British Geological Survey

NATURAL ENVIRONMENT RESEARCH COUNCIL

Achieving Sustainable Catchment Management: Developing Integrated Approaches and Tools to Inform Future Policies. Work Package 1: Characterising the Resource Base

Groundwater Management Programme

Commissioned Report CR/06/095N

BRITISH GEOLOGICAL SURVEY

GROUNDWATER MANAGEMENT PROGRAMME

COMMISSIONED REPORT CR/06/095N

Achieving Sustainable Catchment Management: Developing Integrated Approaches and Tools to Inform Future Policies. Work Package 1: Characterising the Resource Base

B Adams, D Peach, H Bennion and R Williams

Keywords

Sustainable; catchment; management.

Bibliographical reference

ADAMS B, PEACH D, BENNION H AND WILLIAMS R.. 2006. Achieving Sustainable Catchment Management: Developing Integrated Approaches and Tools to Inform Future Policies. Work Package 1: Characterising the Resource Base. *British Geological Survey Commissioned Report*, CR/06/095N. 6pp.

Keyworth, Nottingham British Geological Survey 2006

BRITISH GEOLOGICAL SURVEY

The full range of Survey publications is available from the BGS Sales Desks at Nottingham, Edinburgh and London; see contact details below or shop online at www.geologyshop.com

The London Information Office also maintains a reference collection of BGS publications including maps for consultation.

The Survey publishes an annual catalogue of its maps and other publications; this catalogue is available from any of the BGS Sales Desks.

The British Geological Survey carries out the geological survey of Great Britain and Northern Ireland (the latter as an agency service for the government of Northern Ireland), and of the surrounding continental shelf, as well as its basic research projects. It also undertakes programmes of British technical aid in geology in developing countries as arranged by the Department for International Development and other agencies.

The British Geological Survey is a component body of the Natural Environment Research Council.

British Geological Survey offices

Keyworth, Nottingham NG12 5GG

☎ 0115-936 3241 Fax 0115-936 3488
e-mail: sales@bgs.ac.uk
www.bgs.ac.uk
Shop online at: www.geologyshop.com

Murchison House, West Mains Road, Edinburgh EH9 3LA

☎ 0131-667 1000 Fax 0131-668 2683
e-mail: scotsales@bgs.ac.uk

London Information Office at the Natural History Museum (Earth Galleries), Exhibition Road, South Kensington, London SW7 2DE

☎ 020-7589 4090 Fax 020-7584 8270
☎ 020-7942 5344/45 email: bgslondon@bgs.ac.uk

Forde House, Park Five Business Centre, Harrier Way, Sowton, Exeter, Devon EX2 7HU

☎ 01392-445271 Fax 01392-445371

Geological Survey of Northern Ireland, Colby House, Stranmillis Court, Belfast BT9 5BF

☎ 028-9038 8462 Fax 028-9066 2835
e-mail: gsni@detini.gov.uk

Maclean Building, Crowmarsh Gifford, Wallingford, Oxfordshire OX10 8BB

☎ 01491-838800 Fax 01491-692345
e-mail: hydro@bgs.ac.uk

Columbus House, Greenmeadow Springs, Tongwynlais Cardiff, CF15 7NE

☎ 029–2052 1962 Fax 029–2052 1963

Parent Body

Natural Environment Research Council, Polaris House, North Star Avenue, Swindon, Wiltshire SN2 1EU

☎ 01793-411500 Fax 01793-411501
www.nerc.ac.uk

Foreword

This report is the published product of a study by the British Geological Survey (BGS), University College London (UCL) and the Centre of Ecology and Hydrology (CEH). It was produced as part of the scoping study "Achieving Sustainable Catchment Management: Developing Integrated Approaches and Tools to Inform Future Policies" (project code:RES-224-25-0081), under the Research Councils' Rural Economy and Land Use (RELU) Programme. RELU is funded jointly by the Economic and Social Research Council, the Biotechnology and Biological Sciences Research Council and the Natural Environment Research Council, with additional funding from the Department for Environment, Food and Rural Affairs and the Scottish Executive Environment and Rural Affairs Department.

This report is the product of Work Package 1 of the Scoping Study – Characterising the Resource Base. The Work Package was led by Brian Adams of the BGS and included written contributions from Denis Peach (BGS), Helen Bennion (UCL) and Richard Williams (CEH). Like all Work Package reports in this study, it was peer-reviewed by experts from different disciplines in the social and natural sciences. For consistency between the different work packages, a common structure was adopted. Hence this report does not follow the standard BGS report format.

RELU THEME A SCOPING STUDY
1 July 2004 – 31 September 2005

Achieving Sustainable Catchment Management: Developing Integrated Approaches and Tools to Inform Future Policies

RES-224-25-0081

Work Package 1: Characterising the Resource Base

by

Brian Adams BGS Wallingford
Dennis Peach BGS Wallingford
Helen Bennion UCL
Richard Williams CEH Wallingford

April 2005

A joint Research Councils Programme

RESEARCH COUNCILS UK

RURAL ECONOMY AND LAND USE

co-sponsored by Defra and SEERAD

This report was produced as part of the scoping study "Achieving Sustainable Catchment Management: Developing Integrated Approaches and Tools to Inform Future Policies" (project code: RES-224-25-0081), under the Research Councils' Rural Economy and Land Use (RELU) Programme. RELU is funded jointly by the Economic and Social Research Council, the Biotechnology and Biological Sciences Research Council and the Natural Environment Research Council, with additional funding from the Department for Environment, Food and Rural Affairs and the Scottish Executive Environment and Rural Affairs Department.

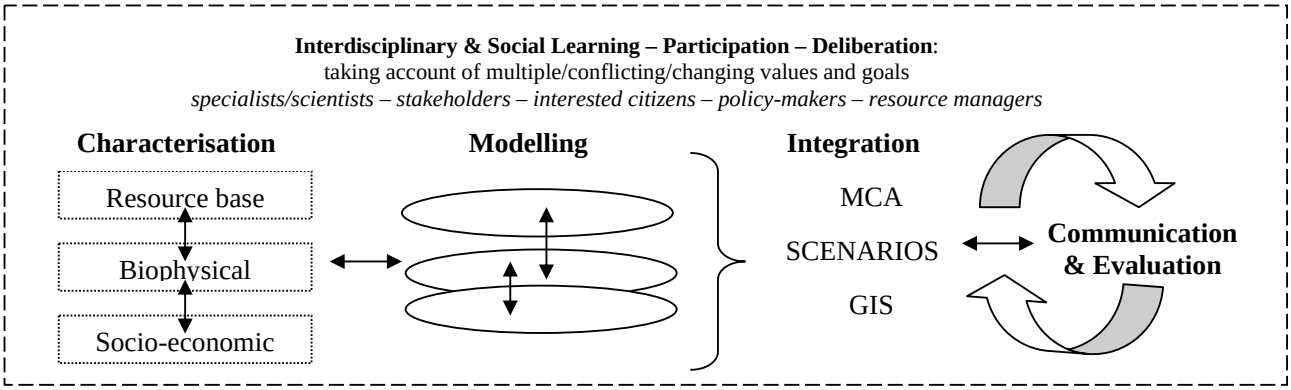
This 15-months project facilitated learning amongst 27 scientists from a range of natural and social science disciplines. The focus was on developing a coherent interdisciplinary framework for the environmental management of water and land resources in the UK. The study addressed how current approaches to catchment management can create barriers to interdisciplinary work. Scoping involved reviewing the theoretical underpinnings of key methodologies, their operational components, typical uses, strengths and weaknesses, and potential synergies or incompatibilities with other methodologies. As illustrated in the diagram below, four main components were identified:

(1) Characterisation: the hydrological and physical resource base; biophysical catchment characterisation addressing ecological characteristics; and establishing criteria to capture socio-cultural and economic factors;

(2) Modelling: current approaches and available data with respect to understanding and explaining ecosystem responses to changes in rural land use and catchment management;

(3) Integration: (i) multi-criteria analysis (MCA); (ii) (participatory) scenario building and analysis; and (iii) geographic information systems (GIS) as potential interdisciplinary meta-methodologies;

(4) Communication and Evaluation: different evaluation approaches and communication tools, their efficacy and transparency to benefit those directly involved in the project as well as end-users and the wider public.



This research is relevant to natural and social scientists with interests in land use policy, catchment management, environmental governance, inclusive deliberative and experiential processes and methodological issues; agencies and public bodies involved in land/water use policy formulation and implementation, and environmental NGOs.

The work package (WP) reports were all peer-reviewed by experts from different disciplines in the social and natural sciences; and all (except WP1) were revised in light of comments. For consistency between the different work packages, a common structure was adopted and the project manager acted as series editor.

Work Package Series Editor: Claudia Carter

WP1: Characterising the Geo-Physical Resource Base
by Brian Adams, Denis Peach, Helen Bennion and Richard Williams

WP2: Characterising the Ecological Resource Base
by Richard Williams, Helen Bennion, Brian Reynolds and Linda May

WP3: Socio-Economic Characterisation of Catchments
by Clive L. Spash and Claudia Carter

WP4: Catchment Modelling
by Robert Ferrier, Russell Manson, Alan Jenkins

WP5: Multi-criteria Analysis
by Jacquie Burgess, Sigrid Stagl and Andy Stirling

WP6: Scenarios and Futures Analysis
by Dale S. Rothman and Klaus Hubacek

WP7: Spatial Data and Related Technologies for Catchment Management
by Cristopher Macleod, John DeGroote, Michael Hughes, Martin Kernan, Kevin Urama and Kirsty Blackstock

WP8: Social Learning, Participation and Deliberative Processes
by Kirsty Blackstock and Judy Clark

CONTENTS

1. AIMS OF THE REPORT

This report discusses the characterisation of the water resources of the United Kingdom within the context of the EU's Water Framework Directive (WFD). This single piece of framework legislation, which came into force on December 22, 2000, was introduced in response to a widespread consensus that water policy within Europe was fragmented in terms of both objectives and means. The WFD expands the scope of protection to all waters, both surface waters and groundwater. In doing so it also contributes to the provision of a supply of water in quantities and qualities needed for sustainable development (i.e. taking into account both anthropogenic and ecological demand).

Under Article 17 of the Water Framework Directive, the European Commission was required to propose specific measures to prevent and control groundwater pollution and achieve good groundwater chemical status. These measures were to include criteria for assessing the chemical status of groundwater and for identifying trends in pollution of groundwater bodies. In order to fulfil the requirement, the Commission adopted the proposed groundwater directive on 19 September 2003. However, the Member States did not approve the proposed Groundwater Directive. Negotiations on its content are still ongoing with significant efforts currently being made to reach agreement. The negotiations also involve the European Commission, European Parliament and the Environment Committee. It is thought unlikely that the Groundwater Directive will come into force before the summer of 2005.

The WFD sets out a planning cycle which consists of four main parts:

- Environmental and economic characterisation of river basin districts and assessment of pressures and impacts on waters within the districts;
- Environmental monitoring informed by river basin characterisation;
- Setting of environmental objectives; and
- Design and implementation of a programme of measures to achieve environmental objectives.

One of the key environmental objectives of the WFD is the achievement of "good status" for all water bodies save exceptional cases. Good status means that certain standards have been met for the ecology, chemistry and quantity of waters. In general terms, it means that waters only show slight change from what might normally be expected under undisturbed conditions. It is therefore important that the resource base can be characterised both in terms of its current 'status' and in terms of the current and possible future pressures upon it. This report discusses the approaches adopted in England and Wales, Scotland and Northern Ireland for the environmental characterisation of water bodies and for assessing the various pressures and associated impacts on those water bodies within the context of the WFD. The competent agencies responsible for these assessments in the various countries are the Environment Agency of England and Wales (EA), the Scottish Environment Protection Agency (SEPA) and the Environment and Heritage Service of Northern Ireland (EHS).

Whilst the WFD includes consideration of coastal and estuarine waters, these have been excluded from discussion in this report which only includes groundwaters and surface waters (lakes and rivers).

2. CONTEXT: DRIVERS OF CHANGE, PRESSURES, IMPACTS / CRITICAL ISSUES

2.1 Drivers of Change

The WFD and the planned daughter Groundwater Directive set the framework for this scooping study. However, whilst the WFD describes the framework and objectives, the methodologies to achieve the objectives are not prescribed. Thus the Member States are at liberty to utilise existing and/or develop new methodologies appropriate to their needs in order to meet the requirements of the objectives.

Within the United Kingdom a Technical Advisory Group (UKTAG) has been established. UKTAG was established in 2001 to provide coordinated advice on technical aspects of the implementation of the WFD and is a partnership of the UK environment and conservation agencies and includes partners from the Republic of Ireland.

In 2003/04, UKTAG's work included:

- Developing guidance on:
  - Identifying and characterising water bodies (including lakes, rivers, estuaries, coastal waters and groundwater) according to their physical characteristics.
  - Assessing the risk of these water bodies failing to achieve the WFD's environmental objectives (The WFD requires this assessment of risk to be based on the analysis of water body characteristics and on a pressures and impacts analysis. The initial assessments had to be completed by the end of 2004).
- Contributing, along with experts from the European Commission, other Member States, accession countries and stakeholder groups, to the development of common approaches to implementation (also known as the Common Implementation Strategy).
- Developing classification systems to support future monitoring and implementation of the WFD as well as inter-calibration across Europe.

In 2004/05, work is also being initiated on:

- Development of a framework for monitoring.
- Supporting development of a framework for setting environmental objectives under the WFD.
- The scoping of principles which underlie future regulatory regimes that are compliant with WFD.

The competent authorities in the United Kingdom responsible for the implementation of the WFD (i.e. EA, SEPA and EHS) are basing their separate characterisation of water bodies on the guidance provided by UKTAG. Thus it is appropriate to look firstly at the guidance provided for the characterisation of surface water and groundwater bodies, and then to comment separately on the application by the separate competent authorities.

It should be noted that the guidance provided by TAG is no way mandatory, and the separate competent authorities responsible for the implementation of the WFD in the United Kingdom can choose to follow a different approach to that advised by UKTAG. Also much of the documentation provided by UKTAG are working drafts, with the expectation that methodologies described will evolve as they are applied.

2.2 Pressures and Impact Assessment

The WFD requires a Pressure and Impact Assessment to review the impact of human activity on surface waters and groundwaters and to identify those water bodies that are at risk of failing to meet the Directive's environmental objectives. The assessment will provide a starting point for integrated catchment management – through the river basin planning process – and will additionally inform monitoring programmes.

The central question of the Pressure and Impact Assessment is: Which water bodies are at risk of failing the environmental objectives set out in the Directive?' 'At risk' does not necessarily mean that the water bodies are already suffering poor status, but it does highlight areas where appropriate management actions should be applied to ensure that good status is maintained, or to ensure it is achieved in future. It is important to note that the assessments represent an **initial** characterisation of water bodies, with the Directive requiring **further characterisation** for 'at risk' and cross-border bodies. Where more detailed assessments are undertaken, the risk category may subsequently change.

The environmental objectives that need to be achieved under the Directive are somewhat complex but in simplified terms are:

For surface water

- Achievement of good ecological status and good surface water chemical status by 2015
- Achievement of good ecological potential and good surface water chemical status for heavily modified water bodies (HMWB) and artificial water bodies (AWB)
- Prevention of deterioration from one status class to another
- Achievement of water related objectives and standards for protected areas

- A progressive reduction in discharges of Priority Substances and a cessation of discharges of Priority Hazardous Substances

For groundwater

- Achievement of good groundwater quantitative and chemical status by 2015
- Prevention of deterioration in status
- Reversal of any significant and sustained upward trends in pollutant concentrations and prevention or limiting of input of pollutants to groundwater
- Achievement of water related objectives and standards for protected areas

Water bodies are to be identified as being at risk if they are likely to fail any of these environmental objectives. The focus of the first Pressure and Impact Assessment is on the risk that water bodies will fail to achieve good status by 2015. It is understood that under the future WFD classification scheme for surface waters, good status will mean that at least mandatory standards need to be met for the following protected areas: shellfish growing waters, bathing waters, freshwater fish designations, nitrate vulnerable zones and areas designated as sensitive under the Urban Waste Water Treatment Directive. Objectives for drinking water protected areas and Natura 2000 sites will also need to be met. Therefore, where existing mandatory protected area objectives are not being met relevant water bodies need to be identified as at risk.

For groundwaters, a new directive is under consultation (see above), which is intended to establish specific measures to prevent and control groundwater pollution, including the setting of chemical standards, which will define good chemical status.

A key challenge in carrying out this risk assessment exercise is that good status has not yet been fully and consistently defined across Europe. This task is underway and will feed into the final classification scheme to be used for further characterisation and reporting. In the meantime, and to ensure consistency within the UK, UKTAG has set out criteria to be used in the current assessments. It should be noted that transitional, coastal and groundwater bodies are typically very large and may be identified as being at risk due to localised pressures affecting only small portions of a water body. Any programme of measures established will take this into account. Although the Directive requires reporting of water bodies as either at risk or not at risk, UKTAG recommended that for UK purposes a further prioritisation is helpful. This more detailed categorisation will enable efforts to be focussed in the first round of river basin management planning. For the first analysis, effort has been concentrated on identifying the most significant risks. In order to help prioritise future action, results are reported using the following agreed UK categories shown in Table 1.

Table 1: Agreed UK reporting categories and subsequent action

Directive reporting category	UK reporting category	Action
At Risk	(1a) Water bodies at significant risk of failing objectives. Consideration of appropriate measures can start as soon as practicable.	Consideration of appropriate measures can start as soon as practicable.
	(1b) Water bodies probably at significant risk of failing objectives but for which further information is needed to make sure this view is correct.	Focus for more detailed risk assessments to determine whether or not the water bodies in this category are at significant risk in time for the interim overview of significant water management issues in 2007.
Not at Risk	(2a) Water bodies probably not at significant risk of failing objectives, or limited data available	Focus on improving quality of information in time for second Pressure and Impact analysis report in 2013.
	(2b) Water bodies not at significant risk of failing objectives.	Review for next Pressure and Impact analysis report in 2013 to identify any significant changes in the situation.

The Pressure and Impact analysis has used a variety of methods and data sets reflecting differences in availability and quality of data. Some assessments have used data recording environmental impacts, e.g. water quality, flora and fauna populations from current monitoring programmes, while others have used the presence of pressures on the environment, e.g. water abstraction sites and locations of physical structures such as weirs which may lead to an environmental impact.

These different approaches reflect the nature of the data and information available to these first assessments. The extent and quality of available data and information will improve in future cycles making later assessments more comprehensive and robust. The following categories are included in the Pressures and Impacts Assessment:

- Point source pollution
- Diffuse source pollution
- Abstraction and flow regulation pressures
- Morphological alterations
- Other human pressures (including alien species)

Evidently, it can be expected that many individual water bodies will be affected by more than one type of pressure, and that water bodies having different characteristics will react to similar pressures in different ways.

3. REVIEW OF CURRENT THEORY AND PRACTICE

3.1 Current Positions, Knowledge and State-of-the-Art

3.1.1 Surface Water Bodies

Rivers

A typology of natural rivers in Great Britain has been constructed to enable reporting of characterisation and water body status to the European Commission as required by the WFD and is which is consistent with typology System A of the WFD. The typology has only been developed to broadly differentiate reference condition biological and supporting quality element values; more precise differentiation is planned as a later stage of the WFD implementation. System A of the WFD uses altitude, catchment size and geology to define river types as shown in Table 2.

Table 2: System A categories of the WFD

Altitude (mean catchment)	Catchment size (km^2)	Dominant Geology
<200m	10-100	Siliceous
200-800m	100-1000	Calcareous
>800m	1000-10,000	Organic

This typology creates 27 possible types. However, in practice many of these do not exist in Great Britain or have very few examples. In total 18 significant types have been identified in the river network in Scotland, England and Wales. This typology does not include canals.

Under Annex II of the WFD a reference condition for each type of surface water body needs to be developed. UKTAG have produced a guidance note (TAG 2004 WP8a (02)v1 PR1 29-06-04) which proposes an outline approach to developing reference conditions and type descriptions for the 18 river types found in Great Britain.

Lakes

To meet the demands of the WFD, a need was identified for a geo-referenced inventory of standing waters. During 2002-2003 the Environment Agency, the Scottish Environment Protection Agency and the Nature

Conservation bodies funded a project to generate such an inventory, known as the GB Lakes database (Hughes et al., 2004; http://ecrc.geog.ucl.ac.uk/gblakes/index.php).

The GB Lakes database includes 43,738 water bodies in England, Scotland, Wales and the Isle of Man and contains basic physical data such as location, surface area, perimeter and altitude. Using data derived from the inventory a risk-based prioritisation protocol has been developed to identify standing waters at risk of harm from acidification and eutrophication (Hughes et al., 2004; Kernan et al., 2004).

The GB Lakes database has proved a valuable tool in developing a lake typology scheme to support implementation of the WFD in ecoregion 18 (Great Britain) (Phillips, 2003). As a first step in the River Basin Characterisation, the WFD requires that all water bodies be allocated to a set of types, differentiated according to their physical and chemical characteristics. For each type the ecological reference conditions, defined as the conditions expected if there were no or only very minor alterations resulting from human activities, must be determined.

Based on expert judgement and evaluation of limited biological data, catchment geology and mean lake depth were considered the most important factors in determining biological communities (Phillips, 2003). Hence, the Core Typology was based on these two factors and divides lakes into potentially 12 types (Table 3). The remaining obligatory factors (altitude, latitude, longitude, size) have a single category for the whole of Great Britain, effectively excluding them from the typology. Nevertheless it was recognised that altitude may be important and to allow for this a Full Typology has also been proposed which includes altitude (Table 4).

Table 3: Summary of Core Typology

3a. Geological types

1st tier types		Abbrev.	Catchment	Alkalinity		Conductivity[1]	Colour
				µeq/l	$mgCaCO_3/l$	µS/cm	MgPt/l
Geology[2]	Organic	P	> 75% Peat				>30
	Siliceous	LA	> 90% siliceous solid geology	< 200	< 10	< 70	<=30
		MA	> 50% siliceous solid geology	200 – 1000	10 – 50	71 – 250	
	Calcareous	HA	> 50% calcareous geology	> 1000	> 50	251 – 1000	
		Marl	> 65% limestone				
	Brackish	B				> 1000	

3b. Depth types

2nd tier types		Abbrev.	Mean depth (m)
Depth	Shallow	Sh	<= 3.0
	Deep	D	>3.0 m

Table 4: Additional division by altitude may be required (full typology)

3rd tier types		Abbrev.	Basin altitude (m)
Altitude	Lowland	Low	< 200
	Mid-Altitude	Mid	201 - 800
	High-Altitude	High	>800

The geology classification was initially based on the dominant geology present in the lake catchments using data held in the GB Lakes database (Hughes *et al.*, 2004). Rock types (1:625,000 solid geology map) were

[1] Conductivity is used only as a guide to type.

[2] Solid geology overridden by base status of drift and soil type using Freshwater Sensitivity Class

aggregated into either calcareous or siliceous following guidance from the British Geological Survey. A similar procedure was used to derive the percentage of peat in the catchment using 1:625,000 drift geology map. An additional source of information on the base status of catchments is provided by the Freshwater Sensitivity (FWS) map which divides lakes into five classes according to their sensitivity to acidification (Hornung *et al.*, 1994). The FWS map is derived from the buffering capacity of the drift and solid geology (Kinniburgh & Edmunds, 1986) and the base saturation of soils. The percentage of each FWS class in a lake catchment was determined and a combined approach was taken whereby an override on the solid geology classification was introduced to reflect the influence of the drift and soil base status. Whilst this improved the prediction of geological types, differentiation remained poor when assessed by comparison with available measured alkalinity data for lakes in each type. It was concluded that a more useful approach was to define a-priori alkalinity boundaries for each type and, where data existed, to allocate lakes to the typology using these data. Alkalinity was chosen as it has a clear biological link to plant productivity via factors such as the availability and form of inorganic carbon. However, conductivity is a potential indicator of total ionic composition and thus base status and in many cases conductivity data may be available when alkalinity data are not. Where no alkalinity or conductivity data are available a lake can be allocated to a geological type using data available in the GB Lakes database. The final scheme has five major geological types plus a further type to cover brackish lakes (Table 3).

Water depth is a critical factor in controlling the potential maximum growth of plants and phytoplankton. In a shallow lake at reference condition it is expected that macrophytes will dominate primary productivity of the whole lake basin and in a deeper lake phytoplankton is expected to be the dominant component with macrophytes confined to the littoral zone. In this context a shallow lake is most appropriately described as one where more than 75% of the lake bed occurs in a depth of less than 5m (Phillips, 2003). Bathymetric data for each lake would be required to determine this. Such data do not exist for most water bodies and thus a pragmatic definition of a shallow lake has been taken whereby a lake with a mean depth of less than 3.0m is classed as shallow. The lake depth typology therefore has two types, shallow lakes with a mean depth of less than or equal to 3.0m and deep lakes with a mean depth of greater than 3.0m (Table 3).

The Core Typology has been applied to all water bodies in Great Britain included in the GB Lakes database with a surface area of greater than 1 hectare. Under Annex II of the WFD a reference condition for each type of surface water body needs to be developed. UKTAG have provided a guidance note (TAG 2004 WP8a (01)v1 PR1 29-06-04) which includes type specific reference conditions for 12 water body types spanning six geology/catchment types and two depths, deep and shallow.

3.1.2 Groundwater Bodies

Groundwater bodies are the unit by which groundwater will be assessed in terms of "good status" and are the unit of reporting to Europe and implementing measures. The UKTAG recommendation is that the first step in delineation of groundwater bodies is to define aquifer types. Based on geological boundaries, aquifer types should be divided so there is little or no flow between aquifer types; these will then form the major units for subdivision into groundwater bodies. Geological units which cannot supply $10m^3/d$ as an average or 50 persons over the whole body, as well as those units which if groundwater were removed would not result in significant diminution in the ecological quality of a surface water body or directly dependent terrestrial ecosystem, would be classed as non-aquifers.

UKTAG then suggests that areas of "aquifer type" could initially be sub-divided at a coarse scale for screening pressures and impacts according to some or all of the following (presented in order of descending order of importance):

- Geological boundaries and/or
- Groundwater divides
- Regional flow lines within and aquifer and/or
- Other reasons with justification (e.g. based on regional groundwater modelling)

In order to determine quantitative status, a water balance between recharge and abstraction will be necessary. The groundwater body should therefore be delineated on the basis of geological and hydrogeological boundaries to allow water balance calculations to be carried out.

It is evidently important to achieve the correct balance between manageability (in terms of total number of bodies) and pressure recognition. So where status is relatively constant, large groundwater bodies would be acceptable, but where this is not the case delineation may necessarily include consideration of the pressures on groundwater resources at different locations. If significance thresholds are adopted which are dependent on the scale of the groundwater bodies, it is important that the bodies are not so large as to lead to thresholds being insufficiently sensitive to target problem areas. Whilst maps will be used for reporting purposes, it is important that their 3-D nature is borne in mind when creating conceptual models of groundwater bodies and/or when carrying out pressure-impact analysis on them. Major differences in the status of groundwater must be taken into account when delineating groundwater bodies, as they should allow an accurate description of groundwater status.

Deep groundwater can be excluded from this characterisation if it:

- cannot adversely affect surface water systems
- is not used for groundwater abstraction
- is unsuitable for drinking water supply
- cannot place the achievement of any other WFD objectives at risk

The characterisation of groundwater bodies within the WFD is also required to involve:

- Review of the impact of human activity on groundwaters
- Review of the impact of changes in groundwater levels which may require the setting of less stringent environmental objectives
- Review of the impact of pollution on groundwater quality which may require the setting of less stringent environmental objectives

3.1.3 Groundwater Dependent Terrestrial Ecosystems and Surface Water Bodies

Groundwater dependent terrestrial ecosystems (GWDTEs) are relevant to "good groundwater status" as the WFD requires there to be no "significant damage" to GWDTEs caused by alterations to either the flow of groundwater, groundwater chemistry, or the concentrations of pollutants in groundwater bodies for good status to be extant. For the purposes of the characterisation process it is necessary to:

- identify terrestrial ecosystems dependent upon groundwaters, and
- undertake an assessment of the risk that groundwater bodies will not be in "good status", partially determined by the damage occurring on the terrestrial ecosystems dependent upon those groundwater bodies.

3.1.4 Protected Areas

Article 6 of the WFD requires Member States to establish a register of all protected areas within each river basin district that have been designated as requiring special protection under specific Community legislation for the protection of their surface water or groundwater or the conservation of habitats and species directly depending on water. Such sites are predominantly, but not exclusively, the Natura 2000 sites designated under the Habitats Directive (93/43/EEC) and the Birds Directive (79/409/EEC). Under these two Directives, Member States are required to have identified Special Areas of Conservation (SACs) and Special Protection Areas (SPAs) for the conservation of specific habitats and species.

Table 5 sets out the ecological criteria UKTAG has used to identify those Natura habitats and species likely to be directly dependent on the status of water. The resultant number of sites designated under this classification is given in the Table 6.

Article 4.1(c) of the WFD requires Member States, in managing their water bodies, to achieve compliance with any water- related standards and objectives for Protected Areas by 22/12/15 at the latest unless otherwise specified in the legislation under which the protected areas were established. An assessment of the risk of failing to meet the water-related standard and objectives for Protected Areas was required by the end of 2004.

Table 5: Criteria for identification of habitats and species likely to be directly dependent on water

Natura 2000 SPECIES		Natura 2000 HABITATS	
1a	Aquatic species living in surface waters as defined in Article 2 of the WFD	2a	Habitats which consist of surface water or occur entirely within surface water, as defined in Article 2 of the WFD.
1b	Species with at least one aquatic life stage dependent on surface water	2b	Habitats which depend on the frequent inundation by surface water, on the level of groundwater.
1c	Species that rely on non-aquatic but water dependent habitats within classification 2b and 2c of this table	2c	Non-aquatic habitats which depend on the influence of surface water – e.g. habitats reliant on the spray or humidity caused by a surface water body.

Table 6: Total numbers of Natura 2000 sites in the UK designated for habitats and species that are directly dependent on the status of water

E= England; ES= crossing the England/Scotland border; EW=crossing the England Wales border; NI =Northern Ireland; S=Scotland; W=Wales; OF=UK offshore

Site Type	E	ES	EW	NI	S	W	OF
cSACs	183	3	3	41	217	84	0
pSACs	17	0	3	9	2	0	1
SPAs	78	1	2	11	135	14	0
SPA candidate	4	0	0	2	5	3	0
TOTAL:	282	4	8	63	359	101	1

3.1.5 Environmental Characterisation in England and Wales

River Basin Districts

11 River Basin Districts have been defined in England and Wales. Two cross the border with Scotland, the Solway Tweed District and Northumbria District and a further two, the Dee and Severn Districts, cross the border between England and Wales. The waters within these River Basin Districts have been further sub-divided into water bodies. These are lakes and parts of rivers, estuaries, coastal waters and groundwater and include artificial bodies such as canals, and heavily modified water bodies, such as deepened and straightened rivers. Environmental objectives will be set for each water body.

Surface Water Bodies

Rivers. The typology constructed for natural rivers in the UK has been described above. Its application in England and Wales (using a catchment size threshold of 10 km^2) has resulted in 5868 river water bodies.

Lakes. The development of the UK's lake typology has been described above. Whilst the WFD applies to all waters, a size threshold of 0.5 km^2, taken from the Directive, has been used to identify lake bodies in England and Wales (0.05 km^2 for lakes which are designated features within Natura 2000 sites or are Drinking Water Protected Areas), resulting in 432 lake water bodies.

Groundwater Bodies

England and Wales are geologically diverse, containing many aquifers with different characteristics. The aquifers can be grouped into categories based on how groundwater flows within them and how much water is available for abstraction and range from low productivity uplands to low-lying, highly productive chalk catchments.

For the purposes of the WFD, groundwater bodies have been identified by dividing aquifers into "aquifer types" according to hydrostratigraphic boundaries, and then dividing them up on Catchment Abstraction Management Strategy (CAMS) catchment hydrological boundaries. Where available, information on groundwater catchment divides was also used. The main groundwater types are Primary, Secondary, Significant Drift and Unproductive Strata. Where groundwater bodies do not fully follow a particular river basin, they have been assigned to the most appropriate river basin district.

356 groundwater bodies have been defined in England and Wales.

3.1.6 Environmental Characterisation in Scotland

Surface Water Bodies

Whilst the WFD applies to all waters, size thresholds taken from the Directive have been used to identify river and loch bodies – 0.5km^2 for loch surface area and 10 km^2 for river surface area. These have been used to define the baseline set of freshwaters; smaller waters will only be investigated where justified by environmental concerns.

Rivers. The typology constructed for natural rivers in the UK has been described above. Whilst the WFD applies to all waters, a size threshold of 10 km^2, taken from the Directive, has been used to identify river bodies in Scotland, resulting in 2380 river water bodies.

Lakes. The development of the UK's lake typology has been described above. Whilst the WFD applies to all waters, a size threshold of 0.5 km^2, taken from the Directive, has been used to identify loch bodies in Scotland, resulting in 334 lake water bodies.

Groundwater Bodies

Scottish aquifers have been categorised on the basis of how groundwater flows within them and how much water is available for abstraction. They range from the low productivity mountainous highlands to low-lying, highly productive sandstone basins. In general, with the exception of a few locations in the central valley and southern Scotland, bedrock aquifers are dominated by flow in fractures and hence the potential for reducing contaminants is minimal. The protection provided by overlying strata is therefore key to the assessment of vulnerability to pollution in bedrock aquifers.

Groundwater bodies have been identifies to reflect the aquifer types. This has resulted in the definition of 124 groundwater bodies of which 57 are islands. However, ongoing pressure and impact analysis might result in the future subdivision of some of the larger groundwater bodies.

In areas above high productivity aquifers, groundwater bodies have been identified using geological and major catchment boundaries. In areas above low productivity bedrock aquifers, groundwater bodies have been identified using surface water sub-catchments as a surrogate for groundwater boundaries. Islands have been included where:

- there is a population of greater than 50 people; or
- a groundwater public supply exists; or
- a groundwater dependent ecosystem or surface water has been identified; or
- current activities already impact groundwater.

Groundwater Dependent Terrestrial Ecosystems, Rivers and Lakes

GWDTEs were identified by SEPA in association with Scottish Natural Heritage (SNH). They considered that land based systems rely on groundwater when:

- groundwater dependent ecosystems have been mapped by SNH; or
- a productive aquifer is at surface and it is predicted that groundwater could be sustaining an ecosystem.

Surface water bodies were considered to be groundwater dependent when there was thought to be a productive aquifer at the surface that was likely to link with the surface water. It is expected that later studies will refine these estimates.

Protected Areas

Apart from the protected areas in Table 6, SEPA also recognises that nationally identified areas (such as Sites of Special Scientific Interest) are also important. A national register of these areas will be established and taken into account during the river basin management planning process.

3.1.7 Environmental Characterisation in Northern Ireland

River Basin and International River Basin Districts

A River Basin District (RBD) is more of an administrative unit and includes coastal/marine waters up to one nautical mile beyond the baseline from which territorial waters are measured. International River Basin Districts (IRBDs) exist wherever a RBD covers the territory of more than one member state. Where IRBDs are assigned, the Member States must work together to ensure the co-ordination of measures for the implementation of the Directive. Northern Ireland has one RBD – North Eastern and three IRBDs; Shannon, North Western & Neagh Bann.

Surface Water Bodies

Rivers. The typology constructed for natural rivers in the UK has been described above. Whilst the WFD applies to all waters, a size threshold of 10 km^2, taken from the Directive, has been used to identify river bodies in Northern Ireland, resulting in 550 river water bodies. Of these 57% have been identified as being "at risk" and 41% as "probably at risk" of failing the WFD objectives.

Lakes. The development of the UK's lake typology has been described above. Whilst the WFD applies to all waters, a size threshold of 0.5 km^2, taken from the Directive, has been used to identify loch bodies in Northern Ireland, resulting in 24 lake water bodies. Of these 42% have been identified as being "at risk" and 54% as "probably at risk" of failing the WFD objectives.

Groundwater Bodies

61 groundwater bodies have been identified in Northern Ireland. Of these only 2% have been identified as being "at risk" and 16% as "probably at risk" of failing the WFD objectives. However, it should be noted that these 18% of groundwater bodies represent 44% of the land area.

Groundwater Dependent Rivers, Lakes and Terrestrial Ecosystems

An assessment was carried out on groundwater dependent river water bodies and lakes to identify those at risk of being significantly damaged as a result of groundwater abstractions and potentially polluting point sources (Macdonald et al. 2004a). A second review (Macdonald et al. 2004b) carried out a similar assessment of groundwater dependent terrestrial ecosystems (GWDTEs). The risk assessment for lakes was restricted to those with an area greater than 50 hectares (as agreed for the initial UK characterisation). However, Lough Neagh and Upper and Lower Lough Erne were reported elsewhere due to their significant scale.

A total of 673 river water bodies were assessed (subsequently certain adjacent river water bodies were combined by EHS to create larger bodies with the overall number of river water bodies being reduced to 550). Of these 673, 564 were classified as groundwater dependent all of which were classified as being "not at significant risk" of failing to achieve the environmental objectives of Article 4 of the WFD in relation to potentially polluting point sources. Flows in 4 river water bodies were assessed as being "possibly at local risk" due to groundwater abstractions and 1 is "probably at risk".

Of the 17 lakes assessed, 10 were classified as being groundwater dependent, none of which were assessed as being "at risk" to either groundwater abstractions or potentially polluting point sources.

22 sites, all Special Areas of Conservation (SACs), have been identified in Northern Ireland as GWDTEs. None of these were found to be at risk of not meeting the WFD's environmental objectives as a result of either groundwater abstraction or potentially polluting point sources, although at one site (Murlough SAC) it is noted that confidence that the available information is comprehensive and reliable is low. It is suggested that improved monitoring at this site would increase confidence in the risk assessment.

3.2 Gaps/Problems

The UKTAG will continue to provide guidance to the competent authorities within the United Kingdom with regard to the requirements of the WFD, and the guidance documents will be updated as experience in their application grows.

The process of environmental characterisation within the WFD is essentially an iterative process. What has been presented in this report is essentially a fairly 'broad brush' approach which, as a first pass, will be used to inform the design of environmental monitoring strategies. The subsequent improved monitoring networks will provide data which can then be used to refine the initial characterisation. Additionally, as time passes, improved understanding of water movement and transport processes occurring within catchments will result in better methodologies for characterising water bodies and the impacts of pressures to which they are subjected. Thus, for example, ongoing research on surface water/groundwater interaction, particularly work on the hyporheic zone, should significantly improve confidence in the characterisation of groundwater dependent surface water bodies and GWDTEs.

4. FUTURE RESEARCH

In order to support public aspirations, and UK and European legislation, future research in the water sector will need to focus on the environmental sustainability of water resources in the context of balancing ecological and human needs with economic interests. Thus appropriate research, supported by strategic data, is required to achieve a better understanding of water supply capacity, and the chemical and biological loads within the surface water, groundwater and user systems. The impacts of climate change and extreme environmental conditions on groundwater and surface water bodies must be investigated, so that mitigation strategies can be properly assessed to minimise environmental, commercial, and social damage. Additionally, research must be continued into diffuse pollution and the impacts of groundwater quality on human and animal health and groundwater dependant ecosystems.

Within the context of the Water Framework Directive, much of the above research can be carried out and/or validated in catchment-based studies where research topics could include:

- Understanding processes and developing methods for estimating rainfall/runoff/groundwater recharge
- Hydrogeological characterisation of Quaternary superficial deposits, particularly glacial till
- Investigation of the hyporheic zone, surface water/groundwater and ecological interactions
- Methodologies and field techniques for 3-D and 4-D groundwater flow delineation and quantification in both the unsaturated zone and in the saturated zone
- Development of methodologies and field techniques for 3-D water-chemistry investigations
- Further understanding of hydrochemical processes and functioning at site-to-catchment scale
- Development of quantitative conceptual models of groundwater flow and solute transport in poorly permeable deposits traditionally regarded as local or non-aquifers, particularly where these deposits support wetlands (e.g. sites of special scientific interest)

REFERENCES / SOURCE DOCUMENTS

Bennion, H. (ed.) (2004). 'Identification of reference lakes and evaluation of palaeoecological approaches to define reference conditions for UK (England, Wales, Scotland & Northern Ireland) ecotypes'. *Final Report to the Scotland and Northern Ireland Forum for Environmental Research*, Project WFD08: 149 pp.

DEFRA web site. http://www.defra.gov.uk/environment/water/wfd/article5

European Union (2000). 'Establishing a framework for community action in the field of water policy'. *Directive of the European Parliament and of the Council 2000/60/EC*. PE-CONS 3639/1/00 REV 1, Luxembourg.

EHS Web site – WFD section

Hornung M. et al. (1995). 'The sensitivity of surface waters of Great Britain to acidification predicted from catchment characteristics'. *Environmental Pollution* **87**: 207-214.

Hughes, M., D. Hornby, H. Bennion, M. Kernan, J. Hilton, G. Phillips and R. Thomas (2004). 'The development of a GIS-based inventory of standing waters in Great Britain together with a risk-based prioritisation protocol'. *Water Air and Soil Pollution: Focus* **4**: 73-84.

Kernan, M., M. Hughes, D. Hornby, H. Bennion, J. Hilton, G. Phillips and R. Thomas (2004). 'The use of a GIS-based inventory to provide a regional risk assessment of standing waters in Great Britain sensitive to acidification from atmospheric deposition'. *Water Air and Soil Pollution: Focus* **4**: 97-112.

Kinniburgh, D.G. and W.M. Edmunds (1986). 'The susceptibility of UK groundwaters to acid deposition'. *Hydrogeological Report **86/3***. British Geological Survey. Wallingford UK.

D. J. Macdonald, A. W. Donald, A. Waterman and P. J. McConvey (2004). 'EU Water Framework Directive: groundwater-dependent terrestrial ecosystems in Northern Ireland'. *British Geological Survey Commissioned Report CR/04/285N*.

D. J. Macdonald, A. W. Donald and P. J. McConvey (2004). 'EU Water Framework Directive: groundwater-dependent rivers and lakes in Northern Ireland'. *British Geological Survey Commissioned Report CR/04/286N*.

Phillips, G.L. (2003). 'Reporting Typology for Ecoregion 18, Great Britain'. *Technical Advisory Group/Lakes Task Team paper number 43*.

Scottish Environment Protection Agency (2004). Pressures and impacts on Scotland's Water Environment: Report and consultation. SEPA. ISBN 1-901-322-49-1. http://www.sepa.org.uk/wfd-characterisation/html/exec_sum.html

UK TAG guidance documents can be found at http://www.wfduk.org/whats_new/TAG_Guidance/view

GLOSSARY – DEFINITIONS USED IN THE WFD

Groundwater: all water which is below the surface of the ground in the saturation zone and in direct contact with the ground or soil

Aquifer: a subsurface layer or layers of rock or other geological strata of sufficient porosity and permeability to allow either a significant flow of groundwater or the abstraction of significant quantities of groundwater

Body of groundwater: a distinct volume of groundwater within an aquifer or aquifers