European Topic Centre on Inland Waters

EUROPEAN FRESHWATER MONITORING NETWORK DESIGN

Edited by

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EXECUTIVE SUMMARY

The European Topic Centre on Inland Waters (ETC/IW) was appointed in December 1994 by the Management Board of the European Environment Agency (EEA) to act as a centre of expertise for use by the Agency and to undertake part of the EEA's multi-annual work programme. The key Task of the first year's programme was to design a freshwater monitoring network for the EEA area. This Task is fully described in this report.

Over the past two decades four European Community Action Programmes on the environment have given rise to about 200 pieces of environmental legislation. While a great deal has been achieved, the general state of the environment continues to slowly deteriorate. This assessment was made in The Fifth Environmental Action Programme based on a Report on the State of the Environment. The Action Programme highlighted the need for 'a more far reaching and more effective strategy' which could only be assured if the quantity and quality of information was good enough. Against this background, it was decided to establish a European Environment Agency.

The main task of the Agency is to provide the European Union and the EEA Member States with:

> '***objective, reliable and comparable*** *information at a European level enabling them to take the requisite measures to protect the environment, to assess the results of such measures and to ensure that the public is properly informed about the state of the environment'.*

The EEA has the duty to update the Dobríš (State of Europe's Environment) report in 1998 and is also required to produce monographs on specific issues such as groundwater quality/quantity and eutrophication.

Information is thus required on:

- the status of Europe's water resources (status assessments); and,
- how that relates and responds to pressures on the environment (cause-effect relationships).

Member States monitor water resources according to their national requirements (e.g. legal and operational) and international obligations (e.g. European Commission (EC) directives and International Agreements). The information arising from this monitoring is potentially a major source for the EEA. However, the information required by the European Commission from Member States is primarily for assessing implementation of and compliance with directives rather than for the provision of information on the general status or quality of water resources. It is this latter type of information, provided in a comparable way from a representative sample of Europe's water resources, that is required. Information from directives is not, therefore, likely to be suitable for the needs of the EEA.

Information from International Agreements will be of use to the EEA. However, to be of use data will have to be comparable between the different agreements, and the data will represent only those waters covered in the agreements, that is the major water bodies/catchments in Europe.

The proposed network for the EEA to obtain the information it requires is designed to give a **representative** view or assessment of water types within a Member State and also across the EEA area. It will ensure that similar types of water body are compared. The need to compare like-with-like has led to a **stratified design** with the identified and defined strata containing similar water bodies. The use of the same criteria for selecting strata and water types across Member States will ensure that valid status comparisons will be obtained.

The EEA network will:

1. Be **representative** of the size/numbers/types of water bodies in the EEA area (e.g. small rivers), variation in human pressures (e.g. population density and land use), and, will include a number of reference and flux stations.

2. For **rivers**, have **reference**, **representative**, **impact** (part of representative network) stations, and **flux** monitoring stations at discharge into sea, or at international boundaries.

3. For **lakes**, have a general surveillance network comprising **reference** and **representative** lakes, and if necessary, (in the light of experience) an **impact** network with lakes selected on the basis of population density. In addition the largest and most important lakes (nationally) will be included and possibly a specific cause/effect network of lakes.

4. For **groundwater**, have a general surveillance network comprising **representative** stations selected in **all nationally important aquifers,** groundwater in porous media, karstic groundwater and others should be covered.

At present there is not enough comparable information to obtain a quantitative assessment of water resources across Europe. This can lead to unfair or incomplete comparisons being made and wrong conclusions drawn. By submitting information within this proposed framework a ‘level playing field’ will be obtained so that Member States will have confidence in the conclusions being drawn. In addition the information will enable European environmental policies to targeted correctly and cost-effectively.

To minimise cost implications, where possible **the monitoring network will be based on existing national and international networks**, use existing sources of monitoring information and create, only if necessary, an EEA database of aggregated data and information rather than of raw non-processed data.

It should be emphasised that the information provided by the network will not be for the assessment of compliance of Member States with the requirements of European Commission directives.

The proposed network has been piloted and tested in four volunteer countries to date. Up to a further six countries have volunteered to pilot the network in the coming year. Results and experience from the piloting will be used to modify, where necessary, the design and the network will be progressively implemented step-by-step across the EEA area.

1. INTRODUCTION

1.1 Background

The European Topic Centre on Inland Waters (ETC/IW) was appointed in December 1994 by the Management Board of the European Environment Agency (EEA) to act as a centre of expertise for use by the Agency and to undertake part of the EEA's multi-annual research programme. The Technical Workplan of the ETC/IW was submitted to, and approved by, the EEA in January 1995, and the key Task of the first year's programme was to design a freshwater monitoring network for the EEA area. This has been achieved through a series of complementary Tasks, the outcome of which is described in this report. This report summarises the main points arising from the complimentary Tasks, in particular how the findings relate to the design of the network, and then outlines the structure of the proposed monitoring network. The detailed reports on each of the associated Tasks will be presented in the Project Record report of the whole year's programme. The network design was presented and discussed at a Workshop 3-4 June 1996 in Madrid. The design has been slightly modified as a result of comments received at the workshop and from further peer review. The network design is during 1996 being piloted in up to ten EEA countries, and will subsequently be progressively implemented throughout the EEA area in a planned and programmed way.

1.2 Role of the EEA

The main duties of the EEA are:

- to provide objective, reliable and comparable information for those concerned with framing, implementation and further developing European environmental policy, and for the wider European public;
- to identify, prepare and evaluate suitable environmental measures, guidelines and legislation;
- to co-ordinate the EIONET network and publish a report on the state of Europe's environment every three years;
- to liaise with other relevant national, regional and global environmental programmes and institutions.

The first priority for the Agency is to establish itself as a reliable and independent source of information on the environment, produced at low cost from the best available sources. The main source of this information will result from national and international monitoring programmes.

Monitoring can be divided into three broad categories or types.

1. Statutory monitoring by which a state meets its legal obligations arising from EC and national legislation and international agreements.

2. Surveillance monitoring through which a broad view and comparison of water resource quality and quantity can be obtained across a State (or across Europe). This type of monitoring is usually used to make spatial and temporal comparisons.

3. Operational monitoring which is undertaken to meet the specific business and operational needs of the regulators or users of water. Examples might be the monitoring of specific discharges, clean-up campaigns on specific catchments or monitoring after pollution incidents.

There are likely to be overlaps between the three categories, and a Member State would be keen to use existing monitoring sites for a number of purposes rather than establish new sites for new statutory needs.

It would seem, therefore, that the main type of monitoring information required by the Agency at present is for surveillance purposes. This type of information was used in the production of the 'Europe's Environment - the Dobríš Assessment, and the Agency may in the future be asked to update that report and to produce more detailed monographs on specific parts of the environment.

In terms of the current work programme for the ETC/IW it was not possible to audit the implementation of EC environmental legislation nor to define what specific monitoring is undertaken for each Directive within each Member State. Our immediate aim was, therefore, to design a surveillance type monitoring network bearing in mind that the needs of the Agency may change according to political circumstances and that the design of the network may need adapting to these changes.

A proposed overall objective of the monitoring network is:

> "To obtain timely, quantitative and comparable information on the status of inland waters (groundwater, lakes/reservoirs, rivers and estuaries) from all EEA Member States so that valid temporal and spatial comparisons can be made and so that key environmental problems associated with Europe's inland waters can be defined, quantified and monitored".

2. STEPS IN DESIGNING THE NETWORK

As already indicated above the work programme for 1995 was structured to produce a freshwater monitoring network through a series of complimentary and sequential projects and tasks. In summary these were:

1. MW1: Description of the water resource monitoring requirements associated with EC legislation and policy, and International Agreements.

2. MW2: Creating inventories of the current national monitoring programmes for water quality and quantity, surface and groundwater.

3. MW3: Design of the freshwater monitoring network by:

- Defining the information needs of the Agency and hence the terms of reference for the network;
- Defining the need for different types of monitoring station;
- Consideration of the selection of sampling sites, sampling frequency and determinands, and the requirements for summary statistics, performance criteria and quality assurance
- Assessment of the representativeness of current national and international monitoring programmes;
- Identification of gaps in current monitoring programmes;

There is clear overlap with the work associated with this project and that being undertaken by other Topic Centres, for example that on 'Catalogue of Data Sources' and on 'Land Cover'. Because of this, aspects of the monitoring and reporting network have not been finalised awaiting the recommendations of these other Topic Centres.

3. INFORMATION REQUIREMENTS OF THE EEA

3.1 Why is information needed?

Over the past two decades four European Community Action Programmes on the environment have given rise to about 200 pieces of environmental legislation. While a great deal has been achieved, the general state of the environment continues to slowly deteriorate. This assessment was made in The Fifth Environmental Action Programme based on a Report on the State of the Environment. The Action Programme highlighted the need for 'a more far reaching and more effective strategy' which could only be assured if the quantity and quality of information was good enough. Several deficiencies in the available environmental information were highlighted:

- a serious lack of base-line data, statistics, indicators and other quantitative and qualitative material required to assess environmental conditions and trends, to determine and adjust public policies and to underpin financial investments;
- an almost complete absence of the more precise, quantitative data on human interventions and influences on the environment which are needed for meaningful modelling exercise and the optimisation of policy and large scale investment decisions;
- information which is available is often not processed or presented in a suitable form for potential end users, administrations, enterprises and the general public and does not take into account the different levels of sophistication or simplification required, nor the fact that different types of decision require different types or levels of information.

Against this background, it was decided to establish a European Environment Agency. This section describes the reporting tasks laid down in the EEA Regulation (No. 1210/90, EEC 1990) and gives a broad indication of the policy issues. These are fully described in the report on the ETC/IW project MW1 (Nixon *et al.* 1996). In addition, key questions that the Agency may need, or be asked, to address were identified by the ETC members.

3.2 The role of European Environment Agency

3.2.1 EEA Regulation

The European Environment Agency was established by Council Regulation (COM 1995) No. 1210/90 of 7 May 1990. The Regulation describes in detail the role and tasks expected of the Agency. The main task of the Agency is to provide the European Union and the EEA Member States with:

> *'objective, reliable and comparable information at a European level enabling them to take the requisite measures to protect the environment, to assess the results of such measures and to ensure that the public is properly informed about the State of the environment'.*

The Regulation also stipulates priority areas of work for the Agency in Article 3, these include 'water quality, pollutants and water resources'. The Agency must also take into account in its descriptions and assessments of the environment:

- the quality of the environment;
- the pressures on the environment; and,
- the sensitivity of the environment.

With regard to monitoring and information gathering Article 2 lists the Agency's tasks to be:

- to establish, in co-operation with the Member States, and co-ordinate the network referred to in Article 4 [EIONET]. In this context, the Agency shall be responsible for the collection, processing and analysis of data, in particular in the fields referred to in Article 3...
- to provide the Community and the Member States with objective information necessary for framing and implementing sound and effective environmental policies; to that end, in particular to provide the Commission with the information that it needs to be able to carry successfully its tasks of identifying preparing and evaluating measures and legislation in the field of the environment;
- to record, collate and assess data on the state of the environment, to draw up expert reports on the quality, sensitivity and pressures on the environment within the territory of the Community, to provide uniform assessment criteria for environmental data to be applied in all Member States. The Commission shall use this information in its task of ensuring the implementation of Community legislation on the environment;
- to help ensure that environmental data at a European level are comparable and, if necessary, to encourage by appropriate means improved harmonisation of methods of measurement;
- to promote the incorporation of European environmental information into international environment monitoring programmes such as those established by the United Nations and its specialised agencies.

3.2.2 The Dobríš report

The pan-European Conference of Environment Ministers at Dobríš Castle in 1991 called for the preparation of a State of the Environment report for Europe and invited the European Commission to take responsibility for the work. This request recognised the need for the compilation of reliable and comparable data in order develop effective policies for Europe's environment.

The report identified a number of problems associated with the aquatic environment in Europe not only in the EEA area but also in central and eastern European countries (CEEC). These included: water scarcity problems in southern European countries, over-exploitation of groundwater (65% of Europe's population is supplied from groundwater), nitrate problems in north-western Europe, pesticides in soil water, river and lake eutrophication, and acidification of rivers and lakes. Important and significant information gaps were also identified including: the absence of regional water resource statistics with the present rates and trends of water abstraction by source and economic sectors poorly known. Comparable and reliable data on groundwater quantity and quality are almost completely lacking and, in general, a comparison of surface water quality across Europe was very difficult due to lack of comparable and reliable data. In particular there is a lack of data on small rivers and lakes, and data on organic micropollutants, metals and radioactivity is patchy and incomplete. The biological assessments of river quality are carried out using a variety of methods and are therefore poorly comparable. There is also no pan-European water quality database and reporting schemes differ markedly between countries.

With regard to marine waters and seas there is very little comparable data on water quality and biology available for the White sea and Barents sea, and estimates of pollutant loads from different human activities and natural sources in general are not available. There is also a need for a unified procedure for estimating land-based emissions to seas so that comparison of contaminant load estimates between different seas can be made. As for freshwater, there is no pan-European marine water quality database and reporting schemes differ markedly between seas.

The Dobríš report also defined prominent European environmental problems which have potential implications on the monitoring required (or at least the data and information required) to define and assess temporal and spatial differences. The Prominent European Environmental Problems (as defined in the Dobríš report) are summarised below.

- Climate change:
  - effects on hydrological cycle
  - sea level rise (salination of freshwaters)
  - effects on aquatic ecosystems
- Acidification
- The management of freshwater:
  - water availability
  - water quality
    - groundwater pollution
    - eutrophication
    - organic pollution (including pathogens)
    - acidification
  - physical changes

Article 2 of the EEA Regulation also requires that a ‘state of the environment report’ is published every 3 years.

3.2.3 Establishment of a pan-European network

It is likely that the area of interest of the Agency will be extended to cover those countries included in the Dobríš assessment and will thus have a pan-European role. To that end the Third UNECE Conference of Environment Ministers held in Sofia on 23 to 25 October 1995 confirmed the pan-European mandate of the Agency. The conference also requested that the Agency should report on progress in respect of the main issues identified in the Dobríš report before the next conference scheduled for 1998. The EU PHARE programme has also endorsed CEEC collaboration with the EEA. Initially two projects will be funded in the 11 PHARE countries one of which includes the setting up of an inland water monitoring network. It will, however, be necessary to establish links with countries not include in the PHARE programme but covered by the Sofia Conference. These will include Belarus, Moldova, the Russian Federation and Ukraine.

3.3 European policy

3.3.1 Groundwater action and water management programme

A Ministerial seminar held at the Hague in 1991, on the long term deterioration of the quality and quantity of water resources, emphasised the special significance of groundwater in the water cycle and in ecosystems, and as a source for drinking water. As a result, the European Council called for a Community Action and required that a detailed action programme be drawn up for comprehensive protection and management of groundwater as part of an overall policy on water protection. This has lead to a draft proposal for a Groundwater Action and Water Management Programme (GAP) which requires a programme of actions to be implemented by the year 2000 at national and Community level, aiming at sustainable management and protection of freshwater resources. The draft proposal develops the basic quality standards for groundwater adding, at the same time, a quantitative dimension to water management. National action programmes should aim for full implementation by 2000 and should address elements such as: mapping and monitoring of quality and quantity of freshwater resources, identification and designation of protection zones for areas of particular ecological interest and sensitivity, including present and future resources for drinking water and other resources. Water quality and quantity should be appropriately monitored in order to provide information allowing Member States to follow developments in quality and quantity of aquifers and, in particular, detection of early signs of deterioration from leaching of dangerous substances towards groundwater reservoirs

3.3.2 Fifth environmental action programme

The United Nations' Conference on Environment and Development (UNCED) held in 1992 in Rio de Janeiro focused the world's attention on the need to promote environmentally sustainable development. Agenda 21 was one of the agreements arising from the Rio Conference which sets out a comprehensive programme of actions for achieving sustainable development, sector by sector for the next century. National strategies and action plans are the key to the implementation of Agenda 21: the 5th

Environmental Action Programme, (EAP) published in March 1992, represents an important starting point for the implementation of Agenda 21 in the EU.

The 5th EAP stated that community policies must aim at:

- prevention of pollution of fresh and marine surface waters and groundwater with particular emphasis on prevention at source;
- restoration of natural ground and surface waters to an ecologically sound condition, thus ensuring a suitable source for extraction of drinking water;
- ensuring that water demand and water supply are brought into equilibrium on the basis of more rational use and management of water resources.

Long term targets to be achieved by the year 2000 are also given. These are in line with the programme of action outlined in the Hague Declaration and the subsequent GAP. The objectives of these targets include for groundwater: the maintenance of uncontaminated aquifers; the prevention of further contamination of contaminated aquifers; and, the restoration of contaminated aquifers for drinking water. For surface freshwaters, the objective is to maintain a high ecological quality with a biodiversity corresponding, as much as possible, to the unperturbed state of a given water; and for marine waters a reduction of discharges of all environmentally hazardous substances to levels consistent with a high standard of ecological quality. For marine waters there is also an action for surveillance of geographic zones with appropriate monitoring techniques. It is likely also that specific monitoring would be required to achieve the other objectives, particularly for groundwater, where relatively little monitoring is apparently undertaken at present.

3.3.3 Transboundary water courses Convention 1992

This was developed under the auspices of the United Nations Economic Commission for Europe to provide a mechanism for prevention of transboundary water pollution and rational use of water resources in Europe. The EU has signed the Convention and the Commission submitted to the Council in 1993 a proposal for a Council decision on the ratification of the Union’s signature. Though not yet ratified by the Council, monitoring programmes, if adopted, would be required for monitoring the condition of transboundary waters, surface and groundwaters. These programmes will be for quality and quantity determinands as appropriate for the water body, and as agreed by the relevant States.

3.3.4 The proposed directive on the ecological quality of surface waters

The concept of directly assessing ecological quality rather than relying solely on chemical and physical measures has gained support over recent years. In recognition of this the European Commission proposed a directive on the ecological quality of water (COM (93) 680 final) which will require Member States to determine the ecological quality of their surface waters. Monitoring of a representative portion of all surface waters in the EU area will be required and will place the emphasis on biological determinands and indicators rather than solely on chemical and physical determinands.

The Commission's Communication on EC Water Policy (COM (96) 59 final) proposes to replace the Ecological Quality of Water proposal with a Water Resources Framework Directive which would have a wider scope of application. The basic requirement to assess ecological quality will, however, remain.

3.4 Identification of key questions

Consideration of the above led to the definition of what issues the Agency might wish to address, or be asked to address, and the questions that they might wish to respond to through the assessment of data and information obtained from an EEA-wide monitoring network.

1. What is the ecological quality of surface waters in the EEA area, and what are the spatial differences and temporal trends and how does this relate to human activities, land use, agricultural practices, point and non-point sources?

2. What is the spatial extent and temporal trends of acidification of water across the EEA area?

3. What is the nutrient status, spatially and temporally, of water resources in the EEA area, and how does this relate to human activities, land use, agricultural practices, point and non-point sources?

4. What is the quality of water resources, spatially and temporally, in terms of pesticides, heavy metals, organic pollution and pathogens across the EEA area and how does this relate to human activities, land use, agricultural practices, point and non-point sources?

5. What is the geographic spread of and trends in water availability (and eventually water usage) across the EEA area and how does this relate to human activities, land use, agricultural practices, point and non-point sources?

6. What is the scale and importance of physical interventions in the hydrological cycle, for example, canalisation, impoundments, engineering, flood defences, in affecting water resources across the EEA area?

7. What are the loads of contaminants entering the estuaries and seas of EEA area from freshwater sources? (This would also have to consider direct discharges downstream of freshwater limits i.e. into estuaries and nearshore waters).

Each of these questions could be sub-divided by further definitions of water types, for example: on headwaters, small rivers or large rivers. Some of these questions would be pertinent to both surface freshwaters and groundwater, and also to estuaries and coastal waters. It should be noted that this report does not include estuaries and tidal waters within the network design. In many of these questions there is an explicit need to try to relate differences in water quality and quantity to human activities in catchments, and thereby try to demonstrate cause/effect relationships. The addition of supportive 'activity' information will add a further layer of difficulty to implementing the network.

There will, therefore, be key determinands (primary and secondary) and indicators that will provide the information to address the questions. Associated with the selected key determinands will be definition of sampling methodologies.

As important for comparability will be the expression of results. For example, annual averages, seasonal averages, percentiles, range, confidence limits and data handling procedures (validation, treatment of "less than" and missing values, identification of outliers etc., data storage and transfer procedures. The precision of aggregated statistics (for example the estimated mean or 10th percentile) depends on the variability (usually random variation, but also systematic variation in some circumstances) of the data as well as the number of sampling stations and the sampling frequency at those stations. The more variability there is the more samples and/or sampling stations will be needed to attain a certain level of precision. It is important to have good precision so that the chances of detecting real differences are satisfactorily high.

3.5 Presentation of results

As has already been described there is likely to be a wide audience for the information provided and reported by the Agency. This will include technical experts, national regulators, pressure groups, national and European politicians and policy makers. It is likely, therefore, that the level or type of information they require (and are able to interpret or understand) will be different ranging from detailed statistical assessments of current status and trends in key sectors to summary colours on maps giving very broad brush comparisons between States across Europe.

In the present Dobríš report a series of coloured pie charts and symbols on maps are provided for comparison using a number of coloured ‘classes’ based on ranges of determinand levels. This implies that some sort of classification may be applicable or desirable giving the requirement for additional technical decisions on how any particular site or water body should be assigned a class. This would potentially be of great (political) importance to individual European States. This is discussed further in Section 7.8. As well as this type of comparison map it is likely that thematic reports will be required in which specific problems will be temporally and spatially assessed and compared. Spatial comparisons would be generally presented again as different colours. There may also be a desire to relate differences in quality and quantity to potential causal agents, that is establish ‘cause and effect relationships’. This in itself raises many difficult technical issues and points of debate. Perhaps it should serve as a reminder that when statistical rules and procedures are applied in the design of the network that all may be reduced to five colours on maps.

It is also understood that the Agency has no desire to establish, and would not be best able to handle, a large database of monitoring data. Rather, it will be the recipient of metadata or summary information. It will be important, therefore, that procedures are introduced with the national data keepers so that comparable metadata will be dispatched to the Agency. It will also be important that thematic and quality reports are produced promptly by the Agency from up-to-date information rather than that collected several years previously. Information from each country would also have to have been collected over the same period (year).

4. THE NEED FOR DIFFERENT TYPES OF MONITORING STATION

The ETC/IW was asked to assess the need for different types of monitoring station to be included within the network. Such stations would provide different types of information for use by the Agency to meet the requirements described in Section 3. Such a structured or tiered monitoring network would also imply that there might be a need for different sample site densities, sampling frequencies and determinands for measurement.

The EEA's need for different types of stations for fresh surface water and groundwater, quality and quantity monitoring is summarised in the following sections and is based on more detailed submissions by members of the ETC/IW The source documents are reproduced in the Project Record for 1994 (ETC 1995).

4.1 Surface water quality

There is a very wide range of terminology used to describe and define different types of monitoring stations, many related to the type of information provided. For example, in Europe and North America the following types of station are described:

- Statutory stations, providing data to fulfil legal commitments, either national (for instance control of raw water for a public water supply) or international (agreement between two countries to control water quality in a transboundary water course, or obligations arising from a EU directive);
- Benchmark (or reference) stations, aiming at characterising catchments undisturbed, as far as possible, by man;
- Boundary stations, aiming at characterising fluxes, either between legal boundaries (between countries or regions), or between media (from a river to a lake or ocean, from a surface stream to groundwater, etc.);
- Impact stations, aiming at controlling the effect of man's interference, namely well defined pollution sources;
- Representative stations that can be used to provide summary information on a larger area, usually with long records;
- Operational stations, located for day-to-day water quality management by local, regional or national agencies;
- Research stations, installed and operated during scientific projects.

There are also examples of aggregating or summarising data from a number of stations to characterise relatively large areas or river catchments. These stations have been termed virtual stations (Santos and Costa 1991).

It would appear that in the context of the EEA network that three types of monitoring station are relevant:

1. Reference stations to give reference points for analysis, regarding what the natural or pristine water quality is likely to be across Europe, and how this is changing with time.

2. Flux stations to estimate fluxes between media, between Member States and between EEA and the rest of Europe;

3. Representative stations to give an assessment of general quality of waters across Europe.

Ideally there would be reference stations for each eco-hydrological zone in a country, though in some countries reference conditions will probably not exist. For instance Portugal should have at least four, characterising the arid Mediterranean area south of Tagus, the Atlantic basins of the north, the coastal basins and the interior forest areas. There should be flux stations on all major rivers crossing borders among Member States, and on each major river just before discharging into estuaries or coastal waters.

Possible ways of aggregating data from a number of representative stations to give broader overviews of quality on a catchment or regional basis will be investigated further during the implementation of the network in 1996 and subsequent years. It will be important to assess whether aggregating stations loses important information and to determine what would be the optimum scale of such aggregation.

4.2 Surface water quantity

Europe has a dense network of flow measurement stations: approximately 19,000 at an average density of 1 per 270 km^2 (WMO, 1987). This is justifiable owing to Europe's wide physical diversity with respect to climate, morphometry and geology and the anthropogenic factors of population density, land and water use. This diversity is reflected in the varieties of river regimes which present a wide range of challenges for flow measurement and hydrometric data acquisition, so much so that estimates of runoff and thence resources may be significantly compromised.

There is growing recognition of the need to measure and monitor river mass fluxes systematically to assist with the rational management of the environment at all spatial scales, from individual river reaches and basins (e.g. UK National Rivers Authority Catchment Management Plans) and semi-enclosed seas bordered by several countries (e.g. the North Sea Conference), through to the world's coastal zones and oceans. This recognition has resulted in significant research initiatives on flux assessment in a number of countries.

There is also a need to monitor in respect of EU legislation and international obligations and conventions. There is only one piece of EU legislation requiring measurement of water quantity relative to surface freshwater, the Exchange of Information Decision (77/795/EEC) and there are nine European international conventions which require flow measurement.

For inland water quantity monitoring, two broad categories of station may be recognised in philosophical terms; in practice, there may be considerable overlap between the categories at individual measurement sites:

- Statutory and operational monitoring arising from national or international obligations or to provide information for the business and operational needs of the regulators, suppliers, users and reclaimers of water.
- Surveillance monitoring to characterise and allow appraisal to be carried out of the state of water resources and, in conjunction with water quality measures and biodiversity, the state of the water environment.

The separation is between that which has to be done to ensure legal compliance or efficient utilisation of the water resource and that which is beneficial in allowing the longer or broader view to inform policy making, assist planning decisions and increase the knowledge base.

Surveillance monitoring may be further subdivided into:

- Reference stations that characterise regimes in catchments undisturbed as far as possible by man.
- Baseline stations which, in total, characterise the generality of runoff behaviour of the region or country and whose data are appropriate for the transfer of hydrological characteristics to ungauged sites.
- Representative (or Index) stations that are a subset of the network to provide summary estimates of the regional or national picture. Typically, these sites will have long records to provide a good historical perspective.
- Impact stations that record and characterise the effects of man's interference with the natural regime.

The EEA requires access to information from a sound surveillance network that would capitalise on existing networks as far as is prudent and establish new sites where justified. The network design should be driven by the need for information to address the legitimate interests of the EEA. These interests extend beyond the monitoring and characterising of the state of the environment (the classical surveillance justification), investigating pressures and assessing remedies, into reviewing selected scenarios related to development strategies. In turn, this requires that the network is capable of quantifying effects and providing insights to processes sufficient to frame scientifically based management or mitigation procedures. This may not coincide with the classical methodology of the theoretical sampling of representative subsets of the geographical, climatic and aquatic environments (WMO 1976, 1982) but would be a pragmatic response to the difficulties in maintaining networks with too narrow a user base. The networks related to water quantity measurement, notwithstanding their historical development, are probably closer to a representative ideal than those related to water quality and ecology measures. Attempts to harmonise the location of water quantity and quality sampling sites are likely to demand an extension or relocation of the flow gauging network (as flow measurement sites are likely to be less critical in their siting).

Example topics for which information on water quantity and mass loads would be obligatory or desirable include:

- sustainable development - extension of models of sustainability from those related to water volumes and temporal distribution to concerns related to resource quality and maintenance and preservation of aquatic environments;
- defining environmentally acceptable flows and quality standards;
- climate change impacts appraisal - examination of the implications for water and environmental management (e.g. development of programmes to monitor extremes of river flow behaviour and to predict possible changes in extremes frequency, review irrigation and agricultural practises) (Kuusisto *et al.*, 1994);
- monitoring and prediction of fluxes of chemical species and suspended solids with possible changes in flow regimes;
- the impact of groundwater pumping in modifying base flow behaviour;
- disaggregation of the effects of man's interference in fluvial regimes.
- Providing the knowledge/data base which will allow the complex interactions between flows and concentrations to be more fully understood.
- Assessing the inputs to sensitive water bodies and the oceans; partitioning inputs between river systems/countries.

It is concluded from this review that:

1. A hierarchy of gauging stations, including reference, baseline, representative and impact stations will be necessary to match the perceived information needs of the EEA.

2. The Agency must capitalise on the capacity of the present networks to provide it with surveillance information.

3. The Agency should assess the information delivery capacity of existing networks in the light of its requirements for the range of information and accuracy it desires

4. There is a need for a class of monitoring station that addresses the measurement of mass loads as its primary purpose.

4.3 Groundwater quality

4.3.1 Background

The purposes and objectives of groundwater quality monitoring include:

a) Collection of basic data for general surveillance purposes for establishment of national groundwater quality databanks, which can be used as planning information for future groundwater abstraction.

b) To gain information for the EC Directives on Groundwater. These data are also important for the assessment of compliance with national legislation. They are important for the future international and transboundary obligations on groundwater.

c) For monitoring the quality of abstracted groundwater and the impact of pollution from both diffuse, air-borne and point sources. To forecast the impact of possible pollution from known sources and the changes of the quality caused by these sources. Identification of the groundwater quality trends.

d) Pollution impacts and its consequences to new abstraction projects by, for example, lowering of the groundwater table. Identification of areas where specific programmes may be necessary to reduce pollution and the assessment of progress made in their implementation.

e) Data support for groundwater quality and quantity modelling: modelling of the transport and decomposition of compounds in solution as a tool for understanding and forecasting of pollution components in the groundwater and as a tracer of the groundwater flow.

f) Collection of groundwater quality data for mapping and observation of groundwater resources, (especially known and used resources, but also potential, but not yet exploited resources). Early warning system in recharge areas of the impact of diffuse pollution. Data can also be used in research and scientific work.

g) Observation of the consequences of groundwater contact with natural minerals and chemical compounds, which can affect the quality of the groundwater: Mineralisation in crystalline rocks and sediments, special compositions of the rocks and sediments and their alteration products, composition of water in areas of volcanic activity, contact with sea water and high salinity deposits (salt water intrusion), occurrence of deposits rich in organic matter as in, e.g. moors.

h) Observation of the effects on groundwater from large scale processes like global climate changes or man-induced changes in reaction-rates of natural processes like acidification caused from acid rain.

4.3.2 Types of monitoring network

The following types of monitoring network can be distinguished:

a) Basic networks;

b) Specific networks;

c) Temporary networks.

Basic networks

The basic network should deliver general information about the quality of the groundwater. The network should cover the entire country, and the monitoring programme should have a permanent character over long time. Stations yielding background information of the natural quality of the groundwater can be a part of the basic network. To be consistent with the surface water quality stations these could be termed ‘reference’ stations. The information from this network forms the basis of the evaluation of the quality trends in the future and is the basis for both country-wide and local hydrogeological scientific and practical investigations. The design of the basic network can follow different concepts of which the following should be considered.

- Representative stations could be placed in a square net or other geometrical pattern with a fixed distance between the stations;
- They should be placed in the main aquifers; and, also
- In other important aquifers of the area selected on the basis of representativeness.

Reference stations providing background information should be established outside areas affected by direct human activities such as groundwater pumping and other anthropogenic changes. In some areas within the EEA (small countries or in densely populated areas) this will not be possible.

Specific networks

Specific networks are constructed for monitoring selected areas or for specific kinds of pollution, for example, point sources. Therefore, they act as impact stations. The stations can form a separate network, or they can be an extension of the basic network, and thereby fulfil the need for data in areas between points on the larger basic network. The specific network can have a permanent character, or will be in operation as long as there are needs for information at that specific place. Around landfills, this could be during the period of activity and for a period after the landfill has been closed. These kinds of networks are regional or local and are often the most important.

Temporary networks

The temporary network stations are established to collect data in connection with particular groundwater projects, and will normally be impact stations. The network will be operational during the project period after which it is closed. Eventually, some stations may be transferred to the basic or specific network. The network will often be very dense and the quality data are included into transport and process studies of an area, often contributing to the verifications of the project findings.

4.3.3 Conclusions

It is concluded that the EEA will need information from reference, representative and possibly impact monitoring stations initially selected form existing national monitoring networks. Information will also have to be obtained from important flux points (stations), for example, between media (surface and groundwater, groundwater and sea) and between countries.

4.4 Groundwater quantity

There was close liaison and co-operation between the two groups undertaking the groundwater quality and quantity assessments, and as a result the main conclusions arising were similar which is not surprising as quite often both would be monitored at the same time for the same purposes.

Groundwater quantity measurement has proven to be indispensable to monitor the anthropogenic induced and/or natural changes in water levels in order to;

- detect early signs of over-exploitation and/or other consequences of human impacts on groundwater levels (e.g. impact of hydraulic engineering, abandoned mines);
- provide the necessary information allowing for ‘tailor-made’ use and need oriented groundwater quantity management; and,
- provide information for the interpretation of groundwater quality data.

A feasible procedure to be followed when planning a network is to consider the multiple purposes and needs the network has to serve. In this manner the following types of networks can be distinguished:

- basic networks;
- bench-mark (or baseline) stations;
- specific networks (or special hydrogeological networks); and,
- temporary networks.

Descriptions of basic, specific and temporary networks have been given in the previous section. An additional type of network and station has been identified for groundwater quantity monitoring, the hydrological bench-mark or baseline station. These provide a continuing series of consistent observations on hydrological and related climatological variables. They should reflect local, regional and geographic differences.

The type of the observed variables also varies with the purpose of the network, the necessary information and the particular characteristics of the groundwater and its regime in the area. As to spatial and temporal densities of the observations, these usually increase with the transition from the national or regional level to the project-specific sites and/or to the level of local warning requirements. The type of field record (e.g. autographic, telemetered, manual) is highly dependent on the available technology of data transmission and processing. Finally, the length of record depends on the duration or the purpose of the network.

Both the specific network and temporary hydrogeological network may be considered as "impact stations" since they monitor the influences of projects and water management systems on groundwater more on a local scale. They should be established in areas which are relatively uninfluenced by past or future anthropogenic changes. Since long records are the essence of a bench-mark station, consideration should be given to existing stations if they meet the other requirements. Climatological bench-mark stations are known as reference stations.

Monitoring and assessment of groundwater quantity is generally indispensable, but of particular importance in areas with quantity and/or quality problems. Detailed information about the situation and trend in water tables on a regional and local level are vital for a special tailored use and need oriented groundwater management. Lacking the necessary detailed information, a system of authorisations - as proposed by the groundwater action programme (EC 1995) - depending on permits and general rules may not be effective and may not meet the expectations put into such a system.

The different types and names of stations (e.g. bench-mark stations, impact stations etc.) for monitoring groundwater quantity are mainly a result of the specific objectives the network has to serve. The type of stations with respect to the type of network (e.g. base-line etc.) has usually no influence on the design and the construction of the observation station as long as the observation of groundwater tables is concerned.

No current EU directive has specific requirements for groundwater quantity monitoring. Nevertheless the need for, and the importance of, monitoring groundwater quantity has been recognised at an European level especially when facing water shortages and quantity problems in large parts of the European Union over the last years. The need for such groundwater monitoring is stressed by the European Commission in its Groundwater Action Programme (EC 1995).

For the reasons mentioned the choice of the appropriate type(s) of groundwater quantity monitoring networks as well as the appropriate level of monitoring effort (density of stations, frequency of observations) are closely linked to the very needs the network has to serve. The economic and environmental benefits of appropriate and sustainable groundwater quantity management in regions with an excessive over-exploitation of limited groundwater resources may justify the costs of a dense network of stations including impact stations on a national, regional and local level. The same network and number of stations in regions with abundant groundwater resources and no quantity problems may be considered as pure luxury, as a much more limited and less dense network might serve the special purposes of water management in those regions.

A Europe wide comparison of results of groundwater quantity monitoring should mainly be based on the aggregated results (e.g. area, number of monitoring stations, monthly and annual changes in groundwater tables) of the basic or principal network, as all other networks (with "impact stations") take into account very specific local effects, which may be not fully comparable throughout Europe.

5. REPRESENTATIVENESS OF CURRENT MONITORING PROGRAMMES IN EUROPE

5.1 Definition of representativeness

Representativeness can be expressed in a number of ways. For example, it can relate to how well represented or quantified are the water resources of a particular country in terms of the total national water resource or total EEA resource. Alternatively it could relate to how well a particular water problem had been quantified, for example acidification of small streams or eutrophication of lakes. There are procedures that can be applied to determine how statistically representative the 'sampled' population' is of the 'total population'. In this sense population refers to the total number of the water type being assessed (e.g. all small rivers, all lakes). Alternatively the representativeness may be expressed in relation to the international requirements and obligations for monitoring (MW1) or against the information requirements of the Agency.

Since much of the source information for the first type of assessment is generally lacking or difficult to obtain in the time scales available (e.g. numbers of small streams, temporal and spatial variability of determinands within and between water bodies) the emphasis in this section has been on the latter, more superficial, type of assessment of representativeness. The main source of information for the assessments was responses to the questionnaires circulated to each EEA State through the National Focal Points. The information and responses obtained from the questionnaires were variable, and any such shortcomings are indicated in the following text. The issue of statistical representativeness is discussed in more detail in Appendix A. Again, the section has been divided somewhat arbitrarily into sub-sections of surface waters quality and quantity, and groundwater quality and quantity. Where there are clear overlaps these are indicated in the text. The sub-sections summarise the main conclusions of work carried by ETC members which is reported in full detail in the Project Record (ETC 1995).

5.2 Surface water quality

This task drew heavily on the work on surface water quality monitoring networks initially funded by DGXI but then also supported by the EEA as part of the 1994 subvention. This section evaluates the representativeness of existing national river and lake monitoring programmes. Focus has especially been put on description of network design (number of sampling sites).

5.2.1 Rivers

Nearly all the countries in the EEA area have a national rivers monitoring programme generally based on chemical and physical indicators of quality. Additionally some international programmes, such as the EU Exchange of Information Decision (77/795/EEC), and the OECD and GEMS/WATER networks, focus on chemical and physical water quality primarily of large rivers. Thirty-one monitoring programmes of this type have been identified, these also include more specific monitoring programmes such as, for instance, monitoring of transboundary rivers and estimation of loadings into coastal areas.

The river monitoring networks can be divided into three categories according to their main purpose:

1. General characterisation of rivers and streams in a country.

2. Monitoring of water quality of rivers draining specific areas such as, for instance, reference sites in forested or uncultivated areas, or leaching of substances from agricultural watersheds.

3. Networks designed to estimate the riverine loading from land into coastal areas, or the loading of transboundary rivers from one country to a neighbouring country.

Many monitoring networks are multi-purpose and may be assigned to more than one of the above categories. The results from a network may, for instance, be used both to make a general characterisation of river water quality and to estimate the nutrient loading of coastal areas.

There are 20 monitoring programmes which have networks specifically designed to elaborate a general characterisation of rivers and streams in a country. Most of these networks are based on more than 100 sampling sites located on all major river systems and rivers in a country. According to most of these programmes, samples are taken annually with a sampling frequency ranging from 4 to 26 sample per year. The number of variables measured varies from 4 to 120, but all programmes generally include the determination of basic variables (e.g. pH, conductivity, water temperature), organic pollution indicators (e.g. dissolved oxygen, BOD), nutrients and suspended solids. Many programmes also include determination of specific ions (e.g. chloride, sulphate, calcium) and heavy metals. Additionally, the determination of more specific contaminants such as organic micropollutants and radionuclides is included in some monitoring programmes.

The areal density of sampling sites varies from one sampling site per 10,000 km^2 to more than five sampling sites per 1,000 km^2, with 1 to 2 sampling sites per 2,000 km^2 generally being found. The density of sampling sites in relation to population varies from 2 to 500 sites per million inhabitants. Each sampling site also represents from 6 to 6,000 km of river. The river length used in this calculation was based on Morris and Kronvang (1994) and only includes rivers mapped at a 1:50,000 scale.

In the Nordic countries, Denmark, Finland, Norway and Sweden, there are monitoring networks with the purpose of monitoring water quality and loading from specific catchments. These monitoring networks generally consist of up to 20 relatively small stream catchments and involve detailed integrated studies of both river water quality and of the catchment (for example, land use, soil type). The main purposes of these networks are to monitor reference areas, loadings from agricultural land or the impact of acid precipitation.

Many monitoring networks are established to estimate the riverine loading of contaminants from land to sea, or in transboundary rivers. Generally these networks consist of sampling sites located at downstream points in all major river systems. Those countries that have a relatively long coastline compared to their area, for example, the United Kingdom, Ireland, Norway, Sweden, Denmark and Greece, generally have a large number of relatively small river systems. Consequently, the number of sampling sites needed to estimate loads to coastal areas is high, whereas fewer sampling sites are required in countries dominated by a few large river systems. In Denmark, for instance, sampling is undertaken in 124 river systems which equates to the loading to sea from around 60 % of the land area, whilst sampling undertaken in the eight largest Spanish rivers equates to approximately 75 % of the loading from the Spanish land area. The sample analysis programmes generally include determination of nutrients and suspended matter. Additionally, loading by heavy metals and organic micropollutants may be measured. The sampling frequency is typically monthly or sometimes more frequent.

In European countries there is a long tradition of assessing river quality by measuring the macroinvertebrate community structure. However, these assessments have primarily been made by local organisations responsible for managing and monitoring specific rivers. In some countries these activities have, however, developed into national surveys of the biological quality of the main rivers. In some cases these national surveys may be based on the results collected by local authorities in accordance with harmonised and standardised procedures (e.g. sampling methods, criteria for site selection, classification schemes, etc.). Most countries do not have separate national monitoring programmes for biological assessment of river quality though in some countries macroinvertebrate studies are included in the general chemical river monitoring programme, macroinvertebrate investigations being sometimes restricted to relatively few sampling sites.

5.2.2 Lakes

Norway, Finland and Sweden have numerous lakes accounting for approximately 5 to 10 % of their total surface area. A large number of lakes are also found in Denmark, the northern part of Germany, Ireland and the northern and western parts of the United Kingdom. In central Europe most natural lakes are situated in mountainous regions, the ones at high altitude being relatively small and those in the valleys being the largest, examples are Lake Geneva, Lake Constance, Lake Garda and Lake Maggiore in the Alps. In addition, several lakes can be found in Austria and the northern parts of Greece. In Portugal, Spain, France, Belgium, the Netherlands, southern England, and the central parts of Germany, there are generally few natural lakes. In these areas man-made lakes such as reservoirs and ponds occur more frequently than natural lakes. In Spain, for instance, there are more than 1,000 large reservoirs.

Only a few countries in the EEA area have national monitoring programmes for the assessment of the chemical and physical water quality of lakes. Some countries, however, undertake local monitoring of lakes. The German Federal States (Länder), for instance, monitor the environmental state of lakes in their respective areas. Local lake monitoring activities are generally not standardised at a national level, and the variables and sampling frequency vary. During the last 10 to 15 years some countries have made national lake inventories and collected data and elaborated reports on the general environmental state of lakes based on locally gathered information. In the Nordic countries, in which there are many natural lakes, monitoring programmes cover a vast number of lakes. Some countries have a long tradition for monitoring large nationally important lakes, Austria has, for example, monitored Lake Constance and Neusiedler See since 1961 and 1972, respectively, and the Norwegian Lake Mjösa has been studied since 1971. Several countries, for example the Netherlands and Portugal, do not have specific lake monitoring programmes, but include their lakes in river or inland water programmes.

The number of determinands measured is generally in the order of 20 to 30. Most programmes include determination of basic variables (temperature, pH, conductivity, dissolved oxygen), organic pollution indicators (total organic carbon, biochemical oxygen demand, chemical oxygen demand), eutrophication indicators (nitrogen and phosphorus species, chlorophyll-a, Secchi depth) and major specific ions (Ca, Mg, Na, K, etc.). Some countries also include determination of heavy metals (Finland, Sweden).

The general national lake monitoring programmes can be divided into two categories: the ‘survey-type’ and ‘intensive’ programmes. The ‘survey-type’ programme typically covers a large number of lakes that are sampled at long intervals. Examples of this type are found in Norway and Sweden, and include around 1,000 lakes in each. In Ireland a national lake survey was performed in the period 1987 to 1990, and included a total of 170 large lakes and some representative smaller lakes. Additionally, a remote sensing survey of 360 Irish lakes was performed in 1989 and 1990. More intensive monitoring programmes with a sampling frequency of several times a year (e.g. in Denmark and Sweden) typically cover a smaller number of lakes. Survey-type lake monitoring programmes provide a general description of the environmental state of a wide range of lakes, whereas more frequent monitoring provides information on dynamics and seasonal variation that may be used to detect trends.

Biological variables are part of the sampling routine of many general lake monitoring programmes as well as programmes concerning specific localities. One Finnish programme includes only biological variables. Sampling and investigation of phytoplankton and zooplankton are components of several monitoring programmes. Apart from a general evaluation of the phytoplankton community, the objectives of some programmes are more specific such as assessment of the occurrence of potentially toxic blue-green algae in waterbodies used for bathing or drinking water supply (for example in the UK). Bottom fauna (invertebrates), macrophytes and fish are also studied in some of the lake monitoring programmes.

The monitoring of acidification effects is co-ordinated internationally in an ECE programme, the International Co-operative Programme on Assessment and Monitoring of Acidification of Rivers and Lakes, arising from the Convention on Long-range Transboundary Air Pollution. Twelve European countries, Canada and USA participate and report chemical and biological variables to the programme centre.

National acidification monitoring programmes are restricted to the countries affected by surface water acidification. Finland, Norway and Sweden have, for instance, a long tradition of assessment of surface water acidification. The acidification monitoring programmes can be divided into:

- nation-wide surveys to assess the extent of acidification; and,
- monitoring programmes involving detailed studies of a few catchments with the purpose of understanding the process of acidification and analysing trends.

Norway, Finland and Sweden each have nation-wide surveys with the purpose of assessing the extent of acidification. The surveys include national sampling of more than 1,000 lakes and are generally performed at intervals of five to ten years. In 1995 a co-ordinated lake acidification survey will be performed in each of the three countries. The countries also take annual samples in fewer lakes; 176 lakes in Finland, 100 in Norway and 85 lakes in Sweden. In addition, a number of small streams are sampled. The annual programmes are used for analyses of acidification trends. One sample is taken from each waterbody both in the survey programme and in the annual programme, and it is then analysed for general acidification variables. The most common variables for all the monitoring programmes are pH, conductivity, alkalinity, total organic carbon, nitrate, four major cations (potassium, calcium, magnesium, and sodium) and anions (sulphate and chloride), and various aluminium fractions. Some monitoring programmes also include measurements of total phosphorus, total nitrogen and ammoniacal nitrogen. The extent of acidification is also assessed using of various biological indicators such as zoobenthos, phytoplankton, and fish.

Seven integrated acidification monitoring programmes are in operation in five countries: Norway, Sweden, Finland, the UK, and Ireland. Generally the programmes include extensive investigations of a limited number of waterbodies or catchments and involve frequent sampling and determination of many variables. Chemical analyses of surface water samples are made and in some cases also of precipitation and groundwater. Water samples are analysed for all the previously mentioned acidification variables. In some of the programmes detailed studies of the biological communities are also performed, examples being studies of macroinvertebrates in streams and the littoral zone of lakes, as well as studies of phytoplankton, macrophytes and fish. In some lakes the record of acidification is reconstructed by use of palaeolimnological indicators (primarily diatoms).

5.3 Surface water quantity

There a lack of sufficiently detailed responses to the MW2 questionnaires to enable a thorough assessment of representativeness of flow gauging stations to be made. Only nine countries had given reasonably detailed information on specific gauging stations by the end of September. From these only five provided information about the altitude of the flow gauges and only one answered all questions giving information on the maximum altitude of each basin draining to a flow gauge, average catchment precipitation and average flow. Some of the countries gave only geographical information (names and co-ordinates) about certain gauges with no information as to the period of activity. However some weak points can be detected, the biggest being the relatively high concentration of gauges in the lowlands. Although also incomplete, the information on monitoring frequency and geographical spread of gauges is currently being analysed.

5.4 Groundwater quality

5.4.1 Summary of information

This evaluation was based on the MW2 returned questionnaires and showed that the objectives ‘general surveillance purpose’ and ‘water quality trend identification’ are part of all monitoring systems. Other objectives include assessment of compliance with national or EC legislation for example the control of drinking water quality (80/778/ECC) or monitoring for compliance with the EC Nitrates Directive (91/676/ECC). Monitoring systems in Italy and France are based on requirements for monitoring drinking water quality. Some other important purposes for groundwater quality monitoring in the EEA area include detection of sea water intrusion and evaluation of impacts caused by airborne pollutants. A sea water intrusion monitoring network has been installed in Spain and this problem is also the subject of investigations in UK and Portugal. The monitoring of impact from airborne pollutants in relation to acidification problems is mostly limited to the northern part of the EEA area (e.g. Norway).

Most monitoring networks include sampling sites which are distributed evenly within the whole groundwater area and/or are concentrated around drinking water wells. The objectives of these two network types may well differ but certainly both differ from the networks which are based on sampling sites concentrated around impacted areas.

Large differences exist between the monitoring networks as far as the number of sites and investigated areas are concerned. This is not only due to the different hydrogeological situations in the EEA area but also due to the different objectives (for example, impact or baseline station network, identification of effects from airborne pollution or effects from agricultural land use). The total national observation area, for example, for groundwater in porous media varies from 35 to 79,258 km^2 over the EEA countries, and sampling site density varies from 0.004 to 0.57 sites/km^2. The variation in the equivalent figures for karst groundwater and other groundwater is also very high.

Groundwater quality parameters can be divided into following groups:

1. Descriptive parameters (e.g. conductivity, pH, turbidity, odour);
2. Major ions (e.g., Ca, Mg, Na, K, $N0_3$, $N0_2$, NH_4, Cl, $S0_4$, HCO_3);
3. Additional parameters (e.g. DOC, boron, fluorine, cyanide, hydrocarbon benzene);
4. Heavy metals (e.g. Cr, Pb, Cd, Hg, Ni);
5. Organic substances including chlorinated solvents (e.g. trichloroethene; tetrachloroethene; 1,1,1 trichloroethane; 1,1-dichloroethene);

6. Pesticides (herbicides, insecticides).

In most monitoring programmes descriptive parameters and major ions are analysed, heavy metals are also often measured. However, there is a difference between the programmes in the case of chlorinated solvents and pesticides. The total number of organic substance determinands varies from 15 to 106 compared to 1 to 64 for pesticides. A further figure for comparison is the number of determinands which are included in ‘basic programmes’, these vary from 14 to 51.

The lowest sampling frequency for basic programmes is once every 2 years compared to the highest frequency of 12 times per year. These differences are due to differences in monitoring purpose or objectives (e.g. specific networks with small number of sampling sites, high sampling frequency and small number of variables).

Little useful information was received on the limits of detection achieved for the determinands. In some cases values above detection limit are only given as an order of magnitude value (mainly in monitoring systems for drinking water), If there are no exact values, statistical evaluations for example analysis of time series, are difficult.

5.4.2 Conclusions

The evaluation of information shows that national or regional groundwater quality monitoring networks in the EEA area have very different purposes and objectives. Because of this the structure and design of the networks are different. This means that in the EEA area existing individual groundwater quality monitoring networks can only be regarded as representative at their national level.

Evaluation of data arising from the existing, highly different monitoring networks in the EEA area (different objectives and different criteria for selection of sampling sites) will not give the reliable results which are needed by the EEA. With regard to the information needs of the EEA, it should be noted that the data are not entirely comparable and would certainly lead to wrong conclusions.

A three step approach could bring together existing, monitoring networks and data needs of EEA.

1. Lay down strategies for EEA groundwater quality monitoring.
2. Analyse which parts of existing national monitoring networks can be used.
3. Establishment of additional elements either in existing or new monitoring networks.

Point 2 and 3 can only be carried out in close co-operation with national institutions. This should be undertaken as part of the pilot implementation proposed for 1996.

5.5 Groundwater quantity

5.5.1 Introduction

The information obtained on groundwater quantity monitoring by the MW2 questionnaire was somewhat limited and patchy for some items and for most countries, which has restricted the scope of this task. For example information that would help to understand and quantify links between the state and pressures arising from human activities, or to assess the state of the aquatic environment was not reported. Therefore, because of this lack of information and data, it is only possible to make a very broad assessment of representativeness based on very simple indicators. It should be noted that no information on monitoring programmes for Greece, Belgium and Luxembourg have been received. Furthermore, Italy did not provide information about sampling density and frequency of observations. Also due to organisational responsibilities 2 countries (France and Germany) have responded though regional authorities.

5.5.2 Objectives of monitoring

It should be noted that no current EC directive addresses specific requirements for groundwater quantity monitoring. Many monitoring networks are multi-purpose: About 90% are oriented to collect basic data, 59% for management purposes and 41% for scientific research purposes. In the context of this last objective the Alsace region of France uses its piezometric network to supply data in order to maintain the mathematical model of the Alsace aquifer. Two countries, Portugal and Spain, have specific networks designed to monitor saltwater intrusion in coastal aquifers. Within the 'management' objectives, 31% of countries/regions use a piezometric network to help the assessment of compliance with national legislation and to a lesser extent for EC legislation and transboundary obligations (Austria, Thüringen - Germany and Portugal). The Nord Pyreneen region of France collects piezometric information from programmes that have other purposes, for example, monitoring underground gas reservoirs.

5.5.3 Sample site density

In porous aquifers the areal density of sampling sites varies from 30 to 40 per 100 km^2 (Austria and the North Rhine Westfalia) to a minimum of 0.1 per 100 km^2 in Ireland. Almost all countries have observation sites evenly distributed within the whole groundwater area and very few concentrated around drinking water wells (Portugal and North Rhine Westfalia, Germany) or impact areas. Ireland and UK have some observation sites non-specifically located.

In karstic groundwater the areal density of sampling sites varies from 33 per 100 km^2 (North Rhine Westfalia, Germany) to a minimum of 0.066 per 100 km^2 in Austria. Almost all the countries have the observation sites evenly distributed over the whole groundwater area and only Portugal has observation sites concentrated around drinking water wells. It should be noted that as most karstic regions are located in mountainous areas, it is not possible to achieve an even site distribution, therefore, sampling stations tend to be situated in flat areas. Again Ireland and UK have some observations sites non-specifically located. In other aquifer systems the areal density of sampling sites varies from 1,000 per 100 km^2 (Finland) to a minimum of 0.6 per 100 km^2 in North Rhine Westfalia, Germany. Almost all the countries have the observations sites evenly distributed over the whole groundwater area. Germany, Spain, Great Britain and Ireland have some observations sites non- specifically located.

In order to know the history of the groundwater system, in particular the identification of short- and long-term changes in groundwater quantity, an appropriate sampling frequency must be used which in itself depends on the hydrogeological system being monitored and its interaction with other systems. Sampling frequencies (e.g. for water levels, temperature) vary a great deal from country to country, from a daily basis in Thüringen, Germany to 2 to 6 times per year in Spain, for basic programmes, and from continuous sampling (Bavaria, Germany) to a 2 to 3 times per year (Portugal), in special programmes. The earliest quantitative groundwater records are from the UK (1845). Only the Netherlands has a complete sampling frequency programme with observation in levels, temperature and other variables near to the proposed requirements. There is less information on the frequency of sampling springs to monitor the water level, the temperature, the discharge, the conductivity and other variables. Springs are also sampled in basic and special programmes. There is also no information with regard to the control of the seasonal changes in frequency of observations in areas with marked changes in groundwater levels during the year (e.g. in water supply areas of tourist centres, areas with important water abstraction).

5.5.4 Evaluation of representativeness

This can be analysed at two different scales: regionally, related to the control of global gradients and trends of the whole aquifer, and locally, more related to impacted areas, for example for the control of the over-exploitation of aquifers in industrial areas or in zones where there is intensive pumping for municipal water supply purposes. It is obvious that groundwater quantity monitoring networks are directly related with quality problems and it must be taken into account in the evaluation of representativeness. Two examples illustrate the point: there is a risk of groundwater contamination produced by saltwater intrusion from downward leakage induced by pumping in areas where the cones of depression extend beneath estuaries or the oceans; and, the risk of horizontal saltwater intrusion in coastal aquifers in areas where there is an over-pumping situation.

The representativeness of a national (reference) piezometric network can be evaluated by calculating the contribution of each existing monitoring station in the geographic aquifer coverage. This can be made by building an indicator based on the spatial correlation between the stations. For instance a method such as kriging provides the estimation of an average value of a specific parameter (i.e. piezometry, temperature) over the whole aquifer, and also an associated estimation error, highlighting the areas with poor monitoring.

The indicator can be improved by incorporating information related to sampling frequency (by simple trend analysis methods) and to the particular features of piezometric surface on the over-exploited areas of the aquifer system (in relation to pumping wells). In order to analyse the spatial and temporal variability of the groundwater quantity parameters a synthetic seasonal piezometric index could be built, based on available information. The index could characterise different trend patterns of piezometric evolution.

With the present information provided by the EEA Members it is not possible to achieve the ultimate objective of this Task as described in the technical work programme. Therefore, the evaluation of the representativeness of the existing monitoring networks was carried out only as a very broad assessment. This is particularly evident for sampling density. In fact no information was reported on the probable clustering of observation stations, the type of impact areas (heavily exploited areas or areas particularly subject to interactions with other systems: rivers, sea, lakes, estuaries) and what groundwater regions are monitored.

5.6 International databases

The Agency’s policy on reporting on the state of the environment is to rely on existing data as much as possible in order to reduce the burden of additional sampling on Member States. A key part of designing a monitoring network is therefore to assess available data held for international monitoring programmes that already exist. This section summarises the findings of a review of international monitoring databases within the EEA (France *et al.* 1996). The review identified a total of 19 databases involved with inland water quality monitoring, these are given in Table 5.1 below.

Table 5.1 Summary of databases holding monitoring data from inland freshwaters of potential interest to the EEA.

Database name	Basic information
AMAP/Freshwater	Arctic Monitoring and Assessment Programme (AMAP) in freshwater systems. Monitoring of selected rivers and lakes of arctic countries. The European countries involved are Denmark, Finland, Iceland, Norway, Sweden and Russian Federation covering a total of four lake areas and eight rivers. Monitoring of heavy metals and persistent organic compounds is considered "essential" in the matrices sediment (in lakes), water and biota.
Bucharest/85	Water Quality Monitoring Programme for the Danube river, according to the Bucharest Declaration 1985. 22 sites are monitored along the river Danube by Austria, Germany and another eight countries outside the EEA area. Flow and quality parameters, such as nutrients, metals, aesthetic, biological, chemical, microbiological, organic pollution, physicochemical and synthetic organic parameters are monitored.
CORINE/WATER	CORINE INFORMATION SYSTEM/WATER. This system was created in the framework of the CORINE (Co-ordination of Information on the Environment) Programme (1985-90) and is maintained by the EEA. Quality and quantity data for rivers and coastal waters are held in a GIS for the EC countries. CORINE database also holds data from the EC Exchange of Information on the Quality of Surface Freshwater Decision and from the EC Bathing Water Directive monitoring activities.
EC Bathing Waters	Quality of Bathing Water, based on the Bathing Water Directive (76/160/EEC). Compliance with the parameters related to the quality of bathing water (aesthetic, microbiological, physicochemical and synthetic organic determinands) has been assessed every year in coastal and inland sites in the EU countries since 1987. For the 1994 campaign, a total of 5382 inland areas (rivers and lakes) were monitored.
EC Freshwater Fish	Implementation of the EC Freshwater Fish Directive (78/659/EEC). Compliance with parameters related to freshwater fish is monitored in the EC countries.
EEA -TF (Dobríš)	The Dobríš Assessment (first State of Environment Report for Europe 1995), prepared by the European Environment Agency Task Force in co-operation with the UN/ECE. A surveillance of water quality of European rivers has been carried out. Data on nutrients, metals, chemical, physicochemical and organic pollution indicators have been reported by fifteen EEA countries (at about 700 stations).

Database name	Basic information
Elbe/89	Water Quality Monitoring Programme for the Elbe river. 16 sites are analysed yearly in Germany, Czech Republic and Slovak Republic. Determinands assessed cover aesthetic, biological, chemical, physical, physicochemical, synthetic organic, organic pollution, microbiological, nutrients and metals.
EU Exchange/ Large rivers database	European Exchange of Information on the Quality of Surface Freshwater, based on the Council Decision 77/795/EEC of 12 November 1977. A total of 77 rivers in Europe are monitored in 12 countries (at a total of 125 stations). The determinands measured are: flow, metals, nutrients, and indicators of organic pollution, physical, physicochemical and synthetic organic.
EUROSTAT/Lakes & Rivers	Water Quality of Selected Lakes/EUROSTAT. Nutrients, metals, organic pollution, chemical and physicochemical parameters are reported by the EU countries from a total of 37 lakes and in 79 rivers since 1970.
FRIEND	FRIEND European Water Archive, (Flow Regimes from International Experimental and Network Data). Daily discharge at 3841 gauging stations of 30 European countries (it covers all the EEA area). It also contains detailed information about the catchment characteristics of the stations (lengths, slopes, base flow index, mean altitude, etc.)
GEMS/WATER	Programme for Monitoring and Assessment of Freshwater and Groundwater Quality (as part of the Global Environmental Monitoring System). A total of 76 rivers, 21 lakes and 9 groundwater sites are monitored in thirteen EEA countries.
GRDC/WMO	Global Runoff Data Centre (GRDC) database operates under the auspices of the WMO under the guidance of an international Steering Committee. The database holds daily and monthly runoff from 487 rivers (597 gauging stations) in Europe (which is considered as region 6 in the GRDC/WMO database) .
HYDABA/ICPR 1976	HYDABA is the database for the Rhine Action Programme. A wide range of synthetic organic, organic pollution, physical, physicochemical and chemical parameters, nutrients, metals and radioactivity are monitored every year by Germany, Netherlands, France and Switzerland at a total of 9 sites in the river Rhine.
JMP	The Paris Commission's monitoring and assessment activities are mainly carried out under the Joint Monitoring Programme (JMP), established by the Commission in 1978. The Joint Monitoring Programme is based on the Convention for the Prevention of Marine Pollution from Land-Based Sources (Paris Convention). Parameters measured metals, nutrients, physicochemical and synthetic organics in water.
LRTAP/ICP-IM	Integrated Co-operative Programme on Integrated Monitoring (ICP-IM) on Air Pollution Effects is part of the Effects Monitoring Strategy under the UN/ECE Long-Range Transboundary Air Pollution Convention. Five subprograms related to quality of freshwater and groundwater have been set up: groundwater chemistry (GW), runoff water chemistry (RW), lake water chemistry (LC), hydrobiology of streams (RC) and hydrobiology of lakes (LB). Data from a total of 50 areas in 32 European countries are held in the ICP-IM database coming from monitoring since 1982.
LRTAP/ICP-Waters	The International Co-operative Programme on Assessment and Monitoring of Rivers and Lakes aims to assess the effects from air pollutants in surface freshwaters according to the Long-Range Transboundary Air Pollution (LRTAP) Convention. The standardised programme assesses manganese, nutrients, sodium, sulphates and total organic carbon in water and also water levels. Data from 13 countries have being reported since 1982.
Regensburg/87	Water Quality Monitoring Programme for the Danube basin, according to the Regensburg Agreement 1987. 14 sites have been monitored by Austria and Germany in 8 rivers of the Danube basin since 1991. Metals, nutrients, biological, chemical, microbiological and physicochemical substances, radioactivity and synthetic organics are assessed yearly.
SIREN-IW/OECD	SIREN (System of Information on Resources and the Environment/Inland Waters) is the compilation of environmental data (published in the OECD Environmental Data Compendium every two years) based on the Recommendations adopted on 31st January 1991 by the OECD Environmental Committee. Water quality is assessed in 60 rivers (62 sites) and 29 lakes (29 sites) in all the EEA area (although there is no information from Iceland). Metals, nutrients and organic pollution are reported annually.
PLCs/HELCOM	The objective of the Pollution Load Compilations (PLCs) is to measure the direct inputs to the Baltic Sea from the land-based uses, (Helsinki Convention, 1974). Parameters include chemical, metal, nutrient, organic pollution and synthetic organics.
Mediterranean Action Plan (MAP)	UNEP undertook an assessment of land based inputs (including rivers) in 1984. More recently flux calculations have been undertaken on a more limited geographic scale under the auspices of the CEC EROS 2000 project.

Four different sources of information were used in order to identify international databases and combine them to produce a detailed database of data sources and information:

- Data relating to International Conventions agreed between the EEA countries, were drawn from the database developed in the project MW1.
- Published reports and other literature, e.g. PARCOM and Helsinki Commission reports, the Dobríš Assessment and UNEP publications.
- Information available on Internet.
- These data were supplemented by circulation of a questionnaire to key organisations.

The constructed database forms a partial catalogue of data sources pertinent to inland waters. It holds the history of monitoring for each country per database, the number of sites, monitored, water types sampled and the number of years of sampling. Additionally it details for each database; areas, regions specific water bodies and other related information that is available such as land use. It is envisaged that this database will provide essential information in selecting sites for the monitoring program.

Liaison with the ETC-CDS is now a priority to inform of the data sources that ETC-IW are aware of and to make them available to the EIONET.

6. EXISTING SOURCES OF MONITORING INFORMATION

Member States monitor water resources according to their national requirements (e.g. legal and operational) and international obligations (e.g. European Commission (EC) directives and International Agreements). The information arising from this monitoring is potentially a major source for the EEA.

The monitoring requirements associated with International Agreements and EC directives have been reviewed by the ETC/IW (Nixon *et al* 1996). The extent to which the information from this monitoring meets the needs of the EEA not only depends on how Member States implement and report the requirements of directives but also on the objectives of the directives. Existing national monitoring programmes have been discussed in Section 5 and have been inventoried and summarised by the ETC/IW: surface water quality (Kristensen and Bøgestrand 1996), surface water quantity, (Rees *et al* 1996) and groundwater quality and quantity (Koreimann *et al* 1996).

Although national monitoring networks are designed to meet their national and international obligations, statutory or otherwise, they also must meet other needs and objectives. For example, general surveillance data from a larger proportion (compared to that required by international statutory requirements) of the total national water resource may be required. Operational data, often at a sub-catchment level, may also be needed, for example, to monitor the impact of specific discharges on water quality. There will be obvious benefit, where possible, in replicating the purpose of sampling points and also in usage of the information obtained. It is likely, therefore, that monitoring networks associated with directive and international obligations will not represent the total monitoring networks of individual nations. For surveillance purposes, sample sites may be located in relation to changes in water quality, perhaps associated with point discharges or tributaries. Where there are gradual rather than discrete changes of quality, for example along a river, the optimum number of sample locations needed to define overall quality would be quantified through an assessment of the spatial and temporal variability of the determinands of interest in that river.

6.1 Monitoring required under EC directives

There are four types of directive used by the EC to control pollution of water. These are related to specific uses (e.g. Freshwater Fish Directive, 78/659/EEC) industry sectors (e.g. Titanium Dioxide Directive, 82/883/EEC), substances (e.g. Dangerous Substances Directive 76/464/EEC) and products (e.g. Detergents Directive, 73/404/EEC). With the exception of the products directives, most of these directives require the implementation of monitoring, either routine programmes or preliminary investigations.

The requirements made in directives have been designed largely independently from each other. The Commission has, however, taken some initiatives to harmonise monitoring requirements and reporting of results in the Exchange of Information Decision (77/795/EEC as amended by Directive 86/574/EEC) and in the reporting of implementation of certain directives as specified in the Reporting Decision (92/446/EEC).

There are 15 directives which require monitoring of fresh surface waters. Several of the requirements are not, however, for routine monitoring:

- the Drinking Water Directive (80/778/EEC) only requires monitoring of the source before exploitation;
- the Nitrates Directive (91/676/EEC) requires monitoring initially and then every four years to identify areas requiring protection: and,
- the Urban Waste Water Treatment (UWWT) Directive (91/271/EEC) (as for the Nitrates Directive.

Routine monitoring is required by:

- the Bathing Water Directive (76/160/EEC);
- the Dangerous Substances Directives (76/464/EEC);
- the Titanium Dioxide Directive (82/883/EEC);
- the Freshwater Fish Directive (78/659/EEC);
- the Exchange of Information Decisions (77/795/EEC and 86/778/EEC).

Therefore, the degree of coverage that water quality data encompasses within each country will be determined by national designations and the prevalence of the industries discharges that are required to be regulated.

Examples of the limitations of the information required by these Directives are given below.

6.1.1 Reporting directive

An example of the type of information provided by the Reporting Directive is the questionnaire for the Dangerous Substance and daughter directives. The questionnaire primarily requests information on numbers of authorisations for direct discharges into surface waters and sewers of List I substances and on the emission standards used for controlling direct discharges into surface waters and sewers. Information is also required on the monitoring stations used to monitor the impact of authorised discharges with annual average concentrations of the substance in the receiving waters, sediment and biota. Member States are due to complete the Reporting Directive questionnaires for the 1993 to 1995 period by September 1996 when a fuller assessment of the value of the information can be made.

6.1.2 Exchange of Information Decisions

The Exchange of Information Decisions (77/95/EEC and 86/574/EEC) established a common procedure for the exchange of information on the quality of freshwater. According to the Decisions, Member States measure 19 specified physical, chemical, microbiological and biological stations at 126 stations, located mainly on the large rivers (75 rivers) of Europe, and report the information to the European Commission each year. The Commission publish a summary of the reported data every three years. which aim to provide surveillance type information. Five EEA countries do not yet provide information under its auspices. The criteria by which rivers and sites are selected (other than large national rivers) are not specified in the Decisions and hence there are national differences in the selection procedure and the sites/rivers may not always be representative of general water quality in a country. The European States currently exchanging information under these decisions are listed in Table 6.1.

The main disadvantage of using just this information for EEA purposes appears to be that the rivers (and other water bodies) are not based on a representative sample of a country's large rivers, (by national standards) and could be biased towards the poorer end of the spectrum of qualities. In addition small rivers are not covered and other water quality issues (e.g. acidification) would not be addressed by this information. However the monitoring and reporting network is in place and States would be readily able to provide information for use by the Agency. If this route was developed then further work would be needed to ensure that submitted data were comparable: at present it is known that there are problems with the information exchanged (Kristensen and Codling, 1995). In addition, supportive information on human activities e.g. land-use, population density and catchment details would be required for the exploration of possible cause/effect relationships.

This database has now been merged with the rivers database created by the Agency's Task Force for the Dobříš assessment report. Though not all sites contained within the database will be relevant to the current EEA area, those sites that are could also be assessed for their representativeness.

Table 6.1 Number of sampling stations in each Member State from which information is required by the Decision and from which information was exchanged during the period 1990 - 1992.

Member State	Number of stations specified in the Decision	Number of rivers* specified in the Decision	Number of stations from which information was exchanged		
			1990	1991	1992
Belgium (B)	9	7	9	9	-
Denmark (DK)	4	4	4	4	4
Spain (E)	15	5	12	15	15
France (F)	16	5	16	16	16
Germany (DE)	12	8	12	12	12
Greece (GR)	6	6	6	6	6
Ireland (IRL)	4	4	4	4	4
Italy (I)	16	5	16	16	16
Luxembourg(L)	1	1	1	1	1
Netherlands (NL)	13	10	13	13	13
Portugal (PT)	13	7	13	13	13
United Kingdom (UK)	17	13	17	17	17
TOTAL	126	75	123	126	117

* taken to river systems/catchments

6.1.3 Freshwater Fish Directive

The EC has recently produced a report on the Freshwater Fish Directive (COM 1995a). The directive requires a national summary of:

- total number of designations of salmonid and cyprinid fisheries and how many of those comply with the standards associated with the directive.
- total length of rivers and area of lakes designated and complying with the directives requirements.
- total area of lakes designated/complying.

Fourteen parameters are required to be monitored but no numerical data are required to be reported to the Commission. Table 6.2 summarises Member State's implementation of the requirements of the directive. It shows that the information on salmonid and cyprinid fishery designations has been presented in 3 ways: as numbers, as percentages (of totals) and as lengths of river. Similarly some monitor all 14 parameters whereas others do not indicate which parameters are monitored or monitor different sized sub-sets. It will, therefore, be difficult to compare designations between States and there will be no quantitative information on the status of designated waters.

6.1.4 Bathing Water Directive

Information on the Bathing Water Directive is reported annually to the Commission and reports on national bathing water quality are produced by the EC. A summary of the information provided to the Commission on inland waters for 1994 is given in Table 6.3 (COM 1995b). National reports are able to be given but there is very little scope for comparison between Member States because of differences in how waters have been designated as bathing waters, in which parameters have been measured and in the number of samples taken to demonstrate compliance or otherwise.

Table 6.2 Summary of implementation of the Fisheries Directive in EU12 Member States (COM 1995a)

	B	DK	D	GR	ES	F	IRL	I	L	NL	PT	UK
Implemented	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y
Salmonid	25	49%	147	9	27	294	33	6	12	2	?	50,400 km
Cyprinid	130	30%	189	16	113	120	-	2	3	352	?	5,600 km
Parameters monitored	ND	All?	Sub-set	Core of 8	ND	ND	Core of 7	ND	All?	Core of 10	ND	All?
Reported	1	1	1	1	0	0	2	0	3	4	0	2

Notes:

B	Belgium	DK	Denmark	D	Germany	GR	Greece
ES	Spain	F	France	IRL	Ireland	I	Italy
L	Luxembourg	NL	Netherlands	PT	Portugal	UK	United Kingdom

Implemented	Has the requirements of the directive been implemented into national legislation
Salmonid	Designations as salmonid rivers
Cyprinid	Designations as cyprinid rivers
Parameters monitored	14 parameters given in directive
Reported	Number of times reported to European Commission

Table 6.3 Summary of Member States' reporting of requirements of the Bathing Waters Directive to the European Commission in 1994. (Number of samples taken as percentage of that required for assessment of compliance).

	Be	DK	D	GR	E	F	IRL	I	L	NL	P	UK
Number of sampling points	86	110	1915	4	310	1666	9	679	20	523	24	0
Total coliforms	91	96	58	100	100	91	100	98	85	22	79	--
Faecal coliforms	92	98	59	100	100	91	100	99	85	54	79	--
Faecal streptococci	95	19	11	100	79	99	89	100	55	6	83	--
Salmonella	64	0	28	0	56	4	33	30	0	2	79	--
Enteroviruses	0	0	3	0	29	0	0	1	0	0	0	--
pH	88	0	81	0	74	64	89	100	85	73	50	--
Colour	81	87	51	100	100	13	100	98	85	22	75	--
Mineral oils	87	98	56	100	100	35	100	99	85	23	79	--
Surface-active substances	88	98	55	100	100	34	100	99	85	30	46	--
Phenols	73	97	54	100	100	32	100	99	85	39	71	--
Transparency	88	0	49	0	100	24	100	98	70	37	4	--
Dissolved oxygen	53	0	23	0	44	14	56	100	85	37	0	--
Floating materials	88	81	41	100	68	3	56	0	85	32	71	--

Notes

B	Belgium	DK	Denmark	D	Germany	GR	Greece
ES	Spain	F	France	IRL	Ireland	I	Italy
L	Luxembourg	NL	Netherlands	PT	Portugal	UK	United Kingdom

6.1.5 Suitability for status assessment

As illustrated above the information required by the European Commission from Member States is primarily for assessing implementation of and compliance with directives rather than for the provision of information on the general status or quality of water resources. It is this latter type of information, provided in a comparable way from a representative sample of Europe's water resources, that is required.

Information from directives is not suitable as:

1. The data are not comparable because the degree of comparability will depend on the interpretation of the designation rules and national differences of how these are implemented.

2. The data are not representative because in the directives which require routine monitoring the requirements are generally site specific, either at sites designated for a specific use, sites affected by a specific discharge, or, for the Exchange of Information Decisions, agreed sites in main rivers. As the choice of sampling location is, for some directives, related to areas designated by the Member States rather than by the European Commission, it is unlikely that, for those directives, a comparison of quality across Europe of these designated waters will give a complete picture of quality.

Even for the Exchange of Information Decision where sites are supposed to be selected on the same basis the information is not representative because only large rivers are included.

6.2 International agreements

There are a large number of international agreements concerning surface waters, however, not all of these make monitoring requirements. Many agreements aim to protect a specific water body and are made between countries within the catchment of that water body. For large rivers and seas this can involve many countries, for example, the agreements made at the North Sea Conferences are made between all countries bordering the North Sea, i.e., Norway, Sweden, Denmark, the Netherlands, Germany, France and the UK. By contrast, there are many agreements which exist between just two countries**.** Thus the scope of application for international commitments varies greatly.

There are also other international organisations that some, if not all, EEA Member States are members of, or co-operate with, that either instigate monitoring programmes, or collect, collate, report and disseminate national monitoring data and information. For example, the Organisation for Economic Co-operation and Development (OECD) has developed a questionnaire on the State of the Environment which since 1988 has been jointly presented with that from EUROSTAT. Before 1992 the OECD concentrated on water abstraction and water consumption (with little breakdown by activities), pollution connected to sewage treatment plants, total polluted water discharged (without reference to its origin), and data on surface water quality for sample stations at the borders of Member States. In addition, EUROSTAT collects data on water quality indicators for selected rivers and lakes. In the last revision of the now joint EUROSTAT/OECD questionnaire on inland waters (during 1990-1991) more detailed questions on water resources and waste water treatment were added. In the questions concerning water abstraction, consumption and discharge, a limited breakdown into activities has been added and determinands have been redefined.

The United Nations Economic Commission for Europe (UNECE) has promoted international co-operation on water issues for over four decades. To meet the dual challenges of sustainable use of water and maintenance of acceptable environmental quality, the UNECE has adopted a number of declarations and decisions resulting from the work of its committee on water problems. These declarations and decisions are intended to provide guidance to UNECE member governments in formulating and implementing water management policies and should assist in fostering co-operation among UNECE Member States. The UNECE has recently developed (1992) the Convention on the Protection and Use of Transboundary Watercourses and International Lakes. The Convention has been signed by 25 European countries as well as by the EU, and will come into force 90 days after it has been ratified by 16 of these countries. The European Commission has made a proposal for a Council Decision (COM(93)271 final), which, if adopted would ratify the Union’s signature of the Convention. The Convention will require establishment of programmes for monitoring the conditions of transboundary waters, surface and groundwaters.

For international agreements sample location is generally related to the purpose of the agreement (e.g. monitoring transboundary water transfer) often being at designated or fixed sites. For example, designated sites are specified for the sampling of water, biota and sediment under the Helsinki Convention, and at fixed stations under the Rhine Convention, the Protocol for Technical Co-operation between Greece and Bulgaria, and the Treaty between Austria and Hungary on Water Economy. Other agreements are less specific about sampling location, perhaps being determined by the research or information needs of the signatories or research programme (e.g. the North Sea Task Force). For many agreements signatory states also have to decide upon exact locations, perhaps within guidelines provided by the relevant Commission, for example, as in the quantification of riverine loads for the Paris Commission. The sampling frequency specified in international agreements is also very variable within agreements and between agreements.

Information from International Agreements will be of use to the EEA. However:

- to be of use data will have to be comparable between the different agreements;
- data will represent only those waters covered in the agreements that is the major water bodies/catchments in Europe.

7. OPTIONS FOR THE BASIS OF THE EEA MONITORING NETWORK

7.1 Introduction

Section 4 described the different types of monitoring stations that are used throughout Europe. The many different types can perhaps be reduced by consideration of the information that they provide. To that end generic ‘types’ that would meet the information needs of the EEA were identified. In Section 5 an assessment of representativeness of current monitoring networks was undertaken. Section 6 describes why existing sources of information are not adequate for assessing the status of Europe’s water resources. This section outlines the main options available to the EEA in implementing a water resource monitoring network, in all likelihood, in a progressive way, learning and modifying the design as experience is gained.

7.2 Options for monitoring site/information selection

Having established that the Agency, at least in the short term, wishes to have a surveillance type monitoring network then there are a number of options on how this can be developed. These would include:

1. Use of current national classification schemes. A number of Member States that have their own general quality assessment schemes or classifications reflecting local national contamination levels/quality using national class limiting thresholds or rating values. These are often based on different indicator determinands, sampling frequencies, and reporting statistics. It is unlikely, therefore, that all national classes would be immediately transferable to a unified European classification scheme. However, the raw data used to derive the national classifications are likely to be more suitable for use in the EEA network if the data were able to be treated or aggregated in a consistent way. It should also be noted that the proposed EC Directive on the Ecological Quality of Water (now encompassed in the proposed Framework Directive on Water Resources) aims to introduce a common rating system across Europe so that different relative values of quality will be equivalent from one country to the next. In the case of river invertebrates national ratings may be able to be translated to a unified scale.
2. Sample and measure all water bodies in a consistent and comparable way which would clearly be very expensive to undertake and co-ordinate, and difficult to manage, interpret and report the resultant large quantity of information. It would probably also be unnecessary in terms of the additional information that would be obtained.
3. Sub-sample a **representative** portion of the total water resources. This would be aided by **stratifying** the total population (e.g. all rivers) into relativity homogenous sub-strata. In selecting the representative portion it would have to be ensured that a statistically biased sample was not being taken or else a ‘true’ spatial and temporal comparison across Europe would not be possible. This would be more difficult to

implement and would probably require a number of sequential phases. The first phase would be the initial selection of sampling sites and data requirements on all types of water body from a number of selected countries. Data from these would be obtained and statistically tested to modify the initial design so that optimum sampling density can be implemented. The revised monitoring protocol would then be progressively implemented in all EEA States.

Option 3 above is considered to be the best option in terms of cost-effectiveness and feasibility.

Stratification serves three purposes.

a) To increase the efficiency of the sampling network by dividing the rivers (say) within member states into more homogeneous subsets thus reducing the variability of the system and hence allocating sampling effort between the strata in some optimal way.

b) To ensure that data are collected for all relevant river types within a member state and to enable fairer comparisons of water quality between member states and regions of the EEA.

c) To attempt to ensure that statistics reported for member states and/or regions are 'representative' of the rivers present in those areas (that is reducing reporting bias).

The following sections outline how this approach has been used in the design of the networks.

7.3 Stratification of sample sites

At the broadest level inland freshwater can be categorised into three broad types, lakes, rivers and groundwater. In reality there would be different 'sub-types', for example, for rivers (headwaters, canals, lowland rivers) that would share certain physical, chemical and biological attributes or characteristics. The simplest level of network design would aim representatively to sample and characterise all these different types of inland waters. To do this fairly and comparably all water bodies must be representatively sub-sampled, both nationally and on a Europe-wide basis.

These assessments would result in such statements as *"over the last 5 years on average 'x' percent of river sites have shown a 'y' % decrease in nutrient levels"*. Such a broad assessment would entail the comparison of a very wide range of determinand levels over a wide geographic area and different water types. This type of assessment could then be related to general statements about the implementation of European policies that might have been responsible for the change but it might be more difficult to make more specific statements about human activities in regions or catchments. Trends could be followed and relative 'hot-spots' identified. It would also require that all water types are representatively sampled and quantified, for example headwaters, or that the number of sites used in the assessment relates to the variability of the system and determinand being monitored.

Often a statistical population (for example all rivers in Europe) can be subdivided into more homogenous sub-populations (for example, in the case of rivers, all 'small, high altitude' streams) and random site allocation can be applied to each sub-population separately. This is stratified random sampling, and it is the single most powerful sampling design that can be used. Stratified sampling is almost always more precise than simple random sampling. In stratified sampling the statistical population of 'N' units is divided into sub-populations which do not overlap and which together constitute the entire population. The sub-populations are called strata by statisticians.

To obtain the full benefit from stratification you must know the sizes of all the strata. In many ecological examples stratification is done on the basis of geographic area. It is not necessary to sample each stratum randomly and one could, for example, sample systematically within a stratum - however, it would be difficult to estimate how reliable such sampling is. Confidence intervals can be narrowed appreciably when strata are chosen well and precision is gained when relatively homogenous strata are selected. The critical factor is always to chose strata that are relatively homogeneous in relation to the differences between strata.

The allocation of site numbers in stratified sampling can be determined using proportional or optimal allocation. In proportional allocation sites are allocated to strata on the basis of a constant sampling fraction in each stratum. To use optimal allocation you need to have rough estimates of the variances in each of the strata and the cost of sampling each stratum. Optimal allocation is more precise than proportional allocation and is to be preferred. Cochran (1977) has shown that with optimal allocation the theoretical expectation is that:

Standard error (SE) (optimal) $\leq$ SE (proportional) $\leq$ SE (random).

There are three useful rules of thumb in stratified sampling (Krebs 1989). Take a larger sample (number of sites) if;

1. The stratum is larger;

2. The stratum is more variable internally;

3. Sampling is cheaper in the stratum.

It is also understood that the desire is to obtain an overview of the general quality of water resources of the EEA area in relation to human activities. Another option is, therefore, to stratify the sample sites and water types to reflect spatial differences in the potential causal activities impacting water resources and the differences in the inherent variability of water types and determinands. Potentially this would have the additional benefit of reducing the amount of variability within the sample data and hence make the network more cost effective in terms of monitoring costs. However, precise definitions and rules would be required to identify the different strata and the additional supportive and interpretative information to the selected appropriate water determinands. This supportive information (for example, stream order, catchment altitude, population density, land-use) would also need to be collected and presented in standardised ways, and this would be difficult to achieve technically in some countries in the short term.

The random selection of sites within strata will also be desirable even if it is from the sites currently being monitored by regional-water-authority-types organisations. The sites could also be randomly selected each year or reporting period, although this may not be so important. To make the network better, sub-strata need to be defined within each stratum to ensure that the sites selected are not over-representative of certain water types (e.g. if the local monitoring is only of dirty waters). These sub-strata could, for example, be defined as clean, medium or dirty sites; rural, suburban and urban sites; etc. (each in proportion to their relative abundances).

The number of sites should reflect the variability within regions or of certain water body types. The numbers should be based on the inter-site variability within the strata (i.e. intra-stratum variability), the required precision and confidence with which differences are to be detected, and the budgeted costs of the network. If the numbers of sites is determined for several determinands together, then the numbers should be calculated based on the most variable and/or important determinand.

Temporal comparisons are harder because there are less opportunities to get temporally different sampling occasions (there could only be 3 to 5 years per reporting period). However, the optimal numbers of sampling occasions could be calculated using temporal variability (say month-to-month variability) within sites within strata.

The accuracy of any statistic summarising the quality in each strata is also affected by certain types of variability in the data. However the variability which affects the accuracy is often different from that affecting the precision. Systematic variation such as biases due to measurement techniques or unaccounted-for seasonal variation cause estimates to be inaccurate. If steps are not taken to reduce or remove inaccuracies then there will always be the danger that comparisons made using these data will fail to detect differences which are really there because the biases mask them, or, conversely, report differences which are only due to the biases.

Biases can also creep into the comparison of statistics which will be made between different parts of the European area. These biases are systematic variations in the measures of water quality which would be there whether or not there was any interference on the part of man. For example, differences in catchment altitudes, stream orders, geological make-up and climate all have bearings on the ‘natural’ state of water bodies. In order that when comparisons are made they are not affected by this sort of bias, it is proposed that the water bodies in a member state are split up into separate categories (termed strata). The strata would be chosen so that the rivers they contain display similar characteristics, such as those mentioned in the previous example. Comparisons of one member state with another could then be done on a by-stratum basis, thereby only comparing rivers which should be roughly the same. If the sampling stations in each stratum are chosen randomly then aggregating their data will produce a fair indication of the state of the rivers in that stratum.

7.3.1 Numbers of sampling stations for quality status

As an example of the way in which the numbers of sampling stations ***may*** be specified consider the following. Suppose that it is required to be able to detect a difference between stratum means of size d with 95% confidence. The number of sampling stations within each stratum (assuming Normality of the mean) is given by

$$N = \frac{u_{95}^2 \sigma_h^2}{\delta^2},$$

where u_{95}^2 is the upper point of the Standard Normal distribution for two-sided tests, and σ_h^2 is the variance within the stratum. Assume that sampling stations are either reference or impact (not both) and their respective numbers are n_r and n_i, so that $N = n_r + n_i$. The optimal allocation of the total number of stations in the stratum, N, between reference and impact is given by,

$$n_r = \frac{N p_r \sigma_r}{p_r \sigma_r + p_i \sigma_i},$$

where p_r is the proportion of the stratum's total river length which can be counted as being of reference quality, and $p_i = 1 - p_r$.

The minimum detectable difference between the mean of the reference stations and the mean of the impact stations, with 95% confidence, will be

$$\delta_{r/i} = \sqrt{\frac{u_{95}^2 (p_r \sigma_r + p_i \sigma_i)}{N} \left(\frac{\sigma_r}{p_r} + \frac{\sigma_i}{p_i} \right)}.$$

The above example is one way of deciding on the numbers of sampling stations used to report quality. Different objectives for the reporting will result in different formulae for the numbers of sampling stations.

7.3.2 Numbers of sites for inter-strata comparisons

Comparisons between strata will involve the combination of the site statistics to make stratum summary statistics. For example, the overall stratum mean would be the mean of the individual site means from within the stratum. The number of sites within each regional strata (n_r) for inter-strata comparisons is given by,

$$n_r \geq \frac{2\sigma_r^2 {u_p}^2}{\delta^2}$$

where σ_r^2 is the intra-stratum variability (i.e. the variability of the stratum site statistics). This is ensuring a certain level of precision and confidence within each stratum. More sites will need to be sampled in regions with greater variability.

7.4 Ecological quality network

The proposed EC Directive on ecological quality of water (COM(93) 680 final) is a major new approach, focusing for the first time on protecting the aquatic ecosystem and water uses as a whole. The proposal is concerned with the adoption of measures to protect all surface waters (lakes, rivers, canals, estuaries and territorial waters) from both point and diffuse source pollution and other anthropogenic influences. The measures adopted must be designed to maintain and improve the ecological quality of waters, with the ultimate aim of achieving good ecological quality.

The main requirements of the proposal are to:

- Set up and introduce monitoring and classification schemes for determining the ecological quality of surface waters;
- Create inventories of point and diffuse pollution sources and undertake assessments of those sources;
- Define operational targets, in terms of good ecological quality, for all surface waters;
- Draw up and implement integrated programmes aimed at achieving the operational targets;
- Inform the public about the outcome of the above initiatives, including consultation over the improvement programmes, and to report on implementation to the Commission.

At least two aspects of the proposal, the monitoring requirements and inventories of point and diffuse sources of pollution, will be of interest and relevance to the Agency. Once established the national monitoring programmes required for this proposed directive will be a major source of information for the Agency. The monitoring will aim to cover a representative sample of the different water types and ecotypes found nationally and across Europe. The selection of reference sites, or reference conditions, indicative of high ecological quality will be crucial to the validity of the quality assessments made under the directive. There are, therefore, common themes between the EEA’s network and the ecological directive’s monitoring requirements.

8. PROPOSED RIVER MONITORING NETWORK

This section deals with the process by which sites could be selected by outlining the options that should be tested in the first phase of network implementation. It would be the intention that the site selection procedure would be modified where necessary in the light of experience gained in the pilot implementation during 1996. In addition, numbers of sites per station type have been given based on existing data sources, largely the review of current surface monitoring undertaken for DGXI and the Agency (Kristensen and Bøgestrand 1996).

The section has the following main recommendations.

1. The sampling sites to be included into the EEA network should be selected from the sampling sites in national monitoring programmes supplemented by additional sites to meet the requirement of the EEA. In cases where no national monitoring programmes exist, the sites to be included will, if possible, be selected from regional sampling sites.

2. The network should be a representative sub-sample of the inland water bodies of the EEA area.

3. The sampling sites to be included in the network should be selected so that they are representative of:

- the size/numbers/types of water bodies in the EEA area (e.g. lake surface area);
- the variation in human pressures (e.g. population density and land use);
- and should include a number of reference and flux sites.

8.1 Definition of river and monitoring station types

8.1.1 Types of river

If a stratified network design is to be used then there are aspects of the target population (e.g. all rivers in Europe) that require definition and identification. First the types of water body to be sampled needs to be defined. At present the emphasis in many States appears to be on the sampling of the most important rivers, lakes and aquifers in terms of, for example, their size, status or use (e.g. for drinking water). These water bodies are likely to be a small proportion of the total river or lake population in terms of length or surface area. In some countries smaller rivers and streams, especially headwaters, may not be so intensively sampled even though headwaters are very important ecologically and some would be particularly susceptible to the effects of acidification. The combined length of small streams would also be a large percentage of the total river length in a country.

Definitions will often be somewhat arbitrary because one is trying to classify into compartments what is, in reality in most cases, a continuum of types not discrete packages. However, for the purposes of this network we have defined rivers as small, medium and large. Their selection would ideally be based on their appearance on a 1:50,000 scale map but, practically, for many States would relate to 1:250,000 maps which have been digitised for GIS. Size of rivers may also relate to flow, width, stream order, catchment area or altitude. There are advantages and disadvantages with each of these often interrelated descriptors. In addition, the information associated with many of the descriptors is often not readily available.

Stream order appears to be a good option but would require the consistent use of the same scale maps in site selection. The EEA have undertaken a pilot study on digitising Europe's catchments on a 1:50,000 scale but such maps would not currently be available for most countries. Stream order (*sensu* Strahler) would then have to be defined on 1:250,000 scale maps. Small would equate to 1 to 3rd order, Medium to 4 or 5th order, and Large to 6th order or greater. Catchment area might also be a good indicator but there would be difficulty in defining a cut-off catchment area for small and medium rivers, for example. Also, catchment details may be missing for some countries. Altitude would be readily available from most maps and so it is suggested that for the pilot study rivers are to be characterised by a combination of stream order and altitude.

Morris and Kronvang (1994) estimated the river length for each country in the EEA area (using a sub-sample of areas from 1:50,000 maps where possible) (Table 8.1). On this basis, it was estimated that the EEA area contains approximately 2 million km of rivers which is equivalent to approximately 0.65 km per km^2 of the surface area of the EEA area. This estimate only applies to rivers significant enough to be mapped at 1:50,000 and artificial drainage ditches are excluded. The estimated river lengths from this study are generally 2 to 3 times greater than the countries report as the national river length. Ireland, for instance, reports its river length as 13,000 km compared to the 33,700 km estimate from the 1:50 000 maps.

Table 8.1 General characterisation of rivers and streams in the EEA area.

Country	Area (km^2)	River length[1] (L km)	Length per surface area (km-L per km^2)	River length given by countries	Number of river mouths[2]
Austria	83,855	47,000	0.56	100,000	0
Belgium	30,519	22,600	0.74	NI	6
Denmark	43,092	28,000	0.65	62,000	281
Finland	338,145	159,000	0.47	20,000	526
France	547,026	563,000	1.03	273,000	370
Germany	357,000	179,000	0.50	NI	184
Greece	131,957	NI	NI	NI	352
Iceland	103,000	NI	NI	NI	NI
Ireland	70,285	33,700	0.48	13,000	341

Table 8.1 continued

Country	Area (km²)	River length[1] (L km)	Length per surface area (km-L per km²)	River length given by countries	Number of river mouths[2]
Italy	301,268	136,000	0.45	NI	902
Luxembourg	2,586	1,330	0.51	NI	0
Netherlands	41,864	20,100	0.48	NI	27
Norway	324,219	210,000	NI	NI	1024
Portugal	91,949	172,000	1.87	NI	1137
Spain	504,782	172,000	0.34	NI	NI
Sweden	449,964	315,000	0.70	NI	702
United Kingdom	244,103	171,000	0.70	53,500	1362
EEA Area	3,665,614	2,200,000	0.65	-	7200

Notes:
NI No information
1 Based on 1:50,000 maps;
2 From Morris and Kronvang (1994) based on 1:200,000 or 1:250,000 maps

Table 8.2 gives an estimate of the number of rivers in the EEA area (excluding Iceland) with catchments of specified sizes. These could be used to stratify sampling sites according to the size of catchment area.

Table 8.2 Estimated distribution of rivers according to catchment area (based on estimates from Morris and Kronvang, 1994)

Catchment area (km²)	Number of rivers in the EEA area
>10,000	123 to 140
>5,000	280
>2,500	420 to 490
>1,000	800 to 1,200
>500	1,000 to 2,500
>250	1,500 to 4,200
>100	10,000

8.1.2 Types of monitoring site

The need for different types of monitoring site or station has been discussed in Section 4, and for the purposes of this section the following station types have been used.

1. Reference sites located on rivers in natural catchments with little or no human activity and with greater than 90% natural landscape. It is likely that such sites will not be present in some parts of Europe.

2. Baseline stations in the context of surface water quantity monitoring which may be required to characterise the generality of run-off behaviour of the region or country.

3. Representative sites that can give a spatial and temporal general assessment of quality and quantity across Europe.

4. Impact sites could form part of the representative network for the collection of supportive and interpretative information, or could form separate impact strata within which sites could be randomly selected. Impact networks could reflect general human activities, for example, urbanisation and agriculture, or more specific impacts such as acidification or saltwater intrusion into aquifers.

5. Flux sites established where rivers discharge into sea, or cross national boundaries, or there is interchange between surface and groundwater.

8.1.3 Examples of stratification options for rivers

Table 8.3 illustrates how a river sampling network might be stratified to provide information on the general quality of small, medium and large rivers. As described in previous sections there would also be a need for reference sites which would be selected randomly from all rivers that met the reference criteria. Flux sites would be selected on the basis of location in relation to transboundary water bodies, and in terms of discharges to sea, in relation to the river’s contribution to total loads. It is likely that many of the latter sites would be those currently used by International Organisations such as HELCOM and OSPARCOM for loads assessments into the Baltic and North Sea, respectively. Austria and Germany have also identified flux stations on the Danube river basin for the purposes of the Danube Commission. Flux sites would not, therefore, not be randomly selected.

Table 8.3 Potential low level stratification of rivers into target populations for sampling

Type of monitoring site	Relative size (1:250,000)	small rivers (1 to 3rd order)					medium rivers (4 to 5th order)					large rivers (6th order and above)				
Reference																
Representative																
Flux																

The sites representative of general quality identified in Table 8.3 could be established and later divided into different types of impact sites based on the supportive information gathered, e.g. land-use, catchment altitude, population density. The disadvantage here would be if areas impacted by different human activities were over or under representatively sampled. An additional layer or stratum could be added if part of the target population was not being representatively sampled, for example, a stratum based on altitude. Such a potential stratification is shown in Table 8.4. This should ensure that upland and lowland headwaters were representatively sampled.

The next, higher, level of definition of strata (Table 8.5) might include differentiation between impacted and non-impacted sites, and within impacted sites between different causal activities, land-use, population etc. Each additional strata would increase the need for supportive information by which the target population can be defined, and for definitions such as what population density represents an urbanised catchment, what proportion of agricultural use a predominately agricultural catchment, the predominant agricultural use, a forested catchment. These definitions would require the assistance of other EEA Topic Centres and may require revision in the light of experience with the network developed during pilot implementation.

Table 8.4 Potential mid-level stratification of rivers into target populations for sampling

Type of monitoring site	Relative size (1:250,000)	small rivers (1 to 3rd order)					medium rivers (4 to 5th order)					large rivers (6th order and above)				
	Relative European altitude (class)	a	b	c	d	e	a	b	c	d	e	a	b	c	d	e
Reference																
Representative																
Flux																

Altitude classes: a = >800 m b = 500 to 800 m c = 200 to 500 m
d = 100 to 200 m e = <100 m

Within impact networks there may also be a case of establishing upstream and downstream sites for comparison purposes. This would be relatively straightforward in the case of large towns and cities but more difficult for more diffuse sources such as from agricultural land. In the latter case they might be established where there is a significant change in land-use. In all cases sites should be located downstream of point sources of contaminants e.g. sewage works discharges and at a point where the effluent has become fully mixed within the flow, in other words downstream of the mixing zone. The latter varies with river discharge and as such should be established at the worst case conditions. Europe's largest and most important rivers would presumably be included in the flux stations as most would be industrialised and urbanised and potentially the most polluted.

There may also be a case for stratification on a regional basis reflecting biogeographic or hydrological regions of Europe.

Table 8.5 Potential high level stratification of rivers into target populations for sampling

Type of monitoring site	Relative size (1:250,000 map)	small rivers (1 to 3rd order)					medium rivers (4 to 5th order)					large rivers (6th order and above)				
	Relative European altitude (class) →	a	b	c	d	e	a	b	c	d	e	a	b	c	d	e
	Catchment/reach characteristics ↓															
Reference or baseline	natural (little or no human activity, >90% natural landscape)															
Representative sites divided according to type/source of impact																
- Impact	urbanised a) with towns > 2,000 inhabitants or >50 inhabitants/km²															
	b) heavily urbanised >100,000 inhabitants or >100 inhabitants/km²															
- Impact	rural - with towns < 2,000 inhabitants < 50 inhabitants/km²															
- Impact	agricultural															
- Impact	forested															
Flux	Tidal limits, transboundary rivers, lakes															

Altitude classes
a = >800 m b = 500 to 800 m c = 200 to 500 m
d = 100 to 200 m e = <100 m

8.1.4 Selection of strata and sites

In the approach described above the selection of strata and sites could proceed through the following steps. The numbers of river reaches/river lengths meeting the criteria associated with each of the matrix cells in Tables 8.3 to 8.5 would be defined. This would ideally involve a comprehensive (probably GIS) database of the national river network. A reach here is defined as the portion of a river that meets the stream order criteria. Not all countries would have entries into each cell of the matrix. For example relatively flat countries would not have altitude categories a and b (Table 8.4) and some may not have reference sites.

As a first estimate ten percent of the river reaches/lengths would then be randomly selected. The current national monitoring site database would then be interrogated to determine how many and which sites appear in each of the selected reaches. In many cases it is likely that several sites would appear on the same reach. These may be located in relation to differences in quality along that reach. The most downstream site per reach should be selected provided that other criteria such as being downstream of mixing zones are met. Other reaches may not have any current sites at all. These gaps would be noted, and if possible as an interim measure, sites from similar reaches would be selected.

Flux sites should be included in the representative site selection but would also be treated and selected separately as flux sites based on existing international requirements.

This procedure would potentially identify gaps, for example if current networks did not adequately cover all small headwater rivers or reference conditions. Where possible all existing national monitoring sites would be used.

As an alternative to selecting river lengths or reaches, existing national or regional monitoring sites could be selected by the strata criteria. This would not give such a representative view of total river resources but might be more easily implemented in the short term. However, there would be a need to fill these gaps in progressively as the networks change to become more representative.

8.2 Indicative example of site selection for rivers

Section 8.1 has described how a representative stratified monitoring network might be established for rivers and this should perhaps be the longer-term aim of the EEA network, and be developed as more information and experience is obtained to test the validity and practicalities of the design. In this section a stratified network is again suggested which could be used as the basis for developing the higher level network described in Section 8.1.

A general surveillance network to obtain information on the general quality of rivers would consist of:

1. A basic network containing 1,781 rivers, made up of around 1,425 (80%) representative and 356 (20%) reference rivers. A reference river would be in a catchment with little or no human activity and the percentage of natural landscape would be higher than 90%. A representative river should reflect the majority of rivers in a region with human activities in the catchment consistent with the region’s activities. These rivers would be selected on the basis of 1 river site per 2,000 km^2 surface area. This density is that typically found across Europe (Kristensen and Bøgestrand 1996).

2. An impact network consisting of 1,588 rivers selected on the basis of population density such that in catchments with:

    - < 50 inhabitants/km^2 there would be 1 river per 10,000 km^2, and
    - between, 50 and 100 inhabitants/km^2, 1 river per 3,000 $km^{2,}$ and,
    - > 100 inhabitants/km^2, 1 river per 1,000 $km^{2.}$

3. The largest and most important rivers in the EEA area comprising approximately 650 in total. In the EEA area there are approximately 450 rivers with a catchment area greater than 2,500 km^2. In addition, the most important or well-known rivers/canals in each country should be included. These would also likely include

those rivers currently monitored for the Exchange of Information Decisions (see Section 6.1.2).

4. Flux stations. All monitoring information from those sites currently being used for the assessment of international transboundary loads or loads entering Europe's Seas should be included in the network. Some of these are likely to correspond to those included in (3) above. There are obviously prime sources of existing information for these sites particularly those in relation to the work of HELCOM and OSPAR quantifying riverine loads entering the Baltic and North Atlantic (104 rivers), respectively. However, methodologies would have to be assessed to determine whether valid comparisons could be made or, at least, any differences identified.

This potential network in summarised in Table 8.6.

Table 8.6 Approximate number of rivers per country in a general surveillance network

Country	Area (km^2)	Representative rivers 1 per 2,000 km^2	Impact rivers	Total*
Austria	83,855	42	38	80
Belgium	30,519	15	31	46
Denmark	43,092	22	17	39
Finland	338,145	169	41	210
France	547,026	272	230	502
Germany	357,000	179	357	536
Greece	131,957	66	34	100
Iceland	103,000	51	NI	at least 51
Ireland	70,285	35	23	58
Italy	301,268	151	283	434
Luxembourg	2,586	1	3	4
Netherlands	41,864	21	40	61
Norway	324,219	162	33	195
Portugal	91,949	46	47	93
Spain	504,782	253	161	414
Sweden	449,964	225	59	284
United Kingdom	244,103	122	191	313
EEA Area	3,665,614	1,832	1,588	3,420

Note:
NI No information
* Excluding flux stations and nationally large rivers not included in other categories

8.3 Selection of sites for surface water quantity monitoring network

Europe has a dense network of flow measurement stations, approximately 19,000 at an average density of 1 per 270 km^2. As has been indicated in an earlier section it is recommended that a hierarchy of monitoring stations is established from which surface water quantity data can be obtained and these, where possible, should utilise existing national gauging networks. The hierarchy of stations are:

- Reference stations that characterise regimes in catchments undisturbed as far as possible by man.
- Baseline stations which, in total, characterise the generality of runoff behaviour of the region or country and whose data are appropriate for the transfer of hydrological characteristics to ungauged sites.
- Representative stations that are a subset of the network to provide summary estimates of the regional or national picture. Typically, these sites will have long records to provide a good historical perspective.
- Impact sites that record and characterise the effects of man's interference with the natural regime.
- Flux stations which when used in conjunction with water quality measurements can be used to quantify loads of contaminants entering Europe’s seas or crossing international boundaries. It is likely that this latter type of station may well also meet the criteria of some of the other stations and hence may serve a dual purpose.

The recommended types of monitoring station/site for surface quantity and quality monitoring are compared in Table 8.7. Some types would ideally be synoptically located as close together as possible, for example for flux/load determinations. Others appear to have a common aim but may not have to be synoptically located on the same river. In the case of impact sites there may be again a case for locating quality and quantity sites as close as possible. There appears to be no equivalence between the baseline stations which might have to be selected independently of surface quality stations. It would appear that the representative and impact sites would equate to the general surveillance sites from which supportive data would be acquired to identify sites with different impacts and levels of impact.

It is recommended for the pilot implementation of the network that the same selection procedure is applied to the surface quantity network as for the river quality network. Where possible quality and quantity sites would be selected at the same location or at least on the same river reaches. Baseline sites should be selected independently. The numbers and density of stations should be based on the variability of the systems being monitored and the desired precision and confidence of the information supplied.

Table 8.7 Comparison of types of monitoring station/site for surface quantity and quality monitoring

Surface quantity → / Surface quality ↓	Reference	Baseline	Representative	Impact	Flux
Reference	≅	✗	✗	✗	✗
Representative	✗	✗	≅	≅	✗
Impact	✗	✗	≅	✓	✗
Flux	✗	✗	✗	✗	✓

✓ synoptic sites
✗ no overlap
≅ equivalent purpose, though specific sites may not have to be synoptic

8.4 Sampling frequency

According to the inventory of river quality monitoring (Section 5.2.1) most monitoring is undertaken annually with a sample frequency ranging from 4 to 26 samples per year. The statistical aspects of sampling frequency and sample numbers are discussed in Appendix A in particular in relation to how the information is to be reported. It is recommended that at least for the pilot implementation study that assessments are taken on data obtained over the whole year, spread approximately evenly over that period (e.g. monthly). In addition, long time series (monthly or more frequent) data should be obtained from a range of hydrological river types to assess relatively short term (e.g. monthly, seasonal) and longer term (yearly) variability. This would enable a more rational sample frequency to be established and take into account problems such as rivers drying out in summer in some countries.

8.5 Selection of determinands

The issues which the Agency may wish to address when determining the state of inland waters have been defined according to the following categories:

- ecological quality;
- acidification;
- nutrient status;
- pesticides;
- heavy metals;
- organic pollution;
- pathogens;
- water availability;
- physical intervention.

Table 8.8 lists the importance of the information required according to water type.

Through previous Tasks in the work programme it has been possible to identify determinands which would provide useful information for these categories. The determinands have been selected on the following basis:

- they are commonly measured under international agreements; and/or,
- they are commonly measured in national programmes.

Table 8.8 Information requirements for each water type

Information required	Rivers	Lakes	Groundwater
ecological quality;	✓✓✓	✓✓✓	
acidification;	✓✓✓	✓✓✓	✓✓✓
nutrient status;	✓✓✓	✓✓✓	✓✓✓
pesticides	✓✓	✓✓	✓✓✓
heavy metals;	✓✓✓	✓✓	✓✓✓
organic pollution;	✓✓✓	✓✓	✓✓
pathogens;	✓✓✓	✓✓	✓✓
water availability	✓✓✓	✓	✓✓✓
physical intervention.	✓✓✓	✓✓	

Notes: ✓✓✓ Key
✓✓ Important
✓ Useful

Table 8.9 lists the suggested primary determinands, that is those that are essential, and secondary determinands, that is those which would be useful but not essential, that would provide useful information to answer specific problems or issues. It should be noted that pesticides, other synthetic organic substances and heavy metals would be selected on the basis of their use in the catchment of interest.

Supportive determinands used to interpret the information listed above for example, salinity when measuring DO in estuaries, land-use, population in catchment will also be required. It is recommended that other Topic Centres, such as that on Land Cover, are consulted about which indicators are most appropriate for quantifying human activities.

Table 8.9 List of suggested primary and secondary determinands required for the river and lake monitoring networks

Indicator determinands ↓	**Problems/issues →**	**EQ**	**AC**	**NS**	**TS**	**OP**	**WU**	**RA**	**PI**	**FL**
	Examples of indicators ↓									
Biological indicators	Macroinvertebrates, Fish Phytoplankton, Chlorophyll	✓✓	✓✓	✓	✓	✓	✓	✗	✓✓	✗
Descriptive determinands	Dissolved oxygen, pH, Alkalinity, Conductivity, Temperature, suspended solids	✓	✓✓	✓	✓	✓✓	✓✓	✗	✓	✓ (ss)
Flow	Flows, levels	✓✓	✓	✓	✓	✓	✓✓	✗	✓✓	✓✓
Additional determinands	Biochemical oxygen demand Chemical oxygen demand Total organic carbon, Secchi disc, Aluminium fractions	✓	✓✓	✓	✗	✓✓	✓	✗	✗	✗
Nutrients	Total phosphorus, Soluble reactive phosphorus, Nitrate Nitrite, Ammonia, Organic nitrogen, Total nitrogen	✓	✗	✓✓	✗	✓	✗	✗	✗	✓✓
Major ions	Calcium, Sodium, Potassium, Magnesium, Chloride, Sulphate, Bicarbonate	✗	✓✓	✗	✗	✗	✓	✗	✗	✗
Heavy metals	Cadmium, Mercury Based on catchment/land-use	✗	✗	✗	✓✓	✗	✓	✗	✗	✓✓
Pesticides	Based on catchment/land-use	✗	✗	✗	✓✓	✗	✓	✗	✗	✓✓
Other synthetic organic substances	PAH, PCBs Based on catchment/land-use	✗	✗	✗	✓✓	✗	✓	✗	✗	✓✓
Microbes	Total and faecal coliforms, Faecal streptococci, Salmonella, Enteroviruses	✗	✗	✗	✗	✓✓	✓	✗	✗	✗
Radionuclides	Total alpha and beta activity Caesium 137	✗	✗	✗	✗	✗	✗	✓✓	✗	✓

Key to problems/issues
EQ Ecological quality
AC Acidification
NS Nutrient status
TS Toxic substances
OP Organic pollution
WU Water use and availability
RA Radioactivity
PI Physical intervention
FL Fluxes

Key to importance:
✓✓ Key determinands - primary
✓ Important but not key determinands - secondary
✗ Not considered as essential

Other:
ss Suspended solids

9. PROPOSED LAKE/RESERVOIR MONITORING NETWORK

9.1 Introduction

Most of 400,000 lakes in the EEA area are in Norway, Sweden and Finland. The majority have a surface area less than 0.1 km^2 (Table 9.1). Lake water depth is also an important parameter with which to characterise the lake environment. It is largely determined by the surrounding topography, lakes in mountainous regions generally being deeper than lowland areas. In lowland countries (e.g. Finland) the majority of lakes have a mean depth less than 10 m. In Austria, in contrast, large shallow lakes, with one exception (Lake Neusiedel) are absent, and most lakes have a mean depth greater than 25 m. As with natural lakes, the deepest reservoirs are located in valleys in mountainous regions.

Table 9.1 Number of lakes in the EEA countries

Country	**Surface area(km^2)**				
	0.01-0.1	**0.1-1**	**1-10**	**10-100**	**>100**
Austria	some hundreds		19	7	2
Belgium	only a few lakes				
Denmark	354	256	74	6	0
Finland	40,309	13,114	2,283	279	47
France	NI	128	23		1
Germany	NI	NI	~100	~20	2
Greece	NI	NI	NI	>16	1
Iceland	7000	1650	176	17	0
Ireland	NI	NI	~100	14	3
Italy	NI	>168	>82	13	5
Luxembourg	NI	NI	NI	NI	NI
Netherlands	NI	NI	NI	47	3
Norway	208,000		2,000	450	7
Portugal	NI	NI	NI	NI	NI
Spain	NI	NI	NI	800	
Sweden	59,500	19,374	3,990	358	22
United Kingdom -England and Wales -Scotland -Northern Ireland	 1,665		 50	 2	 0 1
EEA area first estimate	~300,000	~100,000	~15,000	~2,000	~100

Note
NI No information at present

9.2 General surveillance network

It is proposed that there would be a general surveillance network (Table 9.2) and would comprise:

1. A basic network containing around 1,000 water bodies, 200 of which would be reference lakes and 800 representative. These would be selected at a density of one per 3,500 km^2. The definition of representative and reference lakes would be as for rivers. At this density there will be for most countries at least one lake in each of the national administrative regions. National administrative regions typically have a land area between 2,000 to 35,000 km^2.

2. An impact network containing 800 lakes, selected on the basis of population density to put more emphasis on water bodies in densely populated areas than in sparsely populated areas. Therefore, in catchments with a population density of:

   - < 50 inhabitants/km^2 there would be 1 water body per 10,000 km^2, with,
   - 50-100 inhabitants/km^2, 1 water body 5,000 km^2, and with
   - > 100 inhabitants/km^2, 1 water body per 2,500 $km^{2.}$

3. The largest and most important lakes in the EEA area, equating to around 200 water bodies. There are approximately 100 water bodies with a surface area greater than 100 km^2. In addition, the most important or well-known lakes/reservoirs in each country should be included (for example, lake Windermere, Loch Ness, Lake Lugano).

In addition, there may be a need for a specific cause/effect network to assess specific problems such as acidification and eutrophication. This would be made up of a subset of reference lakes and impacted lakes in specific areas. The need for such a specific lake network should be assessed during the pilot implementation.

9.3 Sampling frequency

As for rivers, ideally statistical testing of monitoring data should be undertaken to determine the optimum sample frequency (see Appendix A). It is recommended that this is undertaken during the pilot implementation project, if possible. However as an interim guide samples should again be taken over a year, with between 6 and 8 samples taken over this period. The lakes in the representative network should have been surveyed at least once in each reporting period and those in the specific temporal/cause and effect network surveyed every year.

9.4 Selection of determinands

The recommended groups of determinands for the river and lake networks are given in Section 8.5, (Table 8.9).

Table 9.2 Approximate number of lakes per country in the general surveillance network

Country	Area (km^2)	Basic network 1 per 3,500 km^2	Impact network	Lakes with surface area >100 km^2	Total*
Austria	83,855	24	20	2	46
Belgium	30,519	9	12	0	21
Denmark	43,092	12	10	0	22
Finland	338,145	97	35	47	179
France	547,026	155	123	1	279
Germany	357,000	102	141	2	245
Greece	131,957	38	22	1	61
Iceland	103,000	29	NI	0	at least 29
Ireland	70,285	20	14	3	37
Italy	301,268	86	116	5	207
Luxembourg	2,586	1	1	0	2
Netherlands	41,864	12	17	3	32
Norway	324,219	93	33	7	133
Portugal	91,949	25	23	NI	48
Spain	504,782	144	92	NI	236
Sweden	449,964	117	49	22	188
United Kingdom	244,103	70	82	1	153
EEA Area	3,665,614	1005	790	94	1889*

Note

NI No information at present

* Excluding the most important lakes in each country

10. PROPOSED GROUNDWATER MONITORING NETWORK

10.1 Selection of sites for groundwater monitoring network

There are two important features that distinguish groundwater from surface waters which need to be considered when designing a monitoring network for groundwater quality and quantity. These are:

- the slow movement in groundwater with relatively large residence times; and,
- the considerable degree of physicochemical and chemical interdependence between water and material of aquifer.

The spacing of the observation wells in the groundwater quality network will depend on the strategy for differentiation between diffuse and point pollution stations, between national and regional stations and with the differences between principal networks, specific networks and temporary networks. The criteria for a monitoring network are very important for the evaluation and comparison of the data. If there is a need to evaluate data from all over the EEA area, the sampling sites should be chosen by the same criteria. If they are not, a consistent report is probably impossible. While minimum densities for groundwater have not been developed, other guidance on station location and sampling may be provided. The density of observation wells in a groundwater network depends on:

- The size of the area or country.
- The geological and hydrogeological complexity of the area.
- The geological and hydrological setting and sizes of the main aquifers.
- The land use of the area.
- The admittance to the area and the possibilities for agreeing the establishment of the stations with the land owners.
- Existing monitoring systems.
- The objectives and time limits of the network.
- Financial limitations for establishment of the network and for routine groundwater sampling through time.

The main general demands of the network are:

- All main aquifers should be observed. These aquifers are defined according to the geological information and the known groundwater resources of the area.
- The distance between the observation wells will depend on the geological conditions.
- The network should be based on existing wells in the area from which, valid hydrogeological information can be extracted. Wells drilled for all different purposes can be used depending on the completion programme for the wells. The

use of existing wells will reduce the cost of drilling and installation of observation devices.

- It is important also to monitor aquifers that at the time are not being used for groundwater abstraction, both shallow and deep aquifers.

Areas with a high rate of infiltration should be monitored more intensively.

A groundwater quality observation station should be able to monitor the general composition of the groundwater with different types of contaminants. Principally there are different sources of contaminants: diffuse sources arising from the atmosphere; diffuse sources from land use, (e.g. from farming); and, point sources such as landfills, contaminated sites and leaking sewer-systems. These three sources need a different approach to the design and establishment of suitable monitoring networks.

It is important to confirm that the monitoring wells which are chosen for the EEA network have been designed and constructed in the same way so it is possible to compare the results from all the Member States. It is also important that all the selected wells are described in detail both concerning the criteria and the technical design. Stations are considered similar whatever network they serve.

10.2 Proposed network

For groundwater the following is proposed.

1. Monitoring station selection should be based on existing national monitoring networks.

2. Where possible all nationally important aquifers (groundwater in porous media, karst groundwater and others) should be covered. The importance of aquifers could be defined with respect, for example, to quantity and/or quality, spatial extension, actual or planned use.

3. The selected monitoring stations within these selected aquifers should be distributed in a more or less regular geometric pattern and, as a rule, with a density of at least 1 site per 20 to 25 km^2 of aquifer.

4. In special cases a less intensive density of sampling stations is acceptable. This might be especially so in large similar hydrogeological structures with only low impacts (e.g. low density of population, small portion of arable land, mostly forests and grasslands, no serious point sources). In spite of their potential high vulnerability this may also be considered for karst areas.

5. The selected monitoring stations should not be exclusively based on drinking water abstraction points (drinking water abstraction is usually concentrated in a few least impacted areas) and on stations monitoring extremely local hotspots of contamination as they would not provide comparable information on a Europe-wide scale.

Table 10.1 summarises (based on best available information) the extent of groundwater monitoring undertaken in EEA Member States (Koreimann *et al*. 1996). It indicates that for the interim network there may be major spatial gaps in the information available.

Table 10.1 Summary of the extent of groundwater monitoring undertaken in EEA Member States

	Total number of monitoring stations in			Total area of groundwater media (km^2)			Monitoring station density (no. per km^2) in		
	porous media	karstic media	other media	porous media	karstic media	other media	porous media	karstic media	other media
Austria	1600	450	*	17000	*	*	11	*	*
Belgium	*	*	*	*	*	*	*	*	*
Denmark	1100	*	*	43216	*	*	39	*	*
Finland	20		30	35	*	30	2	*	1
France	16112	2490	20480	*	*	*	*	*	*
Germany^	2378	80	327	45900	13200	62245	19	165	190
Greece	*	*	*	*	*	*	*	*	*
Iceland	*	*	*	*	*	*	*	*	*
Ireland	*	*	*	*	*	*	*	*	*
Italy	*	*	*	*	*	*	*	*	*
Luxembourg	*	*	*	*	*	*	*	*	*
Netherlands	375	*	5	35000	*	*	93	*	*
Norway	21	*	*	*	*	*	*	*	*
Portugal	74	*	*	*	*	*	*	*	*
Spain	1147	408	1377	79258	54628	38644	69	134	28
Sweden	*	*	*	*	*	*	*	*	*
United Kingdom	346	270	1920	13534	11004	75219	39	41	39

^ Summed data from 3 Länder
* No information

The aim will be to develop a fully statistically representative network for groundwater quality and quantity assessment. In particular the potential gaps in information (Table 10.1) will need to be addressed in the development of the network and the statistical basis of the suggested optimum density of monitoring stations (1 per 20 or 25 km^2) should be further statistically assessed. In addition the applicability of the concept of establishing reference stations in aquifers not affected by human activities will be assessed. Reference stations would be in areas not influenced by groundwater pumping and other anthropogenic activities. In some areas within the EEA (small countries or in densely populated areas) it will not be possible to establish such stations.

10.3 Sampling frequency

The frequency of observations depends on the type of information required, the inherent variability in quality and quantity, and the desired precision and confidence in the results (see Appendix A). When a groundwater network is established, it is often necessary to frequently sample and analyse the groundwater during the first year. When the overall characteristics of the aquifer have been quantified, the optimum sampling frequency can be determined. Also, the variation of quality with the depth of the aquifer should also be considered.

For the proposed general surveillance type network, a sampling frequency of twice a year should initially be assessed. One sampling would ideally have been conducted during a period of high ground water level, that is at the end or immediately after a period of high infiltration and recharge of the reservoir. The second sampling would be at a period of low ground water level, that is at the end of a period of minimum infiltration or maximum abstraction. This sampling schedule relates to groundwater reservoirs relatively close to the surface. When deeper reservoirs occur at the same sampling station they should be sampled at the same time as the shallower ones. In areas of very rapid infiltration like karst-areas other guidelines might be applied, e.g. modified according to seasonal exploitation in water supply areas of tourist centres.

10.4 Selection of determinands

10.4.1 Groundwater quality

The quality parameters on which information might be required can be divided into seven groups (Table 10.2).

1. Descriptive parameters;
2. Major ions;
3. Additional parameters;
4. Heavy metals;
5. Organic substances;
6. Pesticides;
7. Microbes.

Groups 1, 2 and 3 are, at present, measured in all countries with an observation network. Group 4, 5 and 6 are only measured in a few of the EEA countries. The types of parameters included in a programme depend on the purpose of the monitoring network. Group 4 and 5 are important in monitoring programmes on point pollution as landfills and contaminated sites, while Groups 4 and 6 are specially important for diffuse pollution from farming. The number of analysed compounds within each group depends on the purpose of the network and on the economy.

Table 10.2 List of suggested determinands required for the groundwater quality monitoring network

Group		Determinands
1	Descriptive determinands	Temperature, pH, DO, (EC).
2	Major ions	Ca, Mg, Na, K, HCO_3, Cl, SO_4, P_{04}, $NH_{4,}$ NO_3, NO_2, Total organic carbon
3	Additional determinands	Choice depends partly on local pollution source as indicated by land-use framework
4	Heavy metals	Hg, Cd, Pb, Zn, Cu, Cr. Choice depends partly on local pollution source as indicated by land-use framework
5	Organic substances	Aromatic hydrocarbons, halogenated hydrocarbons, phenols, chlorophenols. Choice depends partly on local pollution sources as indicated by land-use framework.
6	Pesticides	Choice depends in part on local usage, land-use framework and existing observed occurrences in groundwater.
7	Microbes	Total coliforms, faecal coliforms

As a basic requirement the descriptive and major ion determinands should have been measured at each sampling site. For the other determinands it is proposed that a framework for relating determinand selection to land use and hence anticipated groundwater quality should be used. Eight activities or types of land-use can be identified as potentially affecting groundwater quality; additional categories may be proposed by Member States after consultation. These are:

- rural arable (includes horticulture, intensive grassland and animal grazing);
- rural sheep;
- rural moor;
- orchards;
- vineyards;
- forests;
- urban/suburban;
- industrial;
- railways;
- airfields.

The most appropriate determinands would then be selected for each aquifer land-use type.

10.4.2 Groundwater quantity

The universal measure of groundwater quantity used in all countries in the EEA is the piezometric level. In karstic aquifers the discharge rate is also important. Both determinands should, therefore, be included in the monitoring information.

11. MONITORING METHODOLOGY

It is not the intention to go into great detail here on the different methodologies used to sample water bodies. However, there is a basic need to incorporate quality control and assurance procedures described in the next section into the taking of samples or into making measurements. This applies equally to quality and quantity measurements, and also to chemical, physical and biological determinands. Mistakes or inconsistencies at this stage can invalidate data as much as poor quality control in the laboratory can.

For chemical monitoring three basic methodologies of obtaining samples can be identified.

1. Discrete manual sampling, in which samples are taken from a water body manually and generally transported to another location for analysis. Such samples represent snapshots in time and space.

2. Discrete or cumulative automatic sampling. Instead of taking samples by hand, machines are programmed for the collection of different sized samples for discrete or cumulative samples collected over a pre-set time span. Again these samples will be snapshots in space but can be more representative of quality/quantity over a time period.

3. Continuous on-line monitoring where a suitable measuring device is placed directly into the water to obtain a measurement, or a sample of the water is pumped to a bankside measuring device. The process is automated, and results and information can be telemetered to a central control location. Continuous monitoring can give real time information and, potentially, also over long time periods. They are widely used as early warning or control monitors, for example, for the detection of step changes in quality perhaps in relation to pollution spills. The use of continuous on-line monitors is often a balance between the value of (near) continuous data, and the cost of constructing and maintaining the instruments at a level where the data are known to have the required accuracy and precision. Continuous monitors are discussed in more detail in Appendix B.

With all of these methodologies quality control must be maintained over aspects such as appropriate sampling vessels (e.g. material, size), sample preservation, sample return (to the analytical laboratory) times, sampling location and times (day, year etc.).

Sampling aquatic biology should also have the same basic quality control considerations as for chemical sampling. Biological sampling is often achieved through the use of nets, pumps or grabs rather than bottles. However, sample treatment and preservation are of equal importance as for chemical determinands.

12. QUALITY CONTROL AND ASSURANCE

12.1 Information transfer to the Agency

The Topic Centre on Catalogue of Data Sources is currently working on many of these aspects of the environmental information network. For example, there must be a common language for determinands, sampled media and units, usually codified in a data dictionary. In terms of water quality and quantity information there will be a requirement for aggregated data rather than raw data to be transferred to the Agency. The Agency will as well as specifying codes, formats etc. for transfer will have to specify the type of information. For example, monitoring information on water should contain site means, standard errors, confidence limits, maxima, minima and percentiles. In this way the variability and validity of spatial and temporal comparisons can be assessed and quantified. Details of analytical procedures, methods, limits of detection, quality control are also likely to be required. The following sections, therefore, just briefly touch on some of the issues that will be at sometime addressed by the Agency with support from the appropriate Topic Centre(s).

12.2 Data quality control

12.2.1 Handling data

The first stage in ensuring the quality of the collected sampling data is the appropriate choice of storage format. The data should be in a form which allows access to all relevant sample details (such as date and time of sampling, grid reference, etc.), which allows the data to be easily examined for erroneous entries, and which permits the data to be divided into subsets as desired. An ideal storage medium is a database system like Microsoft Access, Borland DBase IV or the Oracle RDBMS.

As well as choosing the data format, a further requirement is that all necessary sampling information is recorded alongside the actual sample value. This is important as once the data has been entered and stored it is likely to be difficult, if not impossible, to add retrospectively the missing information. This information will be needed not only for the purposes of the monitoring scheme, but also to help validate the data.

If the data are produced in a computer readable format at the time of sampling, then the direct transfer of the data onto computer will minimise human errors caused by re-entering the data.

In order to prevent mistakes from being made whilst transferring data from one user to another, a universally agreed data transfer format should be used. One example of a standard format is ASCII files (ordinary text) with comma delimited fields and one sample value, plus other details about the sample, per line. Although this format does not make the most efficient use of space, it allows the data to be read into a new database with little or no manipulation of the transfer files. This avoids errors and saves time and money. An example of how the information might look after importing into a database is given below.

Date	Time	Grid Ref.	Sample Code	Determinand Code	Units	Sample Value
12/3/89	10:59	637098 224573	00102	623	mg/l	0.34
12/3/89	13:59	637098 224573	00103	079	mg/l	2.307
12/3/89	13:59	637098 224573	00103	623	mg/l	0.796
⋮			⋮			⋮

The EU and United Nations have invested considerable resources in providing efficient solutions to the problems associated with data transfer. The UN developed EDIFACT (Electronic Data Interchange For Administration, Commerce and Transport) as a world wide standard. The EC sponsored the application of this message system to environmental data exchange through the TEDIS programme. This system standardises the information format and ensures that all of the required supporting information that is sent with the message. This concept has advantages in that one common interface can be used for transfer of data. Unfortunately, the current system falls short of current EEA requirements as it contains no data dictionary to standardise codes associated with determinand, river sampling sites etc.

12.2.2 Detection of incorrectly entered data

The simplest form of check on entered data is to identify those values which fall outside the expected range. These apparently outlying values can then be verified, changed or discarded as appropriate. It is very important to note that data should only be discarded when there they are definitely known to be incorrect. Outliers which occur due to random variation are valid values and their exclusion at this stage can bias results. Range checking methods are listed below.

1. For determinand data, one way of identifying possibly wrong samples is to flag all those which are, for example, more than 3 standard deviations from the mean of that determinand (on a logarithmic scale if the data are skewed to the right). The validity of the flagged data should then be checked with the provider or source.
2. A similar approach is to flag the highest and lowest P% of the data for that determinand (where P% is some suitably small value such as 1%).
3. Errors are not always confined to the determinand data; dates, grid references etc. are just as likely to be wrong. Detection of these incorrect values will be simple in some cases. For example, dates before or after the start or finish of monitoring must be wrong, grid references not corresponding to water bodies will also be wrong.
4. In other cases, other variables can be used to make cross checks. For example, dates which are out of synchronisation with sample codes would imply that either the codes or the dates were wrong.

Another method of quality checking is to use a statistical quality assurance scheme, in a similar way to analytical quality control. A number of data records are selected at random (with replacement) and checked for mistakes. The proportion of errors in the database is estimated from the proportion of errors in the randomly selected records, and a confidence interval for the proportion is also estimated. Quality standards are being met if the true proportion of errors is below some prescribed level with a certain level of confidence.

For example, suppose that the proportion of errors must be no more than 1% with 95% confidence. Table 12.1 below shows the one-sided 95% confidence intervals for different numbers of observed errors from 500 randomly selected records (Ellis, 1989).

Table 12.1 One-sided 95% confidence intervals for the true proportion of errors based on 500 randomly checked records

Number of errors	1 sided 95% CI for true proportion of errors
2	[0%, 1.3%]
1	[0%, 0.9%]
0	[0%, 0.6%]

As can be seen from the above table, if more than one error is observed then the quality standards are not being met and remedial action may be necessary. A disadvantage of such a statistical quality control scheme is that it can be expensive to implement.

12.2.3 Analytical limits of detection and missing values

An agreed system of marking sample values below or above analytical limits of detection (LoD) should be used by all parties. The best system is to include an extra field in the database to indicate the state of the sample (for example, the field could contain a minus sign for samples below the LoD, a plus sign for samples above the LoD, and a blank if the sample was normal).

A convenient way of marking a sample as missing is to replace its value with some non-numeric marker, such as an asterisk.

12.3 Analytical performance

The analytical methods described in Appendix C are the techniques commonly used in laboratories routinely analysing these determinands. This does not however, preclude the use of other methods provided that the analytical performance can be proved to be adequate. They are typically generic methods (e.g. ICP-MS, flame photometry etc.), with most of the references being standard methods drawn up by the UK's Standing Committee of Analysts (SCA). There are of course international organisations such as the European Standardisation Committee (CEN) and the International Standards Organisation (ISO) producing similar standard methods which would be equally relevant.

12.4 Analytical quality control

12.4.1 Background

Analytical Quality Control (AQC) is the term used to describe the procedures adopted to ensure that analytical measurements are of adequate accuracy for their intended purpose. It is worth emphasising that, in any form of monitoring, the aim should not be to seek the ultimate achievable accuracy. The tasks are: (i) to establish sufficient control over measurement errors to allow clear and accurate interpretation; and (ii) to maintain consistency of measurement so that any temporal changes of interest can be discerned.

AQC is the principal practical component of a system of Quality Assurance. Other aspects of Quality Systems (e.g. staff training, instrument maintenance, adequate systems of records) are also important to ensure satisfactory operation of a monitoring programme. For example, it is of little consequence to achieve adequate accuracy, if samples cannot be identified clearly. However, these issues are outside the scope of this section.

12.4.2 Summary of approach to analytical quality control

The following summarises the essential features of Quality Control activities in laboratories undertaking water quality monitoring. The approach is described more fully in the European Standard guidance document "Guide to Analytical Quality Control for Water Analysis" CEN TC230 WG1 TG4, N120.

Laboratories should carry out the following procedures in sequence and obtain satisfactory results before an analytical system is used for routine analysis. The following stages should be observed:

a) Obtain or derive standards of analytical performance (maximum values for random and systematic error) for the determinands, concentration ranges and sample types of interest. Select an analytical system capable of producing results of the required accuracy for the determinand in question. The analytical method must describe unambiguously and in sufficient detail, the full analytical procedure.

b) Estimate the within-laboratory total standard deviation of individual results for a range of sample types or matrices and concentrations representative of the samples and sample types of interest.

c) Estimate spiking recovery achieved using the chosen analytical system for the sample matrix or matrices of interest.

d) Establish a fully documented, routine AQC system based on quality control charts, as a continuing check on analytical performance when the system is in routine use. Any problems indicated by the routine control system should be investigated immediately and remedial action taken.

e) As an independent check on analytical performance, laboratories should participate in appropriate external inter-laboratory quality control schemes involving the distribution of check samples. Any evidence from such participation that analytical errors are larger than the acceptable limits should trigger investigation and remedial action.

It is emphasised that the largest part of AQC effort should be expended on (d), above. The participation on inter-laboratory tests is an important supplement to routine within-laboratory quality control, rather than a substitute for it.

12.4.3 Within-laboratory quality control

Routine quality control within a laboratory is based on the use of control charts. The laboratory must analyse a control sample at least once in each batch of analysis. The results of these control analyses are used to plot a control chart which is used to maintain the analytical system in a state of statistical control.

The control sample should be chosen such that it is subject to the same potential sources of error as samples analysed routinely. As a minimum requirement, the control sample should be a solution which contains a known concentration of determinand no greater than the level of interest. Where sample concentrations are greater than the level of interest, then additional control samples should be used to reflect sample concentrations. The type and frequency of use of control materials will depend on the analytical technique and the nature and likely sources of error which may affect results. Normally, between 5% and 20% of all samples analysed should be control samples. All control samples should be subject to the full analytical procedure. The results for all control analyses should be recorded.

Where the limit of detection is critical (e.g. for calculation of contaminant loads), duplicate blank determinations should be made in each routine batch of analyses. The limit of detection should then be re-estimated at 11-batch intervals from these measurements. Reporting limits should be based on the most recent estimate of the limit of detection.

It is essential that the laboratory has adequately documented procedures which define loss of statistical control and specific actions to be taken when an out of control condition arises. Records of breaches of the control rules need to be maintained and, as a minimum, should include:

- Information to identify the control sample concerned and, via the batch of analysis, the identity of all associated test sample results.
- Details of the breach of control rules including a record of the control result and the control limits in force at the time.
- Action taken to investigate the cause of the out of control condition and any consequent conclusions and remedial measures.
- Action taken with respect to the associated test sample results.

The results of analyses obtained using a system not in statistical control should not be released, except under exceptional circumstances. Any such results should be identifiable for future examination and audit. The circumstances under which such results may be released should be documented clearly and shall include the specification that the cause of the out of control condition must first be identified and shown not to affect results for the analysis of samples.

The control chart should be reviewed periodically and the control limits updated if necessary. The results of all current quality control analyses should be taken into account in calculations of performance and in updating charts, apart from out of control values for which the cause has been identified.

Unless it is agreed otherwise, the laboratory should adhere to the test protocol for an interlaboratory exercise. Samples provided in proficiency testing schemes should be treated as far as is possible in the same way as routine samples with respect to storage, registration, analysis and reporting. Routine AQC procedures should be applied. in particular, any replication of analysis carried out as part of interlaboratory test should as far as is possible be 'blind’. Individual replicates need to be submitted for analysis independently and without reference to one another. No more than the specified number of determinations should be made.

Summary of approach to laboratory AQC

Laboratories should carry out the following procedures in sequence and obtain satisfactory results before any analytical system is used for routine analysis:

1. Select an analytical system capable of producing results of the required accuracy for the determinand in question. The analytical method must describe unambiguously and in sufficient detail, the full analytical procedure.

2. Estimate the within-laboratory total standard deviation of individual results for a range of sample types or matrices and concentrations representative of the samples and sample types of interest.

3. Estimate spiking recovery achieved using the chosen analytical system for the sample matrix or matrices of interest.

4. Establish a fully documented, routine AQC system based on quality control charts, as a continuing check on analytical performance when the system is in routine use. Any problems indicated by the routine control system must be investigated immediately and remedial action taken.

12.4.4 Inter-laboratory quality control

Laboratories should also participate in suitable external interlaboratory quality control schemes involving the distribution of check samples. A sample check scheme typically entails the organising laboratory distributing samples of different matrices (e.g. fresh and salt water) and determinands (e.g. metals and organic substances) to participating laboratories. Analysis is undertaken by the participating laboratory and the results are returned to the organising laboratory. This provides a continuous check on the accuracy and comparability of analytical results obtained in the participating laboratories, and identifies the determinands for which improved accuracy is required, towards which each laboratory should assign priority within its own analytical quality control work.

12.4.5 Existing quality assurance programmes

There are examples of national and international quality assurance programmes in some EEA States and as such these could form the basis of assuring at least the quality of chemical data reported to the Agency.

Table 12.2 summarises the national analytical quality control programmes that were reported to be in use in 1992/93 by 12 of the 17 EAA Member States. (ERM, 1993 cited in Groot and Villars, 1995). It can be seen that most countries reported to have some national analytical quality control programme in place.

There may also a need to establish international quality assurance programmes. Such programmes already exist for marine waters for example the QUASIMEME programme which currently supports 90 laboratories in Europe which submit data to international marine monitoring programmes (OSPARCOM, HELCOM, MEDPOL, ICES). Under Article 2 of the Agency Regulation the EEA is required to co-operate with certain organisation such as the Joint Research Centre (JRC) on certain tasks. The JRC runs a sample check, and a reference material production and dissemination programme, AQUACON, and may, therefore, have an over-seeing role in assuring the analytical quality of data submitted to the Agency.

Table 12.2 Summary of analytical quality control measures in some EEA Member States (ERM, 1993 cited in Groot and Villars, 1995)

Country	Analytical Quality Control
Belgium	Yes. Includes the use of recovery efficiency, blank samples and analytical standards.
Denmark	Yes. Internal AQC includes control charts and inter-laboratory comparisons.
France	Yes. Internal AQC with many laboratories formalising formal procedures in Quality Manual.
Germany	Yes. Internal AQC protocol including recovery checks, blank tests and use of different analytical methods for confirmation.
Greece	No. No formal AQC procedures currently established.
Ireland	Yes. Internal AQC protocol including reference standards, spiked samples and extraction efficiency tests.
Italy	Yes. Internal AQC including recovery efficiencies, blank samples and analytical standards.
Luxembourg	Yes.
Netherlands	Yes. Internal AQC protocols including control charts, reference samples for recovery cheeks, blank samples and inter-laboratory comparisons.
Portugal	Yes. Internal AQC including control charts and reference standards.
Spain	Yes. Internal AQC procedures applied.
UK	Yes. Internal AQC including control charts, reference standards, spiked samples, recovery efficiency tests, etc. Also, participate in interlaboratory checks and all are externally certified.

13. ASSESSMENT OF INFORMATION GAPS IN EXISTING MONITORING PROGRAMMES

13.1 Introduction

Gaps in current national monitoring programmes are defined as the difference between the prospective EEA network's requirements and existing monitoring activities. It has not been the intention to evaluate individual countries and their ability to satisfy the requirements in detail. However, an attempt has been made to assess to what extent national programmes will be directly applicable in terms of the number of stations, water types and proposed variables to be measured and to try to identify major gaps or differences.

A more detailed assessment of gaps and differences that will compromise the aims of the proposed monitoring network should be possible during the pilot implementation project to be undertaken during 1996.

13.2 Rivers

13.2.1 Major gaps

In most of the national river monitoring networks the number of stations in existing national programmes are greater than the proposed number of stations to be included into the general surveillance river network (Section 8.2). However, the number of stations in the national river monitoring programmes in the Netherlands, Germany, Norway, Sweden and Finland are generally lower than the proposed number. In these countries the local authorities are monitoring numerous river stations and some of these stations may be selected to achieve the proposed number of stations. The national river monitoring programmes generally include stations on the major rivers, while the number of stations in small rivers and at reference sites may be low. For many countries it may be necessary to establish some stations covering small river catchments and reference areas.

Most countries conduct annual sampling at their river stations and most of the stations for this network can be selected from the existing national river monitoring programmes. Many of the river stations in the national monitoring programmes are not located at or near gauging stations and the requirement for water flow data on a continuous basis may reduce the number of possible stations, especially in the case of small rivers and reference sites. Hydrological forecasting of flows may be useful here.

Many national monitoring networks are established for estimating the riverine loads from land areas into coastal areas or loads in transboundary rivers. Generally these networks consist of sampling at downstream sites on all major river systems. The aims of these networks will have to be established before the gaps can be evaluated. However, in most countries frequent measurement of important water quality variables at downstream points in the largest rivers are undertaken. This network should not duplicate the work done for the existing international networks but be based on the results from these networks. There is a need for harmonisation/standardisation of the various methods of calculating the loading as well as descriptions of human activities in the catchment and estimating the source apportionment.

The ecological quality network should be established on basis of the national reporting in relation to the proposed Directive on Ecological Quality. In sparsely populated countries it will not be possible to make a census of the ecological quality of all water courses. However, a representative sub-sample should be selected to describe the ecological quality. The river stations in the extensive water quality network could be the basis for this sub-sample.

13.2.2 Gaps in required determinands

Basic physical variables

Information about water flow is an important variable when the state of the environment is to be evaluated. In the river network water flow should either be measured at each sampling site or at a nearby gauging station. In the riverine loading network the water flow should be measured continuously at a gauging station. Water temperature, pH, and conductivity are measured at low cost and may be used for general characterisation the rivers. Many of the river stations in the national monitoring programmes are not located at or near gauging stations and the requirement of water flow data on a continuous basis may reduce the number of possible stations, especially in the case of small rivers and reference sites.

Organic pollution indicators

From an ecological perspective, the estimate of average oxygen concentration based on monitoring programmes may not be the best descriptor of oxygen conditions in rivers. Oxygen levels vary throughout the year and individual days, and the status of aquatic fauna will often reflect episodic or systematic minima in these levels rather than average conditions. The lowest oxygen concentration are generally found during the night and the summer months. Nearly all monitoring of oxygen is undertaken during the day for logistical reasons, so that there is little chance of recording the true annual minimum. However, dissolved oxygen is measured at low cost, and it is measured at the majority of river stations often with a long time series. This variability is also a characteristic of other chemical indicators.

Biochemical oxygen demand (BOD) and ammonium levels can give an indication of organic pollution in rivers. However, especially in the Nordic countries chemical oxygen demand (COD) is measured instead of BOD and dissolved oxygen is not measured at all. In addition, for BOD and COD many different analytical methods are used. For example, BOD can be measured with or without addition of a nitrification inhibitor, and COD is measured either by the potassium dichromate or by the sodium permanganate method. Some standardisation will be necessary to ensure that these data are comparable at an EEA level.

Nutrients

There is generally a close relationship between phosphorus concentration and catchment population density, and between nitrate levels and the percentage of the catchment used for agricultural purposes. It has been recommended that the state of eutrophication at the river stations are evaluated on the basis of measurements of nitrate (oxidised nitrogen, nitrate plus nitrite) and total phosphorus. In some countries total nitrogen is measured instead of nitrate, especially in the Nordic countries with relatively low nitrate levels and relatively high organic nitrogen levels. In some countries soluble reactive phosphate (SRP) is measured instead of total phosphorus.

13.3 Lakes

13.3.1 Major gaps

An extensive lake/reservoir monitoring network with up to 8 samples taken over one year in each reporting period of 3 to 5 years has been proposed. The network should include reference lakes, typical lakes/reservoirs and the largest and most important lakes and reservoirs in each country. In several countries there is no national lake/reservoir monitoring programme, however, in some of these countries local authorities monitor the water quality of lakes/reservoirs, and it should be possible to select the required number of water bodies for the extensive network from the local networks. Several countries are creating inventories of the environmental state of lakes and reservoirs by collating the results from local authority monitoring activities and it may be possible to use this information in producing the EEA extensive lake network.

13.3.2 Variables measured in existing lake monitoring programmes

Basic variables

Variables describing the basic chemical and physical properties of lake water are included in most programmes. Generally, the analysis programmes include measurement of water temperature, pH, dissolved oxygen and conductivity.

Trophic status

Nearly all the lake monitoring programmes include measurement of total phosphorus, total nitrogen, oxidised nitrogen and chlorophyll-a. Measurement of soluble reactive phosphate, ammonium nitrogen and Secchi disc transparency are included in most of the monitoring programmes. In those lake monitoring programmes with more than one annual sample, the sampling frequency of trophic status indicators varies from 3 to 4 samples to 19 samples a year.

Metals

Up to ten metals are measured in the various national lake monitoring programmes.

Biological assessment of lake water quality

Biological variables are included in many general lake monitoring programmes as well as programmes concerning specific localities (e.g. large important lakes). Sampling and investigation of phytoplankton and zooplankton are components of several monitoring programmes. Apart from a general evaluation of the phytoplankton community, the objectives of some programmes are more specific such as assessment of the occurrence of potentially toxic blue-green algae in waterbodies used for bathing or drinking water supply. Bottom fauna, macrophytes and fish are also objects of study in some of the lake monitoring programmes.

13.4 Groundwater

Unlike for groundwater quality, there are no current EC directives with specific requirements for groundwater quantity monitoring, in spite of the intimate relationship between quantity and quality, especially in impacted areas. Consequently difficulties arise in evaluating representativeness of the networks. Conscious of this serious gap, the EC has established through the GAP (Groundwater Action Programme) an urgent priority to formulate the required criteria for the establishment of an EC groundwater (quality and quantity) monitoring network.

A full analysis of gaps in existing monitoring networks was not possible because of the lack of supportive information provided by the EEA Member countries in the MW2 questionnaires. This is particularly so for sampling density evaluation of the baseline and impact networks. There was also no information on the hydrogeological characteristics of each groundwater region and the spatial distribution of the monitoring stations, only general data were provided. Also no characterisation was made of the type of impacted areas, for example, heavily exploited areas or areas particularly subject to interactions with other systems (rivers, sea, lakes, estuaries).

Large differences were found in sampling frequencies among the EEA countries although no interpretative information was provided on the objectives of each monitoring programme which might explain these differences. It will, therefore, be necessary during the pilot implementation of the network to go into more specific details on national networks when selecting sites and other aspects of the EEA network for groundwater.

14. CONCLUSIONS

1. To meet the objective of the EEA monitoring network there is an explicit need to try and relate differences in water quality and quantity to human activities in catchments, and thereby try to demonstrate cause/effect relationships. The addition of supportive 'activity' information will add a further layer of difficulty to implementing the network. There will, therefore be key determinands (primary and secondary) that will provide the information to address the questions. There is, therefore, clear overlap with work being undertaken by other Topic Centres, for example those on 'Catalogue of Data Sources' and on 'Land Cover'.

2. **The clear understanding is that the monitoring network will be based where possible on existing national and international networks, use existing sources of monitoring information and create, only if necessary, an EEA database of aggregated rather than of non-aggregated data.**

3. The desire to relate differences in quality and quantity to potential causal agents, that is establish 'cause and effect relationships' raises many difficult technical issues and points of debate.

4. Any monitoring information received by the Agency will need validation. Key aspects such as statistical confidence, sampling windows and frequencies, sampling methodologies and analysis (e.g. performance, quality assurance, limits of detection) will need to be assessed, so that judgements can be made on the validity of comparisons and differences.

5. There are a number of options on how the network can be developed:

- Use of information from stations used in current international monitoring requirements and programmes such as, in the case of rivers, the Exchange of Information Decisions (77/95/EEC and 86/574/EEC) which aim to provide surveillance type information. This database has now been merged with the rivers database created by the Agency's Task Force for the Dobríš assessment report.
- Use sampling stations and monitoring information obtained nationally to demonstrate compliance with EC Directives such as the Freshwater Fish Directive.
- Current national classification schemes, where they exist, could perhaps (in theory) be translated to a unified European scale.
- An ambitious option is to sample and measure all water bodies in a consistent and comparable way which would clearly be very expensive to undertake and co-ordinate, and difficult to manage, interpret and report.
- Sub-sample a representative portion of the total water resources. This would be aided by stratifying the total population (e.g. all rivers) into relativity homogenous sub-strata.

6. Information from European Commission directives is not suitable as:

- The data are not comparable because the degree of comparability will depend on the interpretation of the designation rules and national differences of how these are implemented.
- The data are not representative because in the directives which require routine monitoring the requirements are generally site specific, either at sites designated for a specific use, sites affected by a specific discharge, or, for the Exchange of Information Decisions, agreed sites in main rivers. As the choice of sampling location is, for some directives, related to areas designated by the Member States rather than by the European Commission, it is unlikely that, for those directives, a comparison of quality across Europe of these designated waters will give a complete picture of quality.

7. The first three options would not necessarily give a representative view of Europe's water resources, and method and data comparability would be an important issue to address. The latter option is the preferred one and is recommended for acceptance by the EEA and its Member States.

8. There is a need for different types of monitoring stations to be included in the networks.

9. Reference stations should be established on rivers in natural catchments with little or no human activity and with greater than 90% natural landscape. It is likely that such stations will not be present in some parts of Europe.

10. Representative stations that can give a spatial and temporal general assessment of quality across Europe.

11. Impact stations could form part of the representative network with the collection of supportive and interpretative information, or could form separate impact strata.

12. Flux stations established where rivers discharge into sea, or cross national boundaries, or there is interchange between surface and groundwater.

13. Baseline stations may also be required to characterise the generality of run-off behaviour of the region or country.

14. For the lakes and reservoirs network reference, representative and impacted lakes and reservoirs should be selected.

15. The largest and most important national rivers, lakes and reservoirs should also be include within the monitoring networks.

16. For groundwater there should be reference and representative stations that would deliver general information about the quality and quantity, and cover the entire area of each Member State. All major national aquifers should be covered. Reference stations should be established in areas not influenced by groundwater pumping and other anthropogenic activities. In some areas within the EEA (small countries or in densely populated areas) it will not be possible to establish reference stations.

17. It will be important to confirm, that the monitoring wells, which are chosen for the groundwater network, should have been designed and constructed in a similar way so it is possible to compare the results from all the Member States.

18. Ideally sampling frequency would be based on an assessment of determinand variability and the desired level of precision in the information. These aspects should be looked at in the pilot project and during the subsequent progressive implementation of the network.

19. Once the network is implemented, monitoring meta-data should be made available to the Agency in the form of summary statistics and measures of data variability to allow assessments of data quality and comparability.

20. Groups of primary and secondary determinands have been identified for surface and groundwater. Substances such as pesticides, other synthetic organic substances and heavy metals should be selected on the basis of their use in the catchment of interest. In addition supportive data on catchment characteristics and land use will be required and should be collected in comparable ways.

21. The Topic Centre on Catalogue of Data Sources is currently working on many aspects of the environmental information network and there will need to be close liaison with the Topic Centre on Inland Waters. For example, there must be a common language for determinands, sampled media and units, usually codified in a data dictionary. Details of analytical procedures, methods, limits of detection, quality control may also have to be transferred to the Agency.

22. Many of the river quality stations in national monitoring programmes are not located at or near gauging stations, and the requirement for water flow data may reduce the number of possible stations, especially in the case of small rivers and reference stations.

23. The Nordic countries measure chemical oxygen demand instead of biochemical oxygen demand, and dissolved oxygen is not routinely measured. In addition, biochemical oxygen demand and chemical oxygen demand are analysed by many different methods. Some standardisation will be necessary to ensure that these data are comparable at an EEA level.

24. In some countries total nitrogen is measured instead of nitrate, especially in the Nordic countries with relative low nitrate levels and relative high organic nitrogen levels. In others soluble reactive phosphate is measured instead of total phosphorus.

25. In several countries there is no national lake/reservoir monitoring programme. However, in some of these countries local authorities monitor the water quality of lakes/reservoirs, and it should be possible to select the required number of water bodies for the EEA network from the local networks.

26. In one country there is no national monitoring network for groundwater quality.

15. RECOMMENDATIONS

1. The recommended overall objective of the monitoring (information) network is: *"To obtain timely, quantitative and comparable information on the status of inland waters (groundwater, lakes/reservoirs, rivers and estuaries) from all EEA Member States so that valid temporal and spatial comparisons can be made, and so that key environmental problems associated with Europe's inland waters can be defined, quantified and monitored"*.

2. The favoured option for the basis of the monitoring network is to sub-sample a representative portion of the total water resources. This would be aided by stratifying the total population (e.g. all rivers) into relativity homogenous sub-strata.

3. It is recommended that the sampling stations to be included into the EEA network should be selected from the sampling stations in national monitoring programmes supplemented by additional stations to meet specific requirements of the EEA. In cases where no national monitoring programmes exist, the stations to be included will, if possible, be selected from regional sampling stations.

4. The network should be a representative sub-sample of the inland water bodies of the EEA area and the sampling stations to be included in the network should be selected so that they are representative of:

- the size/numbers/types of water bodies in the EEA area (e.g. lake surface area);
- the variation in human pressures (e.g. population density and land use);
- and should include a number of reference and flux stations.

5. A representative stratified monitoring network has been recommended with stations stratified according to the type and size of water body, catchment characteristics and human activities. Each additional strata added to the design would increase the need for supportive information by which the target population in the strata can be defined, and for definitions such as what population density represents an urbanised catchment, what proportion of agricultural use a predominately agricultural catchment, the predominant agricultural use, a forested catchment. These definitions would require the assistance of other EEA Topic Centres and may require revision in the light of experience with the network.

6. It is recommended that the optimum monitoring station densities (for example, per country and water type - river, lake or aquifer), sampling frequencies, sample numbers and sampling windows for the proposed networks are defined according to the statistical principles and considerations described in this report. These aspects should be developed during the pilot implementation of the network using non-aggregated monitoring data from a number of countries and water types.

7. The possibility of aggregating data and information from representative stations on a regional, catchment or aquifer basis should be investigated in later phases of implementing the networks.

8. Initially a general surveillance network for rivers could contain a network of approximately 1832 rivers, made up of 1466 representative and 366 reference rivers, and an impact network consisting of 1,588 rivers selected on the basis of population density. The largest and most important national rivers in the EEA area and existing flux stations would also be included.

9. It is recommended that for the pilot implementation of the network that the same selection procedure is applied to the surface quantity network as for the river quality network, and select where possible quality and quantity stations at the same location or at least on the same river reaches. Baseline stations should be selected independently.

10. Initially a general surveillance network for lakes/reservoirs would comprise: a basic network containing around 1,000 water bodies, 200 of which would be reference and 800 representative lakes; an impact network containing 800 lakes, (selected on the basis of population density to put more emphasis on water bodies in densely populated areas than in sparsely populated areas); and, the largest and most important national lakes in the EEA area.

11. Even though sample station density for the groundwater network should be based on national geological conditions and variability in measured determinands, it is proposed that the selected monitoring stations should initially be distributed in a more or less regular geometric pattern and, as a rule, with a density of at least 1 site per 20 to 25 km^2 of aquifer. It will be important to confirm that the monitoring wells, which are chosen for the EEA network, should have been designed and constructed in a same way so it is possible to compare the results from all the Member States.

12. It is recommended, at least for the pilot implementation study on rivers, that assessments are made on data obtained over the whole year, spread approximately evenly over that period (e.g. monthly). In addition, long time series (monthly or more frequent) data should be obtained from a range of hydrological river types to assess relatively short term (e.g. monthly, seasonal) and longer term variability (yearly). This would enable a more rational sample frequency to be established and take into account problems such as rivers drying out in summers in some countries.

13. In the interim it is recommended that the summary information for lakes is based on a minimum of 8 samples a year.

14. For groundwater two samples a year, (one each during high and low ground water levels), should be adequate. When deeper groundwater reservoirs occur at the same sampling station they should be sampled at the same time as the shallower ones.

15. It is recommended that the suggested networks are piloted in a few selected countries during the first half of 1996, and subsequently, progressively implemented throughout the EEA area in a planned and programmed way later in 1996 and in subsequent years. For the pilot project, station selection will be undertaken using the proposed criteria and procedures, and non-aggregated data

will be needed to test and assess intra- and inter-strata variability, and to investigate optimum sample station densities and sample frequencies. In addition, probably in the second half of 1996 and in subsequent years, analytical and sampling methodology will be examined in detail to identify further potential barriers to harmonisation. Finally, the meta-data transfer process to the Agency will be tested once data dictionaries and formats have been developed and finalised. Support will also be required from other Topic Centres on the catchment and human activity information that will be required. All these activities are scheduled into the work programme of the Agency under the control of the Project and Programme Manager.

16. ACKNOWLEDGEMENTS

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Organisation	Comments received
Niels Thyssen, European Environment Agency	6 December 1995
National Environmental Research Institute, Denmark	November 1995
Austrian Working Group on Water	17 November 1995
Finnish Environment Agency	22 November 1995
Instituto Superior Technico, Portugal	24 November 1995
Institut Français de l'environnement, France	22 December 1995
Environmental Protection Agency, Ireland	9 January 1996
Finnish Environment Agency	19 March and 22 April 1996
Directorate-General for Public Works and Water Management, NFP, The Netherlands	25 March 1996
National Environmental Research Institute, NFP, Denmark	27 March, 19 April 1996
Umweltbundesamt, NFP, Germany	28 March 1996
Statens forurensningstilsyn, NFP, Norway	29 March 1996
Umweltbundesamt, NFP, Austria	9 April 1996
Environment Agency, NRC, UK	17 April 1996
Department of the Environment, NFP, UK	23 May 1996
Finnish Environment Institute, NFP, Finland	6 June 1996
Institut Français de l'environnement, NFP, France	12 June 1996
Department of the Environment, NFP, UK	20 June 1996

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APPENDIX A STATISTICAL CONSIDERATIONS IN MONITORING PROGRAMME DESIGN

A1. INTRODUCTION

This Appendix discusses some of the following key steps in designing a monitoring programme:

- Defining the objective;
- Gaining an understanding of variability;
- Defining the target population;
- Choosing the precision and confidence;
- Determining the number of samples;
- Determining when and how often to sample.

A2. DEFINING THE OBJECTIVES

The importance of clearly defined, quantitative objectives to the design and implementation of sound, cost-effective sampling programmes cannot be overstated. Without careful consideration of the aims of the sampling, the data produced may well be inappropriate, and the number of values generated be either too small or unnecessarily great - with obvious cost penalties in either case. The definition of the objectives has been fully discussed in Section 3.

Previous sections in the report have discussed the questions of (a) what determinands to measure, and (b) how to measure them. For simplicity, therefore, the following discussion is in terms of a discrete sampling programme for one particular chemical contaminant of interest. The same basic principles discussed below apply, however, to all other types of sampling, chemical or biological.

A3. GAINING AN UNDERSTANDING OF VARIABILITY

Statistical sampling is primarily concerned with estimating some underlying property of interest (a mean or a 95%ile, perhaps) in an environment of uncertainty. If there were no variability, there would be no need for sampling. Sources of variability involved in measuring the real world can usually be separated into two very distinct types. These are

1. Systematic variability (i.e. due to physical/temporal processes such as seasonality, diurnal cycle, tidal height, long-term trend, etc.), and

2. Random variability (i.e. unpredictable or unexplainable fluctuations).

Variability introduced by the analytical process can fall into either of the above categories. With no extra information about what is being sampled other than the sample values themselves, all the variability appears to be random. However, by adding knowledge, sources of systematic variability can be identified and therefore the random component can be reduced.

The greater the random component of variability, the more samples will be needed to obtain a worthwhile result. That is no more than common sense. The impact of systematic variability, however, is less obvious. A particular systematic cycle that is not taken account of by the sampling programme design can have an effect indistinguishable from random error - and so weaken the effectiveness of the sampling programme. But where knowledge of that systematic cycle is exploited by the programme design - either by sampling at a fixed point in the cycle, or by arranging for the sampling to 'average out' the cyclic effect - the programme can actually be made more effective.

The soundest way of exploring these issues is by conducting a statistical analysis of historical data relating to the water body under investigation (assuming such data are available). This is a valuable preliminary for three main reasons:

i) it provides a measure of the variability (measured by the standard deviation, 's') that is needed for sample-size calculations;

ii) it helps to identify systematic components, and hence - by allowing 's' to be reduced - improve the efficiency of the sampling programme; and

iii) it allows an appropriate statistical model to be determined for describing the random variability. (Normal? Log-normal? Some other distribution? Unrecognisable?)

A4. DEFINING THE SCOPE OF THE SAMPLING PROGRAMME

The scope of the sampling programme is simply the temporal and spatial bounds within which the monitoring will take place, i.e. the sampling population. Ideally this scope would be defined to be the 'target population'. The target population is the collection of all parts of European water resources, temporal and spatial, about which inferences need to be made in order to meet the objectives of the monitoring network. This may be as much as all of Europe's water resources, or it could be a certain part of it defined by the nature of the objectives. For instance, if the objectives require the calculation of the winter mean concentration then the target population would be all water resources sampled during the winter months.

In many situations, however, the scope of the sampling programme will be restricted to a subset of the target population due to practicalities of sampling and costs. This is acceptable if inferences drawn from the sampling population can be reliably extrapolated to the target population. If the sampling population is not an adequate substitute for the target then it is necessary to resolve, or at the very least acknowledge, the conflict between an ideal but impracticable target population, and a convenient but inappropriate sampling scope.

One way of doing this is to change the wording of the objectives so that they take account of the restriction on the target population, enabling future users to judge for themselves the risks involved in extrapolating the results of the sampling programme to other circumstances.

The following examples illustrate the resolution of the scope of the sampling programme.

Example 1

Objective:

To monitor an effluent discharge to check its compliance with an annual 95th percentile concentration limit.

Target population:

All possible equal-sized aliquots that can be drawn from the effluent at very small intervals of time apart (i.e. samples can be taken from any part of the effluent and at any time).

Sampling population:

Could be the same as the target population if there was an automatic sampler (which could be activated at any time of the day or night, any day of the week) drawing from the sole point of discharge.

If sampling was done manually, the sampling population might have to exclude time outside of normal work shifts (nighttime, bank holidays, etc.). This restricted scope would be sufficient if there was no systematic difference between daytime and nighttime concentrations, say.

Alternatively, or in addition, the scope of the sampling programme would be a restricted subset of the target population if there were several discharge points, but sampling could only be done at one of them. The sampling population would be adequate if there were no differences between effluent quality from point to point.

Example 2

Objective:

To estimate the difference between annual mean concentrations of a particular pollutant in a receiving water upstream and downstream of the discharge.

Target population:

There are two parts to the target population. the first is all possible equal-sized volumes of water that can be drawn from the receiving body at very small intervals of time apart, from any depth and any site in the water providing that it is upstream of the discharge and does not contain any part of the effluent. The second is the same as the first with the exception that the possible sampling sites must be downstream of the discharge and not influenced by other discharges or sources of pollutant.

Sampling population:

In addition to the possibility of temporal restrictions such as those outlined in the first example, the scope of the sampling may be limited by other factors. For instance, it may not be possible to establish whether or not a particular upstream sampling site is free of the effluent being monitored as it may depend on stream flow rates and mixing patterns etc. In such a situation, the upstream sampling population might be restricted to sites more than a certain distance upstream of the discharge but downstream of any other sources of pollutant. Results from this sampling population are very likely to be reliably extrapolated to the target population.

A5. COMPLIANCE TESTING/THRESHOLD EXCEDENCE

Most European compliance testing is of the threshold exceedence variety, i.e. no more than 'x' exceedences (failures) out of 'n' tested samples. In this case if information is reported as 'pass' or 'fail' against a level or standard then common numbers of samples are needed for fair comparisons.

A6. PERCENTILE ESTIMATION AND ESTIMATION OF AVERAGES

If all the data used in calculating each statistic, or just the statistic and some estimate of variance (e.g. standard deviation), are provided then it is possible to judge the quality of the estimates and determine how significantly different they are from each other. Having a common sampling frequency for a determinand would not ensure the estimates produced in different areas would have the same quality, or even a minimum quality, because of the differences in variability from area to area.

A better approach would be to specify a minimum level of precision and confidence to which the estimates must conform (i.e. a minimum estimate of quality). The minimum number of samples required to achieve this precision and confidence can then be calculated for each site or area. The following sub-section defines what is meant by precision and confidence and the sub-section after that describes how this can be used to determine the minimum number of samples.

A6.1 Precision and confidence

The reason for designing a sampling programme in the first place is because it is not possible to sample the whole of the target population. Therefore, the values obtained for the statistical objectives are estimated from a (usually) much smaller sub-population of samples and are, consequently, subject to a certain amount of error or uncertainty. Choosing the precision and confidence sets limits on how much of this uncertainty can be tolerated in the results of the programme.

Consider some quantity that has been estimated from the sampled data. This estimate will almost always differ from the true value (i.e. the quantity which would be calculated if the whole of the target population was sampled). Answering the following two questions will define the precision and confidence.

- What is the largest discrepancy that can be tolerated between the answer given by the sampling programme and the true value? This is the desired precision.
- What degree of confidence should there be that the answer obtained does in fact lie within the desired precision? This is the desired confidence.

Confidence is expressed as a percentage, so for example, a confidence of 99% means that if the sampling programme could be repeated 100 times, the answer would be within the precision tolerance on 99 occasions.

A6.2 Determining the number of samples

Once the precision and confidence have been set and some estimate of the random variability of the samples is known (based on previous monitoring results), then the minimum sampling frequency can be derived.

By way of a simple example, suppose that the intention is to estimate the mean of some determinand over a year. The standard formula for calculating the required number of samples (assuming that the random variability of the samples can be modelled by a Normal distribution) is:

$$n = \left(\frac{u \times s}{d}\right)^2$$

where

n is the minimum number of samples needed,
d is the desired precision,
u is a factor related to the desired confidence (obtained from the percentiles of the standard Normal distribution), and,
s is a reliable estimate of the variability (expressed as the standard deviation).

[If the desired confidence is *C*%, then the factor *u* is the $(100 + C)/2$ th percentile of the standard Normal distribution. For example, if *C* is 95 then *u* is 1.96 (the 97.5th percentile).]

Table A.1 below shows the effects of different confidences and precisions on the numbers of samples needed. The table combines the desired precision and the random variability by using the relative precision (the ratio of precision to standard deviation).

Table A.1 Minimum numbers of samples needed to obtain certain precisions and confidences.

Relative precision, *d/s*	Confidence, *C*			
	90% (u = 1.65)	95% (u = 1.96)	99% (u = 2.58)	99.9% (u = 3.29)
0.1	273	385	666	1083
0.2	68	96	167	271
0.3	31	43	74	121
0.4	17	24	42	68
0.5	11	16	27	44
0.6	8	11	19	30
0.8	5	6	11	17
1.0	3	4	7	11

This example relates to the simplest statistical objective, i.e. estimating a mean. However, the same principle applies to more complicated statistical objectives (e.g. the median, 10th percentile geometric mean, etc.).

A7. POTENTIAL IMPACT ON CURRENT MONITORING PRACTICE

To gain some understanding of the levels of sampling ideally required for an EEA network some estimate of variance is required for each determinand. These can best be drawn from current monitoring practices. To take the example of river nutrients a key determinand is soluble reactive phosphorus (SRP). The National Rivers Authority of England and Wales has an extensive network of sites which will monitor for SRP in its proposed general quality assessment scheme (GQA). To obtain an average estimate of variance all means and standard deviations were calculated for all of the 5,000 sites sampled more than 12 times over the three years between 1990-1992.

As riverine orthophosphate levels follow a highly skewed distribution (approximately log-normal) the values of the site standard deviations are spread across a large range (4 orders of magnitude). A log transformation of the sample values before calculating the standard deviations reduces the spread of these standard deviations to one order of magnitude. The advantage of this technique is that the spread of precisions obtained for each site will be correspondingly small allowing a better overall assessment of the number of samples required. The average estimate of standard deviation for the $\log_e$ transformed data was calculated to be 0.74. This estimate of variability can now be applied to assess the number of samples required to meet a particular precision.

The classification used in the Dobríš Assessment (1995) has six classes with boundaries for orthophosphate at 25, 50, 125, 250 and 500 µg/l of PO_4-P. The lowest of these classes represents a site with no anthropogenic input and the highest class indicates a site with high levels of nutrient input either through agricultural run-off or sewage input. We can specify the desired precision and confidence in terms of the width of the classes. For example, we may wish to be 90% confident that a site reported as class B is really class B (i.e. its true geometric mean SRP lies between 25 and 50 µg/l) when its geometric mean SRP is more than 25% of the class width away from the class boundaries. To achieve this we need to take enough samples at the site; the minimum number of samples required is given by the equation in the previous section, i.e.

$$n = \left(\frac{165 \times 0.74}{0.173} \right)^2 \approx 50$$

where 0.74 is the average standard deviation of $\log_e$ SRP and 0.173 is the precision (one quarter of the typical class width on a log scale). This formula can be rearranged to estimate confidence intervals associated with particular sampling frequencies. Table A.2 below presents widths of confidence intervals based on log transformed orthophosphate data.

Table A.2 Widths of confidence intervals based on log transformed SRP data from the National Rivers Authority of England and Wales GQA database

Number of samples	Mean of samples	relative lower 90%	relative upper 90%
6	$\bar{x}$	0.61	1.65
12	$\bar{x}$	0.70	1.43
18	$\bar{x}$	0.75	1.34

Note: This is to gain the required precision at each site. A different number would be required for regional or larger scale aggregation of data.

For example, if the mean orthophosphate concentration of a site sampled 12 times was 100 µg/l we could say with 90% confidence that the value lies between 70µg/l and 143 µg/l. This precision may well be expectable. Few monitoring programs sample their sites at an intensity of 50 times per year. There are several options:

- choosing fewer and/or more widely separated boundaries.
- tolerating the precision and report the values with a lower confidence
- combine samples over a period greater than one year, to produce a rolling classification, that is one year use 1990 to 1992 data, next use 1991 to 1993 data and so on.

For inter-regional comparisons, the number of sites per region needs to be specified having first specified the number of samples per site. If, by way of example, we take the whole area of the National Rivers Authority of England and Wales to be one region (or strata, see Section 6) then we can estimate the number of sites required using the formula given in Section 6.3. The intra-region (intra-stratum) standard deviation of site geometric means is 1.62. If we wanted a precision of one half of the class width and a confidence of 90% for inter-regional comparisons, then the required number of sites is

$$n = \left(\frac{2 \times 165 \times 162}{0.346} \right)^2 \approx 240 .$$

A8. DETERMINING WHEN AND HOW OFTEN TO SAMPLE

Having determined how many samples should be taken, the next task is to decide on the duration of the sampling programme, and how to spread the samples over that total sampling period. In other words, once the question 'How many?' has been answered, the questions 'How often?' and 'When?' then need to be addressed.

A8.1 Defining the timescale

Many objectives - especially those relating to compliance assessment - have a pre-determined duration. For other types of enquiry a period of 12 months is often convenient (though the traditional idea of an annual statement of quality should not be perpetuated merely by default).

Where the choice is more open, it is ultimately a matter of weighing up the extra costs of carrying out the sampling over a shorter time period against the benefits of obtaining the results that much sooner.

A8.2 Allocating the sample times

The main issue here is whether to allocate the samples at random, or whether to spread them systematically (through time, or by volume, or some combination of these, according to the identified target population). The choice depends very much upon (a) the objective, and (b) what is known about the variability of the system. The principal advantage of random sampling is that it is statistically foolproof - a particular advantage when little can be assumed about the system being sampled. (It is also an essential component of any regulatory sampling programme, incidentally, as it is the only way of retaining the element of surprise.)

Strict random sampling does, however, pose severe organisational difficulties Moreover, it does not guarantee that the results from any one sampling programme will be particularly representative. For these reasons, systematic sampling will often be a preferable alternative. With such a regime, however, it is important to be sure that the sample times and dates do not unwittingly move in step with some important cycle in the physical system - unless, of course, it is intended to exclude this from the target population. For example:

- Sampling only at 12:00 every Monday will give no information on either a diurnal or a weekly cycle.

- Sampling at 12:00 every eighth day would systematically cover all days of the week and so incorporate all aspects of the weekly cycle, but still say nothing about diurnal variation.
- Sampling every seven days and 13 hours would eventually cover both the entire 24 hour clock and the seven-day week, and so cover the widest possible target population.
- Sampling at every high tide would also cover diurnal and weekly cycles, but would obviously exclude any effects associated with the tidal cycle.

A9. TIME-BASED AND VOLUME-BASED SAMPLING

There are two fundamentally different ways in which we can visualise quality variations in a river:

- the time-based description (in which concentration is plotted against cumulative time), and
- the volume-based description (in which concentration is plotted against cumulative flow).

If flow was constant through time the two representations would be identical. Otherwise, the volume based description can be thought of as being a 'distorted' time-based version in which the clock is driven by a water-wheel rather than by clockwork.

Virtually all routine water quality monitoring is time-based rather than volume-based. For example, the sampling regime for a river will be expressed as 'sample once a fortnight' rather than 'sample once every 4000 Ml'. As most of the EEA's objectives relate to concentrations, the time-based description is the correct one to use.

When the primary interest is in, say, mean loads, there is an inherent disadvantage with time-based sampling: a straightforward mean concentration will in general lead to a biased estimate of load. As high flows occur for a relatively short time, very few will happen to coincide with the sampling occasions. (There might also, indeed, be a deliberate policy of avoiding sampling on occasions of very high flow for safety reasons.) The resulting concentration versus flow plot will therefore have a great preponderance of low-flow points. As a consequence, evidence for a significant association will always hinge unsatisfactorily on at most a handful of high-flow samples. With sample sizes of only 30 or 40, moreover, there is a real risk that high flows are entirely under-represented. The danger then is that the sample variability badly under-estimates the true variability in the underlying population, and so leads to unrealistically optimistic statements of precision (Ellis, 1989).

With a volume-based approach, in contrast, sampling frequency will automatically be stepped up in periods of relatively high flow (as, for example, with flow-proportional sampling devices), and so the mean concentration at the end of the year provides a direct estimate of mean load.

The report on current EEA surface water quality monitoring networks (Kristensen and Bøgestrand 1996) identifies 19 sampling programmes which are specifically designed to assess contaminant loads in river systems across Europe. The report indicates that without exception these programmes all have time rather than volume driven sampling regimes.

Calculation of loads can be addressed in two ways using an annual average flow to produce a simple arithmetic mean of load or use the instantaneous flow associated with each sample to produce a flow-weighted average. Both of these approaches have their associated pitfalls when compared to flow driven sampling regimes.

Walling and Webb (1985) used a two-year sequence of hourly suspended sediments data from a sampling station on the River Exe, together with corresponding hourly flows provided by South West Water. Using this virtually continuous record, they were able to mimic the results of weekly, fortnightly and monthly sampling programmes and hence demonstrate for any particular load estimation formula (i) its average bias, and (ii) the relationship between precision and number of samples. For the full data set there was a positive underlying association between concentration and flow, and this resulted in load estimates based on the simple arithmetic mean approach to underestimate the true value. In this instance, the estimates from weekly and fortnightly programmes were on average only 38% of the true load, whilst for the monthly programmes the ratio dropped still further to 25%. In contrast, the flow-weighting approach showed negligible bias.

The lack of bias, though desirable, is not everything, and the simulation results also clearly highlighted the greater imprecision necessarily introduced by flow-weighting when there is a positive association between concentration and flow. In other words, errors from repeated use of the flow-weighted approach will average out in the long run, but the estimate in any one application may be a long way from the true figure.

The Helsinki Commission which is responsible for the Convention on the Protection of the Marine Environment of the Baltic Sea Area provides the only identified example of a flow driven sampling program. The approach taken by the commission to produce reliable data includes pollution load compilations (PLC's) from land-based sources. The associated sampling strategy is aimed at providing precise estimates of input load and has three components:

- monitored rivers
- partly monitored rivers
- non-monitored rivers.

Experience has shown the positive correlation between periods of high river flow and high load input, especially for heavy metals, suspended solids and nutrients. For all rivers a minimum of 12 data sets are collected throughout the year, the data does not have to be collected at regular monthly intervals but at a frequency which appropriately reflects the expected river pattern, measurements should, therefore, cover low, mean and high flow data to gain a more representative assessment of contaminant load.

The benefits of flow related sampling are clear to see. These have to be carefully weighed against the increased cost and logistical consideration of adapting this approach to met the Agency's needs.

APPENDIX B AUTOMATIC WATER QUALITY MONITORING

AUTOMATIC WATER QUALITY MONITORING

B1. GENERAL CONSIDERATIONS

The analytical methods employed with automatic water quality monitors (or on-line instruments) are, in the main, fundamentally the same as those used in the laboratory. The main difference between laboratory instrumentation and on-line instrumentation is to do with the robustness of construction and the addition of automatic systems for sample preparation, instrument/sample line cleaning and instrument calibration.

In an ideal world, an on-line chemical analyser would employ low cost non-invasive measurement techniques, produce highly accurate results and never need servicing. In reality a target of achieving results of acceptable accuracy at an acceptable cost, with a service requirement not greater than once per week is likely to be more appropriate. To achieve this, the main features required in an automatic water quality monitor are:

i) appropriate location of sampling point;

ii) purpose-designed robust construction, both in terms of the physical protection provided by the instrument housing and the robustness of the operational methodology;

iii) tolerance to the extremes of temperature likely to be encountered;

iv) resistance to the ingress of dust and water;

v) tolerance of electromagnetic fields, electrical transients and power supply disturbances;

vi) minimum supervision and maintenance requirements;

vii) designed for easy access and fault-finding when maintenance is required;

viii) purpose-designed sample transport and conditioning system.

The two main applications are for monitoring or control. In general, monitoring applications require predictable, long-term analytical performance in terms of accuracy and reproducibility to ensure comparability of the data. On the other hand, fast response time and high sample throughput rates are not usually an issue. In contrast, analysers used in process control applications often have to respond rapidly and reproducibly to small changes in the composition of the process fluid, whereas absolute accuracy is often of lesser importance.

The choice of analysis method and hence instrument has to be made with due regard for the use to which the resulting data will be put. For example, instruments based on well documented colorimetric methods can provide data of predictable and consistent quality. However, depending on the inherent delay in the chemistry involved, they tend to have fairly long response times from the sample entering the analyser to the output of the result. Instruments based on such methods may, therefore, be less than ideal in control applications requiring a fast response, but are suited to monitoring applications. In contrast, electrochemical analysers are less predictable in their performance, thus requiring frequent recalibration. However, their relatively rapid response to changes in the sample stream composition is often an important consideration in process control applications.

The degree of complexity inherent in any given analyser installation is dependent on both the complexity of the measurement technique and the nature of the sample. As an example, the on-line measurement of conductivity can be easily and reliably performed on a wide range of sample types using a non-contact measurement technique. In contrast, the measurement of determinands such as phenol, on a treated or partially treated waste effluent, is fraught with difficulty and requires a high level of operator input.

The basic measuring techniques which are in general on-line use are physical, electrochemical and photometric. Examples of the range of determinands for which on line analysers based on these techniques are available, are listed below.

1. **Physical:** colour, turbidity, suspended solids, conductivity, pressure, depth, level, density, temperature, flow rate, volumetric flow.

2. **Electrochemical:** pH, ammonia, nitrate, bromide, calcium, carbon dioxide, chloride, chlorine, metals, cyanide, fluoride, REDOX, dissolved oxygen.

3. **Colorimetric:** ammonia, nitrate, nitrite, phosphate, chloride, fluoride, sulphate, metals, manganese, phenols.

4. **Other measurement techniques which are available on line include:** High temperature and low temperature methods for organic carbon measurement. Respirometry for BOD and toxicity. Gas chromatography and HPLC for phenols and organics.

Dedicated analysers are available for many of these determinands, but in situations where this is not the case, then a user configurable analyser can be used. Such analysers, often referred to as 'process titrators' or 'process analysers', are available from a number of manufacturers. These instruments consist of a programmable controller and a selection of valves, pumps, sample conditioning devices and sensor options. The flexibility offered by these analysers enables laboratory methods based on titrimetric, colorimetric and electrochemical techniques to be operated on-line.

There are three basic types of process analyser configuration, two of these are continuous flow systems and the third is a batch process in which measured volumes of sample are processed in a series of discrete steps on a continuous basis. The time interval between each analysis is usually user selectable, with a minimum value which is a function of the design of the instrument and the method of analysis. These analysers are usually constructed in a modular form to facilitate simple adaptation to a wide range of analytical methods.

The selection and installation of an on-line analyser should be approached in a similar way to that employed in the selection of appropriate laboratory methodology/instrumentation. The application should be identified in terms of the:

i) determinand to be measured;

ii) reason for making the measurement;

iii) required frequency of the measurements;

iv) consequences of analyser failure;

v) composition of the sample;

vi) accessibility of a suitable sampling point; and,

vii) availability of suitable locations for the analyser installation.

Using this information, the analyser performance requirements should be defined and the sample conditions identified. Points to be considered include:

i) The performance required i.e. systematic error, random error, specificity, limit of detection and response time;

ii) The environment in which the analyser will be installed and hence the degree of environmental protection required. If an appropriately protected analyser is not available then additional protection may have to be provided;

iii) The electrical environment in which the analyser will be operated. A poor quality electrical supply, the close proximity of heavy electrical plant or sources of electromagnetic radiation may necessitate the installation of power supply conditioning equipment or additional shielding;

iv) The requirements for sample transport and conditioning prior to analysis. Limitations on the acceptable range of sample composition at the input to the analyser may necessitate additional sample conditioning to be undertaken. The delays which are likely to occur within the proposed sampling and analysis system should be estimated and compared with the identified measurement response time requirements to ensure that the installation is capable of meeting the requirements.

Sampling systems play a very necessary and vital role in the successful operation of on-line analysers. Unless the sensor is located directly into the waterbody there is a requirement to convey the sample to the analyser. Even in the case of sensors inserted directly into the waterbody the location of the sensor is crucial in obtaining representative results.

There is a temptation to view the sampling system as simply a method of transporting the sample from the waterbody to the analyser, without considering all the potential implications. This can lead to a number of problems occurring:

i) significant changes in the composition of the sample within the sampling system giving rise to unrepresentative results;

ii) insufficient sample flow or long delays between the sample being extracted from the waterbody and delivered to the analyser;

iii) the sample line becoming blocked;

iv) failure of the instrument to live up to expectations or being considered to be unreliable and hence gradually falling into disuse.

It is clear that the sampling system is an integral part of the installation which must be taken into account early in the design stage if the overall objectives are to be met.

The choice of which system to apply will depend on a number of factors such as:

i) the separation between the analyser and the sampling point;

ii) the system response time requirements;

iii) the consequences of changes occurring in the sample; and,

iv) the nature and composition of the sample.

The design of the sampling system should encompass the design objectives listed below. The priority assigned to each of these objectives will depend on the details of the specific application.

i) Representative sampling: The sample that is delivered to the instrument should be representative of the process stream with respect to the determinands being measured.

ii) Compatibility: The sample should be presented to the analyser in a state which is compatible with the measurement technique used by the analyser.

iii) Sample transport delay: The design of the sample system should take account of the inherent time lag, between the sample being taken from the waterbody and delivered to the inlet to the analyser, so as to ensure the overall response time objectives can be met.

iv) Reliability: The sampling system should be reliable and require the minimum of maintenance. If necessary automatic back flushing and/or air purge can be employed, along with a duty and standby system.

v) Safety: The sampling system must be safe to operate and maintain.

vi) Validation: The system should be designed with grab sample tapping points at suitable locations to facilitate system validation both at the commissioning stage and routinely during its operational life.

B2. MAINTENANCE REQUIREMENTS FOR AUTOMATIC WATER QUALITY MONITORS

The majority of on-line analysers require direct contact with the water to be sampled. Wherever this is the case, there is the potential for fouling of the sampling system or sensor to occur, thus affecting the overall performance of the installation. The affect of fouling on the analyser may result in the collection of misleading and unreliable data or the failure of an automatic control system.

The types of fouling encountered in sampling natural waters are usually biofouling, (growth of bacterial/fungal films) and particulate fouling by particles present in the effluent.

More often than not the types of fouling outlined above will form as a combination of different types and form a complex fouling layer. This presents problems in how to predict what type of fouling will occur at a particular stage of the treatment process and the rate at which it will occur.

If sensor fouling is likely to occur there are three main approaches to reducing the affect of fouling. These are manual cleaning, preventive techniques and automatic cleaning.

One method of overcoming sensor fouling is to instigate a rigorous manual cleaning schedule. A procedure needs adopting where the sensor is removed from the waterbody and cleaned manually at an interval which is sufficient to keep the analyser operating within its operational requirements. This may be undesirable because resources may be limited, costs may be excessive, or safety may be an issue.

If manually cleaning on a frequent basis is undesirable then choosing sensor which is less prone to fouling or which incorporates some form of automatic cleaning is an alternative option.

If the fouling cannot be prevented or reduced to an acceptable level, some form of automatic cleaning may be needed. Many analysers are available with automatic cleaning options.

Fouling may be reduced by filtering or separating out particulate matter from the sample fluid before it reaches the sensor. This technique can only be used on analysers that are not affected by the removal of the particulate matter from the sample. Any separation device that is used should be inherently self cleaning, non fouling or require infrequent manual cleaning. Suitable devices include hydrocyclones for the removal of larger particles or cross flow filtration devices that are available in a range of sizes.

B3. PORTABLE MONITORS

Portable monitoring equipment used both in conjunction with automatic monitors and for measuring determinands in situ which cannot be reliably measured by the time the sample has been returned to the laboratory (such as pH, DO and conductivity) are in routine use in many countries.

APPENDIX C COMMONLY USED ANALYTICAL METHODS

C1. COMMONLY USED ANALYTICAL METHODS

The following Table gives details of the commonly used analytical methods for a range of determinands described in main body of the report. Also given is an indication of the limits of detection (LoDs) and precision that are quoted for the methods in the referenced texts. In addition, for some substances LoD’s that can be routinely achieved in good analytical laboratories (by gas-chromatography mass-spectrometry techniques) are given in brackets. The Tables should be used as a guide when aggregated monitoring data are assessed during the implementation phase of the proposed networks. Also given as examples are references for standard methods drawn up by the UK’s Standing Committee of Analysts (SCA). There are of course international organisations such as the European Standardisation Committee (CEN) and the International Standards Organisation (ISO) producing similar standard methods which would be equally relevant

Table C.1 Commonly used analytical methods

Determinand	LoD	Precision	Methods
water temperature		+/- $0.08^{o}C$ (Pt resist)	All waters - liquid in glass thermometer, thermocouple, resistance thermometer, typically used, (20).
pH	n/a	function of equipment used	Fresh/marine/river/ lake waters - Electrochemical potential of a cell which is responsive to the hydrogen ion activity and which contains the test solution analyte (4).
conductivity	Depends on cell construction	1.5%	Fresh/Marine/Lake/River waters - Electrical resistance of the sample in a cell of known dimensions (4).
dissolved oxygen	0.08-0.46 mg L^{-1}	0.5-5%	Fresh/marine/lake/river waters - titrimetric method - DO in solution oxidises freshly precipitated manganous hydroxide. Acidification in the presence of iodide liberates iodine in stochiometric equivalence to DO content. The free iodine is measured titrimetrically (5).
colour			River/lake/fresh waters - the colour difference between a filtered water sample and a deionised water is determined by transmission measurement (400-700nm) in CIELAB units - can be converted to CHUs if required (26).
suspended matter	2 mg L^{-1}	5-10%	Fresh/river/lake/marine waters - Filtration through pre-weighed glass fibre filter/ drying and weighing (14, 37)
turbidity	0.1 NTU	<3%	All waters - Nephelometric method using formazine suspensions as primary standards (36).
BOD	2 mg L^{-1}	1-5%	River/lake/fresh/marine waters - seeding if necessary, DO measurement, incubation for 5 days at $20^{o}C$, measurement of absorbed DO by DO electrode/titration (27).
TOC	10 mg C L^{-1} 0.1 mg C L^{-1}	<5% <5%	All waters - UV-persulphate - non-dispersive IR detector (35) - High temperature catalytic oxidation NDIR (35)
alkalinity	3.2 mg $CaCO_3$ L^{-1}	<1%	Titration of the sample with a standard solution of acid with instrumental detection of end points at pH 8.3 and 4.5 (29) .
Ca	0.38 mg L^{-1}	<10%	River/lake/fresh waters - Acidified sample, treated with lanthanum salt and aspirated into flame AAS (38). Also ion chromatography.
K	0.08 mg L^{-1}	4%	Fresh/river/lake waters - flame photometry (9)
Mg	mg L^{-1}	<5%	Fresh/river/lake waters - Acidified sample, treated with lanthanum salt and aspirated into flame AAS (38) also Ion Chromatography.
Na	0.03 mg L^{-1}	1%	Fresh/river/lake waters - flame photometry (8)
Cl			All waters - Conductivity
SO4	0.1 mg L^{-1} 0.1 mg L^{-1} 2 mg L^{-1}	<10% <5% <10%	All waters - ICP-OES, 180.73nm (32) - Ion chromatography (32) - Automated methylthymol blue colorimetric (32)
aluminium	0.01-0.1 μg L^{-1} 13 μg L^{-1}	0.5-3% 1-20%	Fresh/River/Lake waters - ICP-MS (2) - Pyrocatechol violet/colorimetry (6)

Table C.1 continued

Determinand	LoD	Precision	Methods
total phosphorus	0.003 mg L^{-1} 40 µg L^{-1}	<1% <5%	All waters - various pretreatments e.g. persulphate, followed by molybdate spectrophotometry as for phosphate (33). All waters - ICP-OES (33)
PO4P	0.003 mg L^{-1}	<1%	All waters-Phosphomolybdenum blue - continuous flow spectrophotometry (33).
Kjeldahl nitrogen	0.093 mg N L^{-1}	1-10%	River/lake/fresh/marine waters - digestion with conc. sulphuric acid/peroxide, dilution and determination of ammonia by continuous flow (23)
oxidised nitrogen	0.02-0.56 mg L^{-1} 0.02 -36 mg L^{-1}	1-5% 1-5%	Saline waters-Copperised Cd/continuous flow spectrophometry River/lake/fresh waters - Cu/hydrazine continuous flow (11)
ammoniacal nitrogen	0.009 mg L^{-1} 0.0013 mg L^{-1}	0.5-3% 0.5-3%	Fresh/River/Lake waters - continuous flow spectrophometry using salicylate or phenol/DIC Marine waters - continuous flow Phenol/DIC spectrophometry (12)
silica	0.03 mg L^{-1} 0.01 mg L^{-1}	2.5% <5%	Fresh/River/Lake/Marine waters using molybdate/spectrophotometric determination (10) All waters - ICP-OES (33)
chlorophyll a	ca. 1 mg L^{-1}	ca. 10%	Fresh/river/lake/marine waters - Extraction of pigment into organic solvent (acetone or methanol) - spectrophotometry/fluorimetry (17).
Secchi disc transparency	n/a	n/a	All water - visually detectable turbidity (36).
cadmium	0.01-0.1 µg L^{-1} 0.1 µg L^{-1}	0.5-3% 5-10%	Fresh/lake/river waters - ICP-MS (2) Fresh/Lake/river waters - GF-AAS (21)
chromium	0.01-0.1 µg L^{-1} 0.44-7.4 µg L^{-1}	0.5-3% 1-5%	Fresh/River/Lake waters - ICP-MS (2) - GF AAS (7,30)
copper	0.01-1 µg L^{-1} 0.52 µg L^{-1}	0.5-3% <5%	Fresh/lake/river waters - ICP-MS (2) - GF-AAS (30)
iron	0.1-10 µg L^{-1}	0.5-3%	Fresh/lake/river waters - ICP-MS (2)
mercury	2 ng L^{-1}	10% at 25 ng L^{-1}	Fresh/Marine/Lake waters - cold vapour AAS (3)
manganese	5 µg L^{-1}	1-5%	
nickel	0.01-0.1 µg L^{-1} 1.0 µg L^{-1}	0.5-3% <10%	Fresh/lake/river waters - ICP-MS (2) - GF-AAS (30)
lead	1.0 µg L^{-1} 0.01-0.1 µg L^{-1}	3-20% 1-5%	Fresh/lake/river waters - Solvent extraction AAS (1), GF-AAS (21) - ICP-MS (2)
zinc	0.01-0.1 µg L^{-1} 2 µg L^{-1}	0.5-3% <5%	Fresh/lake/river/marine waters - ICP-MS (2) - Flame AAS (31)

Table C.1 continued

Determinand	LoD	Precision	Methods
solvents - PAH - PCB - chlorophenols - organo-Cl-pesticides	 0.02-0.2 μg L^{-1} 1-2 ng L^{-1} 0.1-0.9 mg L^{-1} 0.021-0.1 μg L^{-1}	 5-10% 4% at 10 ng L^{-1} 1-5% <10%	 Fresh/lake/river waters - phenanthrene/naphthalene pentane extraction/floisil clean-up, GC-FID (22) Fresh/lake/river waters - Extraction with cyclohexane HPLC-fluorimetry (23) - routine method Fresh/lake/river waters-Solvent extraction/derivatisation-GC (13) Fresh/lake/river waters-deriv with PFB esters/extraction GC-ECD (25)
Trifluralin	1-2 ng L^{-1}	<10%	Fresh/river/lake waters - Extraction with cyclohexane HPLC-fluorimetry (23) - routine method
Endosulfan			River/lake/fresh waters - Extraction into hexane, column clean up GC-ECD (34). Also GC-MS
Simazine	6.8 μg L^{-1} (5 ng L^{-1})		DCM extraction GC-ECD (39). Also GC-MS (43).
Atrazine	2.4 μg L^{-1} (5 ng L^{-1})		DCM extraction GC-ECD (39) Also GC-MS (43).
Azinphos ethyl	<01 μg L^{-1} (10 ng L^{-1})		River/lake/fresh waters - Hexane/DCM extraction GC-MS
Azinphos methyl	<0.1 μg L^{-1} (10 ng L^{-1})		River/lake/fresh waters - Hexane/DCM extraction GC-MS
Fenitrothion	0.03 μg L^{-1}	10-20%	River/lake/fresh waters - extraction into hexane or DCM - GC-FPD (15). Also GC-MS (43).
Fenthion			All waters- Extraction GC-TID, or GC-MS.
Malathion	0.13 μg L^{-1} (5 ng L^{-1})	10-20%	River/lake/fresh waters - extraction into hexane or DCM - GC-FPD (15). Also GC-MS (43).
Parathion	0.1 μg L^{-1} (10 ng L^{-1})	10-20%	River/lake/fresh waters - extraction into hexane or DCM - GC-FPD (15) also GC-MS (43).
Parathion methyl	<0.1 μg L^{-1} (10 ng L^{-1})		River/lake/fresh waters - Hexane/DCM extraction GC-MS
Dichlorvos	0.04 μg L^{-1}	10-20%	River/lake/fresh waters - extraction into hexane or DCM - GC-FPD (15) Also GC-MS (43).
Drins	3-14 ng L^{-1} 3-14 ng L^{-1}	up to 50% ca. 50%	Turbid river/lake/fresh water samples - extraction with ethyl acetate, hexane, clean up using alumina-silver nitrate, column chromatography/GC-ECD (19). River/lake/fresh waters - Extraction into hexane, column clean up GC-ECD (34).
DDT	15 ng L^{-1} 15 ng L^{-1} (5 ng L^{-1})	up to 50% up to 50%	Turbid river/lake/fresh water samples - extraction with ethyl acetate, hexane, clean up using alumina-silver nitrate, column chromatography/GC-ECD (19). River/lake/fresh waters - Extraction into hexane, column clean up GC-ECD (34). (Each individual isomer)
Chloridazon	<0.1 μg L^{-1}		All waters extraction with polar solvent - or solid phase extraction, HPLC-UV detection (43).

Table C.1 continued

Determinand	LoD	Precision	Methods
Cyanazine	20 μg L^{-1}		All waters - DCM extraction column switching HPLC-UV detection (43).
1,3-dichloropropene	<0.1 μg L^{-1}		All waters - Purge and trap GC-MS (43, 44).
Diuron	0.7 μg L^{-1} 0.05 μg L^{-1}	<10%	All waters - Liquid/liquid extraction - filament off LC-TSP-MS (43). Also solid phase extraction LC-UV (43).
Dimethoate	<0.1 μg L^{-1}		All waters - Extraction GC-MS (43).
Disulfoton	0.3 μg L^{-1}		All waters - DCM extraction, solvent substitution with MTPE, GC-NPD (40,43).
1,2- dichloropropane	0.02 μg L^{-1}		All waters - Purge and trap GC-MS (43, 44).
Hexazione	0.8 μg L^{-1}		All waters - DCM extraction - GC-NPD (40)
Metabenzthiazuron	0.1 μg L^{-1}		Large volume injection-column switching reversed phase HPLC with UV detection (43).
Metazachlor			all waters - GC-ECD after extraction/clean up
Metholachlor	0.7 μg L^{-1}		All waters - DCM extraction - GC-NPD (40)
Metoxuron	<0.1 μg L^{-1}		Extraction (methanol/acetonitrile) -HPLC (43).
Mevinphos	5 μg L^{-1}		All waters - DCM extraction - GC-NPD (40)
Propachlor	0.5 μg L^{-1}		River/lake/fresh waters - DCM extraction, solvent substitution with MTBE - GC-ECD (41)
Trichloroethylene	1.0 μg L^{-1}	ca. 10%	River/lake/fresh waters - headspace GC-ECD (22)
Tetrachloroethylene	1.6 μg L^{-1}	ca. 10%	River/lake/fresh waters - headspace GC-ECD (22)
Trichlorobenzene	<0.1 μg L^{-1} (50 ng L^{-1})	<20%	All waters - Extraction clean up - GC-ECD or GC-MS (Each isomer)
1, 2 Dichloroethane	<1 μg L^{-1}	<20%	All waters - cryogenic trapping GC-ECD.
1,1,1,- Trichloroethane	0.6 μg L^{-1}	ca. 10%	River/lake/fresh waters - headspace GC-ECD (22)
Dioxins	ca. 0.01 ng L^{-1}	ca. 20%	River/lake/fresh waters - extraction-GC-MS.
HCH	12 ng L^{-1} 12 ng L^{-1} (1 ng L^{-1})	up to 50% up to 50%	Turbid river/lake/fresh water samples - extraction with ethyl acetate, hexane, clean up using alumina-silver nitrate, column chromatography/GC-ECD (19). River/lake/fresh waters - Extraction into hexane, column clean up GC-ECD (34). (Each isomer)
HCB	0.6 ng L^{-1}	20%+	River/lake/fresh waters -separation of HCB by column chromatography-capillary GC-ECD (19)
Carbon tetrachloride	0.13 μg L^{-1}	ca. 10%	River/lake/fresh waters - headspace GC-ECD (22)
Chloroform	0.66 μg L^{-1}	ca. 10%	River/lake/fresh waters - headspace GC-ECD (22)
PCP	0.08 μg L^{-1}		River/lake/fresh waters - hydrolysis at pH 12, solvent wash, acidification, extraction into diethyl ether, derivatise with diazomethane - GC-ECD (42).

Table C.1 continued

Determinand	LoD	Precision	Methods
TBT	1 ng L^{-1} 4 ng L^{-1}	30% at LOD	All waters - derivatisation (sodium borohydride) GC-AAS Solvent extraction AAS (total organic tin) Also GC-MS (43).
TPT	1ng L^{-1}	30% at LOD	All waters - derivatisation (sodium borohydride) GC-AAS Also GC-MS (43).
total coliform			All waters - No./100ml multiple test tube - No./100ml membrane filtration
faecal coliform			All waters - No./100ml multiple test tube - No./100ml membrane filter
faecal streptococci			All waters - No./100ml multiple tube fermentation - No./100ml membrane filter
Salmonella			River/lake/fresh/marine waters - concentration/pre-enrichment-selection-confirmation of bacteria, (16).
Total alpha activity	37 mBq L^{-1}	5%	River/lake/fresh waters - sample acidified/concentrated/sulphated and ignited. Counting source prepared from dried dissolved solid - alpha activity measured using an alpha particle detector system (18)
^{137}Cs	1 Bq L^{-1}		River/lake/fresh/marine waters - Gamma spectrometry, using high purity germanium detector (27).

Key to Table C.1

HPLC	High Performance Liquid Chromatography
GC	Gas Chromatography
MS	Mass Spectrometry
AAS	Atomic Absorption Spectrometry
GF-AAS	Graphite Furnace AAS
ICP	Inductively Coupled Plasma
ECD	Electron Capture Detector
FID	Flame Ionisation Detector
NPD	Nitrogen Phosphorus Detector
FPD	Flame Photometric Detector

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