure, at least, that the realisation of the objectives under Article 4 is not put at risk following, for instance, an industrial accident. In this context, Part A of Annex VI refers to, *inter alia*, the Major Accidents (Seveso) Directive 1996 (96/82/EC) compliance with which is to be fully guaranteed.

Conclusion (1): As a compulsory baseline obligation, Ireland must guarantee that current related EC instruments are complied with and that the measures adopted for that purpose are included in programmes of measures under Article 11.

Conclusion (2): As long as no further deterioration in the status of water bodies occurs, and provided that "good surface water status" and "good groundwater status" are realised and maintained, water abstractions and impoundments will be exempted from prior controls. Ireland may, nevertheless, need to verify that water abstractions categorised initially as resulting in "no significant impact", would retain that categorisation if subsequently found to have "significant impact".

3.2.10.2 Supplementary measures

Pursuant to Article 11(4), part B of Annex VI contains a non-exhaustive list of supplementary measures. Ireland may adopt further supplementary measures in order to provide for additional protection or improvement of waters.

Article 11(5) provides that where monitoring or other data indicate that the objectives set under Article 4 for the body of water are unlikely to be achieved, Ireland shall ensure that the causes of possible failure are investigated, relevant permits and authorisations are examined and reviewed as appropriate, monitoring programmes are reviewed and adjusted as appropriate, and additional measures are established, including stricter environmental quality standards following the procedures laid down in Annex V. However, where the causes of possible failure could not reasonably have been foreseen, Ireland may determine that additional measures are not practicable subject to Article 4(6).

By virtue of Article 11(6), in implementing the programme of measures, Ireland must take all appropriate steps not to increase pollution of surface waters. This requirement shall not apply where it would result in increased pollution of the environment as a whole.

Obligation (1): Ireland must establish programmes of measures by 22 December 2009, achieve those measures by 2012, and review the programmes by 2015 and every 6 years thereafter.

Obligation (2): Where it appears as though these measures may not be achieved by the 2012 deadline, Ireland must investigate the causes of failure, review permits, authorisations and monitoring programmes, and establish stricter environmental quality standards.

4. The original proposal for a list of priority substances [COM(2001)17] was re-submitted to the European Parliament by the European Commission on 6 June 2001.

3.2.11 River Basin Management Plans

Pursuant to Article 13(1), Ireland shall ensure that an RBMP is produced for each RBD lying entirely within its territory. In relation to IRBDs (i.e. those RBDs that straddle the border with Northern Ireland), Article 13(2) provides that Ireland and Northern Ireland shall ensure coordination, "with the aim of" producing a single international RBMP. Should an international plan fail to be produced, Ireland must draw up a RBMP covering those parts of the IRBD falling within its territory. In drawing up RBMPs, Ireland must include the information detailed in Annex VII. In addition, RBMPs may be supplemented by the production of more detailed programmes and management plans for sub-basin, sector, issue or water type, to deal with particular aspects of water management.

Obligations: Ireland must publish all RBMPs by 22 December 2009, and review and update those plans by 22 December 2015, and every 6 years thereafter. In preparing RBMPs, Ireland must include the information listed in Annex VII.

3.2.12 Public information and consultation

Article 14(1) provides that Ireland shall encourage the active involvement of all interested parties in the implementation of the Directive, in particular in the production, review and updating of RBMPs. Ireland must publish timetables and work programmes for the production/updating of the plan, an overview of significant water management issues identified in the river basin, draft copies of the RBMP, and provide access to background documents and information used for the draft RBMP, upon request.

Obligation: Ireland must ensure public participation in the drawing up of draft RBMPs, updates and revisions.

3.2.13 Reporting

Ireland must send copies of the RBMPs and all subsequent updates to the Commission, and to any other Member State concerned (i.e. the United Kingdom) within 3 months of their publication. Ireland shall submit summary reports of analyses required under Article 5 and monitoring programmes required under Article 8 within 3 months of their completion. Finally, Ireland must submit an interim report describing progress in the implementation of the planned programme of measures, within 3 years of the publication of each RBD.

Obligation: Ireland has absolute reporting obligations, to be performed within the time limits set.

3.2.14 Repeals and transitional provisions

Pursuant, to Article 22(1), Directive 75/440/EEC, Council Decision 77/795/EEC and Directive 79/869/EEC shall be repealed with effect from 22 December 2007. Pursuant to Article 22(2) Directive 78/659/EEC, Directive 79/923/EEC, Directive 80/68/EEC and Directive 76/464/EEC shall be repealed by 22 December 2013. Article 6 of 76/464/EEC was repealed on 22 December 2000.

3.2.15 Penalties

Article 23 of the WFD states that Member States shall determine penalties applicable to breaches of national provisions adopted pursuant to the Directive. The penalties thus provided for shall be effective, proportionate and dissuasive.

Conclusion: In drafting legislation to implement the requirements of the WFD, Ireland must include effective sanctions for non-compliance with those requirements.

3.2.16 Transposition

The Directive must be transposed into national law by 22 December 2003. In addition, a large number of other deadlines are provided. Altogether about 40 deadlines are specified in the Directive. These deadlines define the milestones to implementation and are summarised in Chapter 1 (Table 1.1).

Whether or not the individual deadlines are met depends, above all, on whether other water conservation directives are implemented at the same time in the appropriate form and timeframe, and whether integration of the objectives with other directives is successful. For example, 11 environmental directives are to form the basis for the measures which will be adopted in the programmes of measures (Article 11 and Annex VI). The environmental objectives in Article 4 of the Directive and the establishment of those in the programmes of measures cannot,

therefore, be achieved without the implementation and enforcement of other directives, in particular, Directives 91/271/EEC, 91/676/EEC and 96/61/EC. A further difficulty is posed by the repeal of other legislation in Article 21.

Conclusion: Ireland must comply with the relevant deadlines set in respect of the implementation of the various provisions of the WFD. Should Ireland fail to implement its obligations within any of the deadlines set, infringement proceedings may be taken by the Commission under Article 226 of the Treaty.

3.3 The existing Irish legislative framework

As was noted as long ago as 1990, until EC environmental directives were implemented, Irish water pollution control law concentrated on providing mechanisms for pollution control but was silent on the precise objectives or standards to be attained. The water directives enacted since 1975 have prescribed various explicit qualitative and quantitative criteria that must be observed when decision-making on water pollution control is undertaken. The WFD, at least to some extent, builds on this approach, by requiring, firstly, that environmental objectives set in the Directive are implemented into Irish law and, secondly, by prescribing both qualitative and quantitative standards which are required to attain those objectives. It is necessary, therefore, for Ireland to implement both the various objectives and standards into national law, so as to give enforceability to those provisions before the Irish courts.

As Scannell (1990) observed, water quality directives were originally transposed in this jurisdiction by way of administrative circulars, which urged local authorities to use their powers under the Local Government (Water Pollution) Act 1977, to implement various obligations under EC legislation. However, between 1982 and 1996 the European Court of Justice,[5] and in 1989 the Irish High Court,[6] held that directives must be implemented by being given formal legal expression in domestic law by primary legislation or secondary regulations. Consequently, in 1985, the Department of the Environment began implementing water quality directives by regulations with the enactment of the Local Government (Water Pollution) (Control of Cadmium Discharges) Regulations 1985 (S.I. No. 294 of 1985). Since then, EC water pollution directives have been implemented by statutory regulations (i.e. delegated or secondary legislation) under Acts of the Oireachtas (i.e. primary legislation). The substantive Irish primary legislation on water quality comprises:

- the Local Government (Water Pollution) Acts 1977 to 1990;
- the Environmental Protection Agency Act 1992; and
- the Waste Management Act 1996.

The Irish primary legislation that has been used as the procedural vehicle to transpose the various EC directives on water quality into Irish law comprises:

- the European Communities Act 1972;
- the Local Government (Water Pollution) Acts 1977 and 1990;
- the Environmental Protection Agency Act 1992; and
- the Local Government Act 1994.

In terms of implementing the actual objectives and standards contained in individual water quality directives Ireland has, in the main, transposed these into Irish law by means of statutory regulations made under one of the Primary Acts listed above. A complete list of the relevant statutory regulations is shown in Table 3.1, in respect of pollution from particular or point sources, and Tables 3.2 and 3.3 in respect of pollution from diffuse sources.

The WFD makes provision for the regulation of water supply. The justification for doing so rests on the principles of sustainable development and polluter pays, both of which are contained in the Treaty. Consequently, in analysing the Irish legislation for the purposes of assessing how the WFD needs to be implemented, it shall be

5. Cases C-96/81 *Commission v. Netherlands* [1982] E.C.R. 1701; C-131/88 *Commission v. Germany* [1991] E.C.R. I-825; C-361/88 *Commission v. Germany* [1991] E.C.R. I-2567; C-13/90 *Commission v. France* [1991] E.C.R. I-4327; C-58/89 *Commission v. Germany* [1991] E.C.R. 4983; C-262/95 *Commission v. Germany* [1996] E.C.R. I-5729.

6. *Brown v. An Bord Pleanála*, Unreported, High Court, Barr, J., July 27, 1989.

Table 3.1. Irish secondary water quality legislation applicable to point-source pollution.

Local Government (Water Pollution) Regulations 1978 (S.I. No. 108)
Local Government (Water Pollution) Regulations 1992 (S.I. No. 271)
Local Government (Water Pollution) (Amendment) Regulations 1996 (S.I. No. 184)
Local Government (Water Pollution) (Amendment) Regulations 1999 (S.I. No. 42)
Protection of Groundwater Regulations 1999 (S.I. No. 41)
Local Government (Water Pollution) (Nutrient Management Planning Consultation) Regulations 1998 (S.I. No. 257)
Local Government Act, 1994 (Bye Laws) Regulations 1999 (S.I. No. 78)

Table 3.2. Irish secondary water quality legislation applicable to diffuse pollution.

Local Government (Water Pollution) Act 1977 (Water Quality Standards for Phosphorus) Regulations 1998 (S.I. No. 258)
European Communities (Quality of Salmonid Waters) Regulations 1988 (S.I. No. 293)
Quality of Bathing Waters Regulations 1992 (S.I. No. 155)
Quality of Shellfish Waters Regulations 1994 (S.I. No. 200)

Table 3.3. Irish secondary water quality legislation applicable to dangerous substances.

European Communities (Control of Water Pollution by Asbestos) Regulations 1990 (S.I. No. 31)
Local Government (Water Pollution) (Control of Cadmium Discharges) Regulations 1985 (S.I. No. 294)
Local Government (Water Pollution) (Control of Hexachlorocyclohexane and Mercury Discharges) Regulations 1986 (S.I. No. 55)
Local Government (Water Pollution) Acts 1977 and 1990 (Control of Aldrin, Dieldrin, Endrin, Isodrin, HCB, HCBD, and $CHCl_3$ Discharges) Regulations, 1994 (S.I. No. 43)
Local Government (Water Pollution) Act 1977 and 1990 (Control of EDC, TRI, PER, and TCB Discharges) Regulations 1994 (S.I. No. 245)
Water Quality (Dangerous Substances) Regulations 2001 (S.I. No. 12)

necessary to have regard to legislation on water supply, in addition to legislation on water quality. Tables 3.4 and 3.5 show the relevant Irish primary and secondary water supply legislation, respectively.

In addition to the primary and secondary legislation, some local authorities have exercised their discretion under Section 21 of the Local Government (Water Pollution) Acts 1977 to 1990, and brought forward bye-laws that apply within their administrative areas. Table 3.6 sets out the bye-laws in place as of 31 December 2000.

Table 3.4. Irish primary legislation applicable to water supply.

Waterworks Clauses Act 1847
Waterworks Clauses Act 1863
Public Health (Ireland) Act 1878
Public Health Acts (Amendment) Act 1907
Water Supply Act 1942

3.4 Transposing the Water Framework Directive into Irish law

Practically all environmental directives contain a provision that requests Member States to transpose the directive's provisions into national law. Directive 2000/60/EC is no different, as Article 24(1) provides that "Member States shall bring into force the laws, regulations and administrative provisions necessary to comply with this Directive at the latest by 22 December 2003". Generally (see above) transposition into national law has to be done by an express binding legislative or regulatory provision. The purpose of this final section is to evaluate the type of legislation required to implement each of the objectives outlined in Section 3.2. In doing so, and given the confines of space, it is not possible to address the transposition of the WFD's objectives individually and precisely. Rather this section points to the issues which should be taken into consideration, the adequacy of existing legislation to address those issues, and any lacunae that may exist which, if ignored, would prevent the proper transposition of the WFD. Before moving to this evaluation, it is

Table 3.5. Irish secondary legislation applicable to water supply.

European Communities (Quality of Water Intended for Human Consumption) Regulations 1988 (S.I. No. 81)
European Communities (Quality of Surface Water Intended for the Abstraction of Drinking Water) Regulations 1989 (S.I. No. 294)
Waste Management (Use of Sewage Sludge in Agriculture) Regulations 1988 (S.I. No. 148)
Environmental Protection Agency Act 1992 (Urban and Waste Water Treatment) Regulations 2001 (S.I. No. 254)

Table 3.6. Local Authority Bye-Laws made under the Local Government (Water Pollution) Acts to address diffuse pollution from agricultural sources.

Cavan County Council (Water Pollution) (Agriculture) Bye-Laws 2000
Cork County Council (Regulation of Agricultural Practice in the Catchments of the River Lee, the River Gradogue and the River Funshion) Bye-Laws 2000
Tipperary (North Riding) County Council (Water Pollution) (Agriculture) Bye-Laws 2000
Westmeath County Council (Water Pollution) (Agriculture) Bye-Laws 2000

necessary to point out some general principles (see also Krämer, 2000) that should be borne in mind in drafting legislation to transpose the WFD.

3.4.1 General transposition principles

3.4.1.1 Inapplicability of certain instruments

As noted above, the European Court of Justice has rejected Member States' attempts to impose the requirements of an environmental directive into national law by means of a multi-annual plan, an administrative circular or similar instrument. The main argument for this position is that, since directives which fix quality standards also give certain legal rights to individuals, most of the provisions of a directive will have to be transposed into national law by a binding provision. Exceptions to this requirement to implement the provisions of a directive by binding national legislation appear to apply only to provisions in respect of the obligations of the Commission, Council, Parliament or other institutions. Thus, there is no requirement for Ireland to implement, by way of binding legislation, the provisions of Article 18 of the WFD, for example, as this relates to the obligation placed on the European Commission to publish a report on the implementation of the Directive.

3.4.1.2 The whole of the territory

Transposition measures must cover the whole of the territory of Ireland. As it appears as though certain responsibilities under the WFD will be allocated to local authorities, it will be necessary for Ireland to ensure that all provisions of the WFD are transposed by measures that cover the entire territory of Ireland.

3.4.1.3 Numerical values

Where EC environmental law, such as the WFD, sets numerical values such as emission limit values, quality standards or targets, Irish legislation will have to adopt these numerical values. The same applies to bans on substances or products.

3.4.1.4 Sanctions

Generally speaking, a correct transposition requires the establishing of sanctions for non-compliance with EC provisions. The WFD, in Article 23, expressly requires Ireland to determine penalties applicable to breaches of Irish transposing measures, which penalties should be effective, proportionate and dissuasive.

3.4.2 The necessity for primary legislation

Directives are not usually implemented by way of primary legislation in Ireland. However, where directives require the incorporation of new and far-reaching concepts or controls into Irish law, primary legislation tends to be used (Scannell, 1995). Thus, for example, the Local Government (Air Pollution) Act 1977, Air Pollution Act 1987, and the Environmental Protection Agency Act 1992, were all enacted, at least in part, to provide a legislative framework for the implementation of certain water quality, air quality and integrated pollution control directives. Perhaps most relevant of all in this context is the

Waste Management Act 1996, which implements the Framework Directive on Waste (Directive 75/442/EEC, as amended by Directive 91/156/EEC) into Irish law.

In bringing forward the Waste Management Bill in 1996, the then Minister for the Environment recognised that the Bill was a "framework proposal which will provide the necessary enabling and regulatory powers to apply and adapt policy measures".[7] Moreover, whilst "fundamental principles" were stated to be clearly established by the Bill, it was envisaged that:

"*Many of the specific measures and obligations for which provision is made, together with many detailed technical standards and administrative procedures, will remain to be applied by way of secondary legislation, which will follow…after the Bill is enacted*."

It would appear that, as with the implementation of the Framework Directive on Waste, a framework Irish Act may be required to provide for the necessary enabling and regulatory powers to apply and adapt policy measures contained in the WFD. This view is supported by the judgement of the Supreme Court in *Meagher v. Minister for Agriculture*,[8] where it was held that if a directive left the determination of matters of principle or policy to Member States, it would have to be implemented by statute: where this is not the case, legislation by regulation is a valid choice of method of implementation. Thus, the identification of five RBDs, two IRBDs (Foyle and Erne), the nomination of county councils as competent authorities, etc. are matters of principle or policy, which would appear to require the enactment of primary legislation.

The case for primary legislation is also strengthened by the necessity to incorporate provisions for the recovery of water service costs, and the obligation to enact "effective, persuasive and proportionate penalties".

Further, given the necessity for water service costs and other water supply issues to be addressed, an amendment to the existing Local Government (Water Pollution) Acts may not be sufficient. Rather, consideration should be given to the promulgation of a Water Management Act, setting out the general principles of river basin management, regulatory consents, competent authorities, water supply and cost recovery, and penalties. The specific measures and obligations arising under the WFD could then be applied through statutory regulations made under the Water Management Act or, in many cases, under existing water quality legislation.

3.4.3 Implementing the environmental objectives

Given the ambiguity of certain of the terminology within the WFD, it is difficult to come to any hard and fast conclusions as to the precise nature of the obligations set out in Article 4. Some general observations can, however, be made.

Some aspects of the objectives set out in Article 4 appear to lack precision, and, therefore, enforceability. Ireland has the option of transposing these obligations in such a fashion as to provide precision and enforceability. This will involve a higher level of environmental protection, which Ireland can validly adopt pursuant to Article 176 of the Treaty. The effect of adopting such a policy would be to delete phrases such as "with the aim of" and simply require the attainment of "good status" by 2015, without exception. The adoption of such a policy will involve greater expense to industry and local authorities, and may not be feasible for those reasons. Therefore, if Ireland wishes to maintain the imprecision and potential non-enforceability of the Article 4 objectives, an almost *verbatim* transposition will be required.

3.4.4 Exercising discretion in implementing exceptions

The WFD contains considerable potential for derogations from its core environmental objectives. If Ireland wishes to transpose these potential exceptions into its national environmental law, then two steps must be taken. First, a policy decision needs to be taken as to whether such derogations should be implemented in principle. This is neither a trivial matter nor a foregone conclusion. An example, which proves this point, is the implementation of the Urban Waste Water Treatment Directive into Irish law.[9] That directive provided scope for the application of a less stringent standard of sewage treatment where "less

7. Minister for the Environment (Mr. Howlin), Seanad Debates, Vol. 146, col. 237.
8. [1994] 1 I.L.R.M. 1.

sensitive areas" were designated. Ireland opted, for reasons of environmental protection, not to transpose those parts of that directive that facilitated the designation of less sensitive areas, and, therefore, excluded the application of a less stringent standard of treatment. However, should Ireland take a policy decision to transpose these derogations into national law, a second step must be taken. This latter phase would involve the drafting of legislation to include all the preconditions necessary to avail of the exception. For example, Irish legislation will have to mandate that, before an extension of the deadlines for achieving the WFD's objectives under Article 4(4) can be validly extended, the following prerequisites are attained:

- no further deterioration occurs in the status of the affected body;
- the inability to achieve the necessary improvements in the status of bodies of water by 2015 must be for technical reasons, disproportionate expense, or natural conditions;
- the extension of the deadline and the reasons for it must be specifically set out in the management plan,
- a summary of measures required and the expected timetable must be set out in the management plan;
- there must be no permanent exclusion or compromise of the achievement of environmental objectives for other associated water bodies; and
- there must be compliance with all existing EC environmental legislation, even when validly extending the 2015 deadline.

3.4.5 Characteristics of River Basin Districts

Whilst many of the provisions of the WFD are repetitious of obligations contained in pre-existing EC legislation, and, therefore, can be presumed to have been previously transposed into Irish law, Article 5 of the Directive makes provision for matters not previously addressed at Community or national level. Consequently, it shall be necessary for Ireland to specifically transpose the requirements of Article 5 in respect of analysing the characteristics of a river basin, reviewing the anthropogenic impact on surface and ground water and engaging in an economic analysis of water use.

3.4.6 Register of protected areas

Under existing legislation, such as the Habitats Regulations (S.I. No. 94 of 1997, as amended) and Quality of Bathing Water Regulations (S.I. No. 155 of 1992, as amended), a considerable number of specially protected areas have been designated over the last two decades. The obligation posed under Article 6 of the WFD appears to amount to little more than a consolidation of all existing special areas covered by Annex IV of the Directive into a single register for each RBD.

3.4.7 Waters used for the abstraction of drinking water

As the provisions of Article 7 of the WFD appear to reiterate an existing obligation on Ireland, it can be assumed that compliance with the standards set down in the current European Communities (Quality of Water Intended for Human Consumption) Regulations 1998 (S.I. No. 177) (that implement Directive 80/778/EEC relating to the quality of water intended for human consumption) will be sufficient to satisfy the requirements of Article 7 of the WFD. With the possible exception of sub-article (3), the establishment of "safeguard zones, no additional legislation would seem to be required in order to implement Article 7.

3.4.8 Monitoring

As observed in Chapter 5 of this study, the monitoring requirements under the WFD require cross-compliance with the monitoring requirements under other EC environmental laws. However, new obligations are introduced in respect of monitoring by Article 10 of the WFD, which will not have featured in either pre-existing EC laws or their implementing national legislation. An example of these new requirements is provided for by the requirement under Annex V for monitoring to take place on a quantitative basis for each element. Consequently, the WFD's approach to quantitative issues will have to be taken on board by policy-makers and the parliamentary draftsmen in framing legislation implementing the WFD.

9. Directive 91/271/EC, *supra* at n.2, originally implemented by S.I. No. 419 of 1994.

Other monitoring issues which will need to be addressed in WFD implementing legislation include frequency of monitoring, and the re-appraisal of existing regulations relating to monitoring, such as the Nutrient Management Plan Consultation Regulations 1998 (S.I. No. 257).

3.4.9 Recovery of water service costs

The WFD, for the first time at EC level, addresses the issue of the recovery of costs incurred in the provision of water services. However, Irish law has made provision for the levying of water charges since the Local Government (Sanitary Services) Act 1962. The difficulty lies in the fact that Irish domestic legislation on the recovery of costs is antiquated and uneven in its application. For example, whilst Section 65A(1) of the Public Health (Ireland) Act 1878 (inserted in Section 7 of the Local Government (Sanitary Services) Act 1962) allows sanitary authorities to make charges for water supplied by it, an urban sanitary authority cannot make a charge in relation to the supply of water for exclusively domestic purposes.

The WFD imposes a range of new obligations in respect of the recovery of water services costs and the broader issue of water conservation. Consequently, amendment of the existing water supply legislation will be required before Ireland will be in a position to properly transpose all its obligations under Article 9 of the WFD into national law.

3.4.10 Combined approach for point and diffuse sources

Legislation in respect of setting EQSs and ELVs has been in existence in Ireland for over 15 years. However, as with the parent EC legislation, what has been missing heretofore has been the real, as opposed to theoretical, co-ordination of the EQS and ELV regimes. In essence, the two systems have been operating independently of each other, with one concentrating exclusively on the level of pollution from known locations, and the other assessing only the quality of the receiving water.

In order to comply with its obligations under Article 10 of the WFD, Ireland will have to amend, to some extent, its existing legislation to reflect this duality of approach. More appropriately, Ireland will actually have to establish EQSs for bodies of water, a power which it has had for years but which, at least in respect of the dangerous substance regulations, it has been slow to exercise.

3.4.11 Programmes of measures

Article 11 sets out, in considerable detail, the contents of such programmes of measures. Ireland's legislation implementing Article 11 must replicate all this detail, and require its inclusion, in order to properly transpose this obligation into national law.

In addition, if the responsibility for drawing up programmes of measures is to be decentralised to those local authorities comprising the RBDs, it will be necessary for the primary legislation providing for matters of policy and principle to delegate this programme-making power to the local authorities. All other matters of detail can be provided for in delegated legislation, including the 2009 and 2015 deadlines in respect of establishing and reviewing these programmes of measures.

One important aspect of the programme of measures is the requirement to have a system of prior regulation of discharges to water bodies. Prior regulation is a generic term used to describe any form of permission, licence or permit which must be obtained from a statutory authority before certain activities liable to affect the environment may be lawfully undertaken (Scannell, 1990). Pursuant to the Local Government (Water Pollution) Acts and regulations made thereunder, local authorities already possess the power to grant trade and sewage effluents, and, therefore, prior regulation does exist for at least some discharges. However, the discharges that will require prior authorisation pursuant to the WFD are much more numerous, and, therefore, Ireland will have to modify its existing prior authorisation process to reflect this widening of the regulatory parameters. Finally in this regard, local authority bye-laws, such as those listed in Table 3.6, appear to be capable of being included in a programme of measures, and this should be made clear in any implementing legislation.

3.4.12 River Basin Management Plans

One of the few areas of principle or policy arising under the WFD that is already addressed by Irish primary legislation is water management planning. Local authorities already possess the power, under Part VI of the Local Government (Water Pollution) Regulations 1978 (S.I. No. 108), to make water quality management plans (WQMPs). While the content of RBMPs made pursuant to Article 13 of the WFD will be much more intricate than indigenous WQMPs, and indeed will cover certain water supply issues, the existence of local authority water planning powers should ease the transposition burden. Effectively, all that is required is the amendment of the name of the plan, and regulations stipulating the contents of such plans, including the inclusion of the prescribed matters in order to qualify for one of the WFD's various exemptions. Given the probability that a number of local authorities will liase to form an RBMP, legislation should adopt the type of regional planning scenario already provided for in the Planning and Development and Waste Management Acts. Implementing legislation should also include reserve powers in case of default by one or more local authorities, which should circumvent the types of difficulties faced prior to the adoption of the Waste Management (Amendment) Act 2001.

3.4.13 Public information and consultation

Scannell (1990) noted in respect of the making of development plans (land use planning), water and air quality management plans that, "extensive provision for public participation is made in legislation". Consequently, it would appear that Ireland has provision within existing legislation of affording adequate public information and consultation in respect of environmental management plans. The transposition of Article 14 of the WFD should, therefore, not present Ireland with any significant difficulty. In deciding upon the exact method of public information and consultation, Ireland has the modern model of equivalent provisions in the Planning and Development Act 2000. Finally, to ensure complete compliance with both the WFD and the Access to Information on the Environment Directive (90/313/EEC) it would be advisable to make all legislation transposing the WFD amenable to the application of the Freedom of Information Act 1997.

3.4.14 Reporting

Since the mid-1970s, almost all EC environmental directives have contained a provision requiring Member States to report on the implementation of the directive. Consequently, Article 15(3) on the submission by Ireland of interim reports describing progress in the implementation of programmes of measures should prove unremarkable. Similarly, the requirement to submit copies of RBMPs, analyses under Article 5 and monitoring programmes under Article 8 should be capable of being transposed into Irish law with little or no difficulty.

3.4.15 Repeals and transitional provisions

In order to ensure that Ireland does not continue to apply regulations that implement repealed EC Directives, domestic regulations should reflect the provisions of Article 22 in respect of repeals and transitions as accurately as possible.

3.4.16 Penalties

Article 23 requires Ireland to determine penalties applicable to breaches of national provisions adopted pursuant to the WFD. Such penalties must be "effective, proportionate and dissuasive". If Ireland is to determine truly dissuasive penalties, the creation of an indictable offence for breach of national provisions implementing the WFD may be required. Recent environmental statutes, such as the Environmental Protection Agency Act 1992 and the Waste Management Act 1996, have implemented such penalties. In order to avoid any constitutional doubts, it may be necessary to include such penalties in primary legislation.

3.5 Conclusion

As the WFD is, in many respects, a consolidation and updating of pre-existing measures, the task of transposing the Directive into Irish law should not be an unduly onerous one. If the basic policies and principles are implemented by way of primary legislation, the majority of the provisions contained in the WFD can be implemented by way of secondary legislation made under either a new Act or under existing legislation. It is, however, necessary to point out that the WFD does contain new and far-reaching concepts and controls, and some care will need to be

taken to correctly transpose these into Irish domestic law. In particular, concepts such as a truly combined approach to pollution, and the unwieldy exemptions from the Article 4 objectives may be highly relevant in this regard.

It is encouraging that, despite the fact that the Directive has only recently come into force, Ireland has already begun the implementation process. Two sets of water regulations state that they are giving effect to the provisions of Directive 2000/60/EC: the Water Quality (Dangerous Substances) Regulations (S.I. No. 12 of 2001) and the Urban Waste Water Treatment Regulations (S.I. No. 254 of 2001) (see also reference given in Section 1.4 of this report to the activities of the Department of the Environment and Local Government WFD Implementation Group). Given current indications of a political will to implement the WFD, this early start to transposition augurs well for the successful attainment of the objective set in Article 24 of the Directive and that Ireland shall bring into force the laws, regulations and administrative provisions necessary to comply with this Directive by 22 December 2003.

4. Initial Technical Tasks

4.1 Introduction

The Water Framework Directive (WFD) requires Member States to establish a *programme of measures* to ensure that all waters within a river basin achieve the objective of *good* water status by December 2015. In order to achieve that goal there is a need to develop protocols for a number of technical tasks. These are:

- the classification of waters depending on characteristic typologies;
- the establishment of criteria and reference conditions for the determination of quality status for all elements.
- the assessment of anthropogenic risks to waters;
- an economic and impact analysis of water use; and
- an effective monitoring programme.

These tasks are not independent of each other. For example, effective monitoring requires robust standards, which may vary depending on the prevailing physico–chemical and morphological characteristics. An assessment of risk and river basin management requires an understanding of the pressures on waters and the importance of real and indirect economic costs.

The requirements for and the current practice of these technical tasks are the subject of this and the following chapter, where we focus particularly on monitoring. This division of monitoring from the other issues does not suggest that it is a separate process. A distinction can, however, be made in that monitoring is a process designed to assess anthropogenic impact. It alludes to but does not drive underlying pressures. It is also inextricably linked in a practical way to characterisation of waters. In addition, there is an extensive history and often well-established methodology for monitoring in Ireland. In contrast, many of the other technical tasks required by the WFD are new or untested.

4.2 Characterisation of waters

Characterisation of water bodies and determination of water *typology* is fundamental to the operation of the WFD. The design of monitoring programmes, the overall scale of monitoring required and the assessment of quality status depend to a considerable extent on the outcome of the categorisation process specified in Annex II. Of particular importance is the setting of *type-specific reference conditions* (Annex II, 1.3). These must be developed for each water body *type*. These reference conditions will dictate the design of monitoring for the category as a whole. Consequently, the total time and effort to be expended on the design and conduct of monitoring activities will increase with the number of water body types identified. There is a compelling argument to avoid unnecessary sub-division in order to keep the total number of typologies to a minimum. It is also necessary to include an ecologically meaningful number of water types that need to be assessed. Annex II of the WFD provides two options for the characterisation of surface waters (System A and System B). There is general consensus throughout Europe that System A is not sensitive enough and that System B, which allows flexibility to the designation of typologies, will be adopted. It is, however, easy to accumulate hundreds of seemingly relevant typologies. This is likely to be more of a problem in inland waters than coastal ones. Indications from the literature (Boelens *et al*., 1999) suggest that the benthic communities found in coastal waters along the Irish Sea and Celtic Sea coasts of Ireland can be grouped into as few as three to four community types.

It is important to define clearly the objectives of the exercise. This is the provision of a scientific basis for setting type-specific reference values that are broadly applicable within and among water bodies of a particular type. Difficulties arise, however, because the *quality elements* used to classify *ecological status* span hydromorphological, chemical and physical, as well as biological, elements. In view of the ecological focus of the Directive, and the importance of biological elements in determining ecological health, it is recommended that:

for categorisation the greatest weight be given to factors that have a major role in determining and regulating biological communities.

It is evident that categorisation is both a critical and difficult process and that it should involve the most experienced national experts. The categorisation of waters is the subject of North–South working groups, with the intention that this should lead to a common scheme for the entire island of Ireland. Some observations on candidate factors for lakes and rivers are given in Table 4.1 and for transitional and coastal waters in Table 4.2. At the time of writing discussions on typologies were ongoing.

Definition of typology will require refinement in the early stages of the implementation of the WFD. Current EU-funded projects include work on establishing workable typologies and quality criteria for shallow and deep lakes and for modified waters. In Annex V 1.2.5, the WFD provides definitions of *ecological potential* for *heavily modified* waters. For some canalised rivers and impoundments, the recognition of *natural* compared with heavily *modified* will be easy. For many waters, however, it will not be possible for such clear distinction to be made. Notwithstanding pedantic argument, in practical terms this should not be a major conundrum as reasonable interpretation of Annex V 1.2.5 is sufficiently straightforward. The North–South working group have agreed that artificial impoundments of rivers should be treated as being within the definition "heavily modified" under Article 2(9) of the WFD.

Table 4.1. Principal factors to be considered in categorising Irish surface inland waters.

Characterisation factor	Comment
Rivers	
Longitude* Latitude*	Altitude ranges as defined in System A. The relevance of latitude and longitude to be investigated through field trials and consideration of the recommendations of the EU and EPA reference conditions projects.
Geology*	Solid geology – a single category for each of calcareous and siliceous. Drift geology – distinction between peat and non-peat.
Catchment area* Geography	Area categorised using descriptors in System A (10–100 km^2; 100–1000 km^2; 1000–10,000 km^2; >10,000 km^2) (the latter only the Shannon) and further study for value of actual size. Distance from source important.
Morphology/hydrology Chemistry	Mean width, mean depth and river discharge (flow) important. Conductivity range: <50 µS cm^{-1}, 51–150 µS cm^{-1}, 151–600 µS cm^{-1}, >600 µS cm^{-1} thought relevant by N/S TAG. (n.b. EU ECOFRAME project on shallow lakes recommends <100, 101–800 and >800 µS cm^{-1}).
Lakes	
Longitude, latitude and altitude*	See above.
Lake area*	Relevant categories <2 ha, 2–50 ha, 51–100 ha, 101–1000 ha, 1001–10000 ha, >10000 ha.
Depth*	Mean depth: data for mean depth will need collation and/or models (see Chapter 5).
Residence time	Residence time is likely to be critical for lakes and the absence of reliable residence time for many Irish lakes requires collaborative research to address this as a matter of priority.
Geology	Conductivity defines mixed geology lakes and saline incursion.
Other issues	Colour in Irish lakes is clearly important in defining typology, but may be covered by inclusion of drainage from peatlands. Specific lake types such as turloughs, spring-fed lakes, saline lakes, large lakes will need to be addressed separately in terms of hydromorphological typologies. There is a need to collate relevant hydromorphological data for lakes covering a wide geographical range with a view to statistical interrogation.

*Obligatory factor.

Table 4.2. Principal factors to be considered in categorising Irish transitional and coastal surface waters.

Characterisation factor	Comment
Transitional waters	
Latitude* and longitude*	Latitude and longitude are of little relevance in determining the characteristics of Irish transitional waters. They may, however, provide a basis for standardising classification on a broader, i.e. regional, basis possibly including parts of the UK and continental mainland.
Tidal range* Salinity* Mixing characteristics Shape	This group of factors, especially the shape (e.g. longitudinal profile) and salinity/mixing profile, should provide a sufficient basis for dividing Irish transitional waters into a small number of *types*. Propensity for salinity stratification warrants serious consideration as a factor determining boundaries between different transitional water body types.
Coastal waters	
Longitude* Latitude*	Latitude and longitude are relevant factors in determining the biological characteristics of Irish coastal waters, especially the occurrence of planktonic and pelagic species. They may also provide a basis for standardising classification on a broader, i.e. regional, basis possibly including parts of the UK and continental mainland.
Tidal range* Salinity* Current velocity Mean substratum composition Wave exposure	Outside areas influenced by freshwater (transitional waters), salinity is a minor factor in determining the characteristics of Irish coastal waters. Tidal range may be important in the sense that areas with a low tidal range often have strong tidal currents (e.g. SW Irish Sea). Thus, tidal range is linked to current velocity. Of the remaining *optional* classification factors for coastal waters listed in the Directive, the most relevant is the substrate composition; substrate hardness and particle size reflect the dynamics of the area and largely determine the benthic fauna. Wave exposure is a key factor in intertidal and near-shore tidal areas.

*Obligatory factor.

4.3 Reference conditions

Implementation of the WFD and determination of departure from a status of *high quality* of waters is critically dependent on the recognition of, and agreement on, a definition of undisturbed reference state. Previous classification schemes such as that developed by the OECD (1982) make comparisons *among* water bodies and assign quality standards based on fixed boundaries. The current EPA assessment of trophic categories of Irish lakes, for example, considers lakes with a mean total phosphorus concentration of >20 µg l^{-1} as *eutrophic* and *unsatisfactory*. Lakes with a mean concentration <20 µg TP l^{-1} are deemed *mesotrophic* and *satisfactory*. This *fixed boundary* approach has been criticised as not taking into account (a) natural variation around the mean (Premazzi and Chiaudani, 1992), and (b) the natural baseline condition that would be expected in the absence of anthropogenic disturbance (Moss *et al.*, 1996). *Reference* conditions would be expected to vary among water bodies and render common targets irrelevant. The quality scores and ratios required by the WFD (Annex V) require interpretation of measurements of quality elements to be made in relation to changes from *undisturbed* conditions. This requires a fundamentally new approach to the classification of water bodies for which a methodology is poorly or just newly developed.

Options for establishing reference conditions include:

- the determination of values of quality elements in water bodies considered to be, or almost to be, in pristine condition and within robustly defined typologies. Assessment of potential change may then be compared with the relevant reference condition, taking into account natural variability (also see US EPA method below);
- the determination of historical conditions through palaeolimnological techniques (e.g. see Rippey and Anderson, 1996);
- the estimation of previous impacts through *hindcasting* models (e.g. Johnes *et al.*, 1994);
- the use of historical records for the description of quality elements in waters and their catchments. This may be of particular importance for hydromorphological status; and

- the determination of existing distributions of quality states of water bodies, and the subsequent assignment of reference sites based on judgements of the probability of sites conforming to reference standards. For example, the 25 percentile of total phosphorus for all lakes or rivers or 75 percentile for waters considered high quality is used for nutrient assessment by the US EPA (2000a,b) as the boundary for reference sites.

Research is required urgently to determine the feasibility of determining reference conditions for all water bodies. The use of reference states, regardless of how they are derived, should be statistically reliable. The incorporation of reference states into ecological assessment should follow a BATNEEC (Best Available Technology Not Entailing Excessive Cost).

Annex II 1.3(vi) allows for the exclusion of an element where reliable type–specific reference conditions are not available owing to high degrees of natural variability. The WFD does not require the impossible, or unduly costly, estimation of reference conditions.

4.4 The assessment of anthropogenic risk to waters

There are no universally accepted definitions of environmental risk (O'Riordan, 2000). The WFD, however, requires both *identification of pressures* (Annex II, 1.4) and *identification of risks* (Annex II 1.5; Annex V, 1.3.2). Indeed the need for *operational monitoring* (see Chapter 5) is to be determined from risk assessment and the *programme of measures* (Article 11) clearly demands *management* of risk. Generally understandable definitions of risk applicable to the WFD are important. Risk is defined in the Oxford dictionary as *the chance of hazard or of bad consequences.* The interpretation of risk in relation to current Statutory Instruments appears to be more related to change already effected (see Chapter 5) in relation to urban waste water. However, models used to predict loss of nutrients from land to water in Ireland, as used by Daly *et al.* (2000) and Kirk McClure Morton (2001), seem much better examples of risk assessment applicable to the WFD. The modelling approach to estimating nutrient loading (Johnes *et al.,* 1994) from the quantification of land use also appears to be an appropriate tool for risk assessment (Irvine *et al.,* 2001a). In terms of the WFD, the terminology of Smith (1993) would seem to be a correct interpretation:

"**To manage a risk or hazard it must be identified, usually by some form of measurement and quantification, and then assessed to estimate the probability of that risk posing an actual threat to society, before a strategy to minimise it can be formulated."**

The recent work on catchment monitoring programmes and management systems for Lough Derg and Lough Ree (Kirk McClure Morton, 2001) identified pressures and, through quantification, the risks of nutrient emissions to surface freshwaters from a range of activities. Other catchment programmes such as the Lough Conn/Mask catchment group, the Lough Leane catchment project and the Three Rivers Project identified similar threats. The most important of these are:

- diffuse nutrient emissions from agriculture, forestry and degraded peatlands;
- urban waste water treatment plants;
- seepage from septic tanks;
- licensed industry

In Ireland the single greatest risk to the ecological status of the quality of inland waters arises from diffuse nutrient transport from grasslands (e.g. Allott *et al.,* 1998); although there are serious (and arguably less defendable) shortfalls in the management of point sources. The identification of pressures, assessment of risk and programme of measures required by the WFD appear to require a radical new approach to catchment management.

The recent river basin projects funded by the Department of the Environment and Local Government (DELG) have provided an important start for effective catchment management that will reduce pressures on waters. The next generation of river basin projects provides the opportunity to develop strategies of catchment management that will protect and improve the ecological status of Irish waters. The extent of current pressures and the inherent complexities in catchment management should prevent any complacency if the target of *good status* as defined in Annex V is to be achieved for the majority of waters by

2015. A large EPA/*Teagasc* project investigating the impact of agriculture on phosphorus and nitrogen loads to waters is currently under way. This is an important project in quantifying nutrient loss to water and recommending strategies to reduce and mitigate the effect of diffuse nutrient loss.

Land use is clearly important for the identification and estimation of the magnitude of pressures. Techniques for the identification of land use are well developed. These include remote sensing from satellites and low-flying aircraft and the collation of Census data. In Ireland, Census data of livestock are available on a District Electoral Division (DED) basis. This, however, seldom coincides with catchment boundaries. Statistics from individual farms are collected for participants in the Rural Environmental Protection Scheme (REPS) but are not generally available owing to concerns of protection of confidentiality for the citizen. Emissions from licensed industry and sewage treatment plants are available from licensing authorities. Data on chemical fertiliser sales are only available on a national basis. Collation of all land-use data is a useful tool for the identification of pressures and is of potential importance for the quantification of point-source and diffuse nutrient emissions. However, mathematical models may not provide accurate estimations of nutrient supply when applied across a range of catchments (Irvine *et al.*, 2000), although when validated within a particular catchment appear reliable (Johnes *et al*., 1994). For some rivers, the DELG river basin projects have collated extensive data sets of nutrients at high temporal resolution. These are potentially very important for the development of nutrient export models for Irish catchments.

It is recommended that further investigation of catchment nutrient export models are undertaken using the data sets collected by the recent DELG river basin projects. High quality models require more precise information on land use.

While nutrient load may be prevalent, other risks to the ecological status of surface waters and the chemical and quantitative status of ground waters occur. In the long-term, these may be particularly difficult to incorporate into a programme of measures as required by Article 11 of the WFD. These include:

- species introductions;
- the alteration of groundwater levels;
- land and river drainage programmes;
- disturbance of wetlands, including protected areas; and
- over-exploitation of fish stocks

While there have been major hydromorphological changes to inland waters in the comparatively recent past (the WFD must refer to a period of anthropogenic impacts within the last 100 years or so; Neolithic forest clearance is presumably not included) these are less prevalent now. Pressures from land use can pose risks to terrestrial systems and species that have an inherent reliance on water. This includes impacts from industrial, housing and road developments (e.g. drainage affecting turloughs and road construction affecting wetlands). Coastal areas have risks from port and marina developments and dredging.

One very important risk to aquatic ecological status unrelated to land and coastal management is the introduction of species. Inland waters of Ireland have a very restricted natural fauna compared with the rest of Europe. Possible impacts from aliens include: the spread of roach (*Rutilus rutilus*) since the 1960s, which may significantly affect trophic interactions (and hence ecological status) in lakes, canals and, to a lesser extent, rivers; the impact on ecosystem integrity of the amphipod *Gammarus pulex*; and the recent and dramatic colonisation of the Shannon and Erne systems by the zebra mussel (*Dreissena polymorpha*). The latter example highlights that these threats still occur. The impact on ecological status by these organisms is not quantified and provides a difficulty for the classification of waters.

There is a requirement to address the consequences of species introductions for the interpretation of the WFD and, in particular, the relevance this has to measures of undisturbed conditions.

4.5 Economic analysis and impact assessment

4.5.1 Economic assessment

Economic analyses of water uses, in conjunction with reviews of the impact of human activities on water quality (Article 5), are central to the policies underlying the Directive. These analyses and reviews are of particular significance in ensuring that Programmes of Measures developed in accordance with Article 11 will achieve the Environmental Objectives set down in Article 4. In this context, the provisions of Article 4(5) that in certain cases, and where justified on both environmental and socio–economic grounds, the negative impacts of human activities may be tolerated, are especially relevant.

These analyses and reviews are clearly important when estimating costs associated with *water services*, for example where costs are to be recovered in accordance with Article 9. Estimations of environmental and resource cost (also referred to in Article 9) are, however, far more complicated than those associated with well-defined activities such as water abstraction, supply and discharge of waste water. They require estimates of costs that are relatively easy to quantify (e.g. health, economic) and those that are not (e.g. aesthetics, biodiversity), thereby enabling the proper internalisation of costs as a means to determine the most cost-effective use of resources. A pricing policy that fails to cover costs promotes the overuse of water resources and environmental damage (Kahlenborn, 1999).

The guidance on economic analysis given in Annex III focuses on the products of the analysis but nothing is said about the procedures to be applied. The guidance is confined to economic analyses for purposes of Articles 9 and 11. With respect to Article 11, the guidance focuses exclusively on the analysis of the cost-effectiveness of measures to deal with the negative impacts of human activities. It does not suggest that such analysis should also be used to determine the need for measures implied under Article 4(5), although it seems logical that this should be the case. **This is an important point that warrants early clarification**. Analyses need to have well-defined boundaries clearly indicating the scope of issues to be addressed.

It is implicit that all water uses should be subject to economic/impact analysis, including abstraction for either domestic or commercial water supply, waste disposal and presumably any practice or development that affects water quality including water-based recreational and commercial activities. The fact that Member States 'shall take account of the principle of recovery of the costs of water services' (Article 9(1)) provides a hint of possible derogation on this point in specific cases. It does not, however, obviate the need for economic analysis. Article 9 also contains specific requirements regarding the recovery of costs, with reference to the polluter pays principle. This analysis is required by 2004, with implementation into policy and practice by 2010. Currently, costs for IPC licences charged by the EPA are used to support administration, enforcement and monitoring. These charges relate to the operation involved in licensing and do not provide any funds for the general improvement of water services.

For purposes of assessing the need and options for measures to prevent or mitigate unacceptable impacts on water quality, economic analysis may involve comparisons between the environmental costs of these impacts and the socio–economic costs associated with removing or mitigating the causes of the impacts. The valuation of aquatic systems in terms of ecosystem services, biodiversity and maintenance of renewable resources is a relatively new, and somewhat controversial, science. In the case of waste treatment/disposal and other practices essential to society, the analysis will also involve comparing the environmental, resource and socio–economic costs of current practices with those of alternatives. At present, the rather complex procedures for such analyses are not standardised and in Ireland there is limited experience of their use.

This suggests that techniques suited to the requirements of Article 9 will need to be developed. As the analyses and reviews must be completed by the end of 2004, the task is formidable.

While in principle the operation and economic management of the more well-defined water supply and waste disposal services should be straightforward, responsibilities for water distribution are fragmented. Thirty-four county and city authorities have overall statutory responsibility, while 54 urban districts manage water supply,

sewage collection and treatment facilities. There are also many small, highly varied, rural *Group Schemes* that provide water services. Since 1998, County Councils have been required to develop strategic rural water plans to co-ordinate and improve inter-connections between public and group schemes. Implementation of policy and distribution of funds for water services is the remit of the DELG. Substantial EU co-funding that has helped to develop the water infrastructure (£IR 220 million was spent in 1999) will be curtailed in the future, although under the National Development Programme it is anticipated that about £IR 2.9 billion will be spent over the next 6 years (DELG, Annual Report 2000). This reflects the continuing need for an effective water services infrastructure. While these investments will aid progress towards cost effectiveness, recent reports (OECD, 2000) recommend increased public–private partnerships (PPP) and a more co-ordinated approach to water management. There has been progress in the application of the PPP approach in recent years for urban waste-water treatment systems in Dublin (Ringsend), Clonmel and Limerick.

4.5.2 Impact assessment

In the context of the present report, perhaps the most relevant aspect of the economic/impact analysis is the role to be played by *surveillance monitoring* in '*supplementing and validating the impact assessment procedure detailed in Annex II*'. Clearly, the information base on the impacts of human activities on water quality in Ireland is incomplete.

If *surveillance monitoring* is to make a genuine contribution to filling gaps in knowledge concerning the location, nature and extent of impacts in time for the analyses to be complete in just over 3 years time, *surveillance monitoring* activities need to be expanded as a matter of urgency.

Possibly the most crucial determination to be made when reviewing information on the status of surface water bodies, and the human pressures to which they are subjected, is not so much the existence of, or susceptibility to, an impact, but the significance of the impact to the water body as a whole. It will, for example, be important to develop rational and pragmatic criteria for identifying circumstances where the scale and duration of impact, and consequently the ecological risks, are trivial. Similar criteria are needed in identifying cases of pollution, so that the concepts of *harm* and *impairment* contained in the definition of pollution (Article 2) are applied in a common and realistic fashion. Much will depend on how the terms *significant anthropogenic pressures*, *significant [point source/diffuse] pollution* and *significant anthropogenic impacts* (Annex II, 1.4) are interpreted in practice; these terms have both environmental and socio–economic dimensions. Therefore:

It should be established as quickly as possible whether these interpretations are to be made at national or Community level.

In cases where impacts are deemed significant, or in areas deemed susceptible to pollution or otherwise unlikely to meet the requisite environmental objectives, *operational monitoring* must be carried out to assess whether or not the measures introduced to prevent or mitigate the impacts are successful. The ability to carry out such monitoring will depend on the number of situations to be monitored (i.e. logistical factors), the availability of suitable methodologies both for sampling and data interpretation and, inevitably, the scientific resources allocated. A relevant consideration in this regard is that the magnitude, geographical extent and duration of impact must be such that the condition can be detected and accurately quantified using routine methods.

4.6 Conclusions

A number of initial technical tasks are identified as particularly important in preparation for the WFD. These are:

- options for determining statistically robust reference conditions require further research. This is a large, but fundamental, task for implementation of the WFD;
- collation, in a co-ordinated manner, of historical data of potential use for the identification of reference states and monitoring;
- collation of data and supplementary data collections to determine residence times of lakes for which surveillance or operational monitoring will occur;

- research into risk, impact and economic analysis applicable to the WFD;
- the formulation of policy on how alien introductions affect interpretations of quality;
- a concerted effort to implement surveillance monitoring in order to fill gaps in knowledge that will hinder assessment of ecological status. This is very much linked with the requirement to research reference conditions; and
- clarification at an EU level of the definitions of words or phrases such as *harm, impairment, significant anthropogenic pressures*, *significant [point source/diffuse] pollution* and *significant anthropogenic impacts*.

5. Monitoring

5.1 General introduction

This chapter considers the need to monitor surface and ground waters. The chapter begins with some general considerations and then deals in more detail with many of the salient features relevant to the monitoring of surface freshwaters, estuarine (transitional) and coastal waters, and ground waters. There are many issues in common among the different media; the relative significance of which can vary. Monitoring presents particular challenges to *Competent Authorities* and the need for well-designed programmes is frequently made. Even elegant monitoring regimes will be of little overall use for the implementation of the Water Framework Directive (WFD) if not matched with effective strategies for data management and dissemination. Section 5.7 addresses this point. This chapter focuses on monitoring in the Republic of Ireland and the preparation for implementation of the WFD. It does not consider issues relating to monitoring of *modified waters* as separate from other monitoring. An overall view is not yet available on what does and does not constitute a modified water in terms of the WFD, although this forms the topic of a special working group of the EU initiative to develop a *Common Strategy for the Implementation of the Water Framework Directive.* A defined distinction would, in any case, be unlikely to alter the overall considerations necessary for development of an effective monitoring strategy.

Under Article 8, the WFD requires monitoring programmes in order to establish a coherent and comprehensive overview of water status within each River Basin District (RBD). The presentation of monitoring results is to be included as part of the River Basin Management Plans (RBMPs) (Article 13 and Annex VII). The WFD requires implicitly a more co-ordinated approach to water monitoring than heretofore. Each type-specific water body must be subject to *surveillance* monitoring, and where necessary *operational* and *investigative* monitoring, involving sets of measurements designed to assess ecological quality and risks to human health. This calls for a balanced and consistent approach to sampling water bodies in a particular category, particularly with respect to temporal and spatial coverage, as well as common reporting procedures and timeframes. Good planning and co-ordination can achieve considerable economies in the use of equipment, personnel and data management facilities.

Annex II makes specific reference to the establishment of *values* for quality elements. This suggests strongly that a quantification of elements is required in order to set, not just baseline conditions, but also the determination of relative departure from the baseline as required in Annex V, 1.4.1 (ii). Monitoring, in general, would, therefore, appear to require a quantitative approach for each element. The development of guidance on monitoring forms part of the EU *Common Strategy* discussions. A "state of the art" report from this group was planned for January 2002.[1]

5.2 Natural variation

A novel feature of the WFD is that the assessment of biological conditions is based on the presumption that natural, *undisturbed* conditions can be described and quantified. This, combined with the requirement to measure departures from natural conditions on a scale of 1–10 (Annex V, 1.4) presents a major challenge.

In the absence of human intervention, even when climate is relatively stable, most biological entities and processes are subject to wide variation. Complex natural cycles within species, interactions between populations, food chain relationships, competition, disease and other factors give rise to a significant degree of variation on scales of years, decades and longer. Climatic influences, especially during periods of climate change, accentuate this variation with the result that biological conditions are inherently difficult to predict. As for the past, it is hard to imagine any time when a particular ecosystem, or component thereof, was stable; change is a natural and essential feature of biological systems. The dynamic nature of ecosystems is a tenet of ecology. The adage that *lakes are*

1. Minutes of the first meeting of the Work Group monitoring, held 26 June 2001.

young and rivers are old illustrates the temporary nature of lakes, and the meandering back and forth of a river in its floodplain is a feature learnt early by students of geography. Marine systems change on a daily basis. Many biologists subscribe to the view that, at best, biological conditions can be described in terms of a range of qualities or values. Where the 'normal' range spans, for example, several orders of magnitude, even a change of several hundred percent may be undetectable.

Such difficulties are likely to arise with all biological elements to be monitored, irrespective of the parameters chosen to represent those elements (see Box 5.1). It remains to be seen whether or not the inter-calibration exercise envisaged in Annex V, 1.4.1(iv), as a means of harmonising class boundaries for the various quality elements, will assist in determining the normal *status* of waters.

Box 5.1

Exclusions owing to high natural variability

The Directive anticipates problems in setting type-specific reference conditions owing to high natural variability (Annex II, 1.3 (vi)). It is clearly important that measurements of change in ecological quality elements are relevant and reliable. Where judgements on water quality may trigger costly remedial measures, there must be full confidence in the numerical indices that provide the basis for such decisions.

In the absence of a sound scientific foundation for setting *type-specific reference* conditions for a *quality element* in transitional or coastal waters, that quality element should, in accordance with Annex II, 1.3 (vi), be excluded from the assessment of quality status for the surface water type concerned, pending research to resolve the uncertainty.

5.3 Monitoring programmes

5.3.1 Three tiers of monitoring

The WFD requires that monitoring provides a coherent and comprehensive overview of ecological and chemical status within each river basin and shall permit classification of water bodies into five classes consistent with the five definitions of *high*, *good*, *moderate*, *poor* and *bad*. The goals of monitoring are quite well defined, while decisions by Member States will be required in order to determine spatial and temporal scales of sampling, select parameters for biological elements and establish acceptable methodologies for collection and analysis of data. Three tiers of monitoring are required.

(i) Surveillance monitoring is to be undertaken to provide information for:

- supplementing and validating the assessment of impacts;
- the efficient and effective design of future monitoring programmes;
- the assessment of long-term changes in natural conditions; and
- the assessment of long-term changes resulting from widespread anthropogenic activity.

This level of monitoring is intended to provide an *overview* of ecological states within each RBD. It should include a sufficient number of sites to provide an assessment of the overall surface water status within the catchments of the RBD. Quality elements to be included are parameters indicative of all biological, hydromorphological and general physico–chemical elements identified in the Directive.

(ii) Operational monitoring will be undertaken in order to establish the status of bodies identified as being at risk of failing to meet their environmental objectives and to assess any changes in the status of such bodies resulting from the programme of measures. Monitoring is required to be at such an intensity in order to be able to assess the magnitude and impact of the environmental pressures. Elements required for inclusion in operational monitoring are (a) parameters indicative of the hydromorphological and biological quality element, or elements, most sensitive to the pressures of which water bodies are subject and (b) priority substances and other pollutants discharged in significant quantities.

(iii) Investigative monitoring is to be carried out where (a) the reason for any exceedances of standards is unknown, (b) where surveillance monitoring indicates that environmental objectives are not likely to be achieved, and where operational monitoring has not already been established, in order to ascertain the causes of a water

body failing to achieve the environmental objectives and (c) to determine the magnitude and the impact of accidental pollution.

While the overall objectives of monitoring are clear, the details of how to respond to these demands are not. Most attention in Ireland has, so far, been given to surveillance monitoring: the criteria for site selection, frequency of monitoring, the choice of elements. While these important issues, discussed further below, require careful resolution and relate strongly to decisions on *typology*, surveillance monitoring may turn out to be a more straightforward issue, and with less demands on resources, than operational monitoring. The need for operational monitoring to be carried out on all bodies of waters identified as being *at risk* of failing to meet their environmental objectives could have huge implications for Ireland. It could be argued that most of lowland Ireland is at risk from nutrient enrichment (see Chapter 4.4 and Irvine *et al.*, 2001a). On the other hand, it is possible that many of the requirements of surveillance and operational monitoring could be met within a single well-designed and managed, programme. The WFD does not preclude this. For operational monitoring, each quality element will require the use of control (reference) sites which would logically be the same as those established for purposes of surveillance monitoring. Where programme managers adopt this approach, the proximity of sampling sites will be an important factor in site selection. If individual surveys can be designed to meet all WFD monitoring requirements in the areas concerned, there will be considerable savings in scientific and technical resources.

It is recommended that *surveillance* and *operational* monitoring programmes are designed and managed in parallel, with a view to minimising the number of sampling sites and surveys necessary to meet the data requirements of the Directive.

5.3.2 Selection of sampling sites and quality elements

The guidance on sample site selection given in Annex V of the WFD reveals little about the appropriate distribution or density of sites to be sampled. It is implicit, however, that not all water bodies need to be covered by surveillance monitoring and that the status and trends within an RBD may be established by monitoring a selected group of water bodies representative of those areas as a whole.[2] It is not clear, but it is likely, that this includes examples of each typology (see Section 4.2).

The *elements* to be monitored are prescribed in Annex V. Whereas many of these are already included in existing national monitoring programmes, there are important exceptions. For example, existing programmes in lakes and transitional waters do not measure changes in benthic invertebrate communities or the extent of shoreline macroalgae or angiosperms. Monitoring protocols for these elements will need to be developed, preferably adopting common procedures for the entire EU area. While there is no doubt that Ireland has the necessary expertise to design and implement a comprehensive monitoring programme, the requirements of the WFD are not sufficiently precise to assess the applicability of many existing monitoring procedures. The need to measure all elements, for all purposes in all typologies of waters is uncertain. Furthermore, it is uncertain if the present practice of excluding measurements of certain pollutants on the grounds of technical difficulties will be acceptable.

While the elements required to be monitored are listed in Annex V, the details of what is to be measured are not, as Member States are required to "monitor parameters which are indicative of the quality element". For some elements local circumstances may render the precision of data collected to be ecologically meaningless (see also Section 5.2).

Careful interpretation of Annex V is recommended in order to optimise monitoring so as to achieve statistically valid results (Annex V, 1.3.4).

The example given in Box 5.2 illustrates the point.

5.3.3 Frequency of monitoring

The WFD does provide guidance on monitoring frequency (see Box 5.3) but leaves the final decision to Member States. Frequency of monitoring should be a function of the anticipated rate of change as well as the extent of natural variability. Sampling frequencies must be sufficient

2. Paragraph 1.4.2 of Annex 5 nevertheless requires that each body of water be classified in terms of ecological status.

Box 5.2

An illustration of some difficulties in sampling of quality elements: the phytoplankton

The determination of *good status* for the phytoplankton element is defined as a "slight increase in the frequency and intensity of the type specific planktonic blooms". Seasonal variation of phytoplankton can be marked. This may be particularly so in Irish lakes, where a high frequency of hydrological mixing may disrupt the classical "text-book" seasonal succession of phytoplankton. Without a good seasonal template for comparison the judgement of '*slight*', or otherwise, is impossible. Consequently, although it appears necessary to include all the elements stipulated in Annex V (in this case the composition, abundance and biomass of phytoplankton) it may not be necessary to incorporate all the criteria of assessment (in this case an assessment of the frequency of blooms) if it is unrealistic to do so. Such difficulties are, furthermore, recognised for quality elements as a whole in Annex II (vi). These are important considerations for both surveillance and operational monitoring. There seems little point in embarking on monitoring goals that have little chance of attainment. It is better to direct resources into robust monitoring or into research initiatives designed to establish underlying relationships where spatial and temporal patterns are known to be important.

to satisfy the objectives of monitoring but not place unnecessary demands on scarce and costly technical resources. Any departures from the stipulated minimum frequencies must be explained and justified in the relevant management plans. Minimum frequencies of monitoring given in Annex V, 1.3.4 are, therefore, not mandatory. Monitoring programmes are permitted to take technical knowledge and expert judgement into account. The overall goal of the WFD is clear (Article 1) and monitoring programmes designed within that spirit are likely to be the successful ones.

Queries relating to site selection, inclusion of elements and frequency of monitoring form part of the remit of the various technical working groups, established at regional (i.e. Ireland-wide) and community levels. It is expected that the application of suitable techniques will evolve in response to the increased understanding that the WFD will herald.

Box 5.3

Monitoring frequencies

Guidance on the frequency of monitoring for various purposes is given primarily in Annex V. However, there are certain ambiguities that need to be resolved prior to finalising the design of monitoring programmes.

The main guidance on monitoring frequencies is presented in a table at the end of Section 1.3.4 of Annex V, yet the first paragraph of the section suggests that, for surveillance monitoring, the frequencies given in the table are maximum frequencies applicable **only** to the monitoring of physico–chemical quality elements (e.g. chemical pollutants) *viz*. the paragraph states that other elements must be monitored *at least once during the surveillance monitoring period*.

The term *surveillance monitoring period* is, however, not clearly defined. It could be taken to mean a *period of 1 year during the period covered by a River Basin Management Plan* (or, if the previous survey revealed good status and impacts have not changed, *once every three River Basin Management Plans)* as described in Paragraph 1.3.1 of Annex V. Article 13 of the WFD suggests that the latter period is 6 years. For purposes of monitoring *long-term changes* (one of the purposes of surveillance monitoring), especially changes in biological elements, intervals of 6 years would generally be much too long.

For purposes of operational monitoring, the frequencies in the table presented in Section 1.3.4 are intended as a guidance on the maximum intervals between measurements of the various quality elements. Precise intervals are to be determined by Member States. The maximum suggested interval (i.e. 3 years) for biological elements other than phytoplankton is quite long and its suitability for operational monitoring might depend on whether or not the effectiveness of management measures in reducing risks to, or impacts on, these elements could be assessed by one or two surveys (within 3–6 years). High natural variability would dictate otherwise. On the other hand, the intervals for chemical monitoring (i.e. 1–3 months) are quite short.

5.3.4 Monitoring beyond the land–water ecotone

The integrated nature of the WFD dispenses with clearly defined boundaries between water and land. There is intense debate and activity related to the monitoring of catchment activities and a general appreciation that potential impact on waters from activities throughout all

parts of the catchment require consideration if the WFD is to be implemented effectively. This chapter is, however, concerned primarily with the monitoring of those elements discussed in Annex V. It does not deal with the difficulties of monitoring beyond the water ecotone and in the catchment at large. This is not to imply that monitoring in the catchment as a whole is not important. Indeed for the identification of pressures it is essential. However, wider monitoring is not specifically addressed in Annex V. Furthermore, these arguments go to the core of how we view catchments and land use and is a large and complicated issue. Techniques for whole catchment monitoring are not well developed and some recommendations for research applicable to the WFD are given in Section 4.4. In time, however, all of these issues will need to be addressed. A current collaborative project of the EPA and *Teagasc* is investigating nutrient mobility from land to water. This is an important study that should contribute significantly to the debate. Jennings *et al.* (unpublished report to the EPA) have reviewed the literature on the movement of phosphorus and its impact on surface waters. This chapter, therefore, deals specifically with monitoring and related issues *within* the generally recognised boundaries of surface and ground waters.

5.4 Inland surface waters

5.4.1 Introduction

This section of the report summarises the current monitoring requirements and capacity for inland surface waters. Throughout we have been mindful of the requirements and interpretation of the WFD. This section addresses:

- a general introduction to surface water monitoring;
- existing EC Directives and national legislation that dictate monitoring; and
- current and required capacity for monitoring for physico–chemical, biological and hydromorphological elements.

In Ireland, The Local Government (Water Pollution) Act 1977 vested in the local authorities a responsibility for the conservation of aquatic resources and provided for the creation of water quality management plans and the establishment of monitoring programmes. However, other bodies also have a statutory duty for the protection of waters and, necessarily, a duty to monitor. These bodies include, *inter alia*, the Environmental Protection Agency, the Fisheries Boards, Dúchas, the Radiological Protection Institute of Ireland and the Electricity Supply Board (ESB). The array of bodies with remits for the monitoring of surface waters may have provided the local authorities with a justification to limit attention paid to monitoring duties other than those that relate directly to water supply and disposal of waste water. Somewhat paradoxically, local authorities also have a statutory duty, but not necessarily the in-house expertise or experience, to monitor biologically important sites. Duties for the monitoring of designated sites under the Freshwater Fish Directive (78/659/EEC; see 5.4.2 below) are a case in point.

The standard of catchment management planning among local authorities has been variable (EPA, 1999) and, arguably, hindered through limitations in human resources, technical capabilities and legal ambiguity. Water Quality Management Plans (WQMPs) relate to the "prevention and abatement of pollution" but leave the details of the plan at the discretion of the local authority. There is, indeed, an absence of legal stipulation for the content and structure of WQMPs (EPA, 1999). WQMPs have been produced to cover about 50% of the country, with about a further 20–30% covered by draft Plans. Most adopted Plans were produced by forerunners to the EPA, *An Foras Forbartha* or the *Environmental Research Unit.* Plans are generally biased towards beneficial uses of water abstraction and fisheries. The capacity of receiving waters to assimilate waste from point-source pollution is a major concern of the Plans. The features included in 11 WQMPs reviewed in this project are contained in Appendix E. A summary by the EPA (1999) of WQMPs concluded that there had been a general failure of the plans to protect freshwaters in Ireland. Problems included insufficient scope to protect waters from diffuse pollution, inconsistent implementation, the lack of periodic reviews and delays between preparation and adoption. The recent Lough Derg/Ree report (Kirk McClure Morton, 2001) identified some very serious failings of insufficient regulation of local authority licensed industries. Furthermore, the requirement to implement Statutory Instruments that have arisen in response to a number of EC Directives,

particularly the Drinking Water Directive (80/778/EEC) and Urban Waste Water Directive (91/271/EEC) has largely dictated the monitoring programmes of local authorities. The monitoring stemming from these Directives are discussed more fully in Sections 5.4.2 and 5.4.3 below.

Local authorities, by their nature, do not have responsibility for national programmes. The preparation and publication of environmental quality monitoring programmes is, however, required under the Environmental Protection Act (1992). A national programme for rivers has existed since 1972 (Flanagan and Toner, 1972). This evolved into the current 3-year rolling programme co-ordinated and operated by the EPA. In this programme, water quality is assessed primarily on the basis of macroinvertebrate communities with supporting chemical data (Lucey *et al.,* 1999). A national programme for lakes, recently proposed (Bowman and Toner, 2001), is at an early stage. With the exception of the Shannon system (Bowman, 1998, 2000) there has not been an integrated strategy for their monitoring. Although a national survey covered 53 lakes in the 1970s (Flanagan and Toner, 1975), sampling since then has occurred generally as a response to perceived problems of water quality and has focussed on the larger, often "higher profile", waters. The national coverage of lakes has, however, recently increased (e.g. Irvine *et al*., 2001a; Central Fisheries Board (CFB) study). A current EPA programme is assessing ecological conditions in lakes >50 ha (*ca.* 300 water bodies) and, since 2000, many local authorities are monitoring lake water quality in response to the recommendations of Bowman and Toner (2001) and as part of the National Implementation Programme stemming from S.I. No. 258 of 1998, the Local Government (Water Pollution) Act, 1997 (Water Quality Standards for Phosphorus) Regulations, 1998 (Clenaghan *et al.,* 2001).

Ecological assessment of surface waters has also been carried out by the Fisheries Boards. Under the Fisheries Act 1980 (amended 1999), fisheries protection is a mandatory duty of the Boards. Fisheries within the meaning of the Act includes, *inter alia*, the physical habitat, the quantity and quality of the water, the plant and animal life on which the fish depend for shelter and food, and the spawning gravels wherein salmon and trout deposit their eggs (Champ, 2000). Monitoring of aquatic habitats by the Fisheries Board has been ongoing since the 1970s and has resulted in a large and valuable archive of data. The rationale for monitoring by Fisheries Boards has been related primarily to the preservation of aquatic habitats and the maintenance of fish populations for angling tourism (CFB, 1986; Central and Regional Fisheries Boards, 1999). This would be compatible with *surveillance* and *operational* monitoring as described in Annex V of the WFD. *Investigative* monitoring is also compatible with the Boards' duty to protect fisheries. The CFB has maintained long-term monitoring programmes on a number of surface waters (e.g. Champ, 1998; O'Grady, 1998), and a systematic monitoring programme on canals was initiated in 1990 (Caffrey and Allison, 1998). However, while the Fisheries Boards have conducted many important studies and monitoring programmes, funding for these programmes is increasingly reliant on successful competitive tendering to enable research and strategic monitoring to occur.

Data collection on aquatic systems has, throughout the country, increased significantly in recent years. These include the Department of the Environment and Local Government (DELG) initiative on River Basin Projects (Derg and Ree, Lough Leane and Three Rivers) and funding by the EPA Operational Programme for Environmental Services 1994–1999, and a follow up Environmental RTDI programme 2000–2006. Various EC-funded research projects have been implemented through the Universities. The River Basin Projects have provided important enhancement of monitoring capability and infrastructure. Under the National Development Plan, this is set to continue. Interest in *ecological monitoring* is evident among many, but not all, local authorities. The intensity of ecological monitoring by local authorities in response to the 1998 Phosphorus Regulations is, however, quite variable (Clenaghan *et al.,* 2001).

The monitoring of surface waters over the last 30 years has demonstrated a steady decline in the number of high quality waters in Ireland. However, monitoring is only a barometer of change; protection of waters depends on effective policy and awareness. On the other hand, monitoring has been quite successful in establishing the nature

of pressures on waters and the measures needed to reduce them. This provides a platform from which to address the requirements of the WFD for integrated and strategic monitoring programmes within each RBD. This will require further technical developments, the provision of infrastructure and the co-ordination of activities. The infrastructure and experience gained through the DELG-funded River Basin Projects, which have involved both extensive and intensive data collections will facilitate this significantly. Some well-established monitoring, such as that on rivers, can probably be adapted relatively easily in order to meet the demands of the WFD. Others, such as a strategic monitoring programme for lakes (Bowman and Toner, 2001) may require further debate in order to harmonise plans with the requirements of the WFD (Irvine *et al.*, 2001b).

The triennial EPA Water Quality Reports are based on data collations from many different laboratories run by the local authorities, Fisheries Boards and the EPA. In general, the various monitoring programmes appear not to be co-ordinated for optimum return of effort. While relationships among the state and semi-state bodies may be good (although this is not always the case), the goals of the respective monitoring programmes may differ.

In 1999, the Fisheries Boards in Ireland analysed about 7000 samples from rivers and lakes for nitrates and phosphates (CFB and Regional Boards, 1999). There is also a programme for monitoring bacteria and "on-site" physico–chemical variables on the Royal, Grand and Barrow Canals and the Naas Branch Line and the Shannon–Erne Waterway. The Water Quality Report of the EPA (Lucey *et al.*, 1999) covering 1995–1997 did not specify the number of samples collected from inland waters analysed by the EPA as part of the national sampling programme. It would, however, entail thousands of individual analyses. Thousands of analyses are also performed by the local authorities, sometimes through external contractors, and the Marine Institute.

There is a general need for improved co-ordination of sampling effort and standardisation of techniques among organisations that have a statutory role that involves analysis of samples from aquatic ecosystems.

5.4.2 Monitoring in response to the more relevant existing EC Directives

5.4.2.1 The Drinking and Bathing Waters Directives

The Surface Water Directive (75/440/EEC, amended by 91/692/EEC) and the Council Decision (79/869/EEC) on analysis and sampling frequencies of surface water intended for drinking waters were enacted in an attempt to ensure safe sources of drinking water. They are now considered to make little or no contribution to water quality and will be repealed under the WFD. Their role has been largely taken over by the Drinking Water Directive (80/778/EEC), which requires strict standards for the quality of water intended for human consumption. This was amended by Directive 98/83/EC, which requires a new approach to sampling and monitoring. It specifies many of the analytical tests and places a greater demand on the analytical and monitoring capacity of authorities charged with the responsibility of water distribution. Regulations (DELG, 1988) that effected 80/778/EEC into Irish law will soon be obsolete and the new Drinking Water Directive (98/83/EC) is transposed into Irish law by S.I. No. 439 of 2000 which comes into effect on 1 January 2004. The requirement for monitoring under the Drinking Water Directive relates to water intended for human consumption. The overall quality of drinking water in Ireland is high, although there are some significant problems surrounding the numerous private water schemes (EPA, 2000; OECD, 2000). There is a need to improve the quality as well as the evaluation of the quality of many of these small schemes. This matter is likely to be substantially resolved under the National Development Plan. Requirements under the WFD for monitoring source water for human consumption, and the relationship with Directive 80/778/EEC as amended by 98/83/EC and ecosystem quality are covered in Article 7.2 and Annex V, 1.3.5 of the WFD. The intention appears to be that these Directives should operate alongside each other to provide a coherent European policy on domestic water supply until such time as all directives that can be incorporated within the WFD are repealed.

The Bathing Water Directive (76/160/EEC) requires monitoring of a number of physico–chemical and microbiological variables related to health and aesthetics. In

Ireland there are only nine freshwater bathing areas designated under National Regulations (S.I. No. 155 of 1992 and amendments of 1994, 1996 and 1998). All these are in lakes and, in 1995–1998, complied with mandatory limits (Stapleton *et al.*, 2000).

5.4.2.2 Dangerous substances, Nitrates and Urban Waste Water Directives

Dangerous substances and nitrates

Directive 76/464/EEC on pollution caused by certain dangerous substances discharged into the aquatic environment has not been fully implemented through Irish legislation. In January 2001, this resulted in the European Commission proceeding with a case against Ireland relating to the failure to adopt pollution reduction programmes in line with the Directive, especially phosphorus controls. The action against Ireland reflects in part the dissatisfaction of the Commission to the 1998 Phosphorus Regulations (S.I. No. 258 of 1998) and particularly that "the quality objectives in some cases have the effect of creating unjustified official tolerance for a decline in water quality between the 1970s and 1990s." The 1998 Phosphorus Regulations prescribe that an existing biological or trophic assessment is based on monitoring carried out between 1995 and 1997 or, if no data are available, to assess quality rating based on monitoring post-1997. Many Irish waters would have been subject to significant anthropogenic impact prior to 1995. It appears mainly for this reason that the Commission has decided to proceed with taking Ireland to the European Court of Justice for failure to implement Directive 76/464/EEC. Proceedings are also in process in respect of the Nitrates Directive (91/676/EEC) and the failure, until recently, to identify and designate Nitrate Vulnerable Zones (NVZs) in respect of pollution risk to surface and ground waters.

The difficulties of sustainable management of nitrogen and phosphorus are a core issue to be addressed in Ireland's response to the WFD and the programme of measures required by Article 11. In Ireland, where the main impacts on freshwater are from diffuse sources of nutrients, monitoring of both nitrate and phosphorus concentrations is integral to the successful implementation of the WFD. The current EPA river-monitoring programme could be considered to be a means to assess nutrient status through a surrogate measure (Q-value) (see Section 5.4.3.1).

The limited monitoring of toxic substances in Irish inland waters reflects the perception of their low or negligible occurrence. This is a position that has not (implicitly) been accepted by the Commission. The DELG has proposed 13 substances, other than phosphorus, to be considered in a further statutory instrument under the Water Pollution Act to address the requirements of Directive 76/464/EEC. In response to the need to address demands for monitoring, the EPA produced a discussion document on Environmental Quality Objectives and Standards (EPA, 1997) and recently published a survey of dangerous substances in surface waters (Stephens, 2001). Seven pesticides, 28 metals and 45 volatile organic compounds (VOCs) were monitored. It is worth noting that the analyses of these substances require high precision analytical tools and significant cost. Limited information on, particularly, pesticide use hinders the development of appropriate monitoring. The results of the survey concluded that waters sampled were of generally high quality. Concentrations exceeding proposed Environmental Quality Standards occurred for copper and zinc at the Avoca River, which is known to be seriously polluted from past mining activities. An exceedance of aluminium and barium was found at a number of sites, but this result was considered to reflect natural background concentrations. The overall conclusion that monitoring for these substances need only be occasional falls within the thinking of WFD surveillance monitoring (Annex V, 1.3.1). The state of the Avoca River seems a clear example of where operational monitoring (Annex V, 1.3.2) would be implemented as the Avoca River fails to meet the environmental objectives, but the cause of the problem is known.

Urban Waste Water Treatment Directive

The Urban Waste Water Treatment (UWWT) Directive (91/271/EEC) was transposed into Irish law by S.I. No. 419 of 1994. These Regulations were evoked by S.I. No. 254 of 2001 which provides for monitoring and limits of discharge for BOD, COD, total suspended solids and, for sensitive waters, phosphorus and nitrogen. The Regulations prescribe secondary treatment (biological treatment with secondary settlement or other process) for all waste

water discharges, although it is the larger *point sources* that have, naturally enough, been the focus of upgrading and investment. Funding for water supply and waste water treatment infrastructure increased from £IR 110 million to £IR 280 million between 1994 and 1999 (OECD, 2000) and is set to continue under the National Development Plan.

Sensitive waters are defined in Directive 91/271/EEC as "…[surface] waters which are found to be eutrophic or in the near future may become eutrophic if protective action is not taken". Total phosphorus limits of discharge to sensitive water are 2 mg l^{-1} (10,000–100,000 population equivalents (p.e.)) and 1 mg l^{-1} (more than 100,000 p.e.) or a minimum of 80% reduction in both cases. Nitrogen limits are set at 15 mg/l (10,000–100,000 p.e.) or 10 mg l^{-1} (more than 100,000 p.e.) or a minimum of 70% of inflow. Within the ten designated areas reported on by O'Leary *et al.* (2000) there were 45 discharges of greater than 500 p.e. Of these, 27 received secondary treatment and a further 11 received nutrient reduction in addition to secondary treatment. All were inland rivers or lakes (O'Leary *et al.*, 2000). Since that report, a further 27 areas have been designated, including 15 estuaries. There may be many waters in Ireland in receipt of waste water that are not designated as *sensitive* areas under S.I. No. 254 of 2001 because organic load is estimated to be <10 000 p.e. Some of these waters, or part thereof, would be classed as *poor* or *bad* under the assessment criteria of the WFD and, subject to an assessment of the significance of the impacts in terms of risk, scale and duration. These would warrant inclusion in the *programme of measures* described in Article 11.

The progress of compliance with the UWWT Directive provides an indication of how one major sector of environmental management is gearing up to WFD implementation. O'Leary *et al.* (2000) noted a significant increase in the number of sampling results returned to the EPA since the previous report. Returns of BOD results doubled to over 2500 and for total phosphorus from 168 in 1997 to 733 in 1999. Total phosphorus monitoring returns were not limited to discharges to sensitive waters. This improvement followed the enactment of the 1998 Phosphorus Regulations and coincided with progress of the various DELG-funded River Basin Projects and an awareness campaign on the impacts of phosphorus (e.g. DELG, 1997). The response to the goal of decreased phosphorus loads by one industrial sector, often accused as a major contributor to eutrophication, has been positive. By voluntary agreement, the Irish Cosmetics and Detergents Association (ICDA) aims to reduce 95% of the ICDA market share to zero phosphate by 2002.

O'Leary *et al.* (2000) concluded that, while sanitary authorities are aware of their monitoring obligations under the UWWT Regulations, there is still room for improvement in the capacity to collect and analyse samples and to organise monitoring programmes and to use *Environmental Management Systems*. An analysis of treatment plants with a population equivalent of greater than 10,000 indicated that half the samples for BOD were grab samples. The Regulations are quite specific that flow proportionate sampling or 24-hour samples should be collected for compliance. Of particular relevance to the catchment management approach advocated within the WFD is the lack of a willingness by authorities to improve (and in many cases commence) monitoring of sewage sludge and soils to which the sludges are applied. Apart from three sanitary authorities, sampling programmes for soil testing were either non-existent or in need of improvement.

Two further points in the recommendations of O'Leary *et al.* (2000) are worth noting in relation to the precision and scope of monitoring UWWT plants. First, sampling should be carried out by competent personnel and all analyses, where possible, should be carried out by approved or accredited laboratories. Second, all plants with a population equivalent greater than 10,000 should implement monitoring programmes for total nitrogen and total phosphorus in the influent and effluent regardless of whether or not they discharge to sensitive areas.

It is apparent from the UWWT Regulations that sensitive area designation, and hence monitoring for nutrients, is only required for surface waters that are already eutrophic. Risk (see Chapter 4.4) of eutrophication of low or moderately impacted waters appears not to be considered in practice although it is implicit in the UWWT Directive and Irish Statutory Instruments' definition of nutrient sensitive waters. Furthermore, the meaning of the term *eutrophication* is not defined in the UWWT Regulations but is likely to be considered synonymous with the terms

"moderately polluted" and "eutrophic" given in the 1998 Phosphorus Regulations. The relationship between the Urban Wastewater (S.I. No. 254 of 2001) and the Phosphorus (S.I. No. 257 of 1998) Regulations with that of the WFD is exceedingly important for the implementation of the Directive. Neither of the two regulations takes into account a state-change scheme philosophy whereby individual waters are assessed relative to conditions that represent, for a particular typology, minor anthropogenic alterations as described for *high status* in Annex V of the WFD.

Article 10 of the WFD stipulates cross-compliance with Directive 91/271/EEC (until such time as it is repealed) and requires a combined approach to pollution control. Through the programme of measures outlined in Article 11 there is synergy required between the monitoring to implement the Directives listed in Article 10 and the measures required to assess and control diffuse sources of pollutants. This, together with the incorporation of the repealed dangerous substances Directive (76/464/EEC), provides the framework for an integrated monitoring programme within the RBMPs. The techniques for monitoring listed priority substances vary in their development and cost. They will also vary in their applicability to Irish surface waters. The physico–chemical elements required to be monitored are not specified (Annex V) other than they need to assess thermal conditions, oxygenation conditions, salinity, acidification status and nutrient conditions. While the methods for analysis of specific elements are, or will be, available from published Standards, Annex V provides for some flexibility in actual choice. This allows sensible decisions, based on clear objectives and water typology, to be made in the determination of what elements are to be measured.

5.4.2.3 Freshwater Fish and Habitats Directive

The EC Directive 78/659/EEC on the quality of freshwaters needing protection or improvement in order to support fish life (implemented into Irish law by S.I. No. 293 of 1988), places an onus on Member States to protect fish and their habitats. S.I. No. 293 of 1988 designated 22 rivers or stretches of rivers and, additionally, a number of tributaries of the River Moy. A number of these rivers fall within the catchment management planning arising from the 1977 Water Pollution Act (see Section 5.1, above). The more recent, and stringent, Directive 92/43/EEC specifies the protection of habitat types that require protection through the designation of *Special Areas of Conservation* (SAC). This duty lies with *Dúchas* and there could, eventually, be an extensive list of designated sites. Current proposed SAC designations of salmon-bearing waters are extremely limited and are considered by the CFB to be insufficient to conserve fishery habitats.

The assorted Fisheries Acts (1959–1980) were amended in 1999. The EPA lake-monitoring programme (1999) considers Directive 78/659/EEC 79/9243 important because it has been applied widely within catchment planning. It is significant that the duty to implement S.I. No. 293 of 1988 lies not with the Fisheries Boards, who have the duty to protect fisheries, but with the local authorities. However, there appears to be little co-ordination between the local authorities and the Fisheries Boards in relation to the monitoring of sites.

With the advent of the WFD, Directive 78/659/EEC will be repealed in 2013 and the goals of Directive 92/43/EEC incorporated into the Register of Protected Areas (Article 6 and Annex IV). Monitoring of surface waters important for fish is currently undertaken by a combination of authorities but not necessarily with a common strategy (e.g. local authorities, EPA, Fisheries Boards and ESB may all be responding to different demands). The onus for monitoring protected areas currently lies with *Dúchas* and a number of management plans for surface water SAC are in preparation. There is clearly a need for a reappraisal of the roles of the different bodies to maximise use of limited resources.

Recognising the role of *Dúchas* under Directive 92/43/EEC, there is an urgent need to develop and harmonise with other relevant bodies in the assessment and monitoring of fish and their habitats.

The Fisheries Boards have invested considerable effort in the protection, development and management of fisheries. The WFD may, nevertheless, instigate a major change in the operations of the Boards with a greater emphasis on systematic monitoring, particularly of fish stocks. The consequences for their role in wider catchment management is uncertain, because the implementation of the WFD is likely to result in the reappraisal of a

range of monitoring activities. Implementation of the WFD is, however, unlikely to dispense with the need for the Fisheries Boards to monitor physico–chemical variables and activities within catchments. While the requirement to monitor fish specified within Annex V of the WFD is clearly within the remit of the Central and Regional Fisheries Boards, their statutory function extends beyond the assessment of fish stocks *per se*. It would seem desirable that the WFD would increase the role for the Fisheries Boards, particularly in light of the more expansive approach to catchment management required by the WFD. While the CFB has considerable experience in fish stock assessment, the extensive assessment required under the WFD will necessitate the development of new methodologies. In anticipation of this, the Central Fisheries Board has initiated research proposals for co-support from the EPA and the Department of Agricultural and Resource Development Northern Ireland.

5.4.3 Technical capabilities for the monitoring of surface freshwaters

5.4.3.1 Physico–chemical elements

A concise summary of existing activities, methodologies, research needs and outstanding issues relevant to physico–chemical quality elements in inland waters is given in Table 5.1.

In current monitoring of Irish rivers, the emphasis is on the derivation of a biotic parameter (the Q-value) with subsidiary information on chemical variables. The generally strong relationship between benthic biotic communities and phosphorus concentrations permits the EPA-derived Q-value to act as a surrogate of nutrient status in flowing surface waters. In rivers where acidity is considered to be the main problem, greater reliance has been placed on chemical rather than biological assessment (e.g. Bowman, 1991; Allott *et al*., 1997). This is because the ecological mechanism that underlies the well-established relationship between invertebrate communities and water quality, and on which river biotic scores are based (see Section 5.4.3.2), reflects mainly oxygen availability and not toxicity. In lakes, where the existing monitoring network has historically been less intensive, the focus has been on the assessment of water quality through measurement of, mainly, nutrient and chlorophyll *a* concentrations. This has been done primarily through dedicated programmes in response to apparent problems rather than systematic surveys. The main difficulty with a reliance on chemical indicators of ecological quality is that they are prone to large temporal variations. Nutrient concentrations can vary dramatically with changes in rainfall while pollutants from point sources are often sporadic in their discharge and oxygen flux over a diel cycle. In addition, chemistry alone may not provide adequate information on the biotic effects of pollution integrated over time. The WFD does not discount chemical assessment of surface waters, but rather includes it to *support* the biological elements in *ecological* assessment. The implication is that both physico–chemical and biotic monitoring are required to assess the effectiveness of the programmes of measures (Article 11). The scope of monitoring must also be sufficient to assess compliance with related directives and other measures outlined in Annex VI.

As described in Section 5.4.2, the monitoring of physico–chemical and biotic elements in surface waters is already required under a number of existing directives; some of which are already superseded by later directives or which are scheduled to be repealed under Article 22 of the WFD. In developing River Basin monitoring strategies, Member States will need to provide not only conceptual, but also practical, links with the implementation of other directives. However, with the exception of *Priority Substances*, the techniques for assessing the relevant physico–chemical parameters listed in Annex V as important in supporting biological elements are well established in Ireland (see Table 5.1). What is not decided at present is which physico–chemical elements should be measured for the specified objectives. It is also important to emphasise the lack of harmony among some existing techniques. The Directive, and common sense, dictate that standard and reliable methodologies should always be used.

A consensus on the use of techniques, taking into account accepted international practice, should be mandatory across all sectors within and among River Basin Districts. The current ambiguity in the measurement of phosphorus illustrates the point (see Box 5.4).

Table 5.1. Monitoring physico–chemical quality elements in inland surface waters (rivers/lakes): summary table.

Element to be monitored	Methods available	Current activities	Research needs/Outstanding issues	
			Reference values	**Methodologies**
General conditions	Ireland has well-developed capabilities for monitoring physico—chemical variables in lakes and rivers. Harmonisation of methods required. **Contact:** J. Neil (EPA)	Extensive monitoring by EPA, CFB, University research groups and DELG River Basin Projects. Fewer variables, but including bacteria, assessed by local authorities, mainly in relation to legal requirements.	Reference values for nutrients may be problematic in view of high natural (inter-annual) variability. Current reference conditions under Phosphorus Regulation (S.I. No. 258 of 1998) need re-evaluation.	Need to research and agree best practice for spatial and seasonal sampling. This is particularly important for monitoring for phosphorus.
Specific priority substances	See Table 5.5 for current capabilities in relation to EU priority substances. **Contact:** Marine Institute, Abbotstown.	Very little activity in inland waters.	See EPA (1997) discussion document on Environmental Quality Objectives and Standards.	Methods may have to be developed for listed substances in inland freshwaters.

If the reporting of chemical data is to be harmonised across Europe, potential discrepancies in methodology and reporting need to be resolved at an early stage. It is expected that such issues will be addressed within the international working groups set up to develop technical guidance. Difficulties accruing to variation in monitoring protocols among Member States may be obviated in part by the requirement (Annex V, 1.4.1 ii) that biological monitoring results are to be expressed as *ecological quality ratios*. The precise meaning of this section with regard to chemical monitoring is not clear. It would, however, seem reasonable, that the values obtained for physico–chemical monitoring results should be recorded on a similar basis as biological parameters.

The ability to monitor surface waters is greatly enhanced by automatic sampling devices and remote sensing. Both techniques need to be considered in national monitoring programmes. Automated sampling devices for estimation of diffuse nutrient loads are becoming the norm rather than the exception. Such systems, however, can generate large numbers of samples for analysis, with important implications for the use of resources. This requires monitoring programmes to be well designed so as to meet their objectives economically. The use of automated sampling in the recent DELG-supported River Basin Management Projects has been successful (e.g. Dempsey *et al.*, 2001).

One key area that requires further consideration, and which can be addressed at the national level, is the reliability of chemical sampling in the light of temporal and spatial variability. It is, for instance, known that the critical concentration of oxygen for fish health in rivers occurs at night. Therefore:

The frequent practice of day-time measurements of oxygen concentrations at sites designated under the Fish Directive 78/659/EEC, probably leads to an overestimate of site compliance (Lucey *et al.*, 1999) and needs to be reviewed.

Frequency of sampling for a range of physico–chemical variables is also important. The minimum temporal frequency for phosphorus measurements provided for in the 1998 Phosphorus Regulations is probably adequate to evaluate trophic states of lakes but not rivers because of the importance of nutrient pulses (Lennox *et al.*, 1997).

Box 5.4

Difficulties with the measurement of phosphorus – a crucial chemical element

Measurements of phosphorus fractions in fresh waters usually include total phosphorus (TP), dissolved inorganic phosphorus (filtered <0.45 µm) and particulate phosphorus (PP) (filtered >0.45 µm). In addition, some studies include measurements of total dissolved (TDP), dissolved organic (DOP), particulate organic (POP) and particulate inorganic phosphorus (PIP). The standard method for the measurement of the dissolved inorganic phosphorus fraction is that of Murphy and Riley (1962) which is alternatively referred to as dissolved phosphorus (DP), soluble reactive phosphorus (DRP) or molybdate reactive phosphorus (MRP) in different studies. In addition, although the measurement of dissolved phosphorus is most often performed on filtered samples (<0.45 µm) some studies, such as much routine monitoring in Ireland, use unfiltered samples. The 1998 Phosphorus Regulations (S.I. No. 258) do not specify whether MRP, recommended as a quality standard in rivers, should be measured on filtered or unfiltered samples.

In lakes, TP concentrations are generally considered to be a more meaningful measure of phosphorus availability to phytoplankton than DRP concentrations (Reynolds and Davies, 2001). There is, however, evidence that total reactive phosphorus (TRP) (unfiltered, undigested, molybdate reactive) provides a better measure of phosphorus availability in oligotrophic lakes, while total soluble phosphorus (TSP) (filtered, digested, molybdate reactive) is more indicative in eutrophic waters (Bradford and Peters, 1987). A measurement of molybdate reactive phosphorus on unfiltered samples is routinely performed by the Irish EPA and the UK EA and has also been used in some catchment studies. Although Bradford and Peters (1987) recommend the use of TRP in nutrient-poor waters, they emphasise that turbidity can distort absorbance readings and that a blank of *each* water sample, plus a modified reagent, must be used. This step is not usually included in monitoring programmes. Because of these limitations the continued use of measurements of MRP on unfiltered samples to describe phosphorus availability in the total suite of conditions in Irish waters merits further consideration. It has been standard practice up until 1998 that TP and MRP (on unfiltered water) analyses reported by the CFB were made on blank-corrected samples. These points are discussed more fully in Jennings *et al.* (unpublished report to the EPA).

The assessment of trophic status of lakes through a single annual measurement of chlorophyll *a*, as allowed by the 1998 Regulations, may not reflect the annual median or mean value. High seasonal variation of both chlorophyll *a* and phosphorus discredits the reliability of single annual measurements, irrespective of the month of sampling (Irvine *et al.*, 2001b). The guidelines (Annex V, 1.3.4) of the WFD for frequency of sampling for nutrient status in lakes is 3 months. For TP and chlorophyll *a*, this can still result in high confidence limits around mean values.

Spatial variation of physico–chemical and other quality elements is to be considered (Annex V) in monitoring programmes. This is an issue along water courses (including canals) and in large lakes. In rivers, cumulative impacts from diffuse and point sources are an obvious consideration. In lakes, spatial variation in monitored elements can be markedly affected by prevailing conditions, such as wind speed and direction. The EPA (Bowman and Toner, 2001) recommendation for lake monitoring is to collect samples using a boat on large lakes and by casting a bottle from the shore with a fishing rod on small lakes. Irvine *et al.* (2001a) used a bottle attached to a 50-m rope. However, in a test of the temporal and spatial problems associated with sampling on reservoirs in the UK, Hilton *et al.* (1988) found little difference between lake-shore and open-water samples. For infrequent sampling, the limits to precision are more likely to be related to large sampling intervals rather than spatial heterogeneity.

5.4.3.2 Biological quality elements

A concise summary of existing activities, methodologies, research needs and outstanding issues relevant to biological quality elements in inland waters is given in Table 5.2.

Rivers

Benthic invertebrate fauna

Macroinvertebrates are defined as "organisms that inhabit bottom substrata (sediments, logs, macrophytes, filamentous algae, etc.) or the surface of fresh water for at least part of their life cycles and are retained by mesh sizes ≥200–400 µm" (Rosenburg and Resh, 1993). International Standard EN 27828: 1994 referred to in Annex V, 1.3.6 of the Directive suggests a mesh size 0.5–0.75 mm for routine sampling and 0.25 mm for special surveys requiring complete taxa lists. Numerous biotic index and score systems have used macroinvertebrates in water quality assessment (see Woodiwiss, 1964; Chesters, 1980). These indices rely mainly on the sensitivity of taxa to low oxygen concentrations. The scheme used by the EPA to provide a Q-value index of river quality has operated since 1971, with *An Foras Forbartha's* first national survey of river and stream quality. Current monitoring of rivers by the EPA covers the country on a 3-year programme and provides the basis for reporting on water quality in Ireland's rivers (and lakes, see below). In the most recent of these reports covering 1998-2000 (McGarrigle et al., 2002), 3166 locations were sampled. This covered 13,200 km of river channel surveyed at approximately 4-km intervals.

The Q-value system assigns a five-point quality score, based on an understanding of the relationships between water quality and the occurrence and abundance of macroinvertebrate genera or species. Scores are normally based on a 2-min kick sample and recorded at the bankside after examination of the sample. The rapid application of the system depends on the reliability of taxa identification and, hence, sufficient training of operators. Putative taxa should be verified with a microscope in the laboratory. The system is considered by the EPA to be robust provided the recommended protocols are followed. Sampling is normally in riffle areas but can be adapted for use in deep flow areas. Although the Q-value appears to be a suitable procedure, it must be adapted to different river typologies to meet the environmental objectives (Article 4) of the WFD and the provisions of Annex V (see below). The EPA triennial sampling programme is supported by a range of other observations and analysis of water chemistry (see Section 5.4.3.1).

The Q-value methodology for assessing river water quality appears suitable for adaptation for the WFD. It is recommended that application for different typologies with a view to determining reference conditions are investigated without delay, as there is a low cost implication for this exercise.

More sophisticated schemes, such as the recently developed software package RIVPACS, use multivariate anal-

Table 5.2. Monitoring biological elements in inland surface waters (rivers/lakes): summary table.

Element to be monitored	Methods available	Current activities	Research needs/Outstanding issues	
			Reference values	**Methodologies**
Phytoplankton	Methods for sampling and identifying phytoplankton in lakes and for estimating phytoplankton biomass are readily available in Ireland but capacities for taxonomic work are very limited. **Contacts:** J. Bowman EPA; N. Allott, TCD. Generally ignored in rivers.	Phytoplankton communities are monitored in the main Shannon Lakes by the EPA. Chlorophyll is monitored to varying intensity in a number of lakes.	Work is needed to establish a basis for reference values applicable to large areas, e.g. for surveillance monitoring. Chlorophyll levels alone may not be sufficient. More information on natural (seasonal and inter-annual) variability is a pre-requisite.	Large-scale monitoring of type-specific areas for phytoplankton biomass might best be undertaken by remote sensing. Some pilot work done by EPA.
Macrophytes	Semi-quantitative methods are available for measuring biomass, structure and productivity of macrophytes. **Contact:** J. King (CFB)	No history of routine monitoring of macrophytes, but this is becoming a common feature in the EPA rivers programme. There have been many single surveys over the last 30 years. A CFB programme in canals is becoming established.	Macrophyte communities can have high spatial heterogeneity and low abundance October–May. Research needed on feasibility of setting type-specific reference conditions. Trophic ranking schemes used by UK *English Nature* are probably inadequate.	A key question is whether or not macroalgal monitoring should focus on representative communities or species that are indicators of anthropogenic pressures. Surveys in lakes can be very time consuming. Many Irish waters have high colour that will affect predictive patterns.
Benthic invertebrate fauna	Well-established Q-value methodology used in rivers. Only pioneer work in lakes. **Contact:** M. McGarrigle (EPA) Some profundal data **Contact:** B. Quirke (Conservation Services)	Extensive surveys are conducted by the EPA using littoral macro-invertebrates to assess water quality in rivers. Some limited and recent survey work done in lakes.	EPA dataset will help identify reference sites in lakes. This is also a goal of current EPA lakes survey.	EPA dataset needs to be analysed for ability to accommodate typologies in rivers. It would be useful to consider predictive modelling techniques in all waters. Value of indicator taxa should not be discounted
Fish fauna	Well developed methods for assessing status of freshwater fish. Acoustics have been used successfully in some lakes and electrofishing and mark–recapture in rivers/canals. Salmon/sea-trout counters exist but are imprecise. **Contact:** M. O'Grady, CFB	Ongoing monitoring of fish by the CFB. Surveys relate mainly to salmonids. CFB will have responsibility for monitoring, with input from the MI Fisheries Division.	There is immense inter-annual variability in the size and structure of fish populations. There are insufficient historical data to establish reference values.	Introduced coarse fish are probably important for ecological quality. Predictive tools for fish appear possible. Acoustic method development may reduce costs.

yses and compare observed macroinvertebrate assemblages with those predicted in the absence of environmental stress (Wright *et al.*, 1997, 2000). RIVPACS is, however, still at a development stage and, although widely quoted in river assessment work, is not easy to use and is expensive to obtain. Although there are plans to disseminate RIVPACS as a Windows version, this may not to be available for some time. Also it may be applicable only to those areas where it was developed. Like the UK River Habitat Quality Scheme (e.g. Raven *et al.*, 1998), RIVPACS incorporates a variety of habitat attributes in order to assign quality status. It uses a "state-change" approach where sites are assessed by comparison with a theoretical quality status determined for similar sites without significant anthropogenic impact. This is not *sensu stricta* the approach used by the Irish EPA that makes "spatial-change" comparisons among all sites rather than a comparison with a site or topology-specific baseline. It is the latter approach that is called for in Annex V of the WFD. However, it is also one to which the EPA river-monitoring programme may be adapted relatively easily. Recent work in the Zoology Department of UCD has investigated the applicability of a RIVPACS approach to Irish rivers.

Macrophytes, phytobenthos and phytoplankton

While there is a large scientific literature on the potential use of submerged aquatic plants in assessing the ecological status of rivers (e.g. De Lange and van Zon 1983; Newbold and Holmes, 1987; Standing Committee of Analysts, 1987; King and Caffrey, 1998), they are generally not used as a single element in routine monitoring programmes. One reason for this may be the difficulty in linking physical and biotic features of rivers within a single classification scheme (Raven *et al.*, 1998; Baattrup-Pedersen *et al.*, 2001). They are, however, used in detail in some smaller schemes (e.g. Denmark) and as an element in ecological assessment of rivers being developed by SERCON in the UK (Boon *et al.*, 1997) and *System Aqua* in Sweden (Willén *et al.*, 1997). The harmonisation of macrophyte-based quality-rating systems for developing protocols between Northern Ireland and the Republic are currently under discussion. The EPA river-monitoring programme now includes records of submerged and emergent vegetation and there are increasing moves to incorporate macrophytes into the EPA river-monitoring scheme. A river quality-rating scheme based on macrophytes correlated very closely with the national invertebrate-based system (Caffrey, 1985, 1987). There is also a 10-year video record of habitat structure at some river sampling sites.

The increasing use of multivariate techniques such as RIVPACS and SERCON may allow a meaningful use of a combination of physical and biotic elements for monitoring under the WFD. This potential requires research.

Assessment of macrophytes can, however, involve high taxonomic skill and time costs. In Ireland there is good expertise, but limited capacity, for macrophyte and phytobenthos assessment. A considerable amount of information has been collated since 1970, but little before that (King and Caffrey, 1998). One feature of those data, however, is that many are reported in the 'grey literature' or archived within the CFB. Historical data useful for the setting of baseline conditions and the development of monitoring programmes exist within the country but may not be readily available. The intention of the EPA to collate and document records into accessible databases is an important initiative (also see Section 4.3).

Phytoplankton are an important component of the ecology of lowland rivers but their assessment (Annex V) is a neglected aspect of current monitoring. In the present monitoring programme of the River Shannon (Bowman, 2000), phytoplankton are not reported from the river channel between lakes. It might be argued with some conviction, however, that the monitoring of phytoplankton in rivers is not applicable to the implementation of the WFD in Ireland, as most freshwater channels are fast flowing. Monitoring of phytoplankton in canals and estuaries may be important.

Fish fauna

The assessment of fish through much of Europe has, traditionally, been instigated through economic and social considerations rather than ecological ones. Management of inland fisheries in the U.K. and Ireland, for example, have been motivated by the requirement to maintain or promote angling. In Ireland, a significant effort is made in the promotion of angling tourism, although the practical manifestation of this policy is often synonymous with

the enhancement of fish habitat or pollution prevention measures. In recent years, there has been a greater emphasis on ecologically motivated assessment and interest in catchment management. This has included an extensive programme of habitat rehabilitation for salmonid sites under the *Tourism Angling Measure.*

Globally, nets, electrofishing, mark–recapture and acoustics are used in the assessment of fish populations in rivers. There are also recent developments in applying a RIVPACS type approach to fish assessment (Joy and Death, 2001). In Ireland acoustic survey techniques are not widely developed, but have been used successfully in Lough Erne and applied recently in Lough Melvin. Mark–recapture work was important in the development of the fish surveying techniques currently used by the CFB. Some mark–recapture studies are done in their own right in canals. The Marine Institute has monitored anadromous species in some catchments using fish counters; notably the long-term study of fish migrations in the Burrishoole catchment, Co Mayo. The ESB has a statutory responsibility for a number of fisheries and has used both CFB scientists and their own staff and consultants to monitor fish stocks.

In general, monitoring techniques for fish in Ireland are well developed. Surveys have ranged from intensive to extensive, but have tended to be qualitative rather than quantitative. Survey expertise is mainly located centrally within the CFB. Between 1995 and 1999, 11 rivers were surveyed in joint operations of the Central and the Regional Fisheries Boards. In addition, a number of salmonid surveys were carried out in smaller catchments. In order to improve the national database, a national tagging scheme to record the number of all salmon and sea-trout (>40 cm) caught, for commercial or private means, was introduced by the Department of Marine and National Resources in August 2000. The scheme is implemented by the Fisheries Boards.

The WFD could have a major implication for fish assessment and management in Irish rivers. Annex V of the WFD requires *high* and *good status* to show, respectively, minimal and slight deviation from undisturbed conditions. This includes impacts on age structures of fish. The reporting of the ecological status of surface waters will be determined by the lower of the values determined by biological and physico–chemical monitoring (Annex V, 1.4.2). These include offshore commercial fisheries, stocking regimes, arterial drainage schemes, catchment erosion through overgrazing on uplands and animal access to river channels, habitat enhancements (generally considered as improvements), and alien introductions (there have probably been at least seven introductions of freshwater fish in the last 400 years (Reynolds, 1998) of which the roach is almost certainly the most significant for degradation of ecological quality). This array of pressures, some of which date back to beyond the last century, raises debate on the definitions of *good* and *moderate* status contained in Annex V of the WFD. Sites that are not classified as more than *moderate* after 2015 (Article 4 (a) (ii)) could be in breach of the *Environmental Objectives*.

Compliance with the WFD suggests a need for broad discussion and possible reappraisal of inland fisheries management policy. Even a brief consideration of the issues illustrates the resource implications (see Chapter 7) and policy difficulties that are likely to be brought about by the WFD.

Lakes

Benthic invertebrate fauna

The WFD includes benthic invertebrate fauna in lakes as a major category for ecological assessment. While there is a long history of the use of profundal communities in ecological assessment of deep lakes (e.g. Naumann, 1931; Thienemann, 1931; Sæther, 1979; Lang, 1990), there have been few studies on the use of littoral invertebrates (Tolonen *et al*., 2001). However, recent work included in EPA-funded projects (Irvine *et al*., 2001a; McCarthy *et al*., 2001; White, 2001) indicated that biotic groups have potential for inclusion in a national monitoring scheme. These include the chydorid crustaceans (de Eyto and Irvine, 2002) as well as the more familiar macroinvertebrates. Concurrent but, as yet, unpublished work in N. Ireland (P. Hale, personal communication, Industrial Research and Technology Unit) supports the view that littoral macroinvertebrates can be useful indicators of ecological status. Macroinvertebrates are included in the current EPA lake-monitoring project. This study will provide useful data on the benthic invertebrate com-

munities from a much larger number of lakes than was assessed by Irvine *et al*. (2001a). It also has the potential to further resolve technical difficulties related to seasonal and spatial variation that may, otherwise, undermine correct interpretation of monitoring results. The useful application of the assessment of benthic invertebrate communities depends on the ability to set robust reference conditions. This requires careful consideration. While models of multivariate assessment (e.g. Reynoldson *et al*., 1995) will almost inevitably be utilised in this research, **simple univariate metrics or considerations of indicator taxa should not be discounted.** The consideration of simplicity is of particular relevance for the rapid assessment of lakes. How the current EPA lake assessment project will eventually mesh with that for water quality proposed by Bowman and Toner (2001) is uncertain.

Irvine *et al.* (2001a) demonstrated useful relationships, applicable to monitoring, between trophic state and selected *indicator taxa* of the profundal of Irish lakes, although high variations in densities among lakes made it difficult to apply results across lakes. This illustrates the importance of using relevant typologies in the implementation of the WFD as described in Annex 5. A logistical consideration for the use of profundal organisms in lake classification is the time it takes to collect and sort samples. It is also not yet resolved as to the necessity for collecting samples from the open water as opposed to close to the shore for the purposes of monitoring relevant elements (see Section 5.4.3.1). Like many other aspects of monitoring, such decisions should be based as far as possible on a comparative study across a number of lake typologies.

Macrophytes and phytobenthos

Macrophytes and phytobenthos appear to be an obvious element for inclusion in a monitoring scheme for lakes but technical and human resource problems may provide particular difficulties. While depth of growth is associated with light penetration (Jupp and Spence, 1977) the range of colour evident in Irish lakes (Irvine *et al.*, 2001a) may make such an apparently straightforward relationship difficult to interpret within any practically useful typologies. Relative inter-annual changes in maximum depth of growth may, however, be a useful indicator of ecological quality. Macrophyte trophic scoring systems are difficult to apply and spatial heterogeneity hinders sampling. The trophic ranking system (TRS) developed by Palmer *et al.* (1992) was designed for nature conservation assessment and should not be assumed to be an applicable methodology for WFD implementation.

The assignment of correct typology is likely to be critical for macrophyte assessment in lakes. Implementation of the WFD will require cross-compliance with the Habitats Directive (92/43/EEC) and strategic harmony with *Dúchas* is important. A number of standing water habitats listed by Directive 92/43/EEC occur in Ireland. The expertise that exists in the country for assessment of lake and canal macrophyte communities lies mainly with the CFB (see above) but there is also expertise among amateur naturalists, within the Universities and *Dúchas.*

There has been a range of studies of the macrophytes of Irish standing water, ranging from broad-based surveys of distribution (Heuff, 1984) to intensive surveys of individual large lakes such as Lough Corrib (Krause and King, 1994). King and Caffrey (1998) identified a lack of a standardised methodology in macrophyte studies. Therefore, like all other aspects of monitoring for implementation of the WFD a number of decisions are required in the development of a scheme for macrophytes. For example, to what extent will emergent macrophytes be considered and what intensity of sampling is required? Whole-lake coverage has implications for time and, hence, the total number of lakes that can be sampled in a season.

Phytoplankton

Phytoplankton are a common element in lake monitoring and can be quantified by measurements of chlorophyll *a* (a surrogate for standing biomass), direct counts of abundance and estimation of cell volumes. Their use since the 19th Century as tools of biological classification (Willén, 2000) has not, however, been without criticism (Teiling, 1955). Population abundance and community structure are very dependent on physico–chemistry and can vary markedly among lake typologies.

The WFD requires that the tradition of using phytoplankton for monitoring continues but, at least in surveillance monitoring, at a lower frequency than would be usual in

single-site studies. The guideline frequency of sampling (Annex V, 1.3.4) appears to be once within the period covered by the RBMP or at a 6-monthly frequency for operational monitoring. The guidelines are, however, somewhat ambiguous. While it is also recommended that natural variation is considered prior to the design of a sampling protocol, this would be an onerous task if it were to be done, with the necessary replication to provide confidence in the results over the range of likely typologies. Most studies of natural variation of phytoplankton suggest a high level of intra-seasonal variation. Implications of seasonality of phytoplankton are discussed in Box 5.2 (above).

There is a large archive of phytoplankton data within the EPA and the CFB and historical records going back to the beginning of the last century (West and West, 1906). With the exception of detailed surveys on the Shannon system (Bowman, 2000), the monitoring of phytoplankton is not common. Recent exceptions are phytoplankton species total biovolumes reported by Irvine *et al*. (2001a) and Irvine *et al*. (unpublished reports) and work on the Killarney lakes (Allott, unpublished report).

Overall, the capacity in the Republic of Ireland for assessment of phytoplankton appears extremely limited. The current lakes' survey by the EPA includes phytoplankton but faces significant time constraints on sample processing. Surveillance monitoring requires assessment that is indicative of biological quality elements. This may lead back to the use of indicator groups so favoured by some of the early limnologists. Nevertheless:

there is an urgent need for the development of assessment protocols and the development of national expertise to enable monitoring of phytoplankton if this element is to be included in a national monitoring programme.

Fish fauna

Most issues relevant to fish assessment are covered above. The assessment of fish in lakes is, however, logistically more demanding than in rivers. Fortunately there is a high level of experience and expertise for such assessment and various techniques have been applied successfully in many of the larger lakes. A rolling programme to continue this will contribute to the WFD monitoring requirements, but there is a possibility that the intensity of monitoring will decline as a consequence of the need for greater regional coverage. Assessment of fish stocks in many lakes in the world has employed hydroacoustics (e.g. Duncan *et al.*, 1998 for shallow waters). This capability, which could provide a significant reduction in costs of monitoring, has not been used extensively in Irish lakes. It may also be possible to exploit the potential of the recently introduced tagging scheme for salmonids for application to monitoring for the WFD. Methodologies for data returns from coarse anglers might also be explored. Community participation can be effective in regional monitoring programmes (Carlson and Lee, 1995) but requires dedicated management.

5.4.3.3 Hydromorphological elements

A concise summary of existing activities, methodologies, research needs and outstanding issues relevant to biological quality elements in inland waters is given in Table 5.3.

Many rivers and lakes in the country have in some way been affected by alterations to the hydromophological elements described in the definition of *high status* in Annex V of the WFD. Arterial drainage, channelisation and vegetative clearance from water courses have had significant impacts on rivers and, to a lesser extent, lakes. Although the drainage of Irish wetlands was not perfected to the same scale as occurred in the UK (Purseglove, 1989) it has, nevertheless, been significant. Impacts of arterial drainage affect not only river channels and lakes but also wetland fringes, with the consequent detrimental effect on the associated ecological status, such as reductions in wildfowl. Catchments in which drainage is regulated (Rivers Brosna, Erne, Lee, Liffey and Shannon) drain collectively over 50% of the country.

The WFD reflects a new philosophy towards water resources. For hydromorphology, it presents a different set of challenges, requiring different expertise, than much of the other monitoring outlined in Annex V. In order to assess anthropogenic impacts on hydrologic elements, data collection is required from a number of sources. These include: abstractions and discharges for urban water supply, agriculture, industry and hydroelectrical generation; discharges from urban agglomerations, industry and agri-

Table 5.3. Monitoring hydromorphological quality elements in inland surface waters: summary table.

Element to be monitored	Methods available	Current activities	Research needs/Outstanding issues	
			Reference values	Methodologies
Rivers				
Hydrological regime	Channel flow, abstraction and discharge rates using flow meters and gauging stations. Groundwater connection with dye measurements and models.	Hydrometric stations and monitoring devices established by the EPA, OPW, ESB. Monitoring of flood defences.	Examination of historical records, flow regimes and estimate base flows using hydrological models and meteorological records.	Examination of past and current data to determine reliability of reference conditions and link to biological elements.
River continuity	Assessment of channel morphology and GIS.	No specific programme.	Use of historical records and modelling.	Need extensive survey and collation of data, aided by GIS, to establish anthropogenic impediments to river flow.
Morphological conditions	Assessment of mesohabitat structure. Use of models, maps and survey to determine channel disturbance	Assessment of river banks by OPW.	Hydrological modelling to assess natural course of channel and derive predicted structure.	Extensive archive in OPW for conditions in rivers prior to drainage.
Lakes				
Hydrological regime	Bathymetric survey for basin typology and estimation of annual residence time using met. data. Downstream gauging stations for estimates of outflow. Map of impediments (e.g. dams).	Lake level readings and outflow rates of reservoirs and Shannon lakes.	Estimation of residence time available for some lakes and reservoirs.	Develop morphological indices that can be measured on numerical scales and increase extent of bathymetric survey. Consider the development of aerial survey techniques.
Morphological conditions	Bathymetry. Mapping shoreline (including index of *shoreline development*). Ranking substrata through proportions of sediment size fractions.	No routine activities. Sporadic recording of some parameters.	No known records of good baseline data. Some video footage of shoreline recorded in individual projects.	Develop indices that can be measured on numerical scales. Consider use of aerial survey techniques.

culture; river and lake levels; precipitation and evapotranspiration rates; and groundwater losses and recharges. The application of these data necessitates not only accurate data sources, but also appropriate computer models.

In Ireland, hydrological data are collected mainly by the Office of Public Works (OPW), the EPA, the ESB and the Geological Survey of Ireland (GSI) and the local authorities. The role of the GSI relates mainly to groundwater status (see Section 5.6). The EPA is required under the Environmental Protection Agency Act 1992 to prepare a national programme for the collection, analysis and dissemination of information. This scheme is described at http://www.epa.ie/techinfo/default.htm. Where necessary the EPA can direct local authorities to collect and supply information. Data are collated for each of seven regions that comprise individual or groups of river catchments. Aggregations of hydrometric regions comprise the proposed River Basin Districts. Five are proposed, with boundaries for possible two cross-border RBDs, pending further discussions.

River flow measurements are obtained from automatic recorders and staff gauges maintained by the OPW, ESB and local authorities. The proposed hydrometric programme to be implemented by the EPA identifies: hydrometric stations on water courses with natural regimes; automatic recorders for specific design or operational purposes; staff gauges for operating water quality and other monitoring programmes; and a network of boreholes and springs where water levels will be taken at predetermined intervals. In addition, the recent River Basin Projects have operated a number of flow and gauging stations that provide the simultaneous collection of water for chemical analysis. Extensive meteorological data are available from Met Eireann for modelling.

Overall, the existing monitoring programme and associated sampling strategies provide a solid foundation for the assessments required under the WFD. The application of hydrologic data may require a re-assessment of the measurement of impact. To this end, the recent manual produced by SNIFFER (Black *et al*., 2000) may be highly relevant for hydromorphological monitoring. This was produced in response to the demands of the WFD and draws on experience gained from studies on Scottish rivers and lochs. The manual includes a section on the generation of "synthetic" data where natural flows have been disrupted. It also refers to work at the Institute of Hydrology (Institute of Hydrology, 1980; Gustard *et al.*, 1987) to develop a *Micro Low Flows* PC package and work by Richter *et al.* (1996) to compare differences between impacted and unimpacted sites.

In Ireland, the OPW has extensive data on rivers and flood plains, and archives hold extensive and detailed information on the morphology of rivers pre- and post-drainage. This includes data for drainage schemes that were not implemented. Between 1945 and 1995, the OPW completed 34 arterial drainage schemes on river catchments together with 5 estuarine embankment schemes conferring benefit on over 260,000 ha of land. The OPW is responsible for the maintenance of over 11,500 km of channel, in excess of 700 km of embankments, and some 18,500 bridges together with over 750 other structures (such as sluices and pumping stations). The OPW has for a number of years funded on-going research in conjunction with the CFB on the ecological impacts of the maintenance operations. Data on lake morphometry have also been collected by a number of bodies, including the ESB, local authorities, CFB and university groups.

5.4.4 Conclusions – inland surface waters

Historical limitations of resources and varied application of environmental legislation, has hindered the development of a strategic monitoring system for lakes. Good national and strategic monitoring of river water quality has, however, been achieved though a programme initiated in the early 1970s by *An Foras Forbartha* and continued by its successors, the *Environmental Research Unit* and the EPA. Extensive fisheries and habitat data have been collected by the Fisheries Boards. Local Authorities have collected a variety of water quality data in response to legislation arising from a number of interrelated EC directives. Hydrometric data have recently been consolidated by the EPA into a national network. Recent increases in funding and new initiatives by Central Government provide greater optimism for the development of cohesive national monitoring programmes for inland surface waters. These initiatives have arisen both through increased awareness and, significantly, increased pressure

from the EC in regard to the compliance to a number of directives. The last few years have also seen the creation of River Basin Projects and further development of monitoring systems. Collectively, these historic and current events provide the platform from which the monitoring requirements of the WFD will be met. The current efforts of the DELG towards implementation of the WFD are encouraging. There are, nevertheless, a number of areas where attention should be directed if the monitoring programmes currently under discussion are to be optimised. A summary of recommendations for research and monitoring is given in Section 5.8.

5.5 Estuarine and coastal waters

5.5.1 Introduction

Ireland has a well-developed marine environmental monitoring programme that to a large extent is governed by the requirements of relevant EU directives and the OSPAR Convention for the Protection of the Marine Environment of the North-East Atlantic (1992). The main agencies engaged in marine monitoring are the Environmental Protection Agency (EPA), the Marine Institute (MI) and the Radiological Protection Institute of Ireland (RPII). Each of these agencies undertakes monitoring in accordance with its specific role and mandate. Each focuses on particular environmental sectors, impacts and measurements. To date there has been little movement towards an integrated national programme.

This section of the report outlines methodologies, current activities and research needs relating to monitoring estuarine and coastal waters. Issues addressed in the section include:

- the respective roles and responsibilities of Government and its agencies, and associated co-ordination requirements;
- anomalies and uncertainties in WFD Annexes dealing with monitoring and assessment;
- considerations in the identification of type-specific reference conditions;
- adequacy of existing programmes (in terms of specific objectives, spatial and temporal coverage, detection limits, etc.) for monitoring the quality elements for marine areas; and
- prior research needs (i.e. to enable satisfactory design of monitoring).

5.5.2 Physico–chemical elements

A concise summary of existing activities, methodologies, research needs and outstanding issues relevant to physicochemical quality elements is given in Table 5.4.

The Marine Institute (MI) conducts an annual winter nutrient monitoring programme in the Irish Sea, extending into the Celtic Sea to a point west of Waterford Harbour. The area covered is mostly in coastal, rather than transitional, waters. The variables examined include total oxidisable nitrogen, nitrite, orthophosphate and silicate. Water quality surveys, including nutrients and chlorophyll, are carried out by the EPA during the summer months in 25 bays and estuaries (i.e. transitional waters), including the estuaries of most of Ireland's major rivers.

Temperature and dissolved oxygen are monitored routinely during summer in most major estuaries as part of the water quality surveys done by the EPA. There is no systematic monitoring of temperature, oxygen or transparency in coastal waters but temperature data are automatically recorded during cruises of the Irish research vessel *Celtic Voyager*. A network of automated buoys that will record temperature, salinity and other parameters is being installed by the Marine Institute (www.marine.ie/datacentre/projects/databuoy/) but, subject to setting of the baseline for purposes of the Directive (Article 2 (7)), these are likely to be seaward of coastal water boundaries.

The possibility of dedicated cruises to record general water quality parameters and to conduct hydrographic measurements (depths, currents, substrates; see 5.3.5 below) along near-shore transects (i.e. in both transitional and coastal waters) should be investigated.

5.5.2.1 Specific pollutants

Ireland's marine monitoring activities are largely in response to the requirements and programmes of the Con-

Table 5.4. Monitoring physico–chemical quality elements in transitional and coastal water: summary table.

Element to be monitored	Methods available	Current activities	Research needs/Outstanding issues	
			Reference values	**Methodologies**
General conditions	Ireland has well-developed capabilities for monitoring temperature, oxygen, transparency and nutrients in seawater. **Contacts:** P. Cunningham (EPA); Marine Institute, Abbotstown.	General water quality parameters are monitored seasonally in major bays and estuaries (transitional waters) and at aquaculture sites. No regular programme for coastal waters.	Reference values for nutrients may be problematic in view of high natural (inter-annual) variability.	Mainly a question of selecting/agreeing common procedures from the options available.
Specific synthetic pollutants	See Table 5.5 for current capabilities in relation to EU priority substances. **Contact:** Marine Institute, Abbotstown. Methods exist for monitoring Man-made radionuclides in marine media. **Contact:** RPII	Priority contaminants measured in fish and shellfish tissues. Current activities are a form of *surveillance* monitoring but do not distinguish between water body types or transitional and coastal waters; cover food safety and protection of marine life. Man-made radionuclides monitored annually, concentrating on the Irish Sea.	OSPAR has adopted reference values for contaminants in sediments and selected tissues. Values apply to all parts of the marine environment. Refs: OSPAR (1997a), OSPAR (1997b).	Methods may have to be developed for listed substances not currently analysed by Ireland (see Table 5.5). Is there a need to integrate WFD and OSPAR programmes?
Specific non-synthetic pollutants	There are well-established methods for measuring metallic elements in marine media (see Table 5.5 for current capabilities in relation to EU priority substances). **Contact:** Marine Institute, Abbotstown.	Heavy metals (Hg, Cd, Pb, Cu, Cr, Zn) measured in fish and shellfish tissues. Current activities are a form of *surveillance* monitoring but do not distinguish between water body types or transitional and coastal waters; cover food safety and protection of marine life.	OSPAR has adopted reference values for contaminants in sediments and selected tissues. Values apply to all parts of the marine environment. Refs: OSPAR (1997a), OSPAR (1997b).	Will the WFD endorse the OSPAR position that metals need not be monitored in seawater? To what extent, if any, will there be integration of WFD and OSPAR programmes?

vention on the Protection of the Marine Environment of the North-East Atlantic (OSPAR) and EU directives, especially the hazardous substances Directive 79/923/EEC. OSPAR operates a Joint Assessment and Monitoring Programme (JAMP) that provides comprehensive harmonised guidelines for programme design, sampling and sample preparation, analytical tools, normalisation techniques and quality control as well as useful assessment tools (ecotoxicological assessment criteria, background reference values) all of which are relevant to the WFD.

The JAMP for hazardous substances focuses mainly on biota and sediment, as many of the substances of interest are difficult to detect and quantify in seawater. Monitoring of the biological effects of contaminants has also been important in recent years. Results are reported to a central database at the Copenhagen headquarters of the International Council for the Exploration of the Sea (ICES).

The Co-ordinated Environmental Monitoring Programme (CEMP, a component of JAMP) is designed to:

- describe the spatial distribution of a range of physical, chemical, biological and other parameters (including demography, inputs, specific activities);
- determine temporal trends, either as a means of assessing the effectiveness of policy measures, or to assess, using suitable indicators, changes and variability in the quality of the marine environment; and
- establish relations between anthropogenic activities and observed spatial and temporal trends in the marine environment.

The environmental chemistry programme of the Marine Institute includes monitoring of priority hazardous substances and nutrients, primarily in coastal and estuarine waters, to comply with a range of international directives and conventions. For most components of the programme, sampling is annual but supplemental surveys, research and baseline monitoring are undertaken occasionally to investigate particular problems or contaminants (e.g. toxaphene in fish, PCBs in mammals). The programme does not distinguish between transitional and coastal water and the typology of marine water bodies is not considered in monitoring design. Monitoring reports published by the Marine Institute are available on the Institute's website – http://www.marine.ie/frc/environ/

Monitoring of hazardous substances in finfish and in shellfish is carried out to assure the quality of seafood for human consumption and to assess the distribution of contaminants in the marine environment. This work is in compliance with Council Directive 79/923/EEC as well as the OSPAR Joint Assessment and Monitoring Programme (JAMP). Monitoring of contaminants in sediment is undertaken occasionally in selected areas to establish baseline conditions. Ireland's capabilities for measuring hazardous substances identified by the EU are summarised in Table 5.5.[3]

With regard to *operational monitoring*, the Directive focuses on the status of water bodies subject to anthropogenic pressures and the effectiveness of measures to alleviate these pressures. It explicitly requires operational monitoring of water bodies into which priority list substances are introduced from either point or diffuse sources. A large proportion of the transitional and coastal waters of Ireland will fit into this category; many estuaries and bays (transitional waters) are already subject to monitoring in accordance with either national, EU or OSPAR programmes. Whether or not inputs from the atmosphere, such as nitrogen and priority pollutants including PCBs and lindane, which contribute significantly to contamination of coastal waters, are to be assessed through operational monitoring, is unclear. Sample site selection is governed by the requirement to assess the *magnitude and impact* of the pressures (e.g. contaminant inputs) from the different point sources. Only those quality elements indicative of the particular pressures and risks to which the area is subject need to be monitored.

For marine monitoring, considerable complexity is introduced into the WFD by virtue of the distinctions between transitional and coastal waters, and between surveillance and operational monitoring. Arguably, this is not altogether justified. In the first case, salinity is only one of many factors influencing the distribution of substances and impacts in the marine environment. It is seldom a ma-

3. As of 7 June 2001, simazine, diuron and isoproturon were added to the list of priority hazardous substances subject to review. Ireland currently has little or no experience in analysing these substances in marine media.

Table 5.5. Current Irish testing capability for proposed EU-listed hazardous substances in marine media (✓, analytical experience; ×, little or no analytical experience)

	Biota	Sediment	Seawater	Biological effects
EU proposed priority hazardous substance				
• Brominated diphenylether (only pentabromodiphenylether)	×[1]	×	×	×
• Cadmium	✓	✓	×	×
• Chloroalkanes, C10–13	×	×	×	×
• Hexachlorobenzene	✓	✓	×	×
• Hexachlorobutadiene	×	×	×	×
• Hexachlorocyclohexane	✓	✓	×	×
• Mercury	✓	✓	×	×
• Nonylphenols	×	×	×	×
• Polycyclic aromatic hydrocarbons (PAHs)	✓[2]	✓[2]	×	×
• Pentachlorobenzene	✓[3]	×	×	×
• Tributyltin compounds	×	×	×	✓
EU proposed hazardous substances subject to review				
• Anthracene	✓[2]	✓[2]	×	×
• Atrazine	×	×	×	×
• Chlorpyrifos	×	×	×	×
• Di (ethylhexyl) phthalate (DEHP)	×	×	×	×
• Endosulfan	×	×	×	×
• Lead	✓	✓	×	×
• Naphthalene	✓[2]	✓[2]	×	×
• Octylphenols	×	×	×	×
• Pentachlorophenol	×	×	×	×
• Trichlorobenzenes	×	×	×	×
• Trifluralin	×	×	×	×

Notes

1: The MI is involved in an EU project developing PBDE reference materials in biota.

2: The MI has included PAH in past monitoring and proposes re-establishing PAH monitoring in fulfilment of OSPAR/CEMP requirements.

3: The MI is currently developing a methodology for testing this substance in biota.

jor consideration in the design of conventional monitoring programmes apart from certain specialised cases such as the monitoring of dissolved nutrients discharged by rivers and effluents. Boundaries between transitional and coastal waters are almost never distinct and vary with tide, season and weather conditions. Indeed, it is the interaction between coastal and offshore waters that largely determines the distribution of contaminants and their effects on marine ecosystems. The flux of materials transported by water movement is not invariably seaward. In designing monitoring programmes for coastal areas, the transition from freshwater to saline water to full seawater should be seen as a continuum rather than exchanges between adjacent water bodies.

5.5.3 Biological quality elements

A concise summary of existing activities, methodologies, research needs and outstanding issues relevant to biological quality elements is given in Table 5.6.

Table 5.6. Monitoring biological elements in transitional and coastal water: summary table.

Element to be monitored	Methods available	Current activities	Research needs/Outstanding issues	
			Reference values	**Methodologies**
Phytoplankton Transitional waters/coastal waters	Methods for sampling and identifying marine phytoplankton and for estimating phytoplankton biomass are readily available in Ireland but capacities for taxonomic work are very limited. **Contacts:** MI Abbotstown; EPA.	Phytoplankton communities are monitored at 50 sites in coastal waters during summer months. Chlorophyll is monitored regularly in major bays and estuaries.	Work is needed to establish a basis for reference values applicable to large areas, e.g. for surveillance monitoring. Chlorophyll levels alone may not be sufficient. More information on natural (seasonal and inter-annual) variability is a prerequisite.	Large-scale monitoring of type-specific areas for phytoplankton biomass might best be undertaken using aerial surveillance methods, i.e. low-flying fixed-wing aircraft. Methods currently used in monitoring the UK coastline should be investigated, possibly with a view to a joint programme
Macroalgae/angiosperms Transitional waters/coastal waters	Semi-quantitative methods are available for measuring biomass, structure and productivity of macroalgal communities over time (MRI Galway). Standard methods for recording density, biomass & change in angiosperm (seagrass) beds also exist (UCC).	No current routine monitoring of either macroalgae or angiosperms. Qualitative surveys of inter-tidal macroalgae (of commercial value) have been carried out on the west coast. Major survey of seagrasses (*Zostera* sp.) carried out in 1980s – still valid; good baseline.	Macroalgal communities are regulated by local conditions and differ widely. Research needed on feasibility of setting type-specific reference conditions for both macroalgae and angiosperms. Need policy regarding invasive species, e.g. *Spartina* and related ecological impacts.	A key question is whether or not macroalgal monitoring should focus on representative communities or species that are indicators of nutrient enrichment. A standard method for monitoring the composition and density of seaweed beds needs to be developed.
Benthic invertebrate fauna Transitional waters/coastal waters	The overview in O'Connor (2000) provides a good guide to available methods for sampling sub-tidal habitats.	Routine surveys are currently confined to aquaculture sites. **Contact:** MI Abbotstown	The priority is to identify reference sites, remote from human interference (including bottom trawling), for long-term monitoring.	The main task is to select a method suited to routine surveillance and operational monitoring – sensitive but not too labour intensive (i.e. recording major taxa not species).
Fish fauna Transitional waters	There are methods for assessing the status of marine fish populations but not the status of species inhabiting transitional waters. Salmon/sea-trout counters exist but are imprecise.	None. CFB will have responsibility for monitoring, with input from MI Fisheries Division.	There is immense inter-annual variability in the size and structure of fish populations. There is insufficient historical data to establish reference values.	Species to monitor? Acoustic methods to be investigated by CFB. ICES might be consulted regarding suitable techniques for monitoring trends in anadromous fish populations.

5.5.3.1 Benthic invertebrate fauna

Benthic invertebrates are good indicators of environmental quality with well-developed methodologies for qualitative and quantitative surveys of the benthos. An overview of relevant methods and information sources has already been provided to the EPA by O'Connor (2000). This report also describes marine monitoring activities in other EU countries. A manual for the evaluation of estuarine quality, including analysis of sediment macrofauna and the use of biological quality indices, can be found in Jeffrey *et al.* (1985).

A recent and comprehensive account of marine biological survey techniques is available on the UK's Joint Nature Conservation Committee website (http://www.jncc.gov.uk/marine). This is in the form of a draft Marine Monitoring Handbook covering techniques applicable to various marine systems including estuaries, bays and inlets. It also addresses monitoring in the context of managing Special Areas of Conservation (SACs). There would be considerable merit in harmonising the methodologies used by Ireland and the UK to monitor marine areas designated for protection and/or conservation.

Surveillance of benthic invertebrates around the Irish coast has not been part of the Irish national monitoring programme. However, surveys of 15 bays (including control sites) that support aquaculture along the west coast are carried out under contract to the Marine Institute; this is an example of operational monitoring as required under the WFD. In the UK, sediment samples for taxonomic analysis have been collected as part of the National Monitoring Plan (NMP) network of sampling stations for evaluating spatial patterns of environmental quality but, despite proposals to extend this network to the western Irish Sea, there are no equivalent activities in Ireland. On the other hand the BIOMAR programme has provided considerable information on benthic communities around the Irish coast (Erwin *et al.*, 1990). The resulting BIOMAR dataset, which is available on CD-ROM, could be used as a basis for selection of monitoring sites, including undisturbed reference areas, and for setting reference values for diversity and abundance. The dataset will also be of considerable value in determining the typology of marine water bodies.

A priority in planning the WFD surveillance-monitoring programme should be to select sites that can be repeatedly monitored to improve understanding of natural variability in benthic invertebrate communities.

Such sites should be protected from physical interferences such as dredging and bottom trawling and be remote from land-based sources of contaminants. Providing continuity of monitoring was assured, the sites would eventually yield invaluable time-series datasets that could be used to detect trends in diversity and abundance, including the effects of climate change.

5.5.3.2 Macroalgae/angiosperms

Studies of macroalgae on Irish coasts are related to their commercial importance, their use in monitoring contaminants (mainly radionuclides) and the prevalence of certain species in areas subject to nutrient enrichment. Recent surveys to establish the species of macroalgae present have been carried out, mainly between Donegal and Cork. Biomass records are based simply on observed abundances e.g. high, moderate, low. The large macroalgal communities typically found on rocky Atlantic shores have not so far been used as indicators of environmental quality. However, most species are strongly dependent on temperature for their growth and reproduction and are, therefore, considered to be good indicators of climate change. Current knowledge is almost entirely confined to inter-tidal algae.

The structure and density of inter-tidal algal communities is highly variable depending, *inter alia*, on substrate, exposure, temperature and light conditions. There are currently no criteria or reference values representing normal or undisturbed conditions. Biomass can be determined by weighing algal fronds harvested from fixed-area quadrats. Species richness is determined by taxonomic examination. Site descriptions include such features as productivity and community structure. These factors are suitable for comparing different communities over time.

Extensive monitoring of inter-tidal macrofaunal communities is unlikely to be an efficient means of detecting changes due to human activity. On the other hand, monitoring species of green algae that are believed to respond

to excessive inputs of nutrients deserves consideration. Extensive growth of green algae (largely *Enteromorpha* spp.) has been observed during certain periods on beaches of Dundalk Bay (near the mouth of the Castletown Estuary), in the middle reaches of the Boyne Estuary, on the beaches of Wexford Harbour, in parts of the Shannon Estuary and in the Garavogue Estuary. Strandings of *Ectocarpus siliculosus* in nuisance amounts around the margins of Dublin Bay are regular occurrences during summer months.

Although aquatic angiosperms (eelgrasses/seagrasses) have not previously been included in Ireland's marine monitoring programme, there is considerable expertise in Irish academic institutions with regard to their identification, distribution and biology. In the native flora, this group of plants includes species of *Zostera* and *Ruppia* and the fresh/brackish water species *Zannichellia palustris*. It also includes *Spartina* spp. but this is an introduction and a recognised threat to other seagrasses, especially the intertidal form of *Spartina*. They are found in saltmarshes, brackish lagoons and both intertidal and subtidal areas

Outside brackish lagoons, the most widespread genus is *Zostera*. *Z. noltii* is rare, the main beds located at Mulroy Bay (Co. Donegal), the mouth of the River Roe (Co. Derry), Strangford Lough (Co. Down), Bull Island/Kilbarrack (Co. Dublin), Tralee Bay (Co. Kerry), Cunnigar Sand Spit at Dungarvan and Backstrand at Tramore (Co. Waterford). The annual, intertidal form of *Z. marina* is also quite rare, notable beds occurring at Inch and Rossbehy sandspits (Dingle Bay), Tralee Bay (Co. Kerry), Mornington/Boyne Estuary (Co. Louth), Rosslare Backstrand (Co. Wexford) and Dungarvan Harbour (Co. Waterford). However, the perennial subtidal form of *Z. marina* is widespread around the coasts (probably over a hundred small beds) and locally abundant. It occurs on all types of substrate although in the literature it is often associated with muds and fine sands. *Zostera* beds, in particular, provide important nursery grounds for young fish and intertidal beds are notable as feeding grounds for Brent Geese (e.g. Bull Island, Inch and Rossbehy sandspits in Dingle Bay).

There are well-established methods for determining the extent, density and biomass of seagrass beds and for some areas (e.g. subtidal areas on the south coast) there are records extending back at least 20 years. The methods are suitable both for comparing beds at different locations and also for monitoring changes over time. The expertise and capacity to undertake periodic intertidal/subtidal seagrass surveys is available at the Department of Plant Science at UCC, while expertise on saltmarsh and brackish water species is available at UCG and UCD Botany Departments and at the UCD Zoology Department, respectively.

5.5.3.3 Phytoplankton

The monitoring of phytoplankton communities in Irish estuaries, inlets and coastal waters is designed primarily to detect changes related to nutrient inputs from specific sources such as rivers and aquaculture operations. The timing of surveys and the selection of sampling stations is biased towards periods and locations that are most likely to show departures from ambient local conditions. In essence, this is equivalent to *operational* monitoring as defined by the WFD as it focuses on parts of surface waters where there is a risk that environmental objectives will not be met.

Approximately 3000 phytoplankton samples are collected annually from the vicinity of aquaculture operations. Although the focus of these surveys is on harmful species of algae, all species and their abundances are recorded; biomass is not determined. In addition, regular surveys are carried out during summer months in 25 bays and estuaries around the coasts to assess effects due to inputs of organic matter and nutrients. These surveys include measurements of chlorophyll as an index of phytoplankton densities. There are very few locations where phytoplankton biomass is clearly influenced by nutrients derived from human activities. Examples are the Inner Cork Harbour and the Broadmeadow Estuary. Elevated chlorophyll concentrations over limited areas are regular features in some estuaries, notably in the south-east and mid-west, particularly during the summer months and periods of low freshwater flow. Whether this is a response to nutrient inputs or represents natural conditions is unknown. Nevertheless, on the basis of available information (largely nutrient inputs), some 20 estuarine sections (transitional waters) around the Irish coasts could not be conclusively classified as Non-Problem Areas from the

standpoint of eutrophication (OSPAR, 1999). These include the estuaries of the Castletown, Boyne, Broadmeadow, Liffey/Tolka/Dodder, Avoca and Slaney Rivers on the east coast; the Barrow/Nore/Suir, Blackwater, Lee and Bandon Rivers on the south coast, and the Deale, Maigue, Deel and Garavogue Rivers on the west coast. In addition, several bay and inlets including Dublin Bay, Cork Harbour, Killybegs Harbour and Mulroy Bay are classified as 'potential' problem areas.

As part of determining reference conditions for phytoplankton in Irish coastal waters, it will be necessary to select determinands for use as indicators of phytoplankton status. If, as might be the case, there is to be a substantial increase in the number of sites and/or areas to be monitored, field sampling followed by laboratory-based procedures may be impractical. Furthermore, neither chlorophyll *a* nor biomass are entirely satisfactory indicators of trends in phytoplankton production, although they can be useful in conjunction with analyses of community structure. Thus, it would clearly be sensible to precede any long-term and broad-scale monitoring of phytoplankton in marine areas by a programme of research to identify the most cost-effective method for achieving the objectives of such monitoring. This should include the use of aerial surveillance (low-level photographic imagery) to record chlorophyll density patterns and data from the Continuous Plankton Recorder (CPR)[4]; there is considerable experience with both these systems in the UK offering the prospect of a common Irish/UK, if not EU-wide, approach.

It is recommended that a study be conducted to explore (a) the use of aerial photography calibrated by ground truth data, and (b) the CPR, as a means of monitoring patterns and long-term trends in phytoplankton production in estuarine and coastal waters.

5.5.3.4 Fish fauna

The WFD requires the monitoring of fish in transitional waters. Whereas the Marine Institute has extensive experience in monitoring the status of commercial fish populations in coastal and offshore waters, there has been no routine monitoring of fish in bays and estuaries. This type of work has been, in the main, confined to short-term university studies such as occurs in the current *Biodiversity of estuarine fish* project in progress at the Department of Zoology, Trinity College. Although the range of fish species known to frequent areas influenced by fresh water is well documented, there is a lack of historical data on the population size and structure of individual species and considerable research would be needed to establish reference conditions for resident fish communities.

Discussion of the options for monitoring fish in transitional waters are ongoing between the Marine Institute and the CFB. The Marine Institute has agreed to play an advisory role whereas any research and monitoring activities related to fish in transitional waters will be the responsibility of the CFB. It appears that both agencies are inclined to recommend that monitoring be confined to anadromous fish, i.e. salmon and sea-trout. Among the possible monitoring methods are the use of fish counters at dams and weirs and acoustic measurements. However, to date there has been little progress in evaluating the practicality of applying these methods in bays and estuaries or the potential for meaningful interpretation of the data produced.

5.5.4 Hydromorphological quality elements

A concise summary of existing activities, methodologies, research needs and outstanding issues relevant to hydromorphological quality elements is given in Table 5.7.

At present, hydrographic surveys downstream of tidal limits are carried out only in relation to specific research or development (i.e. construction) projects or work related to maintenance of navigation, etc. Freshwater flow is routinely measured at the tidal limits of all major river systems. The assessment of freshwater flow through comparison with *undisturbed conditions* may be problematic in cases where land drainage and physical modification of river channels have caused changes to the natural patterns of freshwater discharge.

There are no systematic surveys to document changes in depth, structure, substrate and condition of inter-tidal areas. Suitably quantified historical records of such features are likely to be scarce, possibly non-existent. Records do exist on the extent and rate of coastal erosion

4. Programme of the Sir Alistair Hardy Foundation for Ocean Science (SAHFOS), Plymouth.

Table 5.7. Monitoring hydromorphological quality elements in transitional and coastal water: summary table.

Element to be monitored	Methods available	Current activities	Research needs/Outstanding issues	
			Reference values	**Methodologies**
Tidal regime				
Transitional waters	Methods available for measuring freshwater flow, i.e. river discharge and salinity.	Hydrometric stations and monitoring devices established at tidal limits of major rivers. **Contacts:** EPA, OPW	Need to examine historical records on freshwater discharges to establish inter-annual variability in relation to rainfall, etc., and freshwater discharge in relation to salinity profiles.	
Coastal waters	Methods for measuring direction and speed of dominant (tidal?) currents in coastal waters exist but equipment may be in short supply. Freshwater flow regime can be determined by salinity measurements.	Currents and freshwater influences (i.e. salinity) measured only for purposes of particular studies – not routinely.	Q. Reference conditions for coastal currents – Does this mean tidal currents?	Need to consider rationale for measuring coastal currents (and current type) in reviewing measurement options. Also consider relevance/ value of salinity and current data from the MI's automated buoys located further offshore.
Morphological conditions				
Transitional waters	Methods are available for measuring depth but there are no standard procedures for ranking the condition of substrates in inter-tidal and sub-tidal zones.	No routine activities suitable for measuring changes and trends; observations may be recorded for purposes of individual research projects.	Baseline data available from only a few coastal locations.	Need to develop indices of morphological condition that can be measured on numerical scales. Consider use of aerial survey techniques.
Coastal waters	Methods are available for measuring the depth, structure and substrate of the sub-tidal seabed, e.g. Roxann. Deployment on small in-shore vessels may be problematic.	No routine activities. Relevant parameters are recorded in some individual surveys.	Baseline data available from only a few coastal locations.	Need to develop indices of morphological condition that can be measured on numerical scales. Consider use of aerial survey techniques.

in certain areas. Along soft, as opposed to rocky, coastlines, there is ample evidence to demonstrate that such shores are unstable, i.e. constantly disturbed by ocean energy.

There are currently, also, no systematic surveys to record the depth, structure and substrate of the seabed in coastal areas or to record the dominant currents in these areas. Periodic surveys of such features could be carried through dedicated cruises of the research vessel *Celtic Voyager* (see Section 5.5.2). A network of automated buoys that will record currents and other parameters is being installed by the Marine Institute but, subject to setting of the baseline for purposes of the Directive (Article 2(7), these are likely to be seaward of coastal water boundaries.

5.5.5 Conclusions – Estuarine and coastal waters

Historically, the rationale underlying Ireland's marine environmental monitoring programmes has been to meet international requirements while also taking account of the relative risks associated with prevailing levels of human activity and the general state of Ireland's marine ecosystems as revealed by monitoring to date. Over the past number of decades, monitoring has shown consistently that, with a few well-documented exceptions, Ireland's near-shore waters are relatively clean and that ecological impacts owing to human activities are small in scale and often transitory (e.g. seasonal). Accordingly, the responsible agencies have maintained their surveillance monitoring activities at levels commensurate with the perceived need.

Although there is persuasive evidence from past monitoring that the ecological status of Ireland's coastal waters and most estuaries and bays is *high* or *good*, it would require a substantial increase in the national investment in marine monitoring and research to confirm this position in the manner expected by the WFD. Paragraph 21 of the pre-amble to the Directive states that the WFD is intended, *inter alia*, to 'make a contribution towards enabling Community and Member States to meet those obligations' contained in international agreements (including the OSPAR Convention) on protection of marine waters from pollution. The implications of this for the respective EU/WFD and OSPAR monitoring programmes are unclear but the statement would seem to offer an opportunity for some degree of integration of these programmes. At the very least, one would assume that efforts will be made to avoid unnecessary duplication and to ensure that scientific resources available for monitoring are not diverted to one programme at the expense of the other. Resource implications for monitoring required by the WFD are discussed further in Chapter 7.

Whereas the ultimate objectives of OSPAR and the WFD insofar as protection of marine ecosystems is concerned are quite similar, the approaches differ. The priority for OSPAR is contaminant reduction without a requirement to demonstrate biological effects, reflecting a rather broad interpretation of the precautionary principle. The WFD on the other hand focuses on maintaining ecological quality and compliance with environmental quality standards. Thus, in the case of the WFD, if ecological quality remains high and standards based on reliable ecotoxicological data are met, contaminant reduction may assume a lower priority.

These differences are reflected in the respective monitoring programmes. While OSPAR concentrates on chemical measurements, it is also developing indicators of biological effects as part of the suite of measurements to be used in monitoring. Until now OSPAR member states have had flexibility in deciding whether or not to apply biological effects measurements. They are not yet applied in Ireland. Thus, for Ireland, implementing the WFD requirement to develop and apply a range of methods for assessing the status of marine plant and animal communities will constitute a major expansion of the national monitoring programme.

5.6 Ground waters

5.6.1 The Groundwater Working Group of the DELG Co-ordination Group

Groundwater expertise in Ireland lies mainly with the Geological Survey of Ireland (GSI) and the Universities. This section of the report summarises the position on the approach to groundwater monitoring agreed by the Groundwater Working Group established under the aegis of the WFD Co-ordination Group (see Section 1.4). The remit of the Group was to assist in the technical interpre-

tation of the Directive, and to provide guidance for River Basin Projects in the delivery and implementation of groundwater work requirements. The opinion expressed in this section represents the interpretations of the working group as of 21 August 2001. The working group on ground water is led by the Geological Survey of Ireland and, in addition, comprises representatives from *Dúchas*, DELG, EPA, two local authorities (Monaghan and Tipperary (SR) County Councils) and one of the co-authors of this report, Paul Johnston. The views of this group have been edited in the context of this overall report and any mistakes are wholly the responsibility of the main author.

5.6.1.1 Requirements of the WFD

The Directive requires Member States to carry out an initial characterisation of all groundwater bodies to assess their uses, and the degree to which they are at risk of failing to meet the *environmental objectives*. For those groundwater bodies identified as being at risk, further characterisation is required in order to establish a more precise assessment of the significance of such risk. Groundwater bodies at risk have to be monitored for those parameters that are indicative of the risk.

However, it should be borne in mind that the exact requirements of the WFD are not fully determined at this stage. In particular, the European Parliament and the Council have yet to adopt specific measures to prevent and control groundwater pollution (Article 17) which, *inter alia*, shall include criteria for assessing good groundwater chemical status (Annex II, 2.2 and Annex V, 2.3.2 and 2.4.5) and criteria definition of starting points to be used for the assessment of upward trends in accordance with Annex V, 2.4.4.

Such criteria are necessary in order to:

- distinguish groundwater bodies at risk of failing to meet the objectives of Article 4 from those groundwater bodies at no risk, or only at negligible risk; and
- finalise the monitoring networks under Article 8.

In the absence of criteria adopted at Community level, Member States are required to establish appropriate criteria at the latest 5 years after the date of entry into force of the Directive. The EPA is currently developing guideline values for the assessment of groundwater quality in Ireland (Proposed Guideline Values for the Protection of Ground waters in Ireland, Draft for Comment, July 2001). It is proposed, on an interim basis and pending further elaboration of groundwater protection measures at national and Community level, that the proposed EPA list of parameters and guideline values be used for the characterisation of groundwater bodies for the purpose of River Basin Projects. It is envisaged that the Groundwater Working Group will continue to provide technical guidance for implementation of the groundwater aspects of the WFD. This guidance will be within the overall framework encompassing surface water, ground water, water-dependant ecosystems, and the pressures and impacts caused by human activities. It is essential that all these aspects are considered together in River Basin Projects and management.

The fundamental theme of the WFD is the evaluation of the hydrological cycle on a (topographic) catchment basis with particular focus on ecological interactions and dependencies. The characterisation of water bodies should, therefore, provide a basic understanding of the surface–groundwater interactions in the principal catchments. This understanding could be described as a 'conceptual model' and form the basis of further analysis of ecological and hydrological impacts.

Traditionally, the study and management of water resources has largely focussed on surface water or ground water as if they were separate entities. This approach will no longer be acceptable. Nearly all surface water features (streams, lakes, wetlands and estuaries) interact with and are hydraulically connected to ground water. The interactions, while difficult to observe and measure, take many forms:

- In most situations in Ireland, surface water bodies gain water and solutes from groundwater systems. Therefore, surface water resources and temporal changes in flow regime and quality are affected by geological materials (soils, subsoils and bedrock) and ground water.
- In some cases, particularly in karst areas, the surface water body is a source of groundwater recharge and

can cause changes in groundwater quality. Therefore, contamination of surface water can cause degradation of ground water and vice versa.

- Pumping of ground water for water supply can deplete water in streams, lakes or wetlands.

- Two of the fundamental controls on water chemistry in drainage basins are the type of geological materials that are present and the length of time the water is in contact with those materials.

The movement of water between ground water and surface water provides a major pathway for chemical transfer between terrestrial and aquatic systems. Therefore, understanding the mixing of ground water and surface water, particularly regarding acidity, temperature, dissolved oxygen and hydrochemistry, can help explain the characteristics of surface aquatic environments and enable predictions of human impacts (e.g. in relation to nitrates). For instance, some wetlands such as turloughs and fens are directly dependent on ground water. In other areas, the flow from ground water to surface water may help explain the aquatic fauna and environment. Also, in extremely vulnerable permeable areas, ground water can act as a significant pathway for phosphorus (and other contaminants) to lakes and streams, thereby being a potential cause of eutrophication (and contamination).

It is clear that, irrespective of the requirements of the WFD, an understanding of the interaction of ground water and surface water is essential to water management and planning. However, work for the WFD now provides an opportunity to integrate all the components of the hydrological cycle. So the conceptual framework for ground water needs to be broadened and expanded to encompass the overground components of the hydrological cycle, including meteorological, hydrological, ecological and hydrochemical aspects.

It is suggested that a 3-D 'conceptual catchment' should be used to help ensure that all aspects are integrated, understood and described. In particular, it would assist water managers to visualise groundwater movement and the interactions with surface water.

5.6.2 Characterisation of the ground water

A major element of groundwater characterisation is the mapping and description of 'groundwater bodies'. Characterisation of ground water, as required by Article 5 of the WFD, is sub-divided into two stages – initial characterisation and further characterisation, where further characterisation is required for groundwater bodies deemed to be *at risk.*

Virtually all of the requirements of the WFD relate specifically to 'groundwater bodies' rather than to 'ground water' and 'aquifers'. As it is a term that is not normally used by groundwater specialists, a description and understanding of the concept is crucial to enable the requirements of the WFD to be outlined and undertaken.

There are three relevant definitions in the WFD:

> *"Ground water" means all water that is below the surface of the ground in the saturation zone and in direct contact with the ground or subsoil.*
>
> *"Aquifer" means a subsurface layer or layers of rock or other geological strata of sufficient porosity and permeability to allow either a significant flow of ground water or the abstraction of significant quantities of ground water.*
>
> *"Body of ground water" means a distinct volume of ground water within an aquifer or aquifers.*

The concept of 'Groundwater Bodies' embraces[5]:

- ground water that can provide for the abstraction of significant quantities of water for human use (i.e. the ground water which can and should be managed to ensure sustainable, balanced and equitable water use); and

- ground water which is in continuity with ecosystems and can place them at risk, either through the transmission of pollution or by unsustainable abstraction that reduces baseflows (i.e. the ground water which

5. Acknowledgement: Much of this Section is based on a draft report from the UK WFD Technical Advisory Group. Further discussion and consideration by this Group should further clarify issues relating to groundwater bodies. One of the authors of this report – Donal Daly – is an observer on this Advisory Group.

can and should be managed to prevent environmental impacts on surface ecosystems).

The *groundwater body* is consequently the management unit under the WFD that is necessary for the subdivision of large geographical areas of aquifer in order for them to be effectively managed. This is the key aspect of the *groundwater body* concept.

Groundwater bodies must be divided into those that:

- are not considered to be *at risk* and subsequently do not require *further characterisation* or a high degree of surveillance (for the purposes of the Directive) but are still management units and will require operational controls; and
- are considered to be *at risk* and, therefore, require *further characterisation* and should be monitored (subjected to trend analysis, management measures and reporting, etc.) as relevant.

5.6.2.1 Groundwater bodies and Irish aquifers

The definition of *groundwater body* means that all groundwater bodies will constitute part of an aquifer or aquifers. Therefore, **an aquifer map must first be completed to enable groundwater bodies to be delineated.**

The aquifer categories defined in *Groundwater Protection Schemes* (DELG/EPA/GSI, 1999) will be the starting point for delineation of groundwater bodies. The aquifer categories are as follows:

1. Regionally Important (R) Aquifers
   - (i) Karstified bedrock (Rk)
   - (ii) Fissured bedrock (Rf)
   - (iii) Extensive sand/gravel (Rg)
2. Locally Important (L) Aquifers
   - (i) Sand/gravel (Lg)
   - (ii) Bedrock which is generally moderately productive (Lm)
   - (iii) Bedrock which is moderately productive only in local zones (Ll)
3. Poor (P) Aquifers
   - (i) Bedrock which is generally unproductive except for local Zones (Pl)
   - (ii) Bedrock which is generally unproductive (Pu)

All Irish bedrock units are defined as aquifers. The only subsoil that is classed as an aquifer is sand/gravel. Consequently:

the total land area of the country, **including all bedrock units and sand/gravel aquifers, will be sub-divided or grouped into groundwater bodies**.

Other subsoils such as till, peat, clays are not classed as aquifers and will not, therefore, constitute groundwater bodies.

5.6.2.2 Requirements of the WFD for initial characterisation

The initial characterisation of ground waters (Annex II, 2.1) will necessitate the location and delineation of groundwater bodies, based on several factors:

- the hydrogeology, as indicated by the aquifer category;
- catchment boundaries;
- information on the strata overlying groundwater bodies so that the vulnerability of ground water and recharge to ground water can be assessed to assist in delineating groundwater bodies *at risk*;
- information on the pressures caused by human activities and the impact of these activities to assist in delineating groundwater bodies *at risk*; and
- information on ecosystems that are either dynamically linked or dependent on ground water.

The initial characterisation includes initial identification of groundwater bodies followed, for each body, by an assessment of pressures, overlying strata, and linkages with ecosystems. As a consequence of these assessments, it is envisaged that the initial identification of groundwater bodies will require revision and sub-division. Ultimately all groundwater bodies will need to be categorised into those *at risk* and those *not at risk*.

Initial tasks

Table 5.8 outlines the current position and initial needs. The first stage in mapping groundwater bodies requires consideration of the aquifers and catchment boundaries. This requires:

- production of a bedrock map of the RBD;
- collection of relevant hydrogeological data from existing sources;
- compiling a map of karst features;
- completion of an aquifer map of the RBD;
- incorporation of the main river catchment boundaries, as these will generally act as groundwater divides;
- delineation of boundaries of groundwater body types based on the hydrogeological characteristics and resource value of the aquifers, and catchment boundaries;
- a description of these groundwater body types, which would include a simple conceptual model (see Section 5.6.3).

It is recommended that the aquifers be grouped as:

- karstic (Rk) aquifers;
- gravel (Rg and Lg) aquifers;
- productive fractured bedrock (Rf and Lm) aquifers;
- poorly productive bedrock (Ll, Pl and Pu) aquifers.

This grouping is based on similarities in (a) hydrogeological properties; (b) resource value; (c) likely monitoring requirements; (d) influence on surface water characterisation; and (e) the likely measures required to manage the ground water. They can be considered as general groundwater body types. They are further sub-divided by catchment boundaries to give a preliminary map of groundwater bodies. This will act as a framework for further sub-division based on areas that are considered to be *at risk* (see Section 5.6.4), and the nature of that risk.

The description of the groundwater body types should include information relevant to surface water characterisation, and should be written so as to allow easy integration with related aspects. The Working Group on Ground Water proposes that the GSI will produce the bedrock and aquifer maps, collect and compile relevant well and hydrogeological data, compile and map karst features, and undertake the initial location and description of groundwater bodies for the following reasons:

- to maintain consistent standards for aquifer delineation country-wide;
- to ensure that geological and aquifer boundaries match across RBD boundaries;
- to enable efficient access to relevant GSI databases and maps, and updating of these databases; and
- to ensure that the experience and expertise of the GSI staff in aquifer delineation and in undertaking groundwater protection schemes are utilised in RBD projects and that the groundwater protection schemes undertaken to-date are integrated with the River Basin Management Systems (RBMSs).

5.6.2.3 Strata overlying groundwater bodies

"Overlying strata" are the geological materials overlying the water table in unconfined groundwater bodies and overlying the top of the geological unit forming confined groundwater bodies. These strata will consist of soils (topsoils) and subsoils such as till, alluvium, lake and estuarine fine-grained sediments, peat, and sand/gravel deposits that are not classified as aquifers or groundwater bodies.

Identification of the general character of overlying strata is required to enable:

- assessment of the potential pathways of contaminants to ground water;
- evaluation of the vulnerability of ground water to contamination; and
- analysis of recharge to ground water.

Information on overlying strata will also assist in risk assessment, identification of measures to prevent contamination and surface water characterisation.

Table 5.8. Information needs, existing situation and recommended tasks for initial characterisation of groundwater bodies.

Information needs	Existing situation	Recommended tasks for RBMS projects	Objectives of work
Bedrock			
Geological unit boundaries (digital) Rock lithologies Structural geology – faults, fracturing	Digital bedrock maps and accompanying reports available in GSI for ~75% of country; the remainder will be available by mid-2002.	Reconfigure maps to suit catchment boundaries. Re-register data and boundaries to a common O.S. topographic base (1:50,000). Assessment of relevant aspects of structural geology	To provide boundaries of aquifers and groundwater boundaries To provide information needed in delineating aquifers
Soils			
	Teagasc soils maps (until 1980s) available for ~45% of country at 1:126,720, but not digitally. New Teagasc maps of remaining areas (FIPS – Irish Forest Soils project) will be complete by 2002. These maps are potentially more useful than existing maps – scale is 1:50 k, different soil classification system is used, e.g. soils sub-divided into wet and dry; maps are digital.	Deliver an integrated mapping programme for the RBD.	To assist in assessing the character of the overlying strata To assist in vulnerability and recharge assessments To provide essential information for surface water characterisation
Subsoils Map showing main types – sand/gravel, till (boulder clay), peat, clays/silts, alluvium, etc.	Subsoil maps are or will be available as part of county groundwater protection schemes for ~50% of country. GSI Quaternary Section is compiling existing information for remainder, but information is variable and is minimal for many areas. Teagasc is producing subsoils maps as part of the FIPS–IFS project. These will include the GSI information. However, current plans are that ~40% country will not be mapped.	Complete full coverage of all RBDs	To enable sand/gravel aquifers to be delineated To assist in assessing the character of the overlying strata To assist in vulnerability and recharge assessments
Map showing outcrops and shallow rock			
	Outcrops digitised for ~20% of country. Depth to rock data compiled or being compiled for ~50% of country, including delineation of outcrop areas.	For counties with groundwater protection schemes: Update databases and maps and ensure digital maps are integrated with RBD GIS. For counties without groundwater protection schemes: Compile and digitise rock and shallow rock areas;. Collect existing depth to rock data and delineate outcrop areas; and estimate 3-m soil/subsoil contour using all available data	To assist in assessing the character of the overlying strata To enable extremely vulnerable areas to be located To assist in recharge assessment

Table 5.8. ***contd.***

Information needs	Existing situation	Recommended tasks for RBMS projects	Objectives of work
Hydrogeology			
Wells – depths, location, yields, drawdowns, depth to rock, etc. Springs – location, outflows Karst features – location, type, description Specific capacity, permeability, transmissivity, specific yield Groundwater level data Low flows in streams (from EPA and OPW) Drainage density (stream length/unit area) Particle size data for gravels	Groundwater protection schemes are completed, in progress or planned for 50% of the country. Hydrogeological chapters in county groundwater protection schemes have been written primarily for groundwater protection and development purposes. Currently, GSI Groundwater Section is undertaking permeability mapping as part of vulnerability mapping for Monaghan, Kilkenny, Roscommon, South Cork and Kildare; and at preliminary level, for Clare and Laois. Vulnerability maps are either completed or in progress for ~50% of country. Mapping of karst features is being undertaken in Roscommon (Teagasc + TCD) GSI has a Karst Database which contains some information on karst features; however, it is not comprehensive. GSI has 20+ years' records of water level monitoring for a limited number of wells; over 100 with more than one year's records. EPA has monthly dipping for ~3–5 years at some 300+ locations. Initial quantification of groundwater resources and abstraction by GSI in 1979 (published by EC in 1982). Information on drainage density and stream frequency on OPW Flood Studies Report, 1975.	Re-evaluate data in counties where groundwater protection schemes have been completed and re-consider aquifer categories. Aquifer categories must be consistent within RBDs but also countrywide. Collect additional well/spring data from GSI, local authorities (incl. well grant data), EISs, IPCLs, waste licences, drillers, consultants, etc. for remaining areas. Attribute grid references for wells/springs and enter into database. Collect and map karst feature information and enter into database. Review sand/gravel particle size data and collect additional data. Summarise data consistently through RBD Delineate aquifers and produce an aquifer map. Produce a map showing 'extremely' vulnerable areas (i.e. areas with <3 m soil/subsoil and in vicinity of karst features). Carry out a preliminary assessment of recharge acceptance and runoff characteristics, concentrating on areas where the quantitative status is under threat. Report on hydrogeology, including groundwater characterisation. Ensure that digital maps are integrated with RBD GIS.	To allow categorisation of aquifers. To provide essential information for delineation of groundwater bodies. To allow an evaluation of groundwater recharge and quantitative status. To allow an evaluation of groundwater vulnerability and the relationship between this, pressures and impacts and qualitative status. To assist in characterising ecosystems dependent on ground water. To assist in the delineation of groundwater bodies 'at risk'.

Table 5.8. ***contd.***

Information needs	Existing situation	Recommended tasks for RBMS projects	Objectives of work
Hydrochemical and water quality			
Water quality data	EPA National Groundwater Quality Monitoring Network comprises some 296 (raw) groundwater sources that are sampled twice a year. Reports on individual samples are available from the EPA regional chemists. Data are published in the Water Quality in Ireland report, currently published on a 3-year cycle. The samples are analysed for routine chemical and bacteriological parameters. GSI reports are available on groundwater quality, as part of groundwater protection schemes: nine are completed; four are in progress. These include a brief description of the hydrochemistry of the ground water in the county; an assessment of the main indicators of groundwater contamination and the impact of human activity; an appraisal of the water quality of selected public supply wells/springs; and, where relevant, an assessment of trends. Assessments of groundwater quality carried out for EISs, IPC and Waste Licences, pollution incidents. Dúchas has information on sites which are already designated as SACs or SPAs on the Habitats and Birds Directive, respectively, or were proposed for designation as NHAs under the Wildlife (Amendment) Act 2001.	Compilation of water quality data Evaluation of data, using the EPA Guideline Values Identification of areas where the groundwater quality is indicating that the status is under threat Abstract the relevant ecosystems from the list of SACs, SPAs and proposed NHAs and sub-divide these sites into the three categories: (1) highly groundwater-dependent ecosystems; (2) dependent ecosystems; and (3) independent to locally dependent ecosystems. Identify the groundwater bodies associated with the sites in the three categories.	To assess the groundwater chemical status. To assist in the delineation of groundwater bodies 'at risk'. To identify surface water and terrestrial ecosystems dependent on ground water To assist in identifying groundwater bodies with dependent ecosystems
Ecosystems – Pressures and impacts			
Sectoral pressures on groundwater bodies	Under Section 9(2) of the Local Government (Water Pollution Act), 1977, each local authority is required to keep a register of abstractions from waters in its functional area, but under Section 37 of the Local Government (Water Pollution Act) Regulations, 1978, it is not necessary to register an abstraction where it is less than 25 m^3 in any period of 24 h. However, the registers while established may contain very little information. The EPA has a database containing some information on groundwater abstractions. The report published annually by the EPA on the Quality of Drinking Water in Ireland also contains some information on abstraction rates supplied by local authorities.	All sources with abstraction rates >10 m^3/day should be located. Abstractions from each groundwater body should be estimated. Deliver a GIS-based database of sectoral pressures and impacts on ground water including information on land use, discharge, abstraction and artificial recharge.	To identify: diffuse sources of pollution; point sources of pollution; abstraction points; and artificial recharge.

The tasks that need to be undertaken to classify strata overlying ground waters are:

- delivery of a soils map of the RBD (this will also be needed for surface water characterisation);
- completion of a subsoils map of the RBD;
- production of a map showing rock outcrop areas;
- compilation of all existing depth to rock data;
- a preliminary map of extreme groundwater vulnerability (i.e. areas with <3 m soil and subsoil); and
- a preliminary assessment of general recharge acceptance and runoff characteristics.

The Groundwater Working Group proposes that *Teagasc* would be a suitable body with the necessary expertise to produce subsoils maps and that the GSI undertake the production of a digital outcrop and depth to rock data map. The GSI holds the relevant information on maps and in various databases and it would be impracticable to undertake the work elsewhere. Further details are given in Table 5.8.

5.6.2.4 Ecosystems and groundwater bodies

The WFD recognises (Annex V, 2.3.2) that *good status* for ground water is dependent on ensuring appropriate groundwater conditions for the maintenance of *good status* for surface waters and the avoidance of significant diminution to the status of terrestrial ecosystems which depend directly on the groundwater body.

Terrestrial ecosystems dependent on ground water occur in areas where groundwater discharges to the surface or the rooting zone of the vegetation in sufficient quantity to determine the ecological potential of the site. Three basic divisions of wetlands that depend to varying degrees on ground water can be recognised:

1. Highly groundwater-dependent ecosystems where reductions in quantity/quality cause major adverse changes in ecosystem structure and function in the short- to medium-term. These include:

- turloughs;
- fens, in particular rich fens and flushes;
- springs;
- marl lakes; and
- dune slacks.

2. Dependent ecosystems which, although surface water may be a dominant influence at certain times, are usually dependent on some ground water in the medium- to long-term. These include:

- rivers;
- lakes;
- swamps;
- estuaries;
- lagoons;
- freshwater marshes;
- poor fens and flushes;
- transition mire and quaking bog;
- riparian woodland;
- wet willow–alder–ash woodland;
- bog woodland;
- non-marine caves; and
- machairs.

3. Independent to locally dependent ecosystems where surface water is the dominant influence and where ground water is generally only locally important. These include:

- raised bogs; and
- upland and lowland blanket bogs.

The WFD sets no lower area or site quality limits for these groundwater-dependent ecosystems. For the purposes of the River Basin Projects, the consideration of ecosystems dependent on ground water is likely confined to sites identified as being of national or international importance for nature conservation.

The following tasks are required:

- identification of all relevant sites which are already candidate SACs under the Habitats Directive (92/43/EEC) or designated SPAs under the Birds Directive (79/409/EEC), or which have been proposed as Natural Heritage Areas (NHAs), with a view to statutory

designation under national legislation. These are listed on the Protected Areas register by the Department of Arts, Heritage, Gaeltacht and The Islands;

- sub-divide these sites into the three categories (1, 2, 3) listed above and incorporate them into the RBD GIS; and
- identify the groundwater bodies associated with each site and conceptualise the relationship between the groundwater body and the ecosystem.

Further details on the information needed for identifying groundwater-dependent wetlands is outlined in Table 5.8.

5.6.3 Proposed methodology for delineation of 'at risk' groundwater bodies

One of the outcomes of initial characterisation (Annex, 2.2) is the identification of sites that are *at risk*. In the context of the WFD *at risk* is the likely failure to meet the environmental objectives set out in Article 4 (see Section 4.4). The advice given in this section is based on current interpretation of the WFD. This interpretation may change somewhat (a) as the work progresses, (b) as the interpretations of other EU countries become available, and (c) as advice is given by the EU.

The first stage will identify the types of groundwater body, which are then sub-divided using catchment boundaries to give the preliminary delineation of groundwater bodies. Each of these groundwater bodies must be examined in terms of the following criteria:

- the pressures on the groundwater body, including point and diffuse sources of pollution, and abstraction of ground water;
- groundwater chemical status;
- groundwater quantitative status, in particular levels of abstraction relative to recharge;
- long-term water level monitoring data;
- evidence of saline intrusion;
- conservation designated ecosystems dependent on ground water;
- the aquifer category (i.e. the value of the groundwater resource); and
- the extent of extremely vulnerable areas;

If the existing groundwater quality data are inadequate to decide on the chemical status, further monitoring is required (see Section 5.6.4).

Good **quantitative status** requires that *'the level of ground water in the groundwater body is such that the available groundwater resource is not exceeded by the long-term annual rate of abstraction'* (Annex V, 2.1.2). Therefore, the principal parameter for assessing quantitative status is the groundwater level. Spring discharges should also be used, particularly in karstic and poorly productive aquifers. The most widespread impact on the quantitative status of a groundwater body is from long-term groundwater abstractions. Consequently, information on the location of abstraction points and rates of abstraction is required. Owing to the relatively low levels of abstraction and the generally high rainfall in Ireland, it is unlikely that there will be many groundwater bodies where the quantitative status is at risk.

If, on the basis of results of the initial characterisation, the risk of not meeting the objectives is found to exist in only a part of a groundwater body, this area may be delineated as a separate groundwater body *at risk*, with the remainder being a groundwater body which is not *at risk*. However, it is recommended that all groundwater bodies should:

- have hydraulic boundaries, e.g. groundwater divides, flow lines, rivers; and
- be at least tens of km^2 in size to make them a practical unit for management.

The nature of development in Ireland and Irish hydrogeological conditions can give rise to localised groundwater quality problems, which are often indicated by microbiological pollution of private supplies, owing particularly to the presence of nearby point pollution source/s. While not specifically referred to in the WFD, microbial contamination of drinking water supplies are clearly covered under Article 7 and the requirements of the Drinking Water Directive 80/778/EEC as amended by Directive 98/

83/EC. This is an issue that requires to be dealt with in the identification of risk. The following are examples of groundwater bodies considered to be *at risk* and requiring further characterisation:

- where area-wide survey findings show poor groundwater quality;
- where area-wide survey findings show high levels of abstraction relative to recharge;
- groundwater bodies which encompass designated wetland habitats or ecosystems dependent on or significantly supported by ground water, and which are affected detrimentally by human activities or are under threat; and
- groundwater bodies where the pressures, vulnerability and aquifer category suggest that the ground water might be *at risk*, but where current monitoring data do not indicate problems. Work carried out during *further characterisation* may elucidate further such risk.

In describing groundwater bodies, and where practicable, it is recommended that where there are similarities in hydrogeology, pressures and impacts adjacent bodies within a river basin district should be grouped. It is recommended that grouping of small, discrete groundwater bodies (such as gravel aquifers) is done within an RBD where the pressures and impacts are similar.

5.6.3.1 Tasks for identifying groundwater bodies at risk

The tasks that need to be undertaken (Table 5.8) are:

- identification and assessment of pressures;
- assessment of the quantitative and qualitative status of ground water;
- assessment of the potential for significant adverse impacts on the ecology of designated groundwater-dependent wetlands taking into account their type, sensitivity to different pressures/impacts, distribution and status; and
- integration of hydrogeological, hydrochemical/water quality, ecological assessments with an evaluation of the pressures and impacts to delineate and describe groundwater bodies that (a) are not considered to be *at risk* and do not, therefore, require further characterisation or a high degree of surveillance; and (b) are considered to be *at risk* and therefore require further characterisation and should be monitored, subject to trend analysis, management measures and reporting, as relevant.

5.6.3.2 Further characterisation

Annex 11, 2.2 of the WFD requires that: *Following [..] initial characterisation, Member States shall carry out further characterisation of those groundwater bodies or groups of bodies which have been identified as being at risk in order to establish a more precise assessment of the significance of such risk and identification of any measures to be required under Article 11*. The tasks that are required for this are:

- detailed mapping and evaluation of pressures (i.e. improving on the evaluation of pressures carried out during initial characterisation);
- collection and assessment of relevant hydrogeological data on the hydraulic properties of the groundwater bodies *at risk*;
- vulnerability mapping and assessment of recharge, as appropriate or mapping of extremely vulnerable areas (we have to choose one of these options);
- collection, compilation and assessment of water level and abstraction data for groundwater bodies under threat from over-abstraction;
- collection and assessment of hydrochemical data, and identification of water types. (Advice and assistance on assessing the hydrochemical facies of different water types and the water quality data would be available from the GSI.);
- evaluation of water quality data, assessment of trends and likely causes of water quality deterioration;
- evaluation of the groundwater quantity and quality aspects of relevant ecosystems;

- refinement, if necessary, of the boundaries of the groundwater bodies delineated at the initial characterisation stage;
- description of the relevant aspects for each groundwater body, which should include a conceptual model of the body;
- establishment of a monitoring programme (see Section 5.6.3) based on the results of further characterisation; and
- identification of a programme of measures, based on the results of further characterisation, to achieve the objectives of *good groundwater status* for *at risk* groundwater bodies.

Further details on the tasks are given in Table 5.9. The list of tasks that need to be undertaken is comprehensive; the actual work required will vary depending on the groundwater body that is being characterised. Also, the work undertaken should be focussed on the objectives and requirements of the WFD. For some groundwater bodies, it may turn out during further characterisation that the risk, which was assumed from the initial characterisation, is negligible. Once this has become clear, continued characterisation is no longer necessary. The outcome of *further characterisation* will be a comprehensive assessment of the natural character (hydrogeological, hydrochemical, ecological, hydrological, as appropriate) of the groundwater body at risk. This must be linked to an assessment of pressures and impacts, and followed by the identification of appropriate measures to protect/enhance the groundwater bodies.

5.6.4 Monitoring groundwater status

5.6.4.1 Background

In the WFD, groundwater quantity and quality are inextricably linked for the purposes of establishing a coherent and comprehensive overview of water status within each basin district (Article 8). Likewise ground water is seen not as a separate system but, through the hydrological cycle, is linked to the other elements of the cycle, including surface water.

The WFD requires the establishment of monitoring networks to determine the groundwater quantitative and chemical status of representative groundwater bodies or groups of bodies. This means that monitoring points are not necessarily required to be located in all groundwater bodies but that they must be located so that they are representative of the groundwater body.

In Ireland, some locally important and poor aquifers, owing to their hydrogeological conditions, have short flow paths and the zone of contribution associated with the monitoring points is very small. Therefore, the usefulness of the existing monitoring points in terms of being representative of the groundwater body must be assessed. In addition the importance of natural springs as monitoring points should be considered.

5.6.4.2 Groundwater quantitative status

In order to establish the groundwater quantitative status, the WFD requires information on the available groundwater resource, the long-term average annual recharge, abstractions, variation in groundwater levels, information on the parameters of the surrounding geological strata and information on groundwater quality. The aim is to achieve *good quantitative status*. The principal parameter for assessing quantitative status is the groundwater level. These measurements are taken at monitoring points such as boreholes and also at spring discharges (as they are the surface expression of the groundwater level).

The available information on the existing groundwater level network as well as the recharge information will be reviewed during the initial and further characterisation stages. These stages will assist in the preliminary identification of groundwater bodies *at risk*.

'Good quantitative status' is established when

- *the groundwater level indicates that the available groundwater resource is not exceeded by the long-term annual average rate of abstraction;*
- *the groundwater level is such that it allows the achievement of the environmental objectives set for associated surface water systems;*
- *it results in no significant diminution in the status of such waters; and*

Table 5.9. Information needs and recommended tasks for *further characterisation* of groundwater bodies.

Information needs	Recommended tasks for RBMS projects
Hydrogeological	
• Hydraulic properties, in particular hydraulic conductivity and effective porosity of groundwater body • Information on degree of confinement • Hydraulic properties of superficial deposits • Evaluation of stratification in groundwater body • Recharge estimates for relevant areas • Baseflow and water balance data	• Identification of relevant hydraulic properties by means of: 1. evaluation of existing data; 2. pumping tests on selected public supplies; 3. numerical modelling, if appropriate. • Location and description of confined aquifers. • If vulnerability maps are not already available, mapping of extremely vulnerable areas (areas with <3 m soil/subsoil, plus karst features) on *at risk* groundwater bodies should be undertaken. Drilling to assess depth to rock is likely to be required. Where feasible and deemed necessary, full vulnerability mapping should be undertaken. Hydrograph/baseflow/water balance analysis, as appropriate. • Assessment of the link between ground water and surface water – evaluation of all relevant factors – baseflow, aquifer categories, vulnerability, etc., as appropriate. • Assessment of recharge (a) in areas where the quantitative status of ground water is at risk (see Section 5.3 for further details), (b) in zones of contribution of abstraction sources.
Hydrochemical and water quality	
• Hydrochemical and water quality data • Identification of groundwater types • Assessment of impact of human activity	• Evaluation of water quality using EPA guideline values. • Subdivision of chemical data into two categories – from sources with relatively uncontaminated water and the rest. • Use of graphical methods, such as Piper or Durov diagrams, to process data from uncontaminated sources into water types. • Assessment of trends.
Ecological	
• Inventory of nature conservation sites on the Protected Areas register and of all highly groundwater-dependent ecosystems with which the groundwater body is linked. • Groundwater quality and quantity requirements of the associated ecosystems.	• An integrated rapid vegetation, hydrogeological, and hydrochemical survey of a representative sample of the sites to characterise the nature of the hydrogeological connections, the hydrological regimes and the hydrochemistry necessary to maintain their ecology.
Hydrological	
• Hazard mapping and assessment of pressures and impacts	
• Inventory of surface systems and bodies of surface water, with which the groundwater body is dynamically linked	• Undertake the inventory

See Annex II, 2.3

– *it results in no significant damage to terrestrial ecosystems which depend directly on the groundwater body.*

In addition, any change in flow direction as a result of a change in groundwater level should not cause saline or other intrusion nor induce a trend in flow direction likely to result in such intrusion. A quantitative groundwater audit is required where a groundwater body does not achieve good quantitative status or the groundwater body is at risk of failing to achieve the objective.

Designing the quantitative status monitoring network

The monitoring network must be designed to provide an early indication of any negative changes on the quantitative status of the representative groundwater body. The network shall encompass both groundwater bodies *at risk*

and those *not at risk*. Additional considerations are required for those groundwater bodies at risk. In particular, attention should be given to the density of monitoring points to assess the impact of abstractions and discharges on the groundwater level.

In the case of cross-border groundwater bodies, the density of monitoring points should be such as to estimate the direction and rate of groundwater flow across the member state boundary.

All groundwater bodies that provide more than 100 m^3/day as an average shall be included in the monitoring programme irrespective of whether or not they are at risk or are cross-border groundwater bodies.

The location of monitoring sites must ensure that the **spatial variability and variability over time of the groundwater surface can be sufficiently well recorded** within a groundwater body. The density of sites must permit the collection of the most reliable data possible, particularly in ecologically sensitive areas. The location and density of the monitoring points is dependent on the hydrogeological conditions and also on the response of the aquifer to recharge.

The frequency of monitoring shall be such as to allow assessment of the quantitative status of each representative groundwater body (or group of bodies) taking account of the short- and long-term variations in recharge and to satisfy the requirements stated above. The frequency is dependent on the hydrogeological conditions and on the response of the groundwater body to recharge. No specific frequency of monitoring has been specified in the WFD. Once suitable strategic groundwater level locations have been identified, data loggers may be installed at them. The time interval at which the data logger is set can be time (e.g. set at 15-min intervals) or event driven (record water levels when levels rise a pre-set amount).

Any groundwater monitoring done within the RBDs needs to support/supplement the existing groundwater level network, and to avoid duplication of national effort, in order to provide a reliable assessment of the quantitative status of all groundwater bodies including an assessment of the available groundwater resource. The anthropogenic and natural changes in water level should be distinguished from each other. This echoes the call for good co-ordination made elsewhere in this report.

The recommended tasks for quantitative status monitoring are:

- following the review undertaken during the initial and further characterisation stages, additional strategically located monitoring points (boreholes or springs) should be nominated;
- the basis for the location and frequency of monitoring needs to be specified. A review mechanism of the suitability of the monitoring points should be built into the monitoring programme;
- compile well-construction data and hydrogeological data for each monitoring point;
- determine the zone of contribution of each of the monitoring locations;
- establish the groundwater quantitative status monitoring programme;
- collate and verify the data and store in a GIS-compatible data management system;
- assess the groundwater quantitative status of each of the groundwater bodies;
- for groundwater bodies that fail to achieve good quantitative status carry out a groundwater audit;
- map the resultant groundwater quantitative status on a colour-coded map; and
- propose a programme of measures for those groundwater bodies that fail to achieve good groundwater quantitative status.

5.6.4.3 Groundwater chemical status

The WFD requires *surveillance* and *operational* monitoring programmes to be established to assess the groundwater chemical status with the aim of achieving *good chemical status.* A number of parameters are used to assess chemical status and a core group should be analysed for in all samples with additional site-specific parameters

being added, particularly for those groundwater bodies *at risk.*

The information gathered in the initial and further characterisation will be used to identify groundwater bodies *at risk* with respect to their chemical status. Although criteria for *good chemical status* are defined in Annex V, 2.3.2 it is worth bearing in mind that the exact requirements of the WFD are not fully determined at this stage.

Designing the chemical status-monitoring network

The WFD requires that a groundwater chemical status monitoring network be set up, comprising a *surveillance* and an *operational* monitoring network. The two networks shall be used for the monitoring of groundwater status in order to establish a coherent and comprehensive overview of the chemical status of ground water within each River Basin District. The networks will also monitor groundwater bodies used for the abstraction of drinking water. The operational network shall also detect the presence of long-term anthropogenically induced upward trends in pollutants. A programme of measures to achieve *good groundwater status* must also be proposed.

River Basin District Management Plans (RBDMPs) should ensure through good co-ordination mechanisms that monitoring supports/supplements the existing groundwater level network, and to avoid duplication of national effort, in order to provide a reliable assessment of the chemical status of all groundwater bodies including an assessment of the available groundwater resource. The anthropogenic and natural changes in water quality should be distinguished from each other.

Surveillance monitoring

The objective of the surveillance monitoring is to supplement and validate the impact assessment procedure and to provide information for use in the assessment of long-term trends both as a result of changes in natural conditions and through anthropogenic activity.

The surveillance monitoring programme must be arranged to ensure that a coherent and comprehensive overview of groundwater chemical status can be given for each representative groundwater body or group of bodies. The network needs to be able to detect, at an early stage, changes of trends in chemical status, to register long-term quality trends and to establish their causes (natural or anthropogenic). The monitoring programme needs to assess the general chemical status of groundwater bodies whether or not they are *at risk.*

The necessary density of monitoring points should be determined by the type and structure of the groundwater body under review and by its use as a water resource. The monitoring sites should cover all geohydraulic typologies. A monitoring site may be considered representative if:

- the quality of the ground water recorded at that point is considered typical of the wider area, or
- the monitoring site, owing to its position in the geohydraulic system, and in view of existing land use in the recharge area, is characteristic of a wider area.

To assess chemical status regular samples shall be taken from the selected groundwater monitoring sites including spring sites. A core group of parameters should be analysed for in all cases and other parameters that are significant in the catchment area of the groundwater body and can constitute a negative influence on the groundwater quality should be included. Groundwater bodies should be monitored for at least pH, electrical conductivity, and oxygen, nitrate and ammonium concentrations.

In addition, groundwater bodies that have been identified as being at significant risk of failing to meet the objectives shall be monitored for those parameters indicative of the impact of those pressures. In the case of cross-border groundwater bodies, they shall be monitored for those parameters which are relevant for the protection of all of the uses supported by the groundwater flow.

The frequency of monitoring shall be such as to allow assessment of the chemical status of each representative groundwater body and to satisfy the requirements stated above. The frequency will be dependent on the hydrogeological conditions and is dependent on the vulnerability and flow regime of the groundwater body. The monitoring frequency for surveillance monitoring should be at a minimum of twice per year (spring and autumn). Groundwater bodies comprising regionally important aquifers

should be monitored more frequently owing to their water resource requirements. In addition, monitoring sites that demonstrate strong fluctuations of concentrations over the period of the year should be examined more often. In the case of karstic aquifers subject to large fluctuations in water quality at times of flooding, continuous monitoring may be required for certain parameters.

Operational monitoring

The results of the surveillance monitoring programme shall be used to establish an operational monitoring programme for the RBDMPs.

The objectives of the operational monitoring programme are to establish the chemical status of all groundwater bodies determined to be *at risk* and to establish the presence of any long-term anthropogenically induced upward trend in the concentration of any pollutant. This monitoring is additional to the surveillance monitoring.

The operational monitoring programme shall be carried out for all those groundwater bodies or groups of bodies that have been identified, either through the *characterisation* or through *surveillance* monitoring, as *at risk* of failing to meet the objectives under Article 4. The selection of monitoring sites should be representative of the relevant groundwater body or bodies. Sites, identified during *surveillance* monitoring, with increased pollutant concentrations or long-term anthropogenic trends should also be used for *operational* monitoring.

The scope of parameters to be measured for *operational* monitoring should generally correspond to that of *surveillance* monitoring and should be extended where necessary to include elements polluting or threatening to the specific groundwater body being assessed.

Operational monitoring shall be carried out at a minimum of once per annum and in between the surveillance monitoring programme. As for *surveillance* monitoring, the frequency of monitoring shall be such as to allow assessment of the chemical status of each groundwater body, as stated above. This frequency will depend on hydrogeological conditions and on the vulnerability and flow regime of the groundwater body.

The following tasks are identified for *chemical status* monitoring:

- following the review undertaken during the initial and further characterisation stages, nominate additional strategically located monitoring points (boreholes or springs);
- provide the basis for the location of the monitoring points and the frequency of monitoring. A review mechanism of the suitability of the monitoring points should be built into the monitoring programme;
- compile well-construction data and hydrogeological data for each monitoring point;
- determine the zone of contribution of each of the monitoring locations;
- establish the groundwater chemical status monitoring programme that comprises a *surveillance* and *operational* network;
- provide an estimate of the level of confidence and precision of the results provided by the monitoring programmes;
- collate and verify the data and store in a GIS-compatible data management system;
- assess the groundwater chemical status of each of the groundwater bodies;
- identify any significant and sustained upward trend in pollutant concentration from the operational monitoring programme;
- map the resultant groundwater chemical status on a colour-coded map; and
- propose a programme of measures for those groundwater bodies that fail to achieve good groundwater chemical status.

5.6.5 Conclusions – ground waters

The DELG Groundwater Working Group has identified a detailed list of tasks required for implementation of the WFD. It is clear that an essential early initiative needs to be the characterisation of ground waters. This inevitably requires significant survey effort to provide the basis of

WFD implementation. A primary task is the completion of the national GSI survey of ground waters. There is also a clear need for survey information to be collated into nationally available datasets. The collation of information must extend to the description and quantification of catchment features such as coverage of soil type in order to assess risk (see Chapter 4) to groundwater quality. The application of such extensive data collations requires the use of GIS and sophisticated data management procedures. Data management in general is considered in the next section.

5.7 Data management requirements for monitoring

The demands for monitoring for the WFD will generate large volumes of data from an array of organisations. The need for an elegant and clearly defined strategy of data management is obvious. Once the procedures for collection and analysis of environmental data that meet the needs of the WFD are established, results from monitoring will be fed into, progressively, local, regional and national reporting structures. This will involve State and non-governmental bodies in the exchange of information and the reporting on quality status. The management of data is helped greatly by an understanding of the effect that catchment characteristics and management have on measured quality states. These can be summarised as *driving forces*, *pressures*, *status*, *impacts* and *responses* (DPSIR). The WFD suggests that this is best achieved through the involvement of all stakeholders. While this can also be a laudable goal of data management systems it would be prudent to start with the inclusion of the main bodies currently involved in data collections.

Current proposals of the DELG indicate that there will be five RBDs in the Republic of Ireland and two cross-border RBDs involving Northern Ireland. Monitoring and data management require co-ordination among a range of separate administrative entities. This involves local authorities with a fairly distinct geographical point of reference, RBMS projects which encompass geographically holistic, but administratively complex regions, and organisations with a remit for national coverage. However, data will be both generated and required at each level of the hierarchy, involving multidirectional flows of information. A transparent and clearly defined understanding of the information base is an essential requirement. This should include the adoption of standard methods on the description of the datasets and their exchange.

A recent EPA-funded project awarded to *Compass Informatics* for advice on *Information Management and Data Interchange between River Basin Management Systems* (RBMSs) *and National Organisation* highlights a number of key tasks on the road to implementation of the WFD. These include:

- a review of information management strategies and existing catchment management tools and datasets;
- the need for a strategic approach to the development and application of GIS and associated databases for RBMSs;
- the definition of datasets and the production of electronic data interchange (EDI) standards for information transfer; and
- an assessment of specific GIS/data interchange requirements for integration of data from cross-border RBMSs.

The development of reporting and analytical procedures, including modelling, should aim to be responsive to changes in pressures and to be predictive in guiding catchment management. The use of GIS in data presentation and management will provide the medium through which data and reporting is channelled. The capability of GIS goes beyond a simple, albeit multi-layered, presentation. Catchment management strategies can benefit from incorporation into GIS of data analysis and modelling. This is important for assessment of risk (as required for initial characterisation of RBDs and the identification of pressures (Article 5; Annex II), specific pollutants (Article 16), groundwater pollution (Article 17) and the response of aquatic systems to the programme of measures (Article 11)). The application of GIS can be enhanced by reference to internationally adopted standards on GIS dataset description (e.g. the US Federal Geographic Data Committee).

The need to establish the extent of data production from the different National Organisations and their availability for WFD implementation will raise commercial and legal

issues as well as technical ones. These include the resolution of potential difficulties to data management on policies of charging, confidentiality and conditions of use. The spirit of the WFD is that data required for assessment of risk, the establishment of monitoring programmes and the *implementation of measures* within River Basin District Management Plans (RBDMPs) need to be, at least, available to the *Competent Authorities.* Currently not all datasets of relevance to WFD implementation are available. This is particularly, but not exclusively, the case with datasets that are classified as commercially sensitive, e.g. Nutrient Management Plans under the Rural Environmental Protection Scheme (REPS). The restriction of data flow owing to commercial confidentiality needs careful consideration and, if deemed to be justified, the creation of protocols that neither restrict the rights of the individual nor the ability to apply optimal catchment management systems. The recent report (Clenaghan *et al.*, 2001) on the implementation of the Phosphorus Regulations (S.I. 258 of 1998) highlights, *inter alia*, unsuccessful attempts by local authorities to obtain farming statistics from the Department of Agriculture, Food and Rural Development. A lesser hindrance to data availability, but nevertheless of some importance, is the restriction of data use owing to high costs, copyright protection and State Agency procedures. Low-cost availability of data collected and analysed by Government or State agencies will facilitate WFD implementation. This is particularly so if, in the longer term, public participation as required under Article 14 is to be a meaningful process.

5.7.1 Modelling and GIS integration

Some datasets of potential use for WFD implementation are complete thematic entities in their own right. Examples are forestry maps from the FIPS database of the Forest Service, datasets on protected areas published by *Dúchas* and the Groundwater Protection mapping under development at the Geological Survey (GSI). Others, especially key OSI datasets are basic building blocks which require considerable editing to derive suitable datasets (e.g. polygonised and attributed rivers and lakes). Consideration needs to be given to the centralisation of national and standardised datasets (e.g. lake identification codes or river reach sectioning and identification codes as developed by the EPA) for use in all RBMS projects.

The identification and description of appropriate software models is important for data management required by the WFD. Issues to be considered in application of software models in RBMS include (1) the need to more fully understand observed patterns (e.g. water circulation regimes in estuaries are difficult to understand without a hydrodynamic model), and (2) the requirement to access the potential change in status arising from a change in conditions (e.g. the examination of alternative management strategies). Model use should also be assessed in the context of scale (e.g. whole catchment compared with an impaired river section). A review of this issue as it relates to phosphorus mobility can be found in Jennings *et al.* (unpublished report to the EPA). However, model development needs to be appropriate to the context of its use.

It is recommended that there is a need to develop GIS interfaces of catchment models in order to incorporate dynamic models and that models used in RBMS should have a clearly defined purpose and well-documented methodology. **The development and application of GIS systems within RBMS projects needs to facilitate linkage with systems operated by a number of organisations and the need for bi- and multi-directional information exchange**.

An optimal GIS should be able to support a variety of functions and operate at a variety of scales or support a nested scale approach. It will be critical to specify the functionality required of the GIS and include long-term requirements for WFD-associated analysis and reporting structures. The application GIS for analysis of catchment processes and dissemination has been, and continues to be, developed by a number of European and international projects.

Reviews of modelling systems have been prepared by, amongst others, the Natural Resources Conservation Service of the US Department of Agriculture (Natural Resources Conservation Service, 2000) and the Water Environment Research Foundation (2000) which serves the water industry in the US. A list of commonly referenced models, of relevance to the WFD, is given in Table 5.10. Most of these models are related to phosphorus mobility. Of significance for hydrologic pathways is the SHE (Systeme Hydrologique European) hydrological model (Abbott *et al*., 1986). This has undergone consid-

erable development, primarily in Europe (e.g. SHE-TRAN (Bathurst and Purnama, 1991)).

The Hydrological Simulation Program-FORTRAN (HSPF) system (Bicknell *et al*., 1996) is a comprehensive system for the simulation of catchment and water quality for both conventional and toxic organic pollutants. It is actively supported by the US EPA and is incorporated within their integrated, GIS-based, water quality management system BASINS (Better Assessment Science Integrating Point and Nonpoint Sources). It has been stated that the HSPF is "the only comprehensive model of watershed and water quality that allows the integrated simulation of land and soil contaminant runoff processes with in-stream hydraulic and sediment–chemical interactions"(US EPA, 1995), although the extent of comparison with the SHE system is unclear. BASINS is based on the proprietary ArcView GIS.

5.7.2 Developments in Ireland and *Catchment Envisage*

The data management project run by *Compass Informatics* will assess the current use and applicability of different GIS formats for application to the data management required for the WFD. GIS as a tool for catchment management is at an early stage of development in Ireland. There is, however, development of a prototype system, *Envisage*, for use in data management by the Local Government Computer Services Board (LGCSB). *Envisage* utilises MS Access and the Mapinfo GIS and was commissioned by the DELG in 1996 as a system for the management of River Basin Projects. It includes modules for rivers and lakes, farms, water quality, discharges, sludge, bathing and geology. An upgrade in 1999 to *Catchment Envisage* has been used in the Three Rivers Project and the Lough Derg/Ree Project. Its goal is to provide reports for catchment management and implementation of local authority nutrient management plans. The data store of *Envisage* is made up of individual *Access* databases, which can be modified and reviewed individually from outside *Envisage*. Stand-alone data management systems can be developed which include, *inter alia*, data from water chemistry monitoring, farm surveys, and hydrometrics. This system has also been deployed in the Lough Derg/Ree project, which had a central data management office in Clare. A “laboratory system” pilot scheme (LabInfo) with a more simplified format is currently in place. There are plans to enable the use of LabInfo from the Internet.

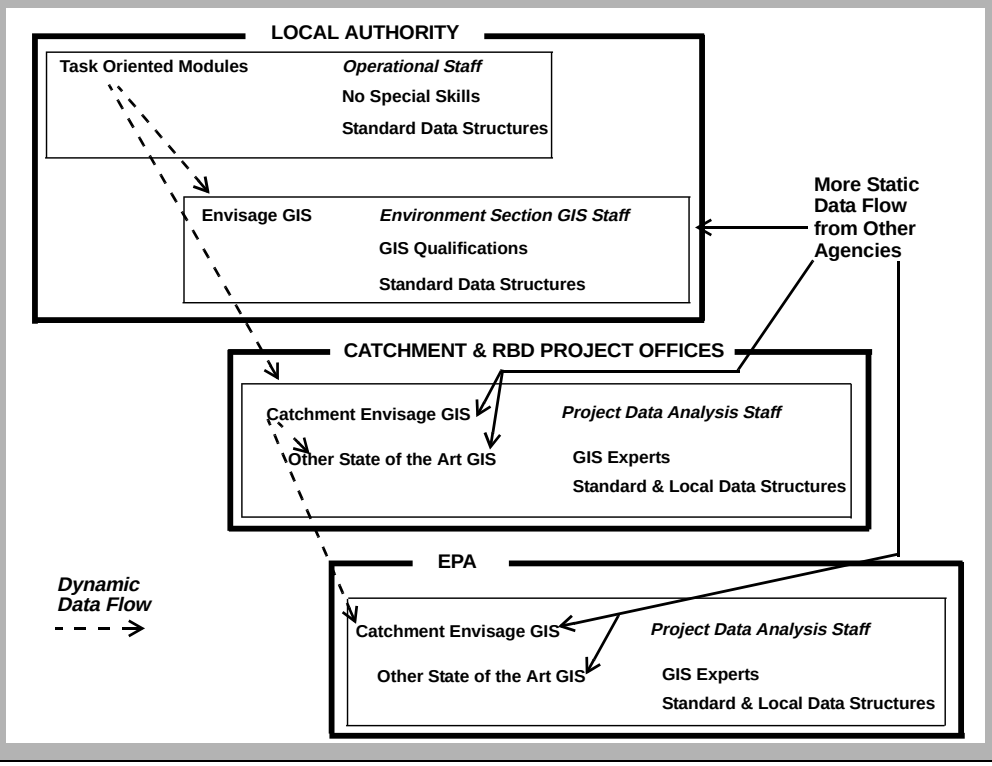
One advantage of the system appears to be the relative ease of use (Box 5.5). However, whether or not *Catchment Envisage* will be used in RBMPs is, pending a thorough review, uncertain. The *Catchment Envisage* system to date has focussed, via a series of task-orientated modules, on tools primarily for the recording and audit trail of survey and laboratory data. It remains to be seen if there is the capacity to expand *Envisage* for multi-scale risk assessment and other tasks involving GIS-based, multi-topic analysis as defined by the WFD.

Table 5.10. Models incorporating nutrient fate and transport elements (adapted from WERF, 2000).

Model acronym	Model name	Sponsor/developer
AGNPS-98	Agricultural Non-Point Source Pollution Modelling System – continuous version	USDA ARS
ANSWERS	Areal Nonpoint Source Watershed Environmental Response Simulation	North Carolina State University
CREAMS	Chemicals, Runoff and Erosion from Agricultural Management Systems	USDA ARS
GLEAMS	Groundwater Loading Effects of Agricultural Management Systems	USDA ARS
HSPF	Hydrological Simulation Program-Fortran	US EPA; USDA
MIKE SHE	Distributed and Physically Based Modelling System for Flow, Water Quality and Sediment	UK Institute of Hydrology and Danish Hydraulic Institute
SHE/SHESED	Basin Scale Water Flow and Sediment	University of Newcastle, UK
SWAT	Soil and Water Assessment Tool	Texas A&M, USDA ARS
SWRRBWQ	Simulator for Water Resources in Rural Basins	USDA ARS

Box 5.5 (Courtesy of LGCSB)

Diagram to represent flow of information and requirement of skills to implement *Envisage*.



5.8 Summary of methodological constraints to monitoring

There are two clear conclusions that arise from a review of monitoring capability for implementation of the WFD. These are:

1. **Monitoring programmes must be carefully planned, adequately financed and tightly co-ordinated. This will necessitate meaningful liaison among agencies and others involved in monitoring. This is essential where there are overlaps of statutory duty.**

2. **Monitoring should have clear objectives related to the need to determine quality ratios based on definitions of reference conditions.**

There are, furthermore, a number of important recommendations for the effective implementation of monitoring. These are:

- The need for agreement on which elements and parameters are required to be monitored.

- The need to develop protocols for the monitoring of most, if not all, biotic elements. These should be robust and subject to measures of Quality Assurance. This will require further research and development.

- The understanding of underlying spatial and temporal distribution is critical for efficient monitoring. All monitoring should take into account natural variability and, wherever possible, incorporate estimates of precision in reporting of the results.

- Monitoring in all the River Basin Districts requires a consensus on the use of techniques, taking into account accepted international practice and published standards.

- *Surveillance* and *operational* monitoring programmes should be designed and managed in parallel, with a view to minimising the number of

sampling sites and surveys necessary to meet the data requirements of the Directive.

- A need to ensure that all monitoring required under existing legislation is brought up to the specified standard without delay.
- A reappraisal of existing Regulations where these appear to be inadequate to meet the monitoring demands of the WFD.
- There should be an extensive collation of relevant and reliable historical records.
- It is clear that an essential early initiative needs to be the characterisation of ground waters. This inevitably requires a significant survey effort to provide the basis of WFD implementation. A primary task is the completion of the national GSI survey of ground waters.
- Technical options for making measurements of all monitoring elements need to be explored, taking into account both state-of-the-art developments and more straightforward techniques.
- Consideration should be given to the development of programmes for training in order to provide an adequate national capacity for quality assured and quantitative measurements of the required elements.
- There is a need to develop refined information systems with the capacity for efficient data transfer among RBDs and national authorities. This should include the development of GIS interfaces of catchment models in order to incorporate dynamic models. Models used in River Basin Management Systems need to have a clearly defined purpose and a well-documented methodology.

6. Towards a national WFD implementation strategy

6.1 Introduction

The Water Framework Directive (WFD) provides for a comprehensive strategy for the protection and management of water resources. It has many implications for water management in Ireland. It requires a shift towards integrated management of all water bodies on a catchment basis, including adjacent coastal waters, as well as the development of quality criteria reflecting conditions in healthy (i.e. undisturbed) aquatic ecosystems. The WFD also requires a systematic assessment of the impacts of water uses linked to measures to protect, and where necessary restore, water quality. The traditional, more piecemeal, approach to water management must be adapted to the requirements of the WFD. This will certainly require changes in the methodologies used to assess the ecological quality of aquatic systems and the anthropogenic pressures on them. It would not, however, appear to necessitate the creation of any new authorities. The view of the DELG is that implementation of the WFD will be achieved through **greater co-ordination** between the existing competent authorities, **without** the establishment of any new authorities and **without** any transfer of functions between authorities. This seems to be the preferred approach being adopted by most EU Member States. It may be necessary, however, to assign *additional* functions to certain authorities (e.g. the making of a River Basin Management Plan (RBMP)). The *Department of the Environment and Local Government* (DELG) has the lead role in relation to the initiation and co-ordination of arrangements for implementation of the WFD. The major portion of the work for implementation of the WFD falls within the water quality management remit of the DELG, local authorities and the Environmental Protection Agency. Important additional elements are envisaged as being contributed by other agencies. The approach adopted by the DELG is that each of the new River Basin Districts (RBDs) will be chaired by a lead authority. These are proposed to be:

- Shannon RBD (Limerick County Council)
- Eastern RBD (Dublin Corporation)
- Western RBD (Galway County Council)
- South-Eastern RBD (Carlow County Council)
- South-Western RBD (Cork County Council)

It is envisaged by the DELG that the National Co-ordination Group will provide the forum for technical guidance.

Regardless of the political arrangements it is clear that the strategy embodied in the WFD needs to be matched by a co-ordinated national strategy for implementation. This is particularly relevant to the planning and conduct of scientific activities, the success of which will depend on good collaboration between agencies and a common understanding of roles and responsibilities. Certain technically complex actions must be completed in less than 4 years. This stresses the need for a well-organised and efficient scientific contribution, especially during this preparatory period. The implementation strategy should clarify the division of responsibilities and procedures for inter-agency co-ordination, for the orderly phasing of related or dependent activities and for the provision of scientific and technical resources. A national strategy would help to harmonise approaches within and between the various RBDs and to ensure the optimum distribution of functions and responsibilities between national and regional authorities.

A *Common Strategy on the Implementation of the Water Framework Directive*, agreed by the EU Water Directors, was issued on 2 May 2001. The document acknowledges that the WFD presents a major challenge to Member States, noting the demanding timetable, the complexity and incompleteness of the text, the diversity of possible scientific approaches, the problems of capacity and the limited availability of human and financial resources. The main purpose of this EU strategy is to clarify and develop technical and scientific information to assist in the practical implementation of the Directive. To this end, a set of 'key' activities is presented, consisting of workshops each with a lead country and broad representation from the Member States that will develop guidance on how particular aspects of the Directive might be imple-

mented. It is, nevertheless, made clear that the responsibility for implementing the Directive lies fully within the competence of individual Member States. Thus, whereas the guidance resulting from this initiative may be very useful, the Common Strategy does not obviate the need for a national strategy.

While it is recognised that the DELG Co-ordination Group is active in formulating requirements for the WFD, it is recommended that a national **WFD implementation strategy** should be drafted and widely distributed to address the following aspects of the Directive:

- designation of functions and responsibilities between agencies (including local authorities);
- national and regional mechanisms for co-ordination and liaison;
- Republic of Ireland/Northern Ireland (North/South) collaboration;
- establishment of technical working groups and workshops;
- contractual arrangements for technical services (e.g. monitoring and assessment functions);
- environmental data management;
- information flow – publication and dissemination; and
- public consultation procedures

6.1.1 Need for a sequential approach

It is clear from the articles and annexes of the Directive that implementation will involve a sequence of activities. This is not only indicated by the deadlines for the completion of particular actions but also by the nature of the scientific and technical tasks that must precede the development of management plans, monitoring programmes and programmes of measures. A schematic representing a logical sequence of actions, highlighting the most important scientific tasks and considerations, is given in Figure 6.1.

6.2 National and regional co-ordination

A fundamental component of the implementation strategy will be the identification of centres of responsibility for the various administrative and technical functions specified under the Directive. Although certain decisions of a procedural or organisational nature may continue to be the responsibility of a national inter-agency WFD Co-ordination Group, **it is strongly recommended that day-to-day activities be managed by a dedicated office**, within an appropriate national agency, with overall responsibility for harmonising activities regionally (i.e. within and between RBDs) while monitoring progress and ensuring that targets are met. It will be particularly important to harmonise activities under Annex V of the Directive and the procedures used in preparing management plans, including the setting of ecological reference values and the design of monitoring programmes.

Similarly, the responsible bodies within RBDs will need to appoint appropriately qualified individuals, operating internally from dedicated offices, to service WFD management groups or steering committees, to liase with national agencies, to co-ordinate activities relevant to their Districts and to assist with the preparation, implementation and ongoing review of Management Plans.

It is important to stress that, although good management and co-ordination will be essential to the success of the WFD, great care should be taken to avoid an excessive number of management committees and meetings. It is particularly important to avoid a situation whereby senior managers and specialists are involved in numerous committees and have too little time between sessions to make productive contributions. Rather, a **slim and efficient management structure** is called for. Accordingly, the national strategy should seek to minimise the number of committees and working groups at regional level.

6.2.1 Preparation of River Basin Management Plans

It appears that management ‘systems’ and ‘strategies’ for RBDs are to be prepared largely by contractors under the direction of management groups and steering committees. While this approach obviates the need in the short-term to recruit additional specialists into the public serv-

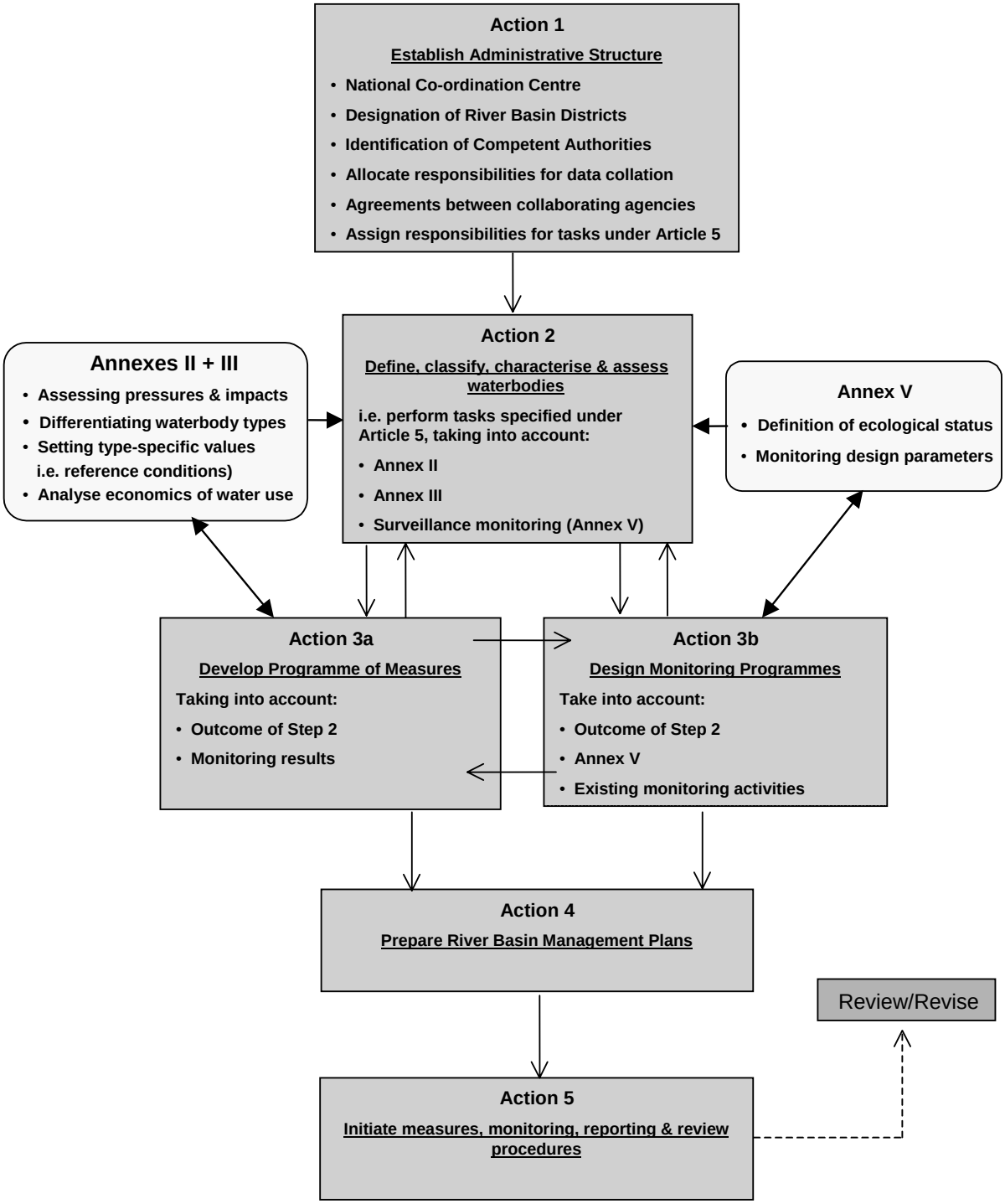


Figure 6.1. Draft scheme for implementation of the EU Water Framework Directive

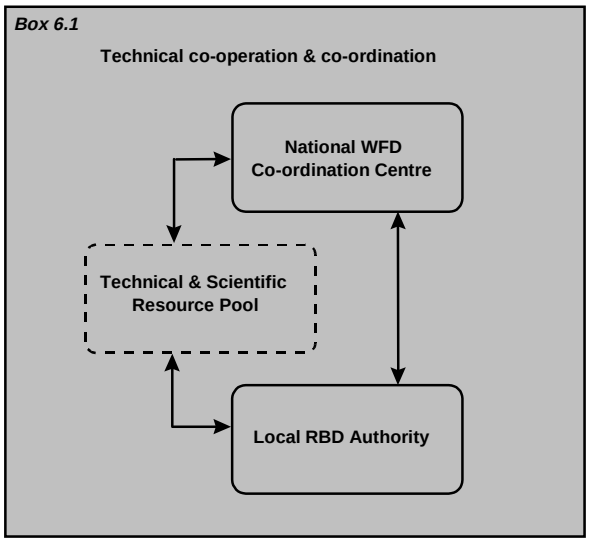
ice, it will not eliminate the need in the long-term to build capacity within the regulatory system to fully implement the Directive. The WFD management system is an iterative process, requiring continuous review and updating according to the rate of progress and the emergence of new water-related issues.

Regional plans for WFD implementation examined to date stress the importance of Geographical Information Systems (GIS) as a key tool in data management and assessment of water quality. Acceptance of the need for trained GIS operators is a positive step. Nevertheless, there are many ongoing scientific and technical aspects of

the Directive that cannot be met by GIS systems. These include the identification of research needs, assessments of natural variability and the impacts of climate change, socio–economic evaluations of water uses and impacts, the review of standards and criteria and the design and development of monitoring programmes. Many of these activities are ongoing. Thus:

whereas consultants might be used for discrete projects in some fields, in the long-term it will be essential to build capacities within the public service to ensure that the necessary manpower is available to manage WFD-related activities and to make judgements and decisions of a technical and scientific nature.

Specialist services, advice and assistance should be readily available to, if not within, the leading RBD agencies. The schematic in Box 6.1 illustrates the relationships between management and technical resource centres envisaged in this report.



6.2.2 Technical responsibilities

An important issue to be addressed by the implementation strategy will be the assignment of responsibilities for research, monitoring and the setting of reference conditions, standards and ecological values. These activities will require inputs from a number of state agencies and it will be important that these agencies adopt approaches to the utilisation of staff and facilities that make the best possible use of existing resources. A major consideration is the need for work to proceed simultaneously in all RBDs while maintaining consistent practices and procedures. This will entail both good co-ordination and supervision.

It is not expected that individual RBDs would have access to sufficient technical resources, either from within their local authorities or through consultants, to undertake many of the scientific activities required under the Directive. Apart from this, it would be very difficult to maintain consistent approaches using a wide variety of personnel with different backgrounds and levels of expertise. Thus, it will probably be necessary to depend on national agencies with relevant responsibilities, knowledge and capabilities to provide specialised services to the RBDs, perhaps on a rotational basis.

A vital part of the national WFD implementation strategy will be arrangements for the analysis of water, sediment and biota samples collected under the various WFD-monitoring programmes. Whereas routine water quality measurements may be undertaken by the existing regional laboratories, more specialised analyses (e.g. hazardous substances, detailed taxonomy) will probably require the services of central laboratories. It will be difficult to assess the adequacy of existing facilities until full details of the design of surveillance and operational monitoring activities become known. Indeed, a strong argument for expediting negotiations and decisions that will precede the development of WFD-monitoring programmes is the time required to organise laboratory facilities, particularly if new methods and capabilities need to be introduced or capacities extended. All laboratories contributing to WFD-monitoring activities will be expected to have in place appropriate internal and external Data Quality Assurance (QA) procedures. In addition, where two or more laboratories undertake the same analytical measurements each facility should participate in regular inter-laboratory comparison exercises. Whereas it seems likely that QA procedures and inter-laboratory comparisons will be organised on an EU-wide basis:

it is strongly recommended that a national centre for WFD/QA co-ordination be established to guide and oversee all such activities.

Where local authorities depend on particular agencies to undertake scientific work on a continuous basis, it would be prudent to draw up agreements or understandings between the authorities and agencies concerned specifying the precise services to be provided and any relevant conditions regarding, *inter alia*, frequency of work, data management and reporting systems.

The monitoring of certain quality elements (e.g. macroalgae and vascular plants in transitional and coastal waters), and even the design of monitoring methods, could be undertaken by private sector consultants under contract to appropriate state agencies. In such cases, it will be important to ensure that the contractor has the necessary combination of expertise and experience, as well as the requisite facilities and equipment, and maintains suitable quality control procedures (preferably some form of accreditation).

6.2.3 Planning and co-ordinating scientific activities

Monitoring is one of a broad set of scientific functions involving the collection and assessment of information on aquatic ecosystems (Box 6.2).

There is a high degree of inter-dependency between the scientific activities required for successful monitoring.

Box 6.2

Scientific activities under the Water Framework Directive

- Characterising water bodies
- Identifying anthropogenic impacts
- Determining variability in water quality
- Setting reference conditions
- Monitoring
  - design
  - sampling
  - data processing & interpretation

For example, reference conditions must take account of natural variability and understanding of variability will depend on the nature and extent of previous research. The design of *surveillance* monitoring must be consistent with the values assigned to the various *quality elements* used to represent reference conditions in the different water bodies. Similarly, the design of *operational* monitoring will depend on conditions currently affecting the ecological quality of water bodies, both in terms of the physical nature of the water bodies, the extent of affected areas and the particular parameters to be monitored. Careful planning and good co-ordination will be needed to ensure the smooth and efficient conduct of the scientific functions under the Directive, including arrangements for technical consultation and data management (see Chapter 5.7).

Initially, scientific priorities will, to a large extent, be dictated by the requirements of Article 5 of the Directive. **The main early tasks are the analysis of river basin characteristics and the review of anthropogenic impacts.** Both tasks will require the collation and review of large amounts of information and data from multiple sources. In essence, these are *stepping stones* to the classification of water bodies, the design of monitoring programmes and the preparation of programmes of measures to mitigate unacceptable impacts. The main scientific considerations to be taken into account in conducting these analyses and reviews are given in the annexes of the WFD, particularly Annexes II and V. The relationships between Article 5 and these two annexes are illustrated schematically in Figure 6.2. This diagram shows interactions that may not be immediately apparent from an initial reading of the Directive. It serves to emphasise the following important points:

- the linkages between requirements of Article 5 and particular parts of Annexes II and V;
- *reference conditions* need to be set in conjunction with the design of *surveillance monitoring*; and
- existing information is unlikely to be sufficient to set meaningful *reference conditions*; research and/or *surveillance* monitoring will be required to fill the gaps.

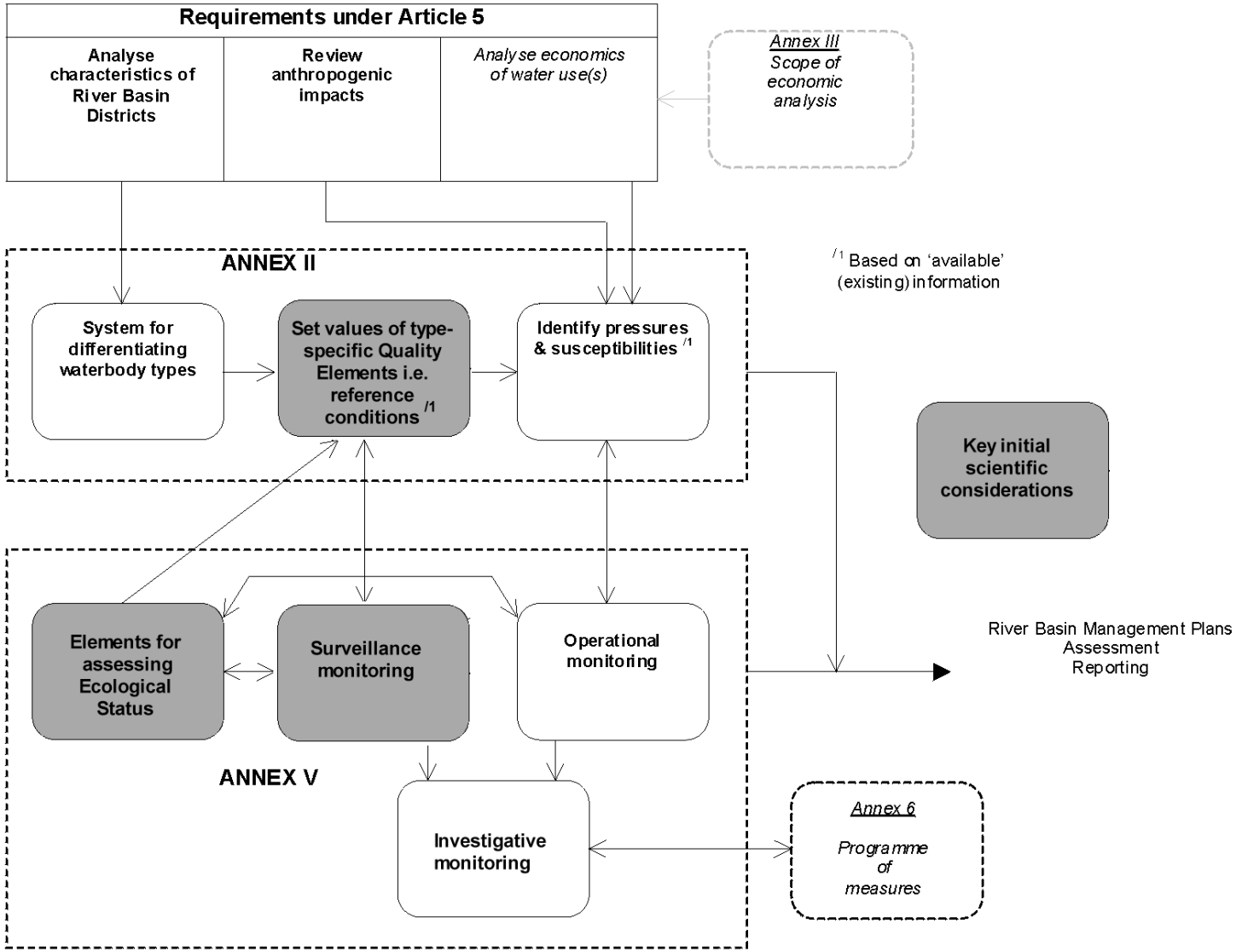


Figure 6.2. The Water Framework Directive: interrelationships between Annexes II and V in the context of Article 5.

The approach to setting reference conditions may vary depending on waterbody types, not least because different agencies are likely to be involved and there are considerable differences in the amount and quality of information available. It seems essential, however, that the *reference conditions* set within each RBD should form a balanced and cohesive set from the upland rivers to coastal waters, recognising the natural transitions that occur within catchments. Thus, as recommended in Chapter 5, the setting of *reference conditions* within each River Basin District should be a carefully co-ordinated and integrated activity.

It will be difficult to comment on the organisational aspects of the tasks required under Article 5, and Annexes II and V, until the results of EU activities in preparing common guidance are known. Much will depend on the amount of work that remains to be done at national level. Nevertheless, the national strategy should aim to consolidate activities to the maximum extent possible, avoiding unnecessary regionalisation. For example, the classification of water bodies could be the responsibility of one or two national working groups. This would be preferable to a regional classification process that might result in a lack of uniformity in the designation of type-specific water bodies.

6.2.4 Marine monitoring under the WFD and OSPAR Convention

In relation to monitoring and assessment of transitional and coastal waters, Ireland has an established programme that responds to the requirements of the Convention on the Protection of the Marine Environment of the North-East Atlantic (OSPAR Convention). A significant proportion of the marine environmental scientific work carried out by the Marine Institute is governed by OSPAR's Joint Monitoring and Assessment Programme (JAMP) which focuses on hazardous substances, eutrophication, offshore activities, man-made radioactivity and maintenance of biodiversity. The national strategy will need to address the relationship between the monitoring requirements of the WFD and JAMP (see also Section 5.5.2).

Although there are some similarities between the monitoring requirements of the WFD and JAMP, there are also significant differences particularly with regard to the monitoring of biological elements and criteria for the selection of monitoring sites. The potential exists for a major increase in the scope and intensity of monitoring in marine areas. This would have implications for the cost, availability and deployment of marine scientific resources. However, paragraph 21 of the Pre-amble to the Directive states that the WFD is intended, *inter alia*, to 'make a contribution towards enabling Community and Member States to meet those obligations' contained in international agreements (including the OSPAR Convention) on protection of marine waters from pollution. It seems likely that this will entail consultation between the EU and OSPAR Commissions to agree common elements of the two monitoring programmes. Ireland should provide an input to this debate, stressing the need to avoid unnecessary duplication or expansion of its current marine monitoring programme. The national strategy should reflect the outcome of any arrangements between OSPAR and the EU with regard to this issue.

7. Conclusions

7.1 Implementation of the Water Framework Directive in Ireland

7.1.1 The current position

This report has outlined the current preparation of Ireland for many of the requirements of the Water Framework Directive (WFD). It has reviewed the current legislation and monitoring activities and provided recommendations for the monitoring, research and co-ordination required to meet the needs of River Basin Management Plans (RBMPs) and national reporting.

A relevant monitoring programme for surface and ground water is dependent on the:

- the identification of appropriate typologies;
- the use of suitable methodologies and protocols;
- refined reporting and data management;
- well-defined and supported co-ordination mechanisms; and
- meaningful risk assessment.

All of these require further research and development, as discussed and summarised in Chapters 4 and 5. Implementation of the WFD will be a large and integrated procedure. It is also one that will be iterative (Articles 19 and 20) as development of the Directive, and especially requirements under Annex V, will continue.

While this report has focussed particularly on monitoring and research, these cannot be considered in isolation from the wider issues. The WFD also requires a broad perspective on the use of water and has significant implications for catchment management. It is an ambitious directive that may radically change anthropogenic use of and pressure on water resources.

7.1.2 The early stages of implementation

The mechanisms for implementing the WFD are at an early stage. However, the timetable set by the WFD and the implementation milestones are highly demanding. It is for this reason that there has already been a concerted effort throughout Europe to both understand the WFD and to instigate practical measures for its implementation. This has produced, and will continue to produce, much discussion and an array of policy documents. For example, the German *Landerarbeitsgemeinschaft Wasser* (Working Group of the Federal States on Water Problems, LAWA) has already produced extensive guidelines on the implementation of the WFD. While this prompt action is likely to have been motivated by the particular complexity of implementation of the WFD in federal states such as Germany, it also provides a useful framework for elsewhere. While the overall timetable of the WFD is prescribed (see Table 1.1), LAWA has produced recommendations for work required to be started immediately (Table 7.1).

The transposition of the WFD into Irish law is unlikely to pose any significant problems as the country does not have a federal (Germany, Austria, Belgium) or regional (e.g. Spain) political structure and existing legislation is broadly adequate (see Chapter 3). Nevertheless, the range of tasks required to meet the deadlines must be addressed early. The LAWA timetable of tasks appears appropriate. Intermediate milestones to implementation in Ireland form part of the discussions of the National WFD Co-ordination Group (See Chapter 1). The centralised structure of agencies with wide responsibility for the environment (EPA), inland fisheries (CFB), coastal habitats (Marine Institute), geology (GSI), river drainage and flood relief (OPW) and wildlife (*Dúchas*) provides the foundation for the management and co-ordination of activities required at a national level (see Chapter 6 general discussion). The recent Department of the Environment and Local Government (DELG) River Basin Projects have provided a prototype for many of the activities required in River Basin Districts (RBDs). Further developments towards WFD implementation will be provided by the forthcoming River Basin Management Projects.

While recognising the research and development that is required in the short-term (see Chapters 4 and 5), and with the exception of the economic analysis required un-

Table 7.1. The identification of early tasks for implementation of the Water Framework Directive produced by the German *Landerarbeitsgemeinschaft Wasser* (February 2001).

Tasks	Conditions/remarks
Co-ordination of the River Basin Districts Designation of Competent Authorities (in particular for comparing data, checking the position of waters and catchment areas)	Begin immediately to avoid any duplication of work in different Länder
Surface waters	
General description (elements) of the River Basin District under Article 5 and Annex II	Immediately: start by compiling data and facts
Examination of geo-databases to ensure standardisation across the whole country	
Establishing significant anthropogenic pressures:	Once relevant criteria have been set immediately:
• from point sources, especially from substances referred to in Annex VIII, above all under the Urban Waste Water Treatment Directive (91/271/EEC), Integrated Pollution Prevention and Control Directive (96/61/EC) and the Directive concerning pollution by the discharge of certain dangerous substances (76/464/EEC) • from diffuse sources, especially from substances referred to in Annex VIII, above all under Directives on nitrates (91/676/EEC), plant protection products (91/414/EEC and biocides (98/8/EC) • in respect of the quantitative status of surface waters... • on the flow characteristics and the water balances • from morphological alterations to water bodies (cf. Annex II, 1.4) • from land-use patterns • from other significant anthropogenic impacts on the status of surface waters	beginning with the analysis of previous reports (under EC Directives) of importance to the WFD. Full survey once the respective criteria have been set; these are currently undergoing national co-ordination, to be followed by international agreement in the EU Project
Assessment of pressures, identification of vulnerable surface waters (i.e. where there is a risk of not achieving quality objectives)	As above
Ground water	
Initial characterisation	
Location and boundaries of groundwater bodies	Immediately, if the sub-basin areas have been defined in the River Basin District
Characterisation of groundwater bodies	Immediately: but work can only be completed after the submission of a hydrogeochemical map (December 2001)
Bodies of water and terrestrial ecosystems dependent on ground water	It is possible to rule out non-dependent ecosystems in advance
Description of pollution by point sources	Immediately
Description of pollution by diffuse sources including a summary of land use	Immediately
Description of pressures for the quantitative status regarding abstraction and artificial discharge	Immediately
Analysis of other anthropogenic impacts on groundwater status	Immediately
Detailed description	The initial characterisation must first be completed
Protected areas Identification and mapping of protected areas (register)	Digitalisation of protected areas under Annex IV of the Directive in GIS format
Additional monitoring requirements for surface waters in protected areas	Can be approximately established

der Article 5, there are no major inherent obstacles to the achievement of the first set of deadlines set for 2004 (see Chapter 1). This does not imply that thoughtful considerations, especially of co-ordination mechanisms are not required (see Chapter 6). However, after 2006, there will be a need for a coherent and comprehensive monitoring programme. Planning for this should begin immediately and include the necessary R&D in order to provide efficient and effective programmes. The resource implications for this and the co-ordination mechanisms that support monitoring are significant.

7.2 Implications for scientific resources

Effective implementation of the WFD will place significant demands on technical and personnel resources. In the course of this project, a consensus opinion was that (a) the WFD would impose greater demands on already limited resources and that (b) it would be impossible to effect the WFD without increased Exchequer funding. The nature or extent of that demand is, however, difficult to predict. Among the factors likely to influence the situation are:

- the typology of transitional and coastal waters (determined in accordance with Annex II);
- the meaning of '*sufficient surface water bodies*' (Annex V, 1.3.1) in the context of selecting surveillance monitoring sites;
- the number of sites for which operational monitoring will be required;
- acceptance (or not) that pre-WFD monitoring results can be taken into account;
- the intentions regarding integration of OSPAR and EU monitoring activities;
- the frequency of monitoring for various purposes; and
- the requirement for research to elucidate underlying patterns of the quality elements.

The scientific resources applied to environmental monitoring comprise scientific and technical staff for programme design, field sampling, laboratory analysis and data management as well as field facilities, including survey vessels, hydrometric recording systems, automatic samplers and specialised laboratory equipment. The human resources need to be supported by appropriate management structures, operating budgets and, where there is a need for new or improved methodologies, research activities.

There are already indications that planning and consultation associated with implementation of the WFD are placing strain on the management and senior scientific staff of some agencies. Meetings, both internal and external, and time spent on reviewing the increasing amount of documentation related to the WFD are conflicting with normal duties and ongoing national programmes. None of the agencies contacted were in a position to allocate personnel specifically to WFD-related functions.

The view of the DELG is that, where appropriate, local authority posts can be created to address new technical skills requirements for implementation of the WFD. This is already happening in some local authorities with the recruitment of GIS data managers. It is, however, a matter for local authorities to assess where new staff are required and where existing staff are suitably skilled to undertake particular functions under the WFD. Consultants will be appointed to manage River Basin Management Projects to assist in carrying out initial baseline work and in establishing River Basin Management Systems (RBMSs). Currently £IR 50 million have been assigned to support local authority expenditure on River Basin Management Projects. Participation in the WFD Co-ordination Group and some centralised dissemination activities will be supported by the DELG.

Most authorities contacted in other EU member states indicated that the planning and implementation of the WFD would require substantial research and development (see Appendix D). In the UK, for example, agencies in Northern Ireland, Scotland, England and Wales have jointly supported a commercial organisation (http://www.sniffer.org.uk) that will manage, commission and contribute to research related to the WFD. Much of this research will be undertaken by the private sector and non-government research institutes.

Although scientific resources available for marine monitoring have been generally adequate to cover essential

OSPAR and national requirements, including quality control activities and inter-calibration studies, the responsible state agencies have seldom had sufficient budgetary flexibility to expand investigative or developmental aspects of marine monitoring. The general opinion is that resources for analogous programmes for inland surface and ground waters are already inadequate. Informal consultations and correspondence with the Marine Institute (Abbotstown Laboratory), the CFB, the GSI and EPA staff clearly indicate that any substantive increase in the frequency or the scope of monitoring (scientific or geographical) cannot be met from existing resources.

Whereas it may be some time before the full extent of the WFD requirement for scientific resources is known precisely, it is unlikely that the planning, research and monitoring associated with implementation of the Directive can be met using the manpower and financial resources currently devoted to these activities. Additional resources allocated through River Basin Management Projects require meaningful co-ordination. The programmes of these projects should not obviate the need for additional core funding to local authorities or to agencies with a national remit of importance for implementation of the WFD.

7.3 Into the future

The WFD provides a major opportunity for concerted action in the protection and improvement of water resources throughout Europe. It is up to the Member States to decide on any subsequent changes in internal matters that may be required to implement the Directive. Early indications are of a positive response. It remains to be seen whether or not that translates into effective implementation to achieve the goals (Article 1) of the WFD. What is certain is that effective implementation will require a revised approach to the appreciation of water in its widest context. The aspirations of the WFD are that this should occur not only at the level of government or state agency, but also include endorsement and participation by NGOs and the public (Article 14). This is not only aspirational as some very practical consequences on issues such as water charging (Article 9) and regulation (e.g. through legal instruments associated with Article 11 and arising from Article 23) are contained in the WFD.

While the focus on national and international implementation groups has been on the more immediate demands (see Section 7.1), longer-term strategies for governmental and public involvement will likely emerge. In the course of this project, we identified an array of bodies with direct relevance to implementation of the WFD. A preliminary matrix of impact analysis is shown in Table 7.2.

The involvement of user groups in WFD implementation (Article 14) provides particular challenges. User groups in Ireland tend to be quiet or, if not, focussed on particular local issues. There is little co-ordination among them and the National Government Organisations (NGOs) are generally poorly supported. Although one national environmental forum contacted in the course of this project did not consider that it had a role in the implementation of the WFD there is, generally, increasing interest in the WFD among NGOs. A strong potential link between the NGOs, Government and the WFD does, however, occur via the Heritage Council. Established in 1995 as an independent body and funded by the Department of Arts, Heritage, Gaeltacht and the Islands, its main function is to propose policies and priorities for the identification, protection, preservation and enhancement of the national heritage. It also has an important co-ordinating and educational role and involvement in many of the sectors relevant to the WFD; these include agriculture, fisheries, energy, and wild life. The consideration in River Management Plans of *supplementary measures* to deal with particular aspects of water management (Article 13.5) is also applicable to such a remit.

The purpose of Directive 2000/60/EC as stated in Article 1 is *to establish a framework for the protection of inland surface waters, transitional waters, coastal waters and ground water which*:

> *[...] prevents further deterioration and protects and enhances the status of aquatic ecosystems and, with regard to their water needs, terrestrial ecosystems and wetlands directly depending on the aquatic ecosystems;*

In this context the WFD provides for a wider discussion than that concerned solely with rigorous and scientifically sound monitoring.

Table 7.2. Matrix of player and impacts in WFD implementation.

	Recreation groups	Bord na Mona	CFB	Coillte	Defence Forces	DAHGI	Dept of Agriculture	DELG	DMNR	Dúchas	ESB	EPA	GSI	Heritage Council	Local Authorities	LGCSB	Marine Institute	OPW	Port Authority	Regional Fisheries Boards	Teagasc	Waterways Ireland	NGOs	ESRI
Transpose WFD to national law								X																
Location and boundaries of RBDs								X							X									
Identification of Competent Authority								X																
Co-ordination of RBDMP			X					X		X		X	X		X									
Characterisation of surface waters			X					X		X	X	X					X							
Characterisation of ground waters								X				X	X											
Register of Protected Areas – abstraction of drinking water								X				X	X	X	X									
Register of Protected Areas – economically significant species	X		X					X	X	X				X			X			X			X	
Register of Protected Areas – recreational waters			X					X		X				X	X							X		
Register of Protected Areas – nutrient-sensitive areas	X						X	X		X		X		X	X						X			
Register of Protected Areas – protected habitats and species										X				X									X	
Economic analysis of water use		X	X	X	X		X	X	X	X	X	X	X	X	X		X		X	X		X	X	X
Ecological status (SW)			X									X		X			X			X				
Reference conditions										X		X	X	X			X	X		X				
Public consultation	X													X									X	
GIS/data management			X				X	X	X			X	X		X	X	X			X	X			
Potential impact																								
Lakes	X	X	X	X	X		X				X				X			X		X		X		
Rivers/canals	X	X	X	X	X		X				X				X			X		X		X		
Ground water		X		X	X		X								X			X						
Transitional					X		X								X			X	X					
Coastal					X				X						X				X					
Review of pressures and impacts on surface and ground waters	X	X	X	X	X		X	X	X	X	X	X	X	X	X		X		X	X	X	X	X	X

7.4 Overall conclusions

The WFD requires a catchment-based approach to the protection and enhancement of water resources. This has come about through a general recognition of the serious pressures that human activities place on water resources and the general failure of existing legislative structures to protect the aquatic environment throughout the European Union.

Implementation of the WFD requires further research for the classification, monitoring and identification of pressures. It requires a quantitative approach. While the existing system of monitoring in Ireland provides the foundation for an overall monitoring network, there is need for further research and development to identify and to quantify parameters indicative of the quality elements described in Annex V and to establish robust typologies and reference conditions required under Annex II. There is a need to further identify and quantify pressures on the aquatic environment through verifiable risk analysis and to promote research on the methods of economic analysis, and their relevance to the WFD. There is an essential requirement for the development and use of effective and refined co-ordination and data management systems.

8. References

Abbot, M.B., Bathurst, J.C., Cunge, J.A., O'Connell, P.E. and Rasmussen, J. (1986). An introduction to the European Hydrological System – Systeme Hydrologique European, 'SHE', 2: structure of a physically based distributed modelling system. *Journal of Hydrology* **87**, 61–77.

Allott, N., Brennan, M., Cooke, D., Reynolds, J.D. and Simon, N. (1997). *A study on the effects of stream hydrology and water quality in forested catchments on fish and invertebrates. Volume 4: Stream chemistry, hydrology and biota, Galway–Mayo region.* AQUAFOR report. EOLAS Contract HEIC/91/304/A, COFORD, Dublin.

Allott, N., Free, G., Irvine, K., Mills, P., Mullins, T.E., Bowman, J.J., Champ, W.S.T., Clabby, K.J. and McGarrigle, M.L. (1998). Land use and aquatic systems in the Republic of Ireland. *In:* Giller, P. (ed.) *Studies in Irish Limnology*, Marine Institute, Dublin.

An Foras Forbartha (1983). *A Review of Water Pollution in Ireland.* Water Pollution Advisory Council, Dublin.

Baattrup-Pedersen, A., Andersson, B., Brandrud, T.E., Karttunen, K., Riis, T. and Toivonen, H. (2001). *In:* Skriver, J. (ed.). *Biological Monitoring in Nordic Rivers and Lakes*, pp. 53–50.

Bathurst, J.C. and Purnama, A. (1991). Design and application of a sediment and contaminant transport modelling system. *In:* Peters, N.E. and Walling, D.E. (eds). *Sediment and Stream Water Quality in a Changing Environment: Trends and Explanation.* IAHS Publication No. 203, pp. 305–313.

Bicknell, B.R., Imhoff, J.C., Kittle, J., Donigian, A.S. and Johansen, R.C. (1996). *Hydrological Simulation Program – Fortran, User's Manual for release 11*. US Environmental Protection Agency, Environmental Research Laboratory, Athens, GA.

Black, A.R., Bragg, O.M., Duck, R.W., Jones, A.M., Rowan, J.S. and Werritty, A. (2000). Anthropogenic impacts upon the hydrology of rivers and lochs: Phase 1. A user guide. Introducing the Dundee Hydrological Regime Assessment Method. SNIFFER Report SB (00) O1 F.

Bloch, H. (1999). The European Union Water Framework Directive: taking European water policy into the next millennium. *Water Science Technology* **10**, 67–71.

Boelens, R.G.V., Maloney, D.M., Parsons, A.P. and Walsh, A.R. (1999). *Ireland's Marine and Coastal Areas and Adjacent Seas: an Environmental Assessment.* Marine Institute, Dublin.

Boon, P.J. and Howell, D.L. (eds) (1997). *Freshwater Quality: Defining the Indefinable?* Scottish Natural Heritage, The Stationery Office, Edinburgh.

Bowman, J.J. (1991). *Acid Sensitive Surface Waters in Ireland. The Impact of a Major New Sulphur Emission on Sensitive Surface Waters in an Unacidified Region*. Environmental Research Unit, Dublin.

Bowman, J.J. (1998). The Shannon. *In:* Moriarty, C. (ed.). *Studies of Irish Rivers and Lakes.* Marine Institute, Dublin, pp. 169–190.

Bowman, J.J. (2000). *River Shannon Lake Water Quality Monitoring, 1998 and 1999*. Environmental Protection Agency, Wexford.

Bowman J.J. and Toner, P.F. (2001). *National Lake Water Quality Monitoring Programme*. Environmental Protection Agency, Wexford.

Bradford, M.E. and Peters, R.H. (1987). The relationship between chemically analyzed phosphorus fractions and bioavailable phosphorus. *Limnology and Oceanography* **32**, 1124–1137.

Caffrey, J.M. (1985). Scheme for the assessment of water quality using aquatic macrophytes as indicators. *Journal of Life Sciences, Royal Dublin Society* **5**, 105–111.

Caffrey, J.M. (1987). Macrophytes as biological indicators of organic pollution in Irish rivers. *In:* Richardson, D.H.S. (ed.). *Biological Indicators of Pollution.* Royal Irish Academy, Dublin, pp. 77–87.

Caffrey, J.M. and Allison, J.P. (1998). Eutrophication in canals. *In:* Wilson, J.G. (ed.). *Eutrophication in Irish waters.* Royal Irish Academy, Dublin, pp. 71–81.

Carlson, R.E. and Lee, J. (1995). *The Great American Secchi Dip-In 1994.* Final Report to the North American Management Society and the U.S. Environmental Protection Agency. Washington.

Central Fisheries Board (CFB) (1986). *Inland Fisheries. Strategies for Management and Development.* Central Fisheries Board, Dublin.

Central and Regional Fisheries Boards (1999). *Annual Report*, Dublin.

Champ, W.S.T. (1998). Phosphorus/chlorophyll relationships in selected Irish lakes: ecological consequence and suggested criteria for ecosystem management. *In:* Wilson, J.G.W. (ed.). *Eutrophication in Irish Waters*. Royal Dublin Society, Dublin, pp. 91–195.

Champ, W.S.T. (2000). Habitat Quality for Fisheries. *In: Water: is its Quality Deteriorating?* Proceedings of the 16th Annual Environmental Conference, Sherkin Island Marine Station, Cork, pp. 64–65.

Chave, P.A. (2001). *The EU Water Framework Directive. An Introduction.* IWA Publishing, London.

Chapman, G. and Baker W.B. (1964). *Zoology.* Longmans, London.

Chesters, R.K. (1980). Biological Monitoring Working Party. The 1978 national testing exercise. Department of the Environment (U.K.). *Water Data Unit Technical Memorandum* **19**, 1–37.

Clenaghan, C., Collins, C. and Crowe, M. (2001). *Phosphorus Regulations National Implementation Report.* Environmental Protection Agency, Wexford.

Daly, K., Coulter, B. and Mills, P. (2000). National phosphorus model. *In:* Tunney, H. (ed.). *Quantification of Phosphorus (P) Losses to Water Due to Soil P Desorption.* Environmental Protection Agency, Wexford, pp. 102–150.

De Lange, L. and van Zon, J.C.J. (1983). A system for the evaluation of aquatic biotopes based on the composition of the macrophytic vegetation. *Biological Conservation* **25**, 273–284.

DELG (1988). *European Communities (Quality of Water Intended for Human Consumption) Regulations, 1988.* S.I. No 81 of 1988.

DELG (1997). *Sustainable Development: a Strategy for Ireland*. Department of the Environment and Local Government, Dublin.

DELG (1998). *Managing Ireland's Lakes and Rivers.* Department of the Environment and Local Government, Dublin.

DELG (2000). *Water Service Annual Report 2000*. Department of the Environment and Local Government, Dublin.

DELG, EPA, GSI (1999). *Groundwater Protection Schemes.* Department of the Environment and Local Government, Dublin.

Demmke, C. (1999). *Implementation and Enforcement of the Council Directive Establishing a Framework for Community Action in the Field of Water Policy in the Member States of the European Union*. Ex-ante study commissioned by the Federal Ministry for the Environment, Nature and Nuclear Safety Protection (BMU). European Institute of Public Administration, Maastricht.

Dempsey, S., Doyle, M., Bennett, J., Wilson, C., O'Keefe, C. and Arnett, E. (2001). *Three Rivers Project Water Quality Monitoring and Management: Year 2 Report.* M.C. O'Sullivan, Dun Laoghaire, Ireland.

DETR and National Assembly for Wales (2001). *First Consultation Paper on the Implementation of the EC Water Framework Directive (2000/60/EC),* March 2001, p. 25. Scottish Executive, *Rivers, Lochs and Coasts: The Future of Scotland's Waters,* July 2001.

Downey, W.K. and Ní Uid, G. (1977). Lake pollution prevention by eutrophication control. *Proceedings of a seminar held in Killarney, Ireland.* May 10–11. National Science Council.

Duncan, A., Butterworth, A.J., Gerlotto, F. and Kubecka, J. (1998). Shallow water fisheries acoustics. Special issue. *Fisheries Research* **35**, 1–2.

European Court of Justice (ECJ) (1990). Case C-359/88 *Zanetti et al.*, E.C.R. I-1523.

European Court of Justice (1994). Case C-435/92 *APAS v. Prefets de Maine-et-Loire et de la Loire Atlantique*, E.C.R. I-67.

EPA (1997). *The Aquatic Environment. A discussion document.* Environmental Protection Agency, Wexford.

EPA (1999). *Water Quality Management Planning in Ireland.* Environmental Protection Agency, Wexford.

EPA (2000). *The Quality of Drinking Water in Ireland. A Report for the Year 1999 with a Review of the Period 1997–1999*. Environmental Protection Agency, Wexford.

Erwin, D.G., Picton, B.E., Connor, D.W., Howson, C.M., Gilleece, P. and Bogues, M.J. (1990). *Inshore Marine Life of Northern Ireland*. Report of a survey carried out by the diving team of the Botany and Zoology Department of the Ulster Museum in fulfilment of a contract with the Conservation Branch of the Department of the Environment (NI), Ulster Museum, Belfast, HMSO.

Flanagan, P.J. and Toner, P.F. (1972). *The National Survey of Irish Rivers: a Report on Water Quality*. An Foras Forbartha, Water Resources Division, Dublin.

Flanagan, P.J. and Toner, P.F. (1975). *A Preliminary Survey of Irish Lakes.* An Foras Forbartha, Dublin.

Grimeaud, D. (2001). Reforming EU Water Law: Towards Sustainability. *European Environmental Law Review* **41**, 125.

Gustard, A., Marshall, D.C.W. and Sutcliffe, M.F. (1987). *Low Flow Estimation in Scotland*. Report No. 101, Institute of Hydrology, Wallingford.

Heuff, H. (1984). *The Vegetation of Irish Lakes*. Wildlife Service, Office of Public Works, Dublin.

Hilton, J., Lishman, J.P., Carrick, T.R. and Allen, P.V. (1988). Annual variability in sedimentary pigment concentration and its implications for trophic status assessment. *Monitoring the Trophic State of Reservoirs.* Final Report DoE PECD 7/7/203. Appendix 3.

Institute of Hydrology (1980). *Low Flows Study*. Institute of Hydrology, Wallingford.

Irvine, K. (1999). European Directives, Irish lakes, and the slow decline of the singing canaries. *Hydrobiologia* **412**, 1–4.

Irvine, K., Allott, N., Mills, P. and Free, G. (2000). The use of empirical relationships and nutrient export coefficients for predicting phosphorus concentrations in Irish Lakes. *Verhandlung Internationale der ereinigung Theoretische und Angewandte Limnologie* **27**, 1127–1131.

Irvine, K., Allott, N., de Eyto, E., Free, G., White, J., Caroni, R., Kennelly, C., Keaney, J., Lennon, C., Kemp, A., Barry, E., Day, S., Mills, P., O'Ríán, G., Quirke, B., Twomey, H. and Sweeny, P. (2001a). *Ecological Assessment of Irish Lakes*. Environmental Protection Agency, Wexford.

Irvine, K., Free, G., de Eyto, E., White, J., Allott, N. and Mills, P. (2001b). The EC Water Framework Directive and Monitoring Lakes in the Republic of Ireland. In: Sutcliffe, D. (ed.). *Lake Assessment and the EC Water Framework Directive .Freshwater Forum* **16**, 48–64.

de Eyto, E. and Irvine, K. (2002). The use of the family Chydoridae (Anomopoda, Branchiopoda) as indicators of lake ecological quality in Ireland. *Biology and Environment*, in press.

Jeffrey, D.W., Wilson, J.G., Harris, C.R. and Tomlinson, D.L. (1985). *A Manual for the Evaluation of Estuarine Quality*. 2nd Edition. Environmental Sciences Unit, Trinity College, Dublin.

Johnes, P., Moss, B. and Phillips, G. (1994). *Lakes-classification and Monitoring. A Strategy for the Classification of Lakes.* National Rivers Authority R and D Project Record 286/6A.

Joy, M.J. and Death, R.G. (2001). Control of freshwater fish and crayfish community structure in Taranaki, New Zealand: dams, diadromy or habitat structure? *Freshwater Biology* **46**, 417–429.

Jupp, B.P. and Spence, D.H.N. (1977). Limitations on macrophytes in a eutrophic lake, Loch Leven. 1. Effects of phytoplankton. *Journal of Ecology* **65**, 175–186.

Kahlenborn, W. (1999). *Environmental and Resource Costs of Water Use in View of the European Community's Future Framework Directive on Water*. Final Report. Ecologic, Institute for International and European Environmental Policy, Berlin.

King, J.J. and Caffrey, J.M. (1998). Macrophytes in Irish lakes and rivers: an overview of investigations and current knowledge. *In:* Giller, P.S. (ed.). *Studies in Irish Limnology.* Marine Institute, Dublin, pp. 101–124.

Kirk McClure Morton (2001). *Lough Derg and Lough Ree Catchment Monitoring Programmes and Management System.* Final Report. Kirk McClure Morton, Belfast.

Krämer, L. (2000). *EC Environmental Law*. 4th Edition. Sweet & Maxwell, London.

Krause, W. and King, J.J. (1994). The ecological status of Lough Corrib, Ireland, as indicated by physiographic factors, water chemistry and macrophyte flora. *Vegetatio* **110**, 149–161.

Lang, C. (1990). Quantitative relationships between oligochaete communities and phosphorus concentrations in Lakes. *Freshwater Biology* **24**, 327–334.

Lennox, S.D., Foy, R.H., Smith, R.V. and Jordan, C. (1997). Estimating the contribution from agriculture to the phosphorus load in surface water. *In:* Tunny, H., Carton, O.T., Broodes, P.C. and Johnston, A.E. (eds). *Phosphorus Loss from Soil to Water*. CAB International, Wallingford, pp. 55–76.

Lucey, J., Bowman, J.J., Cunningham, P., Lehane, M., MacCarthaigh, M., McGarrigle, M.L. and Toner, P.F. (1999). *Water Quality in Ireland 1995–1997.* Environmental Protection Agency, Wexford.

McCarthy, T.K., Barbiero, R., O'Connell, M., Guiry, M., Doherty, D., Cullen, P., King, J. and O'Conner, B. (2001). *Investigation of Eutrophication Processes in the Littoral Zones of Western Irish Lakes.* Environmental Protection Agency, Wexford.

McGarrigle, M.L., Bowman, J.J., Clabby, K.J., Lucey, J., Cunningham, P., MacCárthaigh, M., Keegan, M., Cantrell, B., Lehane, Clenaghan C. and Toner, P.F. 2002. *Water Quality in Ireland 1998-2000.* Environmental Protection Agency, Ireland. ISBN 1-84095-081-1.

Moss, B., Johnes, P. and Phillips, G. (1996). The monitoring of ecological quality and the classification of standing waters in temperate regions: a review and proposal based on a worked scheme for British waters. *Biological Review* **71**, 301–339.

Murphy, J. and Riley, J.P. (1962). A modified single-solution method for the determination of phosphate in natural waters. *Analytica Chimica Acta* **27**, 1–36.

Natural Resources Conservation Service, US Department of Agriculture (2000). *Pilot to Evaluate Water Quality Models for Future Investment*. US Department of Agriculture, Washington.

Naumann, E. (1931). *Limnologische Terminologie*. Urban und Schwarzenberg, Berlin.

Newbold, C. and Holmes, N.T.H. (1987). Nature conservation: water quality criteria and plants as water quality monitors. *Water Pollution Control* **86**, 345–364.

O'Connor, B. (2000). *A Review of Methodologies Used in Relevant Member States of the European Union and the OSPAR Convention for the Characterisation and Monitoring of the Biological Elements of Transitional and Coastal Waters.* Unpublished report to the Environmental Protection Agency.

OECD (1982). *Eutrophication of Waters, Monitoring Assessment and Control*. Organisation for Economic Co-operation and Development, Paris.

OECD (2000). *Environmental Performance Reviews – Ireland.* Organisation for Economic Co-operation and Development, Paris.

O'Leary, G., Fanning, A. and Carty, C. (2000). *Urban Waste Water Discharges in Ireland with population equivalents greater than 500 persons. A Report for the years 1998 and 1999.* Environmental Protection Agency, Wexford.

O'Grady, M. (1998). The Boyne. *In:* Moriarty, C. (ed.) *Studies of Irish Rivers and Lakes*. Marine Institute, Ireland, pp. 27–36.

O'Riordan, T. (2000). *Environmental Science for Environmental Management*. 2nd Edition. Prentice Hall, Harlow.

OSPAR (1997a). *Agreed Background/Reference Concentrations for Contaminants in Seawater, Biota and Sediments*. OSPAR Commission meeting document No. OSPAR 97/15/1, Annex V.

OSPAR (1997b). *Agreed Ecotoxicological Assessment Criteria for Metals. PCBs, PAHs, TBY and some Organochlorine Pesticides*. OSPAR Commission meeting document No. OSPAR 15/15/1, Annex VI.

OSPAR (1999). *Screening Procedure for Irish Coastal Waters With Regard to Eutrophication Status*. Final Report, presented by Ireland 8 Sept. 1999. OSPAR Document NEUT 99/5/3.

Palmer, M.A., Bell, S.L. and Butterfield, I. (1992). A botanical classification of standing waters in Great Britain: applications for conservation and monitoring. *Aquatic Conservation: Marine and Freshwater Ecosystems* **2**, 125–143.

Premazzi, G. and Chiaudani, G. (1992). *Ecological Quality of Surface Waters. Quality Assessment Schemes for European Community Lakes.* Joint Research Centre, European Commission, Brussels.

Purseglove, J. (1989). *The Taming of the Flood*. Oxford University Press, Oxford.

Raven, P.J., Holmes, N.T.H., Dawson, F.H., Fox, P.J.A., Everard, M., Fozzard, I.R. and Rouen, K.J. (1998). *River Habitat Quality*. Environmental Agency, UK.

Reynolds, J.D. (1998). *Ireland's Freshwaters*. Marine Institute, Dublin.

Reynolds, C.S. and Davies, P.S. (2001). Sources and bioavailability of phosphorus fractions in freshwaters: a British perspective. *Biological Review* **76,** 27–64.

Reynoldson, T.B., Bailey, R.C., Day, K.E. and Norris, R.H. (1995). Biological guidelines for freshwater sediment based on Benthic assessment of sediment (the BEAST) using a multivariate approach for predicting biological state. *Australian Journal of Ecology* **20**, 198–219.

Richter, B.D., Baumgartner, J.V., Powell, F. and Braun, D.P. (1996). A method for assessing hydrological alteration within a river network. *Conservation Biology* **10**, 1163–1174.

Rippey, B. and Anderson, N.J. (1996). Reconstruction of lake phosphorus loading and dynamics using the sedimentary record. *Environmental Science Technology* **30**, 1786–1788.

Rosenburg, D.M. and Resh, V.H. (1993). *Freshwater Biomonitoring and Benthic Macroinvertebrates*. Chapman and Hall, London.

Sæther, O.A. (1979). Chironomid communities as water quality indicators. *Holarctic Ecology* **2**, 65–74.

Scannell, Y. (1990). Impact of EC Water Pollution Directives in Ireland, *Environmental Protection and the Impact of European Community Law*, Publication No. 12. Irish Centre for European Law.

Scannell, Y. (1995). *Environmental and Planning Law in Ireland*, Round Hall Press, Dublin.

Smith, K. (1993). *Environmental Hazards: Measuring Risk and Reducing Disaster*. Routledge, London.

Standing Committee of Analysts (1987). *Methods for the Use of Aquatic Macrophytes for Assessing Water Quality 1985–86*. HMSO, London.

Stapleton, L., Lehane, M. and Toner, P. (eds) (2000). *Ireland's Environment: a Millennium Report*. Environmental Protection Agency, Wexford.

Stephens, A. (2001). *Survey of Dangerous Substances in Surface Freshwaters 1999–2000.* Environmental Protection Agency, Wexford.

Sutcliffe, D. (ed.) (2001). *Lake Assessment and the EC Water Framework Directive. Freshwater Forum* **16**. Freshwater Biological Association, Ambleside.

Teiling, E. (1955). Some mesotrophic phytoplankton indicators. *Verhandlung Internationale der Vereiningung Theoretische und Angewandte Limnologie* **12**, 212–215.

Thienemann, A. (1931). Tropische Seen und Seetypen. *Archives für Hydrobiologie, Siupplementa* **9**, 205–231.

Tolonen, K.T., Hämäläinen, H., Holopainen, I.J. and Karjalainen, J. (2001). Influences of habitat type and environmental

variables on littoral macroinvertebrate communities in a large lake system. *Archive für Hydrobiologia* **152**, 39–67.

US EPA (1995). *Lake and Reservoir Bioassessment and Biocriteria*. US Environmental Protection Agency, Washington DC.

US EPA (2000a). *Nutrient Criteria Technical Guidance Manual: Lakes and Reservoirs.* US Environmental Protection Agency, Washington. EPA-822-B00-001.

US EPA (2000b). *Nutrient Criteria Technical Guidance Manual: Rivers and Streams.* US Environmental Protection Agency, Washington. EPA-822-B00-002.

West, W. and West, G.S. (1906). A comparative study of the plankton of some Irish Loughs. *Transactions of the Royal Irish Academy* **B**, 77–116.

Water Environment Research Foundation (WERF) (2000). *WEFTEC 2000 Workshop* **113**, *Assessment of Availability and Use of Water Quality Models.* Alexandria, VA.

Water Quality Report of the EPA (1999). *The Quality of Drinking Water in Ireland. A Report for the Year 1999 with a Review of the Period 1997–1999.* Environmental Protection Agency, Wexford.

White, J. (2001). *Littoral Macroinvertebrates in Lakes: Patterns of Distribution and Potential Use in Ecological Assessment.* Unpublished Ph.D. thesis, University of Dublin, Trinity College.

Willén, E. (2000). Phytoplankton in water quality assessment – an indicator concept. *In:* Heinonen, P., Ziglio, G. and Van der Beken, A. (eds). *Hydrobiological and Limnological Aspects of Lake Monitoring*. John Wiley and Sons, pp. 58–80.

Willén, E., Andersson, B. and Söderbäck, B. (1997). System Aqua: a biological assessment tool for Swedish lakes and watercourses. *In:* Boon, P.J. and Howell, D.L. (eds). *Water Quality: Defining the Indefinable?* Scottish Natural Heritage, The Stationary Office, Edinburgh, pp. 327–333.

Woodiwiss, F.S. (1964). The biological system of stream classification used by the Trent River Board. *Chemistry and Industry* **11**, 443–447.

Wright, J.F., Moss, D., Clarke, R.T. and Furse, M.T. (1997). Biological assessment of river quality using the new version of RIVPACS (RIVPACS III). *In:* Boon, P.J. and Howell, D.L. (eds). *Water Quality: Defining the Indefinable?* Scottish Natural Heritage, The Stationery Office, Edinburgh. pp. 102–108.

Wright, J.F., Sutcliffe, D.W. and Furse, M.T. (eds) (2000). *Assessing the biological quality of freshwaters. RIVPACS and other techniques*. Freshwater Biological Association, Cumbria.

WWF (2000). *Implementing the EU Water Framework Directive – Seminar Series.* http://www.wwf.dk/freshwater/seminars.html.

9. Bibliography

The following documents were collated during the course of the study. Entries include keywords where applicable.

Allott, N., Brennan, M., Cooke, D., Reynolds, J.D. and Simon, N. (1997). A Study of the Effects of Stream Hydrology and Water Quality in Forested Catchments on Fish and Invertebrates. AQUAFOR Report, COFORD, Dublin.

Allott, T.E.H. and Monteith, D.T. (1999). Classification of Lakes in Wales for Conservation using Integrated Biological Data. Countryside Council for Wales. Science Report No. 314.

An Foras Forbartha (1983). A review of water pollution in Ireland. Water Pollution Advisory Council, Dublin.

Behrendt, H., Huber, D., Kornmilch, M., Opitz, D., Schmill, O., Scholz, G. and Uebe, R. (2000). Nutrient Emissions into River Basins of Germany. Federal Environmental Agency, Berlin.

Black, A.R., Bragg, O.M., Duck, R.W., Jones, A.M., Rowan, J.S. and Werritty, A. (2000). Anthropogenic Impacts upon the Hydrology of Rivers and Lochs: Phase 1. A User Manual Introducing the Dundee Hydrological Regime Assessment Method. SNIFFER Report SR (00) 01/ 2F.

Bloch, H. (1999). The European Union Water Framework Directive: Taking European Water Policy into the next Millennium. Wat. Sci. Tec. Vol. 40, No. 10, pp. 67–71, 1999.
Keywords: Water protection; water management; European Union; emission limit values; water quality standards.

Boelens, R., Maloney, D.M., Parsons, A.P. and Walsh, A.R. (1999). Ireland's Marine and Coastal Areas and Adjacent Seas: an Environmental Assessment. Marine Institute, Dublin.
Keywords: OSPAR, Hydrography, Human Activities, Inputs, Contaminants, Nutrients, Biota, Enrichment, Water Quality, Habitats.

Borre, L. and Duker, L. (2000). LakeNet 2000: A Dialogue on Participatory Watershed Management. Monitor International, UNEP.
Keywords: Watershed management, lake management, United Nations Environment Programme, public involvement, problem solving, conservation, tools.

Botterweg, T. and Rodda, D.W. (1999). Danube River Basin: Progress with the Environmental Programme. Wat. Sci. Tec. Vol. 40, No. 10, pp. 1–8, 1999.
Keywords: Europe; Danube; environment; strategy; international co-operation.

Bowman, J.J. (1991). Acid Sensitive Surface Waters in Ireland. The impact of a Major New Sulphur Emission on Sensitive Surface Waters in an Unacidified Region. Environmental Research Unit, Dublin.

Bowman, J.J. (1996). Lough Ree. An Investigation of Eutrophication and its Causes. Environmental Protection Agency, Wexford.
Keywords: Eutrophication; Ireland; phosphorus; nitrogen; algae; water quality; discharges.

Bowman, J.J. (1998). River Shannon. Lake Water Quality Monitoring 1995 to 1997. Environmental Protection Agency, Wexford.
Keywords: Water quality; Shannon; monitoring; sampling; nutrients; DO; BOD; phytoplankton.

Bowman, J.J. (2000). River Shannon. Lake Water Quality Monitoring 1998 and 1999. Environmental Protection Agency, Wexford.

Bowman, J.J. and Toner, P.F. (2001). National Lake Water Quality Monitoring Programme. Environmental Protection Agency, Wexford.
Keywords: Lakes; reservoirs; monitoring; water quality; eutrophication; acidification; EU Directives; sampling frequency; analytical programme.

Bowman, J.J., McGarrigle, M.L. and Clabby, K.J. (1993). Lough Derg – An Investigation of Eutrophication and its Causes. Environmental Research Unit, Dublin.
Keywords: Eutrophication; phosphorus; nitrogen; surface water quality; nutrient sources; waste discharges; non-point sources, point source; treatment plants; agriculture.

Byrne, C., O'Keefe, C. and Earle, R. (2000). The Three Rivers Project – Catchment Water Quality Monitoring & Management Systems. Institute of Fisheries Management – 31st Annual Study Course (TCD 14th September 2000).
Keywords: Catchment based monitoring; Water Framework Directive; eutrophication; Local Authorities; water quality; management; phosphorus loadings; monitoring; ecological status; baseline information; public awareness; GIS; pollution; pilot study areas.

Cate, F.M. (1999). River Basin Management in Lower and Upper Austria: Beginnings and Future Prospects. Wat. Sci. Tec. Vol. 40, No. 10, pp. 185–193, 1999.
Keywords: River basin management; water law; federal system; international basin; EU Water Framework Directive; Danube.

Central Fisheries Board (1986). Inland Fisheries Strategies for Management and Development. CFB, Dublin.

Central and Regional Fisheries Board (1999). Annual Report, CFB, Dublin.

Centre for Ecology & Hydrology (2000). Technical Workshop on the Tools and Data Available and Required to Implement the EU Water Framework Directive. CEH, Wallingford.
Keywords: Water Framework Directive; characterisation; quality status; ecological status; monitoring; planning; tools.

Champ, W.S.T., Cox, M., McGarrigle, M., Norton, R. and Shiel, S. (1997). Lough Conn Progress Report. The Lough Conn Task Force, Castlebar.

Keywords: Phosphorus; Nutrient Management Planning; REPS; sewage treatment; eutrophication; education; catchment; research.

Chave, P.A. (2001). The EU Water Framework Directive. An Introduction. IWA Publishing, London.

Coulter, B., Daly, K., Kurz, I., Coxon, C., Jeffrey, D., Mills, P., Kiely, G. and Morgan, G. (2000). Quantification of Phosphorus Loss From Soil to Water. Synthesis Report. R&D Report Series No. 6. Environmental Protection Agency, Wexford.

Keywords: Phosphorus export; phosphorus desorption; agriculture; overland flow; hydrometeorological; national phosphorus model; catchment.

Council of the European Communities (1975). Directive 75/440/EEC of 16 June 1975 concerning the quality of surface water intended for the abstraction of drinking water in the Member States. O.J. L194/23.

Council of the European Communities (1976). Directive 76/464/EEC of 4 May 1976 on pollution caused by certain dangerous substances discharged into the aquatic environment of the Community. O.J. L129/23.

Council of the European Communities (1978). Directive 78/659/EEC of 18 July 1978 on the quality of freshwaters needing protection or improvement in order to support fish life. O.J. L222/1.

Council of the European Communities (1980). Directive 80/68/EEC of 17 December 1979 on the protection of groundwater against pollution caused by certain dangerous substances. O.J. L20/43.

Council of the European Communities (1991). Directive 1991/271/EEC of 21 May 1991 concerning urban waste water treatment Directive. O.J. L135/40.

Council of the European Communities (1991). Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources. O.J. L375/1.

Council of the European Communities (1996). Directive 96/61/EEC of 24 September on integrated pollution prevention and control. O.J. L257/26.

Council of the European Communities (1998). Directive 98/83/EC of 3 November 1998 on the quality of water intended for human consumption. O.J. L 330/32.

Council of the European Communities (2000). Directive 2000/60/EC of 23 October 2000 establishing a framework for community action in the field of water policy. O.J. L327/1.

Daugvas Projekts (2000). The Daugava River Basin Project. Inception Report.

Keywords: Water Framework Directive; River Basin Authority; River Basin Management; Training; Communication; Stakeholders; Legislative Obligations; River Basin Management Plan.

Department of Agriculture, Food and Forestry (1994). Operational Programme for Agriculture, Rural Development and Forestry 1994–1999. DAFF, Dublin.

Department of the Environment and Department of Agriculture (1999). Code of Good Agricultural Practice to Protect Waters from Pollution by Nitrates. DELG, Dublin.

Keywords: Nitrates; pollution; European Union; organic fertilisers; nutrients; groundwaters; surface waters; storage; application rates.

Department of the Environment and Department of Agriculture, Food and Forestry (1996). The Code of Good Agricultural Practice to Protect Waters from Pollution by Nitrates. DELG, Dublin.

Department of the Environment and Local Government. Managing Ireland's Rivers and Lakes. A Catchment-based Strategy Against Eutrophication. DELG, Dublin.

Department of the Environment and Local Government. Protecting our Freshwater. Nutrient Management planning guidelines for local authorities. DELG, Dublin.

Department of the Environment and Local Government (1997). Sustainable Development: a Strategy for Ireland. DELG, Dublin.

Department of the Environment and Local Government (1997). Managing Ireland's Rivers and Lakes. A Catchment-Based Strategy Against Eutrophication. DELG, Dublin.

Keywords: Eutrophication; Diffuse Source; Point Source; Environmental Quality Objectives; Phosphorus; Nitrogen; Fertilisers; Monitoring; EU Waste Water Treatment Directive; Nutrient Management Planning; REPS; Effluent; Catchment.

Department of the Environment and Local Government (1998). Nutrient Management Planning Guidelines for Local Authorities. Brunswick Press.

Keywords: Waste Management Act; Nutrient; Agriculture; Fertiliser; Phosphorus; Water Pollution; Local Authorities; Management; Statutory Provisions; Application Rates.

Department of the Environment and Local Government (2000). Guidelines for the establishment of River Basin Management Systems. DELG, Dublin.

Keywords: River Basin; Water Framework Directive; Catchment Management; Local Authorities; Qualitative; Quantitative; Monitoring; Programme of Measures; Co-operation; Modelling; GIS.

Department of the Environment and Local Government, Environmental Protection Agency and Geological Survey of Ireland (1999). Groundwater Protection Schemes. DELG, Dublin.

Keywords: Groundwater; Risk Assessment; WFD; Risk Management; Land Surface Zoning; vulnerability mapping; Source Protection Areas; Aquifer; Source Protection Zones.

Downey, W.K. and Ní Uid, G. (1977). Lake Pollution Prevention by Eutrophication Control. National Science Council. Proceedings of a seminar held in Killarney, Ireland, May 10–11, 1977.

Environment and Heritage Service (1998). Proposals for a Water Quality Management Strategy for the River Lagan Catchment. Executive Summary. W.S. Atkins and EHS, Northern Ireland.

Keywords: Water quality; monitoring programmes; legislative framework; water framework directive; catchment;

management; sewage; general quality assessment; ADRIS; water quality targets; trends; pollution.

Environment and Heritage Service (1999). Eutrophication in Northern Ireland's Waters. Proposals for a strategy to control nutrient enrichment. EHS, Northern Ireland.
Keywords: Eutrophication; Northern Ireland; Water Framework Directive; Water Quality Management; Catchment Management.

Environment and Heritage Service (2000). A Groundwater Monitoring Strategy for Northern Ireland. EHS, Printing Unit Northern Ireland.
Keywords: Groundwater; Northern Ireland; Legislative Framework; Monitoring.

Environment and Heritage Service (2000). Northern Ireland River Conservation Strategy. A Draft for Consultation.

Keywords: Heritage; conservation value; Northern Ireland; partnership; habitat; species; landscape; built heritage; river management; biodiversity; designations; water quality; research; education.

Environmental Protection Agency (1996). State of the Environment in Ireland. EPA, Wexford.

Environmental Protection Agency (1997). Environmental Quality Objectives and Environmental Quality Standards. The Aquatic Environment. A Discussion Document. EPA, Wexford.
Keywords: Environmental Quality Objectives; Environmental Quality Standards; Beneficial Uses; EU Directive; Priority Substances; BATNEEC; Legislation.

Environmental Protection Agency (1999). Remote Sensing of Lakes: Improved Chlorophyll Calibration and Data Processing. EPA, Wexford.

Environmental Protection Agency (1999). The Quality of Drinking Water in Ireland. A report for the Year 1999 with a Review of the Period 1997–1999. EPA, Wexford.
Keywords: Drinking water; water quality; regulations; monitoring; Drinking Water Directive; treatment.

Environmental Protection Agency (1999). Measuring Progress towards a Sustainable Development with special reference to the Aquatic Environment, Waste Management and the Urban Environment. A Discussion Document. EPA, Wexford.
Keywords: Sustainable development; EQOs; EQSs; natural resource base; sustainability targets; indicators; resource management; aquatic environment.

Environmental Protection Agency (2000). Environmental Research Programme. A Summary of Work in Progress. EPA, Wexford.

Environmental Protection Agency (2000). Interim Report on the Biological Survey of River Quality. Results of the 1999 Investigations. EPA, Wexford.
Keywords: River quality; Q value; water quality assessment; biological assessment; sampling stations.

Environmental Protection Agency (2000). The Quality of Bathing Water in Ireland (1999). EPA, Wexford.
Keywords: water quality monitoring; designated bathing areas; European Council Directive; Quality of Bathing Water Regulations; sampling; water quality standards; local authorities.

Environmental Protection Agency (2001). Parameters of Water Quality. Interpretation and Standards. EPA, Wexford.
Keywords: Water pollutants; National Legislation; EU Legislation; parameters; limits; concentration levels; water quality directives.

Environmental Protection Agency (2001). Phosphorus Regulations National Implementation Report. EPA, Wexford.

European Commission (1998). Freshwater, a challenge for Research and Innovation: a concerted European Response. European Communities, Italy.

European Commission (2001). Amended proposal of 13 June 2001 for a decision of the European Parliament and of the Council establishing the list of priority substances in the field of water policy.

European Commission (2001). Communication of the European Commission to the Council and to the Parliament on a European Community Biodiversity Strategy. European Commission, Brussels.

European Commission (2001). Strategic Document: Common Strategy on the Implementation of the Water Framework Directive.

Eurostat (1999). Towards environmental pressure indicators for the EU – Water Pollution. Eurostat.

Fanning, A., Crowe, M., Carty, G. and Cleneghan, C. (1999). Water Quality Management Planning in Ireland. Environmental Protection Agency, Ireland.
Keywords: Water Quality Management; Water Framework Directive; EU Directives; Local Government.

Flanagan, P.J. (1992). Parameters of water quality. Interpretation and Standards. 2nd Edition. Environment Research Unit, Ireland.

Flanagan, M.J. (2000). A Report on River Water Quality in County Galway. Environmental Protection Agency, Ireland.
Keywords: River monitoring; water quality; biological quality ratings; water quality index; chemical analysis; pollution trends.

Freshwater Foundation (1992). Managing Minnesota's Lakes. A Report of the Minnesota lake Management Forum.

Heikkinen, K., Vuori, K.-M., Lehtinen, A., Virtanen, M., Eloranta, P., Koskenniemi, E., Laine, A., Heinimaa, S., Vaisanen, T. and Kamari, J. (2000). Integrated management of boreal river basins: Finnish experience and development. EurAqua STR7, October 18–19. 2000, Madrid.
Keywords: Recreational use; non-point sources; river basin management; river pollution control; tools; Water Framework Directive; ecological parameters; river status assessment; land-derived loading; monitoring.

Hontelez, J. (2001). Ed. Making the EU Water Framework Directive Work. Ten actions for implementing a better

European Water Policy. European Environment Bureau, Brussels.

Hyder Consulting (1997). Proposals for a Water Quality Management Strategy for the Foyle Catchment and Lough Foyle. Executive Summary.

Hyder Consulting (1998). Proposals for a Water Quality Management Strategy for the River Erne Catchment. Executive Summary.

Keywords: Pollution; ecology; water quality management; catchment; water quality status; environmental quality objectives; conservation; OECD; Freshwater Fish Directive; sampling; management strategies.

Hygum, B., Madgwick, J., Vanderbeeken, M. and Blincoe, P. (2001). Water and Wetland Index. Assessment of 16 European Countries. Phase 1 Results. WWF European Freshwater Programme.

Keywords: Water Framework Directive; ecological status; sustainable management; monitoring; biodiversity; resource; data quality; fragmentation; invasive species; red list species; Natura 2000.

Irish Government (1972). European Communities Act.

Irish Government (1977, 1990). Local Government (Water Pollution) Acts, 1977 to 1990.

Irish Government. Local Government (Water Pollution) Regulations, 1978 (S.I. No. 108).

Irish Government. European Communities (Quality of Salmonid Waters) Regulations, 1988 (S.I. No. 293).

Irish Government (1992). Environmental Protection Agency Act, 1992.

Irish Government (1992). Waste Management Act.

Irish Government (1992). Local Government Act.

Irish Government. Quality of Bathing Waters Regulations, 1992 (S.I. No. 155).

Irish Government. Local Government (Water Pollution) Regulations, 1992 (S.I. No. 271).

Irish Government. Local Government Act 1994 (Bye Laws) Regulations, 1999 (S.I. No. 78).

Irish Government. Quality of Shellfish Waters Regulations, 1994 (S.I. No. 200).

Irish Government. Local Government (Water Pollution) (Amendment) Regulations, 1996 (S.I. No. 184).

Irish Government. Local Government (Water Pollution) (Nutrient Management Planning Consultation) Regulations, 1998 (S.I. No. 257).

Irish Government. Local Government (Water Pollution) Act 1977 (Water Quality Standards for Phosphorus) Regulations, 1998 (S.I. No. 258).

Irish Government. Local Government (Water Pollution) (Amendment) Regulations, 1999 (S.I. No. 42).

Irish Government. Protection of Groundwater Regulations, 1999 (S.I. No. 41).

Irish Government. Water Quality (Dangerous Substances) Regulations, 2001 (S.I. No. 12).

Irvine, K., Allot, N., de Eyto, E., Free, G., White, J., Caroni, R., Kennelly, C., Keaney, J., Lennon, C., Kemp, A., Barry, E., Day S., Mills, P., O'Ríain, G., Quirke, B., Twomey, H. and Sweeny, P. (2001). Ecological Assessment of Irish Lakes. Environmental Protection Agency, Wexford.

John B. Barry & Partners Ltd. (1998). The Dublin Bay Project. Review of Effluent Quality Standards. Executive Summary.

Keywords: Water Quality Standards; Environmental Quality Objectives; Water Quality Modelling; Waste Water; Nitrogen; Secondary Treatment.

Johnes, P., Moss, B. and Phillips, G. (1994). Lakes – Classification and Monitoring. A Strategy for the Classification of Lakes. National Rivers Authority, Bristol.

Karttunen. (2001). Monitoring and assessment of ecological status of aquatic environments. Nordic Council of Ministers.

Keywords: Water Framework Directive; ecological quality; biological monitoring; macroinvertebrates; macrophytes; fish; indicators.

Kahlenborn, W. (1999). Environmental and Resource Costs of Water Use in View of the European Community's Future Framework Directive on Water. Final Report. Ecologic. Institute for International and European Environmental Policy.

Kirk McClure Morton (1998). Lough Derg and Lough Ree. Catchment Monitoring and Management System. Management Proposals.

Kirk McClure Morton (1998, 1999). Lough Derg and Lough Ree Catchment Monitoring and Management Programme. Interim Report.

Keywords: Catchment; phosphorus; wastewater treatment; water quality status; water quality objectives; key environmental indicators; monitoring; EU cohesion fund; subcatchment; sampling; GIS; agriculture.

Kirk McClure Morton (2001). Lough Derg and Lough Ree. Catchment Monitoring and Management System. Final Report.

Kirk McClure Morton and Pettit Project Design & Management (2000). Lough Leane Catchment Monitoring & Management System. A Catchment based approach for reducing inputs from all sources to the Lakes of Killarney. Second Interim Report. Kerry County Council.

Keywords: Catchment; Eutrophication; Water Quality; Management; Special Study Areas; Monitoring; Ecological Monitoring; Groundwater Monitoring; Dangerous Substances; Water Framework Directive; Nutrient Loadings; Local Authority; Wastewater Treatment; Consultation.

Kirk McClure & Morton, ESBi and W.S. Atkins (1997). Proposals for a Water Quality Management Strategy for the Foyle Catchment and Lough Foyle. Executive Summary.

Keywords: Catchment; legislation; hydrology; geology; uses; water quality; sampling; ADRIS; targets; pollution control; management.

Kisgyorgy, S., Botond, G. and Tyson, M. (1999). Water Quality Management in Hungary – A River Basin Approach. Wat. Sci. Tec. Vol. 40, No. 10, pp. 81–86, 1999.
Keywords: Catchment planning commission; environmental charge; European Union, Hungary; institutional development; integrated river basin management; water quality objectives; water resources framework directive.

Lanz, K. and Scheuer, S. (2001). EEB Handbook on EU Water Policy under the Water Framework Directive. European Environment Bureau, Brussels.

Lucey, J., Bowman, J.J., Cunningham, P., Lehane, M., MacCarthaigh, M., McGarrigle, M.L. and Toner, P.F. (1999). Water Quality in Ireland 1995–1997. Environmental Protection Agency, Ireland.
Keywords: Water Framework Directive; Water Quality; Eutrophication; Water Pollution; Phosphorus; Fish Kills; Sewage Treatment; Nitrogen; Toxic Substances; OSPAR.

Mainstone, C.P., Parr, W. and Day, M. (2000). Phosphorus and River Ecology. Tackling sewage inputs. English Nature and the Environment Agency.
Keywords: Phosphorus; nitrogen; algal growth rates; alternative stable states; ecological change; nutrient enrichment; point sources; diffuse sources.

Marine Institute (1998). A Marine Research, Technology, Development and Innovation Strategy for Ireland. A National Team Approach. Marine Institute, Dublin.
Keywords: Marine resource; technology; fisheries; aquaculture; tourism; development; management; research.

McGarrigle, M.L., O'Mongain, E., Walsh, J., Sommerville, T. and Bree, M. (1990). National Survey of lakes by remote sensing calibration of a low altitude water quality spectrometer. Environmental Research Unit, Ireland.

McGovern, E. (1998). Overview of the Irish Marine Institute's Environmental Monitoring Programme. Environmental Division, Marine Institute Fisheries Research Centre.
Keywords: Marine; monitoring; OSPAR; ICES; EU; contaminants; sampling; analyses; quality assurance.

M.C. O'Sullivan Consulting Engineers. Three Rivers Project: Water Quality Monitoring & Management. Interim Report.

M.C. O'Sullivan Consulting Engineers and HR Wallingford. Three Rivers Project: Water Quality Monitoring & Management. Baseline Report.
Keywords: Catchment based monitoring; Water Framework Directive; Eutrophication; Local Authorities; Water Quality; Management; Phosphorus Loadings; Monitoring; Ecological Status; Baseline Information; Public Awareness; GIS; Pollution; Pilot Study Areas.

Niemi, J., Heinonen, P., Mitikka, S., Vuoristo, H., Pietiläinen, O., Puupponen, M. and Rönkä, E. (2001). The Finnish Eurowaternet – with information of Finnish water resources and monitoring strategies. The Finnish Environment 445. Finnish Environment Institute.
Keywords: Environment; monitoring; water quality; rivers; lakes; groundwater; Water Framework Directive.

Nixon, S., Grath, J. and Bogestrand, J. (1999). EUROWATERNET. The European Environment Agency's Monitoring and Information Network for Inland Water Resources. Technical Guidelines for Implementation. Technical Report No. 7.
Keywords: EUROWATERNET; Water Framework Directive; Inland waters; Monitoring networks; European Environment Agency; water quality; water quantity; rivers; lakes; groundwaters; indicators.

Nixon, S.C., Hunt, D.T.E., Lallana, C. and Boschet, A.F. (2000). Sustainable use of Europe's Water? State, prospects and issues. European Environment Agency. Copenhagen.
Keywords: Water management; quantity; abstraction; consumption; groundwater; eutrophication; phosphorus; nitrate; pollution; metering; Water Framework Directive.

O'Connor, B. (1999). A review of methodologies used in relevant member states of the European Union and the OSPAR Convention for the characterisation and monitoring of the biological elements of transitional and coastal waters. Desk Study Report No. 11. Environmental Protection Agency, Ireland.
Keywords: Monitoring; transitional waters; coastal waters; biological elements; methodologies; EU; OSPAR; ICES; Water Framework Directive.

O'Connor, D.G. (2000). Phosphorus Regulations. Measures Report. January 2000. Fingal County Council. Water & Drainage Division.
Keywords: Phosphorus; environmental management system; water quality; biotic index; groundwater; catchment based analysis; targets; Q-values.

O'Connor, D.G. (2000). Phosphorus Regulations. 1st Implementation Report. November 2000. Fingal County Council. Water & Drainage Division.
Keywords: Phosphorus; water quality; implementation; catchment; pressures; point-source; Q value; run-off; wastewater treatment plant; Nutrient Management Planning; farm survey.

Organisation for Economic Co-operation and Development (2000). Environmental Performance Reviews. Ireland: OECD.

Organisation for Economic Co-operation and Development (2000). Environmental Performance Reviews – Ireland. Introduction and Part 1.2 – Pollution Prevention and Control. Water Management. Paris: OECD.
Keywords: OECD; environmental policies; sustainable development; international co-operation; water management; Water Framework Directive; water resources; water quantity.

Organisation for Economic Co-Operation and Development (2001). Environmental Outlook. Paris: OECD.

O'Leary, G. and Carty, G. (1998). Urban Waste Water Discharges in Ireland – A Report for the Years 1996 and 1997. EPA, Wexford.
Keywords: Waste water; discharges; monitoring; environmental indicators; sewage sludge;, treatment.

O'Leary, G., Fanning, A. and Carty, C. (2000). Urban Waste Water Discharges in Ireland with population equivalents greater than 500 persons. A Report for the years 1998 and 1999. Environmental Protection Agency, Wexford.

Keywords: Waste water; discharges; monitoring; environmental indicators; sewage sludge; treatment.

O'Mongain, E., Collins, A., Green, S., O'Ríain, G. and Caffrey, J. (1999). Remote Sensing of Lakes – Improved Chlorophyll Calibration and Data Processing. Final Report. Environmental Protection Agency, Ireland.
Keywords: Lake water quality; chlorophyll; remote sensing; monitoring; sampling; mapping; database management.

Scheidleder, A., Grath, J., Gotz, B. and Weber, K. (2000). Pilot Implementation EUROWATERNET – groundwater. State of groundwater in selected groundwater bodies with reference to nitrogen. Technical Report No. 39.
Keywords: Groundwater; pilot study; EUROWATERNET; nitrogen; monitoring; quality; agriculture; aquifers; quantity; ammonium; nitrite; nitrate; dissolved oxygen.

Scottish Environment Protection Agency (1999). Improving Scotland's Water Environment. Scottish Environment Protection Agency, SEPA Edinburgh.
Keywords: Environmental quality; water quality; quantity; blue–green algal blooms; groundwater quality; monitoring; habitat quality; pollution; pressures; sewage; agriculture; acidification; urban drainage; abstractions; water quality targets; water quantity targets.

Skriver, J. (2001). Biological Monitoring in Nordic Rivers and Lakes. Nordic Council of Ministers.
Keywords: Water Framework Directive; ecological quality; biological monitoring; organic pollution; nutrient loading; macroinvertebrates; macrophytes; fish; indicators; ecoregions; predictive modelling.

Stanners, D. and Bordeau, P. (1994). Europe's Environment. The Dobríš Assessment: An overview. European Environment Agency, Copenhagen.

Stapleton, L., Lehane, M. and Toner, P. (eds) (2000). Ireland's Environment. A Millennium Report.

Chapter 5: Discharges to Water; Chapter 9: Inland Waters; Chapter 10: Estuarine and Coastal Waters; Chapter 12: Natural Heritage and Biodiversity; Chapter 13: Ireland's Environment, the Main Issues; Chapter 14: Environmental Economics; Chapter 15: Managing and Protecting the Environment; Chapter 16: Future Outlook.

Stephens, A. (2001). A Survey of Dangerous Substances in Surface Freshwaters 1999–2000. Environmental Protection Agency, Ireland.
Keywords: Dangerous substances; discharges; pollution; pesticides; VOC; metals; sampling; quality standards.

The Heritage Council (1999). Policy Paper on the Future of Ireland's Inland Waterways. The Heritage Council of Ireland Series.
Keywords: Inland waterways; built heritage; natural heritage; strategic plan; conservation; management; archaeology; future development.

Thompson, E., Ryan, S. and Cotton, D.C.F. (1998). Management Plan for the Lough Gill Catchment. Sligo County Council.
Keywords: Catchment; baseline monitoring; GIS; resources; groundwater; surface water; water quality; conservation; management; environmental quality standards; environmental quality objectives.

Toner, P.F. and Sullivan, A.J. (1977). Water Pollution in Ireland – A review of the existing situation, current investigations and future research needs. National Science Council, Ireland.

Tunney, H., Carton, O., O'Donnell, T. and Fanning, A. (1998). Phosphorus loss from soil to water. End of project report. Johnstown Castle Research Centre, Wexford. ARMIS 4022.
Keywords: Phosphorus; agriculture; eutrophication; workshop; run-off.

United States Environmental Protection Agency, Office of Water (1998). National Strategy for the Development of Regional Nutrient Criteria.
Keywords: Watershed; Ecoregion; Nutrients; Nutrient Criteria; regional; Waterbody-type; Water Quality Criteria; Standards; Indicators; Management; Research.

United States EPA – Office of Water (2000). Ambient Water Quality Criteria Recommendations. Information Supporting the Development of State and Tribal Nutrient Criteria for rivers and streams in Nutrient Ecoregion II. Environmental protection Agency, USA. EPA 822-B-00-015.
Keywords: Nutrient Criteria; water quality standards; designated uses; reference conditions; chlorophyll a; turbidity; ecoregion; phosphorus, nitrogen; eutrophication.

United States EPA – Office of Water (2000). Ambient Water Quality Criteria Recommendations. Information Supporting the Development of State and Tribal Nutrient Criteria for lakes and reservoirs in Nutrient Ecoregion II. Environmental protection Agency, USA. EPA 822-B-00-007.
Keywords: N.B. Similar recommendations exist for all US Ecoregions.

United States EPA – Office of Water (2000). Ambient Water Quality Recommendations. Information Supporting the Development of State and Tribal Nutrient Criteria for rivers and streams in Nutrient Ecoregion IX. EPA 822-B00-019.

United States EPA – Office of Water (2000). Ambient Water Quality Criteria Recommendations. Information Supporting the Development of State and Tribal Nutrient Criteria for lakes and reservoirs in Nutrient Ecoregion VI. EPA 822-B00-008.

United States EPA – Office of Water (2000). Ambient Water Quality Criteria Recommendations. Information Supporting the Development of State and Tribal Nutrient Criteria for lakes and reservoirs in Nutrient Ecoregion VIII. EPA 822-B00-010.

United States EPA – Office of Water (2000). Ambient Water Quality Criteria Recommendations. Information Supporting the Development of State and Tribal Nutrient Criteria for rivers and streams in Nutrient Ecoregion III. EPA 822-B00-011.

United States EPA – Office of Water (2000). Ambient Water Quality Criteria Recommendations. Information Supporting the Development of State and Tribal Nutrient

Criteria for rivers and streams in Nutrient Ecoregion XI. EPA 822-B00-020.

United States EPA – Office of Water (2000). Nutrient Criteria Technical Guidance Manual. Lakes and Reservoirs. Environmental Protection Agency, USA. EPA-822-B00-001.

Vincent, C. (2001). Approaches to Surface Water Typology across Member States under EC Water Framework Directive – A Discussion Paper. Environment and Heritage Service, Belfast.

Willén, E. (2000). Phytoplankton in Water Quality Assessment – An Indicator Concept. In: Heinonen, P., Ziglio, G. and Van der Beken, A. (eds). Hydrobiological and Limnological Aspects of Lake Monitoring.

Keywords: Algae; phytoplankton; water quality; indicators; trophic status; diversity; seasonal development; environmental changes.

WWF (2000). Implementing the EU Water Framework Directive: A seminar series on water. Proceedings, Seminar 1: Water and Agriculture. WWF European Freshwater Programme. Brussels, 10 and 11 February 2000.

Keywords: Water Framework Directive; agriculture; water quantity; water quality; eutrophication; pollution; tools (technical, economic, legislative, institutional, policy, analytical); sustainable development; Europe; CAP; river basin scale; case studies; information exchange.

WWF (2000). Implementing the EU Water Framework Directive. A Seminar Series on Water. Seminar 2: The Role of wetlands in River Basin Management. Programme. WWF European Freshwater Programme. Brussels, 9 and 10 November 2000.

Keywords: Water Framework directive; wetlands; river basin management; restoration.

WWF (2001). Implementing the EU Water Framework Directive. A Seminar Series on Water. Seminar 3: Good Practice in River Basin Planning. Programme. WWF European Freshwater Programme. Brussels, 29 and 30 May 2001.

Keywords: Water Framework Directive; river basin planning; integration; public participation; stakeholders; transboundary.

WWF and EEB (1998). WWF/EEB Workshop on Water Framework Directive. Implications and Challenges for the Environment. Brussels, 22–23 October 1998.

Acronyms and Abbreviations

BASINS	Better Assessment Science Integrating Point and Non-point Sources
BAP	Best Available Practice
BAT	Best Available Technology
BATNEEC	BATNEC (Best Available Technology Not Entailing Excessive Cost).
BIOMAR	An EU funded research programme to map the coastal biotopes of Britain & Ireland
BOD	Biochemical Oxygen Demand
CEMP	Co-ordinated Environmental Monitoring Programme of OSPAR
CFB	Central Fisheries Board
COD	Chemical Oxygen Demand
CPR	Continuous Plankton Recorder
DAHGI	Department of Arts, Heritage, Gaeltacht and the Islands
DELG	Department of Environment and Local Governments
DMNR	Department for the Marine and Natural Resources
DOP	Dissolved Organic Phosphorus
DP	Dissolved Phosphorus
DPSIR	Driving forces, Pressures, Statistics, Impacts, Responses
DRP	Dissolved Reactive Phosphorus
EA	Environment Agency
EC	European Community
ECJ	European Court of Justice
EDI	Electronic Data Interchange
EEC	European Economic Community
EHS	Environment and Heritage Service
ELV	Emission Limit Value
EQS	Environmental Quality Standard
EPA	Environmental Protection Agency
ESB	Electricity Supply Board
ESRI	Economic and Social Research Institute
EU	European Union
FIPS	Forest Inventory and Planning System
GIS	Geographical Information System

GSI	Geological Survey of Ireland
HSPF	Hydrological Simulation Programme-FORTRAN
ICDA	Irish Cosmetics and Detergents Association
ICES	International Council for Exploration of the Sea
IRBD	International River Basin District
JAMP	Joint Assessment and Monitoring Programme of OSPAR
LAWA	Landerarbeitsgemeinschaft Wasser
LGCSB	Local Government Computer Services Board
MI	Marine Institute
MRI	Martin Ryan Institute (Galway)
MRP	Molybdate Reactive Phosphorus
NGOs	National Government Organisations
NMP	National [marine] Monitoring Plan (UK)
NVZ	Nitrate Vulnerable Zone
OECD	Organisation for Economic Co-operation and Development
OPW	Office of Public Works
OSI	Ordnance Survey or Ireland
OSPAR	Convention for the Protection of the Marine Environment of the North-East Atlantic
PCB	Polychlorinated Biphenyl
POP	Particulate Organic Phosphorus
PP	Particulate Phosphorus
PPP	Public-Private Partnership
QA	Quality Assurance
RBDMPs	River Basin District Management Plans
RBMP	River Basin Management Plan
RBMS	River Basin Management Systems
RBD	River Basin District
REPS	Rural Environmental Protections Scheme
RIVPACS	River Invertebrate Prediction And Classification System
RPII	Radiological Protection Institute of Ireland
RTDI	Research, Technological Development and Innovation
SAHFOS	Sir Alistair Hardy Foundation for Ocean Science (Plymouth, UK)
SAC	Special Area of Conservation

SERCON	System for Evaluating Rivers for Conservation
SHE	Systeme Hydrologique European
SHETRAN	Systeme Hydrologique European Transport module
S.I.	Statutory Instrument
SNIFFER	Scotland and Northern Ireland Forum For Environmental Research
SPA	Special Protection Area
TCD	Trinity College Dublin
TDP	Total Dissolved Phosphorus
TP	Total Phosphorus
TRP	Total Reactive Phosphorus
TRS	Trophic Ranking Score
TSP	Total Soluble Phosphorus
UCC	University College Cork
UCD	University College Dublin
UCG	University College Galway
UK	United Kingdom
US	United States
UWWT	Urban Waste Water Treatment
VOC	Volatile Organic Compound
WFD	Water Framework Directive
WQMPs	Water Quality Management Plans

Appendix A

Summary tables relating to currently identified roles of organisations involved in the implementation of the WFD.

Table A1. Summary table showing organisation and its associated legislation.

Organisation	Relevant legislation
Department of the Marine and Natural Resources	Fisheries Acts 1959–2000 Harbours Act 1946 Oil Pollution of the Sea Acts 1988–1998 Foreshore Acts 1933–1998 Marine Institute Act 1991 Continental Shelf Act 1968 Sea Pollution Act 1991 and 1999 Dumping at Sea Act 1996 Shellfish Waters Regulations 1994
Central and Regional Fisheries Boards	As for DMNR
Department of the Environment and Local Government	Local Government (Water Pollution) Acts 1977 and 1990 Environmental Protection Agency Act 1992 Waste Management Act 1996 (No. 10 of 1996) Local Government (Water Pollution) Regulations 1978, 1992, 1996 and 1999 Protection of Groundwater Regulations 1999 Nutrient Management Planning Consultation Regulations 1998 Local Government Act 1994 (Bye-Laws) Regulations 1999 Water Quality Standards for Phosphorus Regulations 1998 Salmonid Waters Regulations 1988 Bathing Waters Regulations 1992 Shellfish Waters Regulations 1994 Control of Water Pollution by Asbestos Regulations 1990 Control of Cadmium Discharges Regulations 1985 Control of Hexachlorocyclohexane and Mercury Discharges Regulations 1986 Control of Aldrin, Dieldrin, Endrin, Isodrin, HCB, HCBD and CHCL3 Discharges Regulations 1993 Control of Carbon Tetrachloride, DDT and Pentachlorophenol Discharges Regulations 1994 Control of EDC, TRI, PER and TCB Discharges Regulations 1994

Table A1. ***contd.***

Organisation	Relevant legislation
DELG *contd*.	Waterworks Clauses Act 1847 Waterworks Clauses Act 1863, Public Health (Ireland) Act 1878 Public Health Acts Amendment Act 1907 Water Intended for Human Consumption Regulations 1988 Water Intended for Human Consumption (Amendment) Regulations 2000 Surface Water Intended for the Abstraction of Drinking Water Regulations 1989. Urban Waste Water Treatment Regulations 1994 Use of Sewage Sludge in Agriculture Regulations 1998
Environmental Protection Agency	EPA Act 1992 Waste Management Act 1996 Local Government (Water Pollution) Act 1977 (Water Quality Standards for Phosphorus) Regulations 1998
Geological Survey of Ireland	None
Marine Institute	As for DMNR
Office of Public Works	Arterial Drainage Act 1925 Arterial Drainage Act 1945 Arterial Drainage (Amendment) Act 1995
Dúchas (DAHGI)	
Department of Agriculture, Food and Rural Development	None in relation to water quality
Department of Arts, Heritage, Gaeltacht and the Islands	
Local Government Computer Services Board	
Waterways Ireland	

Table A2. Summary table showing organisations and their functions.

Organisation	Functions
Department of the Marine and Natural Resources	• promote and protect the quality of the Marine Environment • to bring into force laws, regulations and administrative provisions necessary to implement marine environment directives
Central and Regional Fisheries Boards	• manage, protect, conserve, develop and improve fish life relating to all aspects of the aquatic environment • sustainable development of inland fisheries resources • maintenance of fish habitats
Department of the Environment and Local Government	**DELG** • primary responsibility for the quality of water in Ireland **LAs** • the making of water quality management plans • the granting, or refusal of licenses to discharge effluent to waters or sewers • the making of bye-laws to prohibit or regulate farming practices in the interests of eliminating or preventing water pollution • the monitoring of water quality • the provision of supplies of drinking water
Environmental Protection Agency	• the licensing and regulation of large industries and other processes • the monitoring of environmental quality • advising public authorities of environmental functions and assisting local authorities in their environmental protection functions • the promotion of environmentally sound practices • the promotion and co-ordination of environmental research • the licensing and regulation of all significant waste disposal and recovery activities including landfills • the preparation and implementation of a national hydrometric programme
Geological Survey of Ireland	• to acquire, interpret and provide the best geological information relating to Ireland's earth resources and physical environment
Marine Institute	• MI is recognised by the EU Commission as the National Reference Lab in Ireland for marine biotoxins in shellfish (Directive 91/492), fish health (Directive 91/64), monitor residues in farmed fish (Directive 96/23) • marine licences vetting committee – regulate dumping at sea, placement of pipe and dumping of dredge spoil • aquaculture licence advisory committee – regulate aquaculture industry • co-ordinate, promote and assist in marine research and development which will promote economic development, create employment and **protect the marine environment**
Office of Public Works	• the OPW is recognised as the body through which Central Government exercises its statutory responsibilities in respect of **river drainage and flood relief** • reducing **risk to life and damage to property from fluvial and tidal flooding** within scheme catchments • preserving the productive potential of the agricultural land served by drainage schemes • providing a Hydrometric service and a flood relief Design service

Table A2. ***contd*****.**

Organisation	Functions
Dúchas (DAHGI)	
Department of Agriculture, Food and Rural Development	• provision of grant assistance for animal housing and waste storage facilities to better **manage farm wastes,** etc. • promoting **good farming practice** as part of a number of DAFRD schemes • promoting farmers to join **REPS** where they must comply with nutrient management plans and other measures
Department of Arts, Heritage, Gaeltacht and the Islands	
Local Government Computer Services Board	
Waterways Ireland	

Table A3. Summary table showing organisations and their current and planned activities.

Organisation	Current and Planned Activities
Department of the Marine and Natural Resources	*See Central Fisheries Board and Marine Institute*
Central and Regional Fisheries Boards	• conducted comprehensive **research into freshwater and marine angling species** and the development of freshwater ecosystems since the 1980s • over the past 10 years have conducted an extensive **rehabilitation programme in channels** that have been artificially modified • in the context of the catchment management programmes, 27 **fish counting devices** were installed in rivers throughout the state – will provide essential fish statistics for RBDM projects • involved in the **analysis and management of anthropogenic pressures** caused by land-use management including urban developments • currently involved with the EPA and universities north and south researching possible correlations between **water quality and fish stocks** – objective is to develop a model which will facilitate the monitoring requirements of the WFD
Department of the Environment and Local Government	• **Catchment-based strategy** – since 1997, DELG has been promoting a catchment-based national strategy to combat eutrophication in rivers and lakes. Major projects have been established in relation to Loughs Derg, Ree and Leane and the Rivers Boyne, Liffey and Suir. • **River basin management projects** – DELG is actively promoting the establishment by LAs of river basin management projects to address all sources of pollution in all inland and coastal waters, including ground waters. • **National development plan** – the major programme of capital expenditure will substantially advance achieving good water quality by LAs and DELG supported by EU funds under the Water Services Investment Fund.
Environmental Protection Agency	• Monitoring programmes • Reference conditions
Geological Survey of Ireland	• producing **groundwater protection schemes** in association with local authorities – will provide much of the information required for the groundwater aspects of RBD characterisation • guidelines for delineation of **source protection areas** have been completed – 75 public groundwater supplies have already been delineated • specification completed for delineating **NVZs** • **groundwater protection responses** • Compilation of subsoils data • plans to advance knowledge of ground water in Ireland, improving **groundwater databases**, understanding of ground water, surface water and habitats and considering groundwater issues in land-use planning and environmental management • in the last 4 years, GSI and Dept. Civil Eng. (TCD) have undertaken research on **vulnerability assessment and mapping** • - new **national aquifer map** is planned for 2002 (1:625,000)
Marine Institute	• **monitoring programme for priority hazardous substances** – in estuarine and marine waters/organisms (including fish and mammal life) ***[note, this testing programme covers most of the parameters with significance for the marine environment proposed in the WFD priority hazardous substances list]*** • **physico–chemical testing** – MI carried out winter nutrients monitoring in the western Irish Sea and Celtic sea since 1990. An assessment of the 10 years data is in progress in accordance with OSPAR recommendations. Other parameters routinely tested are pH and DO

Table A3. ***contd.***

Organisation	Current and Planned Activities
Marine Institute *contd.*	• **phytoplankton monitoring** – sample collected on a weekly basis from shellfish growing waters (in coastal waters form Carlingford Lough to Lough Foyle). Additional samples would need to be taken from certain estuarine locations which could be supplied by EPA survey teams to monitor for WFD purposes • **benthic monitoring –** audit of benthic monitoring of finfish sites in progress. Anticipated benthic monitoring of shellfish required – these should assist in the identification of Habitat and Species protection areas under the WFD
Office of Public Works	• continuation of the **arterial drainage maintenance and priority flood relief programmes** • **environmental work** related to drainage maintenance and flood relief • since 1990, the OPW has a programme in place aimed at examining the **environmental impacts of channel maintenance practice –** this programme is known as the **Experimental Drainage Maintenance (EDM)** Programme and has been in operation in all three Drainage Maintenance Regions since 1997 • **proposal to develop** with the assistance of the CFB and advice from the Rivers Agency in Northern Ireland, an **appropriate river corridor/categorisation programme** so as to provide OPW with a habitat sensitivity baseline to assist maintenance staff to address environmental concerns in relation to rivers works • collection and provision of hydrological data by the OPW Hydrology and Hydrometric Section (data are presently collected by OPW at approximately 330 gauging stations on rivers, lakes and at tidal locations around the country) • **development of flood hazard maps –** the goal of the project is to deliver clear and comprehensive flood hazard maps to stakeholders for their respective uses – local/planning authorities
Dúchas (DAHGI)	
Department of Agriculture, Food and Rural Development	• **Research** – current project by Teagasc on environmental impact and soil fertility with particular emphasis on • water quality • **REPS** – promoting sustainable farming by following good farming practices to promote environmental protection • **Farm Waste Management Scheme** – provides capital investment for proper storage facilities farm wastes • **Investment Aid for the Improvement of Dairy Herd Standards** – objectives are to establish farming practices and production methods which reflect an increasing concern for the environment • **Organic Farming** – financial support for measures involved • **Code of Good Practice to Protect Waters from Pollution by Nitrates** – methods to prevent or minimise the pollution of waters from nitrates by adopting certain farm nutrient management techniques • **IPC Licensing –** scheme has been extended to include intensive pig and poultry rearing units. • **National Climate Change Strategy –** reduce livestock numbers which has a knock on effect for water quality • Good Farming Practice • Ammonia Emissions • Extensification • Redesign of Compensatory Allowances Scheme • Plant Protection Products
Department of Arts, Heritage, Gaeltacht and the Islands	
Local Government Computer Services Board	
Waterways Ireland	

Table A4. Summary table showing organisations and the information they provide and the resources they use.

Organisation	Information and resources
Department of the Marine and Natural Resources	*See Central Fisheries Board and Marine Institute*
Central and Regional Fisheries Boards	• **data on fish populations**, species composition, densities, growth patterns, physical in-stream features (stream width, depth and substrate type), vegetation cover and bank-side characteristics for a large number of sites monitored during the River Rehabilitation Programme
Department of the Environment and Local Government	•
Environmental Protection Agency	• monitoring data for macroinvertebrates and physico–chemistry • IPC licences. • research records • GIS
Geological Survey of Ireland	• **bedrock maps** (at 1:100,000 scale) completed for 75% of the country, coverage of the remaining sectors will be available in 2002 • GSI is repository for all open-file **geological information** generated by mineral and petroleum exploration • **records of well-drilling** and related activities (from 1950s) – represent 10–20% of the country • main repository for **groundwater data** (also the EPA) – includes 3000 fairly complete groundwater analyses plus a roughly equal number of partial chemical and bacterial analyses • records of **groundwater-level fluctuations** in about 40 wells in seven counties (computerised) – give a picture of groundwater levels in Ireland over the past 30 years • database of karst features (more than 2700 entries) • **national aquifer map** (1:500,000 and 1:1.5 million; 1983 and 1995) • **national map of groundwater vulnerability** (1:1500,00) • groundwater vulnerability map of NI • **medium-scale maps** (1:100,000 to 1:50,000), e.g. Nore River Basin, groundwater protection scheme maps, etc. • **large-scale maps** (1:25,000 to 1:10,000), e.g. source area and hydrological maps
Marine Institute	• extensive **scientific and technical staff** experience in marine science • **databases** on contaminants, nutrients, algal blooms and other marine topics available • **monitoring and research** on wild salmon and sea trout • GIS techniques and catchment management • **monitoring results** on fisheries stocks in coastal and offshore waters
Office of Public Works	• **holder of a comprehensive library of historic hydrometric data** in the country and is the **Primary** holder of flood data in Ireland • a considerable volume of material **(topographical data)** exists in relation to engineering surveys and designs of catchment channels, both longitudinal and cross-sectional data. • data exist not only for those catchments where works were carried out under the Arterial Drainage Act, 1945, but also for catchments where works were proposed

Table A4. ***contd.***

Organisation	Information and resources
Dúchas (DAHGI)	
Department of Agriculture, Food and Rural Development	• computerised **maps of soil types** countrywide will be available in July 2002 from Teagasc
Department of Arts, Heritage, Gaeltacht and the Islands	
Local Government Computer Services Board	
Waterways Ireland	

Table A5. Summary table showing organisations and their associated role/function in relation to the WFD.

Organisation	Function/role in relation to the WFD
Department of the Marine and Natural Resources	• to bring into force laws, regulations and administrative provisions necessary to comply with the directive • to co-ordinate the activities, in relation to the WFD, of the Marine Institute, the fisheries boards and other relevant organisations under the aegis of the department
Central and Regional Fisheries Boards	• lead role in fish stock management and development including habitat protection • role within the scope of the Directive to contribute to policies and developments in land-use management strategies likely to impact on aquatic habitats • provide guidance on analyses of pressures and impacts particularly in the identification of anthropogenic pressures • lead role regarding the **assessment of the status of fish stocks** in rivers, lakes and estuaries, to monitor these as additional indicators of ecological quality and to report to the EU on a 3-yearly cycle in conjunction with the DMNR and the MI.
Department of the Environment and Local Government and Local Authorities	**DELG** • to ensure that a co-ordinated approach is adopted toward the achievement of the objectives set out in the WFD • to co-ordinate the activities of LAs in the construction of RBMPs • to provide advice to LAs in relation to setting up RBMD and other requirements of the WFD • to bring into force the laws, regulations and administrative provisions necessary to comply with the directive • to carry out an economic analysis of water use – develop a cost-effective set of measures for achieving the environmental objectives of the WFD • to ensure that techniques/methodologies/ reference conditions are compatible with those of the EU • to develop (with the EPA) guidelines for monitoring • lead role in the **co-ordination of implementation** procedures • lead role regarding **policy and legislation** re water quality and services • lead role by LAs in **development of RBMP**
Environmental Protection Agency	
Geological Survey of Ireland	• compilation of geological and hydrogeological data • aquifer/groundwater body mapping • characterisation of the overlying strata • groundwater qualitative status • groundwater quantitative status • GSI guidelines on source protection zone and NVZ delineation should be followed • monitoring of groundwater status – in advisory role to the EPA • surface water characterisation: geological and hydrogeological aspects – advisory and mapping role • producing a 3D conceptual catchment model

Table A5. ***contd.***

Organisation	Function/role in relation to the WFD
Marine Institute	• primary role in **monitoring programmes for transitional and coastal waters** (it is likely that EU monitoring will be based on methodologies under JAMP/CEMP and HELCOM programmes of OSPAR of which the MI is the main contributor to these groups for Ireland) • lead role in issues relating to **priority hazardous substances in coastal and transitional waters** and for nutrients in marine waters
Office of Public Works	• primary role in **arterial drainage and flood relief** • a role to play in considering the issue of water management (of which flood management is one aspect) when River Basin Management Plans are being prepared. • making available hydrological data to all interested parties.
Dúchas (DAHGI)	•
Department of Agriculture, Food and Rural Development	• involvement at both the planning and preparation phases of RBMPs – technical skills regarding soil characteristics, e.g. nature of topsoil, thickness, permeability, etc. • identification of land uses/management as well as nutrient inputs • indication of how farming systems combined with soil types impact on leaching losses to ground/surface waters
Department of Arts, Heritage, Gaeltacht and the Islands	
Local Government Computer Services Board	
Waterways Ireland	

Table A6. Summary table showing organisations and the associated requirements of the WFD.

Organisation	Requirements of the WFD
Department of the Marine and Natural Resources	*See Marine Institute and Fisheries Boards*
Central and Regional Fisheries Boards	*None given*
Department of the Environment and Local Government	In relation to each RDBP there are several requirements of the WFD which must be considered by the LAs • the determination of the characteristics of the waters concerned • the operation of monitoring programmes in respect of water quality • the control of direct and diffuse charges to water • the review of the impact of human activity on the status of waters • the establishment of environmental objectives aimed at achieving quality targets • the drawing up and implementation of a programme of measures to achieve the established environmental objectives • the carrying out of an economic analysis of water use
Environmental Protection Agency	
Geological Survey of Ireland	**River Basin District Characterisation** Requirements • location and boundaries of the groundwater body or bodies • a description of the groundwater bodies **Groundwater Qualitative Status** Requirements • 'good status' • characterisations of the chemical composition for RBD characterisation • information on trends and trend reversal • groundwater monitoring network • review of impact of pollution on groundwater quality • information on construction of sampled wells • information on the pressures on groundwater bodies **Groundwater Quantitative Status** Requirements • ensure a balance between abstraction and recharge • monitoring of the chemical and quantitative status • review of impact of changes in groundwater levels • a monitoring network • interpretation and presentation of groundwater quantitative status

Table A6. ***contd.***

Organisation	Requirements of the WFD
Geological Survey of Ireland *contd*.	**Protected Areas** Requirements • register of protected areas including water abstraction points, NVZs and areas designated for the protection of species **Surface Water Characterisations: Geological/Hydrogeological Aspects** Requirements • for describing surface water body types – descriptors (calcareous, siliceous, organic, etc.) • information on the hydrogeology and ground water **Monitoring of groundwater status –** largely responsibility of the EPA **Integration of Hydrogeological Aspects –** many tasks are interrelated
Marine Institute	*None given*
Office of Public Works	• flood management • making hydrological data available to all interested parties
Dúchas (DAHGI)	
Department of Agriculture, Food and Rural Development	*None given*
Department of Arts, Heritage, Gaeltacht and the Islands	
Local Government Computer Services Board	
Waterways Ireland	

Likely overlaps:
DAFRD and Dúchas regarding overgrazing in target areas such as National Heritage Areas and commonage
DAFRD and Teagasc regarding fertiliser recommendations
FB and MI in some aspects of transitional and coastal waters fish stock monitoring

Appendix B

Table B1. A contact list of WFD Co-ordination Groups attendees and their organisations (May 2001).

Department/Agency	Contact	Email
Environmental Protection Agency	Mr Jim Bowman	j.bowman@epa.ie
Environmental Protection Agency	Mr Kevin Clabby	k.clabby@epa.ie
Environmental Protection Agency	Mr Larry Stapleton	l.stapleton@epa.ie
Environmental Protection Agency	Mr Andy Fanning	a.fanning@epa.ie
Environmental Protection Agency	Mr Matt Crowe	m.crowe@epa.ie
Department of the Arts, Heritage, Gaeltacht and the Islands	Mr Eamonn Brennan	Ebrennan@ealga.ie
Dúchas	Mr Jim Ryan	Jryan@ealga.ie
Department of Public Enterprise	Mr Donal Daly	Donaldaly@gsi.ie
Department of Finance	Mr Eric Hartmann	Eric_hartmann@finance.irlgov.ie
Department of Agriculture, Food and Rural Development	Mr Martin Farrell	Martin.farrell@agriculture.gov.ie
Department of Agriculture, Food and Rural Development Agriculture House	Mr Matt Sinnott	Matt.sinnott@daff.irlgov.ie
Department of the Marine and Natural Resources, Leeson Lane	Mr Philip McMahon	Philipmacmahon@marine.irlgov.ie
Central Fisheries Board	Mr Trevor Champ	Trevor.champ@cfb.ie
Western Regional Fisheries Board	Dr Greg Forde	Gforde@wrfb.ie
Office of Public Works	Mr Tom Bolger	Tom.bolger@opw.ie
Local Government Computer Services Board	Mr Peter Britton	Pbritton@lgcsb.ie
City and County Engineers Association Monaghan County Council	Mr Billy Moore	Bmoore@monaghancoco.ie
City and County Managers Association Galway County Council	Mr John Colleran	Jcollera@galwaycoco.ie
Environment and Heritage Service, Northern Ireland	Mr Angus McRobert	Angus.mcrobert@doeni.gov.uk
Shannon Navigation/Waterways Ireland	Mr Ray Dunne	
Department of the Environment and Local Government	Mr John Sadlier	John_sadlier@environ.irlgov.ie
Department of the Environment and Local Government	Mr Gerry Flannery	Gerry_flannery@environ.irlgov.ie
Department of the Environment and Local Government	Dr Brian Leech	Brain_leech@environ.irlgov.ie
Department of the Environment and Local Government	Mr Pat Duggan	Pat_duggan@environ.irlgov.ie
Department of the Environment and Local Government	Ms Lisa Clifford	Lisa_clifford@environ.irlgov.ie
Department of the Environment and Local Government	Mr Liam Gleeson	Liam_gleeson@environ.irlgov.ie
Marine Institute	Ms Jacqueline Doyle	Jacqueline.doyle@marine.ie
Fisheries Research Centre	Dr Evin McGovern	

Table B2. Workgroup Contacts (IRELAND) for the EU Common Strategy (WFD).

Project		Lead Country	Contact
2.1	Analysis of Pressures and Impacts	UK and Germany	Dr Conor Clenaghan Environmental Protection Agency PO Box 3000 Johnstown Castle Estate County Wexford Ireland +353-(0)53-606000 c.clenaghan@epa.ie
2.3	Reference conditions for inland surface waters	Sweden	Dr Jim Bowman Environmental Protection Agency Pottery Road Dun Laoghaire County Dublin Ireland +353-(0)1-2852122 j.bowman@epa.ie
2.4	Typology and classification systems for transitional and coastal waters.	UK and Spain	Mr Peter Cunningham Environmental Protection Agency St. Martins's House Waterloo Road Dublin 4 Ireland +353-(0)1-6674474 p.cunningham@epa.ie Dr. Evin McGovern Marine Intsitute Snugboro Road Abbotstown Dublin 15 Ireland +353-(0)1-8228200 evin.mcgovern@marine.ie
2.5	Inter-Calibration Protocol	Commission – Joint Research Centre	Mr Kevin Clabby Environmental Protection Agency Pottery Road Dun Laoghaire County Dublin Ireland +353-(0)1-2852122 k.clabby@epa.ie

Table B2. ***contd.***

Project		Lead Country	Contact
2.6	Economic Analysis	Commission and France	Mr Michael Layde Department of the Environment and Local Government Irish Life Centre Dublin 1 Ireland +353-(0)1-8882000 michael_layde@environ.irlgov.ie
2.8	Assessment and classification of ground water	Austria	Mr Paul Coleman Environmental Protection Agency St. Martin's House Waterloo Road Dublin 4 Ireland +353-(0)1-6674474 p.coleman@epa.ie
4.1	Geographical Information System	Commission – DG JRC-SAI	Mr Peter Britton Local Government Computer Services Board Aras an Chontae Emmet Street Clonmel County Tipperary Ireland +353-(0)52-70024 pbritton@lgcsb.ie

Appendix C

Table C1. A list of websites related to water quality in Ireland. Key to "Content": BM, biomonitoring; CM, catchment management; M, monitoring; Links, links to other sites; WFD, Water Framework Directive; Gen, general content; Health, human health.

Site	Website (precede with: http://)	Description	Content
Irish Char Conservation Group	www.charr.org/news/IFM.htm	Minutes of meetings specifically relating to char conservation	BM
The Shannon Regional Fisheries Board	www.shannon-fishery-board.ie/	Largely angling information, also water quality and CM	BM, CM, M
CFB	www.cfb.ie	Catchment management	CM
Irish Farmers Journal	www.farmersjournal.ie/2001/0623/environment/	Newspaper site; management of catchments by farmers	CM
National Council for Forest Res. and Development	www.coford.ie/	Forestry and related catchment management	CM
Galway Council	www.galway.ie/environment/environ_waste_contents.htm	Waste management plans for the Province of Connaught	CM, M
Loughs Agency for the Foyle Catchment	www.loughs-agency.org/	Management of the Foyle by the Loughs Agency	CM, M
Cork Environmental Forum	www.corkenviroforum.com/min.html	Minutes of meetings on water quality	M
Fluoridation Forum	www.fluoridationforum.ie/forum_reports2.htm	Monitoring of fluoride levels in water	M
Kildare Co. Council	kildare.ie/countycouncil/sanitaryservice/water-monitoring/	Kildare County rural water monitoring scheme	M
L. Conn Task Force and L. Mask Committee	www.iol.ie/~lochanna/	Local council reports and views	M
The Radiological Protection Institute of Ireland	www.rpii.ie/radiation/	Monitoring radiation levels in the environment	M
Three Rivers Project	www.threeriversproject.ie/	EU funded project on the Rivers Boyne, Liffey and Suir	M
Trinity Zoology Department	www.tcd.ie/Zoology/index.html	Internal links to marine and freshwater monitoring studies	M, Links
Western Regional Fisheries Board	www.wrfb.ie/	Monitoring of fish	M, WFD
British Hydrological Society	ewre.cv.ic.ac.uk/bhs/BHS_Meetings.html	British site containing reports relating to Ireland as well	Gen
Centre for the Environment	www.tcd.ie/Centre_for_the_Environment/index.html	TCD-based website, contains many links to other sites	Gen, Links
Citizens Information Database	www.cidb.ie/live.nsf/WEBIndex	Index of information under Freedom of Information Act	Gen
Compass Informatics	www.compass.ie/projects/main.html	Associated with EPA, some current projects listed	Gen
Dúchas	www.heritagedata.ie/index.html	Interactive sites (needs GIS software)	Gen
ENFO (Information on the Environment	www.enfo.ie/	Information for the public on the environment	Gen
Environment Daily	www.environmentdaily.com/articles/	Current news relating to environmental issues	Gen
EU in Ireland	www.euireland.ie/news/environment/0101/waterpol.htm	Commission reports on water quality in Ireland	Gen
Heritage Council	www.heritagecouncil.ie	Document on the Future of Irelands Inland Waterways	Gen
Inland Waterways Association of Ireland	www.iwai.ie	Lots of internal links	Gen
Irish Government Home Site	www.irlgov.ie	Starting Point for general information	Gen
Marine Institute	www.marine.ie/datacentre/projects/databuoy	Off-shore weather information	Gen
Parliament of Ireland	irlgov.ie/debates-00/s20june/sect3.htm	Synopses of debates held in the Irish Parliament	Gen
Teagasc	www.teagasc.org/publications/agrifood1999/paper10.htm	Balancing agricultural needs with environmental protection	Gen
EPA	www.epa.ie	Lots of links within the EPA site	Gen, WFD
Irish Government Site	www.environ.ie/planning/water.html	Lots of internal and external links: also WFD	Gen, WFD
The Institution of Engineers of Ireland	www.iei.ie/journal/dec2000/waterways.html	Engineering website with reference to WFD	Gen, WFD
Geological Survey of Ireland	www.gsi.ie	General data; no groundwater information as yet	Gen, WFD, M
City Analysts Ltd.	www.cityanalysts.ie/	Private firm: health issues concerning waste in water supplies	Health

Table C2. A list of websites related to water quality in Europe. Key to "Content": BM, biomonitoring; CM, Catchment Management; M, monitoring; Links links to other sites; WFD, Water Framework Directive; Gen, general content; Health, human health.

Site	Website (precede with: http://)	Description	Content
Earthwatch Institute	www.earthwatch.org/expeditions/harper/harper_proj.html	Management of the Kenyan Rift Valley Lakes	CM
EU Life-environment project	www.floodplains.org/	Use of floodplains in catchment management	CM
Finnish Government Site	www.vyh.fi/eng/research/euproj/eurolake/eurolake.htm	Information on lakes in Finland, also go to homepage for more links	CM
Integrated catchment model for River Zala, Hungary	www.vituki.hu/publikacio/zalacikk/zalacikk_eng.htm	Excellent description of the development of a model	CM
Internat. Ins. for Environment and Development	www.iied.org/agri/gatekeepers/gk81.html	Participatory Watershed Research and Management	CM
The Ramsar Convention on Wetlands	www.ramsar.org/	Wetlands and catchment management, links to articles internally	CM
The Countryside Agency, UK	www.countryside.gov.uk/cci/yorkshirehumber/041.htm	Management of the Humber Estuary in Yorkshire, UK	CM
The World Conservation Union	www.iucn.org/biodiversityday/costs.html	Catchment management and introduced species	CM
UK Biodiversity	www.ukbap.org.uk/plans/habitats/NBNSYS0000004627.htm	Case study of aquifer-fed naturally fluctuating water bodies	CM
United Nations Environment Programme	maestro.unep.or.jp/ietc/Activities/Freshwater/Index.asp	Small amount on management of water bodies, but might expand	CM
Forest Conservation Portal	forests.org/	Links to articles on catchment management (mostly forestry)	CM, Links
Australian Conservation Foundation	www.acfonline.org.au/asp/pages/policy.asp	Australia's policies on water management	Gen
Coastal Guide	www.coastalguide.org/news/2001-02.html	Information on coastal aspects	Gen
Convention on Biological Diversity (Belgium)	www.kbinirsnb.be/bch-cbd/belgium/services/experts/inlandwaters.htm	Belgian experts on freshwater biodiversity and contact addresses	Gen
Economically Viable Alternative Green	www.altgreen.com.au/Water	Lots of reports relating to water quality in Australia	Gen
Energy, Environment and Sustainable Development	www.cordis.lu/eesd/ka1/policies.htm	Articles on water quality in Europe	Gen
EU Nature Conservation Policy and Legislation	www.ecnc.nl/doc/europe/legislat/conveu.html	Full electronic copy of the EU Nature Conservation policy	Gen
European Inland Fisheries Advisory Commission	www.fao.org/fi/body/eifac/excom/excom01.asp	Summary Record of the Meeting of the Executive Committee	Gen
Geoplace: for geospatial information	www.geoplace.com/ge/2001/0401/0401ir.asp	Geospatial information, this page has information for Ireland	Gen
Global Environment Outlook 2000	www.rolac.unep.mx/geo2000/ENGLISH/0078.htm	Information on water resources in Europe and the world	Gen
Institution of Civil Engineers	www.icenet.org.uk/	Reports on engineering solution to water management	Gen
International Chamber of Commerce	www.iccwbo.org/home/statements_rules/statements/1998/final_water.asp	Industry and freshwater	Gen
Institute for Coastal Research	coast.gkss.de/themen/anthro/topics.html	Reports of projects on coastal water quality	Gen
Northern Ireland Assembly	www.ni-assembly.gov.uk/culture/report1-00r.htm	Inquiry into inland fisheries	Gen
The Australian Academy Of Technological Sci. and Eng.	www.atse.org.au/_vti_bin/shtml.dll/search.htm	List of transcripts re. water management, use search for more	Gen
UK Dept for Environment, Food & Rural Affairs	www.defra.gov.uk/environment/bw/index.htm	Info on UK Inland Waterways, also go to homepage for more	Gen
University of Ulster, Freshwater Group	www.science.ulst.ac.uk/freshwater/buffer.html	Page describing the SU Funded Buffer Project	Gen
EU Joint Research Council	www.jrc.es/pages/projects/water.html	Reports on use of water and CM	Gen, CM

Table C2. ***contd.***

Site	Website (precede with: http://)	Description	Content
AQEM project, part of 5th Framework Program	www.aqem.de/	Internal and external links to sites with info on EU countries	Gen, Links
Environmental Programme for the Danube River Basin	www.rec.org/DanubePCU/	Lots of links to information on the River Danube	Gen, Links
RIZA – Institute for Inland Water Management	www.minvenw.nl/rws/riza/home/publicaties/nieuwsbrieven/jaarverslag2000/annual_report2000-1.html	Dutch site, reports on water quality, also go to RIZA homepage	Gen, M
Scottish EPA	www.sepa.org.uk/publications/index.htm	Articles, links and reports	Gen, WFD, Links
Unilever Industry Website	www.unilever.com/environmentsociety/casestudieslinks/casestudies	Lots of links to case studies and research	M
European Union	europa.eu.int/comm/environment/water/index.html	Official EU site for WFD	WFD
University of Finland	www.helsinki.fi/science/ecru/EMERGE.html	Research group working on WFD, lots of links to other research groups	WFD
WWF	www.panda.org/europe/freshwater/initiatives/wfd.html	Lots of articles and links on water quality and WFD	WFD, Links

Table C3. A list of websites related to water quality in the Rest of the World. Key to "Content": BM, biomonitoring; CM, Catchment Management; M, monitoring; Links, links to other sites; WFD, Water Framework Directive; Gen, general content; Health, human health; Models, downloadable models for application to water quality data.

Site	Website (precede with: http://)	Description	Content
International Potash Institute	www.ipipotash.org/	How to achieve a balance in the use of fertilisers	CM
European Union Site	www.europa.eu.int/comm/environment/water/index.html	EU site for water quality information	Gen
European Water Association	www.ewaonline.de	Current projects and downloadable publications	Gen
National Institute for Environmental Studies, Japan	www.nies.go.jp/	Look under "projects" at bottom for current activities in East Asia	Gen
Canadian Environmental Management System	www.ec.gc.ca/emsinfo/home_e.htm	Good starting point for access to info on Canada, also check "links" page	Gen, Links
International Water Management Institute	www.cgiar.org/iwmi/	Links to projects in different countries	Gen, Links
Santa Clara Valley Water District, CA, USA	www.scvwd.dst.ca.us/otherlnk/index.htm	Very good search engine for water-related sites in the US and abroad	Gen, Links
The World Hydrological Cycle Observing System (WHYCOS)	www.wmo.ch/web/homs/whycos.html	Map of world with links to projects	Gen, Links
US EPA Office of Water	www.epa.gov/ow/region.html	Excellent site. Links to sites in every region and state in the US re water	Gen, Links
Water Environment Federation	www.wef.org/MemberAssoc/MAWebSites/index.jhtml#Asia	Lots of links to associated sites in Asia, Pacific, America and Europe	Gen, Links
Portage County Groundwater	www.uwsp.edu/water/portage/manage/goals.htm	Groundwater management in Wisconsin, USA	GW
Texas Water Info Site	www.txwin.net/Monitoring/GW/Groundwater.htm	Groundwater and Monitoring in Texas	GW, M
Manitoba Conservation, Canada	www.gov.mb.ca/natres/watres/groundwater.html	Site also covers surface water	GW, SW, CM
Japanese Information Network	jin.jcic.or.jp/stat/category_19.html	Statistics for water quality in Japan, updated regularly	M
Boss International, Hydrology Software	www.bossintl.com/	Download models for dealing with limnological data, some are free	Models

Table C4. A list of European websites on biomonitoring.

Site	Website (precede with: http://)	Brief Description	Contact Address
INRA Institut National de la Recherche Agronomique	www.invfmr.org/default.htm	Benthic Invertebrates described.	
Lakenet	www.worldlakes.org/default.htm	A global network promoting conservation of lakes.	info@worldlakes.org.
Department for Environment, Food and Rural Affairs	www.defra.gov.uk/environment/wqd/guide/water.htm	Management, protection and enhancement of water quality.	wq_enquiries@defra.gsi.gov.uk
Environment Agency (UK)	www.environment-agency.gov.uk	Water conservation and demand.	paula.wood@environment-agency.gov.uk
European Environment Agency	reports.eea.eu.int/87-90198-01-8/en	Assessment of European rivers and lakes.	
Scottish Environmental Indicator Series (SEPA)	www.sepa.org.uk/indicators/index.htm	Use of indicators to assess water quality.	
Austrian Federal Environmental Agency	www.ubavie.gv.at/umweltsituation/wasser/karten/biokart1/toc.htm	Reports on the biological water quality of Austrian rivers.	
The Federal Environmental Protection Agency, Germany	www.umweltbundesamt.de/dux-e/wa-inf.htm	The seven step water quality classification system using biological indicators.	
Finnish Environment Agency	www.vyh.fi/eng/orginfo/publica/electro/fe445/fe4451.pdf	Finnish water resources and monitoring strategies	Jorma.Niemi@vyh.fi
Karelian Institute, Finland	www.joensuu.fi/ktl/ekologia/projekti/pj-ps_se.pdf	Biomonitoring projects for Lake Phyaselka.	Anna-liisa.holopainen@joensuu.fi
University of Helsinki – Limnology	www.helsinki.fi/~risco/prosem.htm	The use of diatoms indices to evaluate water in Helsinki.	
Cemagref, Lyon	www.lyon.cemagref.fr/lyon/bea/dsa/BIBLIO.html	List of relevant publications for the Laboratory of Water System Diagnosis.	
Dr Stephane Charvet	members.aol.com/charvetscc/Publications/publications.htm	Biological methods to evaluate water quality.	
General Ecology and Limnology Symposia	www.uni-koeln.de/math-nat-fak/zoologie/oekologie/abstracts.htm	Summary of oral presentations.	Hartmut.Arndt@uni-koeln.de
Prague Environment 1998	www.monet.cz/zp/envi98/ak_021.htm	Water quality evaluation.	
The Danube Dam Group	www.ace.hu/danube_dg/szakert/anyagok/meszaros96/e7ferisu.htm	Biomonitoring of the Danube Dam.	buczko@ella.hu

Table C5. A list of websites from the Rest of the World on biomonitoring.

Site	Website (precede with: http://)	Brief Description	Contact Address
US Environmental Protection Agency	www.epa.gov/ow/region.html	Link to every region in the US.	
Department of Environmental Quality, Oregon State	www.deq.state.or.us/lab/Biomon/biomon.htm	Biological monitoring carried out for the DEQ.	labweb@deq.state.or.us
United States Environmental Protection Agency	www.epa.gov/bioindicators/	Why and how biological organisms are used for the analysis of US water systems.	davis.wayne@epa.gov
Northern Virginia Soil and Water Conservation District (NVSWCD)	mason.gmu.edu/~jarcisze/StreamMonitoring/	Introduction to biomonitoring.	avia@osf1.gmu.edu
US Department of the Interior	water.usgs.gov/nawqa/protocols/OFR-93-406/inv1.html	Methods for the collection of benthic invertebrates as part of the national quality assessment program.	
EnviroScience, Inc. Biomonitoring Specialists	www.enviroscienceinc.com/aquasurvey.htm	Provision of high quality environmental services, including monitoring of aquatic invertebrates.	mail@enviroscienceinc.com
Allied Biological	www.morriscanal.com/abi/aquatic1.html	Fully equipped laboratory for carrying water quality surveys.	
Aquatic Biology Associates, Inc.	www.aquaticbio.com/	An independent laboratory specialising in the analysis of benthic invertebrates.	mjwevers@aquaticbio.com
Freshwater Biological Association	www.fba.org.uk/rivpacs.html	Summary and Contents of book dealing with the assessment of the biological quality of freshwaters.	
The Great Lakes Water Quality Program, Canada	res2.agr.ca/london/env_prog/glwq/glwq1.html	Protocol for the monitoring and assessment of water quality in agricultural streams.	
Department of Biology, UPM, Malaysia	www.fsas.upm.edu.my/~arahim/freshwat/watquality.html	Water quality and water pollution assessment on the river Lopo.	arahim@fsas.upm.edu.my
Walton Hall Nature Trail	www.open.ac.uk/Nature_Trail/R_qual.htm	Water quality on the River Ouzel.	M.E.Dodd@open.ac.uk
Rivers Online	rol.freenet.columbus.oh.us/measure.html	Promotion of student participation in river monitoring programs.	sgordon@freenet.columbus.oh.us
United Nations Environment Programme GEMS/Water	bordeaux.uwaterloo.ca/biology447/modules/module1/gems/overview.htm	Biomonitoring for the Global Environment Monitoring System.	
S.M. Mandaville (Professional Lake Manager)	www.chebucto.ns.ca/Science/SWCS/ZOOBENTH/biotic.html	Biotic indices.	Limnos@chebucto.ns.ca
Netcoast Open Learner IHE DELFT	www.ihe.nl/we/dicea/monitor/biolo.htm	Biological monitoring of coastal regions.	hjv@ihe.nl
The Royal Society of New Zealand	www.rsnz.govt.nz/publish/nzjmfr/1998/4.php	Stark – freshwater invertebrate biotic indices.	ceo@rsnz.govt.nz
The Institute of Entomology, Academy of Science, Czech Republic	www.entu.cas.cz/plan.html	Biomonitoring project for water systems in Central Europe.	

Table C5. ***contd.***

Site	Website (precede with: http://)	Brief Description	Contact Address
The National Newsletter of Volunteer Water Quality Monitoring	library.marist.edu/diglib/envsci/archives/phytozoo/hicks/hicks-bioassessment.html	Wetland bioassessment and methods to be used.	ahicks@umext.umass.edu
ENSR International	www.ensr.com/services/risk/default.htm	Environmental Risk Assessments.	
DEB Research	www.hku.hk/ecology/porcupine/por18/research.htm	Measuring pollution in Hong Kong's rivers.	ecology@hkucc.hku.hk
UniSci – University of Florida	unisci.com/stories/20004/1002005.htm	Newfound snails may be clue to water quality.	ckeen@ufl.edu
New Zealand Limnological Society	www.rsnz.govt.nz/clan/limsoc/limsoc%20news.htm	Notes on the recent research of its members	

Appendix D

1. Preparation
   Is the present framework for water resource management in your country similar or different to that required by the EU Water Framework Directive (WFD)? Will implementation of the Directive present any major difficulties for the government and/or authorities responsible for water management? Please specify or list those difficulties.

2. Article 5
   Will the analyses and reviews required under Article 5 be based on existing information or will it be necessary to collect additional information (from surveys, etc.) before these tasks can begin?

3. Article 8
   (a) Is it possible that in your country monitoring for purposes of the Directive can be undertaken without a significant increase in the resources (human, technical, financial) currently allocated to monitoring the aquatic environment?

   (b) Additional question: Will the identification of surface water body types as specified in Annex II follow a system A or B for each of the named water categories (Rivers, Lakes, Transitional waters, Coastal waters).

4. Articles 3 and 13
   Do River Basin Districts for purposes of water management already exist in your country? If so, do management plans for these districts, consistent with Article 13 of the Directive, already exist?

5. Institutional arrangements
   Does your country already have suitable agencies to administer the Directive, and to co-ordinate the scientific work involved (e.g. assessing ecological status, monitoring, etc.), or will there be a need for new institutional arrangements? Has the Competent Authority been identified?

6. Timetable
   Are any particular difficulties expected in meeting the timetable for the various intermediate stages of compliance with the Directive, i.e. analyses and review (4 years), monitoring (6 years) and management plans (9 years)?

Table D1.

	Austria	Germany	Greece	Netherlands	Denmark	Sweden	Wales	UK	Northern Ireland
Is the present framework for water resource management in your country similar or different to that required by the EU Water Framework Directive (WFD)?	Similar.	Different: No ecological evaluation.	Similar: Need improvement in environmental objectives.	Similar.	Similar.	Different: Management does not follow run-off areas.	Similar.	Similar.	Only partially meets the WFD needs.
Will implementation of the Directive present any major difficulties for the government and/or authorities responsible for water management?	Yes: Financial.	Yes: Currently managed politically independent of catchment.	Yes: Economic dimension in particular.		Yes: River basin approach may require administrative arrangements.	Yes: There is no water authority.	Not able to predict difficulties.	Major task.	Major practical difficulties.
Will the analyses and reviews required under Article 5 be based on existing "information or will it be necessary to collect additional information (from surveys, etc.) before these tasks can begin?	Additional information required.	No or only partly (i.e. economic analysis).	Additional information required.	Primarily based on existing information. Additional information required for economic analysis.	Primarily based on existing information. Additional information required for economic analysis.	Additional information required.	Additional information required and collation of existing data.	A UK/Germany project is examining this.	Needs to be addressed.
Is it possible that in your country monitoring for purposes of the Directive can be undertaken without a significant increase in the resources (human, technical, financial) currently allocated to monitoring the aquatic environment?	Extra resources needed for some aspects.	Not possible.	Current programmes need to be extended and additional programmes established.	Current programmes should suffice. Ecological aspects may require more detailed/extra surveys.	Yes.	Not possible.	Too early to say.	Additional monitoring capacity will be required.	Additional resources required.
Will the identification of Surface Water Body Types follow System A or B for each of the categories (Rivers, Lakes, Transitional Waters, Coastal Waters)?	No transitional waters. Still undecided.	Mixture of both for lakes.	Undecided.	B	B	B	B	B	B
Do River Basin Districts for purposes of water management already exist in your country? If so do management plans for these districts consistent with Article 13 of the Directive also exist?	No.	No.	RBDs identified, plans exist for some. Improvements and more plans required.	Four districts identified. No plans to date.	No.	No.	RBDs proposed.	No, but have good building blocks.	Under discussion with RoI. Some plans exist which are being revised.

Table D1. ***contd.***

	Austria	Germany	Greece	Netherlands	Denmark	Sweden	Wales	UK	Northern Ireland
Does your country already have suitable agencies to administer the Directive and to co-ordinate the scientific work involved (e.g. assessing ecological status monitoring, etc.) or will there be a need for new institutional arrangements?	Yes. No new arrangements required.	?	Yes, but a government water agency has to be created.	Yes.	Yes.	Existing authorities will be re-arranged.	?	Yes.	Yes.
Have Competent Authorities (Article 3 (2)) been identified?	Yes.			Yes.	Undecided.	Yes.	Possibly the Environment Agency.	No.	?
Are any particular difficulties expected in meeting the timetable for the various intermediate stages of compliance with the Directive i.e. analyses and review (4 years) monitoring (6 years) and management plans (9 years)?	No.	Main difficulties with phytoplankton frequencies.	Some problems.	No.	No.	Yes.	Too early to say.	Too early to say.	Too early to say.

Appendix E

Summary points collated from Water Quality Management Plans produced under the Water Pollution (1977) Act. Water Quality Management Plan for Bantry Bay. Main Report. John B. Barry & Partners, Irish Hydrodata Ltd and Reid McHugh & Partners. April 1988.

Objectives	Background Information	Background Information	Water Quality
• Identification of existing conditions in relation to water quality. • Identification of existing beneficial uses. • Identification of future needs and developments. • Setting of water quality standards required to optimise the orderly development of the bay.	• Historical background. • Bathymetry and topography. • Tides and water-level changes. • Wind and wave climate. • Tidal streams. • Meteorological conditions. • Freshwater inflow. • Description of catchment area including geology (mapped) industry and population centres. • Summary of previous study data and conclusions drawn from it. • Population changes and projections. • Predicted developments for fishing, mariculture, industry, shipping recreation and tourism.	**Existing uses:** mariculture and fishing (figures for annual catches and distribution maps for species provided), waste disposal, commercial shipping, recreation and tourism. In addition to a full review of available data the following were carried out: • Installation of an automatic weather station and tide gauge. • Recording Current meter deployments (mapped). • Water quality observations. • Co-ordination of a survey reference grid. • Tidal excursion drogue tracking (location mapped). • Dye dispersion and advection experiments (location mapped). • Fixed location water column profiling. • Plankton monitoring. • Continuous dye release. • Use of tidal dynamics models and dispersion models and summarised results.	• Sampling sites listed and mapped (T, salinity, pH, BOD, DO, SS, orthophosphate, nitrate nitrogen, ammonia nitrogen, metals and microbiology). • Summary of bay circulations and water exchange patterns and their implications. • Classification of shellfish waters in Bantry Bay as 'Conditional' (based on US National Shellfish Sanitation Programme). • Existing town effluents.
Recommendations	**Recommendations**	**Recommendations**	**Recommendations**
• All bathing waters to conform to DELG national limit values, necessitating the relocation of Bantry Town sewer outfall. • No discharges from industries of substances on the EC Dangerous Substances 'Black List', and strict control on grey list' substances.	• Proposed developments, which would discharge effluent, should be preceded by studies to predict effect on the bay waters of these discharges. • Data storage in a central agency so a database may be established in a co-ordinated way. • Confine aquaculture to upper bay area. • Draw up a comprehensive oil spill contingency plan in the event of re-opening of Whiddy terminal.	• Establish Harbour Authority with power to levy harbour dues and responsibilities to control shipping movements in the bay. • Upgrade tourist/recreation facilities including roads, caravan sites, signposting, etc., especially for active recreation and specialist holidays.	• Research into further development of fishing/mariculture industries. • Implementation of Costello Report recommendations if Whiddy Terminal is re-opened. • Similar effluent controls for rivers feeding into the bay. • Five-year review of plan.

Water Quality Management Plan for the River Barrow Catchment. Laois, Offaly, Kildare, Carlow, Kilkenny, Wicklow and Wexford County Councils. June 1985.

Objectives	Background Information	Present Water Quality	Water Quality Criteria and Standards
Overall objective to ensure, in the future, an acceptable quality of water for specific uses at the time and place where it is needed. • Ensure water quality is maintained in a satisfactory condition and where necessary improved, thereby: • Safeguarding public health. • Catering for increasing abstractions. • Catering for needs of commercial game fisheries. • Catering for water-based amenities and recreational requirements.	• Map and description of catchment. • Isohyetal map. • Table of estimated 95 percentile and dry weather flows at selected towns. • Description of main aquifers. • Population and projected population. • Summary of agricultural activity and industrial (present and future) activity. • Beneficial uses: Abstractions, fisheries (salmon, brown trout and coarse fish, sea trout, eels, shellfish), navigation, livestock watering, amenity and recreation.	• pH, colour and hardness min, med and max values for summer and winter 1978–80. • 83% of channel length is class A (unpolluted). • Chemical analysis: DO, BOD, ammonia, orthophosphate and oxidised nitrogen. Min, med and max values for summer and winter at 14 sections. • Summary of water quality data for the estuary and tributaries.	• Based on water quality criteria for salmonid fisheries. • Recommended DO, BOD, ammonia, oxidised nitrogen and orthophosphate standards at different percentile limits. • Recommended use of 7-day low flow criterion instead of 95 percentile. • Calculations for theoretical (BOD) waste assimilation capacity at 15 locations. • Estimated existing and future waste loads (mostly organic biodegradable) with figures for generated and discharged loads at population centres.
Water Quality Criteria and Standards	**Recommendations**	**Recommendations**	**Recommendations**
• Current and future predicted abstractions. • Effluent treatment considerations including a series of tables showing the results of calculations of the effects on BOD concentrations, and on residual waste assimilation capacities, of subjecting present waste loads (domestic and industrial) to various combinations of waste treatment at various locations. • Similar tables for future waste loads. • Summary of estimated treatment costs. • Summary of recommended waste treatment at 15 locations	• Intend to provide as a minimum preliminary and primary treatment for all wastes generated. • Primary treatment removing 40% BOD, secondary 80% and tertiary 95%. • Discharge of wastes in a uniform manner in respect of volume and strength, therefore requiring the provision of balancing facilities at treatment plants. • Properly designed outfall diffuser systems to minimise mixing zones. • Combined treatment of domestic and industrial waste.	• Examination of locations where agricultural wastes are produced in significant quantities, and present arrangements for their disposal. • Exercise control over groundwater quality, and to make a complete inventory of groundwater resources in the catchment. • Summary of stretches requiring improvements in water quality and measures necessary. • Cost of reducing waste loads. • Recommendations for future river gauging. • Detailed industrial effluent surveys at each factory to determine generated and discharged waste loads.	• Increased intensity of water quality monitoring to fortnightly at 15-day intervals, plus every 24 hours during low flows in important reaches. • Expand database of levels of potentially toxic substances. • Extra water quality data for ground waters. • Assessment of threat from non-point sources. • More detailed information on distribution of fish stocks. • Research topics. • Evaluation of economic aspects of water quality management

Water Quality Management Plan River Deel. Limerick County Council. February 1990.

Objectives	Background Information	Water Quality	Water Quality
Ensure water quality is maintained in a satisfactory condition and where necessary improved, thereby: • Safeguarding public health. • Catering for the abstraction of water for domestic, industrial and agricultural purposes. • Catering for the needs of fisheries resources. • Catering for water-based amenities and recreational requirements. • Identify control measures necessary for the satisfactory treatment and disposal of existing and future sewage and industrial effluent discharges. • Identify priorities for investment in public and private wastewater treatment facilities. • Proper control of agricultural activities to prevent waste charges to watercourses.	• Catchment description. • Rainfall data and locations of the five autographic recorders in the catchment. • Estimation of dry weather flows and discharges at various stations. • Population and industrial distribution. • Map and location of sampling stations. • Isohyetal and contour map. • Stage recording sites and OPW weirs map. • Map of catchment geology. • Beneficial uses: • Abstractions (map and location of sources surface and ground waters), angling, fisheries, waste assimilation, hydroelectricity, recreation and amenity and livestock watering.	• General characteristics (pH and hardness). • Q ratings for 1980 and 1986 showing a decrease in unpolluted channel length and increase in slightly polluted. • Q ratings from various locations from biological surveys in 1984, 1986 and 1987. • Tables of 1986/87 physico–chemical assessment results for BOD, NH, TON, phosphates and DO for various stations. • Breakdown of phosphorus loading from all sources in the catchment, showing main cause to be agricultural wastes (52% of total). • Satisfactory DO levels for salmonid and spawning water. • TON well below recommended values. • Map of river water quality (Class A, B and C)	• Water Quality Criteria for salmonids to be adopted to protect beneficial uses. • Site-specific controls where abstractions for drinking water occur. • Recommended standards for DO, BOD, ammonia, oxidised nitrogen and orthophosphate. • Table of water quality criteria, standards and guidelines issued by various agencies for three types of water use. Values shown are max permitted. • Calculation of theoretical waste assimilation capacities at seven locations. • Summary of population figures for 1986 and the type of effluent plants. • Summary of waste loads generated in catchment. • Identification of agricultural wastes responsible for pollution.
Recommendations	**Recommendations**	**Recommendations**	
• Twice yearly biological and microbiological survey. • Monthly physico–chemical survey and once a year at low flow. • Provision of accurate gauges at key locations. • Point sources.	• Non-point sources • Re-stocking of fish in river Deel. Balancing measures in treatment to ensure uniformity of discharges.	• Combined treatment • Inventory of groundwater sources and assessment of likelihood of contamination by point and non-point sources.	

Water Quality Management Plan for the River Liffey Catchment. Dublin Corporation, Dublin County Council, Kildare County Council, Wicklow County Council and Meath County Council.

Objectives	Background Information	Water Quality	Water Quality
• Ensure that the microbiological, chemical and physical quality of the water at Pollaphouca and Leixlip is not impaired, but maintained to the highest practicable level.	• Identification of catchment area and tributaries (OS Map). • Catchment resources identified. • Flow information. • Population, industry and land use. • Beneficial uses: abstractions, fisheries, HEP, pollution abatement, recreation and amenity (salmon fishing, water sports), areas of scientific interest.	• Available data on water quality (biological monitoring from 1991 and chemical from 1987–1990). • Standards based on quality criteria for salmonid-bearing waters. • Waters for abstractions for drinking water to have standards based on EC Quality of Surface Waters Regulations. • Five parameters selected: DO, BOD_5, ammonia, oxidised nitrogen, orthophosphate/TP. • Waste assimilation capacity. • Summary of point source and diffuse pollution.	• Scenario of future domestic waste load generation • Division of the catchment into three regions: Upper Liffey (above Pollaphouca Dam), Middle Liffey, (Pollaphouca to Leixlip Dam) and Lower Liffey (downstream of Leixlip). • Background information for each section and recommendations for management. • Additional considerations.
Recommendations	**Recommendations**	**Additional Considerations**	
• Surveillance and monitoring of areas identified as having a potential for pollution. • Application of ‘Catchment Quality Control’. • Inspection work of smaller drainage channels for litter, sewage fungus, dumped slurry, etc. (especially used pesticide containers). • Routine chemical monitoring (no frequency given). • Secondary treatment for all significant discharges. • Minimise impact of discharges by use of properly designed mixing ones below outfalls. • Increased monitoring frequency.	• Combined treatment and discharge of domestic and industrial waste. • Detailed examination of locations where agricultural wastes are produced in significant amounts. • Further research into fisheries resources, waste loads, non-point sources of waste, accidental discharges. • Additional data on groundwater quantity and quality, and interaction of surface water and ground water.	• Cease developments and slurry spreading in Upper Liffey • Improvements in sewage and effluent treatment. • Baseline survey of fisheries. • Regular water quality monitoring programme to be carried out by LA. • Development of mathematical models. • Monitoring of ground and surface waters adjacent to landfills.	

Water Quality Management Plan for the River Moy. Synopsis. Mayo County Council 1992.

Objectives	Background Information	Water Quality	Water Quality
Assure that the quality of the Moy catchment waters is maintained to satisfactory standards and where necessary improved to these standards thereby: • Safeguarding public health. • Catering for increasing abstraction. • Catering for commercial and recreational fishing, amenities and recreation. • Catering for disposal and treatment of effluent (sewage and industrial).	• Map of catchment. • Lengths of main tributaries. • Populations and projected populations. • Identification of beneficial uses, (abstractions, sport and commercial fisheries, controlled waste disposal, recreation and amenity). • Table of discharges and types of treatment. • Flow parameters at key locations	• Table of river status as unpolluted, slightly polluted or seriously polluted. • Trophic status of Lough Conn and Lough Cullin. • Standards for rivers in Moy catchment (based on salmonid standards), and flow parameters at which they apply. • Calculation of waste assimilative capacity at key locations.	• Identification of problem areas and recommendations for solution. • Cost of improvements for these problem areas. • Summary of costs and necessary works in urban centres to ensure future developments do not affect water quality.
Recommendations	**Recommendations**	**Comments**	
• Standards set are accepted as controls for Moy catchment. • Remedial works to begin as soon as possible. • Monitoring programme continue at present level and lake monitoring begin as soon as possible. • Hydrometric gauging stations be installed upstream of all discharges from effluent treatment plants. • Implement necessary works recommended to prevent future deteriorations in water quality. • Installation of flow measuring equipment on effluent discharge pipes and major discharges to sewers.	• Initiation of education programme for farmers on the dangers of pollution from agricultural wastes. • Consideration given to improving inter-jurisdictional exchange of water-related information in Moy catchment. • Survey for organic micropollutants at all key locations	• No mention of ecology or heritage in objectives • Some economic evaluation • No monitoring frequencies • No mention of public consultation	

Water Quality Management Plan for the River Nore Catchment. Kilkenny County Council, Laois County Council, Tipperary (NR) County Council, Tipperary (SR) County Council and Carlow County Council June 1985

Objectives	Background Information	Water Quality	Water Quality
Ensure water quality is maintained in a satisfactory condition and where necessary improved, thereby: • Safeguarding public health. • Catering for increasing abstractions. • Catering for needs of commercial game fisheries. • Catering for water based amenities and recreational requirements.	• Catchment description and map. • Map and description of rainfall gauging stations and estimation of river flow and run-off. • Table of estimated dry weather flows and 95 percentile flows. • Hydrogeology and identification of aquifers. • Populations and projections. • Agricultural and Industrial activity identified (including future development). **Beneficial Uses (detailed report available in volume 4):** • Abstractions (industrial and domestic), salmonid, eel and shellfish fisheries (monetary value for each tabled), and tourism and recreation.	• Existing quality at selected stations: • General (pH, colour and hardness) for summer and winter, with graphic summary of median variations. • Chemical (DO, BOD, ammonia, orthophosphate, oxidised nitrogen) for summer and winter. • Biological (Q ratings). • % river length classes as unpolluted, slight to moderate and heavy to gross (tabled). • Water quality criteria for salmonid waters to be adopted with special consideration of microbiology irrelevant areas (bathing waters, shell fishery, etc.). • Percentile limits recommended for DO, BOD, ammonia, nitrate and orthophosphate.	• Waste assimilation capacity tabled for 13 locations. • Estimate of generated, discharged and future waste loads at population centres. • Current and future abstractions. • Need for improved effluent control in some stretches. • Present situation and future projection calculated for these areas. • Cost of waste load reductions • Plan to be reviewed at least every 5 years.
Recommendations	**Recommendations**	**Recommendations**	
• Additional gauging stations. • Collection of data on groundwater, especially monitoring of variations in level in aquifers. • Investigate feasibility of increased collection of rainfall data, especially at high altitudes. • Summary of recommendations for waste treatment • Detailed industrial effluent surveys at each factory to determine waste load generated and discharged.	• Increased intensity of monitoring (fortnightly/25 times per annum). • 24-hour surveys at important reaches during summer low flows. • Effluent discharges sampled at 15-day intervals not 14. • Expand database of toxic substances. • Assessment of potential threat from non-point sources	• More detailed information on distribution of fish stocks. • Research topics (modelling of dynamic processes such as DO variations at low flow, economic aspects of water quality management, investigation of groundwater resources)	

The Shannon Estuary. A Model for Water Quality Management. Summary Report. L. Stapleton and B. Mulligan. Water Resources Division, An Foras Forbartha April 1980.

Objectives	Background Information	Water Quality	Water Quality
• Assess the existing 'baseline' conditions of water quality in the estuary, particularly in respect of the dissolved oxygen regime. • Carry out field investigations of the dispersal characteristics of the estuary. • On the basis of filed investigations, to select, develop and test a suitable mathematical model for water quality predictions in the estuary.	• Summary and map of general features of the estuary (location, geology, population). • Tides and table of tidal levels on spring and neap tides. • Salinity. • Beneficial uses: navigation, waste disposal, fisheries (quantity and value given) and recreation. • The River Shannon and tributaries: flows, flow frequencies, location of gauging stations (mapped). • Description and location of industries (Tarbert generating station, Money Point, Aughinish Alumina).	• Calculation of present and future estimated BOD load per person discharged. • Waste effluent discharge from Shannon town (1978). • Table of discharges of water after use by public bodies and after use by industry and others. • Introduction to mathematical modelling of estuarine water quality. • Results of water quality surveys from 1971/72, 1975/76 and 1977/78. • Location of sampling stations (mapped). • Flow, tidal and salinity data from 1977 investigations. • BOD, DO, temperature, ammonia and chlorophyll *a* results for 1977.	• 1978 river water quality results for DO, temperature, BOD, ammonia, pH, phosphate, TP, nitrate and nitrite and chlorophyll *a*. • 1978 estuarine water quality results for salinity, DO, temperature, BOD, Ammonia, pH, P, TP, nitrate and nitrite and chlorophyll *a* (main sampling stations and estuarine traverse). • 1978 turbidity results. • Dye survey to ascertain circulation and dispersion characteristics of the estuary (methods and results). • Tidal dynamics model, mass transfer model, and application of these models to the Shannon Estuary.
Water Quality	Recommendations	Recommendations	
• Mostly satisfactory except downstream of Limerick and the Upper Fergus Estuary. • Good mixing conditions.	• Future major effluent outfalls should discharge to main estuarine channel and have well-designed diffuser system. • Intensive monitoring every 2/3 years of water quality and waste effluent discharges. • Special study of DO regime, benthic fauna and weed growth. • Further study of nutrient enrichment in rivers discharging to the estuary.	• Use of mathematical model as a basic planning tool, especially in the assessment of waste effluent discharges and the interpretation of monitoring results. • Regular refining and update of model. • Develop and implement water quality management plan at earliest practicable date.	

Water Quality Management Plan for the Suir Barrow Nore Estuary. Carlow County Council, Kilkenny County Council., Tipperary SR County Council, Waterford Corporation, Wexford County Council May 1990.

Objectives	Objectives	Background Information	Water Quality
Ensure the quality of the waters is maintained in a satisfactory condition, and if necessary improved to achieve the following objectives: • Safeguard public health. • Protect and promote fisheries. • Protect and promote mariculture. • Prevent objectionable odours and visual offence. • Protect and promote recreational uses. • Determine assimilation capacity for sewage, industrial effluents and other inputs. • Facilitate urban and industrial development by ensuring the assimilation capacity is quantified and adequate reserve capacity exists for future developments.	• Meet the requirements of national and international legislation. • Protect habitats of scientific/conservation importance. • Protect wildlife. • Identify control measures necessary in relation to satisfactory treatment and disposal of existing and future sewage and industrial effluent discharges. • Identify priorities for investment in wastewater treatment facilities • Water should support healthy biological systems compatible with the physical characteristics of the waters. **To be achieved by an EQO approach**	• Summary of existing policy and legislation. • Area covered by plan (mapped). • Tides, freshwater flows and salinity. • Geology, sedimentation and erosion. • Temperature, wind and nutrients. • Population. • Industrial and agricultural development. • Beneficial uses (fisheries for salmon, sea trout, freshwater eels and various sea fishes, mariculture potential, recreation and amenity, wildlife and areas of scientific interest, water abstractions and effluent disposal).	• List of water quality standards for aesthetic qualities, ammonia, bacteria, BOD, cadmium, chlorine, chromium, copper, cyanide, dissolved oxygen, lead, mercury, mixing zones, oxidised nitrogen, oil and grease, pesticides, pH, solids, temperature, zinc. • Objectives based mainly on EPA reports, CEC Directives and Irish regulations on bathing, freshwater fish and shellfish waters and the DOE Water Quality guidelines. • Flow criteria for application of the standards. • Subject to review every 5 years.

Water Quality	Water Quality	Recommendations	Recommended Future Monitoring
• Map and list of sampling stations on each of five estuarine sections and summary of results. • Estimation of point-source and diffuse sources and estimated future waste loads. • Predicative modelling for BOD and DO. • Development of mathematical model for establishing waste assimilation capacity. • Minimum control of effluents. • Effluent treatment.	• Ensure uniform discharge regime over specified discharge period where possible. • Minimise the extent of mixing zones by the use of properly sited and designed outfall diffuser systems. • Agricultural wastes. • Other impacts such as dredging and dredge spoil dumping. • Protection of sediment quality: major outfalls to be located as far as possible from areas of slack currents. • Review of plan every 5 years.	• Improve long-term records of freshwater flow into the estuary, with accurate information on low flows. • Further assessment of the tidal intrusion of saltwater, currents and tidal elevations. • Carry out detailed effluent surveys for all significant waste discharges.	• General water quality sampling every 2 years at neap tide. • Monthly on five reaches. • Single sampling run in reaches not covered above. • Salinity, temperature, DO, Ammonia, metals, pH, nitrate, phosphate, chlorophyll *a*, turbidity, coliform bacteria

Water Quality Management Plan for the River Suir Catchment. Tipperary (NR) County Council, Tipperary (SR) County Council, Kilkenny County Council, Waterford County Council, Waterford Corporation. March 1983.

Objectives	Background Information	Water Quality	Water Quality
Ensure water quality is maintained in a satisfactory condition and where necessary improved, thereby: • Safeguarding public health. • Catering for increasing abstractions. • Catering for needs of commercial game fisheries. • Catering for water-based amenities and recreational requirements. • Identify control measures necessary for the satisfactory treatment and disposal of existing and future sewage and industrial effluent discharges. • Identify priorities for investment in public and private wastewater treatment facilities.	• Catchment location description and map. • Table of flow parameters (long average run-off, estimated 95-percentile flow, estimated dry weather flow). • 38 river gauging stations for collection of hydrometric data, population and population projections and industry distribution (tabled). • Agricultural activity in the catchment. • Geology. **Beneficial uses (detailed report in volume 4):** • Abstractions, salmonid, eel and shellfish fisheries (monetary value summarised), amenity and recreation	• General characteristics (pH, colour and hardness) for 1971 and 1979. • Summary of present water quality as km of unpolluted, moderate or serious. • Water quality criteria for salmonid waters to be adopted with special consideration of microbiology in relevant areas (bathing waters, shellfishery, etc.). • Standards specified for DO, BOD, ammonia, oxidised nitrogen and orthophosphate. • Percentile limits recommended for DO, BOD, ammonia, nitrate and orthophosphate. • Calculation of assimilation capacities at six key locations.	• Estimation of daily domestic and industrial waste loads generated and discharged. • Estimation of future waste loads and abstractions. • Effluent treatment considerations including a series of tables showing the results of calculations of the effects on BOD concentrations, and on residual waste assimilation capacities, of subjecting present waste loads (domestic and industrial) to various combinations of waste treatment at six locations. • Similar tables for future waste loads. • Identification of reaches requiring restoration • Cost of short-term remedial actions.
Recommendations	**Recommendations**	**Recommendations**	**Recommended Research**
• Standards should be met at the 95 percentile and higher flows • Preliminary and primary treatment for all significant discharges • Ensure discharge regime is as uniform as practicable. • Combined treatment and discharge of domestic and industrial wastes in each urban centre where practicable. • Examination of locations where agricultural wastes are produced in significant quantities, and present arrangements for their disposal	• Proposed inventory of groundwater resource. • Review of plan every 5 years. • Improvements recommended for certain river gauges. • Detailed industrial effluent surveys to be carried out at each factory to determine waste loads generated and discharged.	• Increase in level of water quality monitoring, to at least fortnightly. • 24-hour surveys at important reaches during summer low flows. • Effluent discharges sampled at 15-day intervals not 14. • Ground waters. • Assessment of potential threat from non-point sources. • More detailed information on distribution of fish stocks.	• Modelling of dynamic processes such as DO variations at low flow. • Greater evaluation of economic aspects of water quality management in the catchment. • An assessment of the importance of eutrophication caused by excess nutrients introduced by direct and indirect waste discharges.

Water Quality Management Plan for the Upper Shannon Catchment. Cavan County Council, Galway County Council, Leitrim County Council, Longford County Council, Offaly County Council, Roscommon County Council, Tipperary (NR) County Council and Westmeath County Council. March 1990.

Objectives	Background Information	Water Quality	Water Quality Criteria and Standards
Overall objective is to ensure, in the future, an acceptable quality of water for specific uses at the time and place where it is needed. In particular, to ensure that the quality of the waters is maintained in a satisfactory condition and where necessary improved, thereby: • Safeguarding public health. • Catering for the abstraction of increasing quantities of water for domestic, industrial and agricultural purposes. • Catering for the needs of commercial and game fisheries. • Catering for the relevant water-based amenities and recreational requirements. • Identify control measures deemed necessary in relation to the satisfactory treatment and disposal of existing and future sewage and industrial effluent discharges. • Identify priorities for investment in public and private wastewater treatment facilities.	• Members of Steering Committee. • Catchment description. • Estimated DWF and 95-percentile flows for various towns. • Morphological and hydrological characteristics of lakes in the catchment. • Identification and description of aquifers. • Population figures and description of industrial and agricultural activity. **Beneficial uses:** • Water abstractions, angling, commercial fishing, fish farming, cruising, recreation and amenity, areas of scientific interest (mapped), small-scale hydropower.	• Summary of current water quality. • Use of Q ratings. • Summary of DO, BOD, ammonia, oxidised nitrogen and orthophosphate med and max results for 1983–1985. • Table of trophic status of lakes using mean TP, mean chlorophyll, Mac chlorophyll, mean transparency, and min transparency. Results for each lake from most recent survey for each. • Map of river water quality in the Shannon Catchment.	• Standards set to protect beneficial uses: use of water quality criteria applicable to salmonid fish and microbiological controls where necessary. • Standards to be met at and above 95-percentile flow. • Rivers: Recommended standards for DO, BOD, ammonia, TP, orthophosphate. • Lakes: Annual mean concentration of chlorophyll *a*, TP, and less commonly measured pollutants. • Standards for aesthetic qualities and mixing zones. • Discussion and table of waste assimilation capacities at important locations on rivers. • Predicted P inputs to 18 lakes which will give rise to annual average concentrations of chlorophyll *a* of 12 mg m^{-3}. Based on OECD criteria. • Summary of estimated present and future waste load discharges and abstractions
Water Quality Continued	**Recommendations**	**Recommendations**	**Recommendations**
• Summary of recommended strategies for waste treatment at selected locations. • Recommendations for control of eutrophication in lakes. • Summary of treatment costs	• Additional gauging stations. • Investigate feasibility of improving rainfall data collection. • Balancing facilities in treatment plants to ensure uniformity of discharges. • Combined treatment and discharge of domestic and industrial wastes.	• Detailed examination of locations where agricultural wastes are produced in significant quantities and arrangements for disposal. • Inventory to be made of groundwater resources and their present quality. • Five-year review of plan. • Distribution of fish stocks.	• Detailed industrial effluent survey to determine waste loads generated and discharged. • Increased frequency of monitoring (fortnightly and 24-hourly at important reaches during low flows). • Identification and assessment of potential threat from non-point sources. • Recommended research topics.

Water Quality Management Plan for the River Slaney Catchment including the Estuary. Carlow County Council, Wexford County Council and Wicklow County Council. July 1986.

Objectives	Background Information	Water Quality	Water Quality Criteria and Standards
Overall objective is to ensure, in the future, an acceptable quality of water for specific uses at the time and place where it is needed. In particular, to ensure that the quality of the waters is maintained in a satisfactory condition and where necessary improved, thereby: • Safeguarding public health. • Catering for the abstraction of increasing quantities of water for domestic, industrial and agricultural purposes. • Catering for the needs of commercial and game fisheries. • Catering for the relevant water-based amenities and recreational requirements. • Identify control measures deemed necessary in relation to the satisfactory treatment and disposal of existing and future sewage and industrial effluent discharges. • Identify priorities for investment in public and private wastewater treatment facilities.	• Catchment description. • Rainfall. • Resources. • Hydrogeology. • Population. • Industrial and agricultural activity. **Beneficial uses** • Water abstraction, fisheries, livestock watering, irrigation, shipping and some recreation.	• Minimum, median and maximum values for pH, colour and total hardness. • Q ratings. • Summary of analyses for water quality parameters DO, BOD, ammonia, ortho-phosphate and oxidised nitrogen (Nov 78–Aug 80) for the river, tributaries and estuary	• Standards set to protect beneficial uses: use of water quality criteria applicable to salmonid fish and microbiological controls where necessary. • Recommended standards for DO, BOD, ammonia, oxidised nitrogen and ortho-phosphate. • Calculation of the waste assimilation capacity of the river. • Estimation of existing waste loads and water abstractions at population centres. • Estimated future waste loads and water abstractions. • Tables for BOD concentrations and residual waste assimilation capacities at four locations and future predictions.
Recommendations	**Recommendations**	**Recommendations**	**Recommendations**
• Need for accurate records of river flows over a full range of flows. • Hydrometric scheme for the catchment with provision for four water-level recording stations and 15 staff gauges. • Catchment maintenance at established gauging stations.	• Detailed industrial effluent surveys at each factory to determine waste loads generated and discharged. • Increase in intensity of water quality monitoring, to at least fortnightly at key stations or at 15-day intervals. • Additional 24 surveys at important reaches at periods of low flow during summer.	• Expand database on levels of potentially toxic substances. • Extra water quality data for ground waters. • Assessment of potential threat to water quality by wastes from non-point sources. • Public awareness campaign for farmers. • Detailed information on fish stocks.	Recommended research topics e.g. • Modelling of the dynamic processes downstream of discharges, economic aspects of water quality management in the catchment.