The relevance of catchment management to drinking water safety plans with the UK with particular emphasis on Wales.

Keirle, Robert Scott

Prifysgol Abertawe
Swansea University

The Relevance of Catchment Management to Drinking Water Safety Plans within the UK with Particular Emphasis on Wales

Robert Scott Keirle

VOLUME 1 OF 2

Submitted to Swansea University
in fulfillment of the requirements for the
Degree of Doctor of Philosophy of Civil Engineering

2009

THE SUMMARY

My research related to an in-depth investigation of catchment management in the context of Drinking Water Safety Plans, the principal aims of which were to:

1) Establish to what extent catchment management had been implemented in England and Wales, in both historic and current contexts;
2) Identify the roles, remits and activities of the key stakeholders in catchment management in England and Wales;
3) The extent to which climate change could affect future catchment management; and
4) Determine the ability of catchment management to facilitate Drinking Water Safety Planning in Wales, and to identify any scope for possible improvement.

The requisite literature review was necessarily exhaustive and resource-intensive, and encompassed the following subject headings:

- Water resources;
- Water quality;
- Climate change;
- Catchment management;
- Public water supplies;
- Private water supplies;
- Stakeholder engagement;
- Regulatory (at the European, national and devolved levels) and management models; and
- Governance issues.

As the catchment is at the top of the drinking water supply chain, if we address water quality and quantity problems there, the result is a cleaner, cheaper, more secure product for the consumer. Consequently, I decided to develop an Abstraction Safety Index – along with an associated catchment environmental assessment methodology – for determining the overall environmental quality of water within a catchment, and for expressing this quantitatively. This mathematical index has been subject to peer-review by water companies and other environmental stakeholders.

The index was calibrated using a range of different types of catchments – used for both private water supply and public water supply purposes – and it was subsequently used to consider a number of alternative conceptual scenarios, to determine how changes to regulatory, legal and institutional models could feasibly affect the environmental quality of catchments in Wales, in order to improve the quality of abstracted water.

DECLARATION AND STATEMENTS

DECLARATION

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

Signed: (candidate)

Date: 29 January 2009

STATEMENT 1

This thesis is the result of my own investigations, except where otherwise stated. Where correction services have been used, the extent and nature of the correction is clearly marked in a footnote.

Other sources are acknowledged by footnotes giving explicit references. A list of references is appended.

Signed: .. (candidate)

Date: 29 January 2009

STATEMENT 2

I hereby give consent for my thesis, if accepted, to be made available for photocopying and for inter-library loan, and for the title and summary to be made available to outside organisations.

Signed: .... (candidate)

Date: 29 January 2009

Every river flows into the sea,
But the sea is not yet full.
The water returns to where the rivers began,
And starts all over again.

Ecclesiastes 1:7

Thousands have lived without love, not one without water.

W H Auden – "First Things First"

By means of water we give life to everything.

Koran 21:30

Water is the driving force of all nature.

Leonardo da Vinci

ACKNOWLEDGEMENTS

Many people both within and outside of the water industry here in the UK, and also in Australia, New Zealand and Spain, have donated generously of their time and vast collective experience. Regretfully lack of space prevents me from naming them all individually, but I thank them all for fielding my numerous queries and for providing me with otherwise inaccessible information. Particular thanks are given to the five water companies (four from England and Wales and one from Spain) who freely gave me access to information relating to the catchments in the case studies, on condition of anonymising any data and information presented in this thesis.

My supervisor within the Centre for Water and Environmental Management – Dr Colin Hayes – helped keep me focussed and provided support and encouragement when required, and the other students within the Centre provided an invaluable forum for the exchange of ideas and information (in particular my fellow PhD student, Andrew Lobley, who has contributed wisdom and wit in equal measure).

A special mention must be made of the staff of Bangor library, who have processed my numerous inter-library loan requests with patience, professionalism and good humour. Without this vital and often overlooked service, it would not have been possible for me to obtain the vast majority of the research reports, theses and text books I required, the consequence of which would have been a literature review nowhere near as thorough and wide-ranging as the one before you now.

And finally, thanks must also go to the European Social Fund for providing the majority of the much-needed funding, without which this research would not have been even remotely possible.

EUROPEAN UNION
European Social Fund
YR UNDEB EWROPEAIDD
Cronfa Gymdeithasol Ewrop

CONTENTS

FIGURES

TABLES

PICTURES

EQUATIONS

PART 1 INTRODUCTION

1 RESEARCH OVERVIEW

1.1 Aims

This research related to an in-depth investigation of catchment management and its relevance to the implementation of the Drinking Water Safety Plan concept in the UK, and my principal aims were to:

1) Establish to what extent catchment management had been implemented in England and Wales, in both historic and current contexts;
2) Identify the roles, remits and activities of the key stakeholders in catchment management in England and Wales;
3) The extent to which climate change could affect future catchment management; and
4) Determine the ability of catchment management to facilitate the implementation of the Drinking Water Safety Plan concept in Wales, and to identify any scope for possible improvement.

1.2 Objectives

The following list of objectives was drawn up to meet the aims stated in Section 1.1 above:

1) Assess how the Environment Agency (EA) and other related agencies currently undertake catchment management in England and Wales with specific regard to the protection and development of water resources for public supply;
2) Determine the current and likely future relevance of the Water Framework Directive to Drinking Water Safety Plans;
3) Identify the perceived needs of Welsh water companies for them to satisfactorily discharge their responsibilities in relation to minimising risk to their customers arising from public water supplies;
4) Identify the perceived needs of Welsh local authorities for them to satisfactorily discharge their responsibilities in relation to minimising risks associated with private water supplies;

5) Determine the policy positions and aims of the Welsh Assembly Government in Cardiff and the UK Government in London;
6) Determine the likelihood of current institutional and regulatory models satisfying objectives 3), 4) and 5) above and identify any scope for improvement;
7) Review the currently accepted range of climate change scenarios and evaluate how climate change might affect Drinking Water Safety Plans; and
8) Identify how climate change mitigation and adaptation measures might best be incorporated within catchment management processes.

1.3 Research Methodology

The decision was made to break down the aforementioned research programme into a number of discrete work packages; a timetable for these work packages is given in the form of a Gannt chart for each of the two years of my PhD, and these are shown in Section 1.5 and Section 1.6 respectively.

Some of these work packages were bureaucratic yet necessary, for example, to fulfil the Welsh European Funding Office requirements (such as the production of regular reports, and the undertaking of training), but as they were not an integral part of my research they require no detailed explanation here. As for the other work packages, an overview of each one is given below.

1.3.1 Literature Review

Because of the expansive nature of the objectives (see Section 1.2), the literature review that was required was necessarily comprehensive and resource-intensive, and encompassed the following subject headings:

- Water resources;
- Water quality;
- Climate change;
- Catchment management;
- Public water supplies;

- Private water supplies;
- Stakeholder engagement;
- Regulatory (at the European, national and devolved levels) and management models; and
- Governance issues.

As Drinking Water Safety Plans were originally developed by the water industry in Australia, a significant amount of time was spent contacting various water companies, regulators, Government departments and public bodies in a number of Australian states in order to obtain a wealth of background material relating to the different models for catchment management adopted at a state level, and the differing approaches utilised for implementation of Drinking Water Safety Planning; a similar amount of time was also spent contacting the equivalent organisations in New Zealand.

The ultimate goal of this exercise was the preparation of a proposed study tour of both those countries, in order to compare and contrast the UK's approach to management of water resources and catchments with the experiences of both Australia and New Zealand but, unfortunately, it was ultimately not possible to construct a sufficiently robust successful bid for a Research Council grant award within the foreshortened timescale (two years) of my studentship. Nevertheless, the wealth of information obtained from both countries helped inform my opinions and proved to be invaluable when engaging with water companies within the UK.

A proportion of the information provided was subject to the proviso that I did not publicly reference it, along with the catchment-specific information provided by the water companies for the case studies, hence the reason this material does not appear in the (still extensive) references. Nevertheless, the information provided was still invaluable, because the research I undertook would have been virtually impossible to complete without it.

The material presented within this thesis was derived from a number of main sources, including the following:

- Textbooks, official reports, theses and dissertations obtained via inter-library loans;
- Personal visits to the British Library in London and the National Library of Wales in Aberystwyth for reference texts that could not be obtained via inter-library loan;
- Personal visits to local municipal libraries for catchment-specific information;
- The world-wide web;
- Face-to-face meetings with key stakeholders (including regulators and water companies), the principal benefit of which was that I was able to obtain a significant number of additional reports that was not readily available via the routes identified above; and
- Remote contact (such as by email or telephone) with all the significant environmental stakeholders in each of the four parts of the UK, as well as relevant overseas stakeholders.

Using these various sources gave rise to a more exhaustive literature review than just using traditional academic search engines (such as those available via Athens), and the output from this process can be found primarily in Parts 1 to 4 inclusive. Particularly noteworthy are the reviews of the water-related UK Acts of Parliament and regulations, which to my knowledge has never been undertaken in such a comprehensive manner before, hence a significant amount of time was spent collating and reading them, and distilling the main points of interest so that they may be published in a single document (which I also believe is another first). Similar comments can also be made about my review of the significant water stakeholders in England and Wales.

In a general sense the literature review also informed the construction of the catchment environmental assessment methodology and the Abstraction Safety Index methodology.

Part of Chapter 8 (relating to certain European Directives) was used as the basis for a co-authored paper published by the peer-reviewed journal Water, Air & Soil Pollution: Focus. The reference for this paper is:

Hayes, C., Keirle, R., & Lobley, A. (2008) *The Identification of Xenobiotics in the New Context of Drinking Water Safety Planning. Water, Air & Soil Pollution: Focus*, 8, 555-564.

1.3.2 Determine the Scope and Format of Catchment Management in Wales

Once my literature review was substantially complete, I was then able to start determining the scope and format of catchment management in Wales (although I quickly subsequently expanded the remit of this work package to include the other three parts of the UK, for comparative purposes). This took the form of meetings with individuals from the significant environmental stakeholders (including water companies and regulators) in Wales and beyond, as well as telephone discussions and specific requests for information made by email.

1.3.3 Determine Current and Future Policy for Catchment Management and Drinking Water Management within Wales and the Wider UK

The results of the previous work package (see Section 1.3.2) highlighted the fact that, with a few specific exceptions which have been detailed elsewhere in this thesis (see Chapter 12), we do not undertake catchment management on a significant scale either specifically in Wales or generally elsewhere within the UK, and that there is a need for a national catchment management strategy, which is discussed within that same Chapter.

Because this was the first time such a comprehensive review had been undertaken of the approach to catchment management in England and Wales, this Chapter formed the basis of a paper published by the peer-reviewed Water and Environment Journal. The reference for this paper is:

Keirle, R., and Hayes, C. (2007) *A Review of Catchment Management in the New Context of Drinking Water Safety Plans. Water and Environment Journal*, 21(3), 208-216.

This paper has been subsequently used by the EA to help inform its future approach to catchment management; publication of this paper contributed to the peer review of the development of the Abstraction Safety Index.

Despite repeated attempts to establish contact with appropriate contacts within the local authorities in North Wales, the vast majority did not reply to my request for information relating to their activities in relation to private water supplies. As for the two local authorities that did respond, their lack of detailed knowledge meant that that they could only make general comments about the subject, and also in relation to catchment management issues and Water Framework Directive requirements. Nevertheless, I attempted to determine the responsibilities and activities of local authorities with respect to catchment management, as far as I was able, during my literature review.

During the course of my studentship it was anticipated that Wales, England and Northern Ireland would follow the lead taken by Scotland and publish consultations on the revision of their respective private water supplies regulations; it was also widely believed that these consultations would be similar to the one held in Scotland in that they would incorporate large elements of the Drinking Water Safety Plan approach. However, all three consultations have been the subject of repeated and unexplained delay (despite attempts to seek clarification from the respective devolved administrations), so this element of the work package remains unfulfilled at the time of writing (August 2008).

1.3.4 Determine the Extent to Which Climate Change Will Affect Water Resources and Water Quality within the UK

The output of the aforementioned literature review largely helped to meet the requirements of this work package, the results of which are presented in Chapter 14. As with the work package mentioned in Section 1.3.2, the remit of this work package was expanded beyond the Welsh borders, because climate change by definition is a global issue that has serious implications for all four parts of the UK. This also enabled the work package to include research that had been undertaken by other bodies and organisations outside of Wales, which helped to immeasurably improve the quality and integrity of Chapter 14.

Again, this was the first time such a comprehensive review had been undertaken of climate change and its potential impacts on water resources in a UK context, so this Chapter 14 formed the basis of a paper published by the European Water Association in its online peer-reviewed journal E-WAter. The reference for this paper is:

Keirle, R., and Hayes, C. (2007) *A Review of Climate Change and its Potential Impacts on Water Resources in the UK. E-WAter*, 2007(04), 1-18.

Similarly, this paper has also subsequently been used by the EA.

1.3.5 Implementation of Drinking Water Safety Plans

Shortly after embarking on this work package, I realised that, although general information about Drinking Water Safety Plans was becoming more widespread, and water companies were becoming more engaged with the implementation process, nobody had actually made the case for why they were necessary within Europe; contact with the World Health Organisation's European regional office confirmed this.

It was easy to accept why these Plans were a necessity in developing countries, where people were routinely dying because of poor drinking water quality, but it was not apparent that a strong case had been made for them in Europe – and certainly not within the UK – where percentage compliances with national regulatory standards are consistently extremely high. I decided therefore to do some research on environmental water pollution incidents, and determine whether a link could be made with drinking water quality incidents. However, I completely underestimated the length of time it would take to obtain the base data in order to undertake such an examination. For example, it was extremely difficult to obtain data relating to environmental water pollution incidents for the period 1996-2006 inclusive from the EA, because a lot of this data was (actively or mistakenly) concealed from the general public, or the format for recording and reporting these data had changed over the period of interest. Nevertheless, my persistence resulted in obtaining an illuminating dataset.

As for the Drinking Water Inspectorate, they either stonewalled or actively rebuffed my requests for information, which necessitated visits to the British Library and numerous inter-library loan requests so I could obtain the necessary data. Despite these hurdles, I succeeded in completing this exercise, and the result is Chapter 16 which is entitled 'The Need for Greater Protection for Drinking Water Supplies'. Because of the importance I attached to this Chapter, it was published by the European Water Association in its online peer-reviewed journal E-WAter. The reference for this paper is:

Keirle, R., and Hayes, C. (2008) *The Need for Greater Protection for Drinking Water Supplies*. *E-WAter*, 2007(05), 1-28.

All three water companies that are wholly or mainly in Wales were contacted in order to determine how they were implementing the Drinking Water Safety Plan approach. One of these – Albion Water – did not respond, whilst the other two were very accommodating and provided a wealth of information on condition of observing its confidential nature. This process included determining how the water companies had interpreted the regulators' requirements, and analysing the approaches the water companies had taken with regards to implementation.

Another element of this work package was the requirement to identify four catchments – ideally of dissimilar nature – that could be used as case studies. Accordingly, a number of water companies within England and Wales were approached and permissions received, with the condition that any information quoted within this thesis was anonymised.

A study visit to Barcelona was also arranged for September 2007, which gave rise to a major catchment being offered as a case study, which was extremely useful for comparative purposes.

I decided to also consider how the Drinking Water Safety Plan approach can be extended to private water supplies. Consequently, in conjunction with another PhD student, a study visit to Scotland was arranged, where local authorities were already using the Drinking Water Safety Plan approach which formed an integral part of the new Private Water Supplies (Scotland) Regulations 2006. Whilst there, two private water supply catchments were studied in depth, and I subsequently used them for calibration of my Index. This was an interesting exercise to undertake, using both private and public water supply catchments, as I could also determine whether the Index was truly applicable to any type of catchment within the UK.

Consequently, a single catchment was provided by each of four water companies in England and Wales, along with a fifth from a Spanish water company, and a sixth and seventh associated with private water supplies in Scotland, so the final stage of this work package was to gain an understanding of the hydrology and major environmental pressures within each of the catchments.

1.3.6 Develop an Index to Enumerate the Quality of a Catchment

This work package underwent a certain amount of evolution as my studentship progressed, as it became increasingly obvious that the focus of Drinking Water Safety Planning implementation by the UK water industry was on the treatment and distribution elements of the supply chain, whilst both the catchment and consumer elements were effectively being ignored, by water companies and regulators alike.

Elsewhere in this thesis I make the point that, as the catchment is at the top of the drinking water supply chain, if we address water quality and quantity problems there, the result is a cleaner, cheaper, more secure product for the consumer. I therefore decided at a fairly early stage that my focus should be on the catchment.

The comprehensive literature review undertaken in Parts 1-4 inclusive highlighted the fact that, although there are numerous legislative and management impacts on catchments in England and Wales, and that these catchments have a multitude of institutional and non-governmental stakeholders of varying scales, not one of these stakeholders has identified a suitable methodology for quantitatively determining the overall environmental quality of water within a catchment, and for expressing it as a single figure. In discussion with several water companies in England and Wales, it was the general view that the development of such an index would be useful, for internal management purposes, and to better inform the regulators and wider public on catchment issues. I therefore spent some time considering how this could be done, and the Abstraction Safety Index concept is presented in Chapter 21.

In order to assist with the calibration stage of this index, I produced a catchment environmental assessment methodology, which would detail the breadth of information that is generally available relating to the type and 'health' of a catchment, the often disparate organisations that held this information, and how this information could usefully inform the risk assessment process. A final draft of this methodology was made available for review to one of the water companies that provided one of the catchments, and it was subsequently adopted by them for their own catchment risk assessment purposes.

The construction of the initial methodology for the calculation of the index greatly informed the process yet ultimately proved to be fundamentally flawed. The lessons learned from this first iteration of the methodology construction were invaluable in helping to create a more robust second iteration (along with an alternative third iteration that had been requested by one stakeholder). The results from all three methodologies are presented here.

During the construction process, the index was developed in discussion with key stakeholders and validated by peer review, on both an ad-hoc and a formal basis. As part of this latter process, the finished methodology was presented at an international Drinking Water Safety Plan conference held in Lisbon during May 2008 in the form of a poster entitled "UK Experience in Drinking Water Safety Planning: Catchment Risk Assessment and Indexing Methods" (Keirle & Hayes 2008b). This presentation generated a significant amount of positive interest and has lead to a number of requests for collaborative research opportunities.

The methodology was also presented at a Water UK meeting in Birmingham during June 2008, at which the audience consisted of representatives from its public health network (Keirle 2008).

Once satisfied with the results obtained, I then used the index to consider a number of alternative conceptual scenarios, to determine how changes to regulatory, legal and institutional models could feasibly affect the environmental quality of catchments in Wales, in order to improve the quality of abstracted water.

1.4 Thesis Structure

For ease of reference the outputs of the work packages that were identified in Section 1.3 have been grouped into seven thematic parts in this thesis, which will hopefully allow the reader to progress logically through the material presented herein. An overview of the themes of these seven parts is given in the following sub-sections.

1.4.1 Part 1 (Chapters 1-7)

This part (in which this Chapter is situated) opens by providing an overview of my research, and the work packages that were constructed in order to meet the objectives stated in Section 1.2. In order to provide the necessary context of catchment management, an introduction to the composition and nature of the UK water industry is given, with particular emphasis on England and Wales, including the various strategic governmental, regulatory, and non-governmental environmental stakeholders; where relevant, the significant relationships between these stakeholders are also identified.

1.4.2 Part 2 (Chapters 8-11)

A review of the legal framework with respect to water is presented in Part 2. In recognition of the majority of new environmental laws within the UK being driven by the EU, the review starts logically with an overview of European institutions and relationships between them, before summarising current relevant European Directives. The review then progresses to giving an introduction to the next tier of legal instruments – Acts of Parliament – before finishing with a review of the final tier, the regulatory framework.

1.4.3 Part 3 (Chapters 12-15)

A review focussing on catchment management and its influencing factors is presented in Part 3. In the first of the three Chapters in this Part, an overview of catchment management is given, in both historic and current contexts, with particular focus on diffuse pollution. In the second Chapter, an appreciation of the qualitative and quantitative management activities of the Environment Agency in England and Wales is given, as well as an introduction to a number of strategies used to help manage the natural water environment. In the third Chapter, the potential impacts of climate change on water resources are discussed, along with the limitations of current modelling and forecasting.

1.4.4 Part 4 (Chapters 16-20)

A review focussing on Drinking Water Safety Plans is presented in Part 4. First, the case is made for the need for greater protection of drinking water supplies, and why, at the start of the 21st Century, the WHO initiative is an essential tool in the fight against new and re-emerging threats within the catchment, as well as helping to minimise the risks throughout the entire drinking water supply chain. A review of the Drinking Water Safety Plan approach will show that they are more than a bureaucratic nicety, whilst Chapter 14 gives an overview of how Drinking Water Safety Plans are being implemented in the four regions of the UK, with respect to both private and public water supplies. The final Chapter in Part 3 critically evaluates the potential for Drinking Water Safety Plans to minimise the risks associated with four well known 'industry standard' pre- and post-abstraction contamination incidents relating to public water supplies that have occurred in England and Wales in the last 20 years.

1.4.5 Part 5 (Chapters 21-28)

An introduction to the Abstraction Safety Index concept is presented in the first Chapter of this Part, and an overview of its potential applications to environmental stakeholders was given. Seven catchments are used to refine and calibrate the concept, and an anonymised overview of each one is given, along with a detailed catchment environmental assessment methodology that was constructed in order to obtain information relevant to each one.

Three separate Abstraction Safety Index methodologies are presented here, and subsequently tested using the information obtained for each of the seven catchments. As a result of this extensive calibration process, one methodology and one Importance Factor range are identified as being suitable for testing eight alternative conceptual scenarios.

1.4.6 Part 6 (Chapters 29-31)

All the spreadsheets containing the calculations used to derive the results presented in Part 5 are contained on a CD-ROM attached to the inside front cover of this thesis. However, for convenience and ease of reference, hard-copies of three complete calculations – one for each of the three alternative methodologies presented in Part 5 – have been included in Part 6.

1.4.7 Part 7

All references listed in this section have been cited throughout this thesis, many more than once. Because of the extensive nature of this Part, I decided not to include a list of the significant amount of material read, but not subsequently cited.

1.5 Timetable for the First Year of my PhD

KEY STAGE / DELIVERABLE	APR 2006	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN 2007	FEB	MAR
1) Training												
2) Undertake literature review												
- *Review websites*												
- *Review books*												
- *Review available documents*												
- *Review current statutory, regulatory and voluntary regime*												
- *Writing-up*												
3) End of probation review												
4) Periodically check the literature for updates/developments												
5) Determine the scope & format of catchment management in Wales												
- *Establish contact with all relevant bodies (EAW, CPRW, FUW, CCW et al)*												
- *Review their land management policies*												
- *Identify deficiencies & propose improvements*												
6) Determine current & future policy for catchment management & drinking water management within Wales & the wider UK												

KEY STAGE / DELIVERABLE	**APR 2006**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**JAN 2007**	**FEB**	**MAR**
- Establish contact with the relevant bodies (Ofwat, DWI, WAG, DEFRA, EA, SEPA et al)												
- Determine current & future policy position (including preparedness for upcoming new Directives)												
- Establish contact with all Local Authorities in North Wales												
- Gain an appreciation of LAs activities in relation to public & private water supplies.												
- Determine the level of LAs understanding of River Basin Management Plans												
- Assess LAs future requirements for discharging their responsibilities under the new private water supplies regulations												
7) Implementation of Drinking Water Safety Plans												
- Establish contact with all water companies in Wales & analyse how they are implementing Drinking Water Safety Plans												
- Identify 4 different catchments for study												

KEY STAGE / DELIVERABLE	**APR 2006**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**JAN 2007**	**FEB**	**MAR**
- Gain an understanding of how each catchment works												
8) Determine the extent to which climate change will affect water resources & water quality within the UK												
- Identify how climate change will affect water quality (both raw & potable) & catchment management and attempt to quantify its impact												
- Determine the preparedness of the water companies within Wales for climate change, and identify improvements												
- Identify options to incorporate climate change predictions into catchment management												
9) Attend appropriate conferences / seminars / professional meetings												
10) Produce WEFO quarterly report												

1.6 Timetable for the Second Year of my PhD

KEY STAGE / DELIVERABLE	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN 2008	FEB	MAR
1) Develop an index to enumerate the quality of a catchment												
- *Produce a catchment environmental assessment methodology*												
- *Use the methodology to obtain information relating to each catchment*												
- *Determine how each water company is dealing with the risks identified in the catchment environmental assessment*												
- *Calculate the index for each of the 5 catchments*												
- *Use the index to identify alternative management & regulatory models*												
2) Arrange a study visit to Scotland												
- *Identify appropriate contacts within LAs, regulators & Scottish Water & arrange an itinerary*												
- *Undertake site visits & attend meetings*												
3) Arrange a study visit to Barcelona												

KEY STAGE / DELIVERABLE	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN 2008	FEB	MAR
- *Arrange an itinerary*												
- *Undertake site visits & attend meetings*												
- *produce a feasibility study report for Agbar*												
4) Produce 2 more papers for publication												
- *Production of 3rd paper*												
- *Production of 4th paper*												
5) Periodically check the literature for updates/developments												
6) Attend appropriate conferences / seminars / professional meetings												
6) Write-up thesis												
7) Submit final draft of thesis												
8) Produce WEFO quarterly report												

2 THE UK WATER INDUSTRY

2.1 Introduction

A supply chain – in the context of Drinking Water Safety Planning – is the uninterrupted route a water molecule takes from falling on a catchment as precipitation, via the abstraction, treatment and distribution stages, before emerging from a consumer's tap. For major rivers such as the Dee or the Severn there may be a number of treatment works abstracting at various points along it, perhaps operated by different water companies. Then, depending on operational requirements and varying demand profiles displayed by consumers, our conceptual water molecule may be pumped to any one of a number of service reservoirs, through a distribution system which, especially in metropolitan areas may be particularly complex, before reaching a consumer's property. There, the habits and demand profile of the consumer will dictate which tap the molecule emerges from.

It follows that, from the same starting point within a catchment where the molecule landed, it may follow an almost infinite number of routes before being consumed. The following facts should therefore give a feel for the size of the UK water industry, and hence an appreciation of the enormity of producing a Drinking Water Safety Plan for each and every water supply chain:

England and Wales

- Over 1,300 water treatment works;
- 9,000 sewage treatment works;
- 1,000 impounding reservoirs;
- Over 4,600 service reservoirs;
- 330,000 kilometres of water distribution mains; and
- Almost 24 million connections to properties and associated customer supply pipes (Thompson & Gray 2005, Ofwat 2005, Ofwat 2006c).

In addition to the public water supply systems owned and operated by the water companies, there are also approximately 50,000 private supplies in England and Wales supplying 300,000 people.

Scotland

- 368 water treatment works;
- 1,807 sewage treatment works;
- 322 impounding reservoirs;
- 1,104 service reservoirs;
- 46,000 kilometres of water distribution mains; and
- 2,328,000 connections to properties and associated customer supply pipes (Scottish Executive 2008; Scottish Water 2006b; Scottish Water 2006c; Scottish Water 2007a).

There are also approximately 21,000 private supplies in Scotland supplying a resident population of nearly 80,000 people (though this number is significantly increased by tourists) (Scottish Executive Environment Group 2001).

Northern Ireland

- 65 water treatment works;
- 1,124 sewage treatment works;
- 40 impounding reservoirs;
- 490 service reservoirs;
- 26,500 kilometres of water distribution mains; and
- 795,000 domestic, agricultural, commercial and business connections to the public water supply (Northern Ireland Water 2007).

The number of private supplies in Northern Ireland is somewhere between 1,260 and 5,000 supplying upwards of 7,500 people (Environment & Heritage Service 2007, O'Neill 2007).

2.2 An Overview of the Structure of the UK Water Industry

The privatisation of the water industry in England and Wales in 1989 established within the UK three different variations of a drinking water supply model that shared comment elements. These variations of the model have since developed further distinctions and refinements, whilst a fourth variation is now starting to emerge for Wales; some of these changes are discussed in further depth elsewhere in this thesis (principally in Chapters 3, 4, and 5).

All four parts of the UK now have companies (either publicly or privately owned) that are responsible for the supply of drinking water and the provision of sewerage services, and these activities are strictly controlled within a robust legal framework by independent regulators. An overview of the major regulatory stakeholders and the water companies regulated by them is given in the following sub-sections.

2.2.1 England and Wales

There are ten water and sewerage companies in England and Wales, and a further 14 smaller companies which only supply drinking water; all of them are privately owned (Water UK 2006b). These water companies operate within a highly complex regulatory regime which is managed by three regulators: the Drinking Water Inspectorate (DWI) (the drinking water quality regulator) (see Section 5.2), Ofwat (the economic regulator) (see Section 5.3) and the Environment Agency (EA) (the environmental regulator) (see Section 5.4).

2.2.2 Scotland

A single publicly-owned water authority – Scottish Water – provides water and sewerage services to the whole of Scotland, and was formed in April 2002 following the merger of the three former regional water authorities (Scottish Water 2007). Although answerable to the Scottish Parliament, it is structured like a private company, and has over 2.3 million domestic and business customers (Water UK 2006b, Scottish Water 2006a).

The charges that Scottish Water levies, and its levels of service, are regulated by the Water Commissioner for Scotland, which is broadly comparable with Ofwat, the economic regulator for England and Wales (Scottish Water 2006c).

The Drinking Water Quality Regulator regulates the quality of the potable water produced by Scottish Water, and it has a very similar role to that of the DWI for England and Wales (Drinking Water Quality Regulator for Scotland 2006). Indeed, the two regulators appear to be working in close collaboration, an example of which is the virtually identical Information Letters issued on the subject of Distribution Operation and Maintenance Strategies (see Section 18.4.1).

The third main regulator in Scotland is the Scottish Environment Protection Agency, and its powers, structure, responsibilities and accountabilities are on a par with the EA in England and Wales. This public body was established by the same Act of Parliament as the EA – the Environment Act 1995 – and became operational on the same date (1 April 2006) as its counterpart south of the border.

2.2.3 Northern Ireland

As with Scotland, within the Province water and sewerage services remain in the public sector. Until 31 March 2007 these services were offered by the Water Service, which was an Executive Agency within the Department for Regional Development, and the Government originally intended to privatise its four operational Divisions (Water Service 2006, Twort *et al.* 2000). However, as a result of a Government announcement in 2002 regarding its intention to place the provision of water and sewerage services in Northern Ireland on a self-financing basis, the status of Water Service was changed to that of a Government Owned Company (GoCo), and on 1 April 2007 Northern Ireland Water was established (Department for Regional Development 2007; Department for Regional Development and Department of the Environment 2006; Northern Ireland Water 2007; O'Neill 2006).

Adopting a similar model to those utilised in England, Wales and Scotland, regulation of water is split to cover three main areas – environment, economic and drinking water quality.

Responsibility for the water environment is split between the Rivers Agency (which undertakes the duties and responsibilities of the statutory drainage and flood protection authority, the Department of Agriculture and Rural Development) and the Environment and Heritage Service (the overall aim of which is to protect and conserve the Province's natural environment and built heritage) (Rivers Agency 2007, Environment and Heritage Service 2006a).

The Northern Ireland Authority for Utility Regulation is the economic regulator, and is known informally as the Utility Regulator, as it is responsible for the gas, electricity and water markets (Northern Ireland Authority for Utility Regulation 2007). It assumed its gas and electricity responsibilities on 1 April 2003, whilst its water and sewerage functions were transferred to it on 1 April 2007.

The quality of the drinking water produced by Northern Ireland Water is regulated by the Drinking Water Inspectorate, a unit within the Environment and Heritage Service, which itself is the largest Agency within the Department of the Environment (Environment and Heritage Service 2006a). Its role is very similar to the DWI for England and Wales, with one notable addition; it is also responsible for the quality of private water supplies (Environment and Heritage Service 2006b).

2.3 The Water Industry in Wales

The entire range of the water industry is represented in Wales, with one water and sewerage company (Dŵr Cymru Welsh Water), one water supply only company (Dee Valley Water) and one new entrant (Albion Water); a brief summary of each one is given in the next three sub-sections.

2.3.1 Dŵr Cymru Welsh Water

Most of the Principality is supplied by Dŵr Cymru Welsh Water (with the exception of a significant proportion of mid Wales which is supplied by Severn Trent Water), along with some small adjoining parts of England. It provides 900 million litres of drinking water every day to over three million people, and is the sixth largest of the ten water and sewerage companies (Glas Cymru Cyfyngedig Unknown).

Dŵr Cymru Welsh Water is unique in the water industry as it is wholly owned by a not-for-profit parent, Glas Cymru Cyfyngedig, which was formed purely to own, finance and manage the water and sewerage company (Dŵr Cymru Welsh Water 2005). Many functions of the water company – such as asset investment, assess operations, billing and support activities – have been outsourced to a number of contract partners (Dŵr Cymru Welsh Water 2004).

Some 5% of the water supplied by the company is taken from springs, wells and boreholes and requires minimal treatment, whilst the remainder comes from reservoirs and rivers (Dwr Cymru Welsh Water Unknown).

The company's asset base includes:

- 715 service reservoirs;
- 105 water treatment works;
- 532 pumping stations;
- 81 reservoirs; and
- 27,000 kilometres of water mains (Glas Cymru Cyfyngedig Unknown).

2.3.2 Dee Valley Water

The cities of Wrexham and Chester are supplied by Dee Valley Water (a water supply only company), along with the surrounding areas. It provides 71 million litres of drinking water every day to 260,000 people (Dee Valley Water Unknown).

81% of the water company's requirements are provided by two abstractions on the River Dee; a further 14% comes from eight upland impounding reservoirs and the remaining 5% from two groundwater sources (Dee Valley Water 2006).

The company's asset base includes:

- 38 service reservoirs;
- 6 water treatment works;
- 34 pumping stations;
- 8 reservoirs; and
- 1,900 kilometres of water mains (Dee Valley Water Unknown, Dee Valley Water 2006).

2.3.3 Albion Water

Albion Water is the only new water company formed since privatisation that is actually supplying customers (as opposed to the many new companies that have been registered, but have not yet obtained from Ofwat an Instrument of Appointment as a water undertaker). The appointment was made in May 1999 under the Inset Appointment provisions in the Competition and Service (Utilities) Act 1992, when Albion Water became the licensed water undertaker for Shotton Paper Company plc on Deeside (UK Government 1992a). The supply is primarily for industrial purposes but a small proportion is used for domestic purposes and is therefore subject to the drinking water quality Regulations (Drinking Water Inspectorate 2001).

Albion Water supplies on average about 83,000 litres per day to about 300 consumers in the Shotton zone. It has no water treatment works or service reservoirs; instead, it buys a bulk supply of water from Dŵr Cymru Welsh Water, which in turns supplies Shotton Paper direct from its own distribution system (Drinking Water Inspectorate 2001).

2.4 Discussion

The composition and remit of the regulators referred to vary to a certain extent within each of the four devolved parts of the UK, and some of them have greater links with their opposite numbers than others. A common theme to these regulatory regimes though is that the regulation of water is split to cover three main areas – environment, economic and drinking water quality.

What is immediately apparent though about these regulatory regimes is that there is opportunity for stalemate between the regulators, for example, during the periodic price review, as there is no 'senior' regulator which can arbitrate should the three individual regulators disagree about where investment should be made. This has happened on a number of occasions in England and Wales with Ofwat and the EA disagreeing repeatedly about the size of the environmental improvement programme. Similar disagreements have occurred between Ofwat and the DWI over capital improvements as the former regulator has historically assumed a risk-based approach to such improvements, whereas the latter regulator has tended to adopt a risk-averse position.

The full range of the water industry is represented in Wales, which will be useful when alternative regulatory models and institutional arrangements are considered in Chapter 27.

3 KEY GOVERNMENT DEPARTMENTS AND PUBLIC BODIES IN WALES

3.1 Introduction

In Wales there are a number of public bodies and departments in the devolved administration in Cardiff which have responsibility for various aspects of the Welsh environment. An overview of the key stakeholders, along with their respective areas of responsibility, is given below, within the context of catchment management and in order to demonstrate the relationships between them.

3.2 National Assembly for Wales

Until devolution in 1999 the UK Parliament at Westminster had primary legislative (otherwise known as statutory) authority for all matters in England and Wales (i.e. only the two Houses of Parliament could propose, amend, repeal or approve an Act of Parliament). When it was originally established, the National Assembly for Wales only had responsibility for developing and issuing secondary legislation (i.e. regulations, otherwise known as Statutory Instruments) on devolved matters in Wales by means of the Government of Wales Act 1998 within the primary legislative framework established by Westminster (National Assembly for Wales 2006a, National Assembly for Wales 2006c).

The Government of Wales Act 2006 has subsequently enhanced the Assembly's law-making powers by conferring on it primary legislative authority on all subjects within defined policy areas with effect from May 2007 (Wales Office 2005). An overview of these two Acts is given in the following two sub-sections.

3.2.1 Government of Wales Act 1998

The National Assembly for Wales was established by this Act, along with other offices, and provided for the reform of certain Welsh public bodies (UK Government 1998b). This Act made the National Assembly for Wales unique amongst the devolved administrations within the UK, as it is the only one with the explicit statutory responsibility to promote sustainable development.

The Government of Wales Act also detailed the policy areas that were to be devolved to the National Assembly for Wales as soon as it was established (with the provision that other areas could subsequently be devolved from Westminster by Order in Council), which included water and flood defence, the environment, and agriculture. Specifically, Section 28 of the Act provided for the National Assembly for Wales to make an order relating to the statutory functions of the EA insofar as those functions relate to Wales.

Unlike the devolution arrangements put in place at the same time for Northern Ireland and Scotland, the Government of Wales Act did not provide for the legal separation of the executive and legislative branches in Wales (National Assembly for Wales 2006c, Wales Office 2005). The Assembly members delegated their executive powers to the First Minister, who in turn delegated powers to Ministers with their own portfolios of responsibility. The First Minister and his Ministers were collectively known as the Cabinet, which was accountable to the Assembly. This is one of the ways that the National Assembly for Wales worked towards separating the two branches as much as possible, so that people would better understand the roles of the Assembly and what it termed the Welsh Assembly Government (comprising of the Cabinet and the Ministerial Departments).

3.2.2 Government of Wales Act 2006

The term 'Welsh Assembly Government' had no legal status, until the passing into law of a new Government of Wales Bill (UK Government 2005b). This Bill received Royal Assent on 25 July 2006, and came into effect immediately after the Assembly elections in May 2007, from which time the Welsh Assembly Government was established as an entity separate from, but accountable to, the Assembly. With this separation of the legislature from the executive, this second Government of Wales Act brought many aspects of the National Assembly for Wales up to the same level as those of the devolved administrations in Northern Ireland and Scotland (UK Government 2006a).

Another consequence of the Act is that the First Minister is now appointed by the Queen on the nomination of the Assembly, and the First Minister appoints all other Ministers and Deputy Ministers with Her approval. All these Ministers act on behalf of the Crown, rather than as delegates of the Assembly (Wales Office 2005, UK Government 2006a).

With the passing of this Act (subsequently amended by Order in Council) the National Assembly for Wales now has assumed responsibility (i.e. it has 'legislative competence') for the following areas: water supply; water resources management (including reservoirs); water quality and representation of consumers of water and sewerage services; flood risk management; and coastal protection. The following specific exceptions are included in the Act: appointment and regulation of any water undertaker whose area is not wholly or mainly in Wales; and licensing and regulation of any licensed water supplier within the meaning of the Water Industry Act 1991, apart from regulation in relation to licensed activities using the supply system of a water company whose area is wholly or mainly in Wales (UK Government 2006a, UK Government 2007a).

The formal name for the above broad subject areas is 'fields', whilst a 'matter' is a specific defined policy area within a field (National Assembly for Wales 2007a). These fields and matters are contained within Schedule 5 of the Act, which can be amended by another Act of Parliament, or by a Legislative Competence Order (a form of secondary legislation) which must be approved by the National Assembly for Wales and both Houses of the UK Parliament (National Assembly for Wales 2007b, National Assembly for Wales 2007c).

In areas where it has legislative competence the National Assembly for Wales can pass an 'Assembly Measure', which is a piece of law broadly comparable to an Act of Parliament and which has a similar effect (National Assembly for Wales 2007d, National Assembly for Wales 2007a).

It had been suggested by some that an 'export tax' or similar financial instrument be imposed on water that is supplied to England from Wales to sustain the West Midlands and Merseyside (Jones 2006); powers have therefore been given to the Secretary of State for Wales allowing him to prevent the Welsh Assembly Government from taking such a step. For example, section 101(2) allows the Secretary of State to make an order prohibiting the Clerk of the Assembly from submitting a proposed Assembly Measure for approval by Her Majesty in Council if it "might have a serious adverse impact on water resources in England, water supply in England or the quality of water in England"; a similar power is also afforded the Secretary of State in section 114(2) if the Welsh Assembly Government attempts to take such a step by means of a Bill introduced at Westminster (UK Government 2006a).

3.2.3 Welsh Assembly Government Departments

A number of departments of the Welsh Assembly Government have responsibility for different policy areas that directly affect the environment at the catchment level. The principal one is the Department for Environment, Sustainability and Housing, which has broad responsibility for both built and natural environments, and its objectives are (Welsh Assembly Government 2008b):

- To protect and enhance the quality of the environment;
- To manage the built and natural environments in a sustainable way; and
- To reduce waste generation.

The Environment, Sustainability and Housing portfolio includes the following policy areas which are of particular interest from a catchment management point of view (Welsh Assembly Government 2008c):

- Cross-cutting measures of mitigation and adaptation in relation to climate change;
- All aspects of planning policy, including the issue of statutory guidance to local authorities;
- Land drainage, flood prevention and coastal protection;
- Control of marine pollution in Welsh waters;

- Contaminated land;
- The control of water quality and safeguarding of water resources in Wales, including regulation of drinking water quality, and the taking of special measures in time of drought;
- The oversight of Dŵr Cymru Welsh Water and Dee Valley Water, including their activities of those parts of their operational areas in England;
- The construction or enlargement of reservoirs, and the undertaking of ancillary works;
- The three Welsh National Parks;
- All activities of the Countryside Council for Wales and Environment Agency Wales (EAW); and
- Marine, terrestrial and freshwater biodiversity and nature conservation.

A second key department that has within its portfolio policy areas that have a direct impact on the quality of catchments is the Department for Rural Affairs, the objectives of which include (Welsh Assembly Government 2008e):

- Helping the farming, fishing and woodland industries in Wales become more sustainable economically, socially and environmentally (which includes a commitment to reviewing existing agri-environment schemes, as part of the Rural Development Plan);
- Contributing to action on climate change; and
- Helping promote animal health and welfare

The Department for Rural Affairs is also responsible for Forestry Commission Wales, which acts as the Welsh Assembly Government's Department of Forestry (Welsh Assembly Government 2008e).

One other department plays a minor role as far as catchments are concerned, and this is the Department for Social Justice and Local Government, which is responsible for the 22 local authorities in Wales, which in turn have responsibilities relating to the quality of private water supplies (Welsh Assembly Government 2008d).

North West Wales, and is home to just over 26,000 people (Snowdonia National Park Authority 2006);

- Brecon Beacons National Park – Situated in mid-southern Wales, it is home to 32,654 people and it encompasses 1,347 square miles of distinctive upland formations and, in October 2005, it was the first National Park in the UK to achieve UNESCO Geopark status (for Fforest Fawr) (Brecon Beacons National Park Authority 2006a, Brecon Beacons National Park Authority 2006b);
- Pembrokeshire Coast National Park – this is Britain's only truly coastal National Park, and extends for 240km along most of Pembrokeshire's coast, covering an area of 629 square kilometres (Pembrokeshire Coast National Park Authority 2003).

3.6 Discussion

Prior to the elections to the National Assembly for Wales in May 2007, the then Department for Environment, Planning and Countryside had responsibility for the following policy areas (Directgov 2006):

- Water policy;
- Agriculture;
- Environmental issues;
- Fisheries;
- Food;
- Forestry;
- flood defence; and
- Town and country planning.

The National Assembly for Wales had consequently placed all policy areas that may impact on the quality of a catchment in the portfolio of a single department, which was a revolutionary and foresighted approach that had not been taken by any other devolved administration to date. Policies could be coordinated by a single Government department, and a holistic approach could be taken to the management of activities which impact upon natural resources within the catchment.

However, since those elections, a fundamental review of all departments resulted in responsibility for these areas to be shared amongst three newly created departments. It may therefore be concluded that protection of the natural environment has been weakened as a consequence, as it is obviously far easier to coordinate the development of policies that directly impact on the quality of a catchment if all relevant areas of responsibility are within the remit of one department, than if they are shared between three. The existence of three governmental stakeholders may also give rise to areas of conflict, particularly where limited budgets are concerned.

The Department for Environment, Sustainability and Housing has responsibility for two pivotal documents produced by its substantive predecessor, the Department for Environment, Planning and Countryside – 'The State of the Welsh Environment' and the 'Environmental Strategy for Wales' – that have both helped define the Welsh Assembly Government's approach to management of the natural environment.

3.6.1 'The State of the Welsh Environment' Document

The Welsh Assembly Government first reported on the state of the Welsh environment in 1999. Four years later, it produced a further report, reviewing and updating the original report and providing a commentary on progress (or lack of it) made since 1999. The report noted that a reduction in the biological quality of rivers had been recorded during 1995 to 2000, reversing improvements that had been made during 1990 to 1995. This is thought to be due to the effects of diffuse agricultural pollution and flooding. According to the report, the major environmental pressures on freshwater ecosystems include climate change, abstraction, industrial pollution, soil erosion and nutrient enrichment from sewage and fertilizer run-off (Welsh Assembly Government 2003).

With regards to private water supplies, the report noted that the information the Welsh Assembly Government holds on them suggests that the quality of these supplies is poor (Welsh Assembly Government 2003).

3.6.2 'Environment Strategy for Wales' Document

In July 2005 the Welsh Assembly Government issued a consultation on its proposed 'Environment Strategy for Wales', in order to take the agenda forward that it set out in its document, 'Wales: A Better Country' (Jones 2005; Welsh Assembly Government 2003b; Welsh Assembly Government 2005c). A report on the consultation was produced in November 2005, and the finalised strategy was published the following May (Welsh Assembly Government 2005b, Welsh Assembly Government 2006a).

This document represents the Welsh Assembly Government's long-term strategy for the environment of Wales, setting the strategic direction for the next 20 years (Welsh Assembly Government 2006d). Although the strategy doesn't contain any targets relating to the aquatic environment, it does have the following general aims:

- To focus activity on the delivery of the existing duties under the Water Resources Act 1991 and the Water Act 2003 and the regulatory framework arising from those Acts (Welsh Assembly Government 2006d);
- To reduce diffuse pollution through implementation of the Water Framework Directive;
- To manage diffuse pollution from agriculture;
- To manage run-off in urban areas;
- To improve water infrastructure; and
- To maintain high standards of regulation for point source pollution.

These general aims would therefore help address all the main points highlighted in 'The State of the Welsh Environment' as representing the major environmental pressures on freshwater ecosystems. Nevertheless, as the regulatory review within Chapter 10 will demonstrate, the Welsh Assembly Government has not made any new regulations relating to either the Water Resources Act 1991 or the Water Act 2003, and neither has it made any new regulations relating to point source pollution. Instead, in all these instances, it has chosen, to date, to rely on the regulations made by the UK Government and which relate to both England and Wales equally.

Similarly, even though the Welsh Assembly Government now has primary legislative authority for both the water industry and planning issues, it has not made any progress in meeting either the aim to manage run-off in urban areas, or the aim to improve water infrastructure.

As far as the two general aims relating to diffuse pollution are concerned, as is noted in Section 12.9.3, the Welsh Assembly Government is currently managing a project designed to promote catchment sensitive farming. This project, should it be extended to the whole of Wales, in conjunction with the two Welsh agri-environment schemes described in Sections 10.12 and 10.22 will certainly go a long way to achieving these two aims.

Interestingly, as an aside, the strategy notes that the EA has a responsibility for river catchment management (Welsh Assembly Government 2006d) although in practice, as is noted in Chapter 12, the EA does not undertake catchment management as such.

The first Environment Strategy Action Plan was published alongside the strategy, and it contained details of the additional, specific actions that will be taken to deliver the outcomes in the Environmental Strategy. In this Action Plan, the Welsh Assembly Government also committed itself to requiring EAW to undertake a complete revision of its Water Resources Strategy for Wales, and that this should be in place by the end of 2008. By the end of March 2007, it also committed itself to establishing a Water Framework Directive stakeholder group to support the implementation of the Directive in Wales (Welsh Assembly Government 2006a).

4 KEY GOVERNMENT DEPARTMENTS AND PUBLIC BODIES IN ENGLAND

4.1 Introduction

A number of central Government departments and public bodies have responsibility for policy areas that directly impact on the quality of catchments in England. An overview of these departments and bodies, along with their respective areas of responsibility, is given below, within the context of catchment management and in order to demonstrate the relationships between them.

4.2 Department for Environment, Food and Rural Affairs

The Department for Environment, Food and Rural Affairs (DEFRA) is a department of the UK Government which, since devolution, has primarily focussed its activities on England. It brings together the interests of farmers and the countryside, the environment and the rural economy (Department of the Environment Food and Rural Affairs 2006e); it is also responsible for the administration of the Rural Development Programme for England (see Section 12.9.6.2).

As is explained in greater depth in Chapters 9 and 10, many of the UK's water quality and environmental standards are derived from European Directives. On matters within its national remit, DEFRA negotiates with the European Union on behalf of all four devolved administrations within the UK and provides advice to Edinburgh, Cardiff and Belfast relating to the transposition of Directives into national legislation. DEFRA also leads on the development of national water policies (Ofwat 2006b).

DEFRA's aim is sustainable development, and it has identified the following five strategic priorities which will help it reach its aim (Department for Environment Food and Rural Affairs 2004a):

1) Protecting the countryside and natural resource protection;
2) A sustainable farming and food sector including animal health and welfare;

3) Climate change and energy;
4) Sustainable rural communities; and
5) Sustainable consumption and production.

Of these five priorities, the first three are the most relevant to this review, and are considered in greater depth below.

4.2.1 Protecting the Countryside and Natural Resource Protection

DEFRA's goal – in relation to this strategic priority – is the creation of a robust policy framework and evidence base in order to promote the sustainable use and enhancement of the country's natural heritage and ecosystems. It has identified three outcomes it hopes to achieve from this, two of which are important to the field of water policy, and these are (Department for Environment Food and Rural Affairs 2004a):

- To protect and enhance the natural environment, now and for future generations, and to establish a robust framework for future development decisions that respect environmental constraints; and
- Good water quality and a good water environment, with a sustainable balance between water supply and demand.

4.2.2 A Sustainable Farming and Food Sector Including Animal Health and Welfare

DEFRA is striving to help create a sustainable food and farming supply chain serving the market and the environment; putting in place systems to reduce risks of animal diseases, and being ready to control them when they occur (Department for Environment Food and Rural Affairs 2004a).

The outcomes of relevance here are (Department for Environment Food and Rural Affairs 2004a):

- For farming to be more sustainable; and

- Animal health and welfare of kept animals improved, and society, the economy and the environment protected from the impact of animal disease, through sharing the management of risk with the industry.

4.2.3 Climate Change and Energy

The goal for this strategic priority is for DEFRA to make a full contribution, domestically and internationally, to addressing the long-term threats presented by climate change and unsustainable energy use, and to ensure adequate mitigation of the consequences which are already unavoidable (Department for Environment Food and Rural Affairs 2004a).

Of the four outcomes it hopes to achieve from this strategic priority, one is of particular relevance to this review, namely (Department for Environment Food and Rural Affairs 2004a):

- The reduction in UK and global greenhouse gas emissions to avoid dangerous climate change; UK successfully adapting to unavoidable climate change and promoting the need for international adaptation.

4.3 Department for Communities and Local Government

The second of the two main Departments of the UK Government with water responsibilities, the Department for Communities and Local Government (DCLG) was created in May 2006 largely from the former Office of the Deputy Prime Minister (ODPM) (Department for Communities and Local Government 2006). Through its role in planning matters and its responsibility for building regulations, DCLG is able to influence future demand for water (House of Lords 2006c).

4.4 Natural England

The Natural Environment and Rural Communities Act 2006 brought together the functions of English Nature, and certain functions that were performed by the Countryside Agency and the Rural Development Service (formerly a directorate of

DEFRA) to establish an independent, integrated agency called Natural England (UK Government 2005d). Natural England was formally established on 1 October 2006, at which time English Nature and the Countryside Agency were both wound up (UK Government 2006c).

Natural England champions integrated resource management, nature conservation, biodiversity, landscape, access and recreation (Department for Environment Food and Rural Affairs 2006g). Water is an integral part of all these areas, so it will be working closely with the EA. For example, the two bodies will be taking joint action to tackle diffuse pollution.

4.5 Discussion

Since the 1997 general election the policy areas that may impact on the quality of a catchment have been regularly moved and shared between pre-existing and newly created central Government departments (including the Ministry for Agriculture, Fisheries and Food (MAFF), Department for Environment, Transport and the Regions (DETR), Department for Transport, Local Government and the Regions and ODPM) (The London School of Economics and Political Science 2008) until the current situation – as presented in the previous sections – was reached. Now, all relevant policy areas – with the notable exception of planning, which is within DCLG's portfolio – are the responsibility of DEFRA. Consequently, it may be argued that the catchment is afforded slightly greater institutional protection within England than it is within Wales, as there is more opportunity for DEFRA to provided a considered, coordinated approach.

Following the creation in 2001 of DEFRA out of the former MAFF and DETR, Christopher Haskins was asked in 2002 to review the Government's rural policies in England. This review took eight months, and was published in October 2003 (Haskins 2003). The terms of reference for the review were to make recommendations on how best to improve the effectiveness of delivery arrangements for DEFRA's rural policies with a view to (Haskins 2003):

- Simplifying or rationalising existing delivery mechanisms and establishing clear roles and responsibilities and effective co-ordination;
- Achieving efficiency savings and maximising value for money;
- Providing better, more streamlined services with a more unified, transparent and convenient interface with end customers; and
- Identifying arrangements that can help to deliver DEFRA's rural policies and Public Service Agreement targets cost-effectively.

The report devotes an entire chapter supporting the view that there should be a more integrated approach to sustainable land management. Elsewhere within the report Haskins concluded that the Countryside Agency was "no longer necessary"; it also made a number of critical observations in relation to the Rural Development Service. In this chapter, the main recommendation (and, arguably, the most significant of the entire report itself) was that the Government "should establish an integrated agency to promote sustainable use of land and the natural environment". This helped pave the way for the Natural Environment and Rural Communities Act 2006, which established Natural England (see Section 4.4).

This reorganisation was seen at the time to be long overdue, as with the formation of Natural England, England now had an environmental champion broadly similar to the Countryside Council for Wales and Scottish Natural Heritage. However, during its campaign for the 2007 Scottish Parliament elections, the SNP stated that it was its intention to merge the Scottish Environment Protection Agency with Scottish Natural Heritage (the public body charged with caring for the nation's wildlife and landscapes) (The Sunday Herald 2007). This is an interesting development in terms of UK environmental policy, coming so soon after the creation of Natural England so that the institutional arrangements in England would mirror those already established in Wales and Scotland.

As far as English catchments were concerned though, this institutional reorganisation potentially afforded them greater protection by helping avoid duplication of efforts by bodies with sometimes competing priorities, and by providing much greater clarification of environmental goals and objectives. Nevertheless, a significant area of contention has developed subsequent to Natural England's formation.

A House of Commons Select Committee published a report in May 2006 following a review of the EA's effectiveness and funding (House of Commons 2006a). The report noted that the EA and the Natural England federation had been working together to create a "close and constructive working relationship", but was concerned that tensions already exist in relation to the agri-environment budget of £300 million per year which will be controlled by Natural England in order for it to achieve its objectives of biodiversity, landscape access and recreation. However, the EA in evidence stated that the budget was also intended for its own aims of protecting the natural resources of air, land and water. The Committee therefore called for DEFRA to provide Natural England with clear guidance on using this budget in order to achieve the objectives of both bodies (House of Commons 2006a). In response, the Government merely stated that the two bodies "must work together ... to achieve the best outcomes for the environment" (House of Commons 2006b). This response is not satisfactory. It was a sensible request from the Committee for clear guidance to be produced, and this would not have placed a huge burden on DEFRA to produce it. In refusing to do so, it has potentially led to the current tensions increasing in magnitude, and presents a barrier to these two organisations working together harmoniously. Ultimately, the environment will suffer as a result.

Lack of co-ordination such as this was a strong theme within the report. The review found that there are far too many regional strategies, regional co-ordination of delivery is unduly complex, and there are too many initiatives, schemes and services. It therefore made a number of recommendations which should rationalise strategic planning, and the regional co-ordination of rural delivery more efficient. This unfortunately does not seem to have happened in practice though.

Despite this lack of coordination and unnecessary complexity in the delivery of numerous policies and strategies, DEFRA does appear to have adopted a considerably more proactive approach to water policy and sustainable land management than the equivalent departments within the Welsh Assembly Government. Although now in its ninth year of existence, the impression of the

Welsh Assembly Government is that it has taken a more timid approach to catchment issues specifically, and environmental issues generally. Although the two countries share a number of significant environmental pressures and issues – such as diffuse pollution and unsustainable abstractions – there are sufficient differences between the environmental needs of each country for Wales to legitimately adopt a distinctly separate approach to catchment issues than England. However, to date, the image the Welsh Assembly Government has unfortunately projected is that it is very much a junior partner to Westminster, as in many instances joint consultations have been issued by the two administrations which have been produced by DEFRA and merely have the Welsh Assembly Government's logo on them. It is my personal view that the Welsh Assembly Government should be encouraged to establish a separate Welsh identity for environmental policies and initiatives, particularly when it fought so hard to attain legislative authority in all those policy areas that may impact on the quality of a catchment; it now has this authority, so it should not be reluctant to use it.

One possible reason why it has not done so to date is that a number of confidential discussions with key stakeholders in Wales have identified that the Welsh Assembly Government simply lacks the resources (in both skills and manpower) of its English equivalent. Another reason may be that the Welsh Assembly Government is now suffering from 'initiative overload' in other important areas such as education and health, and that it has now stretched itself to the point where realistic budgets to develop similar initiatives for the environment simply cannot be provided. If true, this catchment short-sightedness is worrying and ill-advised.

5 PUBLIC BODIES WITH ENVIRONMENTAL RESPONSIBILITIES SPANNING ENGLAND AND WALES

5.1 Introduction

Since the process of devolution within the United Kingdom started in 1999, the political separation of the environment in England and Wales has been slow and is still ongoing, the consequence of which is that there are a number of public bodies remaining with environmental responsibilities spanning the two countries. An overview of these stakeholders, along with their respective areas of responsibility, is given below.

5.2 Drinking Water Inspectorate

The DWI acts for and on behalf of the Secretary of State for Environment, Food and Rural Affairs and the Welsh Assembly Government to ensure that water companies in England and Wales meet their regulatory obligations in terms of drinking water quality (Jackson 2003).

The DWI's principal method for ensuring these obligations are met is by undertaking inspections and audits of water companies. Inspectors investigate incidents where the quality of water has been seriously affected, or potentially could have been. The DWI considers whether an offence of supplying water unfit for human consumption has been committed and, if so, whether a prosecution is warranted or if enforcement action is required for any breach of the Water Supply (Water Quality) Regulations 2000 and 2001 (see Sections 10.13 and 10.14).

A requirement of these regulations is that water companies analyse samples taken from their water treatment works, service reservoirs and consumers' properties, and that the results are reported annually to the DWI. The results are audited and published in the Chief Inspector's annual report each June.

The DWI has no role in enforcing the regulations relating to private water supplies. Instead, these are the responsibility of local authorities, but the DWI does provide them with technical advice (Ofwat 2006b).

The DWI is a core departmental function of DEFRA, so it is part of the normal departmental structure and staffed by civil servants (Hampton 2005). However, DEFRA is considering merging the DWI with another national regulator (candidates include the Health and Safety Executive, the Health Protection Agency or the Food Standards Agency); a consultation will be issued in due course (House of Lords 2006c).

5.3 Ofwat

With effect from 1 April 2006, the Water Act 2003 abolished the office of the Director General of Water Services, and replaced it with the Water Services Regulation Authority. However, the Authority recognised the strength of the name of its predecessor body, and has made clear that it still wishes to be referred to as Ofwat.

Ofwat is the economic regulator of the water industry in England and Wales. It does this by setting limits on what water companies can charge their customers, encouraging water companies to be more efficient, and helping to encourage competition where appropriate (Ofwat 2006a). Ofwat is a Non-Ministerial Department.

During the quinquennial round of price-setting, Ofwat considers any enhancements water companies need to deliver; there are five criteria that such quality enhancements need to satisfy before Ofwat will consider them for inclusion in the price limits. A quality enhancement must (Thompson & Gray 2005):

1) Be required by the quality regulators, and confirmed by Ministers, or are new obligations under current legislation;
2) Deliver a measured defined output, which is enforceable;

3) Have a clearly defined timetable and due date for delivery in line with regulations or other legislation;
4) Have defined asset improvements or changes to operational procedures to deliver the output; and
5) Have identified costs for the proposed solution which have been challenged and validated by the water company's reporter.

Within the price limits set Ofwat expects each water company to manage and deal with all situations that may arise during the normal course of providing water and sewerage services. This includes managing all incidents including emergencies and the threat of terrorist acts (Thompson & Gray 2005).

5.4 Environment Agency

The EA is the lead environmental regulator for England and Wales, and has responsibilities for the protection, remediation and improvement of our land, water and air. It has a number of objectives, but those which are of interest to this review include (Anderson 2003):

- Reducing the impacts on the environment from agriculture and industry;
- Tackling flooding and pollution incidents; and
- Cleaning up rivers, coastal waters and contaminated land.

Created in 1996 as a consequence of the Environment Act 1995, the EA assumed the roles and responsibilities of the waste regulation authorities in England and Wales, Her Majesty's Inspectorate of Pollution, some functions of the then Department of the Environment, and the National Rivers Authority (NRA). It is the largest agency of its type in Europe, and the second largest in the world. The EA is the largest national regulatory body in the UK, with about 13,114 staff and total funding of £1,002 million (2006/07 figures) (Environment Agency 2007b).

Of this income, £554 million of the EA's grant-in-aid was provided by DEFRA, whilst £49 million came from the Welsh Assembly Government (Environment Agency 2007b). £61.4 million is derived from its discharge consent charging scheme, whilst abstraction licence charges account for £123.1 million (Environment Agency 2007b). Expenditure on water resources is funded entirely by abstraction licence charges (House of Commons 2006a).

The Agency is a Non-Departmental Public Body, and consists of three levels of operation:

- A head office, split between Bristol and London, which sets national policy and helps support the regions;
- Eight regions (South West, Southern, Thames, Anglian, Midlands, North East, North West and Wales), which support the area offices and help coordinate their activities; and
- 26 area offices across England and Wales, which are responsible for the day-to-day operational management of the areas.

Within each region, there are three statutory committees that advise on the operational performance of its functions, regional issues of concerns and regional implications of national policy proposals. These committees are:

- The Regional Fisheries, Ecology and Recreation Advisory Committee;
- The Regional Flood Defence Committee; and
- The Regional Environment Protection Advisory Committee.

There is also an advisory committee for Wales.

5.5 Consumer Council for Water

The Consumer Council for Water (which in abbreviated form is referred to as CCWater, to distinguish it from CCW, the Countryside Council for Wales) was established by the Water Act 2003 and it represents water and sewerage consumers in England and Wales (Consumer Council for Water 2006a). It has ten local CCWater committees, and each water company has been assigned to one of these committees (Consumer Council for Water 2006b).

CCWater took over from WaterVoice on 1 October 2005, and is independent of both the water industry and the regulator.

5.6 Local Authorities

Councils have legal status as corporate bodies. They are required to provide statutory services as set out in legislation and are empowered to provide other services at their discretion. Councils provide some services directly, work in partnership with other organisations, and commission others to provide services on their behalf (Welsh Local Government Association 2006).

With specific reference to water, councils have responsibilities for private water supplies (see Section 10.4), drainage, flood alleviation and regulation of ordinary watercourses (see Section 13.4) that are not in an Internal Drainage District (see Section 5.7) (Samuels et al. 2006).

5.6.1 Local Authorities in Wales

The current model of a single tier of local government in Wales arose from a radical reorganisation in 1996, which created 22 authorities from the previous two-tier model of eight county councils and 37 district councils (Welsh Local Government Association 2006).

5.7 Internal Drainage Boards

In certain low-lying parts of England and Wales Internal Drainage Districts have been designated under the Land Drainage Act 1991 (UK Government 1991a), and each one has an Internal Drainage Board responsible for drainage and flood defence in order to sustain agricultural and developed land use. Each one of the 235 Internal Drainage Boards is run by a board of nominated and elected members, and they have powers relating to conservation, the raising of revenue, and the maintenance, improvement and operation of drainage systems (Samuels et al. 2006).

5.8 British Waterways

British Waterways is a public corporation that is responsible for conserving and enhancing more than 2,200 miles (3,540km) of canals and rivers in England, Scotland and Wales on behalf of the nation (British Waterways 2008a). Its sponsoring departments are DEFRA in England and Wales, and the Finance and Sustainable Growth Department of the Scottish Government. Although British Waterways does not receive any funding, nor direction, from the Welsh Assembly Government, it does "liaise closely" with it (British Waterways 2008d).

A valuable drainage service is offered by British Waterways, particularly in urban areas, as excess surface water can be discharged into its network (for which charges apply) (British Waterways 2008b). This network also receives the final treated discharges from a number of water companies' sewage treatment works, which in certain areas represent a critical resource for maintaining flows and water levels.

Of particular interest from a Drinking Water Safety Planning perspective is the role British Waterways plays in providing raw water to a number of water companies – including Bristol Water, North West Water, Wessex Water and, indirectly, Anglian Water – which is then treated and put into the municipal supply. The volumes of water involved can be significant. For example, it supplies half of Bristol's drinking water via the Gloucester and Sharpness Canal (British Waterways 2008c).

5.9 Forestry Commission

The Forestry Commission is responsible for forestry policy throughout Great Britain; it is both a Government Department and a statutory body with a Board of Commissioners. As forestry is a devolved matter, the Forestry Commission established on 1 April 2003 three separate entities – Forestry Commission England, Forestry Commission Scotland and Forestry Commission Wales – to deliver the policies of the devolved administrations (Forestry Commission 2006a, Forestry Commission 2006b).

5.9.1 Forestry Commission Wales

In Wales, there are 286,000 hectares of woodland, covering around 14% of the Principality (well below the European Union land coverage average of 32%). 38% of this land area is publicly owned and managed by Forestry Commission Wales (FCW), and represents the largest single woodland ownership in Wales (National Assembly for Wales 2001c).

In its corporate plan for the period 2005/06 to 2007/08, FCW aspires to improving the "condition and resilience" of the environment through its activities. It commits itself to working with EAW to support any relevant measures to deliver good ecological water status in Wales by 2015. It will also assist with the interception and infiltration of flood water (Forestry Commission Wales 2005a).

5.10 Centre for Ecology and Hydrology

The Centre for Ecology and Hydrology (CEH) is the UK's "centre of excellence for research in land and freshwater environmental sciences", and is a wholly-owned Research Centre of the Natural Environment Research Council (NERC). CEH currently operates out of nine sites in England, Scotland and Wales (although as a result of a recent review NERC will soon reduce this number to four) (Natural Environment Research Council 2006b, Natural Environment Research Council 2006a)

NERC provides around £23 million of CEH's annual budget, whilst the remaining £11 million comes from external funding (Natural Environment Research Council 2006a).

5.10.1 National Water Archive

The National Water Archive is maintained by CEH at Wallingford, and it manages a broad range of hydrological and related data (Centre for Ecology & Hydrology 2006e). One of the major components of this archive is the National River Flow

Archive which contains flow data for rivers obtained from over 1,300 gauging stations from across the UK (Centre for Ecology & Hydrology 2006d).

Another major component is the National Groundwater Level Archive which, although based at Wallingford is maintained by the British Geological Society and it holds data derived from about 170 boreholes and wells across the UK (Centre for Ecology & Hydrology 2006c).

As well as the National Water Archive, CEH also monitors the flow and level data for any changes or trends, based on a network of benchmark catchments that are not significantly affected by artificial influences (such as impounding reservoirs, river regulations schemes etc) (Dabrowski *et al.* 2005, Centre for Ecology & Hydrology 2006a).

5.11 Discussion

In his 2004 Budget, the Chancellor of the Exchequer asked Philip Hampton to "consider the scope for reducing administrative burdens by promoting more efficient approaches to regulatory inspection and enforcement, without compromising regulatory standards or outcomes". The resulting report – "Reducing Administrative Burdens: Effective Inspection and Enforcement" – was published in March 2005 (Hampton 2005).

The aim of the review was to identify ways in which the administration burden of regulation on business could be reduced, while maintaining or improving regulatory outcomes. After considering the work of 63 national regulators and 468 local authorities, a number of recommendations were made in the final report; only those concerning, or relating to, the aquatic environment and the water industry are considered here.

The so-called economic regulators (such as Ofwat) were excluded from the review, as were regulators that are solely the responsibility of the devolved administrations (such as the Scottish Environment Protection Agency).

The agricultural and rural community has a significant role to play within Wales, particularly from a diffuse pollution point of view. The review found that, although the EA unifies almost all regulation of land, air and water, regulation on farms is the responsibility of over 20 different inspectorates (Hampton 2005). The report therefore recommends that 31 national regulators are consolidated into seven, covering the following seven thematic areas:

- Environment;
- Health and safety;
- Food standards;
- Consumer and trading standards;
- Animal health;
- Agricultural inspections; and
- Rural and countryside issues.

Such a consolidation of regulators would reduce the administrative burden on the companies they are regulating, reduce the risk of conflicting advice being issued, minimise multiple inspections, target scarce resources more effectively and improve regulatory outcomes.

The report states that the following are the right requirements of a regulatory system:

- Standards must be relevant, effective, clear and understood by all;
- Support and guidance information is easily accessible and specific to hazards and industries;
- Enforcement is targeted at the worst offenders, including those responsible for the greatest number and severity of work-related illnesses and injuries;
- Regulators deal with offenders effectively, fairly and visibly, raising the expectation of appropriate but inevitable enforcement; and
- Regulators use a flexible approach to intervention, depending on the motivations and responses of individual employers (Hampton 2005).

Once all of the above are in place, regulators must then take a risk-based approach to regulating their respective sectors. The fundamental principle of risk assessment is that scarce resources should not be used to inspect or require data from businesses that are low risk, either because the work they do is inherently safe, or because their systems for managing the regulatory risk are good (Hampton 2005).

According to the Hampton report, risk assessment should:

- Be open to scrutiny;
- Be balanced in including past performance as well as potential future risk;
- Use all available good quality data;
- Be implemented uniformly and impartially;
- Be expressed simply, preferably mathematically;
- Be dynamic, not static;
- Be carried through into funding decisions;
- Incorporate deterrent effects; and
- Always include a small element of random inspection.

As a direct consequence of this report, the EA has readily adopted a risk-based approach to regulation of all the sectors within its remit, which has generally been met with approval by stakeholders within these sectors.

As the water industry within England and Wales is still effectively a single entity, it is appropriate for the current regulatory model to continue to operate for the time being, with the three national regulators having responsibility for both England and Wales. This is especially so for both the DWI and the EA, as their 'terms of reference' are essentially enshrined within various environmental and water European directives (albeit transposed into national legislation); as these 'terms of reference' apply equally to both England and Wales, there does not appear to be any need to establish separate environmental and drinking water regulators for each of England and Wales.

However, as a separate body of environmental law starts to emerge from the Cardiff administration, this regulatory model may need to be critically examined. Indeed, this separation process has arguably started, as Section 57 of the Water Act 2003 provides for the appointment by the Welsh Assembly Government of a Chief Inspector of Drinking Water for Wales (UK Government 2003c); however the Act does not make clear whether there is also provision for a separate Welsh Inspectorate, or whether the Chief Inspector for Wales would be part of the pre-existing departmental function of DEFRA.

A potential alternative model could already exist though, in the form of the Forestry Commission. As I mentioned in Section 5.9, forestry is a devolved matter, and so the Forestry Commission operates at a Great Britain level, whilst three separate, semi-autonomous subordinate entities operate within each of the devolved administrations' areas. Such a model could well be adapted to deliver both environmental and drinking water policy throughout Great Britain (or even the wider UK) so that the 'Environment Commission' or 'Drinking Water Quality Commission' could ensure that European Directives were implemented consistently and appropriately (and which would help overcome any trans-boundary issues) whilst, for example, 'Environment Wales' and 'Environment England' would deliver the policies of the devolved administrations.

5.11.1 Ofwat

With regards to the third national regulator – Ofwat – it is appropriate for it to operate in both England and Wales, despite it not having 'terms of reference' that were ultimately handed down by the European Union. Ofwat has regularly stated that its ability to compare water companies' activities and costs is a fundamental and essential component of the periodic price review process. Although I mentioned in Section 2.3 that the entire water industry is represented in Wales, only one of each of the current three public water supply models exists within the Principality, so an 'Ofwat Wales' would not have sufficient comparators in order to be able to inform its decision-making process.

In private discussions with senior Ofwat personnel, I was informed that the Drinking Water Safety Plan approach would not be eligible to be considered as a quality enhancement during the periodic review; this was because Ofwat considered the approach to be best practice which water companies should adopt as a matter of course, rather than a fundamental change in the approach taken by water companies to produce safe drinking water. Therefore, water companies would have to fund preparation of these Plans by efficiency savings, or from revenue generated from other non-regulated areas.

Different institutional arrangements within the water industry were also suggested by Ofwat in private, although these should not be taken as position statements nor preferred industry options. For example, in order to satisfy both the requirements of the Drinking Water Safety Plan approach, and to further open up the water industry to competition, one approach may be to disaggregate the drinking water supply chains, along similar lines already adopted in some Australian states and parts of New Zealand. Catchment management authorities could be established, that had responsibility for managing the quality of water within catchments primarily for drinking water supply purposes. This water would then be sold to water companies via bulk water agreements, which would then sell the treated water to retail companies that have responsibility for supplying consumers.

5.11.1.1 The Periodic Review

Ofwat is responsible for setting limits on the amount water companies can charge their customers. At the time of privatisation, it was envisaged that these limits would be determined once every ten years, allowing water companies a reasonable length of time for financial planning purposes (Ofwat 2006d). However, because of the magnitude of the profits reported by the water companies in the years immediately after privatisation, this period was consequently shortened to five years.

In recent years the subject of the length of the periodic review has been considered as part of a number of reviews undertaken by parliamentary Select Committees or Government-appointed individuals relating to the EA and Ofwat. For example, following an inquiry into the 2004 periodic review, the House of Commons Environment, Food and Rural Affairs Select Committee published its findings in December 2003 (House of Commons 2003c).

The Committee received representations that the length of the periodic review should be extended. In their report, the Committee noted that Ofwat is committed to a further price review in 2009, but that after then it planned to consult on the optimum length of the period under review. The Committee therefore recommended that the length of the period should be at least extended to six years, in order to fall into step with the six year review cycle of the Water Framework Directive's River Basin Management Plans, and possibly even up to 12 years with a mid-term review.

This matter was also considered as part of a review undertaken by the House of Commons Environmental Audit Select Committee of the 2004 Periodic Review and the Environmental Programme. In the report it published in May 2004, the Committee noted that the current five-year AMP period was not appropriate, and it recommended that it is extended to six years, or twelve years with a mid-term review, so that it falls into step with the Water Framework Directive (House of Commons 2004a). In the Government's response, it stated that a previous consultation on the optimum length of the AMP period had not reached a consensus. However, it also stated that decisions on the period between price reviews will be for Ofwat to decide, and any change would come into effect after the next Periodic Review in 2009 (House of Commons 2004b).

In July 2005, the House of Lords' Science and Technology Select Committee (one of the four permanent investigative committees of the House of Lords (House of Lords 2005c)) appointed a Sub-Committee to consider water management in England and Wales (House of Lords 2005d). The resultant report was published on 6 June 2006 (House of Lords 2006a, House of Lords 2006c), and the Government published its response to the report the following August (UK Government 2006b).

The report urged Ofwat to consider changing the length of the periodic review cycle to six years, in common with previous reports, so that it is coincident with the review cycle for River Basin Management Plans. However, the Select Committee developed this idea even further, by also recommending that Ofwat issue indicative prices for the six years subsequent to the six year review period, and prospective prices for the next 12 years after that, in order to provide water companies with greater financial and logistical certainty (House of Lords 2006c).

An extension to the current AMP period seems both prudent and overdue. Within the current five-year planning cycle water companies have no incentive to consider longer-term projects, such as those that may be required in relation to climate change mitigation and/or adaptation strategies, or strategic regional development initiatives such as the Thames Gateway. Specifically, it is very difficult for water companies to plan for long-term water resources development as, back in 1994, the then National Rivers Authority (NRA) noted in its Water Resources Development Strategy that "it can take between 15 and 25 years to investigate, promote and construct a major new water resource in the UK" (National Rivers Authority 1994). Consequently, serious consideration should be given to at least extending the planning period to twelve years, with a mid-term review, which would better facilitate longer-term projects.

5.11.2 Environment Agency

Ten years after the EA was created, the House of Commons Environment, Food and Rural Affairs Select Committee thought a review of the Agency's effectiveness and funding (including value for money) was opportune. The inquiry commenced in November 2005, and the final report was published in the following June (House of Commons 2006a).

A number of organisations who gave evidence expressed concerns about a perceived conflict between the EA's twin roles of regulator and environmental champion (although other, mainly environmental NGOs, were broadly supportive in this regard). This led to the Committee recommending that DEFRA investigate these concerns, which should include holding a series of stakeholder workshops "to critically appraise the Agency's ability [to] effectively … deliver its current regulatory functions" (House of Commons 2006a). In its official response to the report, the Government stated that the EA's role and responsibilities was detailed in Statutory Guidance which was produced after wide consultation; this guidance was updated in 2002 and was intended to cover at least five years. The Government said that it could not see any contradiction in the Agency's twin roles, but that it would take into account the findings of the Committee during the next revision of the guidance (House of Commons 2006b). This is quite an extraordinary statement, seeing as this same argument was one of the publicly espoused reasons for the privatisation of the water industry in 1989, in order to separate the then water authorities' twin roles of 'poacher' and 'gamekeeper', that of regulator and environmental champion.

Lack of consistency in its regulatory and enforcement functions has been a longstanding issue for the EA, both geographically and between its policy centre and the inspectors on the ground. Evidence was submitted which alleged there was inconsistency even between individual teams within the Agency. Such inconsistencies are due in part to problems with staff retention, lack of communication between the policy centre and its various Area teams, the increasing centralisation of policy-making, and a difficulty in attracting suitably qualified specialist staff. Although the Committee recognised that the EA had made progress in addressing these problems in recent years, it said that the Agency "must continue to improve its communication processes to ensure a consistent approach across the country to regulation and advice". The Committee also stated that the Agency "should also publish a work plan to indicate what steps it plans to take to further address the problem" (House of Commons 2006a). The Government agreed with these conclusions and said that it would "look to the Agency to continue to make improvements" (House of Commons 2006b).

With regards the problems the EA has experienced recruiting and retaining specialised staff, the Committee accepted that there had been a general decline in specialised degree courses in the UK, so the graduate recruitment pool had shrunk, which had undoubtedly contributed to the problems the Agency had been experiencing. However, it still recommended that the Agency "should issue a work plan with specific deadlines to set out how it aims to solve its recruitment problems, and publish details about its future graduate requirements" (House of Commons 2006a). Although the Government agreed the recruitment and retention was a problem for the Agency, it merely stated that it would continue to monitor the situation (House of Commons 2006b).

Several bodies providing evidence to the inquiry stated that there should be a clearer separation of the policy duties of DEFRA from the enforcement and regulation duties of the EA; in a number of instances, the Agency has shared the policy duty with DEFRA, or even shouldered it entirely on its own. When questioned about this, the responsible Minister of State said that the EA was very closely involved in the production of policy, and was "free to comment on policy", but that policy functions were ultimately the responsibility of DEFRA (House of Commons 2006a). The Government failed to address this issue in its official response (House of Commons 2006b).

It is interesting to note that one of the reasons cited for the abolition of the Countryside Agency and the subsequent formation of Natural England in 2006 was that there was a very similar blurring of the policy role between the Countryside Agency and DEFRA.

A review of the efficiency in water resource management in England[1] by the EA was recently undertaken by the National Audit Office, and a report summarising its findings and conclusions was published in June 2005 (Comptroller and Auditor General 2005).

The purpose of the National Audit Office's review was two-fold:

- To assess the extent to which the management of water resources is efficient in general terms, and
- To then identify those activities where scope for efficiency improvement was greatest (Comptroller and Auditor General 2005).

The review did not consider the effectiveness of the abstraction licensing system as this was the subject of extensive consultation prior to the Water Act 2003 receiving Royal Assent; neither did it consider abstraction licence charges, as this was the

[1] The National Audit Office audits matters "reserved" to the UK Government, and the Comptroller and Auditor General reports to the UK Parliament, not the UxeK Government. In Wales, the environment is a devolved matter for the National Assembly for Wales. The Wales Audit Office covers all sectors of government in Wales, except those matters reserved to the UK Government, and its head – the Auditor General for Wales – reports to the Assembly. The remit of the National Audit Office therefore did not extend to considering how water resources are managed in Wales (Wales Audit Office 2006, National Audit Office 2006).

subject of a separate review undertaken by the EA (Comptroller and Auditor General 2005).

The management of water resources across England and Wales cost about £114 million for 2003/04 (contrast this with the value of resources protected by the EA's abstraction licensing regime; some £72 billion). The EA is required by statute to recover these costs through abstraction licence fees, and two-thirds[2] of the 47,600[3] abstraction licence holders were responsible for meeting these costs (Comptroller and Auditor General 2005).

These costs are mainly incurred by the following activities:

- Developing Catchment Abstraction Management Strategies (see Section 13.4.2);
- Augmenting river flow (such as in the River Dee);
- Issuing and updating abstraction licences;
- Improving, developing and maintaining the hydrometric network (estimated to have a value of £234 million in 2003/04);
- Collecting and analysing data from the hydrometric network; and
- Technical assessments, including modelling, associated with the above activities (Comptroller and Auditor General 2005).

In general, the review found that the EA provided a professional and well-managed service. However, it did find improvements could be made in a number of areas, which the National Audit Office estimated would give rise to savings of between £1.4 million and £2.5 million. In particular, the report recommended that (Comptroller and Auditor General 2005):

---

[2] The other one-third are not liable for abstraction licence charges, either because they are statutorily exempt from such charges, or the volume of water their licence allows them to abstract is less than the amount at which charges become payable.

[3] This figure applies to when the review was undertaken. Since then, changes to the abstraction licensing regime introduced by the Water Act 2003 have given rise to the de-regulation of in excess of 20,000 smaller abstractions.

- More robust cost data on its various water resource management activities needs to be generated;
- Greater consistency is required across the various Regions and Areas in the EA's policies and procedures;
- A single group within the EA should have overall control of the hydrometric network, in order to ensure consistency in design, construction, operation and maintenance of its assets; and
- The EA needs to adopt a nationally consistent approach to cost allocation between flood risk management and water resources, in order to minimise the current practice of water resources funds subsidising flood risk management activities.

The EA recently embarked on a re-structuring, in order to reduce its workforce by 25%. The appropriateness of such a down-sizing must be questioned, at a time when the EA is taking on additional responsibilities, and is stepping-up its approach to implementation of the requirements of the Water Framework Directive. In light of this and the above comments, it may well be timely to re-consider the EA's twin roles of regulator and environmental champion, so perhaps functions such as recreation, biodiversity, fisheries and ecological appraisal should be moved to either the Countryside Council for Wales, or Natural England, as appropriate, as these latter bodies already have elements of these functions.

Another area where the EA is acting as both 'poacher' and 'gamekeeper' is that of navigation. Ensuring that a watercourse is navigable requires an ongoing programme of dredging and weed clearance, and both these activities have an obvious environmental impact on both ecology and water quality. There is therefore obviously a case for such operational activities of the EA to be passed to another body, otherwise it may find itself in the invidious position of constructing a criminal case against itself (as happened in 2005 when its in-river activities on the River Dee caused a plume of re-suspended sediment to impact on fisheries for a long stretch downstream). As British Waterways is the largest by far of the navigation authorities in the UK, perhaps all of the EA's navigation responsibilities should be passed to British Waterways. The EA is responsible for nearly 1,000km of rivers in England

and Wales (as well as being the Conservancy Authority for the River Dee, and the Harbour Authority for Rye), which is a fraction of British Waterways' 3,540km (Environment Agency 2008). This suggestion therefore appears to be the obvious solution that is required in order to separate the operational and regulatory activities of the EA in this particular area.

British Waterways is also responsible for certain un-navigable or so-called 'remainder' waterways, in the most economical way consistent with public health, amenity and safety (Competition Commission 2009). It could be argued that British Waterways should only focus on the navigable 'commercial' and 'cruising' waterways, and that the 'remainder' waterways should be managed by the Countryside Council for Wales / Natural England as appropriate, as this would sit well with their existing recreation, fisheries, biodiversity and ecology responsibilities.

In a Welsh context it is believed that such a rationalisation of the respective activities of EAW, the Countryside Council for Wales and British Waterways would not need primary legislation; the Welsh Assembly Government could feasibly effect such changes using its current devolved powers. Consequently, the proposed relationships and principal responsibilities of these bodies are shown in Figure 1. In this context, EAW's role would be solely that of a regulator, whilst all navigation operational activities would be undertaken by British Waterways, and all other operational activities relating to the natural environment would be carried out by the Countryside Council for Wales.

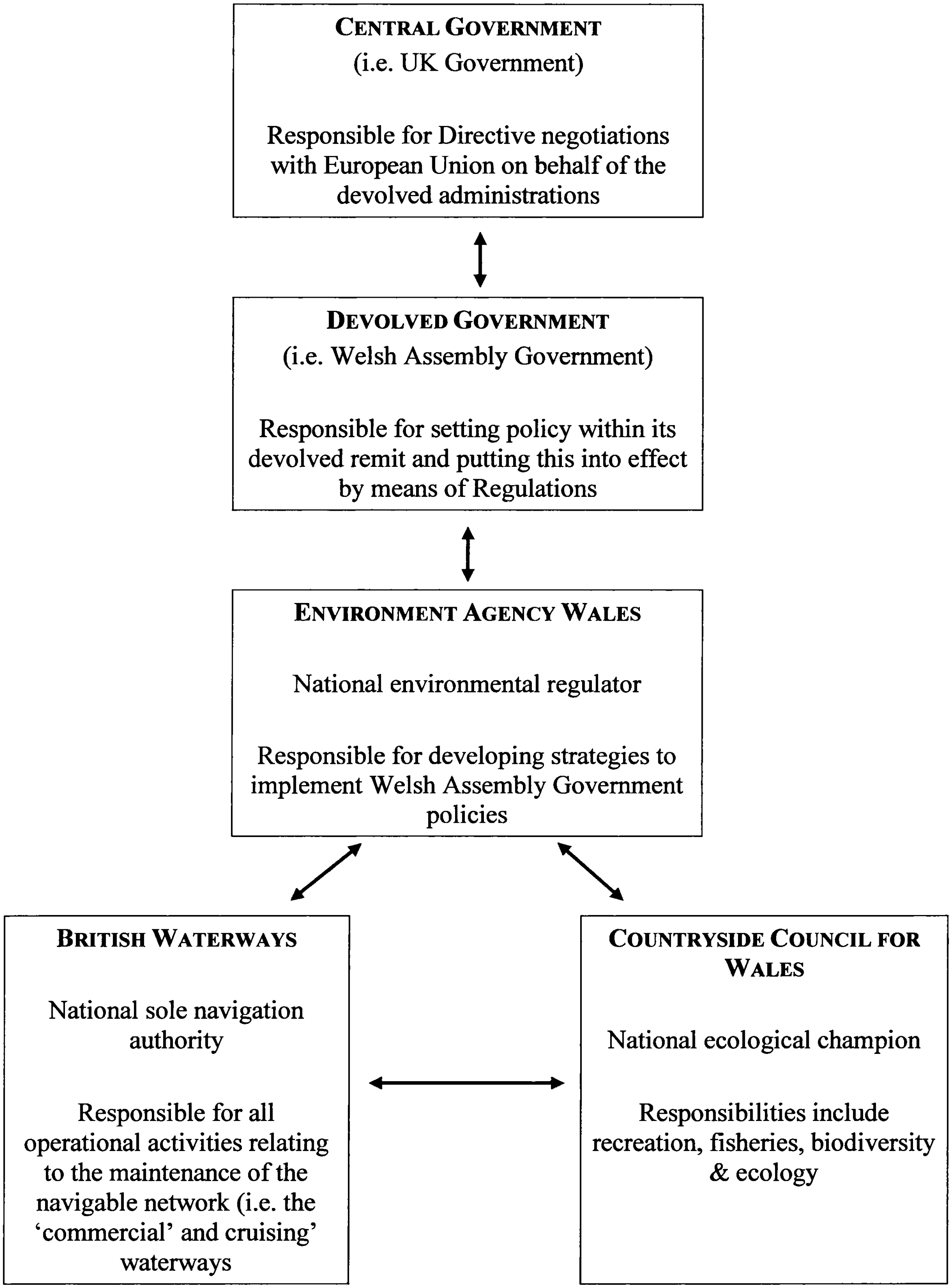


Figure 1: Organogram showing the proposed relationships and principal responsibilities of certain environmental stakeholders in Wales

5.11.3 Local Authorities

As I mentioned in Section 1.3.3, despite repeated attempts to establish contact with appropriate contacts within the local authorities in North Wales, the vast majority did not reply to my request for information relating to their activities in relation to private water supplies. As for the two local authorities that did respond, their lack of detailed knowledge meant that that they could only make general comments about the subject. As EAW confirmed a number of private water supplies did exist throughout North Wales, this suggests that local authorities throughout the region are poorly equipped (possibly in terms of both knowledge and manpower) to effectively enforce the current private water supplies regulations.

Once the new private water supplies regulations for Wales have been consulted on and subsequently implemented, the workload of local authorities throughout the Principality will increase markedly if the new regulations have a similar thrust as those in Scotland (see Section 18.3.1.2), as local authorities will be required to produce Drinking Water Safety Plans for the larger private water supplies. In order to be able to produce them, local authorities should therefore be discharging their sampling obligations under the current regulations, in order to be able to establish a baseline for each private water supply in Wales. Welsh local authorities should therefore not only ensure their current regulatory commitments are resourced sufficiently, but they should also be gearing up for the new challenges the revised regulations will undoubtedly present.

5.11.4 British Waterways

The Haskins Report recognised that British Waterways plays an important role in sustainable management of the landscape. However, Haskins felt that, its specialised activities meant that it should remain a separate organisation, although it would need to work closely with both Natural England and the EA. This is an important observation, as not only does British Waterways own numerous boreholes, wells and reservoirs, in order to maintain water levels throughout the network of waterways in Great Britain, but it also supplies raw water to a number of water companies for subsequent public water supply purposes, and operates some major water transfer schemes for this latter purpose.

In order for it to discharge its navigational and commercial responsibilities, British Waterways has effectively created a number of artificial catchments, which cross-cut natural catchments. For example, all canals are artificial water bodies, whereas river navigations may be heavily modified water bodies, and these are sustained by actively managing its own aforementioned sources of water or from abstracting from pre-existing water bodies.

According to Section 66 of the Water Resources Act 1991, only British Waterways can apply for an abstraction licence for any inland water owned or managed by them (UK Government 1991e). British Waterways then transfers the right to abstract water to its customer by means of a commercial agreement. This means that, should its customer break any of the conditions contained within the abstraction licence, it is British Waterways that has committed a criminal offence, and not their customer. As British Waterways would be prohibited from passing any fines and/or costs associated with a successful criminal prosecution of them onto their customer, the only legal recourse British Waterways has is to pursue a civil prosecution against their customer. If British Waterways cancelled their agreement with the customer, and the customer continued to break any of the conditions, British Waterways would still be liable. Even if British Waterways handed their abstraction licence back to the EA for revocation, I was advised by the EA that they would still pursue a prosecution against British Waterways if their former customer continued to break any conditions, as British Waterways was the last known abstraction licence holder at the location that the criminal offence was occurring!

It is interesting to note that, in its commercial agreements, British Waterways does not guarantee either the quality or the quantity of water that water companies buy from them, which mirrors the lack of guarantees within abstraction licences issued by the EA. However, there is a major difference between the roles of British Waterways and the EA; the former body actively manages water levels within its waterway network, unlike the vast majority of the rest of watercourses, which are merely monitored by the latter body. I therefore presume that, although British Waterways may work with its water company customers in order for them to discharge their risk assessment obligations under the new drinking water regulations, it will not be undertaking catchment risk assessments on its customers' behalf (see Sections 10.23 and 10.24).

Nevertheless, because it obviously has an impact on the aquatic environment through its navigational and commercial responsibilities, and because it provides a number of water companies with strategic raw water supplies, this public corporation must engage with the debate on catchment management, and how it will help with the delivery of the requirements of the Water Framework Directive; it can only do this by working closely with the EA in England and Wales, and the Scottish Environment Protection Agency, and the three national environmental champions (the Countryside Council for Wales, Natural England and Scottish Natural Heritage).

5.11.5 Forestry Commission

In 2001 the National Assembly for Wales produced a document which set out its strategy for trees and woodlands in Wales. This document presents the Assembly's vision for forestry and woodland policy over the next 50 years and sets a direction for the way in which trees and woodlands will contribute to a sustainable future for the people of Wales. In order to achieve true sustainability, the strategy recognises that the physical and biological resources within forests – such as water – must be maintained or improved. The Assembly has therefore committed itself to using catchment management to develop the role that woodlands can play in the management of water and the reduction of flood risks (National Assembly for Wales 2001c). Now, some seven years later, the Welsh Assembly Government has still to put this policy statement into practice. Despite this, Forestry Commission Wales is not averse to working in partnership with EAW. Indeed, these two organisations have been working together on a project entitled the Severn Natural Assets Project with expenditure concentration in Hafren and Lake Vyrnwy forests. Amongst other objectives, this project aims to improve water quality within these forests (Forestry Commission Wales 2005b).

6 OTHER ENVIRONMENTAL STAKEHOLDERS

6.1 Introduction

As well as the Government departments (both central and devolved) and public bodies mentioned in the previous three Chapters, there are also a number of non-governmental organisations spanning England and Wales that, because of their activities, are interested in the management of our catchments and/or aquatic environments. Some of these organisations are only minor stakeholders (such as the Campaign for the Protection of Rural Wales), whilst others could be considered strategic environmental stakeholders, in that they actively strive to influence environmental policy and legislation in both England and Wales, particularly in relation to water and catchments; an overview of these latter organisations and the roles they play is given below.

6.2 Royal Society for the Protection of Birds

The Royal Society for the Protection of Birds is a charity working in all four parts of the UK to "secure a healthy environment for birds and wildlife" (Royal Society for the Protection of Birds 2006d). Without access to water of sufficient quality and quantity, birds and the foods they rely on would not survive. The RSPB therefore has a small but very active Water Policy Unit based at its head office in Bedfordshire.

Addressing diffuse pollution is one area of activity for the Unit, and it is working to persuade the Government to take "prompt and vigorous action to help farmers tackle this serious problem" (Royal Society for the Protection of Birds 2006b). In order to reduce the impacts from diffuse pollution, the RSPB believes that action will be required in five key areas:

- Farmers require better advice to help them manage the problem;
- Farm planning is required to locate and tackle individual problems;
- Smarter rules should be produced to tackle bad practice;
- Support for positive action to restore habitats is required; and

- Financial instruments (such as green taxes or levies) should be used, as these provide an incentive for the wise use of fertilisers, manures and pesticides.

The RSPB is a member of the Stakeholder Forum on Flooding, as it feels DEFRA's new strategy to deal with flood and coastal management in England and Wales "represents a huge opportunity to modernise the approach to managing rivers and coasts, in the light of new challenges, not least climate change" (Royal Society for the Protection of Birds 2006a). It is also involved with the implementation of the Water Act 2003 and the Water Framework Directive.

6.3 The Wildlife Trusts

The Wildlife Trusts consists of 47 local Wildlife Trusts across the UK, plus Alderney and the Isle of Man. It is the largest charity of its type exclusively dedicated to the conservation of habitats and species. Between them, the 47 local Trusts manage in excess of 2,200 nature reserves, covering over 80,000 hectares (The Wildlife Trusts 2006a).

Local wildlife sites can be designated by the individual Trusts, and they may from time to time also receive a delegated role from English Nature (Samuels et al. 2006)

The Wildlife Trusts participate in the Water for Wildlife partnership, working alongside water companies, the EA and other key stakeholders. The aim of the partnership is to coordinate the wetland work of the Trusts, to provide a more consistent and targeted approach to wetland conservation. The project manager of the partnership is based at the Derbyshire Wildlife Trust, but he works across the UK to support officers who are actively involved in partnership projects (The Wildlife Trusts 2006b)

6.4 National Trust

The National Trust is a charity independent of Government, and it works to protect the coastline, countryside and buildings of England, Wales and Northern Ireland (The National Trust 2006e). It owns and manages a largely rural estate of 245,000 hectares. In all, over 80 per cent of the land in the Trust's care is farmed (the vast majority by tenanted farmers – only in exceptional circumstances does the Trust farm in its own right), or depends upon farming to some degree, for its management (The National Trust 2006a, The National Trust 2006d). The National Trust has therefore developed an agriculture policy, which considers how its management of this large estate impacts on the environment (The National Trust 2006b); within this document, it encourages the responsible stewardship of water (The National Trust 2006c).

6.5 Soil Association

The Soil Association is the UK's leading organic organisation, and its work activities include (Soil Association 2006b):

- Setting standards to ensure the integrity of organic food and other products;
- Creating an informed body of opinion through education and information; and
- Working with Government and other stakeholders to improve the climate for organic agriculture (Soil Association 2006b).

Soil Association Certification Ltd (a fully owned trading company of the Soil Association) is the UK's largest organic certification body. It certifies and regularly inspects over 400 farms in Wales, all of them presenting the potential for pollution of watercourses, and many of which are in drinking water catchments. The standards set by the Soil Association Certification Ltd require good management to be demonstrated, particularly in the following areas for pollution prevention purposes (Soil Association 2006a):

- Maximum stocking rates are set per farm to limit the direct application of animal waste to pasture land;

- Proper storage of manure (both in the field and in purpose-built stores, the capacity of which has to be sufficient to contain the waste from winter housing of livestock);
- Composting is recommended to stabilise nutrients in the waste prior to its application to land; and
- Manure must only be applied to land during periods of active nutrient uptake and not within certain distances of watercourses (the weather conditions and the aspect of the land also have to be considered prior to the application taking place).

No dips of any kind can currently be used by organic farmers, so the risk of an associated chemical spill affecting groundwater or leaching into nearby watercourses is nil.

6.6 National Farmers' Union

The National Farmers' Union (NFU) was established in 1908, and is an independent, democratic trade association representing, and providing a voice for, the agricultural community (National Farmers' Union 2008c, National Farmers' Union 2008b). As the largest farming organisation in the UK, the mission of the NFU is to champion British farming (National Farmers' Union 2008c).

The NFU has an environment team that is responsible for the development and implementation of a range of environmental policy areas such as water and climate change (National Farmers' Union 2008a). This team has consequently been very active, for example, on Water Framework Directive and catchment sensitive farming issues. One of the team's more noteworthy outputs has been 'Waterwise on the Farm', which is a document produced in conjunction with DEFRA, the EA and the organisation Linking Environment and Farming, the purpose of which is to describe how farmers can implement a water management plan, in order to reduce consumption (and hence save money), waste, and the risk of causing water pollution (Environment Agency et al. 2007).

6.6.1 NFU Cymru

NFU Cymru is the Welsh arm of the NFU. The Welsh Council is the governing body of NFU Cymru, and it has "sole and total independent responsibility for the development of agricultural and rural policy in Wales" (NFU Cymru 2008).

6.6.2 Farmers' Union of Wales

The Farmers' Union of Wales is separate and completely independent from both the NFU and NFU Cymru. Established in 1955, it has one basic aim, which is to protect and advance the interests of those who derive an income from Welsh agriculture (Farmers' Union of Wales 2008).

6.7 Country Land & Business Association

The Country Land & Business Association was founded in 1907, and it is a membership organisation that describes itself as "the rural economy experts". Its members are owners of land, property and businesses in rural England and Wales.

Although it primarily offers its members professional advice relating to financial and planning matters, as its members' land management activities obviously have a variety of impacts on the environment, it also develops policies and lobbies Government on a number of environmental issues, including agri-environment schemes, water quality, water resources and climate change.

6.8 The Association of River Trusts

The Association of Rivers Trusts (ART) is an umbrella organisation established to represent the rivers trust movement in England and Wales (although it does have a single member in each of Scotland, Northern Ireland and the Republic of Ireland) (Association of Rivers Trusts 2008b, Association of Rivers Trusts 2008a). It works to support its members, emerging community groups and encourage partnerships with Government bodies and others to promote practical and sustainable solutions to environmental issues (Association of Rivers Trusts 2008a).

A River Trust is usually formed to implement solutions, and deliver improvements on the ground, once an environmental issue has been identified (such as the decline of an indicator species, or following a pollution event) (Association of Rivers Trusts 2008c). They are independent organisations, sometimes with charitable status, and are run by a board of trustees (Association of Rivers Trusts 2008c).

6.9 WWF

When WWF was first set up in 1961, the initials stood for World Wildlife Fund. In 1986, this was changed to World Wide Fund for Nature but, since 2000, the charity has simply been known by its initials (WWF-UK 2006a).

WWF is a global charity devoted to conserving endangered species, protecting threatened habitats and addressing global threats. It strives to find long-term solutions that benefit both people and nature (WWF-UK 2006d). The charity is very active in the freshwater arena, and it has a Global Freshwater Programme which has the following three themes (WWF-UK 2006b):

- Conserving river basins and eco-regions;
- Sustainable use of water; and
- Conserving freshwater habitats.

Within the UK, WWF has also recently developed a Natural Rivers Programme, which is "working towards a healthy freshwater environment, aiming to reduce pollution from agriculture, increase the use of natural flood management, and help people to use water more efficiently" (WWF-UK 2006c).

6.10 Chartered Institution for Water and Environmental Management

According to its website, the Chartered Institution of Water and Environmental Management (CIWEM) is the "leading professional and examining body for scientists, engineers, other environmental professionals, students and those committed to the sustainable management and development of water and the environment" (Chartered Institution of Water and Environmental Management 2006c). It is a charity based in the UK, but it has a worldwide presence.

CIWEM has the following aims and objectives (which are enshrined in its Royal Charter) (Chartered Institution of Water and Environmental Management 2006a):

- To advance the science and practice of water and environmental management for the public benefit;
- To promote education, training, study and research in the said science and practice for the public benefit and to publish the useful results of such research; and
- To establish and maintain for the public benefit appropriate standards of competence and conduct on the part of members of the Institution.

In the above context, 'water and environmental management' means the application of engineering, scientific or management knowledge and expertise to the provision of works and services designed to further the beneficial management, conservation and improvement of the environment, in particular in relation to (Chartered Institution of Water and Environmental Management 2006a):

- Environmental management systems;
- Resource protection, development, use and conservation;
- Integrated pollution control;
- Public health, water and sanitation services; and
- Flood defence and land drainage; and associated recreation, amenity and conservation activities.

6.11 Society for the Environment

The Society for the Environment was launched in October 2002 as the "Chartered Umbrella Body for the Environment" (otherwise referred to as CUBE), and it has brought together 12 Constituent Bodies (such as CIWEM) and one Associated Member Body. Each of these environmental institutions and learned societies will retain their unique identity and remain a centre of excellence within its field (Society for the Environment 2006c, Society for the Environment 2006a).

The Society's mission – as set out in its Charter – is "to promote the advancement of, the dissemination of, knowledge of, and education in good environmental practice for the public benefit" (Society for the Environment 2006b).

6.12 Discussion

There are a number of non-governmental organisations that are strategic environmental stakeholders, all of whom are actively involved, to varying degrees, with trying to shape environmental policy and legislation in both England and Wales, particularly in relation to water.

CIWEM organises a number of national and regional conferences, meetings and seminars each year, each of which has a particular environmental theme, and these non-governmental organisations – particularly the RSPB and WWF-UK – have been very prominent at them in highlighting their own initiatives and projects. For example, an overview of a catchment management project the RSPB has been intimately involved with is given in Section 12.9.5.3.

What has come across at these organised gatherings though is that there appears to be very little effective, and constructive, dialogue occurring between non-governmental organisations and other environmental stakeholders. It is relatively easy to criticise regulators and law-makers, but far more difficult and energy-intensive to engage with them and effect real change.

Although these organisations are obviously pursuing agendas that are sympathetic to their core aims and objectives, the environmental initiatives they are concerned with – such as catchment management – match pretty closely with the priorities of regulators and other bodies, including implementation of the Water Framework Directive.

Non-governmental organisations – along with the majority of other environmental stakeholders – are starting to become active and enthusiastic members of the Water Framework Directive stakeholder engagement process, which is to be applauded.

However, there are signs that the adversarial approach that has traditionally marred environmental politics is continuing amongst members of the River Basin Liaison Panels.

By definition, all stakeholders have a stake in their local environment and, as such, have a role to play with its management and protection. The time for this 'us and them' approach must draw to a close, with the focus instead being on constructive partnerships and effective working relationships. Perhaps the Water Framework Directive – along with its requisite stakeholder workshops and public forums – will provide a vehicle for the partnership approach that is sorely lacking within both England and Wales at the moment.

A number of non-governmental organisations have been working together in a coalition for some time now on water issues in a Water Framework Directive context (although regulators, Government departments and local authorities have been conspicuously absent from the coalition) – and its members include the RSPB, ART, National Trust, Wildlife Trusts and WWF-UK (Blueprint for Water 2008). In November 2006 the coalition launched a document entitled 'Blueprint for Water', setting out the following 10 steps it felt were required in order to achieve 'good' ecological status by 2015 (Blueprint for Water 2006):

- Reduce water consumption by at least 20% through more efficient use in homes, buildings and businesses;
- Amend or revoke those water abstraction licences that damage rivers, lakes and wetlands;
- Make household water bills reflect the amount of water people use;
- Ensure that those who damage the water environment bear the costs through more effective law enforcement and tougher penalties;
- Introduce targeted regulations to reduce harmful pollutants in water;
- Upgrade the sewage system to reduce discharges of sewage into urban environments and ecologically sensitive areas;
- Help farmers to prevent pollution and restore degraded soils, rivers and wetlands through advice, training and payments;

- Construct modern drainage systems that prevent pollution entering rivers from buildings and roads;
- Regenerate rivers, lakes and wetlands in partnership with local communities; and
- Restore large areas of wetland and floodplain to create vital wildlife habitats, improve water quality and quantity, and reduce urban flooding.

12 months after the publication of this document, the coalition produced its first annual review of progress relating to each of the above 10 steps; the overall impression arising from this review is that progress is very patchy, with a lot of areas requiring attention or urgent action (Blueprint for Water 2007).

7 CONCLUSIONS FROM PART 1

In Part 1 of this thesis I presented a review of the composition and structure of the UK water industry, with particular emphasis on England and Wales, including the various strategic governmental, regulatory, and non-governmental environmental stakeholders; where relevant, the significant relationships between these stakeholders have also been identified.

From this review I have drawn the following conclusions (for ease of reference the Section to which each conclusion relates is given is brackets):

1) Despite the four devolved areas of the UK having adopted different models for the regulators of their respective water industries, a common theme is that the regulation of water has been split to cover three main areas – environment, economic and drinking water quality (Section 2.4).

2) Consideration should be given by the devolved administrations to establishing an alternative to the current tripartite regulatory regime, to avoid stalemate occurring in discussions between the three regulators about priorities for each periodic review (Section 2.4).

3) Protection of catchments within Wales has arguably been weakened as a consequence of the Welsh Assembly Government's review of its departments since the May 2007 elections. There are now three governmental environmental stakeholders which may give rise to areas of conflict, particularly where limited budgets are concerned (Section 3.6).

4) The Welsh Assembly Government should use the primary legislative authority it has now acquired in the areas of planning and the water industry in order to meet its aim to manage run-off in urban areas, and also its aim to improve water infrastructure (Section 3.6.2).

5) Almost two years since the Environment Strategy for Wales was published, the Welsh Assembly Government should arguably have made much greater

progress in striving to meet the water-related aims than it actually has. It therefore appears appropriate for the Welsh Assembly Government to give consideration to introducing annual reviews of its progress towards realising the aims of its environment strategy (Section 3.6.2).

6) Contrast the position of the Welsh Assembly Government with that of DEFRA, as all relevant policy areas (with the notable exception of planning) relating to catchments is within DEFRA's remit. It would therefore appear that catchments within England are afforded slightly greater institutional protection than within Wales (Section 4.5).

7) DEFRA appears to have adopted a considerably more proactive approach to water policy and sustainable land management than the equivalent departments within the Welsh Assembly Government. In contrast, the Welsh Assembly Government has taken a more timid approach to catchment issues specifically, and environmental issues generally. It should therefore be encouraged to establish a separate Welsh identity for environmental policies and initiatives, bearing in mind the sufficient differences between the environmental needs of Wales and England (Section 4.5).

8) Leading on from the previous conclusion, the Welsh Assembly Government should issue more of its own consultations on environmental issues, rather than relying on joint consultations with DEFRA which are obviously not Wales-specific (Section 4.5).

9) In England, there are far too many regional strategies, initiatives, schemes and services. There should therefore be an urgent review and rationalisation to reduce confusion and potential areas of overlap and conflict, and to make the regional co-ordination of rural delivery more efficient (Section 4.5).

10) As a separate body of environmental law starts to emerge from the Welsh Assembly Government, the current role and remit of both the Environment Agency and the DWI may need to be critically examined, to determine whether separate, successor regulators are required in each of England and Wales, in

order to reflect the differing environmental priorities and political structures in the two devolved areas (Section 5.2 and Section 5.4).

11) A possible alternative regulatory model already exists in the form of the Forestry Commission; such a model could well be adapted to deliver both environmental and drinking water policy throughout Great Britain (or even the wider UK) (Section 5.9).

12) It would not be appropriate to establish separate successor economic regulators to Ofwat, as an 'Ofwat Wales' would not have sufficient comparators in order to be able to inform its decision-making process (Section 5.3).

13) An extension to the current AMP period of five years seems both prudent and overdue. Consequently, serious consideration should be given to at least extending the planning period to twelve years, with a mid-term review, which would better facilitate longer-term projects (Section 5.11.1.1).

14) There does appear to be a clear conflict between the EA's twin roles of regulator and environmental champion, so functions such as recreation, biodiversity, fisheries and ecological appraisal should be moved to either the Countryside Council for Wales, or Natural England, as appropriate, whilst its navigation duties should pass to British Waterways. This would remove the EA's environmental champion role, and would give rise to a streamlined, more focussed regulator, rather than the bloated organisation that currently exists with an expansive, and at times contradictory, remit (Section 5.11.2).

15) There is a lack of consistency across the EA's Regions and Area in its policies, procedures and enforcement (Section 5.11.2).

16) There should be a clearer separation of the policy duties of DEFRA from the enforcement and regulation duties of the EA (Section 5.11.2).

17) The recommendation made in the Hampton report that 31 national regulators are consolidated into seven, covering seven thematic areas, does not appear to

have been enacted, some three years after the report was published; neither does there appear to be any political will to progress this recommendation in the foreseeable future (Section 5.11).

18) Local authorities should ensure they are discharging their sampling obligations under the current regulations, in order to be able to establish a baseline for each private water supply in Wales (Section 5.11.3).

19) Urgent consideration should be given to removing local authorities' responsibility for the quality of private water supplies (either only in Wales, or in both England and Wales), and handing it over to the DWI. Environmental health departments could act as agents of the DWI with delegated responsibility within each local authority area by continuing to take samples, and by taking enforcement action as required, but the DWI could centrally coordinate such activities to ensure fairness and that the approach adopted by each local authority is consistent. The DWI would also be able to ensure all samples are analysed by suitably accredited laboratories, and subsequently publish the results in an anonymised national format (Section 5.2).

20) Because of its strategic role in supplying a number of water companies with raw water, British Waterways must work closely with other strategic environmental stakeholders in order to develop a framework catchment management policy (Section 5.8).

21) Catchments have numerous stakeholders on a variety of scales, ranging from the governmental, regulatory and charities, several of which appear to be pursuing their own agendas without much regard for more strategic policies or 'joined-up' thinking. Non-governmental organisations in particular must abandon their traditional adversarial approach to environmental policy, and focus instead on constructive partnerships and effective working relationships with other stakeholders (Section 6.12).

PART 2 A REVIEW OF EUROPEAN AND UK WATER LAW

8 EUROPEAN UNION LAW

8.1 Introduction

European Union law is to be found in the various treaties from which the European Union is derived, in numerous pieces of legislation passed by Community institutions, in international treaties to which the European Union is party and which become binding on Member States, and in the judgements and principles of the European Court of Justice (Sunkin et al. 1998).

The European Union comprises of three main bodies (Europa 2006c):

- The European Commission;
- The European Parliament; and
- The Council of the European Union.

This so-called institutional triangle produces the laws and policies that apply throughout the European Union; the Commission proposes new laws, and the Council and Parliament adopt them (Europa 2006c).

In addition to these institutions, there are a number of other bodies and agencies that have been established to perform specific, specialised roles, such as the European Investment Bank and the European Environment Agency.

8.1.1 The European Commission

This is the main executive body of the European Union. There are 27 Commissioners nominated by Member States who have a duty to be "completely independent" in the performance of their duties (in accordance with Article 10(2) of the 1967 Merger Treaty) i.e. they do not represent their own country's interests but must act in the general interests of the Union.

The Commission is divided into 18 policy Directorates-General (DG), six external relations DGs, five general services and 12 internal services. The Environment DG has specific responsibility for environmental matters; it is based largely in Brussels and has around 650 staff (Europa 2006b).

The role of the Commission within the European Union is crucial and indeed it has been described as the guardian of the treaties. It plays a major role in law-making by formulating proposals for legislation which are then passed to the Council, and it has wide enforcement powers to ensure Union law is not breached (Sunkin et al. 1998).

The Commission is also responsible for administering the finances of the European Union.

8.1.2 The European Parliament

The European Parliament is made up of 785 members who are directly elected by voters across the 27 Member States (European Parliament 2008). Originally, the Parliament's role was purely advisory. However, the powers of Parliament have gradually been extended by each revision of its founding Treaties, and it now is firmly established as a co-legislator with the Commission, meaning that it can accept, amend or reject the content of European legislation. It also exercises democratic controls over all European institutions and it has budgetary powers (European Parliament 2006b, European Parliament 2006a).

8.1.3 The Council of the European Union

The ministers of the Member States constitute the Council of the European Union, and it is usually the portfolio holder of the matter being considered that will attend (i.e. Member States' Environment Ministers will consider issues relating to the water environment). The presidency of the Council is currently held on a rotational basis, with each Member State holding the post for six months; the UK will next hold the post for the last six months of 2017 (The Council of the European Union 2006).

8.1.3.1 The European Union and the Environment

The original task of the EU as espoused by Article 2 of the Treaty of Rome was to "promote….a harmonious, development of economic activities, a continuous and balanced expansion, an increase in stability and accelerated raising of the standard of living and closer relations between the states belonging to it". The emphasis then was on the need to promote peace in Western Europe through economic co-operation and by raising the living standards of ordinary people. Environmental issues were not addressed by the Treaty and indeed the term 'environment' did not appear in it. It wasn't until the 1972 Declaration of Heads of State and Government that environment was firmly put on the European agenda, and common policies in various sectors of the economy, notably agriculture, fisheries, transport and energy were developed (Sunkin et al. 1998).

1973 saw the promulgation of what became the first of a series of Environmental Action Programmes. Although these programmes did not constitute a legal basis for EU law-making, they were important political declarations of intent.

8.1.4 European Legal Instruments

Article 189 of the Treaty of Rome lists three types of legal instrument which can be used by the EU for the implementation of environmental law; an overview of each is given in the following subsections.

An interesting aside is that, prior to the 1970s, most of the then European Economic Community's Directives (see Section 8.1.4.1) and Regulations (see Section 8.1.4.2) were derived from UK policy and law.

8.1.4.1 Directives

These are binding as the result to be achieved "but shall leave to the national authorities the choice of form and methods"; thus the Member States are given the choice of how to implement directives. In the UK, a directive could be implemented by means of secondary legislation made under section 2(3) of the European

Communities Act 1972 (UK Government 1972). Alternatively, delegated legislation may be made under other enabling legislation, or directives may be implemented by a new Act of Parliament. Perhaps the most important point to stress is that directives are not directly applicable and do require Member States to take implementing measures within a set period specified in the Directive. The bulk of EU environmental legislation takes the form of directives. Unlike regulations, which are not directly applicable in all Member States, Directives do not usually affect the national laws of Member States until actually implemented.

8.1.4.2 Regulations

A regulation is binding in its entirety and is directly applicable in all Member States. Not only do regulations take immediate effect in Member States without the need for enactment by national legislators, but they also take precedence over national law in the event of a conflict. It is relatively unusual for regulations to be used in an environmental context, but not unknown, for example, Regulation (EC) No 1907/2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (see Section 8.13).

Regulations have rarely been used in the development of environmental policy, although the eco-labelling scheme, eco-management and audit scheme and the European Environment Agency have all been established by regulations (Welford & Gouldson 1993).

8.1.4.3 Decisions

This is an instrument binding in its entirety, but only upon those to whom it is addressed. As they do not address general concerns, they are not commonly used in relation to environmental policy (Welford & Gouldson 1993).

8.2 Council Directive 75/440/EEC Concerning the Quality Required of Surface Water Intended for the Abstraction of Water in the Member States

There were several drivers for the adoption of this Directive by the European Community. It had noted that the increasing use of water resources for the abstraction of water for human consumption necessitated a reduction in the pollution of water and its protection against subsequent deterioration (European Community 1975). It also had decided that a Directive was necessary to protect public health and to exercise surveillance over surface water intended for the abstraction of drinking water and over the purification treatment of such water. All surface water used or intended for use in the abstraction and subsequent treatment in order to provide drinking water would be continually sampled, assessed against the prescribed limits and put into one of three categories; A1, A2 or A3:

- Category A1 – Water only requires simple physical treatment and disinfection, (for example, rapid filtration and disinfection);
- Category A2 – Water requires normal physical treatment, chemical treatment and disinfection (for example, pre-chlorination, coagulation, flocculation, decantation, filtration and disinfection); and
- Category A3 – Water requires intensive physical and chemical treatment, extended treatment and disinfection (for example, chlorination to break-point, coagulation, flocculation, decantation, filtration, adsorption (using activated carbon) and disinfection).

This is one of several Directives that will be eventually be repealed by the Water Framework Directive; in the case of this Directive, it will be repealed seven years after the Water Framework Directive came into force (Chave 2001). In its place, a more flexible approach to protection of sources of drinking water will be established by means of Article 7(3) of the Water Framework Directive, which states that "Member States shall ensure the necessary protection for the bodies of water identified [as being used for the abstraction of water for human consumption] with the aim of avoiding deterioration in their quality in order to reduce the level of purification treatment required in the production of drinking water … Member States may establish safeguard zones for those bodies of water" (European Union 2000).

8.3 Council Directive 76/160/EEC Concerning the Quality of Bathing Water

This Directive had the twin objectives of protecting the environment and public health by reducing the pollution of bathing water and to protect such water against further deterioration. Although generally assumed to relate only to coastal bathing areas, the Directive is also concerned with those fresh waters (both flowing and still, for example, rivers and lakes) where bathing is explicitly authorised by a Competent Authority and is practised by a large number of bathers. The European Community expected Members States to meet these objectives by laying down sampling frequencies and limits for certain physical, chemical and microbiological parameters (Sunkin et al. 1998, European Community 1976).

A revised and updated Bathing Water Directive was issued in 2006, taking into account the latest scientific and technical data, and linking it with the Urban Waste-Water Treatment Directive, the Nitrates Directive and the Water Framework Directive (European Union 2006a). Each Member State has until 23 March 2008 to bring into force any new national laws, regulations or administrative processes needed to comply with the revised Directive (Department for Environment Food and Rural Affairs 2008h); until this process is fully completed, the requirements of the 1976 Directive still have to be complied with.

8.4 Council Directive 76/464/EEC on Pollution Caused by Certain Dangerous Substances discharged into the Aquatic Environment of the Community

This is a Framework Directive aimed at eliminating or reducing the pollution of inland, coastal and territorial waters by particularly dangerous substances. It introduced the concept of list I and list II substances, which were listed in the Annex to the Directive. The purpose of the Directive is to eliminate pollution from list I substances and to reduce pollution from list II substances. In 1982, the Commission communicated a list to the Council that included 129 (subsequently increased to 132) "candidate list I substances". 18 of these substances have been regulated in the five following daughter Directives (Europa 2006a, Sunkin et al. 1998):

- The Mercury from the Choralkali Industry Directive (Council Directive 82/176/EEC) (European Community 1982);
- The Mercury from Other Sources Directive (Council Directive 84/156/EEC) (European Community 1984a);
- The Cadmium Directive (Council Directive 83/513/EEC) (European Community 1983);
- The Hexachlorocyclohexane (Lindane) Directive (Council Directive 84/491/EEC) (European Community 1984b);
- The Carbon Tetrachloride, DDT and Pentachlorophenol Directive (Council Directive 86/280/EEC) (European Community 1986); and
- The Aldrin etc Directive (Council Directive 88/347/EEC) (European Community 1988).

The regulation of other "candidate list I substances" was suspended in the beginning of the 1990s due to the preparation of a more comprehensive and integrated permitting system for industrial installations, which culminated in the adoption of the Integrated Pollution Prevention and Control Directive in 1996 (see Section 8.8). This directive also contained the emission limit values for the 18 list I substances covered by the daughter Directives as minimum requirements for large installations (Europa 2006a).

This Directive has been updated and codified as the Dangerous Substances Directive (2006/11/EC), and will be integrated with the Water Framework Directive (see Section 8.9) (Europa 2006a, European Union 2006b).

8.5 Council Directive 80/778/EEC Relating to the Quality of Water Intended for Human Consumption

This Directive is more commonly known as the Drinking Water Directive and was adopted by the Council of Ministers in July 1980. Provision for the transposition of the Directive was made in the Water Act 1989 (UK Government 1989a) (later consolidated into the Water Industry Act 1991 (UK Government 1991d)) and was incorporated into domestic law in 1989 by means of the Water Supply (Water

Quality) Regulations 1989 (as amended) (UK Government 1989c, UK Government 1989b, UK Government 1991f).

This Directive set standards for a range of microbiological, physical and chemical properties (called parameters) to be met in drinking water. In most cases the Directive stated the maximum admissible concentrations for these parameters (and, in a few cases, minimum required concentrations). It also stated the minimum frequency at which tests for each parameter must be carried out.

In November 1998 the council of Ministers adopted a revised drinking water Directive – Council Directive 98/83/EC on the quality of water intended for human consumption (European Union 1998) – that would substantially revised the original Directive. The new Directive was transposed into domestic law by the end of 2000, with most of the new standards having to be met by the end of 2003.

8.6 Council Directive 91/271/EEC Concerning Urban Waste Water Treatment

This Directive is concerned with the collection, treatment and discharge of urban waste water and the treatment and discharge of waste water from certain industrial sectors, with its objective being to protect the environment from the adverse effects of such waste water discharges (European Community 1991a). It sets a default standard of secondary treatment, with more stringent standards for sensitive areas; similarly, there is an option of installing primary treatment only in less sensitive areas. The criteria for the identification of Sensitive and Less Sensitive Areas are given in the following two sub-sections.

8.6.1 Sensitive Areas

A water body must be identified as a sensitive area if it falls into one of the following groups (European Community 1991a):

- Natural freshwater lakes, other freshwater bodies, estuaries and coastal waters which are found to be eutrophic or which in the near future may become eutrophic if protective action is not taken;
- Surface freshwaters intended for the abstraction of drinking water which could contain more than the concentration of nitrate laid down under the relevant provisions of the Surface Water Abstraction Directive; or
- Areas where further treatment than that prescribed within the Directive is necessary to fulfil the requirements of other European Directives.

8.6.2 Less Sensitive Areas

The Directive states that a marine water body or area can be identified as a less sensitive area if the discharge of waste water does not adversely affect the environment as a result of morphology, hydrology or specific hydraulic conditions which exist in that area.

8.7 Council Directive 91/676/EEC Concerning the Protection of Waters against Pollution Caused by Nitrates from Agricultural Sources

The primary source of nitrate pollution of groundwaters is from agriculture. This Directive was therefore adopted to tackle this problem by requiring Member States to designate vulnerable zones where (European Community 1991b):

- Inland waters or groundwaters intended to be used as drinking water sources are likely to contain more than 50mg/l of nitrate if protective action is not taken; and
- Inland or coastal waters are liable to suffer from eutrophication if protective action is not taken.

8.8 Council Directive 96/61/EC Concerning Integrated Pollution Prevention and Control

The Integrated Pollution Prevention and Control Directive has a wide scope, covering as it does emissions to land, air and water and, as such, it is described by the European Commission as being "one of the cornerstones of the European Union's environmental legislation" (European Commission 2007).

The Directive applies to many industrial activities, and it aims to prevent, reduce and eliminate pollution at source through the efficient use of natural resources and the establishment of an EU-wide integrated permitting system (European Commission 2007). It requires operators of prescribed installations to meet the following basic obligations (Sunkin et al. 1998, European Union 1996):

- To use energy efficiently;
- Not to cause significant pollution;
- To take all appropriate preventative measures against pollution, particularly applying the best available techniques; and
- To return the site of operation to a satisfactory state when the installation is decommissioned.

8.9 Directive 2000/60/EC Establishing a Framework for Community Action in the Field of Water Policy

The Water Framework Directive has been described as the most substantial piece of European water legislation to date (Department for Environment Food and Rural Affairs 2006l). Early European Directives were aimed at dealing with specific water issues, such as the quality of bathing waters. The Water Framework Directive takes a far more ambitious and innovative view of water management, as it adopts a holistic approach to the protection all types of water bodies – lakes, estuaries, rivers groundwaters and coastal waters – which will be managed within a river basin context; it is also the first Directive to link water quantity with water quality (Chave 2001).

Over time, a number of other Directives will be repealed, including the:

- Surface Water Abstraction Directive (European Community 1975);
- Freshwater Fish Directive (Council of the European Communities 1978);
- Shellfish Waters Directive (Council of the European Communities 1979);
- Groundwater Directive (European Community 1980a); and
- Dangerous Substances Directive (Council of the European Communities 1976).

The repeal of these Directives will not reduce the level of protection for the water environment, as there is an explicit requirement within the Water Framework Directive that the water environment must be afforded the same protection as it received under these earlier Directives (Environment Agency 2006u).

The Directive entered into force in 2000, and was required to be transposed into Member States' national law by the end of 2003, by which time River Basin Districts also had to be identified. Draft River Basin Management Plans have to be published in 2008, whilst the finalised versions (along with the associated Programmes of Measures to meet the various 'good' statuses) have to be published the following year.

8.10 Directive 2001/42/EC on the Assessment of the Effect of Certain Plans and Programmes on the Environment

This Directive (which is commonly referred to as the Strategic Environmental Assessment Directive) ensures that an environmental assessment is carried out of certain plans and programmes which are likely to have significant effects on the environment (European Union 2001). Member States were required to transpose the requirements of the Directive into domestic law before 21 July 2004; in Wales, the Directive was given effect by means of the Environmental Assessment of Plans and Programmes (Wales) Regulations 2004 (see Section 10.18).

The requirement for consultation is embedded within the Directive, and is required at various stages of the Strategic Environmental Assessment. As well as consulting with the public, there are a number of authorities designated as Consultation Bodies in the Regulations enacting the Directive in the four constituent parts of the UK. For Wales, these Bodies are:

- EAW;
- Countryside Council for Wales; and
- Cadw (the Welsh Assembly Government's historic environment division, which aims to protect the historic environment of Wales by working with partners and private owners (Cadw 2008b, Cadw 2008a)).

8.11 Directive 2004/35/CE on Environmental Liability with regard to the Prevention and Remedying of Environment Damage

The driver for this Directive was the European Union's concern over the dramatic acceleration of the loss of biodiversity over the last few years, and the "many contaminated sites in the Community" (European Union 2004). The objective of the Directive (commonly referred to as the Environmental Liability Directive) is to establish a common framework for the prevention and remedying of environmental damage, at a reasonable cost to society, and enshrines the "polluter pays" principle into European legislation (Department for Environment Food and Rural Affairs 2006d, Scottish Environment Protection Agency 2007).

The following definition of environmental damage (in a water context) has been adopted by the Directive:

"Water damage is any damage that significantly adversely affects the ecological, chemical and/or quantitative status and/or ecological potential of the waters [covered by the Water Framework Directive] concerned..."

(European Union 2004)

In the above context, the following definition of damage has been adopted:

"Damage means a measurable adverse change in a natural resource or measurable impairment of a natural resource service which may occur directly or indirectly."

(European Union 2004)

Member States were required to transpose the Directive into national law by 30 April 2007 (Environment Agency 2007c); the Directive is not retrospective, so it is only concerned with environmental damage that occurs after a Member State's transposition date (Department for Environment Food and Rural Affairs 2006d). Unfortunately though, transposition throughout the UK by the devolved administrations has been delayed, and is now expected to occur sometime during 2008 (Department for Environment Food and Rural Affairs 2007a; Department of the Environment Northern Ireland undated; Scottish Environment Protection Agency 2007a).

Not only is this Directive concerned with historic (but only back so far as 30 April 2007) and current pollution events, it also deals with an "imminent threat of damage", which has been defined as being a sufficient likelihood that environmental damage will occur in the near future. This empowers Competent Authorities (such as bodies including the EA and local authorities) to take pro-active action in order to prevent a pollution event occurring, instead of the more reactive stance these bodies have generally taken in the past.

Member States will be under a duty to ensure that the necessary preventive or restorative measures are actually taken. Member States can decide whether measures should be taken by (Environment Agency 2007c):

- The industrial polluter itself;
- The Competent Authorities; or
- A third party.

However, the industrial polluter may be able to take advantage of two exemptions from the costs of cleaning up the pollution, if the damage (Environment Agency 2007c):

- Is caused by pollution released within the terms of emission permits; or
- Occurred despite the use of best practice.

There are three levels of remediation that the Competent Authority can compel the industrial polluter to take. These are (Scottish Environment Protection Agency 2007):

- Primary remediation (to return the site to baseline condition);
- Complementary remediation (equivalent off-site measures where primary remediation does not return the site to baseline condition); and
- Compensatory remediation (to compensate for the 'interim loss' of natural resources and services pending recovery).

8.12 Directive 2006/118/EC on the Protection of Groundwater against Pollution and Deterioration

The first Groundwater Directive was adopted in 1980 and complemented the Dangerous Substances Directive which does not apply to discharges to groundwater. (European Community 1980a). It has since been repealed by Article 22 of the Water Framework Directive, and has been replaced by a so-called daughter Directive which, for the first time for groundwater, introduces quality objectives (WFD UK TAG 2008, European Union 2006c).

This new Directive establishes a regime which sets underground water quality standards and introduces measures to prevent or limit inputs of pollutants into groundwater and, as such, it complements the Water Framework Directive (European Commission 2008c).

8.13 Regulation on Registration, Evaluation, Authorization and Restriction of Chemicals

REACH is the new Regulation on Registration, Evaluation, Authorization and Restriction of Chemicals, and it entered into force on 1st June 2007 (European Union 2006d). It streamlines and improves the former legislative framework on chemicals of the European Union (European Commission 2008d).

The aim of REACH is to improve the protection of human health and the environment through better knowledge of the intrinsic properties of chemical substances. The European Commission estimates that around 30,000 chemical substances are produced in volumes of 1 tonne per year or more, and REACH will require these chemicals to be registered with a new EU Chemicals Agency by May 2018, albeit "high volume" chemicals must be registered by November 2010 (Hayes *et al.* 2008).

Registration involves the submission of data on properties, uses and safe handling. However, chemical substances used in food or medicinal products are excluded. Evaluation will include the scrutiny of proposals for animal testing to limit it to the absolute minimum and data sharing on such testing is compulsory. Use-specific authorisation will be required for chemicals that cause cancer, mutations or that accumulate in humans or the environment. If necessary, the European Commission can restrict the use of dangerous substances at the EU level (Hayes et al. 2008).

8.14 Discussion

Until 1987 the main environmental policy initiatives of the EC were based upon the application of almost 200 so-called 'command and control' Directives. Since then, when the EC recognised that environmental policy is of little use unless enforced, the focus has shifted to improved enforcement of existing Directives, rather than the rapid adoption of new Directives (Welford & Gouldson 1993). This shift has taken the form of a 'carrot and stick' approach, and has been typified by the parallel use of voluntary measures and economic instruments, alongside the more traditional application of 'command and control' Directives (Welford & Gouldson 1993).

Before critically reviewing some of these Directives, a curious anomaly in Europe's approach to the management of water is worth mentioning; under the Treaty of Nice, water quality proposals are agreed through the qualified majority voting system, whereas quantitative proposals relating to water are subject to unanimity (House of Lords 2006c).

8.14.1 Drinking Water Directive

Neither the original nor the revised Drinking Water Directive directly impacts on the quality of the source water; instead, compliance with the Directive has generally taken the form of 'end of pipe' solutions. However, given the increasing cost of water treatment, improving the quality of the source water is a more sustainable approach (Humphrey & Shepherd 2003).

According to the DWI, a third revision of the Drinking Water Directive is expected no earlier than 2009, and in their Information Letter 6/2004 it states that "the European Commission views Drinking Water Safety Plans as the way forward" for this next revision; this view is also shared by other UK water experts (Drinking Water Inspectorate 2004, Breach & Williams 2006). On the other hand, when a Head of Unit of the European Commission's Environment Directorate-General gave evidence to a House of Lords Select Committee in February 2006, he thought the review of the Directive would take place in 2008 (House of Lords 2006b).

8.14.2 Water Framework Directive

Before considering the Water Framework Directive in detail, it is worth noting that the whole emphasis of environmental directives over the past 25 years has been on quality and pollution control, whilst water quantity and security has tended to be neglected (Rouse 2007). Even though it is the first directive to link water quantity with water quality, there have been some concerns raised about the perceived imbalance in the importance attached to these two areas. For example, Kallis and Butler (2001) noted that quantitative aspects of water resources management are not explicitly targeted in the Directive; the underlying principle is that water quantity should be tackled to the extent that it affects water quality. In the same paper they also noted that critics in the European Parliament have publicly questioned "why the Commission should … make the issue of the quantity of water subordinate to qualitative aspects" (Kallis & Butler 2001).

A specific example of this perceived imbalance is the fact that neither flooding nor drought (perhaps the two most significant and potentially life-threatening quantitative aspects of water) are an explicit focus of the directive; instead, it will only contribute to mitigating the impacts of floods and droughts as an ancillary purpose, identified in Article 1 (Scottish Environment Link 2005). This apparent omission was perhaps one of the driving forces behind the new Floods Directive that came into force in November 2007 (European Commission 2008b).

Another significant omission from the Water Framework Directive is that it does not "does not explicitly mention risks posed by climate change to the achievement of its environment objectives", despite the timescale for the implementation process and achieving particular objectives extending into the 2020s (Wilby et al. 2006a). This has lead to calls to either the Directive being revised, or for the European Commission to consider a Climate Change Directive which will complement environmental initiatives such as the Water Framework Directive.

Despite the laudable spirit of the Directive, a number of problems have been identified during its protracted implementation phase. For example, the Directive states that "Member States shall protect, enhance and restore all bodies of water … with the aim of achieving good surface water status [by 2015]" (European Union 2000). NGOs and the general public tend to believe that the requirement is that all water bodies will achieve 'good' status by 2015, but there is a world of difference in the legal interpretation of "with the aim of achieving" and "will achieve", as a paper by Kallis and Butler (2001) explores.

In the case of "will achieve", Member States could be referred to the European Court of Justice if the status objectives weren't achieved by 2015, and ultimately handed down significant financial penalties. However, in the case of "with the aim of achieving", as long as Member States have produced River Basin Management Plans and implemented appropriate Programmes of Measures and monitoring programmes, failure to meet the status objectives by 2015 wouldn't constitute a liability if all other responsibilities were fulfilled (Kallis & Butler 2001).

Publicly, the EA, DEFRA and the Welsh Assembly Government all talk about achieving 'good' status by 2015. However, privately, it has been stated on several occasions that compliance with this requirement will be achieved over a number of

6-year cycles at least up to 2027, and most probably beyond then. If it is the case that compliance will not be achieved by 2015 – as appears increasingly likely – then the respective regulators and government departments should be sending out consistent messages, both publicly and in private, and ensuring that the expectations of other environmental stakeholders are realistically managed.

Another important element of the Directive is that of public participation, and it encourages all stakeholders to actively participate in water management activities, and should ensure that the whole process of achieving 'good' status is achieved transparently and efficiently (European Commission 2002). However, some concerns have been expressed about the current level of communication and co-operation between the various stakeholders and whether it is sufficient to ensure the Water Framework Directive is fully implemented. For example, CIRIA has called for closer collaborative working between the EA and land use planners (Samuels et al. 2006).

Another potential significant impact of the Directive is on a water company's ability to blend and treat different water sources. Article 7(3) states that:

> *"Member States shall ensure the necessary protection for the bodies of water identified [as being used for the abstraction of water for human consumption] with the aim of avoiding deterioration in their quality in order to reduce the level of purification treatment required in the production of drinking water. Member States may establish safeguard zones for those bodies of water."*
>
> (European Union 2000)

Research commissioned by UKWIR into the economic impact of groundwater quality problems on the water industry (which it described as "being the most comprehensive to date summarising the situation in the UK") noted that, even though the detailed requirements of this part of the Directive are still being discussed, it may result in restrictions being imposed on the use of blending and treatment by water utilities (Chilton et al. 2004). This requirement has been strictly interpreted by some that, in time, no treatment (other than disinfection to maintain a chlorine residual) or blending will be allowed.

For the purposes of the research, three scenarios were used in order to examine the financial implications of complying with this part of the Directive. Scenario C considered that no further blending or treatment would be permitted after AMP4 under the provisions of the Water Framework Directive, and this would lead to some 1,800Ml/day (35% of the total groundwater supplied) having to be replaced by 2027. As the report points out, most major aquifers are already fully committed, so other sources of water would need to be exploited, and it predicts the associated capital costs (for example, for new impounding reservoirs or desalination plants) would be in the region of £2 billion (Chilton et al. 2004). In light of this, one of the two recommendations of the report (the other being that the forecasted costs are revisited when more up-to-date data are available) is that its findings should be used to "guide the policy on the importance and significance of enhanced catchment protection and the needs of the Water Framework Directive" (Chilton et al. 2004).

Because of the importance of the Water Framework Directive, the House of Commons Environment, Food and Rural Affairs Select Committee in 2002 decided to hold an inquiry into the process and impact of implementing the Directive in the UK; the final report was published in March 2003 (House of Commons 2003a).

Throughout the course of the inquiry it became clear to the Committee that, although the Directive offered the potential of "enormous environmental and social benefits", it would "dramatically affect the ways in which farming, industries and others conduct their activities". It therefore recommended that the Directive needed much greater public promotion with all stakeholders, but specifically including the public and local authorities (House of Commons 2003a). In its formal response to the report, the Government agreed that greater public promotion was necessary, and mentioned the stakeholder communications group that had been established, along with the public participation strategy for the implementation of the Directive through River Basin Management Plans that the EA was developing (House of Commons 2003b).

The Committee was concerned about the lack of a comprehensive overview of the current ecological status of water bodies in England and Wales. Coupled with a lack of definition of 'good' status (and no information on the microbiological and physico-chemical parameters that would comprise 'good' status), it was difficult to see how properly informed decisions about the strategies and resources to implement the Directive could be made. Additional parameters than those currently being used to monitor water quality would be required, and a wider range of sources of pollution would have to be considered. The report therefore noted that the EA would have a "significant challenge ... to set evidence-based reference conditions" to achieve 'good' ecological status in water bodies (House of Commons 2003a).

In its formal response to the report produced by the Committee, the Government stated that "any changes in agricultural practice proposed in order to implement the ... Directive will clearly have to be proportionate and cost-effective". It anticipated that a range of policy instruments would be available – regulatory, voluntary, economic and advisory – which would be tailored to suit local circumstances within a River Basin Management District (House of Commons 2003b).

In order to address the above concerns, the Committee recommended that a scientific Steering Group be established, as a matter of urgency, to advise both DEFRA and the EA on the science surrounding the Water Framework Directive (House of Commons 2003a). However, the Government felt that the implementation of this recommendation would lead to unnecessary duplication, as the UK Technical Advisory Group[4] was addressing the issues raised in the Committee's report, and it therefore in effect constituted a scientific Steering Group (House of Commons 2003b).

The inquiry also reviewed the presumption that the EA would be designated as the sole competent authority required by the Directive. Concerns were expressed by those giving evidence that the Agency would not have sufficient resources, either financial or in terms of manpower. It was also pointed out that, such as in the cases of navigation and flood defence, the EA is both regulator and operator, so in certain

[4] The membership of the UK Technical Advisory Group comprises the national environment and conservation agencies of the UK, along with the Republic of Ireland's Department of Environment and local Government. It provides technical advice to, and receives policy advice from, the devolved administrations within the UK (UK Technical Advisory Group 2006).

instances it would effectively be regulating itself and conflicts of interest may well arise (House of Commons 2003a). The Government responded by saying, in its view, "such conflicts will not arise in practice" (House of Commons 2003b). This is of course nonsensical, and has already been discussed in Section 5.11.2.

In conclusion, relating to the administrative aspects of implementation of the Directive, the report noted that "there is a palpable lack of urgency – perhaps even a sense of complacency – in the approach currently taken" (House of Commons 2003a). Perhaps predictably, the Government did not agree with this observation. It stated that both DEFRA and the EA were both working with "all urgency" to progress all aspects of implementations, and that neither body was complacent about the work this entailed (House of Commons 2003b).

As has been reported elsewhere, the Committee also recommended that DEFRA, in association with Ofwat, consider whether the planning cycles for the River Basin Management Plans and the Periodic Reviews should be synchronised (House of Commons 2003a). Similarly, as has also been reported elsewhere, the Government replied that this a matter for Ofwat to address (House of Commons 2003b).

8.14.3 Strategic Environmental Assessment Directive

Of particular relevance to this thesis, is that article 3(2) of the Strategic Environmental Assessment Directive makes strategic environmental assessment mandatory for plans and programmes which are prepared for water management, such as River Basin Management Plans and Programmes of Measures (Office of the Deputy Prime Minister 2005). However, it was decided that the EA's Catchment Abstraction Management Strategies, Water Level Management Plans and Catchment Flood Management Plans were not covered by the Directive. This was the conclusion of a review the EA undertook during early 2004 of all its plans, programmes and strategies, in order to determine which ones would be subject to this Directive; it also sought advice from DEFRA and the Cabinet Office Legal Advisors (Environment Agency: Lucia Susani 2006).

It is difficult to understand the rationale of this decision. Catchment Abstraction Management Strategies, Water Level Management Plans and Catchment Flood Management Plans are all plans that the EA has prepared for the purposes of managing water resources, and yet the EA decided that they did not fall under the remit of the Directive. It could be argued that the first of these plans does not attempt to actively manage water resources, as its primary purpose is to assess the availability of water for abstraction after first considering the environmental needs of a particular area; as such, it is a passive management tool. However, the other two plans set out to actively influence, or even directly change, the management of water resources and, in some cases, the environment in which the water resources are found. Of the three, Catchment Flood Management Plans will play a significant role in protecting both the built and natural environments, and these have a much longer timescale than the Programmes of Measures – 25 years compared to six years – so to decide that this Directive applies to Programmes of Measures, but not Catchment Flood Management Plans, seems ludicrous.

The Strategic Environmental Assessment Directive does not prescribe who is to carry out a strategic environmental assessment, but normally it is the task of the Responsible Authority, i.e. the body which prepares and/or adopts the plan or programme (Office of the Deputy Prime Minister 2005); it is presumed therefore that the EA will be responsible for undertaking assessments of River Basin Management Plans.

In the previous section relating to the Water Framework Directive it was highlighted that the EA has the twin roles of regulator and operator, so in certain instances it would effectively be regulating itself and conflicts of interest may well arise. This issue may also arise in relation to the Strategic Environmental Assessment Directive, if the EA is indeed the Responsible Authority for its own River Basin Management Plans.

A paper produced by Carter and Howe explored the linkages between the Strategic Environmental Assessment Directive and the Water Framework Directive, and they concluded the following benefits could arise from the integrated implementation of the two Directives:

- Strengthening the content of RBMPs;
- Improving the quality and availability of baseline data;
- The advancement of integrated consultation and public participation procedures;
- The development of monitoring procedures; and
- Encouraging the sustainable management of water resources (Carter & Howe 2006).

8.14.4 Environmental Liability Directive

It is interesting that the Environmental Liability Directive states in its preamble that "environmental damage also includes damage caused by airborne elements, as far as they cause damage to water, land or protected species or natural habitats" (European Union 2004). However, air pollution is not within the scope of the Directive; it is only concerned with damage to land, water and biodiversity.

It is worth noting that a number of environmental liability regimes already exist in the UK and which provide for the remediation of environmental damage (Department for Environment Food and Rural Affairs 2006k). As far as water is concerned, the Water Resources Act 1991 (as amended by the Environment Act 1995) places the liability for pollution of controlled waters on anyone who "causes or knowingly permits" the pollution. In such an instance, the Act requires the waters are restored to their previous condition, "if reasonably practicable to do so"; either the person responsible for the pollution has to do this, or the EA (in England and Wales) can undertaken the remediation and recover the costs afterwards from those involved (Department for Environment Food and Rural Affairs 2006d).

The Directive takes an interesting – and pragmatic – stance on the issue of diffuse pollution, as it states "this Directive shall only apply to environmental damage or to an imminent threat of damage caused by pollution of a diffuse character, where it is possible to establish a causal link between the damage and the activities of individual operators". This means that, even though in agricultural Nitrate Vulnerable Zones it is generally accepted that farmers are responsible for the artificially elevated nitrate levels in groundwaters and surface waters, group action cannot be taken against the farmers concerned, unless a causal link has been established. It may therefore be viewed as not being cost beneficial to expend time and resources establishing a causal link; instead, agri-environmental schemes may be more prudent, in order to achieve the same environmental outcome.

9 THE CURRENT STATUTORY FRAMEWORK IN ENGLAND AND WALES

9.1 Introduction

In the following sub-sections a summary is given of the main Acts of Parliament that provide a statutory (or primary legislative) framework in relation to water, as produced by the UK Government at Westminster, and which extend to both England and Wales. At the time of writing (June 2008), the National Assembly for Wales has not produced any Assembly Measures relevant to this review, and neither have any been proposed.

9.2 Food and Environment Protection Act 1985

Although this Act does not contain any specific water-related provisions, it is still worth mentioning due to the provisions contained within Part III of the Act that relate to the regulation of pesticides and substances, preparations and organisms prepared or used for the control of pests or for protection against pests (UK Government 1985). The aims of these provisions include the protection of the health of human beings, creatures and plants, and to safeguard the environment. Section 17 of the Act also empowers the relevant Ministers to prepare and issue codes of practice for the purpose of providing practical guidance in respect of any provision of Part III of the Act or of any related regulations.

9.3 Water Act 1989

The Water Act 1989 paved the way for the privatisation of the water industry by providing for the dissolution of the water authorities and the establishment of their successors – the water companies – and two new regulators (UK Government 1989a). Prior to this Act, the water authorities were to a large extent, self regulating. Now, however, the economic regulation of the water companies would be exercised by the Director General of Water Services (see Section 5.3), and the responsibility for protecting the aquatic environment was vested in the NRA (see Section 5.4).

Section 52 of the Water Act 1989 (consolidated into section 68 of the Water Industry Act 1991) requires all water companies to provide "wholesome" water which is taken to mean that the water shall be safe and pleasant to drink. Section 53 of the Water Act 1989 (consolidated into sections 67 and 69 of the Water Industry Act 1991) enabled the Secretary of State to make regulations which prescribe the requirements for wholesomeness and set out the steps that water companies must take to comply with their duty under section 52 (now section 68). These regulations were known as the Water Supply (Water Quality) Regulations 1989 (as amended), until their enabling authority was repealed by the Water Act 2003 (see Section 10.14) (UK Government 1989c, UK Government 1989b, UK Government 1991f).

Large sections of this Act were repealed by subsequent legislation, mainly the Water Consolidation (Consequential Provisions) Act 1991 and, to a much lesser extent, the Water Act 2003 (UK Government 1991c, UK Government 2003c).

9.4 Environmental Protection Act 1990

This is a substantial Act, with many provisions for the protection of the aquatic, terrestrial and marine environments (UK Government 1990). Whilst it builds on previous legislation, at the time it was a "key piece of environmental legislation which [drew] together and [overhauled] the regulatory structures and requirements of environmental protection in the UK" (Welford & Gouldson 1993).

As far as it relates to water, it made provision for the improved control of pollution arising from certain industrial and other processes, and abolished the unifying Nature Conservancy Council and allowed for the creation of smaller, national councils (English Nature and the Countryside Council for Wales) to replace it.

Section 57 of the Environment Act 1995 inserted a new Part IIA into the Environmental Protection Act 1990, which relates to contaminated land (UK Government 1990). Local authorities are empowered to consider land to be contaminated if, by reason of substances in, on or under the land, significant pollution of controlled waters is being caused or there is a significant possibility of such pollution being caused. The Act states that the questions (a) what pollution of controlled waters is to be regarded as “significant”, and (b) whether the possibility of significant pollution of controlled waters being caused is “significant”, shall be determined in accordance with guidance issued for the purpose by the Secretary of State (UK Government 1990).

The Act goes on to define remediation as:

“The doing of any works, the carrying out of any operations or the taking of any steps in relation to any ... land or the water environment for the purpose of preventing or minimising, or remedying or mitigating the effects of, any significant harm, or any significant pollution of the water environment ... ; or of restoring the land or water environment to its former state.”

(UK Government 1990)

9.5 Water Industry Act 1991

The Water industry Act 1991 consolidated previous enactments relating to the supply of water and the provision of sewerage services (UK Government 1991d).

Sections 77-85 of the Act confer certain responsibilities on local authorities with respect to both public and private water supplies. In particular, section 77(1) states that “it shall be the duty of every local authority to take all such steps as they consider appropriate for keeping themselves informed about the wholesomeness and sufficiency of water supplies provided to premises in their area, including every private supply to any such premises”.

The establishment of the DWI (legally referred to as ‘technical assessors’ until this was formally changed to ‘Drinking Water Inspectorate’ by the Water Act 2003) was provided by section 86 of the Act (UK Government 2003c).

9.6 Water Resources Act 1991

The Water Resources Act 1991 consolidated enactments relating to the then NRA, and now the EA, and the matters in relation to which it exercises functions (UK Government 1991e).

Section 20 of the Act places a duty on the EA, as far as reasonably practicable, to enter into and maintain water resources management schemes with water companies for securing the proper management or operation of:

- The waters which are available to be used by water companies for the purposes of, or in connection with, the carrying out of their functions; and
- Any reservoirs, apparatus or works which belong to, are operated by, or are otherwise under the control of water companies for the purposes of, or in connection with, the carrying out of their functions.

The scope of this duty was later increased by the Water Act 2003 to cover holders of abstraction licences, other than water companies.

The principle of minimum acceptable flows was established by section 21 of the Act, whilst the principle of minimum acceptable levels or volumes of inland waters is established in section 23.

Chapter II of the Act places restrictions on abstraction and impounding, and prescribes a framework for applications, determinations and appeals. In particular, the Water Act 2003 inserted a new section 24A in this Chapter, creating the three different types of abstraction licence (see Section 9.9.1).

Chapter III relates to droughts, and the procedures relating to ordinary and emergency drought orders, and drought permits.

Part III relates to the control of pollution of water resources, and Chapter I of that Part establishes quality objectives for controlled waters. Section 82 allows for the Secretary of State to prescribe a system of classifying the quality of waters (according to criteria specified in regulations), relating to any description of controlled waters. Subordinate legislation arising from this section includes the:

- Surface Waters (Dangerous Substances) (Classification) Regulations 1992 (UK Government 1992c);
- Surface Waters (River Ecosystem) (Classification) Regulations 1994 (UK Government 1994b);
- Surface Waters (Abstraction for Drinking Water) (Classification) Regulations 1996 (UK Government 1996b);
- Surface Waters (Fishlife) (Classification) Regulations 1997 (UK Government 1997b);
- Surface Waters (Shellfish) (Classification) Regulations 1997 (UK Government 1997c);
- Surface Waters (Dangerous Substances) (Classification) Regulations 1997 (UK Government 1997a);
- Surface Waters (Dangerous Substances) (Classification) Regulations 1998 (UK Government 1998f); and
- Bathing Waters (Classification) (England) Regulations 2003 (UK Government 2003a).

Section 83 allows the Secretary of State to establish water quality objectives for the purpose of maintaining and improving the quality of controlled waters, depending on their intended use (Conlan et al. 2006), whilst Section 85 establishes the offence of causing or knowingly permitting any poisonous, noxious, or polluting matter or any solid waste matter to enter any controlled waters.

Chapter III relates to powers to control and prevent pollution, and covers nitrate sensitive areas, water protection zones and codes of good agricultural practice.

9.7 Environment Act 1995

This Act established the EA (see Section 5.4) and the Scottish Environment Protection Agency (UK Government 1995). It also made provision for contaminated land and abandoned mines, further provision for the National Parks, and further provision for the control of pollution.

At the time, one of the objectives of the new EA was truly ground-breaking, as its principal aim is to contribute "towards attaining the objective of achieving sustainable development".

Section 5 of the Act establishes for the EA general functions with respect to pollution control, "for the purpose of preventing or minimising, or remedying or mitigating the effects of, pollution of the environment". General provisions with respect to water are laid down in Section 6, including the general requirements to promote (UK Government 1995):

- The conservation and enhancement of the natural beauty and amenity of inland and coastal waters and of land associated with such waters;
- The conservation of flora and fauna which are dependent on an aquatic environment; and
- The use of such waters and land for recreational purposes.

The EA also has a duty to take all such action as it may from time to time consider to be necessary or expedient for the purpose of:

- Conserving, redistributing or otherwise augmenting water resources in England and Wales; and
- Securing the proper use of water resources in England and Wales (including the efficient use of those resources).

The Scottish Environment Protection Agency has a similar duty with respect to pollution control, but the language used for its duties regarding water is much weaker. It has a duty to promote the cleanliness of rivers, other inland waters and groundwaters in Scotland and the country's tidal waters; and a further duty to conserve so far as practicable the water resources of Scotland.

Section 66 of the Act places a duty on all National Park authorities to prepare and publish a National Park Management Plan. These authorities are also obliged to review their Plans at intervals no greater than five years.

9.8 Pollution Prevention and Control Act 1999

One of the main reasons for this Act was to transpose into UK law the requirements of the Integrated Pollution Prevent and Control Directive (see Section 8.8) (UK Government 1999b). It also regulates, otherwise than in pursuance of that directive, activities which are capable of causing any environmental pollution, and otherwise prevents or controls emissions capable of causing any such pollution. In the Act's definition of "environmental pollution", it refers to harm to the quality of water, amongst other receptors.

9.9 Water Act 2003

This is the most recent – and far-reaching – water addition to the statute book (UK Government 2003c). With certain exceptions, it applies to both England and Wales, and it has four broad aims (UK Government 2003d):

- The promotion of water conservation;
- A measured increase in competition;
- Strengthening the voice of consumers; and
- The sustainable use of water resources.

The main points of the Act relating to water resources and water quality are given in the following four sub-sections.

9.9.1 Changes to the Abstraction Licensing Regime

The changes detailed in the Act represent a significant overhaul of the abstraction licensing regime, which has remained broadly the same since its inception in the 1960s. Section 6 of the Act sets a default abstraction limit of 20 cubic metres in 24 hours (unless the abstraction is otherwise exempt), above which an abstraction licence is required. This simplifies the previous regime, and means that 20,000 abstractions that would have otherwise needed to be licensed are now exempt.

This default abstraction limit can be varied – either upwards or downwards – to reflect the water resources availability within a catchment; the EA can either apply to the Secretary of State, or the Secretary of State can direct it to make such an application, for an Order to vary this limit.

If an abstraction falls within the new regime, an abstractor will have to apply for one of three different types of abstraction licence:

- A temporary licence (where the abstraction occurs for less than 28 days);
- A transfer licence (for the abstraction of water from one source of supply, which is then transferred into another source of supply without any intervening use); or
- A full licence (for any abstraction lasting more than 28 days).

All pre-existing abstraction licences are deemed to be full licences for the purposes of the new regime (by virtue of Section 102(1)), even though some of them (such as those held by British Waterways for navigation purposes) only relate to abstractions that would require a transfer licence. There is no need for existing licences to be converted unless the licence holder wishes to do so (UK Government 2003d).

The last noteworthy point is that transfers of water from one inland water to another by a navigation, harbour or conservancy authority in the exercise of their functions were previously exempt; now, such authorities will have to apply for a transfer licence (with certain exemptions, such as for a reservoir that can only discharge to a canal), although they may wish to apply for a full licence (as this may afford them greater protection from derogation).

Historically, the holder of an abstraction licence has always been protected from civil action should their abstraction cause loss or damage to another person, as long as the licence holder was complying with the terms and conditions of the abstraction licence. Section 24 has now removed that protection.

For abstraction licence holders other than water companies, the EA now has the power to enter into arrangements with them for securing the proper management of the waters they use and the reservoirs and works under their control (UK Government 2003d).

9.9.2 Water Resources Management Plans

For some years now water companies have produced annual water resources plans for the EA on a voluntary basis; Section 62 now makes this a legal requirement, and re-names the plans 'water resources management plans'. The plans will be subject to annual review and revised once every five years, or in any case where the annual review indicates a material change in circumstances or the Secretary of State directs that a revised draft should be prepared (UK Government 2003d). Water companies must also publish and consult on the plans.

Where the EA thinks it appropriate, for the proper use of water resources, it can now (in consultation with Ofwat) propose that a water company enter into a bulk supply agreement with another water company.

9.9.3 Drought Plans

Water companies now also have a duty to produce drought plans, setting out how they will continue to meet their duties to supply adequate quantities of wholesome water during drought periods with as little recourse as possible to drought permits or drought orders. Drought plans must be revised every three years or if there is a material change in circumstances or the Secretary of State otherwise so directs (UK Government 2003d). As with water resources management plans, water companies much publish and consult on their drought plans.

9.9.4 Changes to the Regulation of the Water Industry

With effect from 1 April 2006, the Water Act 2003 abolished the office of the Director General of Water Services, and replaced it with the Water Services Regulation Authority (see Section 5.3).

Section 57 of the Act formalises the name of the DWI (see Section 5.2); in the Water Industry Act 1991, they were generically described as 'technical assessors'. The same section also allows for the Secretary of State to designate a Chief Inspector of Drinking Water, and for the National Assembly for Wales to designate a Chief Inspector of Drinking Water for Wales (UK Government 2003d). Where the same person is appointed to act in both capacities, that person will be known as the Chief Inspector of Drinking Water.

The maximum fine than can be imposed in a magistrates' court for contraventions of the Water Resources Act 1991, the Water Industry Act 1991 or the new Act has been increased from £5,000 to £20,000, in line with other environmental protection offences; if proceedings are brought in a Crown Court, the penalty on conviction would be an unlimited fine.

Prior to the Water Act 2003, enforcement of the provisions of the Reservoirs Act 1975 within England and Wales was the responsibility of some 140 local authorities. With the passing of the new Act, these enforcement functions are passed to the EA (Environment Agency 2006g, UK Government 1975).

9.9.5 Water Supply Licensing Regime

Section 56 and Schedule 4 of the Act makes provision for the licensing of water suppliers, other than the existing water companies, by inserting new sections into the Water Industry Act 1991.

Prospective suppliers can apply for either of the following (Ofwat 2005):

- A retail licence – This is a water supply licence that authorises the holder to use a water company's supply system for the purpose of supplying water to the premises of its customers (the 'retail authorisation'). A retail licence therefore permits the supplier to purchase a wholesale supply of water from the water company and to retail it to customers at eligible premises.

- A combined licence – This is a water supply licence that gives the holder a 'supplementary authorisation' in addition to the retail authorisation. The supplementary authorisation allows the holder to introduce water into a water company's supply system, in order to support subsequent sales of water to customers at eligible premises.

9.9.6 Water Conservation and Efficient Use of Water

The Environment Act 1995 places a general duty on the EA to secure the proper use of water resources in England and Wales. Section 72 of the new Water Act makes clear that this includes a duty to secure the efficient use of those water resources (UK Government 2003d).

Existing discretionary measures relating to the conservation of water have been formalised by Sections 81 to 83 of the Act. Both the Secretary of State and the Welsh Assembly Government have a new duty to take appropriate steps to encourage water conservation and report to Parliament and the National Assembly for Wales respectively on progress every three years. Water companies have also been given a duty to further water conservation. Finally, a water conservation duty has been placed on all public authorities, which applies to both their actual use of water and where their functions might have an impact on water use (UK Government 2003d).

9.9.7 Pollution of Controlled Waters

For some years the Coal Authority has been running a programme to prevent discharges of water from abandoned mines polluting the environment, and for cleaning-up pollution that has already occurred. Section 85 of the Act now provides a statutory basis for this programme, and provides the Coal Authority with powers to prevent and control water emanating from abandoned coal mines which it is responsible for, onto land or any controlled waters.

Section 86 of the Act refines the definition of 'contaminated land' in Section 78A of the Environmental Protection Act 1990 so that it applies only where significant pollution of controlled waters is being caused, or where such pollution is likely to occur (UK Government 2003d).

9.10 Civil Contingencies Act 2004

Disruption of a supply of water is specifically mentioned in this Act regarding civil contingencies (UK Government 2004a). The Act also relates to an event or situation which threatens serious damage to the environment, which is defined as contamination of land, water or air with biological, chemical or radioactive matter, or disruption or destruction of plant life or animal life.

Under section 21 of the Act (section 32 in relation to Scottish Water), water companies are treated as Category 2 responders, and as such must:

a) From time to time assess the risk of an emergency occurring,
b) … assess the risk of an emergency making it necessary or expedient for the company to perform any of its functions;
c) Maintain plans for the purpose of ensuring, so far as is reasonably practicable, that if an emergency occurs the company is able to continue to perform its functions; and
d) Maintain plans for the purpose of ensuring that if an emergency plan occurs or is likely to occur the company is able to perform its functions for the purpose of –
    i. Preventing the emergency;
    ii. Reducing, controlling or mitigating its effects, or
    iii. Taking other action in connection with it…

9.10.1 The Security and Emergency Measures (Water and Sewerage Undertakers) Direction 1998

The Security and Emergency Measures (Water and Sewerage Undertakers) Direction 1998 predates the Civil Contingencies Act 2004; its enabling authority is Section 208 of the Water Industry Act 1991 (UK Government 1998e). It places a duty on water companies to make, keep under review and revise as necessary plans to ensure the provision of essential water supply and sewerage services. In particular, it prescribes that water companies must supply a legally enforceable quantity of drinking water of a minimum amount of 10 litres of drinking water per person per day, even in a major calamity (Department of the Environment Food and Rural Affairs 2005d).

Ordinarily this quantity of water should be delivered by means of a piped supply, but if this has failed unavoidably, any one or more suitable alternative means may be utilised, such as bowsers, tanks and bottled water, as long as the quality of water is ensured to be at all times wholesome at the point of supply (with boil notices being issued if necessary) (Department for Environment Food and Rural Affairs 2004b).

9.11 Discussion

This Chapter has given an overview of the current statutory framework in England and Wales, with specific reference to both water quality and water resources issues. Of all the relevant Acts of Parliament reviewed, probably the most important substantial, and significant, is the Water Act 2003, as it has a number of wide-ranging impacts on water resources issues. As far as water quality is concerned, the most important piece of primary legislation in this area is the Water Resources Act 1991, which provides controls for abstractions, discharges and the establishing of water quality objectives.

An interesting provision – from a catchment management point of view – is made in section 83(2) of the Water Industry Act 1991, which gives a local authority power "to acquire (compulsorily or otherwise) any land or right over land for the purpose of ensuring that private supplies of water to premises in their area are both wholesome and … sufficient for domestic purposes …" (UK Government 1991d). I am unable to confirm though whether any local authority in Wales has exercised this right.

10 THE CURRENT REGULATORY FRAMEWORK IN ENGLAND AND WALES

10.1 Introduction

The following sub-sections provide a summary of the main regulations relating to water, produced by both the UK Government at Westminster and the Welsh Assembly Government. Unless specifically mentioned otherwise, each set of Regulations apply equally to both England and Wales.

This regulatory (or secondary legislative) framework was constructed under powers conferred on the Relevant Secretary of State and/or the Welsh Assembly Government by Acts of Parliament. These powers were either derived from specific Acts of Parliament (and the significant water-related ones were mentioned in the previous Chapter), or from the European Communities Act 1972 (which has been used to transpose a number of European Directives directly into secondary legislation, as it was felt in these instances a specific Act of Parliament was not required) (UK Government 1972).

10.2 Water Resources (Succession to Licences) Regulations 1969

The main focus of these regulations is to deal with the rights of successors to original holders of abstraction licences or Licences of Right, and detail the procedures for handling such successions. The original enabling authority for these regulations was the Water Resources Act 1963, but since the consolidation of this Act these regulations now have effect as if made under the Water Resources Act 1991 (UK Government 1969, UK Government 1963, UK Government 1965).

10.3 Surface Waters (Dangerous Substances) (Classification) Regulations 1989

These regulations (along with a number of amendment regulations) prescribe a classification system for inland and territorial waters, based on the concentration of certain dangerous substances within them (UK Government 1989b; UK Government 1992b; UK Government 1997b; UK Government 1998g).

10.4 Private Water Supplies Regulations 1991

Any water supplied to any premises from a private supply (i.e. other than from a water company) has to comply with the water quality standards laid down in the Private Water Supplies Regulations 1991, as provided for by the Water Industry Act 1991 (UK Government 1991b, UK Government 1991d). In common with the separate regulations relating to the wholesomeness of water supplied by water companies, these regulations cover water used for drinking, washing, cooking or for food production purposes.

The regulations also set out the requirements of local authorities for monitoring the quality of private supplies within their area, the frequency of sampling required for different categories of supplies, and their enforcement powers.

10.5 Nitrate Sensitive Areas Regulations 1994

Nitrate Sensitive Areas are established by these regulations, which also prescribe the qualifying conditions for land and farmers in order for aid to be provided, and the conditions associated with such aid (UK Government 1994a). These regulations have subsequently been subject to a number of administrative amendments (UK Government 1995b; UK Government 1996a; UK Government 1997a; UK Government 1998d; UK Government 2002a).

10.6 Urban Waste Water Treatment (England and Wales) Regulations 1994

The transposition of the Urban Waste Water Treatment Directive (see Section 8.6) into domestic law is effected by these regulations (UK Government 1994c). They establish Sensitive Areas and High Natural Dispersion Areas, and place certain obligations on water companies with respect to minimum levels of treatment of their discharges, based on 'population equivalents'[5].

The regulations also phased out the dumping of sewage sludge from ships to surface waters by 31 December 1998.

10.7 Surface Waters (Abstraction for Drinking Water) (Classification) Regulations 1996

The purpose of these regulations is to establish a classification for inland freshwaters by reference to their suitability for abstraction for supply as drinking water (UK Government 1996b). They prescribe limits for a set of parameters for each class (called DW1, DW2 and DW3), as well as sampling frequencies and methods of analysis. As such, they therefore implement the requirements of the Surface Water Abstraction Direction (see Section 8.2) and Directive 79/869/EEC relating to methods of measurement and frequency of sampling and analysis of such waters (European Community 1979).

10.8 Protection of Water against Agricultural Nitrate Pollution (England and Wales) Regulations 1996

These regulations transposed the requirements of the Nitrates Directive (see Section 8.7) into domestic law (UK Government 1996a). They establish Nitrate Vulnerable Zones – and provide for them to be monitored, reviewed and revised as appropriate periodically – along with their requisite action programmes.

---

[5] 'Population equivalent' is a measurement of organic biodegradable load, and a population equivalent of 1 (1pe) is the organic biodegradable load having a five-day biochemical oxygen demand (BOD5) of 60g of oxygen per day (the load shall be calculated on the basis of the maximum average weekly load entering the treatment plant during the year, excluding unusual situations such as those due to heavy rain) (UK Government 1994c).

A number of administrative and procedural changes were introduced – only in relation to Wales – by means of the Protection of Water Against Agricultural Nitrate Pollution (Amendment) (Wales) Regulations 2002 (UK Government 2002). These amendment regulations also make further provision relating to the implementation of the Nitrates Directive, and they include additional areas as Nitrate Vulnerable Zones.

The 1996 regulations were further amended by the Protection of Water Against Agricultural Nitrate Pollution (England and Wales) (Amendment) Regulations 2006 (UK Government 2006d), in order to effect, in part, the public participation requirements of the Strategic Environmental Assessment Directive (see Section 8.10).

10.9 Groundwater Regulations 1998

The Groundwater Regulations extend to England, Wales and Scotland, and they transposed into domestic law the outstanding requirements of the 1980 Groundwater Directive (European Community 1980a). The regulations place an obligation on the EA, the Scottish Environment Protection Agency and the appropriate Secretary of State to use the additional powers provided by these regulations – along with pre-existing powers provided by other statutes – to prevent the direct or indirect discharge of List I substances to groundwater and to control pollution resulting from the direct or indirect discharge of List II substances (UK Government 1998c).

The regulations also impose a new requirement for anyone wishing to dispose of a List I or a List II substance to apply for an authorisation for its disposal (subject to certain exceptions).

10.10 Action Programme for Nitrate Vulnerable Zones (England and Wales) Regulations 1998

The Protection of Water Against Agricultural Nitrate Pollution (England and Wales) Regulations 1996 designated Nitrate Vulnerable Zones; these 1998 Regulations established an action programme for those Zones (UK Government 1998a). The regulations were subject to some administrative changes in the amendment regulations produced in 2003 (National Assembly for Wales 2003a).

10.11 Water Supply (Water Fittings) Regulations 1999

Prior to 1 January 1999, each water company had their own set of byelaws governing the prevention of waste, misuse, undue consumption and contamination of public water supplies in domestic and commercial plumbing installations (Department of the Environment Transport and the Regions 1999). On that date the byelaws were replaced by the Water Supply (Water Fittings) Regulations 1999 (UK Government 1999e). These regulations are not retrospective, so they do not apply to water fittings that were installed earlier than 1 January 1999.

The water companies have a duty to enforce these regulations; this duty is enforced by either the Welsh Assembly Government or the Secretary of State (as appropriate), or Ofwat.

A number of defects in the original regulations were corrected later in the same year by the Water Supply (Water Fittings) (Amendment) Regulations 1999 (UK Government 1999d).

10.12 Land in Care Scheme (Tir Gofal) (Wales) Regulations 1999

The Tir Gofal agri-environment scheme (see Section 12.9.6.1) – which relates to agricultural production methods that help with the protection of the environment and the maintenance of the countryside – is established by these regulations (UK Government 1999a). The scheme is managed by the Welsh Assembly Government, and applies only to Wales.

Amongst the general environmental conditions the scheme imposes are the requirements that water features (defined as areas of open water including ponds, lakes, streams and ditches) shall be protected and that fertilizers, limes and pesticides shall not be applied to a strip of land one metre wide adjacent to the banks of such features. The prior approval of the Welsh Assembly Government is also required for a number of activities, including:

- Realigning, damming or dredging watercourses or altering the water level of a water feature; and
- Creating new water abstraction points or increasing existing levels of abstraction from established water abstraction points.

Certain minor, administrative changes to these Regulations were effected by the Tir Gofal and Organic Farming (Amendment) (Wales) Regulations 1999 (UK Government 1999c). Further Regulations – the Tir Gofal (Amendment) (Wales) Regulations 2001 – were produced to update references to European legislation contained in the 1999 Regulations, as a result of certain European legislation being amended and replaced (National Assembly for Wales 2001a).

10.13 Water Supply (Water Quality) Regulations 2000

These regulations revoked the previous Water Supply (Water Quality) Regulations 1989 (as amended) with effect from 1 January 2004 (UK Government 1989b; UK Government 1989c; UK Government 2000; UK Government 2001); they generally apply only to water companies whose area is situated wholly or mainly in England, as a similar set of regulations apply to Wales (National Assembly for Wales 2001b) (see Section 10.14). They are primarily concerned with the quality of water supplied by water companies who are wholly or mainly in Wales for drinking, washing, cooking and food preparation, and for food production, and with arrangements for the publication of information about water quality.

The scope of the water quality limits have been extended to specify a point of monitoring (such as a consumer's tap, service reservoir, supply point etc), and a new class of indicator parameters has been established. The sampling requirements haves also been strengthened, as Regulation 5 defines two monitoring regimes – 'audit' monitoring and 'check' monitoring.

Section 38 of the regulations makes provision for local authorities to "… take, or cause to be taken, and analyse, or cause to be analysed … such samples of the water supplied to premises in their area as they may reasonably require".

The relevant local authorities (along with the relevant health authorities) must also be notified by the water company of any event which has, or is likely to, adversely affect the quality of the public water supply and which has caused, or is likely to cause, a significant risk to the health of persons living within the area of those local authorities.

For largely administrative reasons and to correct some errors, these regulations were subsequently amended in 2001 (UK Government 2001, Department for Environment Food and Rural Affairs 2007a).

10.14 Water Supply (Water Quality) Regulations 2001

These regulations are generally the Welsh equivalent of the Water Supply (Water Quality) Regulations 2000 for England, and were made by the National Assembly for Wales (National Assembly for Wales 2001b).

10.15 Water Resources (Environmental Impact Assessment) (England and Wales) Regulations 2003

The implementation of the Assessment of the Effects of Certain Private and Public Projects on the Environment Directive (see Section 8.10) is completed, in relation to water management projects for agriculture in England and Wales, by the issue of these regulations (UK Government 2003g). In these regulations the procedure for determining whether a water management project requires an environmental impact assessment (EIA) is laid out, along with the procedure for undertaking such an EIA and the information it should contain. The powers of the EA and the Secretary of State, in relation to water management projects where an EIA is required, are established, as well as an appeals procedure.

10.16 Water Environment (Water Framework Directive) (England and Wales) Regulations 2003

The Water Framework Directive (see Section 8.9) is transposed into domestic law by means of these regulations (UK Government 2003e). River Basin Districts are established by Regulation 4, and detailed monitoring and analysis requirements for each District are imposed on the EA. The EA is also given the responsibility for proposing environmental objectives and Programmes of Measures for each District. Finally, the regulations deal with the production of River Basin Management Plans by the EA, including the level and extent of public participation.

10.17 Water Environment (Water Framework Directive) (Northumbria River Basin District) Regulations 2003

The Northumbria River Basin District straddles the border between England and Scotland. These regulations therefore adapt and apply the Water Environment (Water Framework Directive) (England and Wales) Regulations 2003 and the Water Environment and Water Services (Scotland) Act 2003 in relation to the District to ensure the requirements of the directive are met for the District as a whole (UK Government 2003f, Scottish Parliament 2003).

10.18 Environmental Assessment of Plans and Programmes (Wales) Regulations 2004

The sole purpose of these regulations is to transpose the requirements of the Strategic Environmental Assessment Directive (see Section 8.10) into domestic law, as regards plans and programmes relating solely to Wales (National Assembly for Wales 2004a). For plans and programmes which relate both to Wales and another part of the UK, they are covered by another set of regulations – the Environmental Assessment of Plans and Programmes Regulations 2004 (UK Government 2004b).

10.19 Drought Plan Regulations 2005

These regulations were made jointly by the National Assembly for Wales and the Secretary of State, and apply to all water companies in England and Wales (UK Government 2005a). They place an obligation on the water companies to prepare and maintain a drought plan, in accordance with the provisions of the Water Act 2003 (see Section 9.9.3).

The regulations prescribe the method of publication of a draft drought plan, how water companies deal with representations made in relation to such drafts, the procedure for an inquiry or another hearing, and the method of publication of the completed drought plan.

10.20 Water Resources (Abstraction and Impounding) Regulations 2006

These regulations contain provisions relating to the licensing of abstraction and impounding of water in the light of amendments made by the Water Act 2003 to the Water Resources Act 1991 (UK Government 2006e, UK Government 2003c, UK Government 1991e). They detail the numerous procedural, administrative and information requirements of the new regimes for applications for abstraction licences and impounding licences, and for transfers of, changes to, or apportionment of, existing licences.

10.21 Water Resources (Environmental Impact Assessment) (England and Wales) (Amendment) Regulations 2006

The requirements of the 1997 Environmental Impact Assessment Directive (which amended the 1985 Environmental Impact Assessment Directive) were transposed into domestic law by means of these regulations, which relate to water management projects for agriculture (European Union 1997, European Community 1985).

The regulations impose procedural requirements in relation to the consideration of applications or proposals for an abstraction or impounding licence. Specifically, Regulation 3 requires an EIA to be carried out for agricultural water management projects (including irrigation projects) which would be likely to have significant effects on the environment by virtue inter alia of their nature, size or location (UK Government 2006f).

10.22 Tir Cynnal (Wales) Regulations 2006

These regulations provide for various grant payments to be made to any person who takes part in the Tir Cynnal agri-environment scheme (see Section 12.9.6.1) administered by the Welsh Assembly Government (National Assembly for Wales 2006b).

The Tir Cynnal scheme aims to provide opportunities for farmers in Wales to take part in work of an agri-environment nature on their land by following a basic set of conditions in order to protect areas and features of environmental importance on their land. The scheme requires levels of environmental protection greater than that of other regulatory requirements, but not as demanding as those of Tir Gofal (National Assembly for Wales 2006b).

The aim of the Tir Cynnal scheme is to prevent loss of biodiversity, protect landscape features, safeguard the historic environment and reduce pollution, which is principally achieved by the development of a Resource Management Plan; this Plan provides the farmer with a structured approach for identifying the risks to soil, water and air so that these resources may be protected and improved (National Assembly for Wales 2006b, Welsh Assembly Government 2006e).

10.23 The Water Supply (Water Quality) Regulations 2000 (Amendment) Regulations 2007

Partially as a result of the cryptosporidiosis outbreak in North West Wales in 2005 (see Section 19.5) the Water Supply (Water Quality) Regulations 2000 (which relate only to England) were amended in 2007 (UK Government 2007d). Some of the main features of the amending regulations include (Department for Environment Food and Rural Affairs 2007a):

- A new requirement for water companies and licensed water suppliers to monitor their raw water sources (in reality all water companies voluntarily sampled water to be used for public water supply prior to the treatment stage, but this activity has now been formalised and made a legal requirement);
- Replacing the existing requirements for risk assessments, monitoring and treatment for *Cryptosporidium* with more general provisions for treatment works and supply systems that address all risks to human health;
- Replacing some existing offences that related to solely to *Cryptosporidium* with more general offences relating to the provision of adequate water treatment and disinfection; and
- Reducing the level of administrative burden on water companies and licensed water suppliers by replacing some of their obligations to publish information in hard copy format with obligations to make available information for public inspection on request and to publish information on the internet.

The regulations also introduce the Water Framework Directive concept of Drinking Water Protected Areas and its requirements.

The 2000 regulations required water companies to carry out a risk assessment for *Cryptosporidium* at each of their water treatment works to establish whether there is a significant risk of *Cryptosporidium* being present in the water leaving the treatment works. This requirement has now been extended to cover all potential dangers to human health. Water companies now have to undertake and document a single comprehensive risk assessment for the treatment and distribution parts of each water supply chain embracing all hazards (Department for Environment Food and Rural Affairs 2006b).

All such risk assessments must be completed by 1 October 2008, and as soon as reasonably practicable thereafter each water company must submit a report to the Secretary of State for Food, Environment and Rural Affairs (or in the case of water companies wholly or mainly within Wales, the Welsh Assembly Government), which in both instances probably means the DWI; each report has to include a description of the risk assessment methodology, a full explanation of any potential dangers that have been identified, and specific measures the water company has made, or will make, to mitigate the risk (UK Government 2007d).

10.24 The Water Supply (Water Quality) Regulations 2001 (Amendment) Regulations 2007

These regulations are generally the Welsh equivalent of the Water Supply (Water Quality) Regulations 2000 (Amendment) Regulations 2007 for England, and which were amended at the same time as those Regulations by means of a joint consultation by DEFRA and the Welsh Assembly Government (Welsh Assembly Government 2007, Department for Environment Food and Rural Affairs 2006b).

10.25 Water Resources Management Plan Regulations 2007

These regulations prescribe how water companies should prepare and publish their draft water resources management plans (UK Government 2007c).

10.26 Discussion

This Chapter has given an overview of the current regulatory framework in England and Wales, with specific reference to both water quality and water resources issues. What is obvious from this is that there has been a proliferation of water-related regulations in recent years, the vast majority of which only focus on a small part of the water environment, and generally have been produced reactively to address specific environmental problems and, in a number of cases, to transpose European Directives into national legislation. As such, none of the regulations reviewed (with two notable exceptions) can be interpreted as taking a holistic approach to catchment management.

The two notable exceptions are the regulations produced to give effect to the two main agri-environment schemes in Wales – Tir Gofal and Tir Cynnal. Although targeted specifically at members of the agricultural community, they are quite wide-ranging in their approach to protection of the natural environment using land management tools. These regulations, in my view, are therefore the closest we have, in either England or Wales, to holistic protection of the natural environment, albeit at a sub-catchment level.

It could be inferred that this proliferation of water-related regulations has actually had an detrimental impact on the environment, as "rapid regulatory changes do not always lead to rapid environmental improvement" (Wescoat & White 2003). Indeed, Wescoat and White (2003) espouse the view that "proliferation of environmental and water resources laws, regulations and policies can actually constrain progress, as when different jurisdictions pass water laws that conflict with or encumber action".

Of all the regulations reviewed, perhaps the Water Supply (Water Quality) Regulations 2000 (Amendment) Regulations 2007 and the Water Supply (Water Quality) Regulations 2001 (Amendment) Regulations 2007 deserve a specific mention here, as this is the first time the proactive, risk-based approach to the protection of public water supplies has been placed on a regulatory footing.

Overall, the intention of the changes introduced by these regulations is to reinforce the importance to public health protection of raw water quality monitoring in terms of risk assessment and risk management generally, and specifically to verify that adequate water treatment safeguards are in place. The regulations also effectively implement the risk assessment approach which underpins Drinking Water Safety Planning, but only insofar as the treatment and distribution elements of the supply chains are concerned; there is an implicit requirement for catchment risk assessments to be undertaken, by means of the raw water monitoring programmes and the requirement for all potential dangers to human health to be considered, but it is not as explicit as for the treatment and distribution elements, whilst the consumer element of supply chains does not even warrant a mention.

Taking this latter element of the drinking water supply chain first, it really is the elephant in the room that no one wants to talk about. Drinking Water Safety Plans apply to the whole of the supply chain but, more contentiously, make the provider of the water responsible for its quality right up to the consumer's tap. For the vast majority of parameters water companies are only generally responsible for them complying with the standards up to the consumer's meter or property boundary. Will it really be the intention of the next revision of the Drinking Water Directive to extend this responsibility to the consumer's tap, potentially making them also responsible for the state of the internal plumbing in the consumer's property? Whatever its intention, no-one within the water industry is publicly considering how to deal with the consumer part of the drinking water supply chain. Will an explanatory leaflet to consumers be sufficient (as is currently being considered by at least one water company), outlining the steps consumers can take to protect the quality of the water once it reaches their homes? An alternative is to amend the existing Water Supply (Water Fittings) Regulations 1999, or perhaps even produce a new set of regulations spelling out the rights and responsibilities of consumers, insofar as water quality is concerned.

11 CONCLUSIONS FROM PART 2

A review of the legal framework with respect to water was presented in Part 2. In recognition of the majority of new laws within the UK being driven by the EU, the review started logically with an overview of European institutions and relationships between them, before summarising current relevant European Directives. The review then progressed to giving an introduction to the next tier of legal instruments – Acts of Parliament – before finishing with a review of the bottom tier, the regulatory framework.

From this review I have drawn the following conclusions (for ease of reference the Section to which each conclusion relates is given is brackets):

1) If, as it is widely anticipated, the next revision of the Drinking Water Directive adopts as its basis the Drinking Water Safety Plan approach, this will represent a marked departure from its two predecessor 'command and control' forms. It will also help improve the quality of source waters, by identifying potential hazards within the catchment, and implementing measures to address the risks they pose (Section 8.14.1).

2) Despite the Water Framework Directive being described as the most substantial piece of European water legislation to date, it contained a number of serious omissions and flaws; some of these have been addressed by the subsequent Floods Directive, but the European Commission should also consider adopting a Climate Change Directive (Section 8.14.2).

3) The UK Government – along with the devolved administrations and regulators – must quickly reach a consensus on their interpretation of the 2015 deadline contained within the Water Framework Directive, and to ensure this is communicated effectively, consistently and clearly, both internally and externally, to all stakeholders (Section 8.14.2).

4) In lieu of guidance from the European Commission, DEFRA (as the body responsible for implementation of the Water Framework Directive across all four devolved regions of the UK) should clarify whether water companies will still be able to use blending as a legitimate means to comply with the relevant water quality regulations (Section 8.14.2).

5) DEFRA should give serious consideration to removing the EA's competent authority status prior to commencement of the first cycle of the Water Framework Directive (covering the six-year period from 2015) and granting this instead to both the Countryside Council for Wales and Natural England (Section 8.14.2).

6) Successful implementation of the Water Framework Directive will bring many environmental benefits, but all stakeholders must ensure that, in order for this to be achieved, they cooperate fully and openly at all levels (Section 8.14.2).

7) As Water Level Management Plans and Catchment Flood Management Strategies are both active management tools, they should be subject to the requirements of the Strategic Environmental Assessment Directive (Section 8.14.3).

8) The EA's twin roles of regulator and operator do not sit comfortably with its obligations arising from being the Responsible Authority in relation to the Strategic Environmental Assessment Directive; this is another reason DEFRA should consider separating the EA's twin roles. Alternatively, the role of Responsible Authority should perhaps be given to the Countryside Council for Wales and Natural England (Section 8.14.3).

9) Although air is mentioned in the preamble to the Environmental Liability Directive, air pollution is not within the scope of the Directive. In order to dispel any confusion, the reference to air should be removed from the preamble, or the scope of the Directive should be extended to cover it. This latter course of action would be preferable, as the Directive would then apply to all three natural media – land, water and air (Section 8.14.4).

10) With reference to the Water Supply (Water Quality) Regulations 2000 (Amendment) Regulations 2007 and the Water Supply (Water Quality) Regulations 2001 (Amendment) Regulations 2007, urgent clarification is required on the extent of the responsibility of water companies for water quality within consumer's properties, and this should be explicitly enshrined within the next revision of the Drinking Water Directive (Section 10.26).

11) A debate should be initiated between the water industry and strategic stakeholders on how implementation of the Drinking Water Safety Plan approach is to be achieved for the consumer stage of the supply chain; arising from this should be a timetable for meeting a number of realistic objectives for this implementation. It is important for this water industry to initiate this, to that they may lead and shape the debate, as the alternative could well be burdensome regulations if a consensus is not achieved (Section 10.26).

PART 3 CATCHMENT MANAGEMENT AND INFLUENCING FACTORS

12 PRINCIPLES OF CATCHMENT MANAGEMENT

12.1 Introduction

Since the advent of the Water Framework Directive, the terms 'river basin' and 'catchment' seem to be used interchangeably within the UK, whilst in the USA a third term is preferred – 'watershed'. For consistency, only one term is used throughout this thesis, that of 'catchment'. In its simplest form, a definition of catchment could be:

"A geographical area drained by a single watercourse."

In reality, there is an almost infinite variation in size of catchments relative to the watercourse they are sustaining, from the smallest stream to the mightiest river; it follows therefore that the catchments of larger rivers are simply agglomerations of all the catchments of smaller tributaries within them. These smaller catchments are sometimes referred to as 'sub-catchments' of the larger cumulative catchment, whilst for the purposes of my research I have taken the term 'river basin' to be an agglomeration of a number of smaller catchments; this concept of a three-tier catchment scale is expressed diagrammatically in Figure 2.

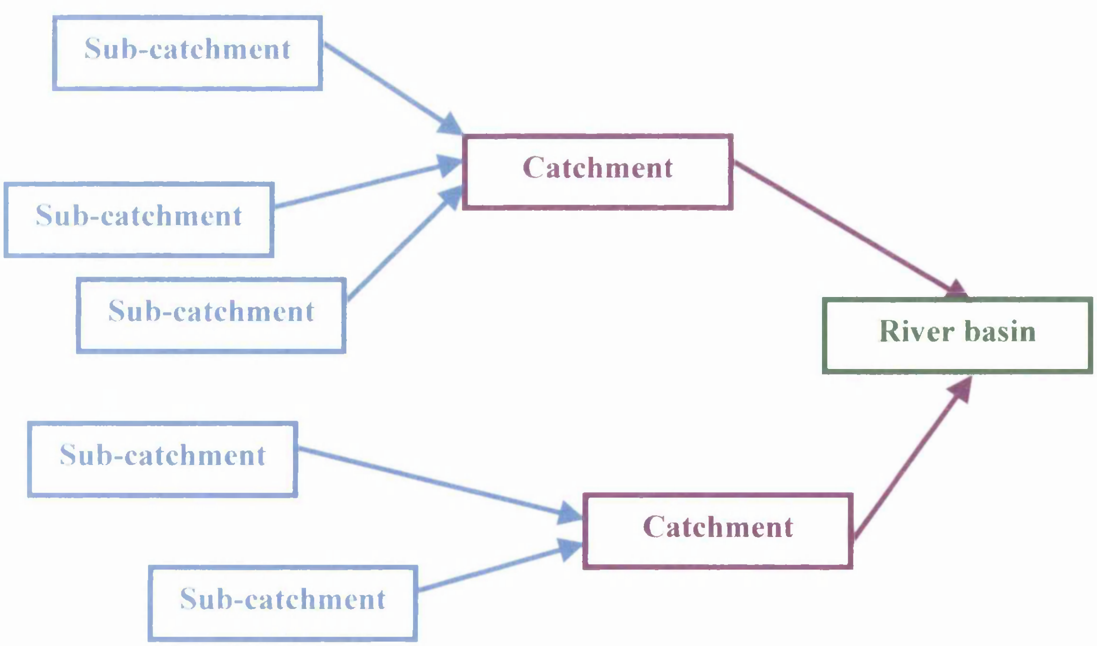


Figure 2: Diagrammatic representation of the three-tier catchment scale

To illustrate Figure 2 using an actual example, the River Severn is the longest river in the UK, and rises at Plynlimon in mid-Wales before flowing into the mouth of the Bristol Channel; its catchment covers an area of approximately 11,000km^2, and so this catchment can be legitimately called a river basin (Environment Agency 2009). This river system consists of a number of tributaries, each of which are viewed as rivers in their own right, such as the Rivers Severn, Avon and Teme, all with their own catchments. In turn, the upland River Severn consists of a number of sub-catchments in Powys each containing significant individual watercourses such as the Afon Hafren and the Afon Hore.

12.2 The Concept of Catchment Management

At its most elemental a definition of catchment management could be:

"The process of managing and using the land within a catchment."

However, there is no consistency across the academic and environmental sectors about what is actually meant by catchment management, which has given rise to a multitude of definitions. Consequently, this lack of consistency has promulgated a great deal of confusion about what is actually meant by the term; this has unfortunately been compounded by a multitude of descriptive variations on the term itself. For example, 'catchment management' and 'integrated catchment management' seems to be used interchangeably within the UK. Furthermore, during the course of his review and evaluation of 'integrated catchment management', Werritty discovered numerous terms for catchment management in use around the world – each being a subtle variation on a theme – and these are reproduced in Table 1 (Werritty 1995).

TERM USED	BASIN/AREA TO WHICH THE TERM RELATES
River basin planning	Gongola/Sokoto, Nigeria Newfoundland, Canada
Integrated river basin development	Nile (especially Sudan)
Integrated river management	Zambezi, Zambia and others
Basin-wide planning	Huang, China
Basin management	Acelhuate, El Salvador Murray-Darling, Australia Colorado, USA
River basin development	Han, China
Total catchment management	New South Wales, Australia
River basin management	Thames (Ontario), Canada Alberta, Canada Germany European Union Member States
Watershed management	Central Ontario, Canada
Comprehensive basin planning studies	Various, Canada
Comprehensive water quality management	Stratford/Avon, Ontario, Canada
Floodplain management	Hunter Valley, New South Wales, Australia
Integrated river basin management	Atchaflaya, USA
River basin management strategy	Tisza, Hungary
Catchment management	New Zealand

Table 1: Examples of terminology centred on the UK's interpretation of 'catchment management'

Within the UK the use of two further terms is starting to become apparent – 'integrated water management', and 'integrated water resources management' – although these, along with the terms listed in Table 1, all appear to be variations of each other, as opposed to separate, distinct disciplines.

Batchelor (1999) attempted to produce his own definition of integrated catchment management, and suggested the following:

"The co-ordinated planning and management of land, water and other environmental resources for their equitable, efficient and sustainable use at the catchment scale."

However, the definition appears to be merely a more complicated re-working of the elementary definition of catchment management given above, and the use of the word 'integrated' appears superfluous. Therefore, throughout this thesis, only the term 'catchment management' has been used.

Catchment management is of considerable importance to the ability to manage water both quantitatively and qualitatively within an area, because land use and water use are inseparable; consequently, many of the changes in quality detected within a water body can be traced back – either directly or indirectly – to man's activities in or on the land within the catchment (Viessman & Hammer 1993). Most catchments are impaired in some way or other by human activities. From minor forest management to intense urban activities, catchments face varying levels of impact (Randhir 2007)

This is because, even in mountainous parts of the country, less than 2% of a catchment is occupied by watercourses. Therefore, more than 98% of rainfall has to flow over or through land on its way to a stream or river, so how the land is being used will be reflected in the quality of this water when it eventually drains into watercourses (Newson 1997). The need for effective catchment management therefore becomes clear when the UK's dense network of surface watercourses is considered in a spatial sense.

There are essentially three elements to catchment management – physico-chemical, biological and socioeconomic (Watson 1996). The physico-chemical element can be taken to cover hydrology, hydrodynamics, chemistry and hydromorphology, whilst the biological element relates to the ecology of the catchment; finally the socioeconomic element encompasses how human activities shape and affect the catchment, in terms of development, land use and industry.

12.3 The Benefits of Catchment Management

According to Boon et al, the primary purpose of catchment management is to understand the catchment in terms of its surface water, groundwater and land uses, and how these assist in either regulating or disrupting the water cycle (Boon et al. 1992). This knowledge can then be used to implement policies and strategies to minimise the range and amount of contaminants entering waters used for public water supply, with resultant benefits for both water companies and consumers. Consequently, catchment management is increasingly being recognised as being at the heart of the water environment (ADAS 2006e). Catchment management is therefore not simply about changing something within a catchment in order to protect or improve water quality, it is also about maintaining those changes over time (Boon et al. 1992).

According to the WHO, effective catchment management – implemented as part of its Drinking Water Safety Plan approach – has many benefits (Davison et al. 2005). By decreasing contamination of sources of drinking water, the amount of treatment and quantity of chemicals needed is reduced, with the double consequence that the production of treatment by-products and operational costs may be minimised. By developing a catchment management plan, an operating manual for those areas containing sources of public water supply is effectively the result, which then becomes the manual for the first part of the drinking water supply chain (Fawell & Watkins 2003). These plans – or manuals – should ideally (Fawell & Watkins 2003):

1) Outline possible sources of pollution;
2) Quantify the likelihood of these sources of pollution affecting surface or groundwaters used for public water supply; and
3) Quantify the possibility of these hazards passing through water treatment works and entering supply.

12.4 Catchment Management and Precipitation

Knowing what's on and within a catchment is not enough; catchment managers also need to have an awareness of external influences on water quality and water quantity within a catchment, and arguably the single biggest external influence is that of precipitation (Keirle & Hayes 2007a).

Rainfall events are one of the most important causes of degradation in source water quality affecting surface waters and groundwaters, which includes (Keirle & Hayes 2007a):

- The re-suspension of sediments;
- The mobilisation of soils through over-land flow;
- Driving the movement of pathogens into and through water bodies;
- Causing combined sewer overflows and emergency overflows to spill into receiving waters;
- The degradation of groundwater through infiltration; and
- The mobilisation of pockets of pollution.

The detection and forecasting of rainfall events is therefore an integral part of a risk-based approach to catchment management. Radar, hydrographic monitoring equipment and remote sensing will underpin the forecasting element, whilst a robust hydrometric network will give information on current rainfall, and water levels in surface waters and groundwaters, which will be invaluable for predicting influences on raw water quality and its subsequent treatment. Appropriate precautionary measures can therefore be taken in order to safeguard drinking water quality (Dufour et al. 2003).

12.5 Control Measures

The WHO states that, in order for the quality of sources of drinking water to be protected effectively, catchment management should include the following elements (World Health Organisation 2004):

- Developing and implementing a catchment management plan, which includes control measures to protect surface water and groundwater sources;
- Ensuring that planning regulations include the protection of both water resources and water quality (land use planning and watershed management) from potentially polluting activities and are enforced; and

- Promoting awareness in the community of the impact of human activity on water quality.

It therefore gives the following as examples of control measures for effective catchment management (World Health Organisation 2004):

- Registration of chemicals used in catchments;
- Control of human activities within catchment boundaries;
- control of waste water effluents;
- Land use planning procedures, use of planning and environmental regulations to regulate potential water polluting developments;
- Regular inspections of catchment areas;
- Diversion of local stormwater flows; and
- Runoff interception.

12.6 Development of a Catchment Management Plan

In order to assess and develop a comprehensive catchment management plan the typical process consists of the following five major steps (Randhir 2007).

Firstly, a catchment baseline is established, by developing a complete inventory of resources and a community profile. This step therefore includes:

- Defining catchment and sub-catchment boundaries;
- Identifying soil and water resources;
- Identifying land use;
- Identifying population and income distribution (i.e. socio-economic aspects) across the catchment; and
- Listing key stakeholders in the catchment.

The second step involves assessing the problem by identifying potential sources of contamination and the nature of pollution transfers. Things to consider include:

- The severity of the problem;
- Observable impacts arising from the problem;
- Underlying causes; and

- Identifying hotspots.

The next step is to identify feasible alternatives, which would include:

- Identifying structural solutions;
- Identifying non-structural solutions; and
- Listing education/outreach approaches.

The fourth step is concerned with identifying effective practices, which involves:

- Evaluating the alternatives based on efficiency, adoptability and economics;
- Selecting solutions that directly address the problem;
- Merging these options into a long-term catchment strategy; and
- Identifying local communities and local resources to target.

The final step is to build the plan, and this includes:

- Listing or mapping options and locations to apply the practices;
- Identifying agencies and communities to be involved;
- Determining resources available;
- Defining who will lead the implementation of the plan;
- Identifying mechanism for feedback and evaluation;
- Assessing potential outcomes (long-term) for each option; and
- Identifying potential pitfalls and developing contingency plans.

12.7 Catchment Management in a Historical Context

After a spate of cholera epidemics in the 1830's and 1840's, Victorian municipal water suppliers devised what we would now recognise as catchment management schemes. At this time water treatment was still in its infancy, so water supply authorities bought large tracts of land (which we would now call 'protection zones') within the upper reaches of catchments and were very prescriptive of land use and land management, in order to minimise the cost and extent of purification. However, with the exception of small upland supplies where the purchase of a significant part of the catchment was economically viable, the joint management of water and land has never historically been a central feature of UK public policy (Boon et al. 1992).

In Wales, catchment management in the form we recognise today arguably coincided with the construction of Lake Vyrnwy in the 1880s; restrictions to access to the Vyrnwy catchment area were commonly enforced, to ensure the purity of the impounded water. However, management of land use within the catchment was quite straightforward, as practically the only other use for land associated with this type of reservoir was for sheep grazing and forestry (Water Committee 1970).
It wasn't that the benefits of catchment management weren't recognised though. When Lord Robert Montague MP was a member of the Royal Sanitary Commission of 1868-71 he wrote a paper entitled "Watershed Board or Conservancy Boards for River Basins". Nevertheless, it wasn't until the Water Resources Act was placed on the statute book in 1963 that the concept was put into practice as a national policy; as a matter of interest, this was a first for the entire world (Water Committee 1970, UK Government 1963).

12.8 Current and Previous Catchment Management Initiatives

According to Gittins, with the privatisation of the water industry in England and Wales in 1989, a process of integrating water management that began in Victorian times came to an end (Gittins 1996). Certainly, as previously mentioned in Chapter 12, the EA is not involved with catchment management as such, although it does have a number of strategies and policies that impact on the catchment in one form or another, and is currently promoting Catchment Sensitive Farming (see Sections 12.9.3 and 12.9.4) as a means to tackle diffuse pollution from agriculture. However, Gittins seems to have overlooked the role of one of the EA's predecessor bodies, the NRA, which is an example in recent times of a national regulator adopting a strategic approach to catchment management (see Section 12.8.1) (Keirle & Hayes 2007a).

12.8.1 National Rivers Authority's Catchment Management Plans

The NRA was established in 1989 as part of the privatisation of the water industry, and all of its various areas of responsibility (such as flood defence and flood warning, navigation, pollution control, promotion of water-based recreation, and conservation of water resources) were focussed on the catchment (Keirle & Hayes 2007a).

However, the NRA came to realise it could only carry out its various activities by adopting the concept of catchment management (National Rivers Authority undated). As there was sometimes conflict between these different areas, the adoption of Catchment Management Plans meant that the NRA could consider the catchment as a whole, so that a decision made in one area must taken into account the possible impact of the decision on other areas (National Rivers Authority undated). Accordingly, in 1992 it started to coordinate and integrate its activities at the catchment level, and for the next four years it remained in existence it started to develop – in consultation with stakeholders and the general public – catchment management plans (Glaisher 1997)[6].

On a strategic level, the plans were designed to balance individual needs within a catchment with national objectives and environmental legislation, so that the NRA could make open decisions about the management of the catchment which best met the needs of the public and the environment (National Rivers Authority 1994).

Amongst the environmental outcomes catchment management plans were meant to deliver were (National Rivers Authority 1994):

- Protection of sites of high conservation value;
- Rehabilitation of such sites that had been degraded;
- National policies, such as the application of minimum acceptable flows; and
- Implementation of statutory water quality objectives.

---

[6] By contrast, north of the border it would take another eight years before the Scottish Environment Protection Agency (SEPA) initiated the development of catchment management plans, using the River Dee and its catchment in the north of Scotland as a pilot. There is an acknowledged bias within the River Dee Catchment Plan consultation document towards the then draft requirements of the Water Framework Directive, but there is also another reason why the water-related issues identified within the document are generally quality driven; at the time of its production, Scotland lacked a comprehensive abstraction licensing system, so SEPA's powers to control abstractions and to regulate rivers were "fragmented and limited" (Scottish Environment Protection Agency undated).

12.8.1.1 Local Environment Action Plans

When the EA was formed in 1996, it decided that the Catchment Management Plans produced by one of its predecessor bodies, the NRA, should evolve into Local Environment Agency Plans (LEAPs). Not only did LEAPs incorporate a stronger stakeholder consultation element, but they also addressed land and air issues (the respective responsibilities of its other two predecessor bodies, the Waste Regulation Authorities and Her Majesty's Inspectorate of Pollution) (Environment Agency 1997). LEAPs were originally conceived as non-statutory action plans which were seen to play a central role in developing liaison between the EA and environmental stakeholders (Calder 2005).

In 2002 the EA undertook an internal review of the LEAP process and it decided not to continue production of any further LEAP documents. Eventually, the CAMS process picked up the water resources elements of the LEAPs (see Section 13.4.2) (Calder 2005).

12.9 Diffuse Pollution

Discrete point sources of pollution like continuous discharges from pipes and outfalls were historically the main cause of water quality problems in England and Wales (Department for Environment Food and Rural Affairs 2003). However, because of their discrete nature they were relatively straightforward to address, and between 1990 and 2005 £15.4 billion have been invested in order to control them (Department for Environment Food and Rural Affairs 2003). Consequently, 96% of the UK population is connected to the sewerage network, and standards of sewage treatment have increased significantly, resulting in a substantial impact in reducing discharges of a range of pollutants (Department for Environment Food and Rural Affairs 2003). Our focus must now turn to addressing sources of diffuse pollution if we are to make the further improvements that are required under a number of European Directives, including the:

- Water Framework Directive;
- Bathing Waters Directive;
- Shellfish Waters Directive;

- Freshwater Fish Directive;
- Nitrates Directive;
- Birds Directive; and
- Habitats Directive.

However, sources of diffuse pollution (also known as non-point source pollution) are generally dispersed (such as that arising from atmospheric deposition) and diverse in nature, and cannot be regulated by means of discharge consents alone or controlled by end-of-pipe technologies (Environment Agency 2006c, Department for Environment Food and Rural Affairs 2004c). Instead, a selection has to be made from a combination of initiatives and policy mechanisms, the selection being dependent on the issues within each catchment.

Within the UK, we refer to two general types of diffuse pollution – diffuse pollution from urban areas, and diffuse pollution from agriculture.

12.9.1 Diffuse Pollution from Urban Areas

Examples of urban diffuse pollution include:

- Heavy metals, hydrocarbons and chloride contained in run-off from roads and motorways;
- Leaching of solvents and heavy metals from contaminated sites, a legacy of over 200 years of industrial activity;
- Leaks and spillages of hazardous chemicals, oils and fuels from industrial estates;
- Soil particles contained in run-off from construction and demolition sites;
- Herbicide residuals being washed into surface watercourses by rain following spraying by local authorities and Network Rail; and
- Phosphates from laundry products.

Although urban diffuse pollution is not as big a problem as diffuse pollution from agriculture, the impact of it is still significant. For example, the EA estimated that 25% of river lengths and 14% of groundwaters are at risk or probably at risk of failing to meet Water Framework Directive objectives because of urban diffuse pollution sources (Department for Environment Food and Rural Affairs 2004c).

A major source of urban diffuse pollution is storm water draining from urban areas. Approximately one-ninth of the river network lies within urban areas (although some of this is culverted), and storm water draining into it contains a multitude of pollutants which have arisen from sources such as maintenance activities, accidental spillages and emissions from traffic (Department for Environment Food and Rural Affairs 2005b).

Another major source is from misconnections (where polluted water outlets have been connected to the surface water system) and leaking sewers. It is estimated that 5% of houses and 20% of industrial properties have wrong connections, totalling over 1.3 million properties. With regards to the sewerage network itself, approximately 23% of its combined length of 350,000 km is classified as being in critical condition; in the Greater London region the loss rate from the network is estimated at 5% (Department for Environment Food and Rural Affairs 2006h).

DEFRA have held a series of stakeholder workshops in order for it to ultimately develop and implement mechanisms to tackle sources of urban diffuse pollution although, judging from its website, progress on this seems to have stalled since May 2005 (Department for Environment Food and Rural Affairs 2006c, Department for Environment Food and Rural Affairs 2006e).

12.9.2 Diffuse Pollution from Agriculture

Examples of diffuse pollution from agriculture include:

- Soil particles contained in run-off from freshly ploughed land;
- Pathogens being washed into surface watercourses from grazed areas; and
- Nutrients (generally nitrates and phosphates, arising mainly from fertilisers and animal waste products) and organic compounds (arising from three main groups – pesticides, herbicides and insecticides) leaching into both groundwaters and surface waters.

Agriculture is the most significant source of diffuse pollution, and contributes about 70% of nitrate, 50% of phosphate and 50% of suspended sediments in water bodies (Chartered Institution of Water and Environmental Management 2006b). The EA has estimated the societal cost of adverse effects of agriculture to the environment to be £1.2 billion (although this includes impacts other than diffuse pollution), and it is estimated that the capital expenditure required to remove nitrates and pesticides from drinking water costs each customer £7 per year (Anonymous 2003; Dwyer et al. 2003; Environment Agency & English Nature 2004; House of Commons 2003c). The extent of the problem is perhaps to be expected as farming and horticulture covers over 70% of the land area of England and Wales (Department for Environment Food and Rural Affairs 2006a).

According to DEFRA, because of diffuse pollution from agriculture, 80% of rivers, 50% of lakes, 25% of estuaries and coasts and 75% of groundwater are currently estimated to be at risk of not complying with the 'good' status requirement of the Water Framework Directive by 2015 (Department for Environment Food and Rural Affairs date of publication unknown).

Although the major user of fertilisers and organic compounds in the UK is the agricultural sector, other major users of herbicides include local authorities, utilities companies, Network Rail and private users, and these all significantly contribute to the diffuse pollution problem (Consultants in Environmental Sciences Ltd 2001).

12.9.3 Welsh Assembly Government's Approach to Tackling Diffuse Pollution from Agriculture

The Welsh Assembly Government is currently managing a project designed to promote catchment sensitive farming. It is working closely with farmers – in partnership with EAW, the Countryside Council for Wales and Snowdonia National Park – to demonstrate and apply measures to tackle diffuse pollution from agriculture. The project is focussing on the following two areas:

- The Deepford Brook catchment (an intensive dairy lowland area) in Pembrokeshire; and

- The Llafar and Twrch catchments (two neighbouring upland livestock farming areas) near Bala (Welsh Assembly Government 2005a, Welsh Assembly Government 2006b).

The catchment sensitive farming project has been designed to complement other existing schemes and initiatives – such as Tir Gofal and Tir Cynnal (see Section 12.9.6.1) – and offers capital grants of up to 60% of actual costs on a range of works (such as storage of dirty water and fencing) intended to tackle pollution of water bodies. The project also offers a number of other services to the farming community, such as free consultation on the application of fertilizers, soil sampling and farm 'health checks'. This work will be undertaken by the Welsh Assembly Government's team of six Catchment Officers and consultants (Welsh Assembly Government 2005a, Welsh Assembly Government 2006c).

EAW will be taking a variety of physico-chemical samples and undertaking ecological surveys throughout the life of the project, the results of which will be fed into models which have been purpose-built for each of the three catchments. These models will then be used to predict the effects of land management, different stocking practices and fertiliser use on water quality (Welsh Assembly Government 2006c).
The findings from this project will be used to develop initiatives to tackle diffuse pollution in other parts of Wales (Welsh Assembly Government 2006b).

12.9.4 DEFRA's Approach to Tackling Diffuse Pollution from Agriculture

In order to meet the objectives of the Water Framework Directive DEFRA established a Catchment Sensitive Farming Programme. Catchment sensitive farming is, according to DEFRA, land management that keeps diffuse emissions of pollutants to levels that are consistent with the ecological sensitivity and uses of rivers, groundwaters and other aquatic habitats, both in the immediate catchment and further downstream (Department for Environment Food and Rural Affairs 2008b). With specific reference to farmers, catchment sensitive farming includes (Department for Environment Food and Rural Affairs 2008b):

- Encouraging best practice in the use of fertilizers, manures and pesticides;
- Promoting good soil structure to maximize infiltration of rainfall and minimize run-off and erosion;
- Protecting watercourses from faecal contamination (e.g. with fencing and livestock crossings), and from sedimentation and pesticides (e.g. with buffer strips); and
- Reducing stocking density or grazing intensity.

As part of this Programme, the Catchment Sensitive Farming Delivery Initiative was rolled out in April 2006 and focussed on 40 priority catchments in England, which would be targeted under a range of measures aimed at improving farming practices and reducing water pollution from agriculture (Department for Environment Food and Rural Affairs 2006i).

Under the auspices of this Initiative, Catchment Sensitive Farming Officers were appointed to help farmers on a one-to-one basis to tackle the causes of diffuse pollution from agriculture. These Officers will also hold workshops and farm demonstrations to encourage best practice (Environment Agency 2006b).

One of the key elements of this Initiative is that it is adopting a multi-agency approach by involving Natural England, the EA, DEFRA, water companies, NGOs such as the RSPB, NFU and other stakeholders, by means of Catchment Steering Groups (Department for Environment Food and Rural Affairs 2008a). Also, the Catchment Sensitive Farming Officers that have been recruited as part of this initiative will be grouped and coordinated at the river basin district level (Department for Environment Food and Rural Affairs 2006i).

12.9.5 Selected Diffuse Pollution Research Projects

In recent years there have been two major reviews of research projects aimed at understanding and mitigating diffuse pollution from agriculture; in 2003 ADAS (on behalf of UKWIR) undertook a review of the 67 projects listed on its UK-ADAPT website as of August 2003 (Humphrey & Shepherd 2003), and as of January 2006

DEFRA reviewed 60 English catchment-specific agricultural diffuse pollution research projects, ten of which had been completed (Horsey 2006).

In particular, the ADAS review found that it was "probable most projects studied lowland agricultural surface water catchments", and that projects were based mainly in England (especially in the North West). ADAS also found that most projects did not cover all pollutants, just one or two, and that only a minority of them included the "full interactive involvement of stakeholders" (Humphrey & Shepherd 2003).

A summary of the more significant projects that were reviewed is given below.

12.9.5.1 Whittle Dene Project

ADAS established this five-year length project in 2002 to enable the sources and causes of diffuse water pollution from agriculture to be understood, and to quantify the effects of farm management on the quality of water leaving agricultural land. The subject of the project is a small, rural micro-catchment (approximately 3.9km^2) in Northumberland and, according to ADAS, it is the only UK catchment project that is monitoring all the major water quality issues from agricultural land (ADAS publication date unknown, ADAS 2006a, ADAS 2006e).

As good communication and close cooperation between stakeholders is vital for effective catchment management, a group was established to guide the project, the members of which were drawn from various bodies including ADAS, DEFRA, the EA, Northumbrian Water and the NFU (ADAS 2006f).

Baseline water quality and flow monitoring was undertaken during the first two years of the project, along with catchment characterisation (which included a survey of soil type, soil structure, field drainage, aquatic invertebrates and macrophytes, farm assessment and management of individual fields), and the data realised were fed into hydrological and water quality models (ADAS 2006f). The impact of policies such as the Single Farm Payment and Cross Compliance are currently being monitored, and a catchment plan has been developed (ADAS 2006h). Although work is continuing, the project has already highlighted that "water quality is insufficiently studied at the small catchment scale" (ADAS 2006g).

12.9.5.2 Phosphorus and Sediment Yield Characterisation in Catchments Project

The **P**hosphorus and **S**ediment **Y**ield **Ch**aracterisation **i**n **C**atchments ('PSYCHIC') Project is funded by DEFRA, the EA and English Nature, and is managed by ADAS. The purpose of the project is to help identify practical and cost-effective options for controlling the transport of phosphorus and particulates from agriculture land to water bodies, as well as evaluating barriers to their uptake, and is focussing on two catchments – the Herefordshire Wye, and the Hampshire Avon (ADAS 2006i, ADAS 2006d).

The project partners include ADAS, CEH, National Soil Resources Institute, and the universities of Sheffield, Exeter and Reading (ADAS 2006j).

12.9.5.3 Sustainable Catchment Management Programme

The Sustainable Catchment Management Programme has been developed by United Utilities in association with the RSPB, with the aim of developing an integrated approach to catchment management within two keys areas of United Utilities' landholding (United Utilities 2006a). The project started in 2005 and will continue until 2010, with the twin aims of benefiting wildlife and water quality; the total project costs are estimated at just over £24 million (Horsey 2006), which has been funded by Ofwat. It is hoped these aims will be realised by a combination of the following (Royal Society for the Protection of Birds 2006c):

- Restoring blanket bogs by blocking drainage ditches;
- Restoring areas of eroded and exposed peat;
- Restoring hay meadows;
- Establishing clough woodland;
- Restoring heather moorland;

- Providing new farm buildings for indoor wintering of livestock and for lambing;
- Providing new waste management facilities to reduce run-off pollution of water courses; and
- Fencing to keep livestock away from areas such as rivers and streams and from special habitats.

As United Utilities has noted, "water treatment starts on the catchment ... and when we get it right there it means we don't need to keep adding more expensive engineering solutions at our treatment works" (United Utilities 2006b).

12.9.5.4 WAgriCo Project

WAgriCo is a three-year Anglo-German LIFE[7] project that commenced on 1 October 2005 in order to draw upon those two countries' experience of drinking water protection in order to support the implementation of the water protection objectives set out in Articles 4 and 7 of the Water Framework Directive (Chartered Institution of Water and Environmental Management 2005, UK ADAPT 2006). Within the UK this project is run by UKWIR and the day-to-day work is being undertaken by ADAS and Wessex Water, in collaboration with the EA and the NFU (Wessex Water: Ruth Barden 2006, WAgriCo publication date unknown).

The objectives of the project are to (UK Water Industry Research 2006b):

- Demonstrate the use of new participation approaches and technologies suitable for programmes of measures to reduce diffuse pollution from agriculture and to promote sustainable water resources management;
- Demonstrate how the policy objectives of the Sixth Environmental Action Programme can be achieved through co-operative action at the local river catchment and farm level;

---

[7] The LIFE programme is a financial instrument of the European Union to fund environmental research.

- Show how Member State agricultural assistance programmes can be amended to aid the implementation of the Water Framework Directive and that synergy effects can be used to increase cost-efficiency in water resources protection;
- Clearly show the links between policy, action and the achievement of environmental water quality objectives with a focus on integrating water resources management objectives in agricultural assistance programmes across the European Union; and
- Assess the costs associated with the implementation of the required measures.

Within the UK the project is focussing on five Wessex Water groundwater sources in the Frome and Piddle catchments in Dorset where peak nitrate levels have exceeded, or will soon exceed, the regulatory limit of 50mg/l; in the same county it has another groundwater source in the Wey catchment in a similar position with respect to pesticides (Wessex Water date of publication unknown). At this latter works – Friar Waddon – the Company has detected a direct correlation between peaks in pesticides concentrations and rainfall (Keirle 2006a).

All three catchments are mainly rural and are extensively farmed. Farming is undertaken in very close proximity to the groundwater boreholes as no buffer zones exist to protect the aquifers serving the boreholes (WAgriCo publication date unknown).

The Company was reluctant to install treatment such as granular activated carbon or ion exchange at the treatment works supplied by these sources as the trends in the nitrate and pesticides concentrations were increasing so Wessex Water felt it was better to deal with the problem at source, rather than install end-of-pipe solutions. It has consequently recruited two catchment advisors to cover the catchments of the six sources. As well as continuing to monitor the situation by means of sampling, the catchment advisors are also imparting advice and information to the agricultural community within the catchments in question. By changing the land management practices of the farmers, the Company hopes to reduce leaching of nitrates and pesticides from the land into the underlying aquifers (Wessex Water date of publication unknown).

12.9.6 Agri-Environment Schemes

The term 'agri-environment scheme' is used to describe national or local schemes that pay farmers to farm in an environmentally sensitive way, and they are the main mechanism the devolved administrations use to encourage landowners and farmers to adopt environmentally friendly practices (Dartmoor National Park Authority 2008, Department of Agriculture and Rural Development 2008).

All members of the European Union are obliged to have an agri-environment programme, as part of the Common Agricultural Policy, and they are co-funded by the European Union as part of their rural development programme (Department of Agriculture and Rural Development 2008); an overview of the voluntary schemes available in both Wales and in England are given in the following two sub-sections.

12.9.6.1 Agri-Environment Schemes in Wales

In Wales the principal agri-environment whole farm scheme is Tir Gofal (see Section 10.12), whilst an alternative whole farm scheme with less demanding requirements is Tir Cynnal (see Section 10.22), and until October 2006 the Countryside Council for Wales was responsible for the delivery of both these schemes, on behalf of the Welsh Assembly Government; since that date, responsibility for both schemes reverted to the Welsh Assembly Government.

The schemes aim to encourage agricultural practices which will protect and enhance the landscapes of Wales, their cultural features and associated wildlife, and they replace previous schemes such as Environmentally Sensitive Areas and Tir Cymen (Welsh Assembly Government 2008a).

The Tir Gofal scheme was introduced in 2000, and now over 3,000 farms are covered by it, accounting for over 300,000 hectares of land (Welsh Assembly

Government 2008g). The Tir Cynnal scheme was introduced much later – in 2006 – but already covers over 3,000 farms (Royal Society for the Protection of Birds 2008). Although information relating to the extent of these schemes is not available, membership of the scheme will be limited to 10,000 applicants, due to budgetary constraints (Welsh Assembly Government 2008f).

12.9.6.2 Agri-Environment Schemes in England

The Rural Development Programme for England applies to the period 2007-2013, and is the successor programme to the similarly-named England Rural Development Programme which ran from 2000 to 2006 (Department for Environment Food and Rural Affairs 2008c).

As the name implies, the Programme only covers England. Its budget of £3.9 billon (which is double the one for its predecessor) is jointly funded by the EU and the UK Government. The vast majority of this – £3.3 billion – will be allocated to agri-environment and other land management schemes, in order to help farmers to manage the land more sustainably and deliver important outcomes on biodiversity, landscape and access, water quality and climate change. The remaining £600 million will be made available to make agriculture and forestry more competitive and sustainable and to enhance opportunity in rural areas (Department for Environment Food and Rural Affairs 2008e).

There are three schemes within the Programme that are currently open to new applicants, and these are (Department for Environment Food and Rural Affairs 2008e):

- Environmental Stewardship;
- Hill Farm Allowance; and
- England Woodland Grant Scheme.

The Environmental Stewardship scheme is managed by Natural England, and it consists of (Rural Payments Agency 2008b, Department for Environment Food and Rural Affairs 2008d):

- Entry Level Stewardship - to encourage farmers to deliver simple yet effective environmental management;
- Organic Entry Level Stewardship - for organic farmers with land not currently receiving conversion aid; and
- Higher Level Stewardship - to reward farmers for delivering significant environmental benefits in high priority situations and areas (Department for Environment Food and Rural Affairs 2006m).

The Hill Farm Allowance is managed by the Rural Payments Agency, an Executive Agency of DEFRA (Department for Environment Food and Rural Affairs 2008f, Rural Payments Agency 2008a). The aims of the scheme are to contribute to the maintenance of the social fabric in upland communities through support for continued agricultural land use, and to help preserve the farmed upland environment by ensuring that land in the Less Favoured Areas is managed in a sustainable way (Department for Environment Food and Rural Affairs 2008f).

The England Woodland Grant Scheme is managed by the Forestry Commission, and the aims of it are to sustain and increase the public benefits given by existing woodlands, and help create new woodlands to deliver additional public benefit (Forestry Commission 2008).

12.10 The European Landscape Convention

The previous sections have shown, in England and Wales, that we currently lack a coordinated, national catchment management strategy, although a number of voluntary schemes and initiatives incorporate the principles of catchment management, albeit generally at the local level. However, we may already have a vehicle for the delivery of a national catchment management strategy, in the form of the European Landscape Convention (Keirle & Hayes 2007a).

A number of existing international legal instruments have some bearing upon landscape, either directly or indirectly. However, because there was no international legal instrument that deals "directly, specifically and comprehensively" with

European landscapes and their preservation, the Council of Europe[8] decided to develop the European Landscape Convention in order to fill the perceived gap (Council of Europe 2006d).

The Convention came into force in 2004 and is the world's first landscape treaty. It applies to all landscapes irrespective of their quality or nature (i.e. they can be rural or urban, built or natural), and it aims to encourage public authorities to adopt policies and measures at local, regional, national and international levels for protecting, managing and planning landscapes throughout Europe (Department for Environment Food and Rural Affairs 2005a, Council of Europe 2006e).

Parties to the Convention undertake to (Department for Environment Food and Rural Affairs 2005a):

- Establish and implement recognised policies on landscape management, planning and protection;
- Recognise landscapes in law as an essential component of people's surroundings and introduce procedures for public participation in landscape policies;
- Integrate landscape into agricultural, cultural, economic, environmental, social and spatial planning policies;
- Undertake awareness raising, education and training, and the identification and evaluation of landscapes;
- Introduce instruments to put landscape policies into effect; and
- Co-operate on the landscape dimension of international policies, exchange experience and information internationally, and encourage trans-frontier cooperation.

The UK signed the Convention in February 2006, but it has not yet ratified it (Council of Europe 2006c). When it does, the Convention could be used as a vehicle for the implementation of a national catchment management strategy as it would

---

[8] The Council of Europe – not to be confused with the Council of the European Union, which is a completely separate organisation – is Europe's oldest political organisation and was founded in 1949. It has 46 member States, and its headquarters is in Strasbourg (Council of Europe 2006a).

provide a framework for all landscape policies, as Article 5(d) will commit the UK "to integrate landscape into its regional and town planning policies and in its cultural, environmental, agricultural, social and economic policies, as well as in any other policies with possible direct or indirect impact on landscape" (Council of Europe 2006b).

When the UK ratifies the Convention, it would be committed to honouring the obligations set out in the text. However, the Council of Europe has no legal powers over the UK so it could not apply any sanctions should any of the UK's obligations not be met (Department for Environment Food and Rural Affairs 2006f).

12.11 Discussion

It is important to realise that the adoption of catchment management is not a panacea for all the environmental problems we are currently experiencing in the countryside. However, effective catchment management can "provide an ideal framework for promoting and facilitating the introduction of technologies and agriculture practices that conserve [and protect] water resources and increase the efficiency and productivity of water use" (Batchelor 1999).

Within the UK water industry, numerous water companies already have detailed plans of their catchments in place, arising from their regulatory obligation to produce *Cryptosporidium* risk assessments (Fawell & Watkins 2003). They have therefore effectively completed the first two steps required for producing individual catchment management plans (see Section 12.6) by studying the baseline within each catchment, and assessing problems; water companies may well have largely completed the third stage as well, by identifying feasible alternatives. In partnership with other local stakeholders, it should not present too much of a challenge to complete the remaining two stages and produce catchment management plans.

12.11.1 Diffuse Pollution

In recent years there have been a number of inquiries by House of Commons Select Committees that have each considered aspects of diffuse pollution as part of their remits.

Following an inquiry into the 2004 periodic review, the Environment, Food and Rural Affairs Select Committee published its findings in December 2003 (House of Commons 2003c). In this report, the Committee stated it is "disheartening to find that … measures to deal with [diffuse pollution] have yet to be put in place", even though the Government had "recognised that the existing controls on diffuse pollution are not comprehensive in their scope and so are inadequate on their own to discharge its obligations under the … directive". Consequently, the Committee is "very concerned at the slow progress by the Government in reaching a decision on how diffuse pollution from agriculture will be tackled", despite the various strategies and reports it had published over the preceding 18 months. Not surprisingly, in its response to the Committee's report the Government denied that it has been dragging its feet over the issue, and stated that it is making "active progress in addressing the agricultural and non-agricultural sources of diffusion pollution" (House of Commons 2004d). However, despite describing at length initiatives it was currently – or would be – pursuing, it didn't provide details of policies that had been implemented, and so perhaps validated the Committee's concerns.

The Committee decided to hold a further inquiry, following the publication of the draft price limits, and published this second report in December 2004 (House of Commons 2004c). The topic of diffuse pollution was considered once more, and the Committee stated they were "particularly disappointed that the Government has been slow to address [it]" and that, as a result, the cost of tackling the problems arising from diffuse pollution would be borne by water companies' customers. It therefore suggested that the Government consider other alternatives for funding the effects of diffuse pollution, along with the effects of climate change. The report also states that "the Government should make clear, at the earliest opportunity, its plans for solving these problems" (House of Commons 2004c). In its official response to the report, the Government denied that its response has been slow, and that it had been busy developing a number of initiatives to tackle these problems (House of Commons 2005).

In 2004 the Environmental Audit Committee undertook a review of the 2004 Periodic Review and the Environmental Programme (House of Commons 2004a). The Committee noted in its report that it was disappointed that the Government had failed to put into place any significant measures to tackle diffuse pollution, and it called for DEFRA to produce a timetable for the implementation of such measures (House of Commons 2004a). In formally responding to the report, the Government stated that it took diffuse pollution "very seriously", and did not accept that slow progress was being made in reaching a decision on how diffuse pollution from agriculture will be tackled. It mentioned a number of initiatives it would be taking (although no actual measures were yet in place at the time the response was written), but omitted producing the requested timetable (House of Commons 2004b).

Evidence was given at an inquiry held by the House of Commons Environment, Food and Rural Affairs Select Committee in 2002, relating to the general improvement of water quality in rivers in England and Wales, which was principally due to the significant investment that had been made in water companies' waste water assets, along with the decline of manufacturing (and hence the decline in discharges from that particular sector). However, generally speaking, there were limited opportunities to appreciably improve the quality from such point discharges any further, so the focus would have to be switched to sources of diffuse pollution (House of Commons 2003a).

Both English Nature and the EA gave evidence that "integrated and widespread action to tackle [agricultural diffuse pollution] is urgently required" to not only meet existing environmental obligations, but also "the more comprehensive demands of new European water legislation". Developing that theme further, the report stated that the Committee was "very concerned about … eutrophication … especially in Sites of Special Scientific Interest", and pointed out that neither DEFRA nor the EA had quantified the extent of the problem of diffuse pollution in any of its public consultation documents. The Committee heard evidence that the primary source of diffuse pollution was agricultural, whilst one organisation went further to say the agricultural sector was the single biggest polluter of water in the country (House of Commons 2003a). The Government stated that, as a result of current and recent consultations relating to diffuse water pollution, it would have developed an Action Plan by the end of 2003-2004 (House of Commons 2003b).

12.11.1.1 Diffuse Pollution from Agriculture

A report produced by Risk & Policy Analysts in 2003 for DEFRA noted that, out of a range of mitigation measures appropriate for tackling the effects of diffuse pollution from agriculture, such as those mentioned above, the actual measures applied would be location-specific, as a number of local factors (such as soil type, geology, hydrology, farming practice etc) would have to be taken into consideration. The report noted that it was essential the river basin management planning process was sufficiently resourced and empowered in order for the right combination of measures to be applied in each area, otherwise "failure to achieve this could result in perverse effects and an unnecessary cost burden where the measures do not match the conditions" (Risk & Policy Analysts Ltd 2003).

This location-specific approach was also advocated in an earlier study by UKWIR, which considered that national policy measures "would be too inflexible and inappropriate to address ... site-specific factors"; it therefore suggested implementing controls on nitrate and pesticide usage by means of land use permits or voluntary agreements (Consultants in Environmental Sciences Ltd 2001).

As far as the EA is concerned though, "good soil management is seen as the single most important factor in bringing about a reduction in diffuse water pollution" as such a reduction "can only be achieved by appropriate land management techniques", and it feels farmers are best placed to "make the greatest improvements by adopting good land management practices" (Environment Agency 2006d, Anonymous 2003).

Proper management of the soil can increase the infiltration of water, and reduce the amount of surface water runoff, with the direct consequence of the amount of nutrients and pesticides ending up in nearby lakes and watercourses is also reduced. However, if infiltration is being encouraged groundwaters will be at greater risk of diffuse pollution unless good soil management is coupled with good nutrient and pesticide management (Anonymous 2003). Furthermore, if land management actions are recommended that are expensive to follow, there is reluctance to take them up (Waters 2005) so, if the actions are voluntary they would need some form of incentive (probably financial), or they would need to put on a regulatory basis.

Accordingly, in recent years DEFRA and its predecessor MAFF have produced for farmers a series of booklets and Codes of Good Practice relating to nutrient management (Dwyer et al. 2003). Most recently, DEFRA produced in 2006 a pesticides strategy (Department for Environment Food and Rural Affairs 2006j).

The EA has also recently appointed a Catchment Officer in each of a number of trial areas, who will work with the farming community to reduce its impact on the aquatic environment. Alongside this initiative, Welsh Assembly Government and DEFRA have developed their own projects for Wales and England respectively (Keirle & Hayes 2007a).

According to a report published by English Nature in 2002, the extent and severity of diffuse pollution is greatly influenced by climate, and this influence can be either adverse or benign. It gives the example of runoff of pollutants from land being higher during periods of heavy rainfall, but higher groundwater levels resulting from increased rain can reduce the relative concentration of such pollutants. The report cautions that the current understanding of diffuse pollution is based on the assumption that the climate remains constant, but the predicted impacts on the hydrological cycle given in Chapter 14 could cause "dramatic changes to the extent of certain diffuse pollution problems" such as leaching of nitrates and pesticides from agricultural land (Dwyer et al. 2003).

12.11.1.2 Diffuse Pollution and the Water Industry

Individually, the sources of diffuse pollution may be small and insignificant, but collectively they can have a significant adverse impact on water quality. In the short-term this may mean that sources of drinking water have to undergo more intensive and expensive forms of treatment, whilst ultimately sources may have to be abandoned (Environment Agency 2006c). For example, 146 groundwater sources have been closed since 1975 primarily because of diffuse pollution, representing a combined loss of at least 425,000 cubic metres in licensed output, or about 7% of current abstraction levels (Environment Agency 2006p).

UK Water Industry Research (UKWIR) has stated that diffuse losses of pesticides and nutrients to groundwater have historically received little attention compared to losses to surface waters (Consultants in Environmental Sciences Ltd 2001). Accordingly, after an extensive study, in 2004 it published its findings of an examination of the overall economic impact of groundwater quality problems (generally arising from diffuse pollution, the significant source of which was from nitrates and pesticides arising from the agricultural sector) on the water industry, and it described the report as "being the most comprehensive to date summarising the situation in the UK" (Chilton et al. 2004). The study found that groundwater quality problems in the UK have cost the water industry £754 million (representing the total of both operating and capital expenditure) since 1975, at 2003 prices, which can be broken down as follows (Chilton et al. 2004):

- £436 million for treatment schemes;
- £134 million for blending; and
- £184 million for replacement water to compensate for source closures.

As at 2004, the UK water industry supplied around 19,000 Ml/day, of which 5,178 Ml/day was derived from groundwater sources. Approximately half of this groundwater (some 2,450 Ml/day) was being blended, treated or replaced because of adverse quality issues (Chilton et al. 2004).

Despite these figures, research undertaken by UKWIR showed that, as far as diffuse pollution from nutrients (nitrate and phosphate) was concerned, "there appeared to be little current research work by water companies or regulators on reducing nutrient inputs by catchment management" (Waters 2005). This appears odd when many environmental stakeholders are in favour of catchment management and the benefits it brings. For example, the EA has estimated that 70% of the improvements required to comply with the Water Framework Directive can be done if farmers adopt good farming practice. In the short-term it is felt this could be achieved by cross-compliance, agri-environment schemes, capital grants, advice and training (Haskins 2003). Other options that could be utilised include cooperative agreements, demonstration farms, taxes and levies, quality assurance schemes and regulation (Dwyer et al. 2003, Environment Agency & English Nature 2004).

12.11.1.3 Diffuse Pollution and the Water Framework Directive

The benefits of catchment management go far beyond helping to underpin the Drinking Water Safety Plan approach which, as has already been mentioned, is not yet even a legal requirement in England and Wales; it can also be employed to meet our obligations arising from the Water Framework Directive (Keirle & Hayes 2007a). WWF-UK states that 93% of rivers, 84% of lakes and 99% of estuaries are at risk of failing to meet good ecological status; the RSPB have come up with similar figures (House of Lords 2006c). If all water bodies are to meet that objective by 2015 it is not difficult to accept that significant time and resources must be committed to adopting a fundamentally different approach to protecting our natural environment, which could be feasibly achievable within a catchment management regime (Keirle & Hayes 2007a).

Perhaps the magnitude of the cost of adopting such an approach is the reason why only 7% of lakes and 31% of rivers in England and Wales were designated and reported to the European Commission in March 2005 as part of the first round of river basin district characterisation (Hansard 2006). Nevertheless, there is already concern that the measures and policies that have been developed so far will not produce results quick enough to ensure compliance with the 'good' status requirement for even these low levels of designation. No less than the EA's Environment Protection Director has stated that groundwater "can take decades or even centuries to recover from pollution", so the chance of achieving 'good' status by 2015 seems small (Environment Agency 2006q). In a joint discussion paper produced by the EA and English Nature in 2004, it is stated that the "clean-up [of the effects of diffuse water pollution] can take many decades" (Environment Agency & English Nature 2004).

Furthermore, the Programme of Measures required by the Directive does not have to be in place until 2012, leaving only three years for it to achieve its environmental objective of 'good' status. As the EA and English Nature have jointly noted, "in many cases, the lead times necessary for changes in farm practice and resulting environmental benefits to take full effect will mean this is insufficient" (Environment Agency & English Nature 2004).

According to Hendy et al, tackling the causes of diffuse pollution "will present significant challenges to the government overall". Furthermore, they feel that "major changes are required to ensure compliance with European and domestic legislation", and that there is "too much contradiction and confusion in agricultural and environmental policy". Only when these issues are addressed do they feel that "any significant changes [will] become evident" (Hendry et al. 2006).

12.11.2 Agri-Environment Schemes

Since World War II, the focus on catchment management has arguably slipped somewhat. The management of the countryside was radically altered by the Agriculture Act 1947, which shifted the production of food from an essentially sustainable system to a highly intensive one aimed at providing a greater level of national self-sufficiency in food production (Environment Agency & English Nature 2004; Robinson and Sutherland 2002; UK Government 1948a). In particular, section 95 of that Act conferred powers on the appropriate Minister to secure production of food by giving directions as to the use of land "for any of the purposes of agriculture". As a direct result, during this post-war period there has been an almost fourfold increase in yield, despite a 65% decline in the number of farms; this trend accelerated with the UK's accession to the European Union in 1973 (Robinson & Sutherland 2002).

Many of the aims of the Agriculture Act 1947 were also encompassed in the Common Agricultural Policy (originally established in 1962), with the result that trends in agricultural practice in the UK are reflected throughout much of Western Europe (Robinson & Sutherland 2002).

Accordingly, most of the problems associated with eutrophication and diffuse pollution can be traced back to the time of this enactment. Indeed, in a joint discussion paper, English Nature and the EA state that it is this intensity of agricultural production, arising from national and European policy over the last 50 years, "that has created the large majority of the pollution problem we see today" (Anonymous 2003).

Eventually, the European Union decided that action was required and, after intensive protracted negotiations, the Common Agriculture Policy was overhauled in 2003 so that financial support was no longer directly proportional to production. The resultant Single Farm Payment was instead linked to meeting the requirements of 'cross compliance', which involves producers complying with legislation and demonstrating that their land is in "good agricultural and environmental condition" (Chartered Institution of Water and Environmental Management 2006b). As part of these reforms, Member States were also required to implement voluntary agri-environment schemes, and the schemes introduced by DEFRA and the Welsh Assembly Government are mentioned in Section 12.9.2.

Also, during the 50 or so years during which intensive agriculture was the norm, the focus on water management during the same period was largely on water quantity, to the detriment of water quality. For example, the fundamental principle of flood defence until fairly recently has been to ensure that, after a rainfall event, as much water as possible is removed from the area as quickly as possible, with very little regard to the consequential effects on water quality. Only now, with the advent of strategies such as Catchment Flood Management Plans (see Section 13.4.4) is the fact that water quality and water quantity are inextricably linked being recognised (Viessman & Hammer 1993).

As involvement with any agri-environment schemes is on a voluntary basis at present, only about 7% (as at 2001) of England's farmers have land within schemes. There are also significant gaps within these schemes – such as diffuse pollution control – which should be addressed. In response to this latter fact, English Nature recommended establishing a pilot project to encourage applications from groups of farmers in priority catchments, although it was unsure whether this recommendation was actually subsequently implemented (Reid & Grice 2001).

In order to improve the efficacy of agri-environment schemes English Nature (one of the predecessor bodies of Natural England) also recommended that these schemes need to be linked with other measures (like quality assurance schemes, cross compliance, nutrient budgeting and catchment management planning) in order to successfully contribute to combating diffuse pollution (Vickery et al. Unknown).

12.11.3 The European Landscape Convention

DEFRA produced a Regulatory Impact Assessment in July 2005 in order to assist the Government to decide if it should sign the Convention. In it, DEFRA noted that "landscape management is increasingly integrated into sectoral land management policies including those for agriculture and forestry", but that "many parts of the UK are not yet covered by agri-environment and woodland management schemes which provide support for landscape management". Once the Convention has been ratified by Parliament, the Government would be required to extend agri-environment policies for landscape management from its current coverage of 10% of farmed land in the UK to something over 50%. Although there would be a cost associated with this, it would be more than offset by the reduction in financial subsidies under the Common Agricultural Policy (as agri-environment schemes tend to encourage lower levels of farm output) (Department for Environment Food and Rural Affairs 2005a).

12.12 Limitations to Implementation of a National Catchment Management Strategy

Despite the obvious benefits of catchment management in tackling the effects of diffuse pollution, it is often complex and challenging because of the amount of information that must be processed and the many tradeoffs to be considered. it therefore necessitates a careful analysis and integration of economic and ecological implications in order to achieve a sustainable outcome (Randhir 2007).

Another key stumbling block to effective catchment management though is that catchment boundaries do not generally coincide with administrative, property and political boundaries (Randhir 2007). Nevertheless, the management of land and water resources on a catchment-wide basis makes more sense than along (often artificial) political boundaries, as catchments represent a natural way of dividing the landscape for management and planning purposes (Randhir 2007). DeBarry agrees with this view, making the point that streams and rivers rarely follow political boundaries, and so he asserts that managing the whole is better than managing or correcting the sum of its parts (DeBarry 2004); this aspect of catchment management is considered further in Section 12.8. DeBarry further develops his idea by stating that a catchment is like an interdisciplinary puzzle (consisting of the biological, physiographic, hydrologic, hydraulic, political and social), and that the catchment management plan puts all the pieces of this puzzle together (DeBarry 2004).

According to Batchelor, the main reason why the approach to catchment management in England and Wales is not as well advanced as it is in certain other European countries is that "there is far less recognition of the intimate links between land use, land management and different components of the hydrological cycle". He feels this is due to two main reasons (Batchelor 1999):

1) No single body within the UK has overall control of agriculture and water, as the remits for these two areas are split between government departments, regulatory authorities and privatised water companies;
2) It is only very recently that environmental matters have featured prominently on the political agenda in the UK.

This first point has also been identified as a Europe-wide weakness within the water industry by the Water Supply and Sanitation Technology Platform in the Vision Document of its Water Management Thematic Working Group, and so a primary focus of this Working Group is both horizontal and vertical integration (Water Supply and Sanitation Technology Platform 2005b).

The Working Group recognises there are numerous stakeholders in various sectors (agricultural, industrial, domestic etc) across Europe involved with the management of water resources, each of which manages water in accordance with its own priorities and agenda, which it states has led to "conflicting, fragmented and un-coordinated approaches to water allocation" (Water Supply and Sanitation Technology Platform 2005b). Also – echoing Batchelor's view of no single body within the UK having overall control of agriculture and water – the Working Group feels that when water is managed in a fragmented, even polarised manner, nature often does not have a 'voice', leading to solutions being adopted for particular problems that do not take into account the wider impacts of the solutions on the environment, which may well have detrimental effects; this is why the Working Group is promoting an integrated approach involving all of the water environment's stakeholders in order to achieve sustainable development (Water Supply and Sanitation Technology Platform 2005b).

Another factor that inhibits the implementation of a national catchment management strategy in this country is the lack of alignment amongst the current management boundaries of the water supply only companies, the water and sewerage companies, the EA[9] and local authorities. Where developments straddle these boundaries, it is the view of CIRIA that this can hinder sustainable water management and communication can be complicated because of the number of organisations involved and their sometimes conflicting priorities (Samuels et al. 2006).

---

[9] The current management structure of the Environment Agency consists broadly of Areas, supra-Areas (see footnote 12), Regions, and Head Office, and there are a number of instances where its internal management boundaries are not aligned, either between or across disciplines. For example, the activities of its Flood Risk Management and Environmental Management disciplines often cut across catchments and the activities of other disciplines, such as water resources and water quality.

This lack of boundary alignment and horizontal and vertical integration could also present a problem during the ongoing implementation of the Water Framework Directive, which requires that the water environment be managed on the basis of "meaningful environment boundaries" (i.e. river basins). Although CIRIA concedes that cross-boundary developments are not common at present, such issues may increase in number as the implementation of the directive is fully underway (Samuels et al. 2006).

As far back as 1996, at the time of the last reorganisation of management boundaries and responsibility for the environment, at an international conference on catchment management it was noted that "arbitrary government boundaries which fragment catchments create serious impediments to effective action; they undermine catchment consciousness and impede integrated catchment management" (Tané 1996). As was shown in Section 10.1, the development to date of regulations in England and Wales has tended to follow disciplines and the responsibilities of individual government departments and national regulators. DeBarry therefore asks the pertinent question: Why are different aspects of water resources regulated differently (DeBarry 2004)?

Perhaps we should therefore be looking overseas at the catchment management models adopted by New Zealand and Australia to learn how catchments may be afforded greater protection and managed in a more holistic, integrated way.

In New Zealand, the boundaries of regional councils were more closely realigned with catchment boundaries, so the catchment could be the focus of all water-based and environmental activities. The catchment, to the point of abstraction, is the domain of the Resource Management Act, which is administered by the Ministry for the Environment and, at the operational level, by the regional councils. From the point of abstraction to the consumer's boundary is the domain of the Ministry of Health, and water suppliers have responsibility for this part of the water supply chain (Environmental Science & Research 2006).

The State of Western Australia has been even bolder, and on 2 January 2006 established a new government department – the Department of Water – to provide a whole-of-government approach to water management (Department of Water 2006).

Elsewhere in Australia, Catchment Authorities have been established to manage specific catchments and to supply bulk water to its customers, such as water companies and local councils (Sydney Catchment Authority 2006).

13 THE MANAGEMENT OF WATER RESOURCES IN ENGLAND AND WALES

13.1 Introduction

Wales' plentiful water resources are a consequence of the high rainfall experienced in the Principality[10]. On average, Wales receives 1,310mm of rain each year; after accounting for evapo-transpiration, the amount of rainfall left (called the effective rainfall) is about 730mm. In 1997, about 25% of this effective rainfall was taken from the environment in Wales for human use. The EA's regional water resources strategy for Wales therefore concludes that, although there are some areas in the Principality where improvements to the water environment are necessary, there is no need for new large reservoir schemes to support demand (Environment Agency 2001d).

Nevertheless, the soils, geology and landscape within the Principality provide few natural stores for this water, so during extended dry periods supplies can quickly become scare and river flows can fall to relatively low levels (Environment Agency 2001d, Welsh Assembly Government 2003).

Although over 150 storage reservoirs have been developed throughout Wales, and the available groundwater is exploited extensively, demand for water can still outstrip supply. This is particularly the case in rural areas because of the expense of moving water over large distances. Climate change can only increase the extent and frequency of supply shortages (Welsh Assembly Government 2003).

It is therefore apparent that these water resources need to be managed – sometimes actively, other times in a passive sense – in order to balance the competing demands of various stakeholders and the wider environment. From a legal perspective, the water in England and Wales is owned by the nation, whilst the management role is

---

[10] According to Plaid Cymru's Water Policy Study, the Principality's water resources have been exploited by its neighbouring English cities because of this apparent abundance of water (Owen 2002).

fulfilled on the nation's behalf by the EA; it is presumed the same legal principle applies in Scotland, and water resources north of the border are managed by the Scottish Environment Protection Agency.

According to Holmes et al the EA manages water through integrated catchment management, but the reality is much more simplified than that (Holmes et al. 2005). The EA undertakes routine water management activities which fall into four broad categories:

- Flood risk management (formerly referred to as flood defence);
- Sampling and monitoring (which covers such programmes such as the General Quality Assessment (GQA) scheme (see Section 13.3));
- The determination of abstraction licence applications (see Section 9.9.1); and
- The determination of discharge consent applications.

13.2 Management Structure for Water Quality and Water Resources

Within the overall management structure of the EA identified in Section 5.4, each discipline (such as water resources and water quality[11]) has a Policy and Process Team within the head office that produces policies and provides advice and procedural guidance to the operational staff in the Area offices (Samuels et al. 2006).

With respect to water resources planning, this responsibility is split between three teams:

- Wales (with responsibility for Dŵr Cymru Welsh Water, Dee Valley Water and Albion Water);

[11] Hydrometry was historically always part of the water resources function. However, within the last few years it was established as a discipline in its own right within the Environment Agency structure until October 2004, when hydrometry was combined with the telemetry element of the mechanical and electrical discipline to form Field Monitoring and Data.

- A supra-Area[12] team covering the north of England (with responsibility for Northumbrian Water, Yorkshire Water, South Staffordshire Water, Cambridge Water, Essex & Suffolk Water, North East Water, United Utilities, Severn Trent Water and Anglian Water); and
- A supra-Area team covering the south of England (with responsibility for Bournemouth & West Hampshire Water, Sutton & East Surrey Water, Tendring Hundred Water, Three Valleys Water, Wessex Water, Cholderton & District Water, Bristol Water, South West Water, Southern Water, Folkestone & Dover Water, South East Water and Thames Water).

The water resources planning teams – in conjunction with the Area water resources teams – consider, amongst other things, the water resources management plans (see Section 9.9.2) and the drought plans (see Section 9.9.3) produced by water companies.

Other region-wide issues relating to water quality and water resources are dealt with by a Regional Strategic Unit based in each Regional office (in Wales, this Regional Strategic Unit is known as 'Strategic Unit Wales') (Samuels et al. 2006).

The EA also has a Water Demand Management Team (formerly the National Water Demand Management Centre), which considers national and international water resources, demand management and water conservation (Environment Agency 2006s). This Team provides four main services (Samuels et al. 2006):

- The provision of advice to the EA, the Welsh Assembly Government and the UK Government departments in London on demand management and water conservation issues;
- Steering the EA's research and development programme relating to demand management and water conservation;
- The dissemination of advice and information, and the promotion of best practice issues, by means of media events, publications and seminars; and

[12] The name adopted by the Environment Agency for a team that covers an area greater than that covered by an Area office, but which is not part of the Agency's Regional structure.

- The development of demand management methodologies and the implementation of technical assessments.

- The topics covered by the Water Demand Management Team include (Samuels et al. 2006):
- Levels of service;
- Tariffs and economic incentives;
- Water use restrictions;
- Industrial and agricultural demand;
- Demand forecasting;
- Education on efficient water use;
- Leakage from customer and water company pipes;
- Domestic and non-domestic metering; and
- Water-saving technology and management.

13.3 Qualitative Management Activities

The EA uses a variety of standards and targets to help it take action to protect and improve water quality. They have a number of uses, such as:

- Determining what conditions must be imposed on discharges in order to protect water quality;
- Assisting the Agency to check national progress in protecting water quality; and
- Prioritising its work programme, according to where action is needed.

Most of the standards (for example those concerning bathing waters, habitats, shellfish and freshwater fish) support the requirements of European Directives. Others, like River Quality Objectives, stem from special requirements in England and Wales (Environment Agency 2006h).

The EA utilises a national monitoring scheme for rivers and canals called the GQA scheme. This provides a general measure of four aspects of water quality – biology, chemistry, nutrients and aesthetic quality – irrespective of their intended use

(Environment Agency 2006n, Conlan et al. 2006). The GQA scheme is designed to provide an accurate and consistent assessment of the state of water quality and changes in this state over time, and it allocates one of six grades (A being the best quality, and F being the worst) to each stretch of water (Environment Agency Unknown).

One of the ways that water quality is protected and improved is by means of discharge consents, which set limits on the quality and volume of liquid waste that industry or a householder can discharge to the water or land (see Section 9.6). The EA monitors the discharges to ensure they comply with the conditions laid down in the consent (Environment Agency 2006e).

13.4 Quantitative Management Activities

The EA monitors how much water is in the environment by means of a hydrometric network of gauging stations, river level stations, rain gauges, climate stations and observation boreholes. If someone wishes to take water from the environment they generally have to apply for an abstraction licence from the EA, which stipulates how much and when they can take the water (Environment Agency 2006t).

There is a legal distinction in the river network between 'main rivers', which are the strategically important waterways that drain a catchment, and 'ordinary' watercourses, which cover everything else. Main rivers are not always the biggest rivers in a catchment but they are hydraulically important to how water drains a catchment – the definition also extends to any structure or appliance for controlling or regulating the flow of water in, into or out of the main river. They are defined by lines drawn on a statutory map held by DEFRA (for England) or the Welsh Assembly Government (for Wales); copies of these maps are kept at the EA's Area offices (Environment Agency 2006l, Environment Agency 2006i).

The EA has permissive powers, but not a duty, to carry out flood defence works on main rivers, whilst local authorities (and, where relevant, Internal Drainage Boards) have similar powers to carry out works on ordinary watercourses. In some parts of the country there are separate Internal Drainage Boards (see Section 5.7) who carry out works on their scheduled watercourses (often known as 'main drains'). These are primarily agricultural areas with special drainage problems (Environment Agency 2006l, Environment Agency 2006i).

Ordinary watercourses which have the potential to put large numbers of people and property at risk of flooding are called 'critical ordinary watercourses'. Over time, responsibility for critical ordinary watercourses is being transferred from local authorities to the EA (Environment Agency 2006l).

The EA has a statutory duty to secure the proper and efficient use of water resources in England and Wales (Barker 2006). This is no easy task considering the UK has less water available per head than Afghanistan, so it has developed a number of strategies and policies to enable it to do this (the main ones are briefly reviewed in the following sub-sections) (Pearce 2006).

13.4.1 Water Resources Strategy

In 2001 the EA published its water resources strategy for England and Wales, establishing the principles for the management of water resources over the next 25 years (Environment Agency 2001c). Alongside this document, the EA also produced eight regional documents – seven for each of its English Regions, and one for Wales – which provided further detail for the management of water resources.

Overall, the strategy stated that resource development of about 1,800 Ml/d would be required by 2025 for the whole of England and Wales which, after environment improvements have been taken into account, would realise an additional 1,100 Ml/d. Wales is arguably in a far better position than most of its English regional counterparts, in that the amount it has allowed for resource development is up to 7 Ml/d, whilst water savings of up to 27 Ml/d are forecasted (Environment Agency 2001c).

13.4.1.1 National Rivers Authority's Water Resources Development Strategy

Although this was the first such strategy produced by the EA, its roots could be found in a water resources strategy for England and Wales produced in 1993 by one of the Agency's predecessor bodies, the NRA. Following on from this original strategy, the NRA published a water resources development strategy in March 1994, whilst the EA this time round has chosen not to produce a similar, updated document, instead choosing to incorporate resource development issues within its water resources strategy.

One of the specific objectives of the NRA's water resources development strategy was to identify development options and to determine whether they were required within the 30-year timeframe of the document (National Rivers Authority 1994).

Although the NRA's document stated that climate change could influence its water resources development strategy, it noted that there was "insufficient evidence available to allow assumptions [about its impacts] to be incorporated at the present time". The NRA listed a number of conventional water resources development options (including the partial redeployment of Vyrnwy Reservoir to regulate the River Severn) but concluded that "there is a strong possibility that demands can be managed to avoid the need for large scale water resources developments over the next 20 years or so". However, certain major resource developments would be required under some demand scenarios (such as in East Anglia and the Thames catchment), so the strategy noted that "early planning ... is necessary" (as is notes "recent experience has shown that it can take between 15 and 25 years to investigate, promote and construct a major new water resource in the UK") (National Rivers Authority 1994).

Finally, mention is made in the strategy of the NRA's policy of catchment management planning, and it is noted that it is "essential" for the strategy to be integrated into future catchment management plans (see Section 12.8.1) (National Rivers Authority 1994).

13.4.2 Catchment Abstraction Management Strategies

In 1998 the Government decided to undertake a review of the abstraction licensing system in England and Wales, and they issued a consultation document inviting views and comments (Department for Environment Transport and the Regions & Welsh Office 1998). After the consultation had been concluded, the Government published its proposals, outlining its decisions, in March 1999 (Department for Environment Transport and the Regions & Welsh Office 1999). One of the principal proposals contained in this document related to the development of Catchment Abstraction Management Strategies (CAMS).

The EA in 2001 published its detailed proposals for the productions of CAMS and the management of time-limited licences (Environment Agency 2001b). CAMS make more information on water resources publicly available and allow the balance between the needs of abstractors and those of the aquatic environment to be determined in consultation with the local community and interested parties (Environment Agency 2001a). CAMS is also seen to be part of the EA's Water Resources Strategy (Calder 2005).

Since then, the EA's abstraction licensing manual has been revised and updated to reflect the requirements and objectives of CAMS. In order to support the sustainable water management and water efficiency aims of CAMS, the EA also commissioned WRc to provide benchmark data and information for a number of industrial and agricultural sectors, so that its licensing officers could ensure that abstractors were using the water optimally and that any further requests for water were reasonable (Rees et al. 2003).

13.4.3 Restoring Sustainable Abstraction Programme

The Restoring Sustainable Abstraction (RSA) Programme was established in 1999 in order to address the concerns that the unsustainable abstraction of water from surface waters and groundwaters could be having a detrimental affect on water bodies, including sites of national and international conservation importance (Environment Agency 2006m, Environment Agency 2006v).

The RSA Programme is a way of prioritising the sites for investigation, examining the concerns raised using a methodical approach, and identifying cost-effective solutions to return the abstraction to a sustainable basis (Environment Agency 2006a, Environment Agency 2006v).

It is worth noting that only sites that are thought to be adversely affected by abstractions are included in this programme; sites thought to be affected by drought, water quality problems or land drainage are to be dealt with by other means (Environment Agency 2006k).

13.4.4 Catchment Flood Management Plans

The traditional approach to flood defence schemes in the UK has been to consider each scheme on a location-specific basis, without much – if any – regard to issues elsewhere within the catchment. Realising that a more strategic approach to flooding was required, the EA is developing catchment-wide flood risk management policies (Halcrow year unknown).

Catchment Flood Management Plans (CFMP) are high-level documents which form the basis of an integrated approach to flood risk management across the whole of a catchment, with a 50-year horizon. A CFMP will identify the significant factors influencing flood flows and flood risk, and assess how they may change over time. Once a plan has been produced for a catchment, it will outline sustainable flood risk management policies that will provide a balance between cost effectiveness, social needs, demands upon land use for development and the environment over the lifespan (50 years) of the plan (Environment Agency 2006k).

Of particular interest – from a water resources/catchment management perspective – is the fact that CFMPs will guide the future land use and development planning of the catchment, taking due account of the flood risks and provide information to decision makers (Halcrow year unknown). CFMPs may therefore play a significant role in protecting the quality of the natural waters within a catchment.

13.4.5 Drought Plan

The EA is responsible for monitoring, reporting and acting to reduce the impact of drought on the environment and people. As such, it recently produced draft drought plans for consultation for each of its areas and English regions, one for Wales, and a strategic document covering the whole of England and Wales. The plans set out the Agency's roles and responsibilities, and how it will manage water resources in a drought (Environment Agency 2006j).

These plans complement the drought plans produced by each water company, which detail the range of actions a water company may use to manage their water resources during a drought in order to ensure security of public water supply (Environment Agency 2006r).

13.4.6 Water Level Management Plans

Although not strictly a means for managing water resources, Water Level Management Plans do have some water resources implications, hence they are mentioned here for completeness. These Plans were essentially designed to meet the needs of vulnerable ecosystems which depend on water levels being maintained at certain types of the year; they are usually drawn up in association with the national statutory advisor for nature conservation (either the Countryside Council for Wales or Natural England), along with other stakeholders as appropriate (such as the RSPB).

13.5 Discussion

In July 2005, the House of Lords' Science and Technology Select Committee (one of the four permanent investigative committees of the House of Lords (House of Lords 2005c)) appointed a Sub-Committee to consider water management in England and Wales (House of Lords 2005d). The resultant report was published on 6 June 2006 (House of Lords 2006a, House of Lords 2006c), and the Government published its response to the report the following August (UK Government 2006b).

The report's key message was that "the Government must work harder to integrate environmental, social and economic interests in the management of water" (House of Lords 2006a). In the Sub-Committee's view, "the root of the problem is the Government's failure to ensure properly integrated water management". Numerous other recommendations and observations on various aspects of the water industry were made in the report, but only those comments that fall within the scope of this thesis are mentioned below.

It was also the view of the report's authors that the responsibility for water management is "dispersed and unclear". They therefore call for "clearer lines of responsibility and greater accountability". In their view water management should be "a partnership in which the water companies, the regulators, Government and the consumer can all engage in a constructive dialogue". Consequently, the recommendation is made for long-term integrated water management plans to be drawn up by regional boards – one for each River Basin District required by the Water Framework Directive – comprised of local representatives of the EA, the Consumer Council for Water and Ofwat. This would have the twin advantages of (House of Lords 2006c):

- Ensuring the security of supply is maintained in such a way as to reflect the needs and pressures of each individual region; and
- Enabling all three components of sustainable development – environmental, social and economic – to be factored into the setting of water prices far more effectively.

Although both the Government and the EA advocate a twin-track approach of demand management and resource development, the Sub-Committee felt that both were biased towards the former, and were neglecting the latter. The report therefore makes the observation that "this is a damaging state of affairs that could endanger security of water supply". One of the key objectives of the enquiry was to establish which of the regulators was responsible for ensuring that essential resource development was undertaken; it transpired that none of them had this responsibility. The report therefore recommended that the EA fundamentally changes its current stance so that it takes a "realistic approach towards the need for resource development". It goes on to make the reasonable observation that the Agency's "environmental priorities should not cloud a responsible judgment of whether [a water company's] resource development plans are necessary, particularly since the EA is responsible for advising Ministers". It must therefore "not allow its environmental priorities to impact adversely upon the need to ensure security of supply".

13.6 Water Management and Sustainability

The UK Government has given the EA, Ofwat and the Consumer Council for Water the responsibility to promote sustainable development. However, as the House of Lords Science and Technology Select Committee noted, sustainability is still an "uncertain, elusive and contested concept" (House of Lords 2006c). The Committee goes on to state that at present neither the water industry nor the regulators have an agreed methodology to include sustainability within the decision processes relating to water management, preferring to concentrate on those aspects of sustainability important to their sectors of activity. Nonetheless, the EA believes that the principles of sustainable development should be at the centre of the water resources planning process (Barker 2006).

In 2006 CIRIA produced a report on sustainable water management in land-use planning, in which they considered water management to cover water supply, waste-water treatment, surface water drainage and environmental protection. In this report CIRIA defined sustainable water management as:

> *"The management of water to support the development of the economy, providing water for people, agriculture, commerce and industry, while protecting and improving the environment for the future."*
>
> (Samuels et al. 2006)

- Issues that may need to be considered in delivering the sustainable management of water include (Samuels et al. 2006):
- Reducing point source pollution at source;
- Processing waste water to an adequate and appropriate standard;

- Maintaining river water quality;
- Effective management of the demand for water;
- The use of sustainable drainage systems;
- Raising awareness of the impact that people's consumption of water has on the environment and the vital role they have to play in sustainable water management;
- The efficient use of water;
- Ensuring the protection of rivers and groundwater sources; and
- The protection of floodplains and their functions.

Catchment management can therefore be viewed as a strategic – and possibly the most important – element of sustainable water management, as it encompasses many of the issues identified above; the subject of catchment management is dealt with in much greater depth in Chapter 12.

13.6.1 Catchment Abstraction Management Strategies

CAMS operate on a six-year review cycle, which coincides perfectly with the review cycle of the River Basin Management Plans required by the Water Framework Directive. However, it has been suggested that this should be shortened to five years, so that it is coincident with the AMP planning cycle.

The impacts of climate change are not currently included in the CAMS methodology for assessing available water resources or for determining abstraction licence applications. This perceived oversight could be due to the relatively short time-span of the CAMS cycle – whether it remains at six years or is shortened to five – the reason being that the timescale is far too short for any pre-emptive or mitigating measures to have any effect. Nevertheless, a report produced in 2001 by the Stockholm Environment Institute on the Climate Change and the Demand for Water project stated that the impacts of climate change would be significant in certain EA regions (Downing et al. 2003); it should therefore be considered in the context of CAMS.

Another major deficiency was highlighted in a recent House of Lords Select Committee report; the fact that CAMS does not view the water resource issue in terms of water quality implications. The report's authors therefore recommended that the EA consider the water quality implications of each CAMS plan (House of Lords 2006c).

Entec are currently undertaking a review of the CAMS methodology with a view to making proposals for improvements for the second CAMS cycle which will start shortly, so it is possible these deficiencies will be highlighted by them and acted upon (Keirle 2006b, Keirle 2006c).

13.6.2 Catchment Flood Management Plans

CFMPs represent a significant change in policy in how we deal with floods in England and Wales. Historically, floods have only been considered from a quantitative point of view; the qualitative element was often frequently ignored.

It has long been recognised that the degree to which rainfall is captured by, and released from, the catchment affects the frequency, duration and magnitude of flooding within it. Now it is accepted that a well-managed catchment will not only reduce flood flows, but it will also have less impact on – or even improve – water quality and biodiversity (Hunt 2004).

Small catchments in particular are highly sensitive to the effects of changes in land use and other overland flow factors; therefore, appropriate forms of land management can provide a particularly effective method of flood mitigation (Hunt 2004).

14 THE POTENTIAL IMPACTS OF CLIMATE CHANGE

14.1 Introduction

"Climate change is the most severe problem that we are facing today – more serious even than the threat of terrorism."

Sir David King, Chief Scientific Advisor to the UK Government

(House of Lords 2005a)

It is now widely accepted that climate[13] change is already happening and further change is inevitable; over the last century (between 1906 and 2005), the average global surface temperature rose by about 0.74°C. This has occurred in two phases, from the 1910s to the 1940s and more strongly from the 1970s to the present (Intergovernmental Panel on Climate Change 2007a).

The 1990s were the warmest decade on record, and nine of the ten warmest years in a dataset jointly compiled by the Hadley Centre and the University of East Anglia's Climate Research Unit have occurred in the period 1995-2004 (Dabrowski et al. 2005). In its recently released Fourth Assessment Report the Intergovernmental Panel on Climate Change (IPCC) has updated these statistics slightly by stating 11 of the 12 warmest years on record have occurred in the past 12 years (Intergovernmental Panel on Climate Change 2007a).

Many studies into the detection and attribution of climate change have found that most of the increase in average global surface temperature over the last 50 years is attributable to human activities (Intergovernmental Panel on Climate Change 2001b).

It is estimated that, for the 20th Century, the total global mean sea level has risen 12-22cm (Three Regions Climate Change Group 2005, Intergovernmental Panel on

[13] Climate is defined by the Hadley Centre as being "the description of the long-term averages of weather, usually taken over a 30-year period"; the Hadley Centre opened in May 1990 and is a division of the Met Office, and is the UK Government's research centre into climate change (Hadley Centre for Climate Change and Prediction 2005a, Dale 2004).

Climate Change 2007a). This rise has been caused by the melting of snow cover and mountain glaciers (both of which have declined on average in both hemispheres) (Intergovernmental Panel on Climate Change 2007a), and the thermal expansion of sea water. Observations since 1961 show that the average temperature of the global ocean has increased to depths of at least 3,000m and that the ocean has been absorbing more than 80% of the heat added to the climate system (Intergovernmental Panel on Climate Change 2007a).

The IPCC (IPCC)[14] also notes that observations over the past century show that changes are occurring in the amount, intensity, frequency and type of precipitation globally (Intergovernmental Panel on Climate Change 2007a), and that further changes are likely (Roesch & Stewart 2006).

With regards to future climate change, based on six emissions scenarios, the IPCC has stated that, for 2090-2099 relative to 1980-1999, the best estimate for projected global average surface warming lies within the range 0.6 to 4.0°C, whilst the projected sea level rise lies within the range 0.18 to 0.59m (Intergovernmental Panel on Climate Change 2007a).

14.2 Modelling Climate Change

In order to estimate the impacts of global warming on climate, a mathematical model called a Global Circulation Model (GCM) has to be constructed of the complete climate system, which must include the atmosphere, oceans, land and cryosphere (glaciers and ice sheets). This model is a mathematical description of the Earth's

---

[14] At this point it is worth mentioning the role and remit of the IPCC, which was established in 1988 by the World Meteorological Organisation and the United Nations Environment Programme; its role is to "assess on a comprehensive, objective, open and transparent basis the scientific, technical and socio-economic information relevant to understanding the scientific basis of risk of human-induced climate change, its potential impacts and options for adaptation and mitigation" (Intergovernmental Panel on Climate Change 2007b). The IPCC does not carry out research nor does it monitor climate related data or other relevant parameters. Since 1998 it has produced four Assessment Reports (the most recent of which was published in 2007), which are based mainly on peer reviewed and published scientific/technical literature (Intergovernmental Panel on Climate Change 2007b).

climate system, firstly broken down into layers (both above and below sea level) and then each grid is broken down into boxes or 'cells' (Hadley Centre for Climate Change and Prediction 2005a).

A number of research centres around the world have developed their own versions of GCMs; the Hadley Centre's latest model is known as the Hadley Centre Global Environmental Model version 1 (HadGEM1). The horizontal resolution of each cell within this model is 135km x 135km, which is a significant improvement on their previous model's (HadCM3) resolution of 270km x270km (Hadley Centre for Climate Change and Prediction 2005a). However, in order to start assessing the regional impacts of climate change, much smaller scales need to be used, hence the need for developing Regional Climate Models (RCMs) which are driven by the outputs from the GCMs. These RCMs generally utilise 50km x 50km cells, and only look at part of the globe (typically 5,000km x 5,000km, equivalent to placing a box around Australia) (Hadley Centre for Climate Change and Prediction 2002). The Hadley Centre is currently using its third generation RCM, known as HadRM3, and it has a horizontal resolution of 50km, with 19 levels in the atmosphere (from the surface to 30km up into the stratosphere) and 4 levels in the soil (Dale 2004).

Because of the resourcing requirements of RCMs (both in terms of IT infrastructure and appropriately personnel), the Hadley Centre has configured the HadRM3 so that developing countries may produce their own climate change predictions and scenarios. The result is a product called PRECIS, which may be run on a fast PC (Hadley Centre for Climate Change and Prediction 2004, Hadley Centre for Climate Change and Prediction 2002).

14.3 Impacts of Climate Change in the UK

Here in the UK, we are apparently already experiencing the consequences of climate change, as changes in precipitation have been detected from actual measurements of rainfall dating back to 1766 in the England and Wales Precipitation Record, which shows an increase in winter rainfall and a decrease in summer rainfall (Hadley Centre for Climate Change and Prediction 2005a). Considering data gathered since

1914 to 2006, three of the five worst rainfall droughts have occurred since 1990 (Wade et al. 2006).

Looking to the future, the main impacts of climate change on the UK are predicted to be (Institute of Environment Science University of Wales Bangor et al. 2000a; Marine Climate Change Impacts Partnership 2006; National Farmers' Union 2005; Stern 2006; UK Climate Impacts Programme 2002; Wade et al. 2006):

- Possible higher winds;
- Rising sea levels and increasing storminess and wave height, leading to greater risk of coastal flooding and erosion;
- Hotter, drier summers;
- Possible intensification of the urban heat island effect;
- Increased evaporation from the world's oceans due to higher air temperatures (giving rise to an increase of up to 10% water vapour in the atmosphere on an average day), leading to an intensification of the water cycle;
- Warmer, wetter winters, leading to increased flood risk;
- So-called 'short' droughts (lasting one or two seasons) will increase significantly by the 2050s and be commonplace by the 2080s; and
- Extreme rainfall events may happen twice as often by the 2080s.

14.3.1 Impacts of Climate Change in Wales

Although the UKCIP research programme considers the impacts of climate change at both the national and the regional level, the National Assembly for Wales considered that UK-led policies would not fully solve the problems of Wales for a number of reasons, hence it decided it should also be considering the impacts of climate change. The facts that helped the National Assembly for Wales to come to this decision include Wales' position as a net exporter of water to England, and its ability to change is limited by the relatively low mean Gross Domestic Product and poorer skills base compared with other parts of the UK (Institute of Environment Science University of Wales Bangor et al. 2000b).

Accordingly, the University of Wales Bangor, the University of East Anglia, the Centre for Ecology and Hydrology (Bangor) and ECOTEC Research and Consulting Ltd produced a scoping report for the National Assembly for Wales in May 2000 of the possible impacts on Wales of climate change up to 2080 (Institute of Environment Science University of Wales Bangor et al. 2000a). This report represented the first step of fully integrating the impacts of climate change into the Assembly's commitment to sustainable development (see Section 3.2.1).

The report noted that modelling undertaken by the UK Climate Impacts Programme predicts summer rainfall will reduce by 7-14%, whilst winter rainfall will increase by 7-24% (Institute of Environment Science University of Wales Bangor et al. 2000b). This is in line with precipitation observations made in Wales over the last century, which showed that summer rainfall has fallen by 15%, whilst winter rainfall has increased by 10% (Welsh Assembly Government 2003). By 2080, the annual precipitation experienced in the Principality will increase by between 2 and 9% (Institute of Environment Science University of Wales Bangor et al. 2000b)[15].

Sea levels around Wales are predicted to rise by either between 11cm and 71cm (Welsh Assembly Government 2003), or between 18cm and 79cm. the report notes that a significant proportion of coastal land in Wales is less than 1m above current sea level, so the frequency of flooding of low-lying areas is expected to increase greatly[16] (Institute of Environment Science University of Wales Bangor et al. 2000b).

---

[15] These trends were confirmed qualitatively, to a certain extent, by Holt in 1993 when he undertook trend analysis using the least squares method on long-term rainfall data obtained from rainfall stations within Dŵr Cymru Welsh Water's area of supply, which appeared to show a seasonally controlled response. The majority of his results pointed to a statistically significant increase in precipitation during the spring and autumn, and a decline in summer rainfall, but results for winter rainfall were inconclusive. However, Holt's analysis was limited to only eight sites, as these were the only ones that had records exceeding 50 years in length (up to a maximum of 110 years for one site) (Holt 1993).

[16] The figures relating to predicted changes in precipitation and sea level were obtained from the UKCIP98 scenarios derived from a Global Circulation Model (see Section 14.2) with a spatial resolution of 250km x 250km, which meant that Wales was represented by only one grid cell. The scenarios therefore could not differentiate between lowland and mountainous areas within the Principality, nor coastal and inland areas. However, the authors of the report undertook a preliminary examination of results obtained from the Hadley Centre's Regional Climate Model (RCM) HadRM2

14.4 Impacts of Climate Change on Water Resources and Water Quality

The climate affects all aspects of the water cycle so a change in the climate is likely to affect the quality, quantity, timing, location and reliability of water supplies, along with ecosystems that rely on one or more of these aspects of water supplies (Frederick 2002). Four years after Frederick espoused that view, results of a review and synthesis showed that there was "increasing evidence" for intensification of the global water cycle, although there is "still considerable uncertainty related to the rate of warming and its impacts on UK river flows" (Vidal & Wade 2007).

HR Wallingford has attempted to demonstrate whether or not climate change has already had an impact on river flows (HR Wallingford Ltd 2005b). Although they have found a small number of upward trends in autumn/winter runoff, they feel it is too early to attribute them to climate change over and above natural variability. However, it is generally accepted that within the UK we will experience increased demand for water, changes in seasonal river flow and groundwater recharge, and more frequent droughts (HR Wallingford Ltd 2005a). Other, specific, effects on water resources and water quality within the UK – and, by extension, the water industry – that have been predicted include the following (CAG Consultants and Oxford Brookes University 2004; Fenn 2006; National Farmers' Union 2005; Roesch and Stewart 2006; Vidal and Wade 2007; Wade et al. 2006):

- Deterioration in summer surface water quality, due to increased evapo-transpiration, lower flows and rivers becoming warmer, making the management of water treatment works (and subsequent compliance with the drinking water quality regulations) more challenging;
- Large decreases in average summer river flows and small increases in average winter flows throughout the UK;
- Water supply pipes and sewerage pipes damaged by subsidence caused by shrinkage and settling of ground during droughts;

(with a spatial resolution of 50km x 50km, which meant that Wales was represented by approximately 18 grid cells), and found that the climate responses of the GCM and the RCM are consistent (Institute of Environment Science University of Wales Bangor et al. 2000a).

- An increase of between 1% and 2% in the demand for water for domestic water supply by the 2020s (although the impacts on peak demand, particularly during the summer months, are likely to be more significant);
- Water shortages and rationing during the hotter, drier summers;
- A resource loss of between 25% and 77% of water companies' target headroom in 2030;
- Sewage and water treatment works on floodplains and in coastal areas at increased risk of flooding[17] due to rising sea levels and increased, more intense, rainfall;
- Increase of the risk of saline intrusion in coastal aquifers because of rising sea levels;
- Contaminants tend to accumulate on land surfaces during prolonged droughts, which can give rise to significant diffuse pollution loadings to watercourses as a result of subsequent precipitation events;
- The location of raw water intakes could be increasingly vulnerable to precipitation extremes;
- Sewage discharges and combined sewer overflows in coastal areas may have to be re-located due to rising sea levels; and
- Back-up occurring with greater frequency in the sewerage network leading to flooding and cross-contamination due to increased, more intense, rainfall.

Meanwhile, with regards to potential impacts on rainfall in the UK, precipitation data from the Hadley Centre has been analysed by HR Wallingford and they concluded that by the 2080s dry summers will be twice as frequent, although the frequency of winter droughts will not change (HR Wallingford Ltd 2005a).

---

[17] It is worth noting that the Environment Agency produces indicative floodplain maps showing the extent of land that may be at risk from flooding from rivers or the sea; however, these maps do not take into account forecasted changes in flood risk as a result of climate change (CAG Consultants & Oxford Brookes University 2004).

14.4.1 Review of Selected Research into the Potential Impacts of Climate Change on Water Resources and Water Quality

A small body of research has focussed on the potential quantitative and qualitative impacts of climate change on surface waters and groundwaters, and an overview of some of the more significant research projects is presented in Sections 14.4.1.1 to 14.4.1.6.

14.4.1.1 UKCIP's "RegIS" Report

DEFRA funds the UK Climate Impacts Programme (UKCIP) which coordinates research to help organisations in all four devolved parts of the UK assess how they might be affected by climate change, so they can prepare for its impact (UK Climate Impacts Programme 2006). In May 2001 it published a report on its first attempt to quantitatively model the cross-sectoral impacts of climate change within an integrated framework at a regional scale within the UK. The project was called RegIS (from "**Reg**ional Climate Change **I**mpact and Response **S**tudies in East Anglia and North West England") and it considered the impacts of climate change on various sectors, including water (UK Climate Impacts Programme 2001).

RegIS is the first project to incorporate the following two important aspects of climate change impact studies within a regional context (UK Climate Impacts Programme 2001):

- The simulation of the likely changes in land use distribution and the consequent impacts of these changes on the water system; and
- The simulation of entire regions at the sub-regional or catchment scale.

However, because such models require catchment-by-catchment calibration and verification, the data required for this limits the number of catchments that can be modelled. Accordingly, only five out of 88 catchments in East Anglia were modelled, and four out of 95 catchments in the North West. According to the authors of the water section of the report, this number "is insufficient to incorporate the great variability in catchment hydrology and response caused by land use, climate, soils and geology" (UK Climate Impacts Programme 2001).

14.4.1.2 Stockholm Environment Institute's Report

Almost two years after the publication of the RegIS report, the Stockholm Environment Institute published a DEFRA-funded extensive research programme into demand management, demand forecasting, sensitivity of demand to climatic variations, and sources of risk and uncertainty. This research built upon the work of the RegIS project and others, but its remit was broader in one key area – it also considered the impact of climate change on demand for water (Downing et al. 2003).

For the area covered by EAW, this project predicted a rise in domestic demand of between 0.93% and 2.79% by the 2050s due to the impacts of climate change, and a rise in the combined industrial and commercial demand of between 2.3% and 5.2% by the 2050s. With reference to agriculture and horticulture, the forecasted increased in demand for water is between 1% and 4% by the 2050s[18] (the current amount of irrigation in Wales is about 1% of the total amount used for irrigation in both England and Wales (Downing et al. 2003).

The study did consider the impacts of climate change on the demand for water within the leisure sector, but the report noted that no specific methodology has been developed for this purpose. It therefore noted that such impacts are likely to be very location specific, and therefore would not be detected in a region by region analysis, such as presented in the report (Downing et al. 2003).

14.4.1.3 Environment Agency's National Report on Climate Change

The EA's first national report on climate change was launched in Spring 2005 (Environment Agency 2006q). Within the report it mentions a number of case studies and statistics relating to water resources and water quality that can be attributed to climate change, but does not mention how it proposes to tackle the impacts of

---

[18] Although not a significant issue for Environment Agency Wales, nationally in England and Wales some 3% of water for irrigation purposes is currently taken from the mains water supply, whilst the figure for the South East is some 20%; this latter figure could grow substantially in the future if the impacts of climate change cause direct abstractions to be significantly curtailed during the summer, with implications for water companies' water resource management plans (Downing et al. 2003).

climate change, possibly because its research is still in its early stages (Environment Agency 2005).

14.4.1.4 Third Assessment Report of the Intergovernmental Panel on Climate Change

In its Third Assessment Report published in 2001 the IPCC could only present a series of hypotheses relating to the impacts of climate change on groundwater, in lieu of a robust body of research (Intergovernmental Panel on Climate Change 2001a).

Aquifers are generally recharged directly by local rainfall, rivers and lakes, so their rate of recharge will be directly affected by changes in precipitation, as well as changes in the duration of the recharge season. It has been argued that the increase in winter precipitation that has been forecasted for the UK will generally result in increased groundwater recharge (Holt 1993). However, this may well be offset by increased rates of evaporation during summer months, which may give rise to soil deficits persisting for longer and commencing earlier (Intergovernmental Panel on Climate Change 2001a).

In the case of shallow unconfined aquifers in floodplains, these are recharged by seasonal streamflow and can be depleted directly by evaporation. Climate change may have variable impacts on streamflow so a net change to groundwater storage in these situations is difficult to forecast; what is more certain is that climate change-induced increases in evaporative demand would tend to lead to lower groundwater storage (Intergovernmental Panel on Climate Change 2001a).

Sea level rise over the next 100 years will give rise to increased instances of saline intrusion in coastal aquifers, with shallow aquifers most at risk, so communities from the atolls in the Pacific Ocean to Long Island, New York will find their drinking water supplies increasingly under threat[19]. This problem can only be exacerbated if

---

[19] Holt notes that within Southern and Eastern England the aquifers which supply most of the drinking water to those areas are already located near present sea levels and, with the threat of saline intrusion, these aquifers will have to be utilised under less dependant operating rules (Holt 1993).

groundwater over-pumping is a factor as well (Intergovernmental Panel on Climate Change 2001a).

As far as confined aquifers are concerned, these are far less sensitive to localised precipitation, as their recharge zones may be anywhere up to several thousand miles away (and therefore may not be adversely influenced by seasonal or inter-annual variations in precipitation or temperature); recharge rates of confined aquifers can also vary from a few days to decades. These factors consequently make it difficult to estimate the impacts of climate change (Intergovernmental Panel on Climate Change 2001a).

Taking the above into consideration, it is therefore easy to accept the report's general conclusion that groundwater modelling efforts need to be intensified (Intergovernmental Panel on Climate Change 2001a).

14.4.1.5 UKWIR "Review of the Microbial Implications of Climate Change for the Water Industry"

As part of its drinking water quality and health research topic area, UKWIR published a review in 2004 of the microbial implications of climate change for the water industry. The review found that, as climate change will undoubtedly have a significant impact on the UK's weather over the next 50 years, it could also have an impact on the microbiological quality of surface water available for drinking water and supply (Hall et al. 2004).

If our summers do indeed become warmer and drier, one likely result is that we will experience lower river flows that have an increased percentage of sewage effluent relative to the norm, and such discharges could remain an important component of river flows for protracted periods. With lower flows comes a reduced ability for rivers to dilute effluent discharges, leading to greater nutrient and pathogen loadings. The consequences of this for the UK water industry are that surface waters will suffer from increased turbidity, particularly after storm events, and they will contain higher numbers of indicator bacteria and pathogens; cyanobacterial blooms will also occur more often (Hall et al. 2004).

Although the authors of the review felt that these issues would create greater challenges for water treatment works (particularly where direct river abstraction is used), they are unlikely to pose a threat if the works are well managed; however, problems could be caused for private water supplies, surface water supplies without filtration, and groundwater supplies under the influence of surface water, unless they are adequately filtered (Hall et al. 2004).

14.4.1.6 UKWIR Report on the "Effect of Climate Change on River Flows and Groundwater Recharge"

In 2005 UKWIR published a report describing an analysis of 10 groundwater observation wells and 47 river flow records for the period 1970 to 2002, the main objective of which was to detect trends in river flows and their possible attribution to climate change (Dabrowski et al. 2005).

The report found that there were a small number of short- to medium-term trends in winter and autumn runoff (but none in spring and summer runoff), but that these changes could not be attributed to climate change over and above natural variability. No trends were found in groundwater annual minimum or seasonal average groundwater levels, but this may be due to the small number of sites included in the study (Dabrowski et al. 2005).

In mitigation though, it is pointed out that attempting to detect a link between climate change and changes in river flows is challenging for a number of reasons, including the following (Dabrowski et al. 2005):

- The high variability of river flows and groundwater levels generally masks any underlying trend;
- Rivers respond to changing land use and other human influences as well as changes in rainfall and evaporation patterns;

- Rainfall (and by supposition runoff) in some parts of the UK is strongly influenced by the North Atlantic Oscillation;
- There is inherent uncertainty in climate change scenarios so it is unclear how fast the climate will change due to rising greenhouse gas emissions.

It is also stated that it may take a period of decades before any clear patterns of changing rainfall and catchment water balance can be detected across the UK, so the report recommends that the study is repeated regularly, possibly with more sites (Dabrowski et al. 2005).

14.5 Recent Parliamentary Reviews Relating to Climate Change

The UK Parliament has held two inquiries in recent years relating to climate change, and an overview of the findings of each inquiry that are relevant to this thesis is given in the following two sub-sections.

14.5.1 'Climate Change, Water Security and Flooding' Report

In 2004 the House of Commons' Environment, Food and Rural Affairs Select Committee conducted an inquiry into the likely implications of climate change for water policy in England. In particular, it considered (House of Commons 2004a):

- Whether existing water supplies are adequate, and what additional sources of water might be needed; and
- What the impact on resource management would be.

When the report was published in September 2004, it confirmed that less water would be available within the UK, at least at certain times of the year. It recognised that there is a pressing need for wider public understanding of the way climate change may affect water use. The Committee therefore recommended that water companies, Government and the EA "take the lead in raising awareness about the value of water and the potential for water scarcity if it is not managed wisely" (House of Commons 2004a). In its formal response, the Government noted that the Water Act 2003 placed new, and enhanced existing, duties of water conservation on water companies, DEFRA, the National Assembly for Wales and the EA (House of Commons 2004b).

As reported in Section 13.5, both the Government and the EA publicly advocate a twin-track approach of demand management and resource development. However, in providing evidence to the enquiry, the EA took the view that "building new reservoirs or enlarging existing ones should be considered only once demand management and leakage had been addressed". As the report noted, "reservoirs are expensive and take many years to go through the planning system". The Committee therefore took the view that, "as it seems likely that some new capacity will be necessary, water companies, the EA and environmental groups should engage in open and frank discussion of the environmental and economic consequences of providing greater reservoir capacity". In its response, the Government reaffirmed its support for the twin-track approach and makes reference to the water companies' new statutory duty to prepare draft water resources plans for consultation, which would provide an opportunity for any proposed reservoir development or enlargement to be debated (House of Commons 2004b).

In evidence to the inquiry, the EA stated that "the availability of water resource should be a material issue in the planning system which it currently is not". The Committee agreed with this view, and recommended that "planning guidance to local authorities should require that water availability be taken into consideration"; it also made a number of other recommendations relating to demand management, metering and efficient use of water (House of Commons 2004a). At the time of its official response to the report, the Government noted that various consultations were addressing these points (House of Commons 2004b).

With regards to water companies' ability to put together effective investment programmes to cope with the impacts of climate change on water resources, concern was repeatedly expressed by organisations providing evidence to the inquiry that the current five year AMP period did not facilitate long-term planning. The Committee therefore called for all water industry regulators, Government and the water companies to work together in order to plan adequately for long-term expenditure. It was a surprise to the Committee that – with a very few exceptions – Ofwat "had not begun to allow [water] companies to include the cost of managing the impacts of climate change in [the 2004 Periodic Review]" (House of Commons 2004a).

14.5.2 'The Economics of Climate Change' Report

The House of Lords' Economic Affairs Select Committee has the remit to consider economic affairs. Accordingly, it decided to conduct an inquiry into aspects of the economics of climate change. Evidence was gathered over a six month period by means of both verbal and written submissions, and the final report was published in July 2005 (House of Lords 2005a); three months later, the Government's response to the report was published (House of Lords 2005b).

The EA regulates abstractions in England and Wales, and protects water resources worth £72 billion to licence holders (Comptroller and Auditor General 2005). It is widely accepted that climate change will have a dramatic effect on rainfall and river flows and, by extension, to groundwaters as well. It is unfortunate therefore that the Committee's report does not specifically consider the economic impacts of climate change on water resources. This is an unfortunate oversight and represents a missed opportunity to provide the community of abstractors with an initial assessment of the financial impact of global warming on their collective business.

However, the report does contain some interesting – and alarming – projections relating to the number of people around the world who are at risk from water shortage in the 2050s and 2080s[20], based on three global temperature increases of 1°C, 2°C and 3°C respectively, and these are summarised in Table 2 (House of Lords 2005a). The scenarios predict that up to about three billion additional people – or 40% of the world's population at that time – will face water problems. However, the figures presented in this Table are 'business as usual' estimates, i.e. the estimates do not consider climate change mitigation or adaptation, and so will be most probably subject to some change in the coming years.

---

[20] All international climate change models use the period 2070 to 2100 as the target date for future forecasting, and this period is often referred to as the 2080s (Kellagher 2004).

TEMPERATURE INCREASE (^{o}C)	ADDITIONAL PEOPLE AT RISK FROM WATER SHORTAGE (MILLIONS)	
	2050s	2080s
1	1,250-2,250	-
2	2,100-3,000	2,750-3,250
3	-	3,000-3,500

Table 2: The number of people around the world who are at risk from water shortage in the 2050s and 2080s, based on three global temperature increases of 1°C, 2°C and 3°C respectively

The report also affirms a number of elementary qualitative statements regarding the impact of climate change worldwide. For example, it states that morbidity and mortality due to changes in the availability of drinking water are more likely in the future as a result. It also states that water pollution can be expected to increase, water availability in some parts of the world will decrease, and saline intrusion will affect freshwater supplies in some coastal areas. Again, it is unfortunate that potential financial impacts aren't assigned to these statements.

References to the impacts of climate change on water resources are even scarcer in the official Government response to the Select Committee's report. Perhaps only one is noteworthy for the purposes of this thesis, where reference is made to work within the UK that has identified potential benefits for agriculture (such as the extended growing season), but that this work "also needs to take into account changing water resource availability" (House of Lords 2005b).

14.6 Discussion

This review has demonstrated that, with a high level of certainty, climate change is occurring. A weighty volume of research has been acquired by numerous researchers worldwide which has critically informed this opinion but, somewhat surprisingly, "there is a general lack of focus [in the research that has been undertaken] on the water industry and insufficient detail to enable decision making at a regional level" (Hossell et al. 2007). This is thought to be due to the following reasons:

- Uncertainties relating to the climate change predictions;
- Uncertainties with the GCMS themselves;
- The generally course spatial resolution of GCMS when considering climate change impacts on water resources; and
- A lack of high quality data of sufficient quantity to drive the GCMs.

It must be said that there is a significant body of scientists and researchers who are ardent climate change sceptics (Science & Environmental Policy Project 2008, The Washington Post 2006, Strandberg 2006), and perhaps this scepticism is in no small part attributable to these identified deficiencies and uncertainties. However, for those people who refuse to accept that accelerated global warming has an anthropomorphic driver, many of the actions required in response to climate change can be justified for other reasons. For example, conserving water resources is an "immediate environmental and economic necessity" (CAG Consultants & Oxford Brookes University 2004).

The above four general areas of deficiencies relating to climate change models and predictions are explored in greater depth in the following sections.

14.6.1 Modelling Climate Change

It must be stressed that all of the potential impacts listed in Sections 14.3 and 14.4 are only predictions, based on quite a wide-ranging suite of climate change scenarios produced by different research organisations around the world and, as Holt notes, it should be remembered that these scenarios are not themselves predictions or forecasts, merely plausible representations of the future situation (Holt 1993).

All predictions contain uncertainties, for example, because future emissions of greenhouse gases are unknown, and so numerous emissions scenarios have been developed; therefore, different scenarios will obviously produce different results (Wilby et al. 2006b). However, the largest uncertainty arises from the models themselves. Even if each of the different GCMs use the same emissions scenario, they will give quite different predictions due to the different ways they represent aspects of the climate system (Hadley Centre for Climate Change and Prediction 2004, Davies *et al.* 2005). The ability of these models to accurately represent cloud-related water processes and radiative transfers is also an area of major uncertainty (Garbrecht & Piechota 2006). In fact, the IPCC notes that "models continue to have significant limitations" in certain areas, although in its opinion, models "have consistently provided a robust and unambiguous picture of significant climate warming in response to increasing greenhouse gases" (Intergovernmental Panel on Climate Change 2007a).

14.6.2 Modelling Hydrological Responses to Climate Change

When it comes to quantifying the potential impacts of climate change on water resources, even more problems arise. Climate change scenarios are derived from GCMs, but there are methodological difficulties in using these to estimate the impact of global warming on water resources. GCMs generally operate at a seasonal or annual timescale across continents, but much smaller scales (in both time and space) are required for catchment hydrological modelling (Bergkamp *et al.* 2003, Roesch & Stewart 2006). For example, the spatial resolution of the Hadley Centre's HadGEM1 model is 135km x 135km, which means that for a very large river such as the Danube its catchment is only represented by 45 grid squares (as the area of its catchment is about 817,000 km^2), whilst a number of rivers in Cornwall are only a few kilometres from source to sea, so the spatial resolution offered by HadGEM1 is wholly inadequate (Chave 2001).

The generally coarse spatial resolution of GCMs also presents a significant problem when rainfall is being considered. GCMs usually generate an estimate of the average rainfall over a large grid square for the GCM time-step, but they fail to take into account localised temporal and spatial variations in rainfall which, on a smaller scale, can produce highly significant results (Calder 2005). The climate across the British Isles is extremely variable at all scales, "with inter-annual climatic variability particularly significant". Unfortunately though, this natural variability is often overlooked in climate impact studies (Davies et al. 2005).

The situation is further complicated because of the exceptional diversity demonstrated across the UK in terms of its climate, geology, land use and patterns of water use, all of which directly influence regional and more local hydrological responses to climatic variability; for example, rivers draining a chalk catchment may be expected to respond very differently from nearby urban watercourses (Centre for Ecology & Hydrology 2006b).

The Hadley Centre has used its HadGEM1 model to predict likely changes in the global water cycle (which is likely to get more intense), but has not yet focussed its research on the catchment level, which perhaps is understandable taking the above points into account (Hadley Centre for Climate Change and Prediction 2005b). Consequently, it is therefore "extremely difficult for water resource planners to rigorously account for uncertainty in climate change" (Davies et al. 2005). According to Roesch and Stewart "at the regional and local scales relevant for water utilities, current scientific understanding does not yet allow confident projections of the magnitude or precise nature of climate change", which is undoubtedly due in no small part to the aforementioned modelling limitations (Roesch & Stewart 2006). Such deficiencies, and the continued dearth of small-scale models developed for UK catchments may have been the basis for comments in a recent House of Lords Select Committee report which stated that it will be "important to make progress in producing smaller-scale, catchment-specific models that will allow a better understanding of climate change impacts at the local level, thus allowing water companies and others to plan with more confidence" (House of Lords 2006c). However, such observations are not a new phenomenon – Arnell et al in 1997 highlighted that linked quantity-quality models should be developed, to allow the investigation of influences of climate and other changes on water quality, and hence water supply potential (Arnell et al. 1997).

The same report goes on to say that the Select Committee "saw insufficient evidence to convince [them] that the potential consequences of climate change are being adequately factored into long-term planning for water management", which would be rooted in accurate models. It therefore recommended that both Ofwat and the EA "take steps to make the process whereby such issues are addressed within long-term planning more transparent and open to scrutiny" (House of Lords 2006c).

Before accurate catchment-specific models can be built though, the uncertainties that are inherent in every GCM and hydrodynamic model must first be addressed, and UKWIR is currently attempting to generalise the three main sources of uncertainty (climate variability, hydrological uncertainty and uncertainty in future projections) and is aiming to complete this work by March 2008 (Davies et al. 2005).

Taking all the above uncertainties into account, the IPCC has posed an interesting question: How can water management efficiently adapt to climate change, given that the magnitude (or possibly even the direction) of change is not known (Intergovernmental Panel on Climate Change 2001a)?

14.6.3 Data Required for Hydrological Modelling

In theory, based upon the issues identified in Section 14.6.2, a separate hydrological model should be built for each catchment and significant sub-catchment, and a huge volume of water quality and hydrometric data (vastly in excess of the current amount being acquired) would be essential for calibration of the models. A similarly significant volume of data would be required for subsequent verification of the models; this data is used for 'backcasting', in which the models are used to reconstruct historic climates and the results compared against actual events to determine their accuracy, before they are used for forecasting purposes (Keirle & Hayes 2007b). It is therefore useful to consider the data we have acquired to date within the UK.

The majority of the hydrological data streaming into the National River Flow Archive and the National Groundwater Level Archive is collated and validated by Government bodies from hydrometric networks generally owned and maintained by them – the EA (for England and Wales), the Scottish Environment Protection Agency (for Scotland), and the Rivers Agency[21] (for Northern Ireland). These networks have expanded and contracted over time, in accordance with changing operational requirements and funding regimes (Keirle & Hayes 2007b).

[21] An Agency within the Province's Department of Agriculture and Rural Development (Rivers Agency 2006).

Unfortunately, relatively few small, undisturbed catchments (or aquifer units), of the type best suited to establish benchmark conditions and identify climate change signals, are currently being monitored. Moreover, catchments of this type with an appropriate length of hydrological record suitable for this type of research are rare; the average record length in the National River Flow Archive is less than 23 years, and fewer than 15 sites offer "sensibly continuous" records of more than 50 years. CEH therefore states that any apparent trends detected in a flow or level hydrograph need to be treated with caution; an apparently compelling trend over, say, a 20-year period, may be seen to be a mere perturbation when viewed in the context of a 100-year time span, as such short records "do not always capture the full range of variability in our current climate" (Centre for Ecology & Hydrology 2006b; Centre for Ecology & Hydrology 2006c; Davies et al. 2005).

Although CEH states that the few very lengthy hydrometric records currently available in the UK are of immense value, the ability to distinguish any global warming-induced change or trend amongst the background anthropomorphic 'noise' is a "considerable scientific challenge". The ability to undertake this task is further complicated when changes in measurement technologies and data processing procedures are factored into the equation, with the unfortunate implication that few hydrometric time series can be considered truly homogeneous (Centre for Ecology & Hydrology 2006b).

The shortage of water quality data was highlighted by a recent UKWIR research project, which considered the potential impact of predicted climate change on water quality in UK rivers (Conlan et al. 2006). The subsequent report noted that one of the most difficult problems faced by the project was lack of water quality data, which would need to be addressed in future modelling strategies.

Consequently, taking all the above points and limitations into consideration, catchment and aquifer models only exist for only a small proportion of the supply sources in the UK (Arnell 2003).

It is therefore timely that a review of the quality and quantity of data (both hydrological and relating to water quality) collected across the European Union has been proposed by the Water Supply and Sanitation Technology Platform's Water Management Thematic Working Group, as part of the EU's Seventh Environment Action Plan (which runs from 2007-2013) (Water Supply and Sanitation Technology Platform 2005a). The proposal includes research into (Water Supply and Sanitation Technology Platform 2005a):

- Development of more comprehensive and effective integrated monitoring networks; and
- Standards for responsible authorities carrying out monitoring and reporting in Member States (including identifying the minimum staffing and financial resources requirements needed to do the job properly).

Alongside this European review, it would appear that a review of our national dataset is also urgently required, so that measures can be put into place to plug any gaps in the national hydrometric network and to ensure data of consistently high quality is captured.

14.6.4 Impact of Climate Change on Hydrometric Data

An issue that rarely gets a mention is the impact climate change will have on hydrometric data. Accurate return periods of floods and droughts are essential to many people such as civil engineers, water resources planners and town planners. These have conventionally assumed that the future water resources base will be the same as in the past, so estimates of such indices that are based on past data will also apply in the future. However, the use of these indices becomes increasingly unwise as global warming causes hydrographs for rivers and coastal waters to be re-drawn (Keirle & Hayes 2007b).

According to the International Union for Conservation of Nature and Natural Resources, "extrapolations from observed data are becoming increasingly unreliable", which "suggests that the data and assumptions used in the past can no longer be regarded as valid for the future" (Bergkamp et al. 2003); this view is echoed by Roesch and Stewart, who state that "past hydrological patterns may become an increasingly unreliable guide to the future" (Roesch & Stewart 2006).

14.6.5 Climate Change in the UK

As well as these seasonal changes, we have also experienced changes on much shorter timescales, which is evident in the extreme weather events we have experienced over the past few years – localised, yet devastating flash floods in Cornwall and Yorkshire, widespread flooding during Autumn 2000 and a series of regional droughts – and these events have been popularly and quickly ascribed to climate change (Keirle & Hayes 2007b).

However, making this connection is not always supported by actual measurements. For example, when flood data over the past 80-120 years was analysed statistically, no proof of a consistent trend or links to climate change was provided, as such events could be explained by natural variations in our climate rather than climate change (Dabrowski et al. 2005). Indeed, as a recent UKWIR report noted, the UK climate is characterised by large variations from year to year, decade to decade and over even longer timescales. This natural variation (in particular, relating to precipitation) is such that "any changes due to climate change will be masked by natural variability for many years" (Vidal & Wade 2007).

The potential impacts of climate change on rainfall within the UK have also been considered by some researchers, but the results have not always been conclusive. For example, UK temperatures over the last 150 years have statistically demonstrated significant seasonal warming, but researchers' ability to detect seasonal trends in regional rainfall has been less successful; some studies have reported no trends in annual rainfall and few significant seasonal trends, whilst others have stated that trends do exist (Dabrowski et al. 2005).

14.6.6 Climate Change in Wales

Although Wales is reported to lead the way with agri-environment schemes, neither Tir Cymen nor Tir Gofal deal specifically with climate change impacts (Institute of Environment Science University of Wales Bangor et al. 2000b). However this may be because we do not yet know enough about the consequences of climate change to predict with any certainty how grass and cereal growth will respond to start incorporating mitigation policies into these schemes; at this stage, the belief that the agricultural sector will be "substantially affected" can only be asserted (Institute of Environment Science University of Wales Bangor et al. 2000a).

Again, possibly due to a lack of knowledge at this stage, only passing reference is made in the summary report produced for the National Assembly for Wales in 2000 to the impact of climate change on water resources and water quality in Wales, although it is recognised that the water industry will face "major challenges"; these will come in the form of temporal changes in the availability of water for abstraction (making the provision of water for human use "much more difficult"), and the current capacity of the sewerage system not being sufficient for the forecasted severity of winter storms and increased intensity of daily precipitation. The need for "different public and private sector bodies to be involved in planning for the impacts of climate change on water resources" is consequently identified (Institute of Environment Science University of Wales Bangor et al. 2000a, Institute of Environment Science University of Wales Bangor et al. 2000b).

These topics are understandably covered in greater depth in the associated technical report, which effectively only serves to highlight the lack of research into, and understanding of, the impacts of climate change on water resources and water quality. These intellectual deficiencies relate in no small part to highly complicated and inter-related catchment processes (such as nutrient dynamics and releases), the poor understanding of disciplines such as hydroecology (for which there is no national research programme because of the cost involved), and the "dearth of published information from Wales and the UK" (Institute of Environment Science University of Wales Bangor et al. 2000a, Keirle 2006b).

The probable increase in the frequency and severity of flooding is mentioned though, and it is suggested that flooding events will be between 10 and 50 times as frequent by 2090. The report therefore states that managed retreat "must be considered for significant sections of the Welsh coast", as the cost of maintaining existing coastal defences, and installing new defences, may neither be cost-effective or sustainable (Institute of Environment Science University of Wales Bangor et al. 2000b).

In conclusion, the report states that, in order for Wales to adapt to climate change, the following need to be put in place (Institute of Environment Science University of Wales Bangor et al. 2000b):

- Policies for adapting to climate change (including the need for the Assembly "to develop economically viable strategies which recognise the interactions between climate change, agriculture, conservation and water resources";
- Strategies to improve communications and integrate planning; and
- Programmes to collect information on climate trends and to research impacts and adaptation options (including the development of socio-economic scenarios, and encouraging and supporting research).

The report is also optimistic about the effects of climate change for Wales, as "many, if not all, of the deleterious impacts … can be avoided by timely planning and action", although it noted that this can only be achieved if bodies that don't work closely together now start integrating their activities. Also, it identified some socio-economic benefits of climate change, such as increased revenue arising from the tourist industry (Institute of Environment Science University of Wales Bangor et al. 2000a).

14.6.7 Impacts of Climate Change on Water Resources and Water Quality

If the predicted impacts of climate change on water resources and water quality turn out to be correct, there will be significant ramifications for a number of the EA's policies and strategies, not least of all in the areas of abstraction and discharge consenting. For example, research commissioned by UKWIR considered the potential impact of predicted climate change on water quality in UK rivers, with particular reference to abstractions and discharges by the water industry (Conlan et al. 2006). Due to the increased risk of drought and increased likelihood of low flows, water companies may have to rethink their abstraction regimes during summer months, due to a combination of reduced volumes of water available for abstraction and water quality problems (the latter issue can apply to both abstractions for direct water supply and to water used to supply raw water storage reservoirs). With regards to discharges from waste water treatment works, compliance with discharge consents will become increasingly challenging as receiving water attenuation is reduced during the summer months; more stringent discharge consent conditions therefore appear likely.

The same research found, almost as an aside, that the EA's discharge consenting policy should be reviewed in anticipation of climate change. This policy is underpinned by the Agency's GQA scheme (see Section 13.1), which the research highlighted is "relatively insensitive" to climate change. The majority of water quality samples taken in relation to this scheme are taken during periods of "typical" river flow and do not specifically target extremes. However, climate change is more likely to influence the extremes, but the few samples taken in periods of significantly induced flow and/or water quality change may not be sufficient to alter the statistical basis of GQA classification, so unless the discharge consenting policy is reviewed there is a danger of consents being issued that will have a detrimental effect on receiving waters during extreme conditions.

As identified in Chapter 12, the EA has a number of plans relating to the management of water resources within England and Wales, ranging in scale from the short term (such as CAMS) through to its longer-term Water Resources Strategy. However, as HR Wallingford identified in a recent report produced for DEFRA relating to the development of practical guidance on how to manage water resources in a changing climate, many of these plans "either do not consider climate change or are poorly integrated with water resources plans so the impacts of climate change on water are not fully considered in many land use planning activities" (Wade et al. 2006). This is undoubtedly due to the difficulties and issues highlighted above. Indeed, even the Water Framework Directive itself is based upon the assumption that today's climate will not change (ADAS 2006c).

In the same report, and again probably for the same reasons, it is stated that "it is not possible at this stage to determine the adequacy of the river basin management planning process for helping to adapt to climate change", so the report's authors could not, at the time of writing, make detailed recommendations on potential improvements to the process. However, as the production of River Basin Management Plans is a cyclical process, there will be opportunities to update them in the future as our understanding of the detailed impacts of climate change on water resources improves (Wade et al. 2006).

It is worrying that, although climate change is undoubtedly the single biggest environmental challenge facing the UK (indeed, the world) today, there appears to have been very little dialogue to date on how it will affect either water management or regulation of the water industry. In fact, it is the opinion of Water UK (the industry association that represents all UK water and waste-water service suppliers at national and European level (Water UK 2006a)) that insufficient attention was given to impacts of climate change within the most recent Periodic Review undertaken in 2004. They even call for a European directive on responding to climate change with a focus on the protection of water resources (House of Lords 2006b). Others have put forward an opposing argument, by stating that the impacts of climate change are so uncertain and so far in the future that they pale in significance when compared to more immediate concerns facing the water industry, such as uncertainties relating to funding and management re-structuring (Roesch & Stewart 2006).

Despite the prediction that the UK's total annual precipitation may actually increase as a result of climate change, the amount available for abstraction will probably fall (Watts 2006). As well as affecting water companies' abstraction regimes, this will affect other sectors such as agriculture markedly, particularly when irrigation of crops is concerned. For example, a study by DEFRA identified an increase in water for irrigation for agriculture of around 20% by the 2020s, and around 30% by the 2050s. Already, many farmers experience restrictions on their summer abstractions, and this situation can only get worse unless greater investment is made in winter storage reservoirs, more efficient water use is promoted and crops with greater drought resistance are grown instead (National Farmers' Union 2005).

It could be inferred that in the future we will be using more water, but less will be available for abstraction than now, and it is likely that we will move towards a climate more like Spain's. It is sobering to think that, during the severe drought of 1995, Yorkshire Water came within days of completely running out of water; secret plans were drawn up to evacuate Halifax and Bradford (representing up to one million people) should that position have been reached (Pearce 2006).

Finally, it is an interesting aside that, as a result of climate change warming the water within our rivers, more people may want to swim in them. For the first time, this may bring the UK's rivers under the scope of the Bathing Waters Directive (Environment Agency 2006o).

14.6.8 Research into the Potential Impacts of Climate Change on Water Resources and Water Quality

There has been limited research into the effects of climate change on the quantity and quality of surface water resources, and even when research has been undertaken it can be inconclusive, and this is probably due to the problems and deficiencies highlighted in Sections 14.6.1, 14.6.2 and 14.6.4.

When it comes to groundwater, even less research has been carried out, despite it being a major source of drinking water in Europe (and indeed, throughout the rest of the world) – for example, 28% of the UK's drinking water is derived from groundwater (rising to 80% in the water-stressed South East (Gooddy et al. 2001)), whilst in Austria this figure is 99% (Chave 2001); groundwater is also the predominant source in the UK for private water supplies (Gooddy et al. 2001).

Despite this importance of groundwater, in the IPCC's Third Assessment Report it stated that the direct impact of climate change on water quality in surface waters and in groundwater "may be very small in relative terms", as it is "heavily dependent on direct and indirect human activities" such as land-use and agricultural practices, and water management and land management policies and strategies (Intergovernmental Panel on Climate Change 2001a). However, research commissioned by UKWIR into the potential impact of predicted climate change on water quality in UK rivers appears to contradict this, as it showed "there is a noticeable water quality response to climate change", although the report noted that this is in contrast to previous studies. The predicted impact was also found to vary between parameters. For example, the research found that nitrate and total phosphorus levels will increase, whilst ammonium levels will reduce (Conlan et al. 2006). Furthermore, they found that the effects of climate change would be exacerbated in the south of England, when compared with the north.

Nevertheless, the IPCC's view appears to be supported by research undertaken by UKWIR, which assessed whether available, calibrated water quality models for five UK rivers and one reservoir were capable of assessing changes in water quality under likely climate change scenarios; it concluded that no significant effects on water quality would result, though it qualified this by stating that it was not valid to conclude that significant effects will not occur, because of the nature of the models used, the way changes were assumed to happen, and the nature of the climate change scenarios themselves. One of the recommendations of this report was that it was important for water quality models to allow for the effects of diffuse sources of pollution, which UKWIR felt meant that effective land-use models should be developed, and linked to appropriate water quality models (Humphrey 2001).

Even though there may be conflicting views as whether climate change will directly affect water quality, it may well have fundamental implications for how we use the land in the future, which in turn is likely to have a significant influence on river water quality (Conlan 2003).

At a workshop organised recently by the European Commission scientists, policy-makers and practitioners from all over Europe agreed that there was a clear need for further research into the impacts of climate change on the water cycle. In order to help address the knowledge and research gaps that remain, an international conference on climate change and water was held in Berlin in February 2007, as part of the German six-month presidency of the European Union (Community Research & Development Information Service 2006, Federal Ministry for Environment Nature Conservation and Nuclear Safety 2006).

The shortage of research into the potential impacts of climate change on water resources has also been highlighted by the Water Supply and Sanitation Technology Platform's Water Management Thematic Working Group, and it has proposed research into changes in the hydrological cycle in different regions and impacts on water management, including effects at the local level, for mitigation and adaptation purposes, as part of the EU's Seventh Environment Action Plan. The Working Group has also proposed research into a new generation of hydrological models in order to facilitate integrated water resources management (Water Supply and Sanitation Technology Platform 2005a).

There may be other reasons why limited research has been undertaken. According to the International Union for Conservation of Nature and Natural Resources, "the water sector has paid little attention to, and is often unaware of, the expected impacts of climate change on future water resources", which it feels is probably due to there having been "few serious attempts to inform water experts about the links between climate change and the water sector". It therefore urges for more attention to be paid to incorporating climate change considerations into water resources planning, as development of new resources can "often take decades to materialise" (Bergkamp et al. 2003).

14.6.9 Climate Change Adaptation and Mitigation

There are two main ways we can respond to climate change (National Farmers' Union 2005):

- Mitigation (to minimise and/or alleviate the effects); and
- Adaptation (changing our ways to adapt to the new situation).

In March 2006 the UK Government produced its mitigation strategy for the whole of the UK, which set out its policies and priorities for action in the UK and internationally. The primary aim of this document is to set out how the Government intends to reduce anthropogenic emissions, in order for it to achieve its Kyoto Protocol commitments and, as such, does not consider in detail the potential impact of climate change on water resources (HM Government 2006).

Some bodies – including the National Assembly for Wales – feel that, provided appropriate, timely action is taken, many, if not all of the adverse impacts of climate change can be mitigated (Institute of Environment Science University of Wales Bangor et al. 2000a), whilst others are of the opinion that they can make a significant positive contribution to such action. For example, the NFU feels that agriculture is in a "unique position to affect the management of land, the environment and climate"

(National Farmers' Union 2005). Agriculture certainly makes a large contribution to the greenhouses gases produced by the UK – estimated agricultural emissions of methane were almost 47% of the country's entire methane emissions in 2003, whilst for the same year the estimated agricultural emissions of nitrous oxide were 67% – and the NFU calls for new techniques and methods to be explored in order for these emissions to be reduced (National Farmers' Union 2005).

Discussions about implementing potential mitigation measures advanced even further whilst the UK Government's Climate Change Bill navigated its way through Parliament; it is now poised to receive Royal Assent during Summer 2008 (Department for Environment Food and Rural Affairs 2008g). This Bill, once enacted, will put into statute the UK's domestic targets to reduce carbon dioxide emissions through domestic and international action by at least 60% by 2050 and 26-32% by 2020, against a 1990 baseline (Department for Environment Food and Rural Affairs 2007b). In doing so, Friends of the Earth stated that "the UK will be the first country in the world to introduce a legal framework for reducing carbon emissions" (Department for Environment Food and Rural Affairs 2007b).

However, as far as adaptation is concerned, "there is an increasing need to adapt to the impacts that are already apparent and to plan for further effects" (Hossell et al. 2007). Hossell et al. (2007) states that most research prefers to focus on climate change impacts, rather than on adaptation options. To my mind this focus could not be more misdirected, and this imbalance between mitigation and adaptation must be addressed as a priority; greater attempts must be made in order to quantify the predicted impacts on the water industry in general, and water resources in particular, so that adaptation effects can start to be put in place.

I quoted in Section 5.11.1.1 that, back in 1994, the then NRA noted "it can take between 15 and 25 years to investigate, promote and construct a major new water resource in the UK" (National Rivers Authority 1994). Experience gained by the water industry since 1994 has shown that this view is pretty accurate, which means that we must now be identifying water resources augmentation schemes, so that they are starting to come online as the impacts of climate change become even more acute in the UK.

This statement should be borne in mind when reviewing the water resources strategy for England and Wales (see Section 13.4.1) produced by the NRA's successor, the EA. In this strategy the EA notes that there is "mounting evidence" for global warming, and the role that man has played in this. However, for the purposes of the strategy, it has assumed that over the 25-year span of the document, most public water supply systems will retain their existing yields. It also mentions the likely qualitative impacts of climate change on water resources (such as changes in the availability of, and demand for, water) but, because of a lack of research at the time of writing the strategy, the EA was unable to quantify these impacts (Environment Agency 2001c).

The strategy also recognises that land use has a significant impact on the water environment, and states that changes in land use and drainage "will exert further pressures". However, the strategy does not take into account changes in land use (Environment Agency 2001c).

Although it is noted that climate change is an "important element of uncertainty in water resources planning", the EA did not feel it was the greatest source of uncertainty in aspects such as water use, and states that societal change and economic growth will also be important. It therefore felt that it would be difficult to justify any new water resource developments solely because of climate change (Environment Agency 2001c).

Despite it concluding that additional water resources would be required, the EA was of the opinion that there was no need for large-scale transfers of water around England and Wales, even though this option has been advocated by various bodies such as ADAS and the Institution of Civil Engineers and periodically promoted since the early 1990s by British Waterways (ADAS 2006g; Environment Agency 2006t; Griffith 2006; Poulter 2006; Sheriff et al. 1996). The EA's opposition to the proposal was re-affirmed in a report published in September 2006, specifically relating to the possibility of large-scale transfers of water from the north of England or Wales in light of the recent drought, in which it concluded that there was "no new evidence of a need" for such transfers (Environment Agency 2006f).

Such a stance by the environmental regulator is inexplicable, particularly as the UK Government continues to pursue its strategic policy of encouraging large-scale developments in the water-stressed south-east of England. Despite being presented with overwhelming evidence of climate change, the fact that parts of England and Wales are already experiencing water-stress (even before future developments and climate change are taken into consideration), and the timescale for development of new water resources schemes, the EA is still firmly of the opinion that we do not need large-scale transfers of water, nor can it justify any new water resource developments solely because of climate change.

15 CONCLUSIONS FROM PART 3

A review focussing on catchment management and its influencing factors was presented in Part 3. In the first of the three Chapters in this Part, an overview of catchment management was given, in both historic and current contexts, with particular focus on diffuse pollution. In the second Chapter, an appreciation of the qualitative and quantitative management activities of the Environment Agency in England and Wales was given, as well as an introduction to a number of strategies used to help manage the natural water environment. In the third Chapter, the potential impacts of climate change on water resources were discussed, along with the limitations of current modelling and forecasting.

From this review I have drawn the following conclusions (for ease of reference the Section to which each conclusion relates is given is brackets):

1) Since the demise of the NRA, and their Catchment Management Plans, protection of catchments and an integrated approach to their management has arguably been progressively weakened, with the development of one cycle of LEAPs, which were then followed by CAMS. The implementation of a national catchment management strategy will help reverse this trend, and it would also have other advantages. Not only will it help underpin the Programme of Measures required by the Water Framework Directive, but it will also assist with the implementation of the Drinking Water Safety Plan approach (Section 12.8).

2) The Council of Europe's European Landscape Convention – of which the UK has become a recent signatory – could be a suitable vehicle for the implementation of a national catchment management strategy (Section 12.10).

3) A number of studies of diffuse pollution arising from agriculture have now either been completed or are at an advanced stage. The focus of both DEFRA and the Welsh Assembly Government must now be urgently shifted to deciding how this problem should be addressed (Section 12.11.1.1).

4) As agriculture is the single biggest contributor to diffuse pollution within the UK, the four devolved administrations should give serious and urgent consideration to making membership of the currently voluntary agri-environment schemes compulsory, particularly in light of the fact that the 2015 deadline of the Water Framework Directive is only six years away (Section 12.11.2).

5) In lieu of any leadership, guidance or action from the EA – either in England or Wales – water companies should consider working together with other local stakeholders in order to produce catchment management plans for those catchments used for public water supply purposes (Section 12.12).

6) Careful consideration should be given to how a national catchment management strategy could be implemented, either within the current regulatory and management structure within the water industry, or by looking overseas at how catchment management is effected in other countries and identifying how our structure can be improved (Section 12.12).

7) For catchment management to work properly, close coordination and effective communication between the various stakeholders will be essential. Projects such as DEFRA's Catchment Sensitive Farming Delivery Initiative will provide invaluable opportunities for lessons to be learnt in these two key areas (Section 12.12).

8) Following criticism by a House of Lords Sub-Committee, the EA must ensure that it takes a realistic approach towards the need for resource development, particularly bearing in mind the long lead-in time for such projects which is generally measured in terms of decades (Section 13.5).

9) The EA has developed a number of strategies and policies in order for it to comply with its statutory duty to secure the proper and efficient use of water resources in England and Wales. However, these generally do not consider water quality and quantity issues on an equal basis, and neither do they appear to be explicitly linked to land use. These shortcomings may be addressed by

Catchment Flood Management Plans, but at this early stage in their implementation it is not possible to say with any certainty that this is indeed will be the case (Section 13.6.2).

10) The review of the potential impacts of climate change has highlighted some of the difficulties associated with modelling climate on both a global and a regional scale. Efforts must be intensified in order to overcome these difficulties, to ensure that the most accurate outputs possible are practicably obtained (Section 14.6.1).

11) Although it is now almost universally accepted that climate change will have significant impacts on water resources, greater attempts must be made in order to quantify these predicted impacts so that mitigation effects can start to be put in place (Section 14.6.2).

12) In order for the quantification of the impacts on water resources to be undertaken, robust hydrometric data of sufficient volume are required. It would appear that a review of the national dataset is urgently required, so that measures can be put into place to plug any gaps in the national hydrometric network and to ensure data of consistently high quality is captured (Section 14.6.4).

13) There is currently a dearth of research being undertaken into the impacts of climate change on water resources, which is in part due to the lack of sufficient data and hydrological models being available. Urgent action must be taken in order in order to redress this (Section 14.6.7).

Prifysgol Abertawe
Swansea University

The Relevance of Catchment Management to Drinking Water Safety Plans within the UK with Particular Emphasis on Wales

Robert Scott Keirle

VOLUME 2 OF 2

Submitted to Swansea University
in fulfillment of the requirements for the
Degree of Doctor of Philosophy of Civil Engineering

2009

PART 4 DRINKING WATER SAFETY PLANS

16 THE NEED FOR GREATER PROTECTION FOR DRINKING WATER SUPPLIES

16.1 Introduction

A reliable supply of clean drinking water of sufficient quantity is essential to protect the health of individuals and communities. Indeed, In November 2002, the United Nations Committee on Economic, Social and Cultural Rights affirmed that access to adequate amounts of clean water for personal and domestic uses is a fundamental human right of all people (United Nations 2007b). However, this right has no basis in international law, despite the efforts of campaigners such as Green Cross International (Green Cross International 2007). Nevertheless, it is anticipated that global initiatives such as the World Health Organisation's (WHO) Drinking Water Safety Plans will strive to help deliver this most basic of human rights.

In the context of the need for greater protection for drinking water supplies, it is therefore useful to consider – on global, European and UK scales – the pressures on water resources and the challenges governments face in attempting to provide everyone with safe drinking water.

16.2 Drinking Water and Public Health: An International Overview

At the end of the 20th century there were just over 6 billion people living on our planet, whilst by 2025 this figure is projected to increase by approximately one third to just under 8 billion (US Census Bureau 2008). The provision of a safe supply of drinking water in sufficient quantity to all these people will arguably be the one of the biggest challenges facing the world, particularly when it is considered that, currently, more than half the water in our rivers and lakes – 90% of the world's liquid fresh water – is polluted, putting a billion people at risk (Ward 2002). 40% of the world's population carry their water home from wells, rivers, ponds or puddles outside of their homes, whilst almost one in five of all the people living on the planet do not have access to an adequate supply of clean water (Ward 2002).

The WHO states that 1.1 billion people lack access to safe water supplies, whilst 2.6 billion people lack adequate sanitation (World Health Organisation & UNICEF 2005, United Nations 2007a), and in its view this has led to widespread microbial contamination of drinking water (Vuorinen 2007). Consequently, a child dies every eight seconds from drinking contaminated water (de Villiers 2001).

When presented with such statistics, a typical first impression is that the figures have been skewed by the lack of facilities in the developing world. Indeed, roughly 40% of the population of the African continent do not have access to improved water supply and sanitation (Hutton & Haller 2004). However, what is less well known are the issues developed countries face.

For example, looking beyond Europe, America would most probably be cited as the country where the safest water can be found. Superficially, this would appear to be the correct response, as the whole of the North American sub-continent has access to improved water supply and sanitation (Hutton & Haller 2004). Nevertheless, the United States' Natural Resources Defense Council estimates that some 53 million inhabitants of that country drink tap water contaminated with lead, faecal bacteria or other serious pollutants (Barlow & Clarke 2002). As a result, each year about 560,000 people may suffer from a moderate to severe waterborne infection, and that 7.1 million people will contract a mild to moderate waterborne infection (Dufour et al. 2003). Because of pollutants like industrial herbicides and insecticides, nearly 40% of the rivers and streams in the United States are too dangerous for fishing, drinking or swimming (Barlow & Clarke 2002).

Elsewhere in the world, many parts are experiencing gradual destruction and increased pollution of fresh water resources, and numerous nations are finding it increasingly difficult to ensure an adequate supply of drinking water for their people (Hunter et al. 2000b).

Contamination of course does not always arise from man's activities – it can also be natural, the scale which can be significant. For example, upwards of 77 million of the total population of 125 million of Bangladesh may be exposed to undesirable levels of arsenic through their drinking water (World Health Organisation 2003b).

16.2.1 The European Situation

Here in the WHO's European region (which consists of all the countries within Europe, the Russian Federation, the former Soviet satellite countries, Cyprus, Iceland, Turkey and Israel), as at 2000, approaching 1 in 20 of its inhabitants (or 26 million (World Health Organisation & United Nations Children's Fund 2000)) were without access to an improved water supply[22]. In urban areas, 100% of the population had access to an improved water supply, but amongst the rural population this figure was only 87% (World Health Organisation & United Nations Children's Fund 2000).

Thanks to initiatives such as the Drinking Water Directive (European Union 1998), consumers of such improved water supplies throughout the EU are confident that the water is safe to drink, although a large number will be ignorant of the standards to which the water has been treated (Anderson 2003). But is this confidence well grounded?

A joint report produced by the WHO and the European EA stated that "although high standards have been reached in some countries [in the WHO's European region], outbreaks of waterborne diseases continue to occur across Europe, and minor supply problems continue to occur in all countries" (Bartram et al. 2002). This report goes on to state that "the standard of treatment and disinfection of drinking water is inconsistent across Europe and ... can be insufficient", and that "reliable data are lacking on the quality of the source water and the drinking water supplied, and the detection and investigation of outbreaks are generally poor in most countries".

[22] The WHO and UNICEF Joint Monitoring Programme for Water Supply and Sanitation considers the following to be 'not improved' – unprotected well, unprotected spring, vendor-provided water, bottled water and tanker truck provision of water – whilst the following are considered to be 'improved' – household connection, public standpipe, rainwater collection, borehole, protected dug well and protected spring. (World Health Organisation & United Nations Children's Fund 2000).

16.2.2 A UK Perspective

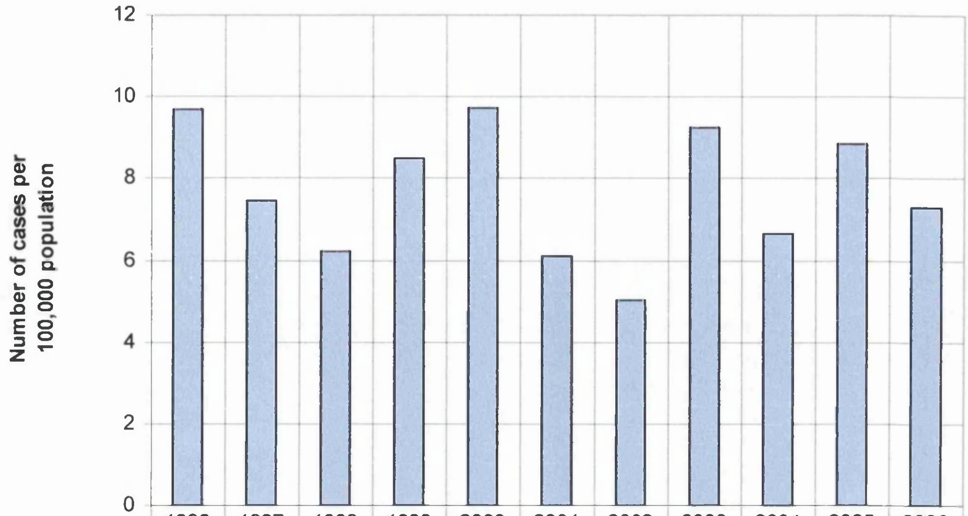
A review by Galbraith et al (1987) found that there were 34 outbreaks of waterborne disease recorded in the UK between 1937 and 1986, comprising over 11,794 cases and at least six deaths. The majority of these outbreaks (21) were due to contaminated public water supplies, whilst the remaining 13 outbreaks arose from contaminated private water supplies (Galbraith *et al.* 1987, Watkins *et al.* 2001).

Contrast these results with a similar review undertaken by Hunter et al. (2000a), but for a much more recent period (1991 to 1998), which found there were 35 outbreaks of disease linked to drinking water in the UK; by comparison, during the same period there were 113 in the United States (Hunter et al. 2000a).

According to Watkins et al. (2001) the link between drinking water and the occasional outbreak of gastrointestinal illness is beyond doubt, and the WHO encourages the use of health-based targets when considering the risks associated with public water distribution systems. However, this type of analysis is difficult to carry out in developed countries such as the UK where the incidence of mortality or illness linked to the public water supply is very low and cannot be reliably measured (Dufour et al. 2003).

For example, in the case of a low-level incident (such as an intense rainfall event in a heavily-grazed upland catchment containing an impounding reservoir use for public water supply), a significant proportion of gastrointestinal illness of a waterborne origin such as cryptosporidiosis is likely to be undetected by the health authorities as the symptoms are usually mild and only last a few days, so people will generally not be sufficiently concerned to see their GP (Dufour et al. 2003).

Because of this element of under-reporting, care has to be taken when reviewing incidences of cryptosporidiosis in the UK, such as the data presented in Figure 3 which relates to the period 1996 to 2006 inclusive (World Health Organisation Regional Office for Europe 2007).



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
United Kingdom	9.7	7.45	6.21	8.51	9.72	6.09	5.02	9.26	6.64	8.85	7.29

Figure 3: Incidences of cryptosporidiosis in the UK during the period 1996-2006 inclusive

The data appear to show a slight downward trend over the 10-year period. However, this information must be read with some caution. Not only should under-reporting be taken into consideration, but also visitors who contract diseases such as cryptosporidiosis whilst on holiday contribute a significant proportion of cases of such illness in a number of European countries, including the UK. Tourists are especially likely to contract enteric diseases, such as gastroenteritis, from pathogens the resident population may be able to tolerate (Bartram et al. 2002).

16.3 Contamination of Drinking Water Supply Chains

If drinking water supply chains were hermetically sealed, with uncontaminated precipitation falling on catchments, the risk of this water being polluted on its way to perfectly performing purification plants was zero, and then delivered via chemically inert, leak-free pipes, there would be no need for this thesis. The reality though, is that these supply chains can potentially be exposed to an immense number of risks, for example, arising from contamination incidents, industrial accidents, poor catchment management, deficiencies in treatment, distribution or monitoring or even malicious intent (Gray & Thompson 2003). Consequently, the safety of, and confidence in, tap water around the world varies markedly.

With regards to the provision of drinking water, contamination of water supplies can be grouped into a number of different categories (such as private and public water supplies, or relating to their source or the size of the supplies), but for the purposes of this thesis it is considered in terms of two broad categories – contamination occurring within the catchment prior to water being abstracted for treatment purposes, and contamination occurring post-abstraction (during treatment and its subsequent distribution to customers). An overview of the scope of these two categories is given in Sections 16.4 and 16.5, along with relevant data obtained from the appropriate regulators in England and Wales.

16.4 Pre-Abstraction Contamination

Within the catchment water contamination is a very general term that refers to the accidental as well as the deliberate introduction of undesired and/or harmful agents in surface waters or groundwaters, and by extension into water supplies (Persoone et al. 2003).

Even with the generally high standards of drinking water that we currently enjoy across Europe, new threats (both natural and accidental) to the safety of our drinking water supplies have emerged or become of greater concern over the last few years, such as *Cryptosporidium* and *Giardia* (both of which are protozoan parasites (Health Protection Agency 2007b, Health Protection Agency 2007a)), diffuse pollution and climate change.

Between 1972 and 1999, 35 new agents of disease were discovered (the significant ones are given in Table 3 (Hrudey & Hrudey 2004)), and many more have re-emerged after long periods of inactivity; the WHO has stated that the total of emerging and re-emerging waterborne pathogens is 175 (World Health Organisation 2003a).

YEAR IDENTIFIED	PATHOGEN
1972	Small round structured viruses (SRSVs, calciviruses)
1973	Rotaviruses
1976	*Cryptosporidium parvum*
1977	*Campylobacter spp.*
1983	*Escherichia coli O157:H7*
1992	*Vibrio cholerae O139:H7*

Table 3: Major waterborne pathogens causing diarrhoeal disease identified since 1972

According to the WHO, there are many reasons why human pathogens emerge or re-emerge (World Health Organisation 2003a). Climate change is one such significant reason, because if extremes of drought and rainfall intensify as predicted, this will create new environments; infectious diseases such as cryptosporidiosis would therefore probably increase as a result (Vuorinen 2007).

16.4.1 Water Pollution Incidents in England and Wales

The EA is the lead environmental regulator for England and Wales, and has responsibilities for the protection, remediation and improvement of our land, water and air (Environment Agency 2007a). As such, it is therefore responsible for investigating pollution incidents within catchments (which would fall under the heading of 'pre-abstraction contamination') and co-ordinating any subsequent clean-up operation.

The EA categorises each pollution incident according to its severity. There are four categories, with Category 1 being the most serious, whilst Category 4 has no impact on water, land and/or air. Category 1 water pollution incidents have the following characteristics (Environment Agency 2007d):

- Persistent and extensive effects on quality;

- Major damage to the ecosystem;
- Closure of a potable abstraction;
- Major impact upon amenity value;
- Major damage to agriculture and/or commerce; and
- Serious impact upon man.

Category 2 water pollution incidents (defined as significant but less severe) have the following characteristics (Environment Agency 2007d):

- Significant effect on quality;
- Significant damage to the ecosystem;
- Non-routine notification of abstractors;
- Reduction in amenity value;
- Significant damage to agriculture and/or commerce; and
- Impact upon man.

Data published by the EA relating to water pollution incidents during the period 1996-2006 inclusive are presented in Figure 4 (Environment Agency 2007c; Environment Agency 2007d; Environment Agency 2007e; Environment Agency 2007f; Environment Agency 2007g; Environment Agency 2007h; Environment Agency 2007j; Environment Agency: Matt Starr 2007).

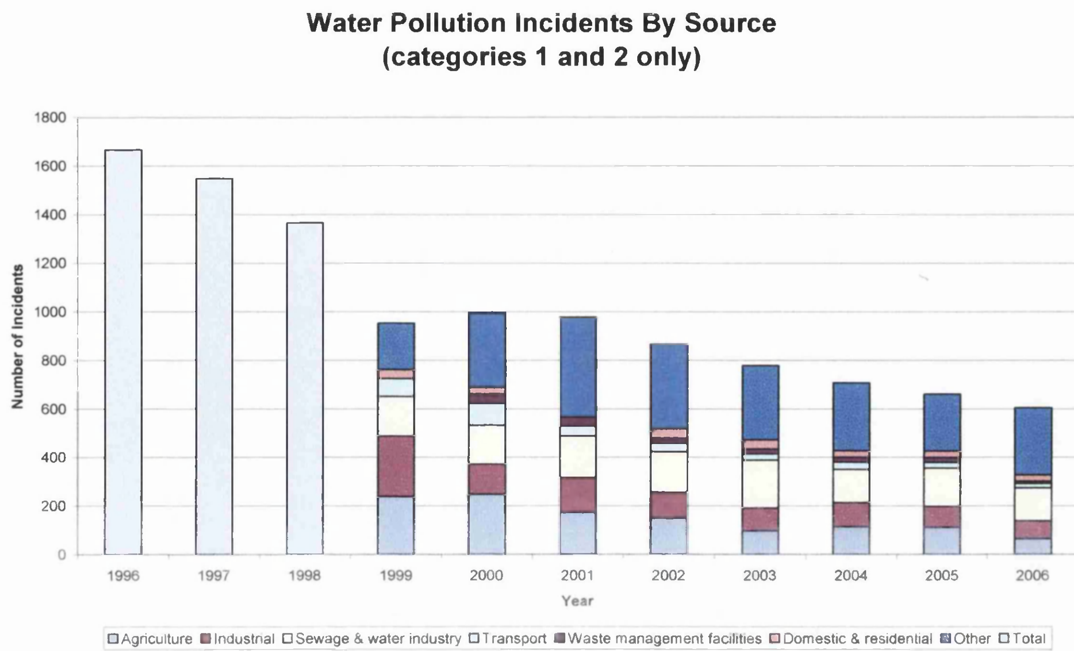


Figure 4: Number of water pollution incidents by source (Categories 1 and 2 only)

Prior to 1999 the EA did not record water pollution incidents by source, hence only the total of category 1 and 2 pollution incidents can be shown in Figure 4 for the years 1996, 1997 and 1998. Nevertheless, the marked decline in the total number of pollution incidents hides an important fact – the source of a significant number of pollution incidents cannot be identified, and these are included in the 'other' category. The data relating to 'other' sources is plotted in Figure 5 (Environment Agency 2007c; Environment Agency 2007d; Environment Agency 2007e; Environment Agency 2007f; Environment Agency 2007g; Environment Agency 2007h; Environment Agency 2007j; Environment Agency: Matt Starr 2007), and it can be seen that the percentage for 2006 is the highest value in the period for which data are available (Environment Agency 2007e).

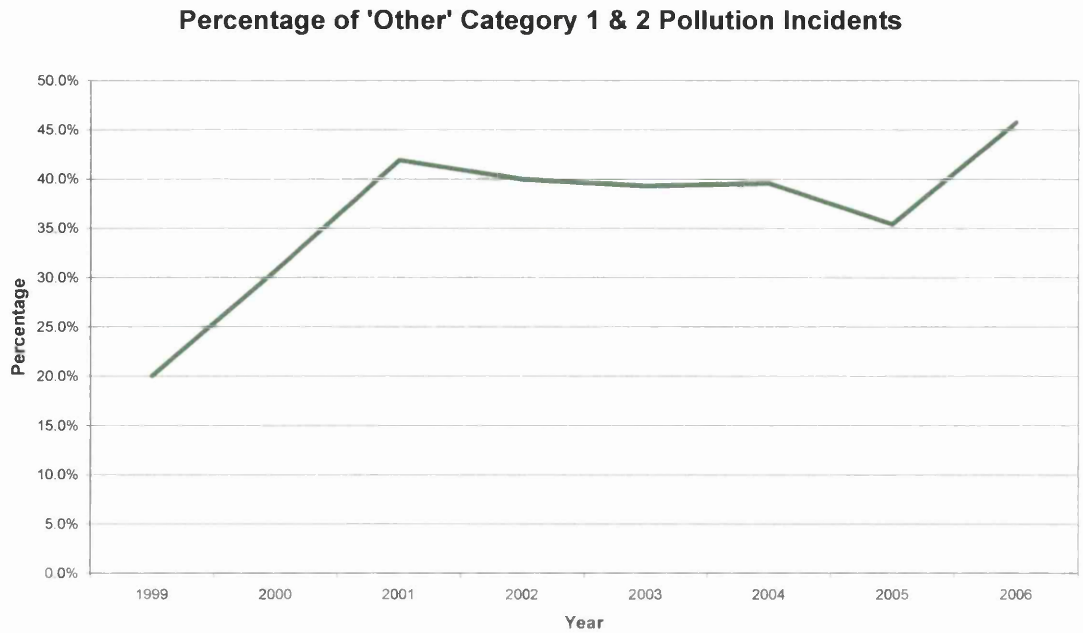


Figure 5: Percentage of Category 1 and 2 pollution incidents in the 'other' category for the period 1999 to 2006 inclusive

16.5 Post-Abstraction Contamination

Just because a community has access to a high quality source of water from a relatively pollution-free catchment does not mean it is invulnerable to drinking water related illnesses. This is because distribution systems have the potential for efficiently transporting microbial pathogens (perhaps arising from a treatment failure or a back-siphonage incident) to large numbers of people (Keirle & Hayes 2008a).

A failure (accidental or otherwise) of the electrical supply in an area may lead to a partial shutdown of the system (Deininger 2003). A major fire may cause flow reversals within part of a distribution system, as the fire brigade draws water from it to supply its hoses, which could give rise to re-suspension of historic sediments within a main, or even instances of back-siphonage (World Health Organisation 2007, Wessex Water 2007).

Although we often tend to focus on such accidental contamination incidents, natural events such as tornados or major flood events can also adversely affect the quality of drinking water after it has entered the distribution system, sometimes with devastating results.

For example, the unprecedented widespread floods across central England during Summer 2007 left up to 350,000 people in Gloucestershire without safe mains water supplies due to flooding at Mythe water treatment works which had not been predicted, despite the forecasted heavy rain and flood warnings (BBC 2007a; Severn Trent Water 2007a; Severn Trent Water 2007b; Severn Trent Water 2007e). This water treatment works was the sole source of supply for Gloucester, Cheltenham and Tewkesbury but was evacuated early on 22 July 2007 due to the site being flooded to a depth of 18 inches (Severn Trent Water 2007a). Full access was regained three days later, and mains water supplies were reinstated on a phased basis over the next few days (Severn Trent Water 2007c). As a precaution, customers were advised to boil the water, until analytical results confirmed the mains water was safe to drink, and the 'boil water' notice was lifted on 7 August 2007 (Severn Trent Water 2007b).

A distribution system can also be vulnerable to earth movements, ranging from the micro end of the scale (such as caused by shrinkage and expansion of the clay – which itself is naturally corrosive to cast iron mains – in many parts of London, giving rise to the numerous bursts and leaks experienced by Thames Water (Guardian Unlimited 2007; Thames Water 2007a; Thames Water 2007b)) to the macro (such as earthquakes).

16.5.1 Incidents Affecting the Quality of Public Water Supplies in England and Wales

Because it is difficult to directly determine the influence drinking water has on non-outbreak levels of illness in developed countries, it is necessary to look at secondary indicators to identify potential risks. Two such indicators are published by the DWI. In this context, as the EA is responsible for investigating incidents of pre-abstraction contamination, the DWI has responsibility for investigating incidents of post-abstraction contamination.

All water companies in England and Wales are required to notify the DWI of "the occurrence of any event which, by reason of its effect or likely effect on the quality or sufficiency of water supplied by it, gives rise or is likely to give rise to a significant risk to the health of persons to whom water is supplied", in accordance with Section 9 of the Water Undertakers (Information) Direction 1998 (subsequently replaced by Section 7 of the Water Undertakers (Information) Direction 2004) (UK Government 1998g, UK Government 2004e). Examples of events include discolouration arising from disturbance of oxidation products in water mains as a result of changes in flow, microbiological contamination, and loss of pressure and/or supply (Drinking Water Chief Inspector 2007).

An incident is a sub-set of events defined by the DWI to include (Drinking Water Chief Inspector 2001):

- An unusual deterioration in water quality; or
- A significant risk to the health of consumers; or
- Adverse water quality changes perceived by consumers as significant; or
- A cause for significant media interest.

A non-incident is any other event notification which is not an incident.

The DWI reports yearly on the number of events notified to them, whilst the other useful secondary indicator is the number of prosecutions brought by the DWI under Section 70 of the Water Industry Act 1991 (UK Government 1991d) for water "unfit for human consumption" (UK Government 1991d).

Data relating to the event secondary indicator are presented in Figure 6 (Drinking Water Chief Inspector 1991; 1992; 1997; 2001; 2002; 2003; 2004; 2005; 2006; 2007a; b; c). Since privatisation of the water industry in 1989, there have been three Information Directions for water companies; the Water Undertakers (Information) Direction 1992 related to the provision of information in emergencies, whilst the two successive Information Directions mentioned above defined the requirements for information relating to events, incidents and emergencies (Rouse 1999, Department of the Environment & the Welsh Office 1992). Changes in the information requirements may account for the sharp rise in non-incidents from 1997 to 1998.

Nevertheless, despite showing a decrease in the more serious threats to water quality from 1999 onwards, over the entire period of the dataset, the number of events has increased significantly, from 176 in 1996 to 502 in 2006.

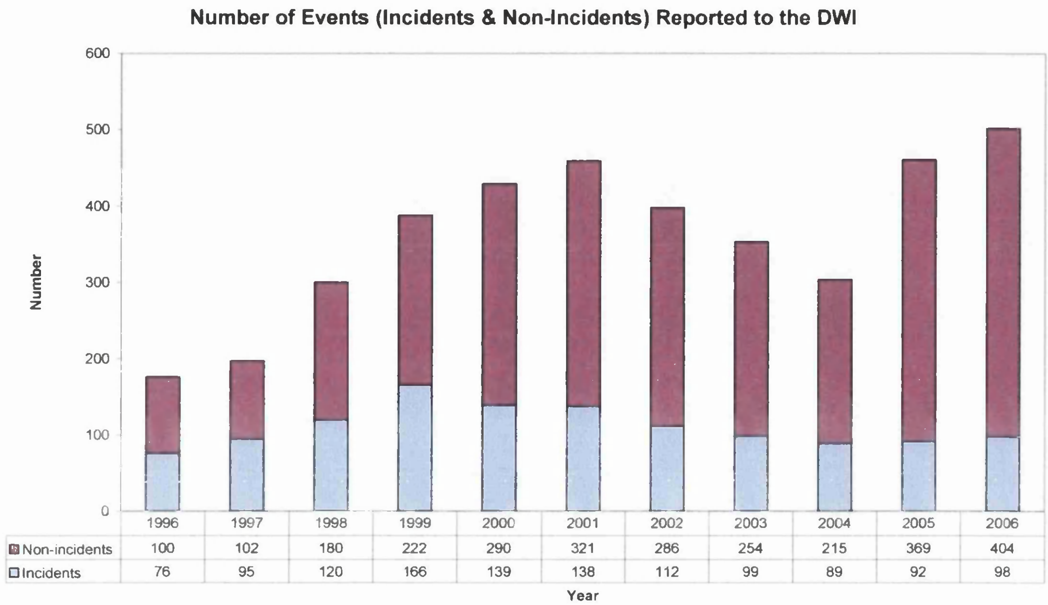


Figure 6: Number of events (incidents and non-incidents) reported to the DWI by water companies in England and Wales for the period 1996-2006 inclusive

Data relating to the prosecutions secondary indicator are presented in Figure 7 (Drinking Water Chief Inspector 1991; 1992; 1997; 2001; 2002; 2003; 2004; 2005; 2006; 2007a; b; c) which appears to show a general decline in the number of prosecutions over the 11-year period, although any interpretations of the data must be viewed with some caution due to the small number of data points.

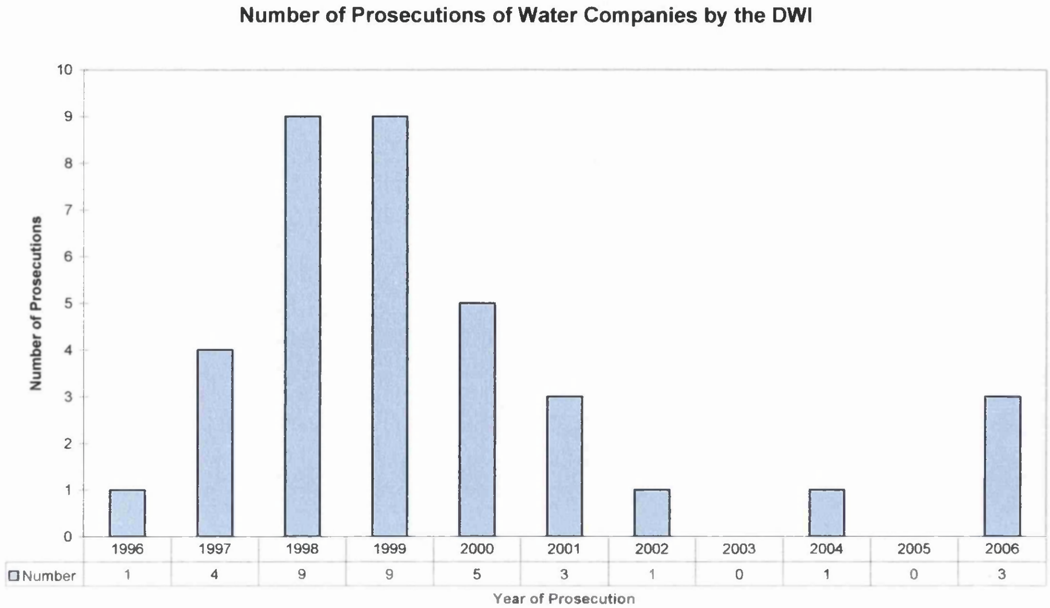


Figure 7: Number of prosecutions of water companies in England and Wales by the DWI for the period 1996-2006 inclusive

16.5.2 Private Water Supplies in the UK

A private water supply is defined as being "a supply of water provided otherwise than by a water undertaker" (UK Government 1991d) and they are generally derived from boreholes, wells and springs; approximately 1% of the UK's population obtains their drinking water from them (Watkins et al. 2001). Whilst water supplied by the water undertakers throughout the UK is generally of very high quality (which for 2006 resulted in an overall compliance of 99.96% with the Regulations in England and Wales, 99.76% in Scotland, and 99.34% in Northern Ireland (Drinking Water Chief Inspector 2007, Scottish Water 2006b, Northern Ireland Drinking Water Inspectorate 2006)), private water supplies can sometimes be of dubious quality. Private water supplies are five times more frequently contaminated than private commercial water sources and the smaller the supply, the more likely it is to be contaminated (Clapham 2003). According to Watkins et al (2001) "it is likely that drinking water from private supplies accounts for a significant burden of gastrointestinal illness … in the UK".

A study by Said et al. (2003) found that, for the period 1970 to 2000, private water supplies in England and Wales were involved in 36% of drinking water outbreaks, and gave rise to a 22-times higher risk of contracting diseases than public water supplies (Hrudey & Hrudey 2004).

If the quality of private water supplies is so bad, then why are there not significant instances of gastro-intestinal illnesses in rural communities? Clapham (2003) is of the opinion that, a resident population continually exposed to pathogens – including *Cryptosporidium* – eventually develop high immunity levels. In association with this theory, it is interesting to note that a study in 1996 found that people on private supplies consulted their doctor less often than those supplied by water companies, resulting in disease under-reporting (Clapham 2003).

16.6 Discussion

The provision of safe drinking water of sufficient quantity is an ongoing worldwide challenge and this review has highlighted some of the risks still inherent in the supply of drinking water, despite the numerous advances in water treatment technology, record levels of investment by the water industry and increasingly robust national and supra-national legislation. Consequently there are still many issues ahead for the water industry – in both the UK and across Europe as a whole – to address. For example, one area where effort must be particularly focussed is within the catchment, up to the point of abstraction. Although the total number of water pollution incidents by source within the catchment has declined during the period 1996-2006 inclusive, it is a matter of concern that there appears to be an increase in the percentage of incidents over the same period in the 'other' category (which includes incidents where the source of the pollution could not be identified).

This is a worrying development for the provision of safe drinking water supplies; how can water companies put effective control barriers in place, if they do not know what (or where) the hazards in the catchment are, and what risks they pose? Effective catchment management (see Chapter 12) will surely have some impact on the presence of micro-pollutants in our natural environment, but this may only be limited at best.

Consequently, we must remain vigilant to the threats from existing hazards, emerging hazards and re-emerging hazards (such as new strains of pathogens thought to have been eradicated in many parts of the world). Instead of being satisfied with record levels of compliance with the regulations, we must therefore facilitate a fundamental shift in how we ensure the safety of our drinking water, from a reactive, end-of-pipe testing situation, to a proactive, risk-based approach. Such an approach is enshrined within Drinking Water Safety Plans, and an overview of this approach is given in the next Chapter.

17 PRINCIPLES OF THE DRINKING WATER SAFETY PLAN APPROACH

17.1 Introduction

As Hrudey & Hrudey (2004) noted, if our goal is to provide "safe drinking water", we need to decide what we mean by the term 'safe'. The Cambridge Dictionary defines 'safe' as:

"Not dangerous or likely to cause harm."

(Cambridge Dictionaries Online 2008)

It can therefore be inferred that 'safe' in a drinking water context cannot, and does not, mean zero risk; some residual risk will always remain, but it is the magnitude of risk that is acceptable which is subject to debate. This is due in no small part to 'safe' being a subjective, and emotive, term – what one person would describe as safe is completely unacceptable to another.

Furthermore, as has already been demonstrated in the previous Chapter, our drinking water supplies are under siege from all quarters, throughout the four main stages of the supply chain (catchment, treatment, distribution and consumers' properties). It would therefore be wholly impossible, completely impractical and prohibitively expensive to remove all hazards – and the risk associated with them – from the supply chain. Hrudey & Hrudey (2004) therefore suggest that a realistic definition of 'safe' in a drinking water context is that we should "not expect to die or become seriously ill from drinking or using our tap water".

In our everyday lives, the terms 'safe' and 'risk' are often used, interchangeably, albeit erroneously (for example, compare use of the phrase "it is risky" with "it is not safe"). Indeed, the use of the two terms is combined as far as Drinking Water Safety Planning is concerned, in order to come up with the following "pragmatic notion of safety":

"A level of risk so small that a reasonable, well-informed individual need not be concerned about it, nor find any rational basis to change his/her behaviour to avoid a negligible but non-zero risk."

(Hrudey & Hrudey 2004).

The provision of safe drinking water is therefore essentially an exercise in risk management (Hrudey & Hrudey 2004, Australian Government 2004).

17.2 Compliance Monitoring

In order to detect whether post-abstraction contamination has occurred (or indeed, whether any pre-abstraction contamination has passed through the treatment stage), water companies have traditionally relied on a process called compliance monitoring to assess whether treated water is fit for human consumption, by testing samples taken from various stages of the treatment, distribution, and consumers' properties elements of the supply chain, typically as the water leaves the treatment works, from service reservoirs within the distribution system and from randomly chosen domestic properties (Canadian Council of Ministers of the Environment 2004).

The principal drawbacks of this process are that the volume of water sampled, compared with the volume of water supplied and subsequently consumed, is miniscule, and that the process itself is retrospective (Hayes et al. 2008); microbiological results will not start to be available until the day after the sample has been submitted for analysis, whilst more complicated tests (such as for pesticides) may take in the region of ten days. By then, if a problem is detected, the water would have entered the distribution system and may well have been consumed (Dufour et al. 2003). It is conceivable that, in the case of a contamination event, consumers could have actually fallen ill before the event could be identified and satisfactorily resolved.

Another major problem with compliance monitoring is that it is virtually impossible to address the entire range of potential health concerns, as this process only deals with microbiological pathogens and/or contaminants for which a prescribed numerical guideline value or established method of analysis has been developed (Canadian Council of Ministers of the Environment 2004).

As such 'end-product' testing comes too late to ensure safe drinking water, the focus has to shift further up the drinking water supply chain, and a combination of integrated proactive techniques and approaches (which is collectively known as the multiple barrier concept – see Section 17.4.3) have to be adopted, such as (Dufour et al. 2003, Fawell & Watkins 2003):

- Catchment management (to minimise the occurrence of pre-abstraction contamination) (see Chapter 12);
- Assessment and minimisation of risks; and
- Continual monitoring of the quality of the water throughout the supply chain, from the top of the catchment to the consumer's tap.

Consequently, 2004 saw the publication of two key documents – the Bonn Charter and the WHO's third edition of its Guidelines for Drinking Water Quality (International Water Association 2004, World Health Organisation 2004). These two complementary documents together describe a common framework for the effective provision of safe drinking water.

17.3 The Bonn Charter

The Bonn Charter was developed by senior representatives from research institutions, regulatory authorities, the WHO, the European Commission, the water industry and professional bodies and provides a high-level framework describing the operational and institutional arrangements that are basic requirements for managing water supplies from catchment to consumer (International Water Association 2004, Brandt & Wooster 2005); it has its roots in a workshop held in Bonn in October 2001, and it was subsequently refined at a second workshop held in February 2004. The framework incorporates the development of Drinking Water Safety Plans and the measurement of drinking water quality against relevant standards and is a means of assuring the quality of drinking water in the 21st century; at its core is the premise of Hazard Analysis and Critical Control Points (Brandt & Wooster 2005).

The goal of the Bonn Charter is "good safe drinking water that has the trust of consumers". An implementation guide – to be linked to the WHO guidelines – will be produced in due course in order to assist the water industry to attain this goal.

In order to create the management framework for the reliable provision of good, safe drinking water, the Charter recognises that a number of key principles need to be addressed, and these are reproduced here (International Water Association 2004):

1) Management of the whole water supply chain should always be set in the context of management of the whole water cycle, including, but not limited to:
    a) Management of water resource provision including, where necessary, resource augmentation;
    b) Management of water and land interactions, taking into account agricultural practices and urban development; and
    c) The collection and treatment of waste water.
2) Systems to ensure drinking water quality should not be based solely on end-of-pipe verification (testing against predetermined standards). Rather, management control systems should be implemented to assess risk at all points throughout water supply systems and to manage such risks.
3) Such an integrated approach requires close cooperation and partnership between all stakeholders including governments, independent regulatory authorities, water suppliers, local public authorities, health agencies, environmental agencies, land users, contractors, plumbers and manufacturers of relevant materials and products, and consumers themselves.
4) Open, transparent and honest communication between all stakeholders is essential to developing trust. It contributes to the development of effective water supply systems.
5) The roles and responsibilities of the different institutions contributing to the delivery of safe and reliable drinking water need to be clearly defined and ensure complete coverage of the system from catchment to consumer. Governments should establish the legal and institutional arrangements necessary to assign appropriate responsibilities among the various parties.

6) The way in which decisions are made relating to standards for the quality and reliability of water supplies should be transparent.
7) Water should be safe, reliable and aesthetically acceptable. In progressively realising the goals, however, the standards applied may legitimately vary from location to location and over time.
8) The price of water should be set so that it does not prevent consumers from obtaining water of sufficient quality and quantity to meet fundamental domestic needs.
9) Any system for assuring drinking water quality should:
    a) Be based on the best available scientific evidence; and
    b) Be sufficiently flexible to take account of the different legal, institutional, cultural, and socio-economic situations of different countries.

It is worth noting at this point that the Charter recognises that access to good, safe and reliable drinking water is a need, and not a right. Compare this stance with the view of the United Nations that such access is a fundamental human right (see Section 16.1).

17.4 The World Health Organisation's Guidelines for Drinking Water Quality

In 1958 the WHO published its first document dealing specifically with the quality of drinking water supplies, entitled International Standards for Drinking Water. The document underwent two revisions subsequently under the same title, until the first edition of the WHO's Guidelines for Drinking Water Quality was published in 1984-85; the third edition is the most recent revision of the guidelines, and it was published in 2004 (World Health Organisation 2004). The primary aim of these guidelines is the protection of public health, and in the latest edition the value of Drinking Water Safety Plans has "repeatedly been highlighted" (Davison et al. 2005)

Originally developed by the water industry in Australia, Drinking Water Safety Plans have now been adopted by the WHO and are being actively promoted by it (Hall

2006). One of a number of documents produced by the WHO in order to support the guidelines – entitled Water Safety Plans: Managing Drinking Water Quality from Catchment to Consumer – is of particular relevance to this thesis (Davison et al. 2005).

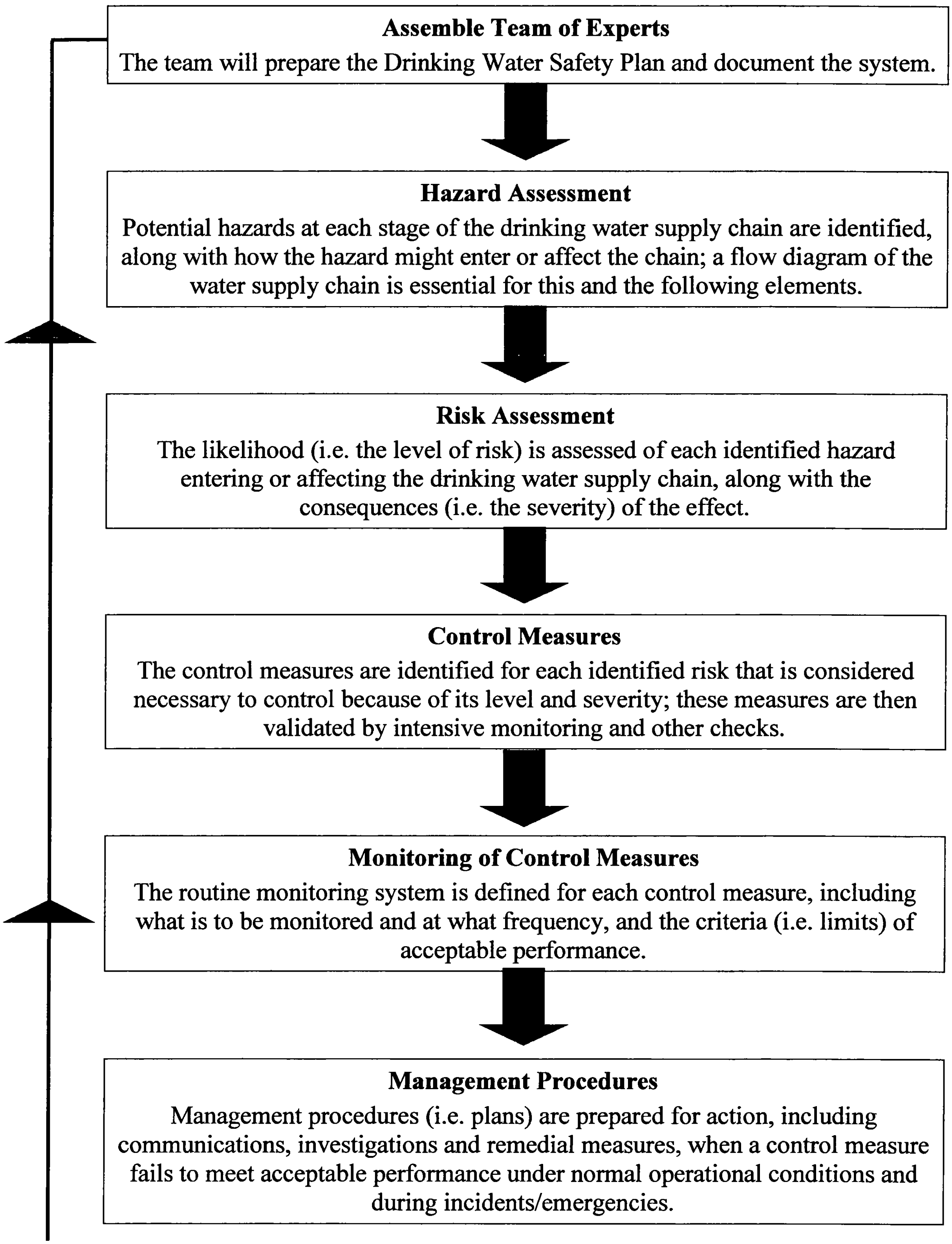
The major benefits of developing and implementing a Drinking Water Safety Plan is that they provide for a systematic and detailed assessment of all risks across the whole of the supply chain, a prioritisation of these risks, and the development of barriers and control measures to minimise, eliminate or mitigate the risks. Consequently, they can vary in complexity depending on the number, magnitude and type of risks encountered throughout the supply chain (World Health Organisation 2004).

In addition, these plans provide for a structured and organised management system to minimise the chance of oversight or human error adversely impacting on the integrity of the supply chain, and for contingency plans to respond to incidents (operational or environmental) (World Health Organisation 2004).

Drinking Water Safety Plans combine a number of systematic management approaches such as Hazard Analysis and Critical Control Point principles, management and assessment of risks and the multiple barrier concept, and they can be broken down into three key components (World Health Organisation 2004):

1) Management arrangements (including communication, capital and rehabilitation plans and documentation associated with quality assurance systems);
2) System assessment and design (to ensure the whole of the drinking water supply chain can provide consumers with a product of sufficient quality and quantity in order to comply with legal and environmental obligations); and
3) Operational optimisation and monitoring, so that if there is any deviation from normal operating parameters it can be speedily identified and prompt appropriate action taken.

A comprehensive account of the preparation of a Drinking Water Safety Plan is outside of the aims of my research, but an overview of this process is given in Figure 8 for reference (Drinking Water Inspectorate 2005a).



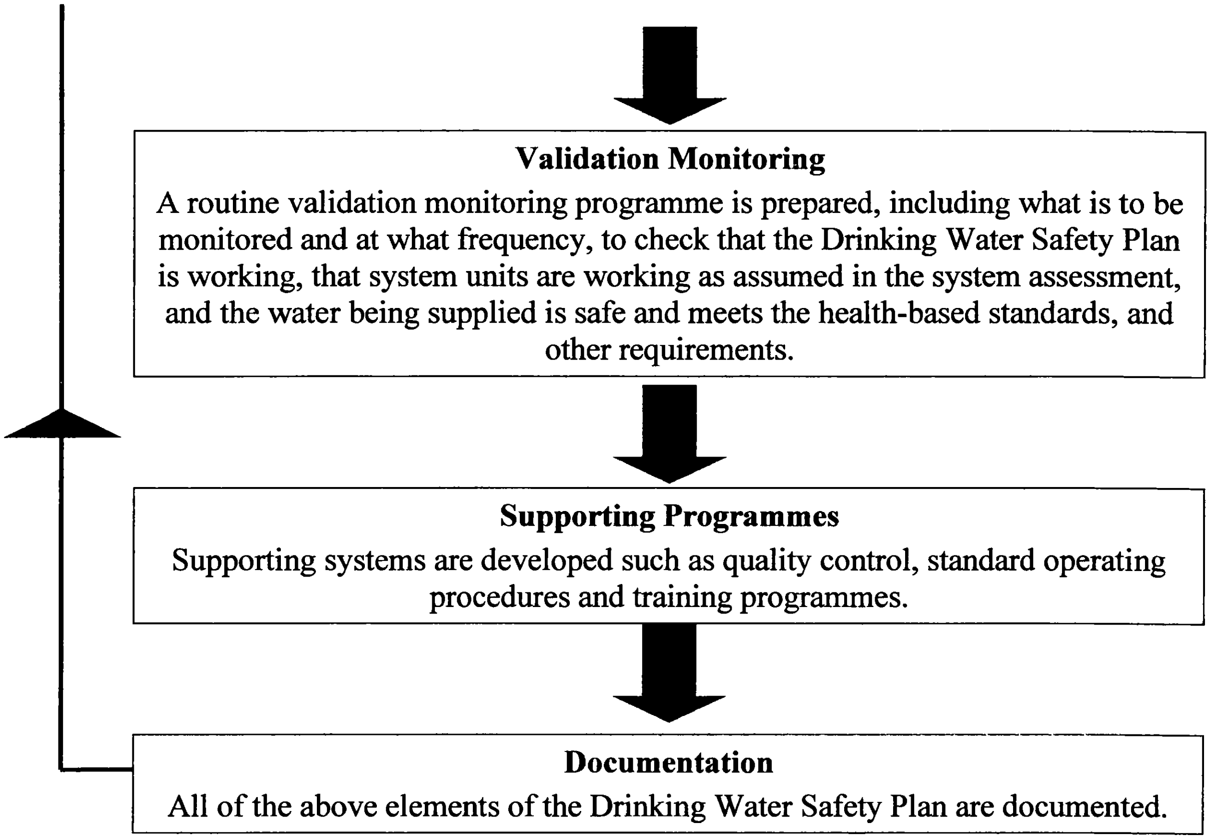


Figure 8: A flow diagram showing the steps required to produce a Drinking Water Safety Plan

17.4.1 Control Measures

Control measures are activities or measures (including strategies and policies) that are implemented in order to reduce, minimise or avoid the risk of the drinking water supply chain becoming contaminated by a particular hazard. Some hazards may require a combination of control measures for effective control, whilst some control measures will be effective against a number of hazards (World Health Organisation 2004). Also commonly referred to as 'barriers', control measures may take the form of activities or measures designed to (Ministry of Health 2005):

- Prevent contaminants gaining access to the water within the catchment;
- Remove hazards from the water;
- Inactivate pathogens in the water; and
- Maintain the quality of the water during distribution.

Whilst each of these types of control measures help to reduce the risk to public health from the drinking water supply, the greatest protection is gained when all are in place (see Section 17.4.3) (Ministry of Health 2005).

Control measures can be effective in reducing the levels of hazards in a number of ways, by (Davison et al. 2005):

- Reducing their entry into the water supply;
- Reducing their concentration once in the supply; or
- Reducing their proliferation.

Control measures that are alike can be represented on a flow diagram as one process step – these steps can be referred to as 'critical control points' (Davison et al. 2005).

17.4.2 Hazard Analysis and Critical Control Point System

The Hazard Analysis and Critical Control Point (HACCP) approach is a food safety management system that was originally designed for the US National Aeronautical and Space Agency to assure the safety of the food produced for the US space programme (Hulebak & Schlosser 2002, Hrudey & Hrudey 2004). Since then the approach has been revised and modified until it was subsequently implemented in its current form by the United States Department of Agriculture's Food Safety and Inspection Service by virtue of its HACCP Rule (Food Safety and Inspection Service 2007).

The HACCP approach has now been widely adopted by the food industry to minimise the risk of consumers contracting food poisoning from their products (Brandt & Wooster 2005); it is defined as:

"A system which identifies, evaluates and controls hazards which are significant for food safety."

(Thompson & Gray 2005)

The approach works by identifying hazards within the food preparation and production processes, which may be microbiological (such as salmonella), chemical (for example, cleaning materials used within the production lines in the factory) or physical (such as plastics from the packaging used for the ingredients). Control measures are then identified and implemented (at critical control points), which are then closely monitored in order to ensure that the food is safe to consume, and appropriate remedial measures are identified should things go wrong (HACCP Now 2006). The outcome of adopting this approach is the production of a HACCP plan which is defined as:

"A document prepared in accordance with the principles of HACCP to ensure control of hazards which are significant for food safety in the segment of the food chain under consideration."

(Thompson & Gray 2005)

From the above it can therefore be deduced that a HACCP system has two main characteristics (Hulebak & Schlosser 2002):

1) An identification and assessment of hazards; and
2) The implementation of critical control points.

Because of the obvious analogies between food preparation and the provision of water supplies, application of HACCP to assuring the safety of drinking water was proposed, and it is starting to be widely adopted around the globe (Hrudey & Hrudey 2004). Within the water industry, the identification of hazards and the implementation of key control measures to deal with them has always been good practice, so these elements of HACCP are not new. What is new to the industry though, is the general application of formal HACCP procedure, which is why HACCP is still in its infancy in this sector (Damikouka et al. 2007). Australia is arguably at the forefront of the implementation of this new approach, along with New Zealand, Iceland and Switzerland.

As has been previously mentioned, the premise of HACCP is at the core of Drinking Water Safety Plans. However, there are few really critical control points that can be applied to the drinking water supply chain, when compared to interventions in the food industry (such as pasteurisation), and the principle ones are given below (Kistemann et al. 2001):

1) Source water protection;

2) Abstraction system;
3) Treatment processes;
4) Disinfection;
5) Storage of treated drinking water; and
6) Distribution system.

Nevertheless, Drinking Water Safety Plans put great emphasis on the multi-barrier concept, which is not the case in HACCP.

17.4.3 The Multiple Barrier Concept

The primary purpose of water treatment is to provide drinking water which is wholesome, free from pathogens and aesthetically acceptable to consumers. Because no single treatment process can be relied upon to remove all pathogens and other undesirable contaminations, all water companies in the UK today, and the majority of the suppliers of drinking water worldwide, employ the multiple barrier concept as part of their overall plans for providing safe water. The idea behind this concept is that, if one barrier (or control measure) were to collapse or fail to work optimally, then the other barriers would still be in place to minimise the presence of pathogens in the water entering the public supply system, thus making an outbreak much less likely (Dufour et al. 2003; Fox 2000; Hrudey and Hrudey 2004).

A good definition of the multiple barrier concept is:

"An integrated system of procedures, processes and tools that collectively prevent or reduce the contamination of drinking water from source to tap in order to reduce risks to public health."

(Canadian Council of Ministers of the Environment 2002)

It therefore follows that the multiple barrier concept encompasses all elements of the water supply chain, and it can be broken down into the following five broad areas (Dufour et al. 2003, Fox 2000):

1) Selection of the best available source of water;
2) Catchment management;

3) Water treatment;
4) Consumer protection and distribution; and
5) Education.

Further clarification of each of these five areas is given in the following sub-sections.

17.4.3.1 Selection of the Best Available Source of Water

The first crucial step in supplying safe drinking water to an area is the careful choice of the best available source of water; the most protected waters will be the easiest and the cheapest to treat (Dufour et al. 2003).

Generally speaking, groundwaters are afforded greater natural protection than surface waters because of their overlying strata. The water percolating through these layers may well contain pathogens and have a high suspended sediment content, but these can be effectively removed by biological processes and filtration. Pathogen die-off is also an important factor in reducing microbial risk, during the extended time taken for the water to travel from the surface to the aquifer. Again, in general, the deeper the groundwater (taken from confined or semi-confined aquifers), the less the risk from contamination (Dufour et al. 2003).

Consideration has to be given to the aquifer's overlying strata, as course or fractured strata will greatly increase the risk of contamination of the groundwater (for example, by shortening either or both of the route or time of transmission of pathogens from septic tanks, soakaways, cesspits and agricultural stores of manure), as well as the geochemistry of the strata and aquifer (for example, a high natural arsenic or fluoride content may render the groundwater unsuitable for supply) (Dufour et al. 2003).

When considering a surface water source, upland catchments should usually be considered in preference to lowland catchments, as the risk of contamination from discharges and pollution incidents will be significantly reduced. However, the risk of faecal contamination from livestock, wild animals and humans (via soakaways and cesspits) is greater.

Whereas the quality of groundwaters tends to be very consistent, the quality of surface waters can be highly variable, on both temporal and spatial scales. For example, the quality of water within a storage reservoir can vary season by season, due to factors such as algal blooms and changes in the quality and quantity of inflows. Storm events can cause peaks in turbidity, suspended sediments, organic matter and faecal material, caused by spills from combined sewer overflows and emergency overflows, urban and agricultural run-off, and re-suspension of sediments (Dufour et al. 2003).

17.4.3.2 Catchment Management

Once the source has been identified, its catchment should be managed in order to prevent undesirable substances and pathogenic organisms from entering the drinking water supply chain. Effective protection of the drinking water source, including the control of land use within the catchment or recharge area, will greatly reduce the potential for pollution of the source. This in turns reduces reliance on treatment processes to ensure water is produced that meets regulatory standards and which is acceptable to consumers (Ainsworth 2004).

It follows that if a catchment is proactively managed to minimise contamination of sources of supply, the degree and range of treatment required can feasibly be reduced (along with water companies' operating costs and disinfection by-products), and ultimately the eventual cost to the consumers may well fall. Catchment management covers a multitude of policies and techniques, including land management, minimising the impact of discharges, reservoir management, building and development policies, and any other activity that would reduce contamination of sources of supply (Fox 2000).

In order for catchment management to be robust, information would be required on (Dufour et al. 2003):

- Sources of contamination within the catchment, including their nature and location;
- The natural variability over time of the quality of the abstracted water, and how it reacts to meteorological events (such as drought, storms and flooding);
- Efficacy of the different treatment processes employed at eliminating contamination peaks in the abstracted water; and
- The hydrology and hydrogeology of the catchment.

This information could then be used to predict peak contamination events, enabling effective catchment control measures to be identified and implemented.

In general, within England and Wales the emphasis of water companies has more commonly been placed on treatment than catchment management. This is a pragmatic situation as treatment is wholly within the control of the water company, whilst it has little or no control over the use of the land in the catchment of its sources of supply where its landholding may be small or even insignificant (ADAS 2006b, Morris & Cunningham 2008).

For catchment management to be truly effective many different stakeholders (such as local authorities, landowners, public bodies and NGOs) need to be involved, which is very difficult to put into practice (Dufour et al. 2003); the need for different bodies to be involved is so that control measures may be planned and implemented, which will require close coordination and effective communication across several disciplines (World Health Organisation 2004).

Further information on catchment management is given in Chapter 12.

17.4.3.3 Water Treatment

Water treatment is key to both the multiple barrier concept and to protecting public health (Canadian Council of Ministers of the Environment 2002), and it covers all the different techniques that are at the water industry's disposal to produce safe, wholesome drinking water. Examples of these include filtration, dissolved air flotation, ozonation and the use of granular activated carbon. The water treatment barrier can only be fully effective though if the individual treatment elements are designed, maintained and operated properly (Fox 2000).

17.4.3.4 Consumer Protection and Distribution

Following abstraction and treatment, drinking water becomes a vulnerable and perishable product (Dufour et al. 2003). Once the water has entered the distribution system, its quality may be compromised by pathogenic organisms introduced through inefficient treatment or breaches of the integrity of the pipe network, and subsequently harboured within biofilms, sediments and corrosion products (Ainsworth 2004).

Consequently, before the water leaves the treatment works, water companies in the UK are legally obliged to add more chlorine to it (either on its own or in conjunction with ammonia to produce chloramines) so that a disinfection residual is maintained as the water passes through the distribution system on its way to the consumers. This residual helps prevent the re-growth of organisms and provides some protection against subsequent contamination (such as during a burst or back-siphonage). As with the water treatment critical control point, the distribution system must also be designed, maintained and operated properly in order to help preserve the integrity of the drinking water (Fox 2000). A robust inspection, cleaning and maintenance programme of the distribution system, coupled with its proper operation, is therefore essential.

The final stage of the drinking water supply chain – when the water leaves the distribution systems and enters buildings – can also present hazards to drinking water quality, in the form of poorly performing or badly fitted point-of-use devices such as water coolers and filters. Water within a building's internal plumbing can stagnate if left for long periods, giving rise to taste and odour problems, microbiological problems and dissolution of plumbing metals. Particular buildings at risk include (Ainsworth 2004):

- Hotels with intermittent room occupancy;
- Schools during holiday periods;
- Sections of hospitals closed for long periods; and
- Office buildings unoccupied during weekends or holiday periods.

17.4.3.5 Education

This last barrier complements the other four specific areas, as it relates to the education of everyone involved with the water supply chain, from the farmers in the catchment, through to the water industry's operatives and finishing with the consumers. Everyone needs to understand and appreciate the impacts their actions could have on the integrity of drinking water supplies, from the unwitting disposal of pesticides in a remote stream to the use of a hosepipe to fill a pond without a non-return valve being in place. Training should therefore be a central component of a water company's investment plans; if a water company operative doesn't understand the importance of the chlorination process, then he may not be particularly bothered if it's not functioning properly, with potentially catastrophic consequences (Fox 2000).

17.4.4 Hazards, Hazardous Events and Risks

The adoption of a risk-based approach, such as the multiple barrier concept, is essential to the effective management of drinking water systems. Hazard identification and risk assessment are valuable tools for understanding the vulnerability of a drinking water supply and for planning effective risk management strategies to ensure drinking water is kept clean, safe and reliable (Canadian Council of Ministers of the Environment 2004). It is therefore prudent to consider appropriate definitions of hazard, hazardous event and risk, and how these terms are inter-related.

In 2004 the Australian Government produced guidelines to "provide a framework for good management of drinking water supplies that … will assure safety at point of use" (Australian Government 2004). Although not mandatory legally enforceable standards, the Australian Drinking Water Guidelines (to give them their formal title) apply to any water intended for consumption, irrespective of the source and, as such, provide a highly useful and authoritative reference (Australian Government 2004). These Guidelines espouse the following practical definitions (and which have been adopted in this thesis) (Australian Government 2004):

- A **hazard** is a biological, chemical, physical or radiological agent that has the potential to cause harm.
- A **hazardous event** is an incident or situation that can lead to the presence of a hazard (what can happen and how).
- **Risk** is the likelihood of identified hazards causing harm in exposed populations in a specified timeframe, including the severity of the consequences.

In order to illustrate the proper use of the above terms, *Cryptosporidium parvum* is a hazard; failure at a water treatment plant leading to *C. parvum* passing into the distribution system is a hazardous event; and the likelihood of the organism being present in source water and passing through the treatment plant in sufficient numbers to cause illness is a risk (Australian Government 2004).

17.4.5 Hazard Identification and Risk Assessment

The Australian Drinking Water Guidelines suggest the following six steps in order to undertake hazard identification and risk assessment (Australian Government 2004):

1) Define the approach and methodology to be used for hazard identification and risk assessment;
2) Identify and document hazards, sources and hazardous events for each component of the water supply system;
3) Estimate the level of risk for each identified hazard or hazardous event.
4) Evaluate the major sources of uncertainty associated with each hazard and hazardous event and consider actions to reduce uncertainty;
5) Determine significant risks and document priorities for risk management; and
6) Periodically review and update the hazard identification and risk assessment to incorporate any changes.

Once potential risks and the hazardous events giving rise to those risks have been identified, the probability of the hazardous event occurring should be assessed initially, followed by the likely severity the risk poses. The probability of a risk occurring, along with the severity of harm caused should the risk occur, both generally tend to be split into five categories, and example descriptive terms are given in Table 4 and Table 5 respectively, along with the weighting each category tends to attract (Dufour et al. 2003, Ministry of Health 2005).

CATEGORY	DEFINITION	WEIGHTING
Almost certain	Is expected to occur in most circumstances (for example, once a day)	5
Likely	Will probably occur (for example, once in 1 or 2 years)	4
Possible	Might occur at some time (for example, once in 10 years)	3
Unlikely	Could occur (for example, once in 100 years)	2
Rare	May occur only in exceptional circumstances (for example, once in 1,000 years)	1

Table 4: Example descriptive terms and weightings for probability of occurrence

CATEGORY	DEFINITION	WEIGHTING
Catastrophic	Major impact for large population	5
Major	Major impact for small population	4
Moderate	Minor impact for large population	3
Minor	Minor impact for small population	2
Insignificant	No impact or not detectable	1

Table 5: Example descriptive terms and weightings for severity of harm

Using the information detailed in Table 4 and Table 5, this semi-quantitative approach to risk assessment uses a simple risk score calculation matrix, such as the one given in Table 6, so that the risks may be ranked in order of importance.

PROBABILITY OF OCCURRENCE (with weighting)	SEVERITY OF HARM (with weighting)				
	INSIGNIFICANT	MINOR	MODERATE	MAJOR	CATASTROPHIC
RARE	1	2	3	4	5
UNLIKELY	2	4	6	8	10
MODERATE	3	6	9	12	15
LIKELY	4	8	12	16	20
ALMOST CERTAIN	5	10	15	20	25

Table 6: Simple risk scoring table for prioritising risks

Using the example given in Table 6, the score of 9 is taken as the cut-off; hazards with a score of 9 and below will be considered in future iterations (shaded as blue in the example), whilst hazards scoring greater than this figure will require further attention, so that a programme of assessment and implementation of control measures can be identified and implemented. Hazards scoring greater than 9 are sub-divided, so that those scoring higher than 16 require immediate and urgent attention (shaded red in Table 6).

17.5 Discussion

The process for developing a Drinking Water Safety Plan can be distilled down to the following four basic questions (Fawell & Watkins 2003):

1) What is the hazard?;
2) What is the risk associated with that hazard?;
3) How do we fix the hazard?; and
4) How do we ensure that the hazard stays fixed?

According to Fawell and Watkins (2003), the implementation of Drinking Water Safety Plans has other benefits, as the "process matches well with catchment management plans and should fit well with the requirements of the Water Framework Directive".

It is anticipated that the Drinking Water Safety Plan approach, in combination with the requirements of the Water Framework Directive, will be very successful in reducing the risks associated with macro-pollutants such as pesticides and nitrates, as these are hazards that are well known, and much time and effort has been spent understanding their origins and the impacts they have on the environment and human health. However, what is questionable is what impact Drinking Water Safety Plans – as well as the Water Framework Directive – will have on trace pollutants, such as xenobiotics, which are poorly understood.

Nevertheless, Drinking Water Safety Plans must consider all potential hazards to supply chains, both on the macro- and the micro-scale. In the UK it has not been common to monitor water sources used for drinking water supply (let alone other environmental waters) exhaustively for the purpose of detecting trace pollutants, beyond those that are specifically regulated. The current focus of risk assessments associated with the implementation of the Drinking Water Safety Plan approach in the UK appears to be on a relatively small number of parameters and which are listed within the drinking water regulations (National Assembly for Wales 2001b, UK Government 2000). This seems appropriate, as these parameters are generally well understood, and have established methods of analysis associated with them. It is therefore a relatively straightforward process to undertake risk assessments when such information is available.

However, it is difficult to appreciate how risk assessments can be undertaken of trace pollutants and emerging hazards if knowledge of them is poor and/or there is little information relating to their extent and potential impact on human health. It could be argued therefore that the providers of both private and public water supplies should be required to implement a comprehensive monitoring and sampling policy for these parameters, in order to ensure the risk assessment process is robust and well informed. Nevertheless, if such a policy were to be made mandatory, the cost would be prohibitive (Hayes et al. 2008).

In theory, Drinking Water Safety Plans should be developed for each supply chain, although in practice this may neither be realistic or cost-effective for small systems, and a model plan (with guidelines for its development and application to the supply chain) may be more appropriate. Indeed, this is the approach the Scottish Executive took when it overhauled its private water supplies regulations, by producing a technical manual containing guidance, risk assessment pro-formas and survey templates (Scottish Executive 2006f, Scottish Executive 2006e).

When it comes to public water supplies though, neither the DWI (for England and Wales), nor the Drinking Water Quality Regulator (for Scotland) has formally issued any guidance on how to produce such a Plan; indeed, the only document within the public domain produced by either regulator was an introductory guide produced by the DWI in October 2005 (Drinking Water Inspectorate 2005a). Instead, the regulators appear content for water companies to develop their own individual formats, whilst having due regard to the guidelines produced by the WHO (World Health Organisation 2004). Indeed, the DWI has stated that "it will not be prescriptive on the contents of a Drinking Water Safety Plan" (LaTrobe-Bateman 2007, Barrott *et al.* 2007).

Nevertheless, water companies have asked for the DWI to provide a checklist or set of criteria which they intend to use to audit Drinking Water Safety Plans (UK Water Industry Research 2007, Barrott et al. 2007).

18 MOVING FROM CONCEPT TO IMPLEMENTATION

18.1 Introduction

The previous Chapter gave an overview of Drinking Water Safety Plans, and the principles that underpin them; the purpose of this Chapter is to show how the Drinking Water Safety Planning concept is being introduced across the UK as a legal requirement, ahead of anticipated changes to legislation at the European level.

18.2 European Commission

In October 2003 the European Commission initiated a consultation on the proposed revision of the Drinking Water Directive, by means of a Drinking Water Seminar which was held in Brussels in order to give all stakeholders the possibility to give their views on the current directive and provide their thoughts on the preferred content of the revised directive (European Commission 2003).

Following the publication of the WHO's third edition of its Guidelines for Drinking Water Quality in 2004, in May 2006 the Commission started a joint project with the WHO, in order to draw upon experience gained by the various Member States of adopting a risk-based approach to the supply of drinking water, and to help it decide whether to include such a risk-based approach in the next revision (Cortvriend & Hulsmann 2006).

The project's working group (which consisted of a number of representatives from various Member States' governments, regulators and national bodies) met with water companies in a number of Member States, and the outcome was a report published in October 2007, in which one of the main recommendations was to advise the European Commission "to proceed with a revision of the current … directive to include [the Drinking Water Safety Planning] approach within a wider holistic context of a framework for safe drinking water" (World Health Organisation - Europe Region 2007).

At the same time as the publication of this report, the European Commission held a further stakeholder consultation in Brussels, which had the following objectives (European Commission 2008a):

- To present the main orientations of the revision of the Drinking Water Directive;
- To present the progress made on the topics identified by the Drinking Water Seminar in 2003; and
- To provide an overview of the timetable for the implementation of the revised directive.

The earliest anticipated date for the new directive is either 2008 or 2009, depending on the source, and a likely deadline for the transposition of the directive into UK law would probably be some three years after this. Nevertheless, the UK Government has already started to incorporate the requirements of Drinking Water Safety Plans with necessary updates to other water legislation (starting with the private water supplies regulations), and the water industry regulators are promoting the virtues of taking such a risk-based approach to drinking water safety.

18.3 Private Water Supplies

The issues highlighted in Section 16.5.2 may be one of the reasons why it was decided that, on a modest scale, the Drinking Water Safety Plan approach will be at the heart of the new regulatory regimes for private water supplies in the UK (Department of the Environment Food and Rural Affairs: Sharon Watkins 2006).

In March 2005 Edinburgh was the first of the devolved administrations to publish a consultation on the draft private water supplies regulations and a proposal for a private water supplies grant scheme (Scottish Executive Environment Group 2005). The other three devolved administrations in Belfast, London and Cardiff will be producing consultation documents within the new few months, each tailored to their own particular needs and requirements.

18.3.1 The Impact of Agriculture on the Quality of Private Water Supplies in Scotland

As a consequence of a number of outbreaks of *Escherichia coli* poisoning in Scotland (both waterborne and derived from contaminated foodstuffs), an *E. coli* task force was established in September 2000 by the Minister for Health and Community Care. Chapter 7 of the report the Task Force produced focussed on the possible routes of contamination of both public and private water supplies, and considered measures to protect and improve these supplies (Task Force on *E Coli* O157 2001). In the report it is noted that an investigation undertaken by the Water Research Council found that there was no evidence to suggest *E. coli* O157 was more persistent in the environment or more resistant to water treatment processes than the non-pathogenic *E. coli* found in the gastrointestinal tract. It is also noted that the preliminary findings of another study suggested that *E. coli* O157 can survive for up to 21 days in water. After assessing all of the evidence relating to public water supplies it had amassed the Task Force decided that the treatments in place appeared to be effective against *E. coli* O157.

With regards to private supplies, the Task Force found that the source of private supplies was often not stock-proofed, or had insufficient protective coverings, thus allowing direct faecal contamination of the water by livestock. They also received evidence that, on occasion, slurry spreading had taken place up to and over the source of supply (Task Force on *E Coli* O157 2001).

The report noted that observance of the 'Prevention of Environment Pollution from Agricultural Activity' code of practice (see Section 18.3.1.1) was highly variable throughout Scotland. The report considered the advice given in the code to be very sensible, and recommended that the code be revised to include a requirement for fencing-off water sources, and that the Scottish Executive should consider means of making this a mandatory requirement for private water supplies.

In their joint response to the Task Force's report, the Scottish Executive and the Food Standards Agency noted that the question of whether there should be a mandatory requirement for fencing-off private supplies featured in the consultation on private water supply regulation issued by the Executive in November 2001 (Scottish Executive & Food Standards Agency undated). However, this statement appears to be erroneous as this question does not feature in the consultation referred to (Scottish Executive Environment Group 2001), nor in the report on the consultation issued the following April (Scottish Executive Environment Group 2002).

The joint response also stated that the Scottish Agricultural Pollution Group would be asked to take account of the Task Force's recommendation that requirement for fencing be included in the next revision of the code of practice (Scottish Executive & Food Standards Agency undated).

18.3.1.1 'Prevention of Environment Pollution from Agricultural Activity' Code of Practice

This code of practice was produced to provide practical guidance on minimising the risk of environment pollution from farming operations (Scottish Executive 2005). Whilst the document provides guidance on the minimisation of pollution of land, water and air, it also acts as the requisite code of practice for the purposes of the Nitrates Directive (see Section 8.7).

The latest revision of the code was published by the Scottish Executive in January 2005, and now includes the recommendation of the *E. coli* Task Force. The code states that "it is essential to ensure that public and private water supplies are protected from grazing animals and land-spreading activities", and plenty of general advice is given throughout the document to minimise or prevent the pollution of watercourses. The main way of providing this protection is by fencing-off watercourses to prevent direct excretion of livestock into them, and that water troughs should be provided instead. It also states that "springs, wells and boreholes for drinking should be adequately fenced to prevent faecal contamination from grazing stock" (Scottish Executive 2005).

Another recommendation is that buffer strips between watercourses and field activities (such as slurry spreading or the spraying of pesticides) are created to reduce runoff and diffuse pollution; in particular, livestock slurries must not be spread within 10 metres of a watercourse, and 50 metres of a drinking water supply (Scottish Executive 2005).

18.3.1.2 Private Water Supplies (Scotland) Regulations 2006

In Scotland almost 80,000 people regularly use private water supplies to provide their drinking water, with a further 69,000 people being occasionally supplied by them (for example, whilst on holiday) (Scottish Executive Environment Group 2001). The quality of water from these private supplies can be highly variable, so the overriding objective of these new regulations is to ensure the provision of clean and wholesome drinking water (Scottish Executive 2006c).

When they came into force in July 2006, the regulations met the requirements of the Drinking Water Directive, and implemented many recommendations of Scotland's *E. coli* Task Force Report and the WHO's third edition of the Guidelines on Drinking Water Quality (Scottish Executive Environment Group 2005). Both these latter documents are underpinned by a risk assessment approach to the entire water supply chain, from a supply's headwaters to the consumer's tap (Scottish Executive 2006b). Risk assessments are therefore an important aspect of the new regulations, and are enshrined in Schedule 4 to the regulations (Scottish Executive 2006e).

Private water supplies in Scotland were previously regulated by the Private Water Supplies (Scotland) Regulations 1992 (as amended) (UK Government 1992b, UK Government 1998d), which allowed local authorities to have considerable discretion to develop and tailor policies to their specific priorities and circumstances (Scottish Executive Environment Group 2005). Now, because of the revised Drinking Water Directive, the new regulations are much more formal and local authorities must be more focussed in ensuring the quality of private water supplies meet the stringent requirements of the directive.

The regulations place a duty on local authorities to monitor the following types of private supplies (called 'Type A' supplies in the regulations) (Scottish Executive 2006e):

- Those that provide more than 10 cubic metres per day;
- Those that supply more than 50 people; and
- Any that supply commercial or public activities (irrespective of size).

Local authorities now have a duty to undertake an assessment of the potential health risks associated with all Type A supplies, which will comprise the following (Scottish Executive 2006e):

- Documentation on and a description of the supply, including the catchment from which the supply draws water;
- A hazard assessment and risk identification (covering the catchment, the type of water – i.e. surface water or groundwater – its treatment, storage and distribution);
- An identification of the measures by which risks may be controlled; and
- Establishment of verification procedures.

With regards to all other private supplies (so-called 'Type B' supplies) not falling into the above three categories, local authorities will continue to have discretionary powers similar to those that used to exist under the old regulatory regime. Also, the responsibility for undertaking risk assessments of Type B supplies will lie with the owner/operator of the supply, but the local authority is required to give that person such advice and assistance as they require to enable that person to undertake an assessment.

In theory, Drinking Water Safety Plans should be developed for each supply chain, although in practice this may neither be realistic or cost-effective for small systems, and a model plan (with guidelines for its development and application to the supply chain) may be more appropriate. It is presumed that local authorities in Scotland will be developing such a model and associated guidelines to discharge their obligations toward Type B private water supplies.

It is estimated that there are approximately 2,000 Type A supplies in Scotland, and about 19,000 Type B supplies.

It is the long-term expectation of the Drinking Water Directive that all private water supplies will eventually meet the new quality standards that it contains. However, the directive does realise that the standards cannot be met straight away, so it allows for temporary derogations from the chemical standards (derogations from the microbiological standards are not permitted on health grounds), provided that they do not "constitute a potential danger to human health and provided that the supply of water intended for human consumption in the area concerned cannot otherwise be maintained by any other reasonable means" (European Union 1998). This is a significant departure from previous provisions relating to private water supplies.

If a local authority is satisfied with an application for such a derogation, then it may authorise one for up to three years; the authorisation will include details of the programme of work required to ensure the private supply will subsequently meet the standards, an estimate of the costs associated with this work, and provision for reviewing the work's progress. If, once a review of the programme of work has been undertaken, the local authority believes the standards will not be met within the timescale of the derogation, a second (and even a third, if required) derogation can be authorised. It is worth noting that the directive does not make provisions for private supplies that do not meet the water quality standards after a third derogation.

If a Type A supply experiences an exceedance of one of the quality standards (or the quality standards are likely to be exceeded), then the local authority is obliged to investigate in order to identify the cause and provide the person responsible for the supply with appropriate advice. In the case of a Type B supply, the local authority has discretionary powers to investigate failures where, in the interests of public health, they consider action to be appropriate (Scottish Executive Environment Group 2005).

The regulations also prescribe sampling frequencies, parameters that constitute the basic minimum requirements for a wholesome and clean supply of water intended for human consumption, and so-called indicator parameters that can provide an early warning of whether the standards are likely to be breached.

18.3.1.3 Private Water Supplies (Grants) (Scotland) Regulations 2006

The Scottish Executive noted that the implementation of the Private Water Supplies (Scotland) Regulations 2006 had financial implications due to (Scottish Executive 2006c):

- Increased monitoring requirements; and
- Capital costs being incurred where a water supply requires improvement.

The Private Water Supplies (Grants) (Scotland) Regulations 2006 therefore commits the Executive to provide non means-tested grants of up to £800 per premises supplied by a private supply as a contribution towards the costs of improvements in order to comply with the Private Water Supplies (Scotland) Regulations 2006 (Scottish Executive 2006a). In exceptional cases, a local authority can consider making a grant in excess of £800 if it is satisfied that, without such a grant, the owner/operator of the supply could not finance the requisite improvements without undue financial hardship (Scottish Executive 2006a).

Based on the total number of Type A and Type B supplies (see Section 18.3.1.2), the maximum financial liability to the Executive if all the grants are taken up is £16.8 million (assuming no individual grants in excess of £800 are made). However, the Executive has calculated that the health benefit savings over a 15-year discounted period could be up to £61.5 million. The overall cost-benefit outcome (taking into account the annual increased monitoring cost to the local authorities) over a 15-year discounted period is +£10.8 million (Scottish Executive 2006c).

18.3.1.4 Private Water Supplies (Notices) (Scotland) Regulations 2006

These Regulations modify section 76G of the Water (Scotland) Act 1980 to place a duty on local authorities to serve notices in the case of Type A supplies which do not meet the requisite water quality standards set out in the Private Water Supplies (Scotland) Regulations 2006 (Scottish Executive 2006d).

18.4 Public Water Supplies

It is not currently a legal requirement for the UK water industry to produce Drinking Water Safety Plans, although as a consequence of recent regulatory changes in England and Wales (see Sections 10.23 and 10.24) water companies must now undertake risk assessments of the treatment and distribution elements of their drinking water supply chains.

Nevertheless, despite water companies not being legally obliged to produce these plans, both the Drinking Water Quality Regulator (for Scotland), and the DWI (for England and Wales) support the concept and have issued Information Letters on the subject (Drinking Water Inspectorate 2004, Scottish Executive Environment Group: Drinking Water Quality Division 2004).

The Environment and Heritage Services' Drinking Water Inspectorate (in Northern Ireland), has not yet developed a policy relating to Drinking Water Safety Plans, presumably because of the major reorganisation that has recently occurred within the Province's water industry (see Section 2.2.3).

18.4.1 Distribution Operation and Maintenance Strategies

An important precursor to Drinking Water Safety Plans was the development of a policy by the DWI for England and Wales (and which was subsequently adopted and promoted by the Drinking Water Quality Regulator for Scotland), relating to the operation and management of water companies' distribution systems. These so-called Distribution Operation and Maintenance Strategies (DOMS) represented a forward-thinking and risk-based approach to the operation and maintenance of water companies' distribution systems, and established an informed process to identify their future funding requirements in order to safeguard (and improve, where necessary) water quality on a continuing basis (Parker 2006).

When this policy was first promulgated for the water industry it represented a fundamental shift away from simply monitoring current drinking water quality against the regulatory standards, which is both retrospective and reactive (WRc 2006). The DOMS approach is also geared towards reducing customer complaints that are not always related to simple measurement of water quality parameters.

Although, as with Drinking Water Safety Plans, DOMS are not a legal requirement, both regulators support these strategies, and have issued guidance and deadlines for their implementation. Both regulators feel that recent improvements in the quality of drinking water should not be compromised by inadequacies in the maintenance and operation of water companies' asset base, and so the development of DOMS should prevent such compromises from occurring (Drinking Water Inspectorate 2002, Scottish Executive Environment Group: Drinking Water Quality Division 2003).

The two regulators' initiatives have been supported by their respective economic regulator counterparts (the Water Industry Commission for Scotland, and Ofwat), who have taken them into account in their respective price reviews (Heywood & Lumbers 2006b).

The purpose of a (DOMS) has been defined as:

> *"The identification of the operational and capital maintenance policies and interventions required to provide consistent or improving water quality to customers in the most effective manner."*
>
> (UKWIR 2006)

The scope of a DOMS should include (Heywood & Lumbers 2006a):

- All water company assets downstream of the water treatment works;
- All aspects of water quality that may be affected by the state or operation of these assets, and which are covered by regulations or are of concern to customers; and
- All actions taken on these assets that may affect water quality.

DOMS can now be viewed as a sub-set of the Drinking Water Safety Plan approach, as they both contain the following elements (UK Water Industry Research 2006a):

- Control measures and interventions;
- Operational monitoring;
- Distribution assets;
- Qualitative risk assessments; and
- Documentation of procedures, work instructions etc.

Where they differ, is that Drinking Water Safety Plans apply to the whole of the water supply chain, from the top of the headwater within the catchment, to the consumer's tap, whilst DOMS only applies downstream of the water treatment works. DOMS also go further than Drinking Water Safety Plans in two key areas; they consider economic analyses and quantitative risk assessments (UKWIR 2006) (these differences are represented diagrammatically in Figure 9 (Heywood & Lumbers 2006b)).

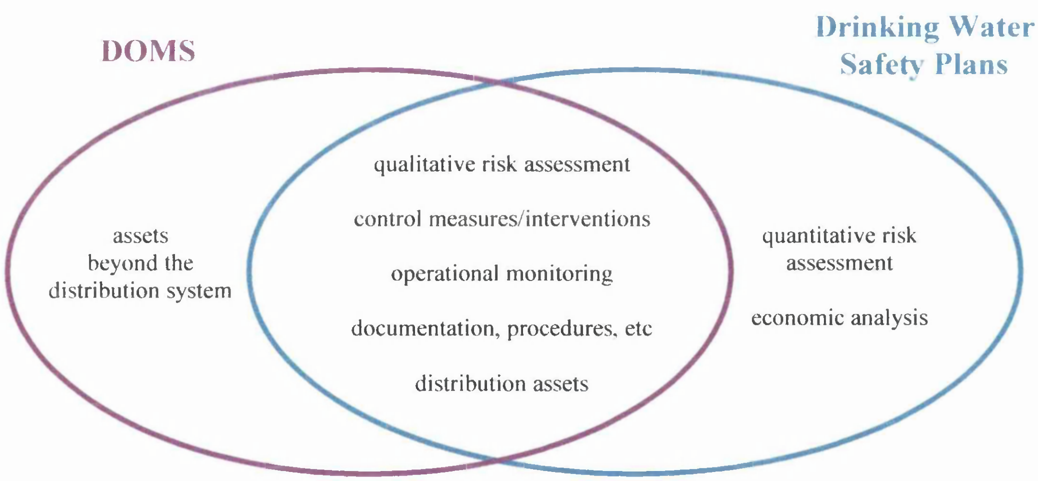


Figure 9: Inter-relationship of Drinking Water Safety Plans and DOMS

In the medium term both regulators recognise that there is a need for DOMS to be linked with the introduction of Drinking Water Safety Plans, although neither regulator has yet formulated their requirements for such plans within the distribution system (Heywood & Lumbers 2006b). Further specific information on the role the two regulators has adopted with the implementation of DOMS is given in the following two subsections.

18.4.1.1 England and Wales

The idea of water companies requiring a policy "on the use, operation and maintenance of its resources and assets" was first promulgated by the DWI in their Information Letter 7/98, which set out the information water companies would need to provide to the DWI if they wished to seek the Inspectorate's technical support for proposals for works to improve drinking water quality (Drinking Water Inspectorate 1998b).

The DWI issued further guidance on their information requirements in their Information Letter 13/98 a few months later, at which point the policy had evolved into the requirement to develop what was called at that time a Strategic Operations and Maintenance Strategy (Drinking Water Inspectorate 1998a). The purpose of a water company developing such a strategy was that it would reassure the DWI that, "having invested in improvement programmes to deal with known water quality problems, companies will operate and maintain their distribution systems proactively to ensure the quality of water supplied to consumers continues to comply with regulatory requirements".

Four years later, and the strategy had evolved further and acquired its present name of DOMS. Its purpose has also been refined as facilitating the "proactive management of drinking water distribution systems" (Drinking Water Inspectorate 2002). By this stage, the DWI had also made them a specific requirement of the Section 19 distribution system Undertakings that the DWI accepted from the water companies in 2000 (Heywood & Lumbers 2006a). Consequently, most water companies submitted draft strategies to the DWI which decided that, due to the quality and scope of such strategies varying quite widely, further guidance needed to be produced. The DWI subsequently decided that all water companies should develop a DOMS, not just those that have distribution system Undertakings, and so its requirements and expectations were set out in Information Letter 15/2002 (Drinking Water Inspectorate 2002); all water companies were required to submit a DOMS to the DWI by 31 December 2005.

Although the DWI recognised that each water company would develop a DOMS that reflected its own circumstances, they all should contain the following key elements (Drinking Water Inspectorate 2002):

- Proactive investigations of water quality within a supply system leading to programmes of planned maintenance work where necessary;
- Monitoring of actual or impending water quality problems at a local level leading to timely responsive maintenance;
- Control of operational activities (including undertaking a risk assessment before each activity, and adopting standard procedures where risks do not vary appreciably);
- Regular inspection and maintenance related to risks of water quality; and
- Cyclic review of the DOMS and its components.

The DWI notes that, although DOMS themselves do not have a regulatory basis, they regarded them as a "development and reinforcement of current good practice, and consistent with Regulation 17(1) of the 2000 and 2001 Regulations" (Drinking Water Inspectorate 2002; UK Government 2000c; UK Government 2001a). Therefore, the lack of DOMS conforming to the DWI's expectations would not be a matter for enforcement action, though in the event of a breach of the 2000 and 2001 regulations, the lack of a DOMS may be a material consideration.

A further information letter – 15/2005 – was distributed in October 2005, stating that the deadline for water companies to submit their updated DOMS document had been set back to 30 June 2006 (Drinking Water Inspectorate 2005b). The DWI felt that this revision of the deadline was necessary, as an UKWIR project reviewing industry experience of DOMS was expected to deliver recommendations and guidelines by 31 March 2006.

18.4.1.2 Scotland

Although the implementation of DOMS in Scotland has been delayed – probably primarily due to the fact that structure and regulation of the water industry has been through significant changes in the past few years, bringing it broadly into line with the model adopted in England and Wales – their structure, purpose and key elements are almost identical to the model the DWI has been advocating. This is not surprising, as the two regulators have worked quite closely on this, and other, drinking water quality issues.

The Drinking Water Quality Unit of the Scottish Executive set out their requirements and expectations for the preparation and implementation of a DOMS in a letter to Scottish Water dated 4 August 2003 (Scottish Executive Environment Group: Drinking Water Quality Division 2003). A further letter (serving the same purpose as the DWI's Information Letter 15/2005) was sent on 11 October 2005 (Drinking Water Quality Regulator for Scotland 2005).

18.4.1.3 Northern Ireland

Presumably for the same reason noted in Section 18.4, the Environment and Heritage Services' Drinking Water Inspectorate in Northern Ireland, has not, as yet, made the implementation of DOMS a requirement of their water supplier.

18.4.2 Implementation of Drinking Water Safety Plans in England and Wales

The DWI introduced its policy towards Drinking Water Safety Plans in their Information Letter 06/2004 of May 2004 (Drinking Water Inspectorate 2004). Because of their concern about the number of samples taken from water treatment works and service reservoirs failing the microbiological standards, the DWI views the development of Drinking Water Safety Plans as a "tool for developing and reinforcing existing good practice" and encouraged water companies to adopt this approach. The Information Letter also noted that the European Commission views Drinking Water Safety Plans "as the way forward for the Drinking Water Directive", although a new directive would be unlikely before 2009.

At the time the DWI conceded that Drinking Water Safety Plans did not, as yet, have a regulatory basis. However, they stated that, should a water company experience contraventions of the water quality standards, and they did not have such a Plan in place, then the DWI may consider initiating enforcement action under section 18 of the Water Industry Act 1991 (Drinking Water Inspectorate 2004, UK Government 1991d). Consequently, as at August 2006, ten of the 26[23] water companies in England and Wales were moving towards implementing Drinking Water Safety Plans (Breach & Williams 2006).

Any breach of the water quality standards contained in the regulations constitutes a criminal offence. Historically though, the DWI (under powers delegated from the Secretary of State) can consider such a breach to be "transient and trivial" if it did not constitute a threat to human health and there was no evidence to suggest it was part of a widespread or ongoing problem. However, in this same Information Letter, the DWI stated that it is their view that triviality is no longer applicable to failures of the microbiological standards at water treatment works and service reservoirs (Drinking Water Inspectorate 2004). Consequently, they would view any such failures as a failure to adequately treat and/or disinfect the water in contravention of Regulation 26, unless there was evidence to the contrary (UK Government 2000, UK Government 2001a).

Finally, the Information Letter noted that separate guidance would be issued on breaches of the microbiological standards at consumers' taps, and how the Drinking Water Safety Plan approach "would be taken forward by the Inspectorate in relation to distribution system integrity and water supply hygiene practice". At the time of writing (March 2008) this guidance has yet to be issued.

18.4.3 Implementation of Drinking Water Safety Plans in Scotland

The Drinking Water Quality Division of the Scottish Executive sent a letter very similar to Information Letter 06/2004 (see Section 18.4.2) to Scottish Water in June 2004 (Scottish Executive Environment Group: Drinking Water Quality Division 2004).

---

[23] As a result of mergers since August 2006, this number has reduced to 24, as at March 2008.

The main difference between the letters from the two regulators relates to the issue of triviality. The Scottish water quality regulations permit up to 5% of samples taken from service reservoirs in a calendar year to contain coliform bacteria, so the Drinking Water Quality Regulator does not have a triviality policy.

As with the DWI's Information Letter, this letter also contains a statement regarding the future issue of guidance relating to breaches of the microbiological standards at consumers taps; similarly, to date, no such guidance has been issued.

In 2006 the Drinking Water Quality Division of the Scottish Executive clarified its requirements for the production of Drinking Water Safety Plans, by referring Scottish Water to reports produced by UKWIR on the subject (Scottish Executive Environment Group: Drinking Water Quality Division 2006). It also set out a deadline for the production of the plans, and how they will be audited and signed-off.

18.5 Discussion

This Chapter has given an overview of the move from the Drinking Water Safety Planning as a concept, towards its implementation, with regards to both private and public water supplies, and some area-specific comments are given below.

18.5.1 Private Water Supplies

Amongst the four devolved administrations, Edinburgh was the first to revise its private water supplies regulations in order to incorporate the Drinking Water Safety Plan approach. Arguably, this was perhaps more to do with Edinburgh's reaction to water quality incidents experienced in Scotland in relation to private water supplies, rather than a proactive adoption of the WHO requirements. Nevertheless, Scotland has now established a model for the protection of the quality of private water supplies that the other three administrations would be well advised to study closely, in order to inform the consultations each of them will issue in due course when it comes to their turn to revise their own private water supplies regulations.

It would appear that the Scottish regulatory model will have one significant difference to the models being considered by the other three administrations, in that at the time of writing (March 2008), it does not appear that any of them will contain any element of grants, non means-tested or otherwise. This could potentially be an area of great concern to a consumer of a private water supply who has been advised by their local authority that the water quality fails to comply with the relevant standards, but who cannot afford the necessary capital improvements.

If the local authority serves an enforcement notice on the consumer demanding that improvements are undertaken within a certain timeframe in order to protect human health, would that local authority be given powers to physically cut the supply to the consumer's property on public health grounds should the consumer not comply? If the consumer is also the owner of the public supply, and they are not supplying the water to any third parties, would the serving of an enforcement notice or any subsequent disconnection represent an infringement of their human rights? Furthermore, would that same local authority be comfortable with ultimately taking that consumer to court should they fail to comply with the enforcement notice and continue consuming the non-compliant water?

18.5.2 Public Water Supplies

This Chapter has given an overview and timeline of the evolution of DOMS, an important precursor to Drinking Water Safety Plans, and has compared and contrasted the approach towards implementation of DOMS in the four constituent parts of the UK. It is interesting to note that the DWI (for England and Wales) advocated a proactive approach to the management of the distribution part of the drinking water supply chain some six years before the WHO started to officially promote Drinking Water Safety Plans in its third edition of its Guidelines for Drinking Water Quality.

Even though they are not yet a legal requirement, it is important to stress that many water companies will already have developed a number of elements of a Drinking Water Safety Plan to a certain degree so the development and implementation of such a Plan will merely represent a review, update and consolidation of existing management systems and procedures, rather than the implementation of a completely new management regime (Hall 2006). Existing systems and procedures may include (Barrott et al. 2007):

- Training plans;
- Communication policies;
- Emergency/incident plans;
- Distribution Operation and Maintenance Strategies (see Section 18.4.1);
- Site operational manuals; and
- Quality assurance systems developed in accordance with international standards, such as ISO 9001.

What will be missing though are some individual components of a comprehensive plan or the organisational and management structure for that plan (Thompson & Gray 2005).

As far as implementation of Drinking Water Safety Plans in England and Wales is concerned, there is a marked contrast between the enthusiasm and level of support for them from the DWI and Ofwat. The aspiration of the DWI is that Drinking Water Safety Plans "will become an effective tool for risk management, identifying hazards within drinking water supply systems that could lead to risk, and for identifying, and where necessary improving or developing, interventions to mitigate those risks and ensuring that the safety of drinking water is maintained through the effective management and maintenance of barriers" (Barrott et al. 2007). Ofwat's view though is that the adoption of the Drinking Water Safety Plan approach merely formalises what water companies should already be doing to minimise the risks to consumers from supply interruptions and breaches of the drinking water quality regulations. It therefore sees the approach as an administrative procedure which demonstrates due diligence, and that it should be built into "business as usual" (Barrott et al. 2007).

There is also a fundamental difference of opinion between the two regulators on the role Drinking Water Safety Plans should play in 2009's Periodic Review. The DWI feels that, should a water company require its support for a water quality related improvement to an asset, the DWI expects the required improvement to have been identified through a Drinking Water Safety Plan risk-based approach. However, Ofwat is of the opinion that Drinking Water Safety Plans "are not seen as justification for individual schemes at all"; instead, it feels that the principles of the Capital Maintenance Planning Common Framework approach are the primary 'framework' for the identification of capital investment needs, and that Drinking Water Safety Plans are just one of several tools that are to be used in order to produce information that can be fed into that framework (Barrott et al. 2007).

Because of Ofwat's stance that the development of Drinking Water Safety Plans should be built into business as usual, it is firmly of the view that they should not be funded via the Periodic Review process. This position contrasts starkly with the position adopted by the Water Industry Commission for Scotland, which has provided funding for Scottish Water via its own version of the Periodic Review specifically for the development of such plans; for each of the periods 2006-10 and 2010-14 it allocated £4.5 million against DW16, one of a group of drinking water quality drivers (Water Industry Commission for Scotland 2005).

The Scottish Executive's Drinking Water Quality Division (part of the Executive's Environment Group) imposed conditions on the use of this funding, in its Information Letter 1/2006, by stipulating the first tranche of funding would be used to produce Drinking Water Safety Plans for water supplies covering 50% of Scottish Water customers by 2010, and the second tranche used to complete the production of these Plans for the remaining supplies by 2014 (Scottish Executive Environment Group: Drinking Water Quality Division 2006). Furthermore, this letter stated the Drinking Water Quality Regulator required Scottish Water to "include the full range of water supply size and treatment type available … and [to] contain an element of risk-based prioritisation", in its first stage of production of these plans, instead of targeting a relatively small number of larger water treatment works in order to most readily achieve the initial target figure of 50% of customers (Scottish Executive Environment Group: Drinking Water Quality Division 2006).

18.5.3 Bottled Water Supplies

A topic that has been conspicuously absent from the debate about the Drinking Water Safety Plan approach is that of bottled water, and whether this approach should be extended to bottled water supply chains. Bottled water – whether labelled mineral, spring or simply filtered tap water – is obviously sourced from catchments, which can be subject to many of the same hazards associated with public water and/or private water supply catchments. Water intended for the bottled water market may be pumped or captured via springs, wells or boreholes, possibly subjected to minimal treatment (perhaps the elimination or addition of carbon dioxide) and then bottled and transported to retailers' premises, prior to being purchased by consumers (European Community 1980b).

The provision of both private and public water supplies is a continual process, with samples being taken regularly and results made available retrospectively. Compare this with the sampling approach taken with respect to bottled waters; the number of parameters being tested for is far less, but the water is not released for public consumption until the results are available. Nevertheless, the parallels between bottled water supply chains, and supply chains relating to both private and public water supplies, are obvious. What is far less obvious though is why the Drinking Water Safety Planning debate hasn't encompassed bottled water supplies.

In Section 16.5.2 I stated approximately 1% of the UK's population obtained its water from private supplies. Assuming a UK population of 60 million, and that each person consumes on average 3 litres of tap water per day, the annual consumption of water derived from private supplies is 657 million litres. Compare this with figures relating to the sale of bottled waters. In 1998 annual sales of bottled water was around 500 million litres, and was worth approximately £400 million per annum. Within five years the annual sales had quadrupled to two billion litres, making the industry worth an estimated £1.2billion (BBC 2008). Using these elementary calculations, the volume of bottled water supplied within this country is far more significant than the amount of water consumed from private supplies.

In many countries water companies are under a regulatory requirement to stockpile supplies of bottled water in order to provide adequate supplies during emergencies (Chartered Institution of Water and Environmental Management 2008). Indeed, in the UK, water companies are required to deliver a minimum amount of 10 litres of drinking water per person per day, in accordance with the Security and Emergency Measures (Water and Sewerage Undertakers) Direction 1998 (see Section 9.10.1). Usually these supplies are taken from the water companies' own water treatment works and, as such, have a vital advantage over purchased bottled water supplies; they contain a chlorine residual. Nevertheless, such emergency supplies should still be treated as a perishable product.

It follows that emergency supplies of bottled water, and regular supplies coming from consumers' taps, share the same first two parts of the drinking water supply chain, namely the catchment and treatment stages; where there is a significant departure is during the distribution stage, as during an emergency a water company may use plastic bottles, as well as bowsers and flexible plastic containers (Chartered Institution of Water and Environmental Management 2008).

During an emergency, such as the one experienced by Severn Trent Water during the extensive flooding in Gloucestershire during summer 2007 (see Section 16.5), a water company may be under unprecedented pressure in order to provide alternative supplies of drinking water in as short a timescale as possible. It is therefore feasible that a water company may be tempted to cut corners with regards to cleansing of these receptacles, in order to turn them round expeditiously; alternatively, the prevailing environmental conditions may offer an increased number of possibilities for such receptacles to become contaminated during delivery. The application of the Drinking Water Safety Plan approach to emergency water supplies, as well as purchased bottled waters and both private and public water supplies, would therefore appear to be both prudent and a necessary extension to the WHO's public health protection philosophy.

The reliance of water companies on emergency supplies in order to discharge their supply obligations can also be a matter of routine, as well as in exceptional circumstances. For example, Scottish Water relies on tankering water supplies to more remote parts of its supply system on a regular basis, as it has many supplies consisting of stream sources that are very vulnerable to the impact of dry spells, and the flows in them can drop very quickly to the point where they need to be supplemented (Fawell et al. 2005). Such a practice can lead to a number of potential hazards and increased risks, because the provision of water by tanker necessarily involves breaking the drinking water supply chain, in order to fill the tanks, and then connect them to the supply system "through a potentially vulnerable point" (Fawell et al. 2005). Therefore, it is important that this practice is included in the distribution part of a water company's Drinking Water Safety Plan – alongside the more traditional mains network, pumping stations and service reservoirs – particularly if the water company regularly utilises tankering.

The quality of purchased bottled water within England and Wales is afforded protection by various recent regulations, which are underpinned by an EU directive (UK Government 2007b, UK Government 2003b, UK Government 2004c, National Assembly for Wales 2003b, National Assembly for Wales 2004b, UK Government 2004d, European Community 1980b). Nevertheless, with voluntary and regulatory change already occurring in relation to both private and public water supplies, it seems sensible to consider whether a pro-active risk-based approach to the protection of the quality of both purchased and emergency bottled water supplies should also be taken, in order to ensure consistency of approach across the entire water supply sector.

19 POTENTIAL LIMITATIONS OF DRINKING WATER SAFETY PLANS: A REVIEW OF RECENT CONTAMINATION INCIDENTS

19.1 Introduction

In Sections 19.2 to 19.5 a review of a small number of selected pre- and post-abstraction contamination incidents relating to public water supplies is presented, in order to illustrate the different types of incidents experienced by the water industry in England and Wales in recent years, and how they have helped to shape the regulatory regime and the enforcement of the various drinking water quality regulations. A variety of sources has been used to formulate this review, including journal publications and reports where available, supplemented by media coverage in written form (which, although may not be as scientifically robust, has the beneficial currency of immediacy).

Taking each of the pre-and post-abstraction contamination incidents in turn, the principles of control measures were then applied, in the form of a desktop exercise, in order to determine whether the events in each case may have been affected if the respective water company had had a Drinking Water Safety Plan in place; the findings of this exercise are given in Section 19.6.

19.2 Introduction of Aluminium Sulphate to the Distribution System in Camelford

This is probably the most significant (and notorious) accidental post-abstraction contamination of the public water supply in the last 20 years.

On 6 July 1988 a contractor made a delivery of 20 tons of liquid aluminium sulphate to the un-manned Lowermoor water treatment works operated by South West Water Authority (SWWA) (Committee on Toxicity of Chemicals in Food Consumer Products and the Environment 2005). The contractor was a relief driver unfamiliar with the layout of the works and delivery procedures. Consequently, he emptied the contents of his tanker into the chlorine contact tank by mistake, and the aluminium sulphate entered the local distribution system (Cooperative Research Centre for Water Quality and Treatment 2002); he was able to do this "because he was given a key which fitted every lock in that and all other SWWA water treatment plants within a large area of North Cornwall" (Skudder 1998).

Although this large-scale contamination event is normally referred to as the Camelford incident (which is a small town of 2,500 people near the north Cornish coast), a number of other small towns in the area were also supplied by treated water from the works. It has been estimated that the summer population supplied by water from Lowermoor was 20,000, of which 12,000 were resident and the other 8,000 holidaymakers (Committee on Toxicity of Chemicals in Food Consumer Products and the Environment 2005, Clayton 1991).

Later that same day, customers began to complain to SWWA about the unpleasant taste to the water, and that it had a sticky feel to the touch. Although these problems were incorrectly attributed by SWWA to the lime-dosing plant at the water treatment works, at 11.00pm it began to flush out the acid water from the distribution pipes, which removed a significant amount of the aluminium sulphate from the distribution system. This process of flushing caused the death of 60,000 fish in the Allen and Camel rivers, before the full extent of the contamination was realised (The ENDS Report 1999a, Committee on Toxicity of Chemicals in Food Consumer Products and the Environment 2005); it also had the unfortunate effect of drawing more of the contaminated water into the distribution system through which it was dispersed according to the complexities of the system and the varying demands placed on different parts of it (Clayton 1989).

It was estimated that SWWA's customers were exposed for up to three days to water with pH as low as 3.9 to 5.0 (the pH of the upland water supplied to the water treatment works by Crowdy Reservoir usually lies within the range 5.1 to 7.1) (Clayton 1989; Committee on Toxicity of Chemicals in Food Consumer Products and the Environment 2005; Cooperative Research Centre for Water Quality and Treatment 2002). This gave rise to a secondary source of contamination coming from the customers' own plumbing systems within their properties, as the low pH of the water dissolved metals such as copper, zinc and lead from pipes and storage tanks (Committee on Toxicity of Chemicals in Food Consumer Products and the Environment 2005).

Samples taken from customers' properties gave rise to levels of copper or zinc up to 9,000µg/l being recorded in water from 'cold' taps, and up to 22,500µg/l from 'hot' taps (2,000µg/l is the legal limit for copper; there is no legal limit for zinc in the UK as it rarely occurs in drinking water at levels of concern) (Clayton 1989, UK Government 2000). Although lead plumbing was not widely used in the area, where it was present concentrations of up to 350µg/l recorded in 'cold water' samples and up to 460µg/l in 'hot water' samples (the legal limit was 50µg/l) (Department of Health 1996, UK Government 2000).

Furthermore, an aluminium content of up to 620µg/l was recorded in the water supply (the legal limit is 200µg/l), whilst a sulphate concentration of up to 4,500mg/l was recorded (250mg/l is the legal limit) (Committee on Toxicity of Chemicals in Food Consumer Products and the Environment 2005, UK Government 2000).

It is possible that in some parts of the distribution system the gross contamination persisted for longer than three days but there is no clear evidence to this effect (Clayton 1989). Nevertheless, after two or three days, the pH was restored to normal in most parts of the distribution system, as were the levels of copper, sulphate and zinc. However, compliance with the legal limit of 200µg/l for aluminium was only achieved after a period of intensive cleaning and flushing (Clayton 1989).

Despite the numerous complaints about the astringent taste and discoloured appearance of the water, and its effect on skin, plumbing and fixtures, the cause was not identified until two days later. Even when the cause was known, SWWA assured the public that the water supply was safe to drink (Skudder 1998; The ENDS Report 1999a; Thompson and Gray 2005). In fact, at no time did SWWA inform their customers not to ingest the drinking water, although they did eventually provide alternative supplies of water, such as bottled water or from bowsers (Skudder 1998, Committee on Toxicity of Chemicals in Food Consumer Products and the Environment 2005). Neither its customers nor the relevant public authorities knew the true nature of the incident until 17 days later when the regional paper ran a small article on its sports page (Thompson & Gray 2005).

The official advice, based on the toxicological literature and the information available in August 1988 on water quality in the area following the incident was that no delayed or long-term effects on health were to be expected (Clayton 1989). The immediate health after-effects included injuries to the skin, mouth and stomach, gastro-intestinal complaints, and a worsening of pre-existing conditions, amongst other disorders and, despite the official advice, other long-term adverse health effects have been slowly emerging since the incident (Thompson & Gray 2005).

Although nobody claimed that anyone had died directly as a result of the contamination arising at the time of the incident, there were "unusual mortalities" at some farms where stock were watered with mains supplies. Some 1,300 hens died at one farm, and 40 Muscovy ducklings died at another. Lambs on another farm also died, and a piggery suffered a decline in fertility and increased post-natal mortality. Analyses of tissue samples showed elevated levels of aluminium, copper and iron in liver, kidney, bone and hair (The ENDS Report 1999a).

A Lowermoor Incident Health Advisory Group was convened in January 1989 to provide independent expert advice on the implications for the health of the population supplied by contaminated water from Lowermoor water treatment works, and its report was published in July 1989; one of the reports main conclusions was that the Group considered it "unlikely in the extreme that long-term effects from copper, sulphate, zinc or lead would result from exposures of the degree and short duration that occurred after this incident". With regards to aluminium, the Group concluded that "delayed or persistent effects following such brief exposures are unlikely" (Clayton 1989).

However, as a result of ongoing public concern, the Group was re-convened in October 1990 "to assess reports which have become available since July 1989 of persistent symptoms and clinicopathological findings amongst people" who consumed the contaminated water, and its report was published in November 1991 (Clayton 1991). The Group concluded that the research reported to it "did not provide convincing evidence that harmful accumulation of aluminium [had] occurred, nor that there [was] a greater prevalence of ill-health due to toxic effects of the water in the exposed population" (Clayton 1991).

Despite these two official reports, public concerns were not assuaged at all, perhaps in no small part due to a paper published by Altmann et al. (1999) in the British Medical Journal in 1999 which concluded that "people who were exposed to the contaminated water at Camelford suffered considerable damage to cerebral function, which was not related to anxiety"; however, it did also state that "follow up studies would be required to determine the longer term prognosis for affected individuals" (Altmann et al. 1999).

Consequently, in August 2002 the Department for Environment, Food and Rural Affairs announced that the health effects of the incident would be re-investigated for a second time (Committee on Toxicity of Chemicals in Food Consumer Products and the Environment 2005). With respect to copper, aluminium, lead, iron, sulphate, zinc, and manganese, in each case the subsequent consultation report published in January 2005 stated that it was not anticipated that "they would have caused, or would be expected to cause, delayed or persistent harm to health" (Committee on Toxicity of Chemicals in Food Consumer Products and the Environment 2005).

19.3 The Wem Incident

In the morning of 15 April 1994, Severn Trent Water started to receive taste and odour complaints from its customers in the Worcester area, which was readily traced to the Company's Barbourne water treatment works on the River Severn. The works was shut down, and its customers were advised not to drink the water as a precaution until the source of the problem was identified and eliminated. Later that same day, a further water treatment works – Strensham and Mythe – downstream of Barbourne, was also shut down after taste and odour tests were carried out (Furness 2003). A third works in Tewkesbury was also shut down briefly, but was quickly brought back online as it had granular activated carbon filters which proved to be effective at removing the contaminants (The ENDS Report 1994b).

Over 140,000 people living within the city of Worcester and its surrounding area were affected by this incident, whilst customers as far away as Coventry experienced disruptions to their water supplies for a time after Strensham and Mythe water treatment works was closed down and alternative supplies were unable to meet demand (The ENDS Report 1994b).

Although one of Severn Trent Water's own samplers had detected a solvent smell in the discharge from Wem sewage works in Shropshire on 12 April, no action was taken by the Company until 16 April, when the source of the contamination was traced back to Wem Industrial Estate, at which time the police and the NRA (one of the predecessor bodies of the EA) attended the site and samples were taken for analysis (The ENDS Report 1994a, Furness 2003). The contamination was intercepted at the sewage works and tankered out of the catchment, and the company believed to be responsible for the contamination – Vital Scheme – was informed (Furness 2003, The ENDS Report 1994a). Consequently, on 17 April, the River Severn had no remaining trace of odour, and customer complaints rapidly subsided (Furness 2003).

Eventually it was determined that the chemical primarily responsible for the taste and odour problems was 2-ethyl-5,5-dimethyl-1,3-dioxane (2EDD), which did not appear to have been previously detected in UK waters (The ENDS Report 1994a).

The subsequent investigation found that there was no cause for concern about the safety of the drinking water, although its taste and odour made it aesthetically unpleasant. Although 2EDD would have been absorbed by activated carbon, no such treatment existed at Barbourne water treatment works as it was scheduled for closure (Furness 2003).

Severn Trent Water was eventually prosecuted for supplying water not fit for human consumption under Section 70 of the Water Industry Act 1991, which had never been tested in court before (The ENDS Report 1994b). The case was initially heard in Worcester Magistrates' Court in January 1995 but they decided their powers were insufficient to deal with the case, and so it was passed up to the Crown Court (The ENDS Report 1995d).

Seven so-called specimen charges were considered, each relating to particular premises in Worcester whose water supplies had been contaminated. The Company pleaded guilty to three of these, and the other four were allowed to lie on file. On passing sentence, the judge imposed a fine of £15,000 for each of the three charges, and ordered the Company to pay £67,000 in costs (The ENDS Report 1995a).

19.4 Cryptosporidiosis Outbreak in Torbay, Devon

An outbreak of cryptosporidiosis during the months of August and September in 1995 was shown to be associated with water supplied by Littlehempston water treatment works. The normal incidence of cryptosporidiosis at that time of year was about 15 cases, but during the outbreak 575 people were affected. Oocysts were found in the final treated water from this works, and the DWI concluded that South West Water could not demonstrate due diligence as a previous cryptosporidiosis outbreak within the area had also been linked to the same water treatment works (Hrudey and Hrudey 2004; The ENDS Report 1997a; Waite and Jiggins 2000).

It appeared that South West Water's culpability had been compounded by the fact the Company had inadvertently put their own water treatment works at risk, by abstracting some six kilometres downstream of their Buckfastleigh sewage treatment works the discharge from which contained "massive quantities" of *Cryptosporidium* at the time of the outbreak and which had "heavily contaminated" the River Dart as a result (The ENDS Report 1999b, The ENDS Report 1995c). Indeed, subsequent genotyping of specimens from 49 cases showed all of them to be *Cryptosporidium parvum* genotype 1, the genotype transmitted by humans (i.e. human sewage contamination was the most likely source) (Hrudey & Hrudey 2004).

The robustness of the treatment processes at Littlehempston water treatment works had already been called into question on two previous occasions – an outbreak of cryptosporidiosis affecting at least 160 people in the Torbay area during the second half of 1992 had been statistically linked to this works, and the detection of *Giardia* in 1993 in service reservoirs supplied by Littlehempston (The ENDS Report 1995b, The ENDS Report 1997a).

The DWI decided to pursue a prosecution, and the case was heard in the Crown Court in September 1997. The cornerstone of the DWI's case was an epidemiological investigation contained within the report produced by the Outbreak Control Team, but the judge in the case ruled that the report was inadmissible as the defence were unable to controvert every piece of information contained within it. The DWI offered no further evidence and South West Water was acquitted of all charges (Waite & Jiggins 2000, The ENDS Report 1997b).

19.5 Cryptosporidiosis Outbreak in North West Wales

In 2005 cases of cryptosporidiosis were higher than expected in late summer throughout the whole of the UK, including Wales. More people in Anglesey and Gwynedd contracted the illness than the previous year, but up to the beginning of November, laboratory reports covering the whole of Wales also showed an overall increase. The *Cryptosporidium hominis* strain of the parasite is more frequently isolated during the autumn peak, and this same strain was found in Gwynedd and Anglesey residents (National Public Health Service for Wales 2006).

Because of the increased illness in the area, Dŵr Cymru Welsh Water began monitoring water supplies daily for *Cryptosporidium* at the beginning of November and provided mapping of local cases. GPs were also asked to look out for people with symptoms of cryptosporidiosis (National Public Health Service for Wales 2006).

An Incident Management Team of public health experts and Dŵr Cymru Welsh Water staff met on 7 November to discuss these findings and to plan more detailed investigations. Results from this work showed background levels of disease were specifically higher for people living in the area supplied with water derived from Llyn Cwellyn (National Public Health Service for Wales 2006); this was despite Cwellyn water treatment works being in accordance with regulatory requirements (BBC 2007).

On average, three or four cases of cryptosporidiosis are confirmed each month in the Anglesey and Gwynedd areas, but in this instance local cases rose rapidly to more than 100 by the end of November, and doubled by mid-December (Gibbons 2006); this steep rise in infections was not evident in other parts of Wales (National Public Health Service for Wales 2006).

By 29 November, a questionnaire study had shown an association between diarrhoeal illness due to *Cryptosporidium* and drinking tap water, even though records revealed the water treatment works for Llyn Cwellyn had been operating normally. Although *Cryptosporidium* oocysts were found in the water in the reservoir, the concentrations remained well within treatment standards (National Public Health Service for Wales 2006).

However, the combination of a steep increase in local cases of cryptosporidiosis and the results of the questionnaire, led to an outbreak being declared and, as a precautionary measure, the Outbreak Control Team advised Dŵr Cymru Welsh Water to issue a 'boil water' notice to residents receiving water from Llyn Cwellyn on 29 November (National Public Health Service for Wales 2006).

After investigations and the installation of ultra-violet treatment at Cwellyn water treatment works, the Outbreak Control Team advised that the 'boil water' notice could be rescinded as from 30 January 2006 (National Public Health Service for Wales 2006, Gibbons 2006). In total, the number of confirmed cases of cryptosporidiosis in the Anglesey and Gwynedd areas since the beginning of the outbreak was 231, however it must be stressed that not all of these were linked to the outbreak because a certain number of background cases were to be expected (Gibbons 2006).

In August 2007 the DWI brought a case against the Company in Caernarfon Magistrates' Court for supplying water unfit for human consumption, and in October 2007 it pleaded guilty to four specimen charges, for which it was fined £15,000 for each charge; it was also made to pay just under £70,000 towards prosecution costs (BBC 2007b; Consumer Council for Water 2007; Drinking Water Inspectorate 2007a).

Prior to the court case, Dŵr Cymru Welsh Water had already paid £25 to each of its customers inconvenienced by the outbreak, and subsequent to the court's verdict, the Company said that it would "settle all claims for compensation where medically proven" (Anonymous 2007).

19.6 Discussion

In Section 17.4.1 the concept of control measures was introduced. To summarise, control measures can be effective in reducing the levels of hazards in a number of ways, by (Davison et al. 2005):

- Reducing their entry into the water supply;
- Reducing their concentration once in the supply; or
- Reducing their proliferation.

Taking each of the pre-and post-abstraction contamination incidents in turn, the principles of control measures were applied, in the form of a desktop exercise, in order to determine whether the events in each case may have been affected if the respective water company had had a Drinking Water Safety Plan in place.

Such an exercise was useful for a number of reasons. Principally, the four incidents that were presented in the previous sections are arguably held up to be 'industry standards' as far as contamination incidents are concerned, and have been subsequently analysed and reviewed on a number of occasions. Indeed, as I have identified, a number of lessons have been learnt, giving rise to fundamental regulatory changes as a result of an analysis of two of the incidents, whilst the other two incidents have greatly informed the incident management process, and augmented our understanding of criminal law and corporate culpability.

To my mind, this retrospective analysis of these four incidents with specific regard to the requirements of Drinking Water Safety Plans has never been previously undertaken, which in some small way will hopefully add to the body of opinion that has already been formed about these incidents, and identify whether any element of these incidents was actually unavoidable.

Leading on from that point, the secondary purpose of this exercise was to test the integrity of the Drinking Water Safety Plan approach. Many bodies and individuals have given the impression that, once implemented, Drinking Water Safety Plans will enable 100% compliance with the regulatory standards, and ensure that drinking water contamination will never occur again. To perpetuate such an opinion may indeed be desirable in some quarters, in order to facilitate the rapid implementation of these Plans by the UK water industry, and perhaps even to halt the seemingly relentless increase in the popularity of bottled water over tap water, partly due to the perceived inferiority of the quality of our mains supplies.

As part of this exercise, I also attempted to determine whether a specific control measure, catchment management (either on its own or as part of a Drinking Water Safety Plan), would have any effect on the central hazard in each incident.

19.6.1 Introduction of Aluminium Sulphate to the Distribution System in Camelford

The Camelford incident is the most notorious post-abstraction contamination incident in recent years, principally because it highlighted a number of systematic failures by South West Water Authority that could have been wholly avoided. For example, if a thorough risk assessment had been undertaken at Lowermoor water treatment works, one of the potential hazardous events that would have been highlighted is the lack of signage at the chemical receiving points. If the chlorine contact tank and the aluminium sulphate tank had been clearly labelled, the subsequent incident would have been wholly avoided. The undertaking of risk assessments is the fundamental principle which underpins Drinking Water Plans, so this point should have been readily identified and acted upon.

Furthermore, as a result of a wholesale review and tightening of procedures arising from the lessons learned by the water industry subsequent to this incident, all deliveries at operational sites by non-water company staff are now met by suitably trained and knowledgeable water company employees, so that the confusion that the relief driver experienced on 6 July 1988 would now be avoided. As operational procedures and training plans form part of Drinking Water Safety Plans, it is hoped that this point would have been addressed at the time should a Plan have been in place, so that the relief driver would not have been able to gain unsupervised access to the chemical delivery point.

Also, these Plans also incorporate security arrangements, and so now it would be inconceivable for a non-company employee to be provided with a key that would allow them access to sensitive areas of a large number of operational sites. Indeed, many water companies have now implemented security systems that have a both a hierarchical access basis, as well as a geographical element. For example, water companies now may have a number of divisions with different keys required for different divisions. Furthermore, within these divisions, company employees and contractors may only have keys for non-sensitive parts of operational sites (perhaps just the grounds themselves for the purposes of grass-cutting), but their keys do not work in locks leading to more sensitive parts (which are generally tiered according to their importance) of the site. At the top of the scale, treatment operatives now have keys that operate all locks on the site.

Consequently, if South West Water Authority had used a robust risk assessment methodology in order to inform the Drinking Water Safety Planning process, and implemented appropriate operational procedures, training plans and security policies, the resulting Plan would have been successful, at the minimum, in reducing the amount of aluminium sulphate that entered the company's distribution system, whilst the best case scenario would have been that the chemical would have been prevented in its entirety from causing the subsequent contamination incident.

Water company incident management plans have considerably improved since this incident occurred, but as these also form part of a Drinking Water Safety Plan (along with corporate communication plans), the deficiencies in South West Water Authority's operational arrangements that at the time led to confusion amongst its customers, a lack of available information, and actions that arguably perpetuated the incident would have been largely addressed. Indeed, if the company had had a Plan in place, it would hopefully have recognised the significant detrimental impact the company's flushing programme would have had on the ecology of the Allen and Camel rivers. If the company's knowledge of its own distribution system had been more comprehensive, it should have also recognised the effect the flushing programme would have had on potentially uncontaminated parts of it, and the fact the flushing programme actually drew more of the contamination into the distribution system.

If these points had been appropriately addressed, as part of a Drinking Water Safety Plan, they most probably would not have reduced the entry of the aluminium sulphate into the distribution, but they would have been effective at both reducing its concentration once in the supply, and reducing its proliferation.

As this was a post-abstraction contamination incident, it is clear that the principles of catchment management would have had no effect on the hazard in question. However, there was a chance that if a catchment management plan were in place at the time of this incident, this may well have highlighted the risk the flushing of the distribution system presented to the Allen and Camel rivers, thus reducing or even entirely avoiding the ecological disaster that ensued.

19.6.2 The Wem Incident

This is the first of the three pre-abstraction contamination incidents presented within this Chapter.

Even though the regional public health authority had advised the 2EDD posed no risk to health, the Crown Court judge decided if Severn Trent Water's customers did not like the taste then the water was unfit (The ENDS Report 1994b, Furness 2003). This was a groundbreaking ruling at the time, as previous 'unfit' rulings had only been applied where there were public health implications (Furness 2003, The ENDS Report 1995a).

As far as Drinking Water Safety Plans are concerned, it is difficult to see how control measures could have reduced the entry of 2EDD into the water supply. This appears to have been the first time this chemical had been detected in UK waters and, as has already been explored in Section 17.5, how could Severn Trent Water have put effective control measures in place, if they had no knowledge of the chemical, nor did they anticipate it occurring in the River Severn? Furthermore, it would have been implausible – if not downright impossible – for the water company to have undertaken a risk assessment in relation to this hazard when its knowledge of 2EDD was minimal and there was little information relating to its extent and potential impact on human health.

However, it could be argued that perhaps there was a deficiency in the training of the sampler that had detected a solvent smell in the discharge from Wem sewage works; if that person had had a greater awareness of the river environment, they would have realised that there was an abstraction point downstream of the discharge and perhaps they would have flagged up the unusual smell with an appropriate person within the Company, thus potentially reducing the four-day delay in investigating the source of the contamination. Whether this would have reduced the entry of 2EDD into the water supply is questionable though.

Again, because 2EDD was not a known hazard either within the River Severn itself or the wider catchment, the Company would not have reasonably been expected to be monitoring for it, either in the abstracted water, or the final treated water as it entered the distribution system. At the time, the only regulatory requirements for final treated water related to microbiological standards, along with the obligation to main a chlorine residual. Furthermore, many water companies may well have undertaken taste and odour sampling at the same time, but these samples were taken on a purely voluntary basis, and so the aesthetically unpleasant taste and odour of the chemical may well have gone unnoticed, depending on the time that had elapsed between sampling.

Even today, with the many technological advances in analytical techniques, it is still impractical to provide cost-effective real-time online monitoring of taste and odour parameters, so I can therefore only conclude that even if Severn Trent Water had had a Drinking Water Safety Plan in place at the time of the incident, 2EDD would still have entered the distribution system. Consideration should therefore be given to whether control measures would have been effective in either of the other two ways, by either reducing the concentration of 2EDD once it was in the distribution system, or by reducing its proliferation.

In the subsequent incident report Severn Trent Water was generally commended for its response to the incident, although it noted there were "serious weaknesses" in the Company's water quality monitoring arrangements, along with shortcomings in operational procedures and the level of treatment afforded at the works affected by the incident (The ENDS Report 1994a). However, it is difficult to determine the basis for this criticism as, not only is it unrealistic to monitor for an unknown parameter, it follows that it is only reasonable to have in place treatment processes which will eliminate known hazards, or reduce their concentrations to levels which will not impact on human health. If the incident report was seriously suggesting that water companies should install treatment processes (such as ozone at all water treatment works) to deal with both known and unknown parameters the cost consequence would be phenomenal, and would most likely not be supported by Ofwat during the periodic review. This is because the regulator requires a cost-benefit analysis of any proposed improvements, which would prove impossible to undertake in any serious fashion in this instance because the analysis would be attempting to quantify unknowns which, by definition, are unquantifiable.

For similar reasons, the comment within the incident report about the Company's monitoring procedures should have also been challenged at the time, as only known contaminants, for which authorised analytical techniques exist, can be analysed for. It is of course feasible to detect the presence of unknown contaminants within a sample using a wide-ranging analytical technique such as Gas Chromatography Mass Spectroscopy, but much time, money and effort has to be expended to determine the specific nature of the many peaks produced. Baseline monitoring must subsequently be undertaken within the catchment at various locations, so trends and peaks may be detected, in order to inform the risk assessment process. Again, this is placing an unacceptable burden on water companies, and cannot be viewed as a serious suggestion within the incident report.

Overall, it is perhaps reasonable to suggest that, although a Drinking Water Safety Plan would most probably not have prevented the contaminant from entering the water supply, it may have had some quite limited impact on reducing its concentration once in the supply, and reducing its proliferation, but this would only arise from making Severn Trent Water's existing procedures and policies more robust, rather than suggesting there were some serious shortfalls in the Company's management and/or operational capability that such a Plan would address.

In Section 17.4.3.2 I stated that, in order for catchment management to be robust, information would be required on (Dufour et al. 2003):

- Sources of contamination within the catchment, including their nature and location;
- The natural variability over time of the quality of the abstracted water, and how it reacts to meteorological events (such as drought, storms and flooding);
- Efficacy of the different treatment processes employed at eliminating contamination peaks in the abstracted water; and
- The hydrology and hydrogeology of the catchment.

If a catchment management plan were in place for the River Severn, then the source of the chemical (Wem sewage works) would undoubtedly have been identified as a general source of contamination, being as it is upstream of Barbourne water treatment works. Whether a plan would have identified the specific source of the 2EDD – Vital Scheme – is questionable though.

As the chemical was traced via Wem sewage works, it is obvious that Vital Scheme had discharged it in their waste-stream to the sewerage system, for which they should have held an industrial discharge consent issued by Severn Trent Water. If this was an illegal discharge, then it would not have been identified in the catchment management plan, as this can only consider known sources of contamination within the catchment. However, if Vital Scheme's discharge was indeed authorised, and assuming that Company was complying with the conditions contained within the authorisation, then traces of this chemical within the River Severn should have been anticipated by Severn Trent Water, and appropriate treatment installed at all its water treatment works downstream of Wem sewage works. Unfortunately, as further detailed information relating to the industrial discharge authorisation is unavailable, along with details of monitoring of Vital Scheme's discharge, I am unable to say with any certainty whether a catchment management plan alone would have helped to prevent this incident, although it is probably fair to say that were a number of large gaps and deficiencies in Severn Trent Water's knowledge of the catchment, and the inter-play of processes within it.

19.6.3 Cryptosporidiosis Outbreak in Torbay, Devon

The court case that followed this cryptosporidiosis outbreak was extremely significant for the regulation of drinking water quality in England and Wales. As was mentioned in the previous section relating to the Wem incident, it was relatively straightforward to secure a conviction of a water company when the water it supplied was aesthetically unacceptable, but in the Torbay case where there were clear health implications associated with the water supplied by Littlehempston water treatment works, a conviction could not be secured (Waite & Jiggins 2000).

As it was decided it would be impractical to undertake an epidemiological study for a future outbreak in order to meet the standards of evidence required, the UK Government decided a different, regulatory, approach was required in order to restore the public's confidence in public water supplies. The solution they identified was to establish a new low limit of *Cryptosporidium* oocysts in water leaving a water treatment works, regardless of whether any disease could be shown to ensue. Water companies were also required to undertake a risk assessment for all their sources to determine if there was a risk of oocysts entering the public supply (Waite & Jiggins 2000). These requirements were inserted into the 1989 Regulations by the Water Supply (Water Quality) Regulations 1999 (UK Government 1989c, UK Government 1999f).

Of the 1,388 water treatment works in use in England and Wales in 2000, 332 were identified as being at risk as a consequence of these new requirements. Of these, 95 were either abandoned or mothballed (Waite & Jiggins 2000).

When new drinking water quality regulations were produced in 2000 and 2001 to transpose the requirements of the 1998 Drinking Water Directive into law in England and Wales respectively, the new regulations retained the requirements relating to *Cryptosporidium* (UK Government 2000; UK Government 2001a; Waite and Jiggins 2000).

It seems to be beyond question that a Drinking Water Safety Plan would have prevented this incident from occurring. South West Water were abstracting six kilometres downstream of one of their own waste water assets, the discharge from which was known to contain at times "massive quantities" of *Cryptosporidium*, and that the robustness of the treatment processes at Littlehempston water treatment works had already been called into question on two previous occasions. Even the most elementary of pre-abstraction risk assessments should have readily identified the water treatment works to have been at high risk of oocyst breakthrough, and appropriate upgrades should have been implemented.

I was unable to obtain the official incident report relating to this outbreak of cryptosporidiosis, so I cannot make an assessment of whether control measures would have reduced the concentration of oocysts once in the supply, and/or reduced their proliferation, but it would be reasonable to assume, based on other water companies' practices at the time, that South West Water would not have had any control measures in place that would have had a significant positive impact in either case.

As far as catchment management is concerned, this is a far more straightforward incident than the previous one, although there is one significant similarity; the water company was abstracting downstream of one of its own sewage works. In this instance, the risk should have been immediately apparent, even without a catchment management plan in place. Nevertheless, such a plan would have readily highlighted the risk to South West Water from its own Buckfastleigh waste water asset.

Of the four areas identified in Section 17.4.3.2 where information relating to the catchment is required, three of them would have helped to confirm that the Company's Littlehempston water treatment works was at risk in the following ways:

- The sewage works upstream would have been identified;
- The natural variability over time of the quality of the water abstracted from the River Dart, and how it reacts to meteorological events, would have been realised, either through spot sampling or by more robust means (such as hydrodynamic modelling); and
- Using this information, decisions would have been made by the Company with regards to the efficacy of the different treatment processes employed at Littlehempston water treatment works.

In conclusion, there is a very high level of probability that a catchment management plan on its own would have prevented this incident from occurring. Taken in conjunction with a Drinking Water Safety Plan, a catchment management plan would have made the supply chain even more robust, and afforded greater protection to South West Water's customers.

19.6.4 Cryptosporidiosis Outbreak in North West Wales

The subsequent investigation of the outbreak found that there were at least five direct or indirect sewage inputs to Llyn Cwellyn, one or more of which appear to have been faulty. However, at no time had Dŵr Cymru Welsh Water breached the then regulatory standard of less than 1 *Cryptosporidium* oocyst per 10 litres. The Company had also undertaken a risk assessment in accordance with the 1999 Regulations and considered the site to be low risk. Dŵr Cymru Welsh Water therefore concluded it did not have to install upgraded treatment (UK Government 1999f, Hines 2006).

Nevertheless, in conclusion, the Outbreak Control Team decided that all the available evidence and expert opinion pointed to Cwellyn reservoir being the probable source of the outbreak, as the associated water treatment works had "no effective barriers" in place to stop *Cryptosporidium* reaching the mains supply, and that there could be "no alternative explanation" (Gibbons 2006, BBC 2007). Despite there being no direct causal link between the reservoir and any of the 231 confirmed cases of cryptosporidiosis, Dŵr Cymru Welsh Water said it accepted that the outbreak was linked to the mains water supply from Cwellyn reservoir (BBC 2007). The subsequent successful prosecution of the Company was the first of its kind since the *Cryptosporidium* regulations were introduced as a consequence of the Torbay cryptosporidiosis incident (The ENDS Report 2007).

Taking the above into consideration, it is difficult to appreciate how a Drinking Water Safety Plan could have made the supply chain more secure. Indeed, the Outbreak Control Team's official incident report did not contain any recommendations for the Company, as it seems to have conducted itself properly throughout the incident. Dŵr Cymru Welsh Water believed it had taken all necessary steps in order to determine the degree of risk of its customers contracting cryptosporidiosis and, on the basis of its risk assessment, was confident that the treatment control measures it had in place were appropriate. Hence, it was the Company's firm view that its policies and procedures would at least have reduced the entry of *Cryptosporidium* into the water supply, and ensure their concentration once in the supply was below non-infectious levels and was fully compliant with the regulations.

In the official incident report it was noted that the infectious dose may be as low as a single oocyst of *Cryptosporidium hominis*. This statement may have been why the lessons learned from this outbreak contributed to a consultation on the revision of the drinking water quality regulations for England and Wales, which consequently gave rise to The Water Supply (Water Quality) Regulations 2000 Amendment Regulations 2007 (UK Government 2007d) (see Section 10.23), from which the regulatory *Cryptosporidium* standard was removed.

Although a catchment management plan as such did not exist for the Cwellyn catchment, it appears that Dŵr Cymru Welsh Water had collated a lot of the information such a plan would require, as this was necessary for it to undertake a *Cryptosporidium* risk assessment at the water treatment works. Therefore, for the same reasons given for why it is difficult to appreciate how a Drinking Water Safety Plan could have made the supply chain more secure, I cannot see how a catchment management plan would have afforded greater protection to the Company's customers.

20 CONCLUSIONS FROM PART 4

A review focussing on Drinking Water Safety Plans was presented in Part 4. First, the case was made for the need for greater protection of drinking water supplies, and why, at the start of the 21st Century, the WHO initiative is an essential tool in the fight against new and re-emerging threats within the catchment, as well as helping to minimise the risks throughout the entire drinking water supply chain. A review of the Drinking Water Safety Plan approach has shown that they are more than a bureaucratic nicety, whilst Chapter 14 gave an overview of how Drinking Water Safety Plans are being implemented in the four regions of the UK, with respect to both private and public water supplies. The final Chapter in Part 3 critically evaluates the potential for Drinking Water Safety Plans to minimise the risks associated with four well known pre- and post-abstraction contamination incidents relating to public water supplies that have occurred in England and Wales in the last 20 years.

From this review I have drawn the following conclusions (for ease of reference the Section to which each conclusion relates is given is brackets):

1) It can be inferred that compliance monitoring still has an important role to play in the Drinking Water Safety Plan approach, but it is no longer the primary tool; instead, it is now to be used in conjunction with others (Section 17.2).

2) The Drinking Water Safety Plan approach must be seen for what it is – essential for the protection of our drinking water, rather than merely a bureaucratic, procedural exercise. There will also be other benefits to adopting this approach, such as making a significant contribution to the requirements of the Water Framework Directive. Although many of the hazards giving rise to these risks cannot be removed entirely from the drinking water supply chain, the implementation of Drinking Water Safety Plans should reduce the risks to more acceptable levels (Section 17.5).

3) The impact the implementation of Drinking Water Safety Plans will have on trace pollutants is questionable, without first acquiring data relating to their

extent and potential impacts on human health, which undoubtedly would be at significant cost. It is therefore extremely questionable whether Drinking Water Safety Plans are the panacea that many have promoted them to be (Section 17.5).

4) Although the position Edinburgh has adopted of providing non means-tested grants for requisite improvements to private water supplies could be construed as being overly generous, the other three administrations should, at the very least, consider providing them as well, in order to establish commonality of approach across the four devolved regions of the UK (Section 18.5.1).

5) The stance the drinking water quality regulators have taken with regards to the implementation of Drinking Water Safety Plans is undoubtedly leading to duplication of efforts by water companies, and unnecessary expenditure. There is therefore an opportunity for the regulators to re-consider developing a standard Drinking Water Safety Plan model for the UK water industry, which can then be adapted by water companies to their own individual needs and circumstances. Alternatively, water companies themselves could come to a consensus for such a model (Section 18.5.2).

6) Both Ofwat and the DWI need to resolve the differences in their attitudes towards Drinking Water Safety Plans, to avoid any further uncertainty developing within the water industry; one area of particular concern is their respective opinion of the role Drinking Water Safety Plans should play in the 2009 Periodic Review (Section 18.5.2).

7) Another area of concern – as far as water companies in England and Wales are concerned – is that of funding for the development and subsequent implementation of Drinking Water Safety Plans; the Drinking Water Quality Regulator has provided funding for Scottish Water, whilst Ofwat believes the water companies it regulates should fund them from their own, pre-existing, operational expenditure (Section 18.5.2).

8) The implementation of Drinking Water Safety Plans is not currently a legal requirement in any of the four devolved regions of the UK; however, in Wales, England and Scotland it is a requirement of the regulators, which is something entirely different (Section 18.5.2).

9) The devolved administrations should give careful consideration to extending the requirements of Drinking Water Safety Plans to both bottled waters, as well as the routine supply of alternative, non-piped water supplies by water companies (Section 18.5.3).

10) The integrity and robustness of the Drinking Water Safety Plan approach by has been tested by retrospective analysis of four 'industry standard' pre- and post-contamination incidents in turn with specific regard to the requirements of this approach; this exercise highlighted that although many of the risks associated with these incidents may have been greatly reduced, although it can be concluded (with a high level of confidence) that two of the four incidents – at Camelford and Torbay – would potentially have been completely avoided (Section 19.6).

11) Just considering catchment management on its own (and ignoring the impact a Drinking Water Safety Plan may have had if it were in place), it can be concluded (with a high level of confidence) that only one – at Torbay – of the four incidents would potentially have been completely avoided if the respective water company had developed a catchment management plan (Section 19.6).

PART 5 THE DEVELOPMENT AND TRIALLING OF THE ABSTRACTION SAFETY INDEX

21 THE ABSTRACTION SAFETY INDEX CONCEPT

21.1 Introduction

The comprehensive literature review undertaken in Parts 1-4 inclusive highlighted the fact that, although there are numerous legislative and management impacts on catchments in England and Wales, and that these catchments have a multitude of institutional and non-governmental stakeholders of varying scales, not one of these stakeholders has identified a suitable quantitative methodology for determining the overall environmental quality of water within a catchment, and for expressing this as a single figure.

In discussion with several water companies in England and Wales, it was the general view that such a concept would be useful, for internal management purposes, and to better inform the regulators and wider public on catchment issues. I initially intended this concept to be used by water companies for catchments that were used for public water supply purposes, but I subsequently extended its remit to cover private water supply catchments as well. Indeed, the use of this concept could ultimately be extended to any catchment, and not necessarily just those that are used for water supply purposes, although this idea was outside the scope of my research so will not be considered further in this thesis.

21.2 Principles of the Abstraction Safety Index Methodology

The challenge was set by the water companies to construct a methodology that was simple to use yet robust, and which could be easily applied and provide meaningful results. The aforementioned discussions also gave rise to the view from the water companies that such a methodology would have to have a hazardous events basis, as it was not – in their view – possible to use a parameter-based approach. (In this context, 'parameter' has the same meaning as that used in the drinking water quality regulations currently in operation in England and Wales, and the term can be used interchangeably with 'hazard', which is defined in Section 17.4.4.) An example of a typical catchment risk assessment pro-forma, as used by many of the UK's water companies, is given in Table 7.

SOURCE / HAZARDOUS EVENT	**HAZARD(S)**	**LIKELIHOOD (L)**	**SEVERITY (S)**	**LEVEL OF RISK**
Intensive agriculture	Pesticides Herbicides	(1-5)	(1-5)	(L * S)
Pastoral farming	Microbiological *Cryptosporidium*			
Application of fertilisers	Chemical Taste and odour			
Wildlife	Microbiological *Cryptosporidium*			
Illegal dumping within catchment	Chemical Microbiological			
Camping and other recreational activities	Chemical Microbiological			
Industrial chemical spillage	Chemical Microbiological Taste and odour			
Discharge consents	Chemical Microbiological Taste and odour			
Waste water facilities – treatment plants etc	Microbiological			
Roads – spills of hazardous materials	Chemical Microbiological			
Land use changes	Chemical Microbiological			
Private sewerage systems within the catchment	Microbiological			

Table 7: An example of a typical catchment risk assessment pro-forma

Nevertheless, I decided from the outset that a parameter-based approach was my preferred option, so that if a parameter within a catchment was of particular concern the hazardous events giving rise to it could be readily identified from the methodology and its associated risk assessment. I felt that this would make the concept much more attractive to the various regulators – not least of all the DWI –

and enable them to work more closely together to adopt an integrated approach to catchment management.

The term 'Abstraction Safety Index' was adopted, as the concept is concerned with the overall influence of the catchment (and the hazards and hazardous events it contains) on the quality of water within it, right up to the point of abstraction. After this point, the environment has minimal effect on the quality of the abstracted water once it enters the water company's infrastructure. The inclusion of the word 'safety' was deemed appropriate as the methodology has been designed to be directly relevant to the Drinking Water Safety Plan approach, as it will identify areas of concern within the catchment, and help underpin catchment management improvement programmes.

Schedule 1 of the current drinking water quality regulations list 40 parameters, whilst Schedule 2 (indicator parameters) lists a further 12 (UK Government 2000, National Assembly for Wales 2001b). I considered the methodology would be too unwieldy if 52 parameters had to be considered in the context of every different hazardous event for each catchment, so the decision was made to agglomerate related parameters. The following list of parameter groups was therefore drawn up:

1) Herbicides;
2) Pesticides and insecticides;
3) Hydrocarbons;
4) Pathogens;
5) Chemicals;
6) Suspended solids/turbidity;
7) Heavy metals;
8) Taste and odour;
9) Radiation;
10) Nitrates and phosphates; and
11) Colour.

Subsequently I decided upon a number of significant hazardous events that could give rise to each hazard (or parameter), and these are identified in Table 8 to Table 18 inclusive.

HAZARD	HAZARDOUS EVENT
Herbicides	Spraying of road margins and central reservations
	Spraying of railway margins
	Dumping/fly tipping
	Forestry activities
	Domestic use
	Agricultural use

Table 8: Significant hazardous events included in the 'herbicides' group

HAZARD	HAZARDOUS EVENT
Pesticides and insecticides	Dumping/fly tipping
	Forestry activities
	Domestic use
	Agricultural use
	Spraying of agricultural land

Table 9: Significant hazardous events included in the 'pesticides and insecticides' group

HAZARD	HAZARDOUS EVENT
Hydrocarbons	Run-off from roads
	Agricultural storage tanks
	Aquatic leisure and tourism activities (e.g. boating)
	Other storage tanks (local authority etc)
	Building/development sites
	Accidents/spillages
	Sewage treatment works
	Landfill
	Dumping/fly tipping

Table 10: Significant hazardous events included in the 'hydrocarbons' group

HAZARD	HAZARDOUS EVENT
Pathogens	Industrial discharges
	Sewage treatment works
	Burial pits
	Cemeteries
	Agricultural grazing land
	Agricultural storage of animal waste
	Muck-spreading
	Cesspits/soakaways
	Wildlife

Table 11: Significant hazardous events included in the 'pathogens' group

HAZARD	HAZARDOUS EVENT
Chemicals	Industrial discharges
	Sewage treatment works
	Dumping/fly tipping
	Landfill
	Accidents/spillages

Table 12: Significant hazardous events included in the 'chemicals' group

HAZARD	HAZARDOUS EVENT
Suspended solids/turbidity	Over-grazing of agricultural land
	Over-grazing of other land
	Inadequate stock-proof fencing along waterways
	Mining activities
	Geology of the catchment
	Aquatic, leisure and tourism activities (e.g. boating)
	Forestry activities
	Inappropriate land management facilitating soil erosion
	Off-roading facilities
	Poorly managed public footpaths and by-ways
	Building/development sites
	Flooding
	Dumping/fly tipping
	Run-off from roads
	Run-off from buildings
	Industrial/commercial discharges
	General run-off from land

Table 13: Significant hazardous events included in the 'suspended solids/turbidity' group

HAZARD	HAZARDOUS EVENT
Heavy metals	Mining activities
	Geology of the catchment
	Dumping/fly tipping
	Landfill
	Run-off from roads
	Industrial discharges

Table 14: Significant hazardous events included in the 'heavy metals' group

HAZARD	HAZARDOUS EVENT
Taste and odour	Algal blooms
	Reservoir stratification
	Geology of the catchment
	Industrial discharges
	Dumping/fly tipping
	Landfill
	Agricultural application of pesticides/herbicides
	Accidents/spillages

Table 15: Significant hazardous events included in the 'taste and odour' group

HAZARD	HAZARDOUS EVENT
Radiation	Nuclear power stations
	Industrial/medical uses of radioactive material

Table 16: Significant hazardous events included in the 'radiation' group

HAZARD	HAZARDOUS EVENT
Nitrates and phosphates	Industrial discharges
	Agricultural grazing land
	Sewage treatment works
	Burial pits
	Landfill
	Aeolian deposition
	Agricultural storage of animal waste
	Cemeteries

Table 17: Significant hazardous events included in the 'nitrates and phosphates' group

HAZARD	HAZARDOUS EVENT
Colour	Industrial discharges
	Accidents/spillages
	Drainage from peaty areas

Table 18: Significant hazardous events included in the 'colour' group

It is obvious that there is some duplication within the above Tables, as a number of hazardous events can give rise to more than one hazard (or parameter). For example, the discharge from a sewage treatment works can contain hydrocarbons, pathogens, chemicals, suspended solids/turbidity, nitrates and phosphates. Even though it did not appear possible to avoid such duplication, it became apparent during the risk assessment stage that such duplication was actually desirable.

Using the example of a discharge from a sewage treatment works, there are many different types of such installations around the country, as the range of pollutants encountered in the raw sewage, as well as the demographic breakdown of the population served by the sewage treatment works, varies markedly. The risks posed by hazards contained within the final treated effluent from any two installations can therefore be significantly different, and it is entirely feasible for these risks to vary on a temporal basis as well as a geographical basis, hence the reason it is preferable to consider related risks in the aforementioned separate groups, rather than attempting to assign a single risk value to a final treated effluent discharging to a receiving water.

This index could feasibly be used as both a performance indicator and for benchmarking purposes, and these two principles are explored further in the following two sections.

21.3 Performance Indicators

According to Alegre et al. (2006), the assessment of a water company's performance with the use of performance indicators can measure the quality of service and the company's efficiency and effectiveness, provide benchmarking between similar companies and encourage them to provide an improved service.

By specifically considering the use of my index as a performance indicator, this index can provide a robust assessment of the environmental quality of a catchment, by comprehensively evaluating all of the significant impacts (both natural and anthropogenic) on water resources and water quality. A water company can then use this information to check that its treatment processes are suitable and effective, and ensure that its customers are provided with a safe, high quality product.

The potential users of performance indicators include (Alegre et al. 2006):

- Water companies;
- The consumers;
- The indirect stakeholders (who do not have a direct connection to the water company but may be affected by its actions or its impacts on the surrounding environment, such as by the consequences of a burst, or the quantitative and/or qualitative impacts of water abstraction);
- The non-governmental stakeholders (such as environmental organisations, consumer protection agencies and other pressure groups);
- The policy-making bodies (both central and devolved Government, at local, regional and national levels); and
- The regulators.

Performance indicators can be of use to all the above entities, as they have the following potential benefits and uses (Alegre et al. 2006):

- For water companies, they can:
    - Provide key information that supports a proactive approach to management, with less reliance on apparent system malfunctions (which is the historic reactive approach);
    - Assist with the implementation of a Total Quality Management regime, as a way of emphasising all-round quality and efficiency throughout the organisation;
    - Facilitate the implementation of benchmarking routines, both internally (for comparing the performance at different locations or systems) and externally (for comparison with other similar companies) thus promoting performance improvements;
    - Highlight strengths and weaknesses of departments, identifying the need for corrective measures to improve productivity, procedures and routines.
- For the central or devolved policy-making bodies, they can:

  - Provide a common basis for comparing the performance of water companies and identifying possible corrective measures;
  - Support the formulation of policies for the water sector, within the integrated management of water resources, including resource allocations, investments, and the development of new regulatory tools.
- For regulators, they can:
  - Provide key monitoring tools to help safeguard consumer interests in a monopoly service supplier situation, assessing the performance and benchmarking the water companies, and monitoring compliance with contracted goals.
- For consumers and non-governmental stakeholders, they can:
  - Provide the means of translating complex processes into simple-to-understand information and of transmitting a measure of the quality of service provided.

Performance indicators are a powerful management tool as has been demonstrated through their systematic use in many industries for decades (Alegre et al. 2006).

21.4 Benchmarking

Generally speaking, there are two different approaches to benchmarking: 'metric', and 'process'. The first is intended as a quantitative comparative assessment of company performance, normally measured by performance indicators. It enables comparisons to be made between peer utilities, and trending information and target levels of performance to be established. The second is intended as a mechanism for identifying specific work procedures to be improved by emulating external examples of excellence that can be set as the best standard (Larsson et al. 2002).

Metric benchmarking identifies areas of under-performance where changes need to be made to the way things are done, whilst process benchmarking is a vehicle for achieving this change, and the improvement required can be imported from other best practice partners (Larsson et al. 2002).

Using these definitions, it can be determined that the Abstraction Safety Index can be useful for metric benchmarking, and using a standard methodology it can be applied on a number of different scales:

- For an individual catchment (perhaps by a local organisation wanting to monitor improvements over time to a site entirely contained within a single catchment);
- Different catchments that are used by the same water company (which can then be assessed and ranked in terms of overall environmental quality, thus enabling capital investment to be prioritised and targeted);
- On the national level for comparative purposes (for example, between water companies within the same operating group, or by regulators to undertake a national assessment of catchments, and to set targets for environmental improvements).
- On a UK or even a European level, again for comparative purposes (by the UK Government or the European Commission for example, to monitor compliance with supra-national legislation).

At a recent workshop organised by UKWIR, my decision to use the Abstraction Safety Index for metric benchmarking purposes was vindicated by representatives of the UK water industry. Although it was recognised that the format of Drinking Water Safety Plans varied across the country, it was agreed that the risk assessments that underpinned them should be the same; this was of particular importance when different water companies used the same catchment, or shared the same resources within a catchment (such as the River Dee) for their own public water supply purposes (UK Water Industry Research 2007, Barrott et al. 2007).

21.5 Overview of the Calculation of the Abstraction Safety Index

I ultimately developed three different methodologies for calculation of the Abstraction Safety Index. The first of these was fundamentally flawed, but which helped better inform the development of the subsequent two methodologies. The initial stages of the calculation of the index are the same for all three methodologies, and these are described below.

21.5.1 Risk Assessment

The first – and arguably, the most important – stage of the calculation of the index is to undertake a risk assessment of the catchment. In order for the risk assessment to be robust and unassailable, it must necessarily consider a large amount of information, obtained from a number of sometimes disparate sources. Therefore, it was prudent for me to develop a catchment environmental assessment methodology, and this is considered in much greater depth in Chapter 22.

Using the information thus obtained, an assessment of the likelihood of each hazardous event being present within the catchment is made, along with the severity of the impact of that hazardous event on environmental water quality within the catchment, using the traditional risk assessment matrix concept with a linear 1 to 5 scale that was first introduced in Section 17.4.5.

The adoption of this scale generated quite a bit of debate within my research group, as a strong argument was made for a 0 to 5 scale to be adopted instead. However, my view was that a catchment is obviously an open environment, so it would never be possible to exclude all hazards and associated hazardous events from it. such hazardous events would therefore always present a risk to environmental water quality, so a pristine catchment is unattainable in practice; although a risk may be assessed as being infinitesimally small, it was still a risk, so assigning a value of '0' could not be justified.

However, extending this argument to the other three parts of the drinking water supply chain (treatment, distribution and consumer), it could be argued that each of these is a closed environment, and so the use of a 0 to 5 scale is appropriate. This is despite a slight majority (55%) of water companies in England and Wales adopting the 1 to 5 scale (Darlow 2007).

The risk assessment matrix that was adopted is given in Figure 10, whilst an extract from the Abstraction Safety Index spreadsheet is given in Figure 11.

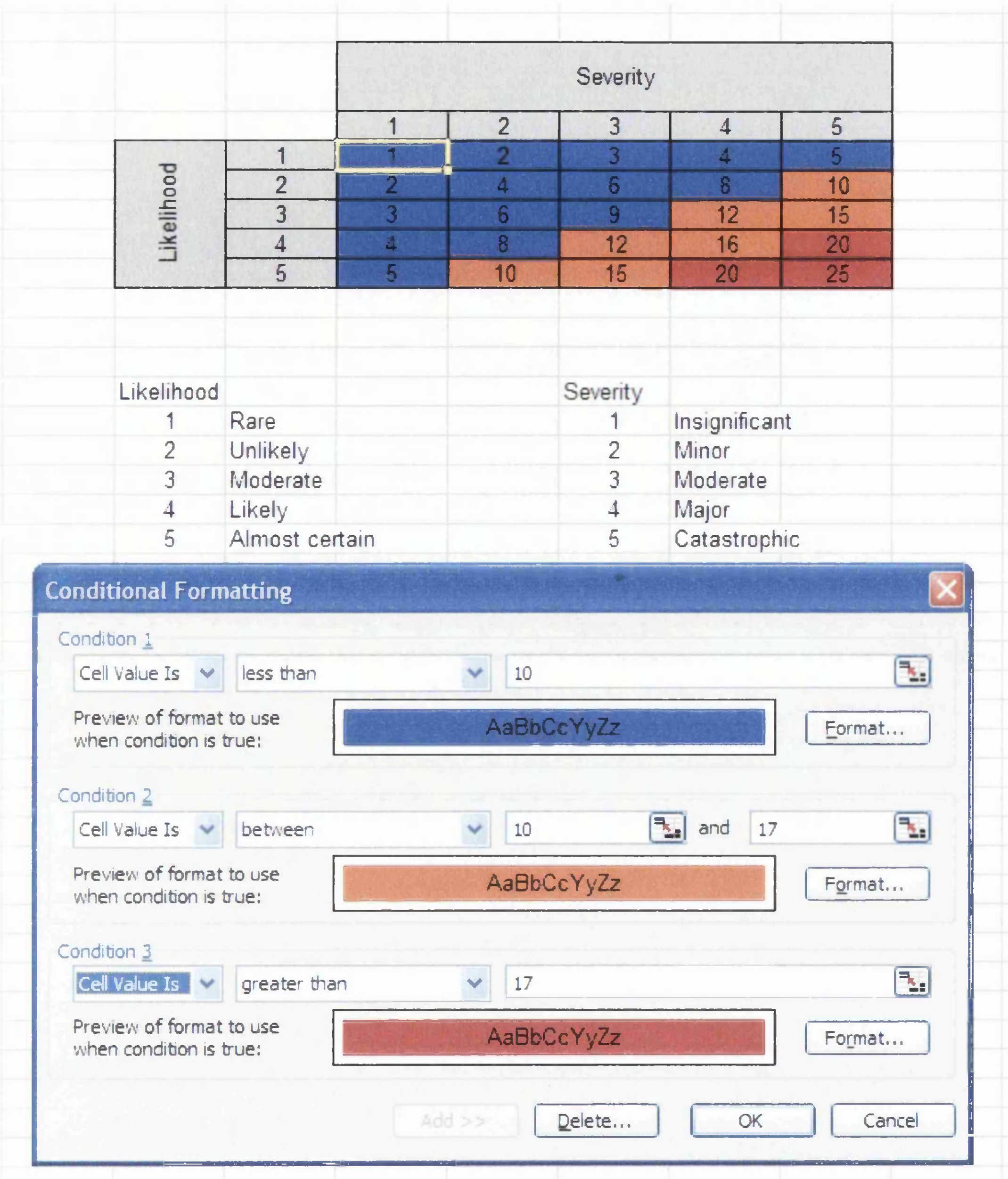


Figure 10: The values used in the risk assessment matrix, along with the conditional formatting used

Hazard	Source of Hazard	Risk (Before Importance Factors are Applied)		
		Likelihood	Severity	Magnitude of Risk
Herbicides	Spraying of road margins & central reservations	1	1	1
	Spraying of railway margins	1	1	1
	Dumping/flytipping	2	1	2
	Forestry activities	1	1	1
	Domestic use	2	1	2
	Agricultural use	3	3	9
Pesticides & insecticides	Domestic use	2	1	2
	Forestry activities	1	1	1
	Agricultural use	3	3	9
	Dumping/flytipping	2	1	2
	Spraying of agricultural land	3	3	9
Hydrocarbons	Run-off from roads	4	2	8
	Agricultural storage tanks	2	3	6
	Aquatic leisure & tourism activities (eg boating)	2	3	6
	Other storage tanks (local authority etc)	2	3	6
	Building/development sites	2	3	6
	Accidents/spillages	2	3	6
	Sewage treatment works	2	3	6
	Landfill	1	1	1
	Dumping/flytipping	2	2	4
Pathogens	Industrial discharges	2	2	4
	Sewage treatment works	5	2	10
	Burial pits	1	2	2
	Cemetaries	4	2	8
	Agricultural grazing land	5	4	20
	Agricultural storage of animal waste	3	4	12
	Muck-spreading	5	4	20
	Cesspits/soakaways	5	1	5
	Wildlife	5	2	10
Chemicals	Industrial discharges	2	2	4
	Sewage treatment works	2	3	6
	Dumping/flytipping	2	1	2
	Landfill	1	2	2
	Accidents/spillages	2	3	6
	Over-grazing of agricultural land	3	3	9
	Over-grazing of other land	2	2	4

Figure 11: An extract from the Abstraction Safety Index spreadsheet, showing the first stage of the calculation, which incorporates the risk assessment matrix shown in Figure 10

This risk assessment matrix has been constructed to be a standard industry-wide template, in order to facilitate the comparison of catchments in different locations yet subject to the same institutional and legal frameworks. It is envisaged that this matrix is reviewed and updated as necessary prior to each Periodic Review, in order to take into account any institutional and legal changes, or emerging issues (such as xenobiotics) which do not yet appear in the 11 parameter groups.

Conditional formatting within the spreadsheet has been utilised, to assist the user in readily identifying differing degrees of risk. The traditional red-orange-green colour scheme has not been used in this instance (even though this 'traffic light system' is still widely used throughout the water industry in a risk assessment context (Darlow 2007)), as it is becoming increasingly common to adopt alternative colour schemes in recognition of the prevalence of colour blindness. Accordingly, throughout the Abstraction Safety Index spreadsheet numbers shaded blue generally are low risk, orange denotes medium risk, whilst red identifies the highest risks.

With reference to the boundary conditions for the shading used in the 'magnitude of risk' column shown in Figure 11, these are shown in Figure 10, i.e. numbers shaded blue were less than 10, numbers shaded orange were between 10 and 17 inclusive, whilst numbers shaded red were greater than 17.

At this stage, an unweighted Abstraction Safety Index can be simply calculated, and which serves a useful purpose: to determine to what extent (if any) the application of the Importance Factors has on the risks that have been calculated, which can easily be done by eye by assessing the difference (if any) between the unweighted and weighted figures for the Abstraction Safety Index.

Data validation was used to make the spreadsheet more user-friendly, and to avoid data input errors, and examples of the input messages are given in Figure 12.

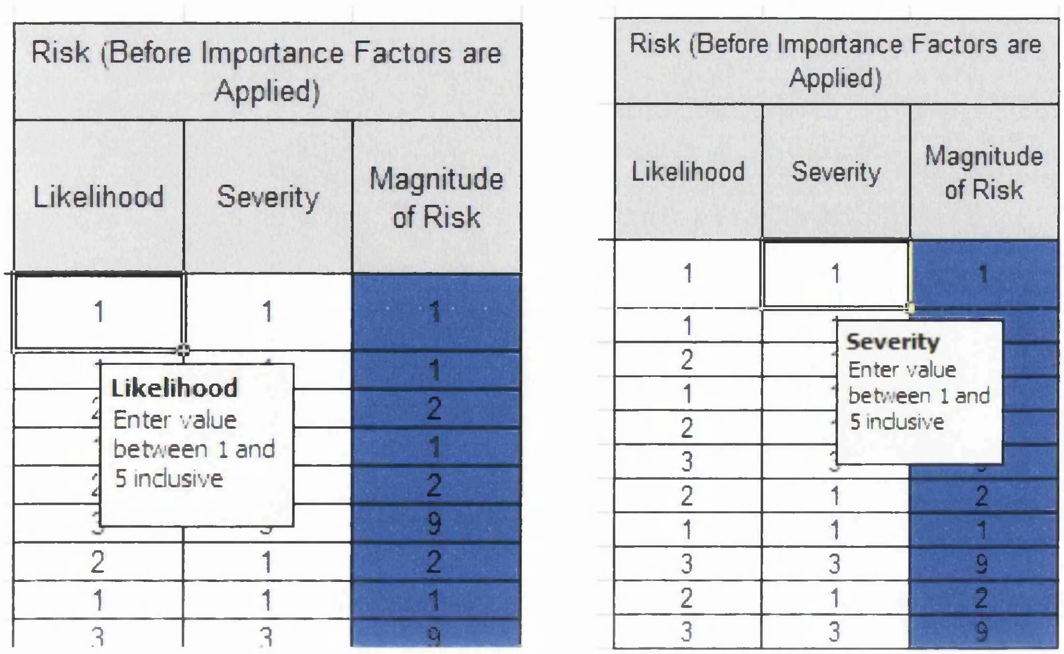


Figure 12: Examples of the input messages designed to assist users of the risk assessment element of the Abstraction Safety Index Spreadsheet

21.5.2 Importance Factors

Where this methodology represents a significant departure from merely using the traditional risk assessment matrix, is by use of a process of weighting in the form of what I have termed Importance Factors.

It was recognised at an early stage of the development of the catchment environmental assessment methodology that the available information relating to specific catchments could vary significantly. For example, there was the perverse situation in a number of instances where for some important hazards there was a dearth of information, yet for other less significant ones, it was abundant.

Also, the usability of this information is also an important consideration when undertaking a risk assessment. For example, there may be an extensive hydrographic record for a particular strategic river but, because it has not been digitised, it cannot be easily examined or assessed. Furthermore, I found many instances of information relating to hazards that water companies would consider very important but, because they were not aware of its existence, they obviously could not include it in their risk assessment. Sometimes, this lack of awareness arose because of poor communication between strategic stakeholders, or this inter-stakeholder (or indeed, even intra-stakeholder) communication occurring at inappropriate levels.

I therefore considered that it was insufficient to consider the risk posed by each hazard or hazardous event based on the traditional risk assessment matrix alone; instead, a holistic approach to risk evaluation was required. This approach would necessarily consider all the significant qualitative processes, policies and institutional arrangements, which for convenience were grouped under five headings or Importance Factors.

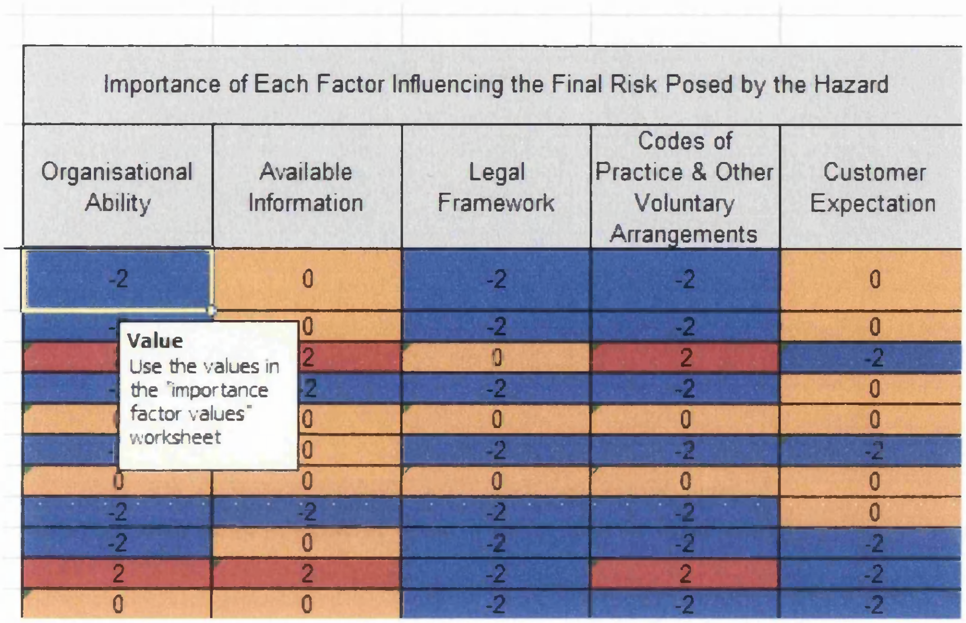
In total, five generic Importance Factors were developed, and these considered the impact of the following areas on the magnitude of risk associated with a hazard or hazardous event (Keirle 2008):

- Organisational ability;
- Available information;
- Legal framework;
- Codes of practice and other voluntary arrangements; and
- Customer expectation.

I subsequently reasoned that a process of weighting should be adopted in order to modify the traditional risk assessment approach, in order to obtain a risk value that more closely reflected actual conditions and circumstances within a catchment, in order to give a 'real' magnitude of risk, as opposed to the usual 'academic' value.

Taking the risk value that had been calculated in the first stage of the Abstraction Safety Index methodology, the impact on the magnitude of this risk was considered in turn for each of the five Importance Factors. If the Importance Factor being considered in relation to a specific hazard had a positive impact on the magnitude of risk, then the result would be that Importance Factor's contribution to the cumulative weighted magnitude of risk would be reduced proportionately. Similarly, if the Importance Factor had an adverse impact, the magnitude of risk would increase.

In this section data validation was again utilised, and an example of the input message is given in Figure 13.



Importance of Each Factor Influencing the Final Risk Posed by the Hazard				
Organisational Ability	Available Information	Legal Framework	Codes of Practice & Other Voluntary Arrangements	Customer Expectation
-2	0	-2	-2	0
[illegible]	0	-2	-2	0
[illegible]	2	0	2	-2
[illegible]	-2	-2	-2	0
[illegible]	0	0	0	0
[illegible]	0	-2	-2	-2
0	0	0	0	0
-2	-2	-2	-2	0
-2	0	-2	-2	-2
2	2	-2	2	-2
0	0	-2	-2	-2

Figure 13: An example of the input message designed to assist users of the Importance Factor element of the Abstraction Safety Index

In this instance, blue generally means a 'low' value for the Importance Factor under consideration, orange generally means 'medium', whilst red generally means 'high'; further information on each of the five Importance Factors, as well as their associated three levels of weighting, are given in the following sub-sections.

21.5.2.1 Organisational Ability

This Importance Factor is concerned with the ability of national and regional statutory bodies, regulators, and non-governmental organisations to manage the hazard in question, irrespective of the regime (regulatory, voluntary etc) in which the hazard exists, or which has been constructed in order to reduce or remove the impact of the hazard. This Importance Factor also considers – in a qualitative sense – both the inter- and intra-communication ability of the bodies in question.

There are three levels of 'organisational ability':

- Highly effective;

- Only partially effective; and
- Strong adverse effects.

21.5.2.2 Available Information

Some hazards (such as radiation) may have a lot of information relating to its presence within a catchment, and the magnitude of the hazard's impact on the environment and, by extension, to consumers of water abstracted from the catchment, whilst others (such as xenobiotics) are barely understood. This Importance Factor is therefore concerned with the amount of information available – from whatever source (such as routine baseline monitoring by regulators and water companies, bespoke catchment-specific surveys, or known deleterious effects of the hazard) – and a qualitative assessment of the quality of that data.

There are three levels of 'available information':

- Plenty of information available;
- Some information available; and
- Little or no information available.

21.5.2.3 Legal Framework

The 'legal framework' Importance Factor considers the existing legal framework (in both statutory and regulatory terms), and the effectiveness of this framework in controlling, reducing and/or ameliorating the hazard in question.

There are three levels of 'legal framework':

- Highly effective controls exist;
- Some effective controls exist; and
- Little or no controls exist.

21.5.2.4 Codes of Practice

In some cases Codes of Practice may have been produced to control one or more hazards within a catchment, some of which may have a statutory basis, whilst other are voluntary and have been produced by non-governmental organisations. This Importance Factor therefore considers whether any such documents have been produced, or other related initiatives such as operating agreements or other voluntary management tools, and if they impinge on the hazard in question (either directly or otherwise).

There are three levels of 'codes of practice':

- Highly effective tools exist;
- Some tools exist; and
- Minimal, or no, tools exist.

21.5.2.5 Customer Expectation

This Importance Factor relates to the expectation/anticipation of a water company's customers being supplied with water from the catchment in question, irrespective of any other controls or factors that may apply. For example, the pesticide concentration of a source of water used for public supply may well be below the prescribed health-related limit, but "understandably consumers do not wish there to be any pesticides [present]" (Drinking Water Chief Inspector 1997).

Conversely, customers may not realise that wildlife (for example, large numbers of birds over-wintering in a reserve) may be a significant source of pathogens in a particular catchment, so their appreciation of the magnitude of this impact may be low or non-existent.

There are three levels of 'customer expectation':

- Customers have high expectation;
- Customers have some expectation; and
- Customers have minimal, or no, expectation.

21.5.3 Ranges of Values Used for Importance Factors

A number of different ranges of numerical values have been used to quantitatively weight the 'high', 'medium' and 'low' levels for the Importance Factors, for each methodology, and these are explained in greater detail in Chapter 24, Chapter 25 and Chapter 26 respectively. For example, the screenshot of the input message given in Figure 13 has, in this particular case, used a value of -2 for 'low', 0 for 'medium' and 2 for 'high'.

Once the risk assessment has been completed for a particular catchment, the next stage is to determine what values to assign for each Importance Factor, for each hazardous event, according to the definitions given in the previous five sub-sections. The values assigned to the Importance Factors are utilised in the same way during the initial stages of the calculation of the Abstraction Safety Index for each of the three methodologies, so a worked example is given below to illustrate these calculations, whilst further detail for each methodology is given in Chapter 24, Chapter 25 and Chapter 26 respectively.

In Figure 14, the hazardous source 'spraying of road margins & central reservations' has been risk assessed, and the value given for the likelihood of it occurring in the catchment under consideration is 1, and the severity of its impact on environmental water quality is also 1, which gives rise to a magnitude of risk of 1 multiplied by 1 i.e. 1.

The definitions of the five Importance Factors given in the previous five sub-sections have been applied to this hazardous source, and the following values have been assigned:

- Organisational ability: -2
- Available information: 0
- Legal framework: -2
- Codes of practice and other voluntary arrangements: -2
- Customer expectation: 0

Hazard	Source of Hazard	Risk (Before Importance Factors are Applied)			Importance of Each Factor Influencing the Final Risk Posed by the Hazard				
		Likelihood	Severity	Magnitude of Risk	Organisational Ability	Available Information	Legal Framework	Codes of Practice & Other Voluntary Arrangements	Customer Expectation
Herbicides	Spraying of road margins & central reservations	1	1	1	-2	0	-2	-2	0
	Spraying of railway margins	1	1	1	-2	0	-2	-2	0
	Dumping/flytipping	2	1	2	2	2	0	2	-2
	Forestry activities	1	1	1	-2	-2	-2	-2	0
	Domestic use	2	1	2	0	0	0	0	0
	Agricultural use	3	3	9	-2	0	-2	-2	-2
Pesticides & insecticides	Domestic use	2	1	2	0	0	0	0	0
	Forestry activities	1	1	1	-2	-2	-2	-2	0
	Agricultural use	3	3	9	-2	0	-2	-2	-2
	Dumping/flytipping	2	1	2	2	2	-2	2	-2
	Spraying of agricultural land	3	3	9	0	0	-2	-2	-2
Hydrocarbons	Run-off from roads	4	2	8	2	0	2	0	2
	Agricultural storage tanks	2	3	6	0	2	0	0	2
	Aquatic leisure & tourism activities (eg boating)	2	3	6	0	2	0	0	2
	Other storage tanks (local authority etc)	2	3	6	0	0	-2	0	0
	Building/development sites	2	3	6	0	0	-2	0	0
	Accidents/spillages	2	3	6	0	0	0	0	-2
	Sewage treatment works	2	3	6	-2	-2	-2	0	0
	Landfill	1	1	1	-2	-2	-2	0	-2
	Dumping/flytipping	2	2	4	2	2	0	2	-2
Pathogens	Industrial discharges	2	2	4	-2	-2	-2	0	-2
	Sewage treatment works	5	2	10	-2	-2	-2	0	-2
	Burial pits	1	2	2	0	0	-2	0	0
	Cemetaries	4	2	8	-2	-2	-2	0	-2
	Agricultural grazing land	5	4	20	2	2	0	0	2
	Agricultural storage of animal waste	3	4	12	0	0	0	0	0
	Muck-spreading	5	4	20	0	2	0	0	0
	Cesspits/soakaways	5	1	5	0	2	0	2	2
	Wildlife	5	2	10	0	2	2	2	2
Chemicals	Industrial discharges	2	2	4	-2	-2	-2	0	-2
	Sewage treatment works	2	3	6	-2	-2	-2	0	-2
	Dumping/flytipping	2	1	2	2	2	0	2	-2
	Landfill	1	2	2	-2	-2	-2	0	-2
	Accidents/spillages	2	3	6	0	0	0	0	-2
	Over-grazing of agricultural land	3	3	9	2	2	2	-2	2

Figure 14: The second stage of the Abstraction Safety Index spreadsheet, showing the introduction of the Importance Factors

Hazard	Source of Hazard	Risk (Before Importance Factors are Applied)			Importance of Each Factor Influencing the Final Risk Posed by the Hazard					Risk Component of Each Individual Importance Factor				
		Likelihood	Severity	Magnitude of Risk	Organisational Ability	Available Information	Legal Framework	Codes of Practice & Other Voluntary Arrangements	Customer Expectation	Organisational Ability	Available Information	Legal Framework	Codes of Practice & Other Voluntary Arrangements	Customer Expectation
Herbicides	Spraying of road margins & central reservations	1	1	1	-2	0	-2	-2	0	-2	0	-2	-2	0
	Spraying of railway margins	1	1	1	-2	0	-2	-2	0	-2	0	-2	-2	0
	Dumping/flytipping	2	1	2	2	2	0	2	-2	4	4	0	4	-4
	Forestry activities	1	1	1	-2	-2	-2	-2	0	-2	-2	-2	-2	0
	Domestic use	2	1	2	0	0	0	0	0	0	0	0	0	0
	Agricultural use	3	3	9	-2	0	-2	-2	-2	-18	0	-18	-18	-18
Pesticides & insecticides	Domestic use	2	1	2	0	0	0	0	0	0	0	0	0	0
	Forestry activities	1	1	1	-2	-2	-2	-2	0	-2	-2	-2	-2	0
	Agricultural use	3	3	9	-2	0	-2	-2	-2	-18	0	-18	-18	-18
	Dumping/flytipping	2	1	2	2	2	-2	2	-2	4	4	-4	4	-4
	Spraying of agricultural land	3	3	9	0	0	-2	-2	-2	0	0	-18	-18	-18
Hydrocarbons	Run-off from roads	4	2	8	2	0	2	0	2	16	0	16	0	16
	Agricultural storage tanks	2	3	6	0	2	0	0	2	0	12	0	0	12
	Aquatic leisure & tourism activities (eg boating)	2	3	6	0	2	0	0	2	0	12	0	0	12
	Other storage tanks (local authority etc)	2	3	6	0	0	-2	0	0	0	0	-12	0	0
	Building/development sites	2	3	6	0	0	-2	0	0	0	0	-12	0	0
	Accidents/spillages	2	3	6	0	0	0	0	-2	0	0	0	0	-12
	Sewage treatment works	2	3	6	-2	-2	-2	0	0	-12	-12	-12	0	0
	Landfill	1	1	1	-2	-2	-2	0	-2	-2	-2	-2	0	-2
	Dumping/flytipping	2	2	4	2	2	0	2	-2	8	8	0	8	-8
Pathogens	Industrial discharges	2	2	4	-2	-2	-2	0	-2	-8	-8	-8	0	-8
	Sewage treatment works	5	2	10	-2	-2	-2	0	-2	-20	-20	-20	0	-20
	Burial pits	1	2	2	0	0	-2	0	0	0	0	-4	0	0
	Cemetaries	4	2	8	-2	-2	-2	0	-2	-16	-16	-16	0	-16
	Agricultural grazing land	5	4	20	2	2	0	0	2	40	40	0	0	40
	Agricultural storage of animal waste	3	4	12	0	0	0	0	0	0	0	0	0	0
	Muck-spreading	5	4	20	0	2	0	0	0	0	40	0	0	0
	Cesspits/soakaways	5	1	5	0	2	0	2	2	0	10	0	10	10
	Wildlife	5	2	10	0	2	2	2	2	0	20	20	20	20
Chemicals	Industrial discharges	2	2	4	-2	-2	-2	0	-2	-8	-8	-8	0	-8
	Sewage treatment works	2	3	6	-2	-2	-2	0	-2	-12	-12	-12	0	-12
	Dumping/flytipping	2	1	2	2	2	0	2	-2	4	4	0	4	-4
	Landfill	1	2	2	-2	-2	-2	0	-2	-4	-4	-4	0	-4
	Accidents/spillages	2	3	6	0	0	0	0	-2	0	0	0	0	-12
Suspended solids/turbidity	Over-grazing of agricultural land	3	3	9	2	2	2	-2	2	18	18	18	-18	18
	Over-grazing of other land	2	2	4	2	2	2	-2	2	8	8	8	-8	8
	Inadequate stock-proof fencing along waterways	5	3	15	2	0	2	0	2	30	0	30	0	30
	Mining activities	2	1	2	0	0	0	0	0	0	0	0	0	0
	Geology of the catchment	1	1	1	0	-2	2	2	2	0	-2	2	2	2
	Aquatic leisure & tourism activities (eg boating)	1	1	1	0	2	0	0	2	0	2	0	0	2
	Forestry activities	1	1	1	0	0	0	-2	2	0	0	0	-2	2
	Innappropriate land management facilitating soil erosion	4	3	12	2	-2	2	-2	2	24	-24	24	-24	24
	Off-roading facilities	2	1	2	2	0	2	0	2	4	0	4	0	4
	Poorly managed public footpaths & by ways	3	1	3	2	0	2	0	2	6	0	6	0	6
	Building/development sites	2	3	6	-2	-2	-2	-2	0	-12	-12	-12	-12	0
	Flooding	5	4	20	2	-2	0	0	-2	40	-40	0	0	-40

Figure 15: The third stage of the Abstraction Safety Index spreadsheet, showing the results of applying the Importance Factors to the 'magnitude of risk' values

Hazard	Source of Hazard	Risk (Before Importance Factors are Applied)			Importance of Each Factor Influencing the Final Risk Posed by the Hazard					Risk Component of Each Individual Importance Factor					Cumulative Risk
		Likelihood	Severity	Magnitude of Risk	Organisational Ability	Available Information	Legal Framework	Codes of Practice & Other Voluntary Arrangements	Customer Expectation	Organisational Ability	Available Information	Legal Framework	Codes of Practice & Other Voluntary Arrangements	Customer Expectation	
Herbicides	Spraying of road margins & central reservations	1	1	1	-2	0	-2	-2	0	-2	0	-2	-2	0	-6
	Spraying of railway margins	1	1	1	-2	0	-2	-2	0	-2	0	-2	-2	0	-6
	Dumping/flytipping	2	1	2	2	2	0	2	-2	4	4	0	4	-4	8
	Forestry activities	1	1	1	-2	-2	-2	-2	0	-2	-2	-2	-2	0	-8
	Domestic use	2	1	2	0	0	0	0	0	0	0	0	0	0	0
	Agricultural use	3	3	9	-2	0	-2	-2	-2	-18	0	-18	-18	-18	-72
Pesticides & insecticides	Domestic use	2	1	2	0	0	0	0	0	0	0	0	0	0	0
	Forestry activities	1	1	1	-2	-2	-2	-2	0	-2	-2	-2	-2	0	-8
	Agricultural use	3	3	9	-2	0	-2	-2	-2	-18	0	-18	-18	-18	-72
	Dumping/flytipping	2	1	2	2	2	-2	2	-2	4	4	-4	4	-4	4
	Spraying of agricultural land	3	3	9	0	0	-2	-2	-2	0	0	-18	-18	-18	-54
Hydrocarbons	Run-off from roads	4	2	8	2	0	2	0	2	16	0	16	0	16	48
	Agricultural storage tanks	2	3	6	0	2	0	0	2	0	12	0	0	12	24
	Aquatic leisure & tourism activities (eg boating)	2	3	6	0	2	0	0	2	0	12	0	0	12	24
	Other storage tanks (local authority etc)	2	3	6	0	0	-2	0	0	0	0	-12	0	0	-12
	Building/development sites	2	3	6	0	0	-2	0	0	0	0	-12	0	0	-12
	Accidents/spillages	2	3	6	0	0	0	0	-2	0	0	0	0	-12	-12
	Sewage treatment works	2	3	6	-2	-2	-2	0	0	-12	-12	-12	0	0	-36
	Landfill	1	1	1	-2	-2	-2	0	-2	-2	-2	-2	0	-2	-8
	Dumping/flytipping	2	2	4	2	2	0	2	-2	8	8	0	8	-8	16
Pathogens	Industrial discharges	2	2	4	-2	-2	-2	0	-2	-8	-8	-8	0	-8	-32
	Sewage treatment works	5	2	10	-2	-2	-2	0	-2	-20	-20	-20	0	-20	-80
	Burial pits	1	2	2	0	0	-2	0	0	0	0	-4	0	0	-4
	Cemetaries	4	2	8	-2	-2	-2	0	-2	-16	-16	-16	0	-16	-64
	Agricultural grazing land	5	4	20	2	2	0	0	2	40	40	0	0	40	120
	Agricultural storage of animal waste	3	4	12	0	0	0	0	0	0	0	0	0	0	0
	Muck-spreading	5	4	20	0	2	0	0	0	0	40	0	0	0	40
	Cesspits/soakaways	5	1	5	0	2	0	2	2	0	10	0	10	10	30
	Wildlife	5	2	10	0	2	2	2	2	0	20	20	20	20	80
Chemicals	Industrial discharges	2	2	4	-2	-2	-2	0	-2	-8	-8	-8	0	-8	-32
	Sewage treatment works	2	3	6	-2	-2	-2	0	-2	-12	-12	-12	0	-12	-48
	Dumping/flytipping	2	1	2	2	2	0	2	-2	4	4	0	4	-4	8
	Landfill	1	2	2	-2	-2	-2	0	-2	-4	-4	-4	0	-4	-16
	Accidents/spillages	2	3	6	0	0	0	0	-2	0	0	0	0	-12	-12
Suspended solids/turbidity	Over-grazing of agricultural land	3	3	9	2	2	2	-2	2	18	18	18	-18	18	54
	Over-grazing of other land	2	2	4	2	2	2	-2	2	8	8	8	-8	8	24
	Inadequate stock-proof fencing along waterways	5	3	15	2	0	2	0	2	30	0	30	0	30	90
	Mining activities	2	1	2	0	0	0	0	0	0	0	0	0	0	0
	Geology of the catchment	1	1	1	0	-2	2	2	2	0	-2	2	2	2	4
	Aquatic leisure & tourism activities (eg boating)	1	1	1	0	2	0	0	2	0	2	0	0	2	4
	Forestry activities	1	1	1	0	0	0	-2	2	0	0	0	-2	2	0
	Innappropriate land management facilitating soil erosion	4	3	12	2	-2	2	-2	2	24	-24	24	-24	24	24
	Off-roading facilities	2	1	2	2	0	2	0	2	4	0	4	0	4	12
	Poorly managed public footpaths & by ways	3	1	3	2	0	2	0	2	6	0	6	0	6	18
	Building/development sites	2	3	6	-2	-2	-2	-2	0	-12	-12	-12	-12	0	-48
	Flooding	5	4	20	2	-2	0	0	-2	40	-40	0	0	-40	-40
	Dumping/flytipping	2	1	2	2	2	0	2	-2	4	4	0	4	-4	8
	Run-off from roads	4	2	8	0	0	0	0	2	0	0	0	0	16	16

Figure 16: The fourth stage of the Abstraction Safety Index spreadsheet, showing the calculation of the 'cumulative risk' values

Hazard	Source of Hazard	Risk (Before Importance Factors are Applied)			Importance of Each Factor Influencing the Final Risk Posed by the Hazard					Risk Component of Each Individual Importance Factor					Cumulative
		Likelihood	Severity	Magnitude of Risk	Organisational Ability	Available Information	Legal Framework	Codes of Practice & Other Voluntary Arrangements	Customer Expectation	Organisational Ability	Available Information	Legal Framework	Codes of Practice & Other Voluntary Arrangements	Customer Expectation	
Suspended solids/turbidity	Inadequate stock-proof fencing along waterways	5	3	15	2	0	2	0	2	30	0	30	0	30	90
	Mining activities	2	1	2	0	0	0	0	0	0	0	0	0	0	0
	Geology of the catchment	1	1	1	0	-2	2	2	2	0	-2	2	2	2	4
	Aquatic leisure & tourism activities (eg boating)	1	1	1	0	2	0	0	2	0	2	0	0	2	4
	Forestry activities	1	1	1	0	0	0	-2	2	0	0	0	-2	2	0
	Innappropriate land management facilitating soil erosion	4	3	12	2	-2	2	-2	2	24	-24	24	-24	24	24
	Off-roading facilities	2	1	2	2	0	2	0	2	4	0	4	0	4	12
	Poorly managed public footpaths & by ways	3	1	3	2	0	2	0	2	6	0	6	0	6	18
	Building/development sites	2	3	6	-2	-2	-2	-2	0	-12	-12	-12	-12	0	-48
	Flooding	5	4	20	2	-2	0	0	-2	40	-40	0	0	-40	-40
	Dumping/flytipping	2	1	2	2	2	0	2	-2	4	4	0	4	-4	8
	Run-off from roads	4	2	8	0	0	0	0	2	0	0	0	0	16	16
	Run-off from buildings	4	1	4	-2	-2	-2	-2	0	-8	-8	-8	-8	0	-32
	Industrial/commercial discharges	2	2	4	-2	-2	-2	0	-2	-8	-8	-8	0	-8	-32
	General run-off from land	4	2	8	0	2	2	0	2	0	16	16	0	16	48
Heavy Metals	Mining activities	2	1	2	0	0	0	0	0	0	0	0	0	0	0
	Geology of the catchment	1	1	1	0	-2	2	2	2	0	-2	2	2	2	4
	Dumping/flytipping	2	1	2	2	2	0	2	-2	4	4	0	4	-4	8
	Landfill	1	2	2	-2	-2	-2	0	-2	-4	-4	-4	0	-4	-16
	Run-off from roads	4	2	8	0	0	0	0	2	0	0	0	0	16	16
	Industrial discharges	2	2	4	-2	-2	-2	0	-2	-8	-8	-8	0	-8	-32
Taste & Odour	Algal blooms	4	4	16	0	-2	0	0	0	0	-32	0	0	0	-32
	Reservoir stratification	4	4	16	0	-2	0	0	0	0	-32	0	0	0	-32
	Geology of the catchment	1	1	1	0	-2	2	2	2	0	-2	2	2	2	4
	Industrial discharges	2	2	4	-2	-2	-2	0	-2	-8	-8	-8	0	-8	-32
	Dumping/flytipping	2	1	2	2	2	0	2	-2	4	4	0	4	-4	8
	Landfill	1	2	2	-2	-2	-2	0	-2	-4	-4	-4	0	-4	-16
	Agricultural application of pesticides/herbicides	3	3	9	0	0	-2	-2	-2	0	0	-18	-18	-18	-54
	Accidents/spillages	2	3	6	0	0	0	0	-2	0	0	0	0	-12	-12
Radiation	Nuclear power stations	1	5	5	-2	-2	-2	0	-2	-10	-10	-10	0	-10	-40
	Industrial/medical uses of radioactive material	1	5	5	-2	-2	-2	0	-2	-10	-10	-10	0	-10	-40
Nitrates & phosphates	Industrial discharges	2	2	4	-2	-2	-2	0	-2	-8	-8	-8	0	-8	-32
	Agricultural grazing land	5	4	20	0	0	0	-2	-2	0	0	0	-40	-40	-80
	Sewage treatment works	3	3	9	-2	-2	-2	0	-2	-18	-18	-18	0	-18	-72
	Burial pits	1	2	2	0	0	-2	0	0	0	0	-4	0	0	-4
	Landfill	1	1	1	-2	-2	-2	0	-2	-2	-2	-2	0	-2	-8
	Aeolian deposition	3	2	6	0	0	0	2	2	0	0	0	12	12	24
	Agricultural storage of animal waste	3	4	12	0	0	0	-2	0	0	0	0	-24	0	-24
	Cemetaries	4	2	8	-2	-2	-2	-2	0	-16	-16	-16	-16	0	-64
Colour	Industrial discharges	2	2	4	-2	-2	-2	0	-2	-8	-8	-8	0	-8	-32
	Accidents/spillages	2	3	6	0	0	0	0	-2	0	0	0	0	-12	-12
	Drainage from peaty areas	4	3	12	2	0	2	0	2	24	0	24	0	24	72
				470											-540
	ABSTRACTION SAFETY INDEX:			75.9%										WEIGHTED ABSTRACTION SAFETY INDEX:	78.0

Figure 17: The final stage of the Abstraction Safety Index spreadsheet, showing the calculation of the Abstraction Safety Index, both before (on the left of the spreadsheet) and after (on the right) the Importance Factors are applied

Figure 15 reveals the third element of the spreadsheet, in which the value assigned to each of the Importance Factors is in turn multiplied by the magnitude of risk calculated in the first element of the spreadsheet. Continuing with the example of the 'spraying of road margins & central reservations' hazardous source the magnitude of risk is 1, so the risk component of each Importance Factor is calculated as follows:

- Organisational ability: 1 multiplied by -2 i.e. -2
- Available information: 1 multiplied by 0 i.e. 0
- Legal framework: 1 multiplied by -2 i.e. -2
- Codes of practice and other voluntary arrangements: 1 multiplied by -2 i.e. -2
- Customer expectation: 1 multiplied by 0 i.e. 0

The next stage of the calculation is revealed in Figure 16, where the risk components of each individual Importance Factor are summed to provide a weighted cumulative risk in relation to each hazardous source. In the case of the 'spraying of road margins & central reservations' hazardous source, the weighted cumulative risk is simply (-2 + 0 + -2 + -2 + 0) i.e. -6.

The final stage of the calculation is revealed in Figure 17 which shows the calculation of the Abstraction Safety Index, both before and after the Importance Factors are applied. The details of these calculations vary for each methodology, so these are described separately in Chapter 24, Chapter 25 and Chapter 26 respectively.

21.6 Discussion

The principles of the Abstraction Safety Index concept have been presented in this Chapter, which has been constructed in order to meet the needs of the UK water industry.

Because of the adoption of a standard risk assessment matrix, it can be used equally effectively as a performance indicator and for benchmarking purposes, making it attractive to water companies, regulators, consumers and other interested stakeholders. This matrix went through several iterations before the final version was adopted that has been presented in this Chapter, and this process was greatly informed by the development of the catchment environmental assessment methodology; this is presented in the next Chapter.

Not only does the Abstraction Safety Index allow dissimilar catchments to be ranked, enabling action programmes and capital investment to be targeted and prioritised, but it also embraces two fundamental departures from how the UK water industry is currently risk assessing hazards associated with catchments. Firstly, the risk assessment matrix is parameter based, rather than the standard approach of being hazard based, and secondly, it uses an innovative weighting system in the format of Importance Factors, enabling both quantitative and qualitative influences on environmental water quality to be taken into consideration.

Where the risk assessment matrix does share common ground with the approach currently taken by the UK water industry is that there is an element of subjectivity inherent within it. Consequently, in broad terms, it is entirely feasible a scientist may arrive at scores that are different to those obtained by an engineer or an accountant. Therefore, it is still important for a broad team to be constructed – as espoused by the WHO in the preparation of Drinking Water Safety Plans – in order to consider each and every risk assessment, so that any differences in scores may be discussed, and a consensus achieved, thus minimising as far as possible the effects of any subjectivity.

In an extremely limited capacity, I tested the appropriateness of this consensual approach with an environmental science MRes student; we both undertook a risk assessment of the same catchment and, somewhat remarkably, the vast majority of 'likelihood' and 'severity' scores that we assigned independently were within 1 of each other when they were subsequently compared. In only a small number of cases did we arrive at significantly different scores, and the reasoning behind the values assigned was discussed, and a consensus was obtained.

As part of the evolution of the Abstraction Safety Index concept, three different mathematical methodologies were derived, and these are presented in Chapter 24, Chapter 25 and Chapter 26 respectively, along with the results these methodologies yielded. In order to calibrate these three methodologies, seven catchments spanning a wide range of scenarios that the Abstraction Safety Index could encounter (covering both surface water – including both upland and lowland impounding reservoirs and direct river abstraction, and groundwater) were used, and an overview of these is given in Chapter 23.

22 CATCHMENT ENVIRONMENTAL ASSESSMENT METHODOLOGY

22.1 Introduction

Seven catchments were used in order to calibrate the Abstraction Safety Index methodology, and an overview of each of these catchments is given in Chapter 23. In order to do so, it was necessary to obtain pertinent information relating to potential impacts on both water resources and water quality, specific to each catchment. The amount of information relating to the type and 'health' of a catchment can be abundant and held by numerous disparate organisations. I therefore constructed the following catchment environmental assessment methodology, which attempts to break a catchment down into separate categories, identifies the information that may be relevant relating to each category, and suggests which organisations need to be contacted in order to acquire the information.

This methodology is necessarily generic by nature, because of the differing geographic locations of the catchments (Wales, England and Scotland[24]), and it must be recognised that the same information (for example, location of private soakaways) may be held in differing forms by different local authorities, and the quality of the information may be highly variable, if it indeed exists in the first place.

This methodology is not meant to be an exhaustive list, as for any particular catchment there may be other organisations (for example, single-issue pressure groups) that have a wealth of information relating to one narrow aspect of the catchment. However, by contacting all the organisations listed within this Chapter the existence of such additional information may well be highlighted.

---

[24] It was not necessary for me to adapt this methodology to obtain information relating to Catchment 'D' (situated in Spain) as, because of the relatively short period of time that I was in the country studying the catchment, I did not have to obtain the information personally; instead, a 'shopping list' of information required was sent to the water company prior to my visit, and which was given to me whilst I was there.

22.2 Catchment Characteristics

Before detailed information relating to what is going on within the catchment can be assembled, it is prudent to collate information relating to the catchment itself, so that its characteristics (geology, topography etc) may be defined.

22.2.1 Drift and Solid Geology

Mid-scale information relating to the geology (both drift and solid) of a catchment can be readily obtained from the British Geological Survey, and which should be supplemented by small-scale information that can be derived from guide books and local geological groups (details of which may be obtained from the Geological Society, or found in local libraries within the catchment).

22.2.2 Topography and Aspect

The topography and aspect – and, to a lesser extent, drainage patterns – can be determined from ordnance survey maps. In the case of particularly small catchments, further detailed information can be obtained from bespoke surveys.

22.2.3 Vegetative Cover

Vegetative cover can affect both drainage patterns and water quality, and so should be considered in a catchment management context. Ordnance survey maps can give an initial overview of vegetative cover within the catchment, but detailed information will need to be derived from bespoke surveys.

Any organisations with land management interests or responsibilities should also be consulted, as they may have practices or policies that may impinge on water quality within the catchment. For example, relevant local authorities and national park authorities may have rhododendron and/or Japanese knotweed eradication policies.

22.2.4 Wildlife

Populations of significant species may inadvertently pose problems for both water quality and quantity within a catchment. For example, the keeping of water levels artificially elevated by means of a Water Level Management Plan (see Section 13.4.6) in order to sustain wading birds may significantly affect drainage patterns and encourage the mobilisation of pollutants; similarly, the presence of a Special Site of Scientific Interest may also have an adverse effect on the amount and quality of water abstracted for drinking water purposes. The EA (or the Scottish Environment Protection Agency, as appropriate) can advise on whether any such populations or designations exist within a catchment. The local Wildlife Trust can also be a useful source of information, along with the appropriate national ecological body (Natural England or the Countryside Council for Wales).

22.3 Water Quantity

The EA operates and maintains the hydrometric network for England and Wales, which records information relating to surface water levels and flows, groundwater levels and precipitation. All main catchments will have at least one level and/or flow monitoring station within it, but many smaller sub-catchments do not; the distribution of rain gauges is also patchy in places. An approach should therefore be made to the EA in the first instance for any available hydrometric data, after which a decision can be made whether any additional monitoring is required.

For information relating to drainage patterns, the prime source will be the EA, whilst the local authority may also hold some information.

If the catchment is agricultural, spray irrigation may be a significant feature during the summer months, which will affect both surface flows, drainage and water quality, so the EA may be able to give a view on this; certainly, it is worth contacting the local office of the NFU / NFU Cymru / FUW as they may be able to provide useful information relating to cropping patterns and irrigation water usage.

As far as bulk transfers of water are concerned, the EA will be the prime source of this information, with the secondary source being the operator or beneficiary of the transfer (such as a navigation authority, power generation company or water company).

With regards to groundwater, as part of the aforementioned hydrometric network, the EA may have details relating to flow rate and direction, aquifer characteristics and depth to the water table, along with their recharge areas. However, since the enactment of the Water Act 2003, when many smaller boreholes were made exempt from abstraction licensing, the volume of data provided annually to the EA by abstractors has been reduced.

22.3.1 Abstractions

For details of abstraction licences (including licences of right), contact the local Area office of the EA. The EA has to maintain a public register containing this information, which can be consulted for free during normal office hours. This register should contain the location of the abstraction, along with the prescribed abstraction rates, and the purpose for which the water is being abstracted (for example, for public supply).

However, this information only relates to authorised abstractions, or those greater than the minimum daily abstraction rate threshold. For qualitative information relating to small-scale abstractions – which may be significant in rural and/or agricultural areas – it may be prudent to contact the local office of the NFU / NFU Cymru / FUW; also, contact should be made with the local Water Resources Officer of the EA.

22.3.2 Private Water Supplies

Some information relating to private water supplies may be held by the local Area office of the EA. However, since the enactment of the Water Act 2003 and deregulation of small water supplies, this information may be patchy and will become increasingly out-of-date with the passing of time.

Local authorities have a responsibility for the quality of private water supplies, so the appropriate council(s) within the catchment should be contacted to determine what information they hold (if any) on private springs, wells and boreholes used for the supply of drinking water.

Finally, the local water company should be able to determine which of the properties within the catchment area do not appear on its drinking water billing database, so by deduction these properties must be obtaining their drinking water from a source other than the public water supply.

22.3.3 Drought and Flooding

Although included under water quantity, drought and flooding can also have a significant effect on the quality of both surface waters and groundwater. At the same time as acquiring hydrometric data from the EA, enquiries can also be made of the EA's Flood Risk Management and Water Resources teams.

Other useful sources of information include the water company's drought plan and water resources plan, and the local authority (particularly from a flooding perspective).

Local street and road names may also yield information relating to historic instances of flooding (such as 'Water Lane'), or point to long since culverted watercourses which no longer feature on water companies' databases.

22.4 Water Quality

Alongside the results of sampling relating to a specific discharge (see Section 22.4.1), the EA also takes samples from surface waters catchment-wide, as part of its GQA scheme; the EA provides this information freely available upon request, although a charge may be applied for large volumes of date. With regards to groundwater though, it would be very unlikely that any such data is held. In this case, the British Geological Survey should be approached.

If the water body – whether it is an aquifer or surface water – is used for public water supply, the water company will also hold raw water quality data, although it is not under a duty to release this information to the public, and may therefore be reluctant to do so.

In certain catchments the Strategic Health Authority may have a view on certain parameters in water sources used for public water supply (such as arsenic in certain parts of Somerset, and radon in Devon and Cornwall), and it is worth contacting them for their views.

22.4.1 Discharges

As with abstractions, the EA maintains a public register containing information relating to all consented discharges and this may be consulted free of charge during normal office hours. This register should contain the location of the discharge, along with any conditions relating to the discharge.

In order to monitor compliance with a discharge consent, the EA will from time to time take samples from the receiving water, and these results should also be available to the public.

The above only relates to consented discharges. However, spillages (both accidental and deliberate) and unauthorised discharges also occur, and enquiries should be made of the appropriate EA Environmental Management team for any information relating to these. Similar enquiries could also be made of the local authority's Environmental Health team.

In a rural catchment soakaways and cesspits may be of significant interest, and it is highly possible that any information the local authority has on these will be limited at best, and will not present the whole picture. Accordingly, an approach should be made to the water company to determine which properties within the catchment are not paying a sewerage charge; those that aren't are either connected illegally to the sewerage network, or disposing of their waste by other means.

22.5 Recreation

There can be many forms of recreational activities within a catchment, some of which will have more of an impact on water resources and water quality than others; a brief overview of the more important activities (as far as potential risks to either water resources and/or water quality are concerned) is given in the following sub-sections, along with potential sources of information.

22.5.1 Aquatic

If there are navigable rivers, canals or other watercourses within the catchment, contact should be made with the appropriate navigation or port authority, for any pertinent information (such as that relating to storage of fuel and waste, the operation of any pump-out facilities, and the location of any marinas and car parks). These authorities may also hold water quality information, particularly if they have undertaken investigations into, for example, pollution incidents and potential transfers of water.

Consideration should also be given to other organised recreational users of water bodies (either flowing or standing) within the catchment area, and examples of these include sailing clubs and fishing associations. Particularly in isolated catchments, any facilities provided for these users may not be connected to the mains sewerage system, and consideration must be given to the risk of vandalism if there are fuel tanks present.

Details of specific pollution incidents (such as blooms of blue-green algae) relating to or affecting water bodies should be kept by the EA, or the Environmental Health department of the local authority.

22.5.2 Terrestrial

Consideration should be given to areas of land used for recreational purposes, such as golf clubs, sports grounds and campsites, particularly if they are in close proximity to sensitive water bodies. Of particular interest is whether any herbicides or fertilizers are used, or if they have an artificial irrigation scheme during the summer months.

22.6 Land Use

As was detailed in Chapter 12, how we use the land within a catchment will have an impact on both water resources and water quality. However, within the context of a catchment environmental assessment methodology we must not only consider current land use, but both historic and future land use as well.

22.6.1 Historic Land Use

Much useful information can be derived from old maps of the catchment, principally held by local libraries within the area. The local authority may also have information about the former use of brownfield sites which, even though the use has long been discontinued, may continue to have a bearing on groundwater; for example, tanneries and heavy industry.

There are numerous former landfill sites dotted around the country, many of which do not appear on maps and knowledge about them is patchy at best. In the first instance, enquiries should be addressed to the local Area office of the EA; they may also have some knowledge of any recent or historic burial pits within the catchment. Another source of information may be the local authority.

Local street and road names may also yield information relating to historic use of sites (such as 'Limekiln Way'), and local historians may be able to shed further light on these.

22.6.2 Current Land Use

Again, maps are a quick and useful source of information relating to current land use and, for example, the proximity of industrial sites to strategic watercourses can be readily determined. Site reconnaissance also proves useful in this regard, perhaps in conjunction (should budgets allow) with a helicopter fly-over of the catchment. Alternatively, aerial photographs may be freely downloaded from several websites (such as Google and Multimap).

With regards to agricultural catchments, the local office of the NFU / NFU Cymru / FUW may be able to provide information relating to current cropping plans, along with irrigation schemes.

In an agricultural catchment, local officers of both the NFU / NFU Cymru / FUW and the EA (indeed, the EA may have a dedicated Agriculture team covering the catchment) may also be able to provide an overview of the types of farms present, along with their size and the extent of storage of fuel and chemicals (such as fertilizers, herbicides and pesticides), and whether there are any storage facilities present for waste products. Ultimately though, this detailed level of information can only be determined by contact with individual farms, by means of questionnaires and/or site visits.

In a mixed or urbanised catchment, the EA should have undertaken a pollution risk inventory, and will have details relating to specific industrial sectors, such as petrol stations, dry cleaners, and stores of chemicals and other noxious materials.

If any local, regional or national organisations (for example, the National Trust, local Wildlife Trust, Forestry Commission, RSPB or national park) have significant landholdings within a catchment, it is worthwhile obtaining a copy of their land management policies, as these may (inadvertently or otherwise) impinge or directly effect water quality within the catchment.

22.6.3 Future Land Use

The best source of information relating to the future use of land within a catchment would be the local authority's development plan for the area, which will highlight those area of currently undeveloped land that have been earmarked for future development.

On a more strategic level, the appropriate Government Office and Regional Development Agency (for England) or the Planning Department of the Welsh Assembly Government (for Wales) may also be able to provide some useful information with regards to future developments across a wider area.

22.6.4 Roads

Information from the Highways Department of the local authority should be obtained with regards to their use and application of herbicides along road margins; they should also be asked to confirm whether they act as an agent of the Highways Agency (HA) with regards to trunk roads within the catchment, or if the HA makes its own herbicide application arrangements.

At the same time, information can be sought on the respective organisation's gritting/salting policy during the winter months.

With significant arterial routes, such as trunk roads and motorways, information relating to the drainage of these routes would be useful, and whether they drain directly into surface watercourses or into a separate foul water system.

22.6.5 Railways

As with roads, information should be obtained from Network Rail with regards to their use and application of herbicides along rail margins.

22.7 Discussion

A catchment environmental assessment methodology that was constructed in order to provide as wide a range as possible of available information for the calibration of the three different Abstraction Safety Index methodologies was presented in this Chapter; the exhaustive literature reviews that were undertaken with regards to legal, institutional and voluntary frameworks – the outcomes of which are presented in Parts 1-3 inclusive – greatly informed this construction process.

An advanced draft of this methodology was given to one of the water companies that had provided one of the seven catchments, in order to test its robustness and usability. It was confirmed that the methodology was a useful tool for catchment risk assessment purposes, and they only had one, minor, observation to make, which was to include the suggestion to refer to the agricultural statistics published by DEFRA on their website. However, these statistics do not appear to be useful at either the catchment or sub-catchment level, so this suggestion was not acted upon.

The water company concerned has since adopted this methodology for its own purposes.

23 CATCHMENTS USED FOR CALIBRATION OF THE THREE ABSTRACTION SAFETY INDEX METHODOLOGIES

23.1 Introduction

In the following Sections a brief overview is given of each of the seven catchments used to calibrate the three Abstraction Safety Index methodologies presented in Chapter 24, Chapter 25 and Chapter 26, whilst a summary of their principal characteristics is given in Table 19. Five of these catchments relate to public water supplies (four of which are from England and Wales, and one is from Spain), whilst the remaining two are private water supply catchments from Scotland.

CATCHMENT	SURFACE / GROUNDWATER	SOURCE OF ABSTRACTION?	PUBLIC / PRIVATE SUPPLY?	UPLAND / LOWLAND CATCHMENT	RELATIVE WATER QUALITY IN CATCHMENT
A	Surface	River	Public	Lowland	Fair
B	Surface	Impounding reservoir	Public	Upland	Good
C	Surface	Impounding reservoir	Public	Lowland	Good
D	Surface	River	Public	Lowland	Poor
E	Groundwater	Springs	Public	Upland	Generally excellent
F	Groundwater	Spring	Private	Upland	Excellent
G	Groundwater	Burn	Private	Upland	Excellent

Table 19: A summary of the principal characteristics of each of the seven catchments A-F

A quantitative risk assessment has been undertaken of each of the seven catchments, and these are included in the spreadsheets contained on the CD-ROM attached to the inside front cover of this thesis; these risk assessments are sufficiently detailed for all of the main hazards within each catchment to be identified. However, for ease of reference, a brief summary of the main impacts on environmental water quality are given in the following overviews.

A condition of being able to study these catchments was that all data and information presented in relation to them should be done in such a way that the catchments themselves (or the associated water companies) could not be readily identified; hence the following overviews are in anonymised format.

23.2 Catchment 'A' Overview

The chemistry and flow regime of the River 'A' is heavily influenced by the karst topography in which it rises, which is in a gorge on the southern flank of a carboniferous limestone massive. From here the river flows south for about a mile, before changing direction sharply to flow generally in a north-west direction for about 17 miles towards the coast, before discharging into the sea.

The river flows through a low-lying poorly-drained peat moor of national ecological importance. This land is also of great agricultural importance as well, and a number of Internal Drainage Boards manage water levels by means of a complicated network of small watercourses. In general the hydraulic gradient in this area can be anywhere between 1:1,000 and 1:6,000, and consequently it is virtually impossible to determine direction of flow by eye alone in many of the smaller channels.

A view of the river – as taken from the Water Company '1's pumping station, is given in Picture 1, in which the low-lying nature of the catchment is clearly visible.

Picture 1: A view of the river, with the pumping station off-take grille in the foreground

Water Company '1' currently holds an abstraction licence for the River 'A', allowing it to pump up to 4,750 megalitres from the river during the months November to April inclusive for the purpose of topping-up its reservoir, which is situated approximately a mile to the north-east of the abstraction point. The water is pumped via a pipe bridge over a smaller watercourse between River 'A' and the reservoir to a pre-treatment plant (which is currently being upgraded) adjacent to the reservoir, before being introduced to the reservoir itself. Water is then taken from the reservoir on the opposite side, and treated before being put into supply.

This reservoir was constructed in the 1930s, and has a capacity of over 6 million cubic metres, and is supplied by a series of springs within one of the gorges in the carboniferous limestone massive; a general view of the reservoir is given in Picture 2.

Water quality in the reservoir is good, whilst the water quality in the river less so, and Water Company '1' has experienced algal problems in the reservoir once the river water has been introduced to it; the reservoir is generally oligotrophic, but the introduction of the river water turned it eutrophic. Consequently, the last time water was abstracted from the river was approximately three years ago.

The treatment processes at the water treatment works includes micro-strainers, slow sand filtration, chlorination, de-colourisation, and phosphate dosing (for plumbo-solvency control). When it is running at full capacity, it can supply 40,000 cubic metres per day. Approximately 40,000 people receive their supply direct from this works, whilst a further 30,000 can be supplied indirectly by it via a treated water supply to another water treatment works.

Picture 2: A general view of the reservoir, with the draw-off tower just visible in the left of the picture

23.2.1 Principal Issues Affecting Water Quality within the Catchment

Because of the predominantly dairy land use within the low-lying parts of the catchment, the principle hazards as far as the river is concerned are related to the fairly intensive grazing bordering the river on both sides, and associated activities. Of particular concern are pathogens produced directly by the animals themselves, as well as arising from the storage, and subsequently spreading, of the waste.

Direct and indirect agricultural sources of nitrate and phosphate were also deemed to have a significant detrimental impact on water quality at certain times of the year, particularly during flood events. When the river abstraction has been utilised, this has led to algal blooms and taste and odour issues within the reservoir, so both of these sources of hazards scored quite highly.

An associated consequence of the grazing animals is the impact they have on the turbidity of the river, by 'poaching' the land and by breaking down the unfenced river banks in order to gain access to the river to drink.

23.3 Catchment 'B' Overview

The impounding reservoir that was considered for this case study is part of a complicated reservoir system which is connected by tunnels, pipelines and leats (open contour channels); it was first used for public water supply purposes in the 1880s. There are four other reservoirs within this system, some of which have dual uses for the generation of hydroelectric power and public water supply.

A general view of this reservoir is given in Picture 3, whilst a general view of the type of grazed landscape comprising the catchments of the reservoir system is given in Picture 4.

Picture 3: A view from the dam of the impounding reservoir

Picture 4: A general view of the type of grazed landscape comprising the catchments of the reservoir system

This reservoir system is situated on the left bank of a river valley which lies on the border of Ordovician and Silurian rocks. On the left bank of the river are the hard resistant Ordovician rocks, whilst the less resistant Silurian rocks can be find on the right bank.

Water flows under gravity from the impounding reservoir to the water treatment works owned by Water Company '2', where it is treated before being supplied to 76,000. The treatment processes at this Works includes ozonation, GAC filtration, disinfection (using both UV and chlorine dioxide), pH correction and orthophosphoric acid dosing (to minimise plumbo-solvency) and it can supply an average of 29,000 cubic metres per day to an estimated population of just over 97,000.

The floor of the river valley is very fertile, and a mixture of dairy and arable farming is practiced here. Higher up the slopes of the valley, the soil is much thinner and of poorer quality, and is generally only used for rough grazing purposes. These basic soils are unable to neutralise the slightly acidic, but substantial, rainfall, so acidification is a problem in these upland areas.

23.3.1 Principal Issues Affecting Water Quality within the Catchment

Because of the upland, completely undeveloped nature of this catchment, only three significant impacts on water quality were identified; pathogens arising from the few sheep on the steep upstream slopes around the impounding reservoir, and infrequent taste and odour problems associated with algal blooms and stratification within the reservoir itself.

23.4 Catchment 'C' Overview

An impounding reservoir was constructed in a shallow low-lying valley in 1938 by damming River 'C' (in reality a minor watercourse), along with an associated pumping station and water treatment works, in order to provide the then largest industrial site in the nearby town with a secure supply of water. The reservoir extends to over 80 acres. A general view of this reservoir from the dam is given in Picture 5, whilst a view of the dam is given in Picture 6.

Picture 5: A view from the dam of the impounding reservoir

Picture 6: A view of the dam, with the water treatment works just visible to the right of the picture

The entire catchment of the reservoir is rural, and the land use is predominantly a mixture of arable, dairy and beef farming, although there are some small areas of woodland and open access land.

In 1962 the reservoir started to be topped up regularly during the summer months by pumping water approximately one mile from a canal within British Waterways' network. Water levels in the canal are maintained approximately 10 miles south by taking water from another river. Water Company '3' – the current owner of the reservoir – now has an agreement with British Waterways to abstract up to 4,300 megalitres per year from the canal.

The treatment processes at the water treatment works includes coagulation using sulphuric acid and aluminium sulphate, dissolved air flotation, pressure filters, granular activated carbon, pressure filters and super- and de-chlorination.

No customers receive their water supply purely from this works alone; instead, it is blended in a local service reservoir with the output from two other water treatment works, before going on to supply approximately 45,000 people.

23.4.1 Principal Issues Affecting Water Quality within the Catchment

The main issues identified within this catchment are very similar to the ones related to Catchment 'A', as they are both predominantly agricultural (although there is an additional element of crop production in this catchment). The population and socio-economic distributions across the two catchments are broadly similar, but the presence of a nuclear power station some miles away means that radiation has been assessed as being a higher risk in this catchment.

As with the two previous catchment, algal blooms and stratification have been experienced in the impounding reservoir in Catchment 'C', although at a greater frequency; again, agricultural sources of nitrate are phosphate are the principal causes for these.

23.5 Catchment 'D' Overview

Catchment 'D' is situated in north east Spain, and it has been subject to a significant amount of environmental degradation over many generations. There is currently a lot of heavy industry within the catchment, including metal reclamation, paper mills, textile factories, chemical factories, a sugar refinery and a PVC factory. There is also some livestock kept at the top of the catchment.

The River 'D', under natural conditions, would be an ephemeral creek, and would only flow for part of the year; hence it is necessary to regulate the flow within it by means of reservoirs. The average flow within the river is 12-15 cumecs, whilst the typical flow is 3-4 cumecs. However, during flood periods the flow can exceed 1,000 cumecs.

Water company '4' owns and operates a water treatment works on the lower reaches of the river, only a few kilometres from the sea the maximum output of this works is 5 cumecs, so during drier periods all of the flow within the river is abstracted. To facilitate this, the abstraction grille extends across the whole width of the river channel, and this is visible in Picture 7. There are a number of salt mines in the upper reaches of the catchment, and the liquid waste from these mines is collected and flows in a pipe (known colloquially as 'the brine collector') adjacent to River 'D', until the brine is discharged just below the abstraction point for this works; the discharge can been seen in Picture 8.

Picture 7: The off-take for the water treatment works

This water treatment works abstracts from the river, and this water is usually blended with groundwater pumped from a major aquifer underlying the river. When abstraction from the river has to stop (due to pollution incidents for example), the water treatment works is supplied solely by groundwater. The aquifer is currently overexploited, which in one way is actually fortunate; there are many pockets of contamination and areas of landfill overlying the aquifer, but as the water table is some 25m below this pollution the quality of the water is not affected by it. However, should the aquifer recover (perhaps as a consequence of complying with the Water Framework Directive), then the water table would rise and probably breach these contaminated areas.

Both the river and the groundwater have a high salinity – the salinity of the river is generally 1.8mS/cm, whilst the value for groundwater is slightly higher at 2.1mS/cm.

Because the quality of the river water can be highly variable, the processes at the water treatment works includes pre-chlorination, coagulation (using aluminium sulphate & iron chloride), sand filtration, ozonation, granular activated carbon, and final chlorination. The treatment at this site is currently being upgraded to incorporate reverse osmosis, in order to address the high salinity and organic load of the raw water.

Picture 8: The river immediately downstream of the off-take; the water in the foreground is the discharge from the 'brine collector'

23.5.1 Principal Issues Affecting Water Quality within the Catchment

This is by far the most polluted of the seven catchments that were studied, and the environment is heavily degraded throughout by heavy industry, exacerbated by inappropriate development and weak (or in certain cases, non-existent) regulatory controls. Particularly acute issues arose in the hydrocarbons, chemicals, heavy metals, colour and taste and odour parameter groups, all associated with the myriad industrial discharges throughout the catchment.

Inappropriate and/or intensive use of the land had a cumulative impact on the turbidity of the river, whilst organic inputs (principally nitrate and phosphate) were associated with industrial discharges, landfill and insufficient treatment of sewage discharges.

Conversely, the use of herbicides, pesticides and insecticides were generally not deemed to be a particular problem with the catchment.

23.6 Catchment 'E' Overview

This is an artesian springs catchment, which is located some 5km east of a small town, and the site of the springs is situated on a valley side between a main 'A' road defining the northern boundary and a dismantled railway to the south. To the south of the site is a heavily wooded area, whilst to the north is a fairly steeply sloping field. Within the vicinity of the springs site the area is predominantly rural, with mixed sheep and beef farming being the most widespread practice in the less fertile upland areas. A view of the site appears in Picture 9, in which the grazed field on the upper adjacent slopes is just discernible.

Picture 9: The site of the springs

This springs source is one of only two groundwater sources utilised by Water Company '5'. As the water issuing from the springs is generally of very high quality, the only treatment it receives other than initial screening is chlorination, before being supplied to a population of 6,706. The normal daily output range of the source is 2.5-3.0Mld, whilst the maximum design capacity of the water treatment works is 3.0Mld.

The size of the catchment for the springs is unknown, but it is in turn part of the much larger catchment for one of the UK's major rivers. This larger river catchment is a generally high quality environment, although some of its tributaries are adversely affected by sewage or agricultural pollution. Historic industrial activities have also left large areas of contaminated land, some of which is adjacent to, or possibly just within, the catchment for this source. Some of the upper areas within the larger river catchment suffer from the effects of acidification.

There are two distinct aquifers at the site of the springs. The upper aquifer is the sand and gravel horizon within glacial till deposits. The lower aquifer is the bedrock strata which would normally be the sandstone horizons although limestone can also act as an aquifer. The upper aquifer is thought to be in direct hydraulic continuity with the lagoon and springs.

Water quality from the site (both raw and treated) is very consistent, and the springs have a slow reaction time to both droughts and wet seasons, with the timed delay between rainfall and peaks in the output from the springs appearing to be about 12 months. However, low numbers of *Clostridium perfringens* have been detected on an infrequent basis in the treated water which has given Water Company '5' some cause for concern, as the source of these pathogens was not immediately apparent.

C. perfringens is the most characteristic member of the sulphite-reducing clostridia group and is exclusively of faecal origin. Its spores can survive in water for very long periods and are quite resistant to disinfection. The presence of *C. perfringens* in groundwaters in the absence of *E. coli* and entercocci is indicative of historic pollution and suggests a source may be liable to intermittent contamination. As it is relatively resistant to disinfection, *C. perfringens* must be removed by some form of filtration, as terminal disinfection is unlikely to inactivate them (Dufour et al. 2003).

23.6.1 Principal Issues Affecting Water Quality within the Catchment

As with Catchment 'B', this catchment is similarly undeveloped and upland, so it also only has three identified significant impacts on water quality; pathogens, nitrate and phosphate, all arising from the assorted agricultural animals grazing in close proximity to the springs site.

23.7 Catchment 'F' Overview

Farm '1' is located on the southern bank of the Firth of Clyde, within the jurisdiction of Inverclyde Council. The occupants of the farm and some of their livestock obtain their water supply from a spring source just to the south-east of the main farmhouse. The exact location of the spring was not known by the occupants however, the land that most likely falls within the recharge area of the spring is entirely used for grazing purposes, as it is particularly rough and uneven, and unsuitable for arable crops. A general view of the catchment is given in Picture 10.

Picture 10: A general view of the catchment

23.7.1 Water Supply Overview

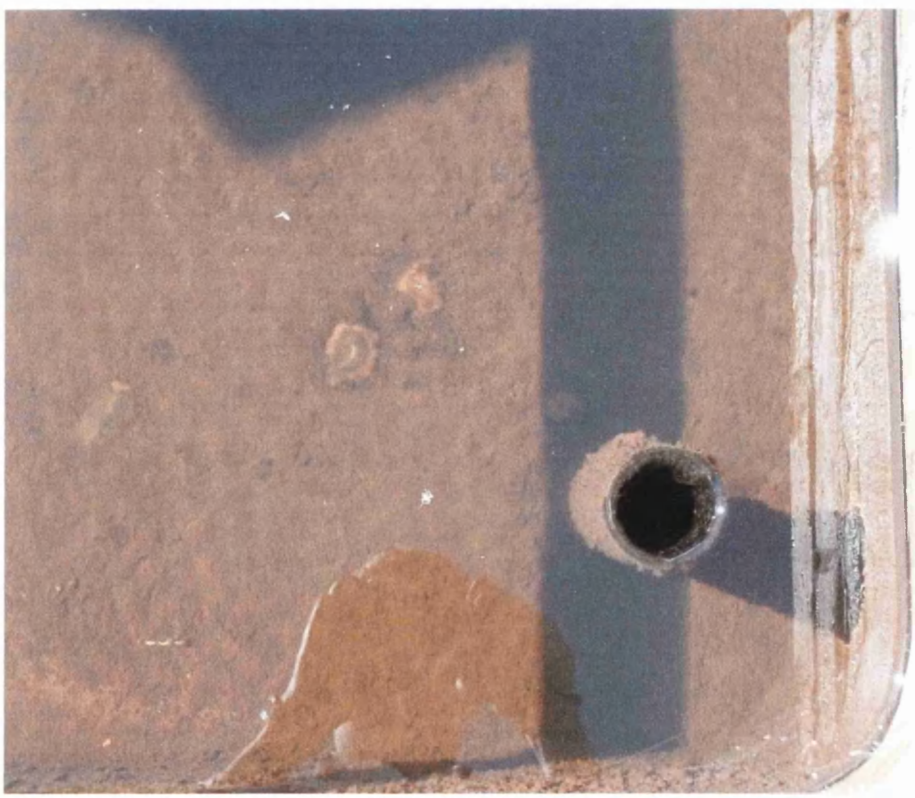
Although the exact location of the spring source could not be located during a site visit undertaken 23 July 2007, the occupants of the farm believed that the water flowed into a collection chamber, and then via a pipe of unknown construction into a second collection chamber consisting of inter-connected settlement cells (see Picture 11).

Picture 11: A view of the second collection chamber, consisting of three inter-connected settlement cells, looking east towards Farm '1'

Water from the spring source flowed into the first of the three settlement cells by means of a plastic pipe (see Picture 12), from where it flowed it flowed into the second and third settlement cells by means of a pipe at the bottom of the dividing wall between each of the cells. A thick layer of sediment was present in each cell, and it also encrusted the sides of the cells and the outflow pipe (see Picture 13 and Picture 14).

Picture 12: The first of the 3 interconnected settlement cells, showing water flowing from the inlet pipe

Picture 13: The third of the three interconnected settlement cells, showing the outflow pipe



Picture 14: A close-up of the overflow pipe; the sediment at the bottom of the settlement cells, and the encrusted sides and pipe, are clearly visible

The water did not appear to be particularly clean in the first cell, and there was a thick creamy froth present on the water's surface, although the water issuing from the inlet pipe appeared to be fairly clear. However, the water appeared to be clear by the time it reached the third cell, despite the pipe connecting the three cells being situated at the bottom instead of at the top.

Each cell had an individual covers which consisted of some form of metal alloy, with only one cross-strut on their underside. The lids were not lockable, and neither did they appear to be watertight.

The land on which the second collection chamber is situated is rented out for six months of the year throughout the summer, and the occupants of the farm were not aware of any restriction on the numbers of animals allowed to graze on the land.

23.7.2 Principal Issues Affecting Water Quality within the Catchment

In relative terms, this was the most pristine of all the seven catchments. There was no development at all within the catchment, and the rough ground contained within it was only lighted grazed by a few sheep. However, the impact of pathogens arising from agricultural animals was scored very highly in the risk assessment, because the second collection chamber was situated in a field where cows were kept for several months of the year; the chamber was not fenced off, and the three (non-watertight) covers on the chamber were effectively at the same level as the surrounding land, thus making them vulnerable to ingress of overland flow.

23.8 Catchment 'G' Overview

Farm '2' is also within the jurisdiction of Inverclyde Council, and is located just over 2 miles away from Farm '1'.

The occupants of the farm, and of a neighbouring property, obtain their water supply from a burn just to the north of the two properties. The land within the burn's catchment is used for both grazing purposes and arable crops, and a general view of the catchment is given in Picture 15.

Picture 15: A general view of the catchment

23.8.1 Water Supply Overview

A site visit to the catchment was undertaken on 24 July 2007, and the route of the water supply was traced backwards from the farm to its source. The collection chamber was inspected first, and this was covered by a thick sheet of metal, held in place with large stone slabs (see Picture 16). The metal lid was not lockable, and neither was it watertight. Water from this chamber fed both Farm '2' and a nearby property.

When the chamber's lid was lifted, the water appeared to be very clear, and a large colony of slugs was present above the waterline (see Picture 17 and Picture 18); the base of the chamber contained a thick layer of sediment.

The field in which the chamber was situated was currently laid out for wheat, whilst the adjoining field immediately up-gradient contained barley. According to the occupants of Farm '2', the farmer was known to apply pesticides, fertilizers and slurry to the fields.

Picture 16: The settlement chamber, covered by a thick metal sheet, which is held in place by 3 broken stone slabs

Picture 17: One of the metal sheets removed, to reveal the settlement chamber and the inlet pipe (curved downwards) and the outlet pipe (to the right of the inlet pipe)

Picture 18: Close-up of the inlet and outlet pipes

The occupants of the farm believed their water supply was a blend of water taken from two separate burns, and the inspection point of where these two waters were blended was visited next. This inspection point was located at the perimeter of the same field in which the collection chamber was situated, and was covered by a small piece of corrugated metal weighed down with stones (see Picture 16).

Picture 19: The abstraction point for the water supply, upstream of the settlement chamber

However, when this corrugated metal was lifted, the yellow polyethylene pipe that was believed to convey water from the second burn to combine it with the water in this first burn was found to be shut off by means of a valve situated a few inches from the end of this pipe (see Picture 20). This therefore meant that the water supply to Farm ‘2’ was derived in its entirety from the first burn.

Picture 20: The abstraction point with the corrugated sheet removed, revealing a yellow polyethylene pipe and a small burn

For completeness, the now-redundant abstraction point on the second burn was also inspected, which was situated some 100 metres from the inspection point on the first burn. It appeared that this abstraction point had been recently upgraded, and was surrounded by stock-proof fencing and a small weir had been created within the burn in order to maintain a suitable depth of water for continuous abstraction (see Picture 21 and Picture 22).

Picture 21: The abstraction point on the second burn, surrounded by stock proof fencing

Picture 22: The abstraction point on the second burn, showing the off-take (with water over-spilling), and the weir regulating the water level

23.8.2 Principal Issues Affecting Water Quality within the Catchment

Although the aspect and topography of this catchment, coupled with its undeveloped nature, are very similar to Catchment 'F', there were slightly more significant impacts on water quality noted, solely arising from the documented use of herbicides and pesticides on the arable crops both surrounding the collection chamber and immediately up-gradient of it. As with the previous catchment, the top of the chamber was not much higher than the surrounding field, particularly on its up-gradient edge, and was therefore vulnerable to ingress of overland flow.

23.9 Discussion

In this Chapter a brief overview was given of each of the seven catchments used to calibrate the three Abstraction Safety Index methodologies. I was extremely fortunate in being granted access to a wide range of catchments used for both private and public water supplies, and which are derived from surface water as well as groundwater sources; this undoubtedly strengthened the calibration process, the results of which are presented in Chapter 24, Chapter 25 and Chapter 26.

Four of these catchments are within England and Wales, whilst the two private water supply catchments are located in Scotland. The number of similarities between the legal, institutional and voluntary frameworks within these three devolved regions of the UK were deemed to far outweigh the differences, so it was felt appropriate to apply the same set of Importance Factor values to each of these six catchments. Where the calibration process could be challenged though is with the adoption of the same set of values for the Spanish catchment, as there are a number of significant differences in the legal and institutional frameworks between the UK and Spain. However, it was not possible to identify within the UK a sufficiently degraded catchment that was being used for either public or private water supply purposes. Therefore, it was necessary to obtain a European catchment in order to provide a lower boundary parameter for the values yielded by the three Abstraction Safety Index methodologies.

24 ABSTRACTION SAFETY INDEX CALCULATIONS USING THE FIRST METHODOLOGY

24.1 Introduction

In this Chapter the first of the three Abstraction Safety Index methodologies is presented in some detail.

24.2 Formulae Used to Calculate the Abstraction Safety Index

The following two sub-sections describe how unweighted, and weighted, values respectively for the Abstraction Safety Index are calculated.

24.2.1 Calculation of the Unweighted Abstraction Safety Index

The first stage of the calculation of the Abstraction Safety Index provides an unweighted value for the index, and the formula for this stage can be expressed as follows:

$$ASI_{UW} = \frac{(\text{no. of sources} * \text{max calculated risk}) - \text{sum of individual risks}}{\text{no. of sources} * \text{maximum calculated risk possible}} * 100\%$$

where ASI_{UW} = unweighted Abstraction Safety Index

Equation 1: Calculation of the unweighted Abstraction Safety Index

The number of sources of hazards in the template I have constructed is 78, whilst the maximum calculated risk is 5 (the maximum likelihood) multiplied by 5 (the maximum severity), i.e. 25. The above formula can be simplified and expressed thus:

$$ASI_{UW} = \frac{1950 - \text{sum of individual risks}}{1950} * 100\%$$

where ASI_{UW} = unweighted Abstraction Safety Index

Equation 2: Simplified calculation of the unweighted Abstraction Safety Index

It therefore follows that, as the cumulative individual risks increases, the unweighted Abstraction Safety Index decreases. Therefore, a catchment with a higher index than another catchment obviously contains fewer risks and would be a better choice for public water supply purposes.

When this calculation is examined closely, it becomes apparent that you can never have an index of 100% for a catchment. This is because it is not possible to apply values of zero for likelihood and severity using the risk assessment matrix I have adopted (see Section 21.5.1), and so the lowest risk that may be calculated for any source of hazard is 1 x 1 i.e. 1. Consequently, the highest value that may be obtained is (1950 – 78)/1950, or 96.0%.

24.2.2 Calculation of the Weighted Abstraction Safety Index

Each of the five Importance Factors has three levels, and these are described in some detail in Section 21.5.2. Each of these levels has been assigned a value, and the value is dependent on which numerical range has been used; further information on the number and magnitude of the ranges used is given in Section 24.3.

In order to calculate the weighted Abstraction Safety Index, the value for the level of each of the five Importance Factors is multiplied by the magnitude of risk determined from the risk assessment for each individual source of hazard. The following five identical formulae are therefore used to calculate the contribution of risk associated with each of the five Importance Factors for each individual source of hazard:

$$RC_{OA} = IF_{OA} * \text{magnitude of risk}$$
$$RC_{AI} = IF_{AI} * \text{magnitude of risk}$$
$$RC_{LF} = IF_{LF} * \text{magnitude of risk}$$
$$RC_{CP} = IF_{CP} * \text{magnitude of risk}$$
$$RC_{CE} = IF_{CE} * \text{magnitude of risk}$$

where
RC = risk component
IF = Importance Factor
OA = organisational ability
AI = available information
LF = legal framework
CP = codes of practice and other voluntary arrangements
CE = customer expectation

Equation 3: Calculation of the contribution of risk associated with each of the five Importance Factors

The sum of risk components for each individual source of hazard are subsequently summed, to give a weighted magnitude of risk for each individual source of hazard, according to the following formula:

$$WMR_{IND} = RC_{OA} + RC_{AI} + RC_{LF} + RC_{CP} + RC_{CE}$$

where WMR_{IND} = weighted magnitude of risk for each individual source of hazard

Equation 4: Calculation of the weighted magnitude of risk for each individual source of hazard

The next, and final, stage for the calculation of the weighted Abstraction Safety Index requires the following equations:

$$WMR_{MAX} = MR_{MAX} * (5 * IF_{MAX})$$
$$= (5 * 5) * (5 * IF_{MAX})$$

$$= 25 * (5 * IF_{MAX})$$

where WMR_{MAX} = maximum weighted magnitude of risk for each individual source of hazard

MR_{MAX} = maximum magnitude of risk for each individual source of hazard

IF_{MAX} = maximum Importance Factor value

Equation 5: Calculation of the maximum weighted magnitude of risk for an individual source of hazard

The maximum total of the weighted magnitude of risk for each individual source of hazard is expressed as follows:

$$TWMR_{MAX} = WMR_{MAX} * \text{no. of individual sources of hazard}$$
$$= WMR_{MAX} * 78$$

where $TWMR_{MAX}$ = maximum total of the weighted magnitude of risk for the entire catchment

Equation 6: Calculation of the maximum total of the weighted magnitude of risk for the entire catchment

The total of all the weighted magnitude of risk values for each individual source of hazard is expressed as follows:

$$WMR_{TOTAL} = \Sigma WMR_{IND}$$

where WMR_{IND} = weighted magnitude of risk for each individual source of hazard

Equation 7: Calculation of the total of all weighted magnitude of risk values for each individual source of hazard

The formula used to calculate the final value of the weighted Abstraction Safety Index is as follows:

$$ASI_W = \frac{TWMR_{MAX} - WMR_{TOTAL}}{TWMR_{MAX}} * ASI_{UW}$$

where ASI_W = weighted Abstraction Safety Index

Equation 8: Calculation of the weighted Abstraction Safety Index

24.3 Ranges of Importance Factors

In total 16 different ranges of Importance Factors were used, in order to determine the effects different ranges would have on the values for the weighted Abstraction Safety Index. Investigating the effects of difference ranges of Importance Factors had the following objectives:

- To ensure that the weighted Abstraction Safety Index values remained within the boundary values of 96.0% and 0.0% i.e. the rule 0.0% < Abstraction Safety Index < 96.0% must be observed;
- To ensure application of the Importance Factors did not simply universally increase or decrease the weighted Abstraction Safety Index values; instead, the aim was to demonstrate, in an easily accessible manner, both the positive and negative impacts of the Importance Factors on the final values; and
- To accentuate the sometimes subtle impacts of significant qualitative processes, policies and institutional arrangements, on the weighted Abstraction Safety Index.

For each range, the median (or 'medium' level) Importance Factor was kept as 1. The original intention of this was so that if any of the Importance Factors neither had a beneficial or detrimental affect on the magnitude of risk associated with any particular individual source of hazard, the weighted magnitude of risk would be the same as the unweighted magnitude of risk. However, this approach was fundamentally flawed, as will be explored in Section 24.5.

Table 20 to Table 23 inclusive show the percentage variation from the median Importance Factor (i.e. 1) with differing upper and lower Importance Factors. In each Table, the lower Importance Factor is kept the same, whilst the upper Importance Factors are varied. The same information is also presented graphically in Figure 18 to Figure 21 inclusive.

IMPORTANCE FACTOR RANGE	PERCENTAGE VARIATION FROM THE MEDIAN IMPORTANCE FACTOR	
	Lower IF	Upper IF
0.05 to 2.0	5%	200%
0.05 to 5.0	5%	500%
0.05 to 10.0	5%	1,000%
0.05 to 20.0	5%	2,000%

Table 20: The percentage variation from the median Importance Factor (i.e. 1.0) with differing upper Importance Factors, whilst keeping the lower Importance Factor the same at 0.05 in each case

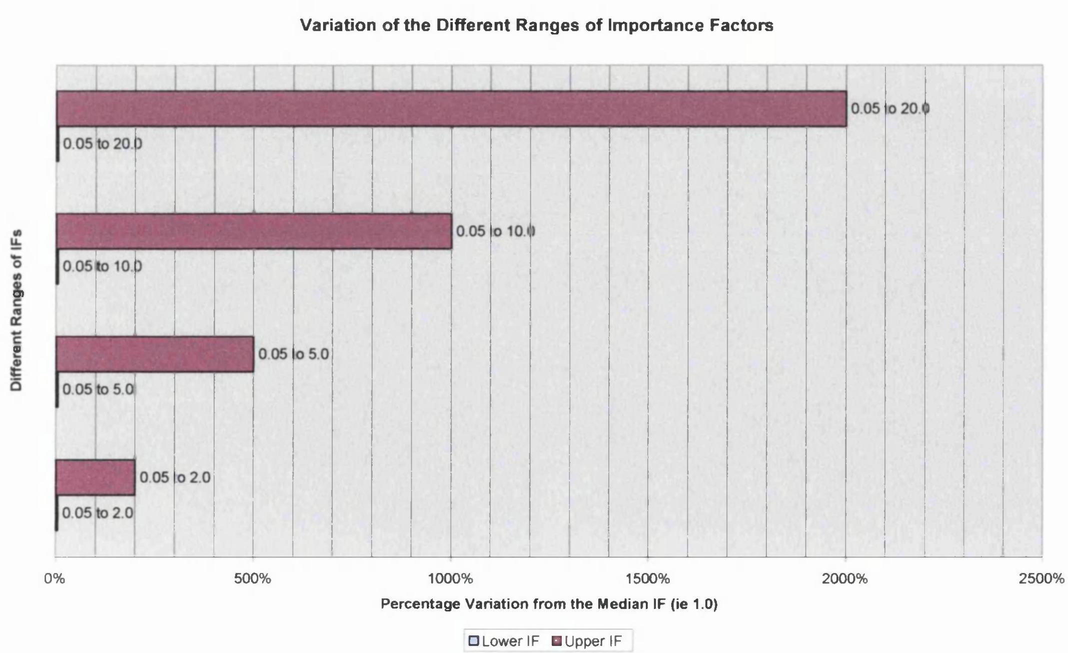


Figure 18: A graphical presentation of the data given in Table 20

Importance Factor Range	Percentage Variation From The Median Importance Factor	
	Lower IF	Upper IF
0.1 to 2.0	10%	200%
0.1 to 5.0	10%	500%
0.1 to 10.0	10%	1,000%
0.1 to 20.0	10%	2,000%

Table 21: The percentage variation from the median Importance Factor (i.e. 1.0) with differing upper Importance Factors, whilst keeping the lower Importance Factor the same at 0.1 in each case

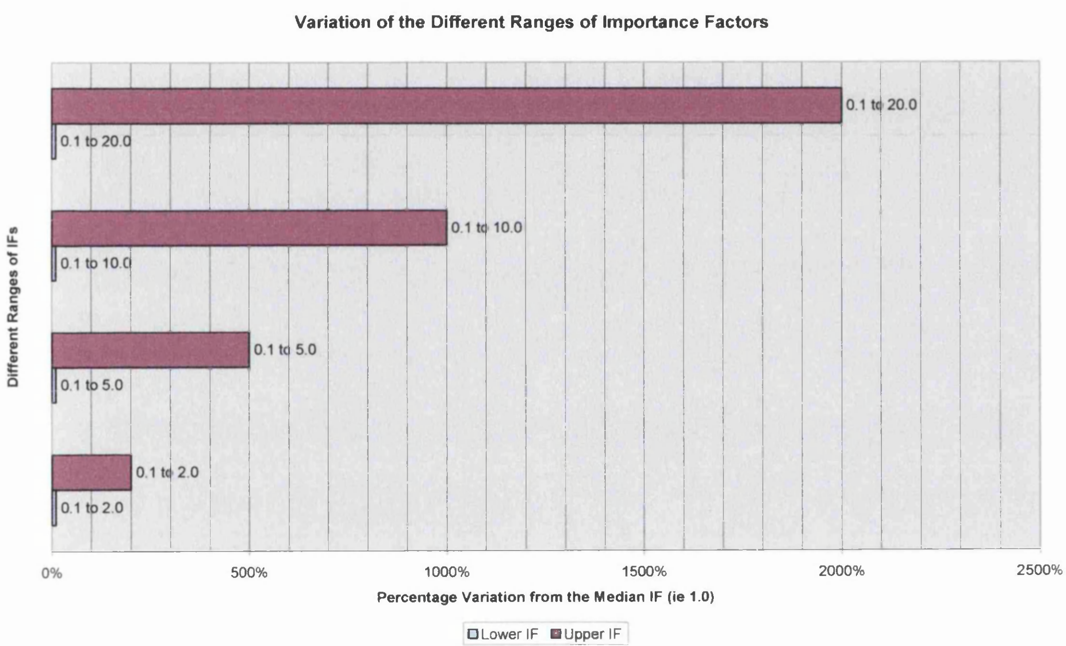


Figure 19: A graphical presentation of the data given in Table 21

Importance Factor Range	Percentage Variation From The Median Importance Factor	
	Lower IF	**Upper IF**
0.2 to 2.0	20%	200%
0.2 to 5.0	20%	500%
0.2 to 10.0	20%	1,000%
0.2 to 20.0	20%	2,000%

Table 22: The percentage variation from the median Importance Factor (i.e. 1.0) with differing upper Importance Factors, whilst keeping the lower Importance Factor the same at 0.2 in each case

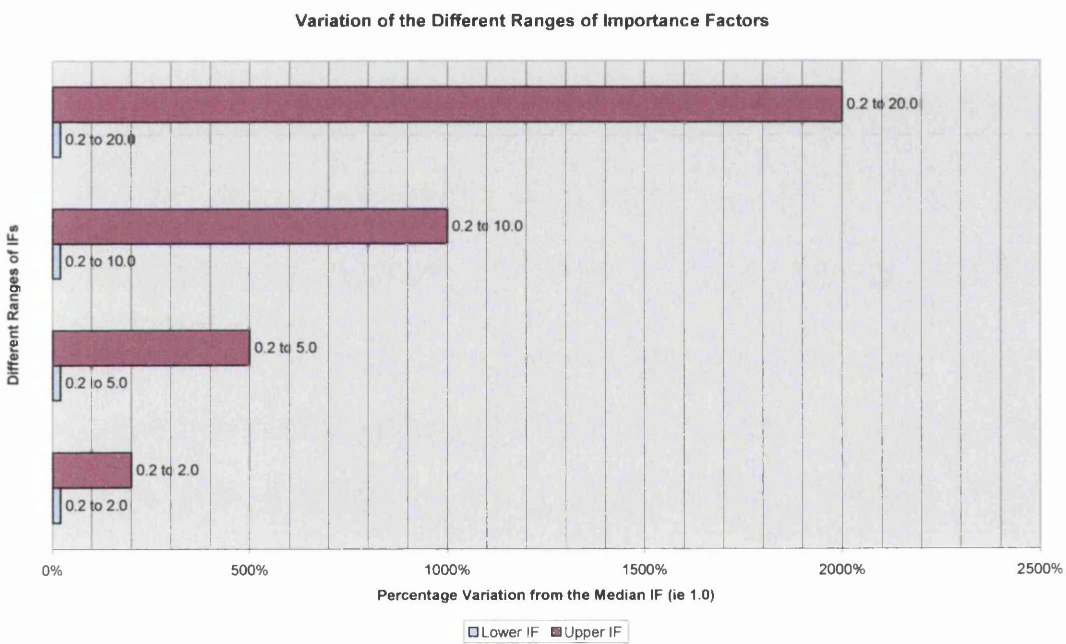


Figure 20: A graphical presentation of the data given in Table 22

IMPORTANCE FACTOR RANGE	PERCENTAGE VARIATION FROM THE MEDIAN IMPORTANCE FACTOR	
	Lower IF	Upper IF
0.5 to 2.0	5%	200%
0.5 to 5.0	5%	500%
0.5 to 10.0	5%	1,000%
0.5 to 20.0	5%	2,000%

Table 23: The percentage variation from the median Importance Factor (i.e. 1.0) with differing upper Importance Factors, whilst keeping the lower Importance Factor the same at 0.5 in each case

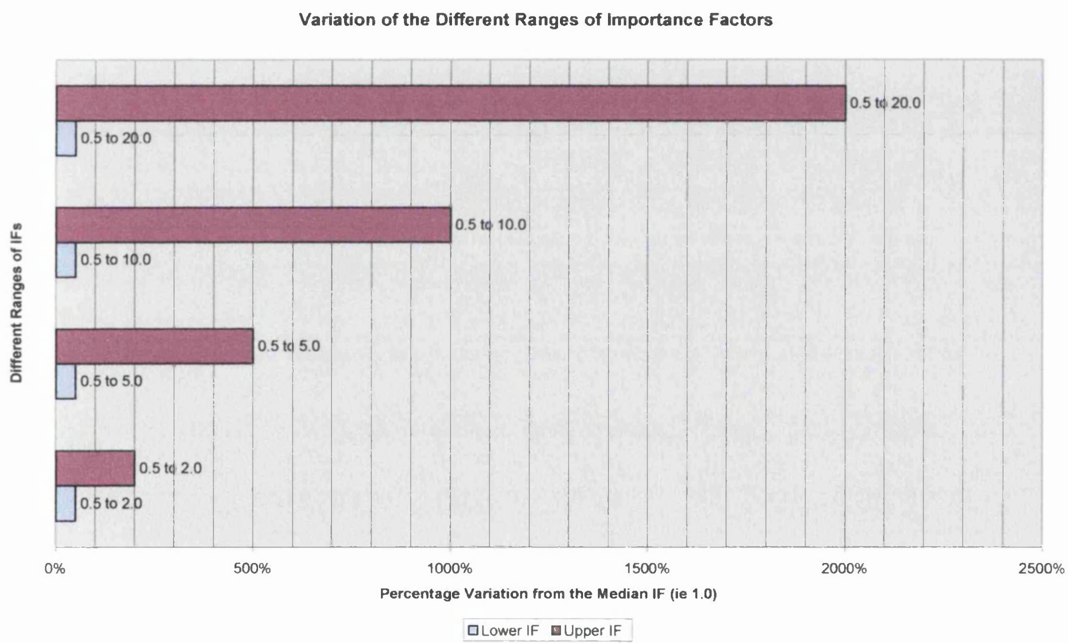


Figure 21: A graphical presentation of the data given in Table 23

24.4 Variation of Calculated ASIs with Different Importance Factor Range

All the spreadsheets containing the calculations used to derive the results presented in this Section are contained on a CD-ROM attached to the inside front cover of this thesis. Within these spreadsheets, conditional formatting has been used in an attempt to assist the interpretation of the data presented within them, and the colours (and associated numerical ranges) that have been adopted for the risk assessment and Importance Factors elements of the spreadsheets has already been described in Section 21.5.1 and Section 21.5.2.

Within both the third and fourth elements of the spreadsheets (entitled "Risk Component of Each Individual Importance Factor" and "Cumulative Risk" respectively), conditional formatting has again been used.

In the case of the third element of the spreadsheets, conditional formatting has been used to visually represent the impact of each Importance Factor on the individual risk component for each hazardous source (i.e. RC_{OA}, RC_{AI}, RC_{LF}, RC_{CP} and RC_{CE}, see Equation 3). As with conditional formatting used elsewhere in the spreadsheets, three colours have been used, according to the following criteria:

- Blue – represents 'low' risk component (i.e. up to one-third of the maximum possible value associated with the particular range of Importance Factors used);
- Orange – represents 'medium' risk component (i.e. between one-third and two-thirds of the maximum possible value associated with the particular range of Importance Factors used); and
- Red – represents 'high' risk component (i.e. in excess of two-thirds of the maximum possible value associated with the particular range of Importance Factors used).

In the case of the fourth element of the spreadsheets, conditional formatting has been used to visually represent the contribution of each weighted magnitude of risk for each individual source of hazard (i.e. WMR_{IND}, see Equation 4) to the overall value for the weighted Abstraction Safety Index. Again, three colours have been used, according to the following criteria:

- Blue – represents 'low' weighted magnitude of risk (i.e. up to one-third of the maximum possible value associated with the particular range of Importance Factors used);

- Orange – represents 'medium' weighted magnitude of risk (i.e. between one-third and two-thirds of the maximum possible value associated with the particular range of Importance Factors used); and
- Red – represents 'high' weighted magnitude of risk (i.e. in excess of two-thirds of the maximum possible value associated with the particular range of Importance Factors used).

The numerical boundaries used for both sets of conditional formatting obviously vary with differing Importance Factor ranges, so the boundaries for each range are given in Table 24.

LOWER IF	UPPER IF	RISK COMPONENT OF EACH IMPORTANCE FACTOR				CUMULATIVE RISK			
		Cell Min	Cell Max	Lower Limit (1/3 of Cell Max)	Upper Limit (2/3 of Cell Max)	Cell Min	Cell Max	Lower Limit (1/3 of Cell Max)	Upper Limit (2/3 of Cell Max)
0.05	2	0.05	50	16.6	33.3	0.25	250	83.3	166.6
	5	0.05	125	41.6	83.3	0.25	625	208.3	416.6
	10	0.05	250	83.3	166.6	0.25	1250	416.6	833.3
	20	0.05	500	166.6	333.3	0.25	2500	833.3	1666.6
0.1	2	0.1	50	16.6	33.3	0.5	250	83.3	166.6
	5	0.1	125	41.6	83.3	0.5	625	208.3	416.6
	10	0.1	250	83.3	166.6	0.5	1250	416.6	833.3
	20	0.1	500	166.6	333.3	0.5	2500	833.3	1666.6
0.2	2	0.2	50	16.6	33.3	1.0	250	83.3	166.6
	5	0.2	125	41.6	83.3	1.0	625	208.3	416.6
	10	0.2	250	83.3	166.6	1.0	1250	416.6	833.3
	20	0.2	500	166.6	333.3	1.0	2500	833.3	1666.6
0.5	2	0.5	50	16.6	33.3	2.5	250	83.3	166.6
	5	0.5	125	41.6	83.3	2.5	625	208.3	416.6
	10	0.5	250	83.3	166.6	2.5	1250	416.6	833.3
	20	0.5	500	166.6	333.3	2.5	2500	833.3	1666.6

Table 24: Conditional formatting limits used for the range of Importance Factors

The results obtained from using the 16 different ranges of Importance Factor are presented in Table 25 to Table 28 inclusive, whilst the same data are presented graphically in Figure 22 to Figure 37 inclusive.

CATCHMENT	NO IF APPLIED	IMPORTANCE FACTOR RANGE			
		0.05 TO 2.0 IF RANGE	0.05 TO 5.0 IF RANGE	0.05 TO 10.0 IF RANGE	0.05 TO 20.0 IF RANGE
A	75.9%	89.1%	92.6%	93.7%	94.3%
B	89.1%	93.9%	95.5%	96.0%	96.2%
C	74.3%	87.0%	90.5%	91.7%	92.3%
D	57.9%	73.8%	80.0%	81.9%	82.8%
E	83.4%	91.8%	94.0%	94.8%	95.1%
F	94.0%	96.8%	97.5%	97.8%	97.9%
G	91.7%	96.4%	97.4%	97.7%	97.9%

Table 25: Variation of ASI calculated for each catchment with differing upper Importance Factors, whilst keeping the lower Importance Factor the same at 0.05 in each case

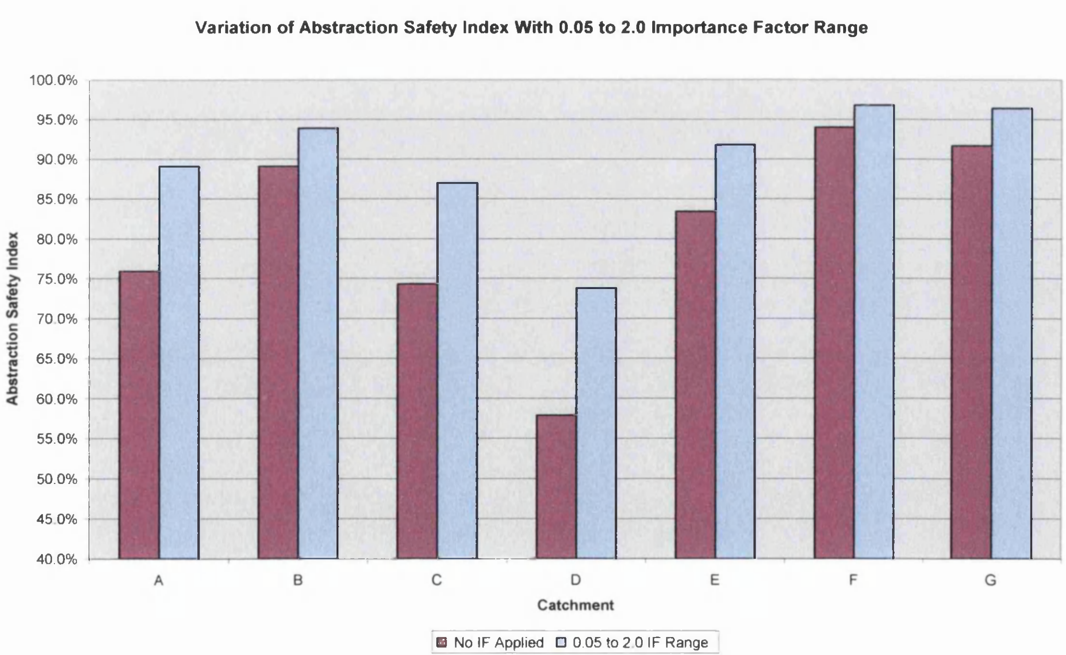


Figure 22: A graphical presentation of some of the data given in Table 25, showing the variation of ASI calculated for each catchment, with a lower Importance Factor of 0.05, and an upper Importance Factor of 2.0

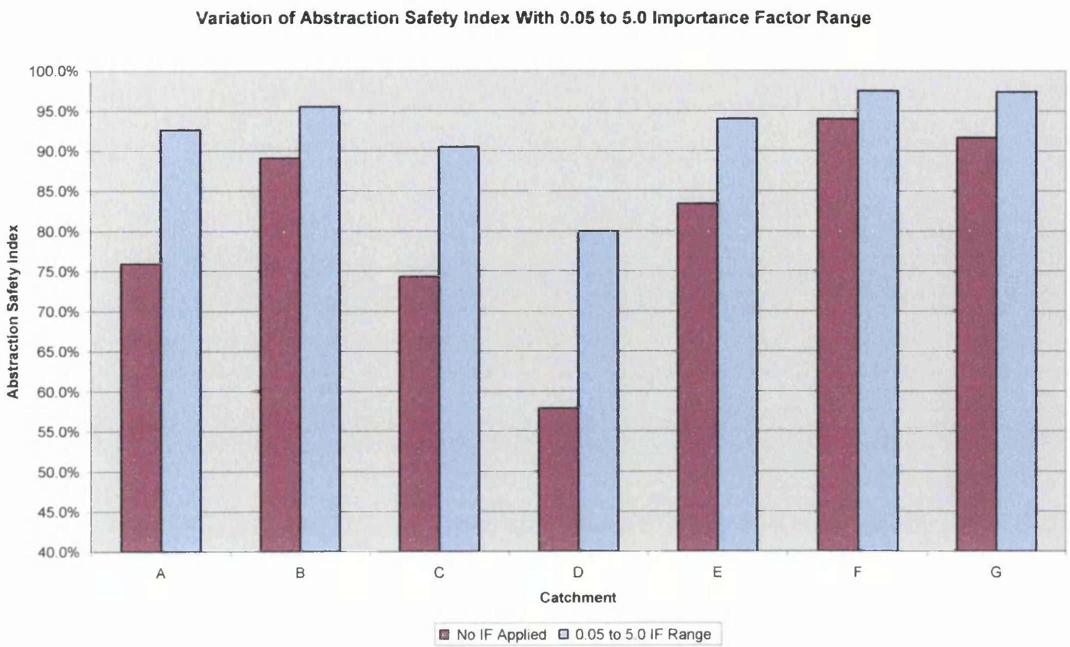


Figure 23: A graphical presentation of some of the data given in Table 25, showing the variation of ASI calculated for each catchment, with a lower Importance Factor of 0.05, and an upper Importance Factor of 5.0

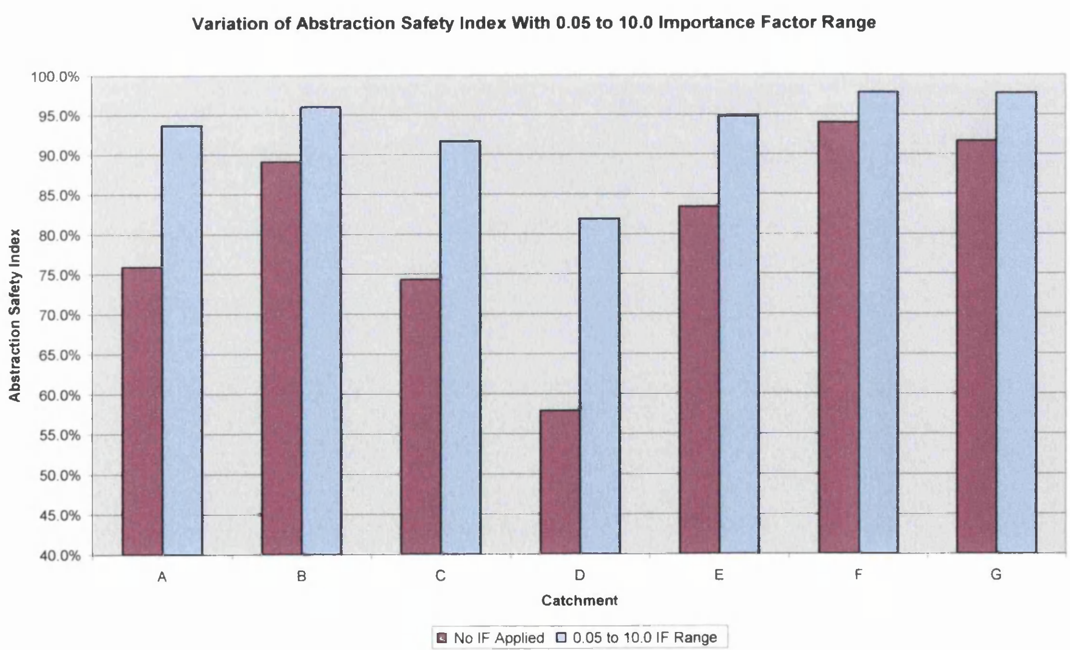


Figure 24: A graphical presentation of some of the data given in Table 25, showing the variation of ASI calculated for each catchment, with a lower Importance Factor of 0.05, and an upper Importance Factor of 10.0

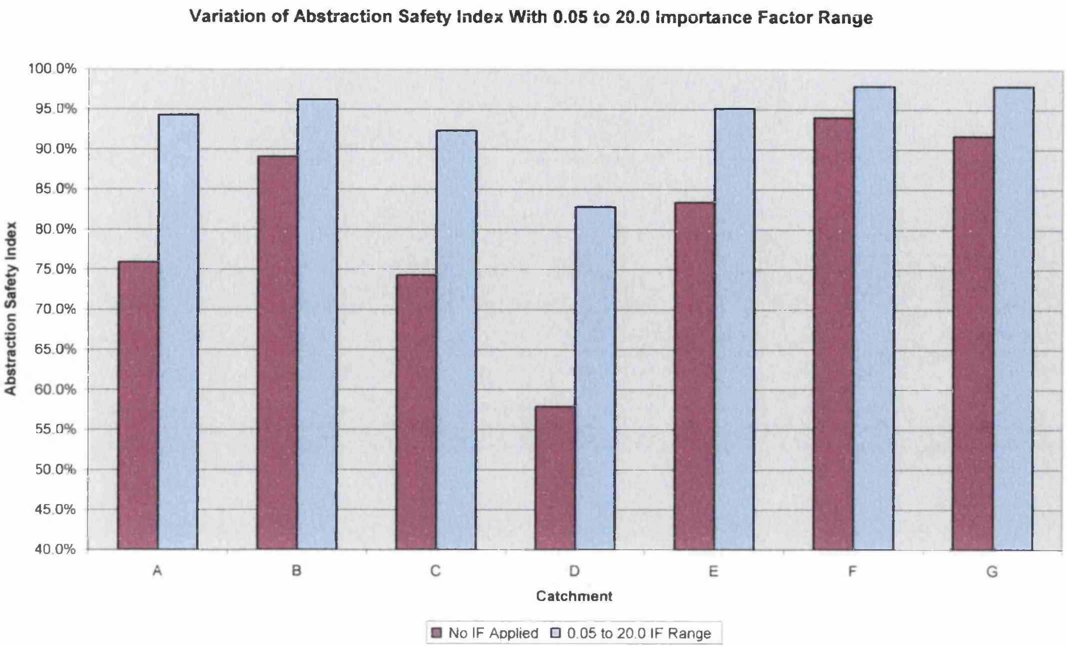


Figure 25: A graphical presentation of some of the data given in Table 25, showing the variation of ASI calculated for each catchment, with a lower Importance Factor of 0.05, and an upper Importance Factor of 20.0

CATCHMENT	NO IF APPLIED	IMPORTANCE FACTOR RANGE			
		0.1 TO 2.0 IF RANGE	0.1 TO 5.0 IF RANGE	0.1 TO 10.0 IF RANGE	0.1 TO 20.0 IF RANGE
A	75.9%	89.1%	92.5%	93.7%	94.3%
B	89.1%	93.9%	95.4%	96.0%	96.2%
C	74.3%	86.8%	90.5%	91.7%	92.3%
D	57.9%	74.2%	79.9%	81.9%	82.8%
E	83.4%	91.6%	94.0%	94.7%	95.1%
F	94.0%	96.9%	97.5%	97.8%	97.9%
G	91.7%	96.5%	97.4%	97.7%	97.9%

Table 26: Variation of ASI calculated for each catchment with differing upper Importance Factors, whilst keeping the lower Importance Factor the same at 0.1 in each case

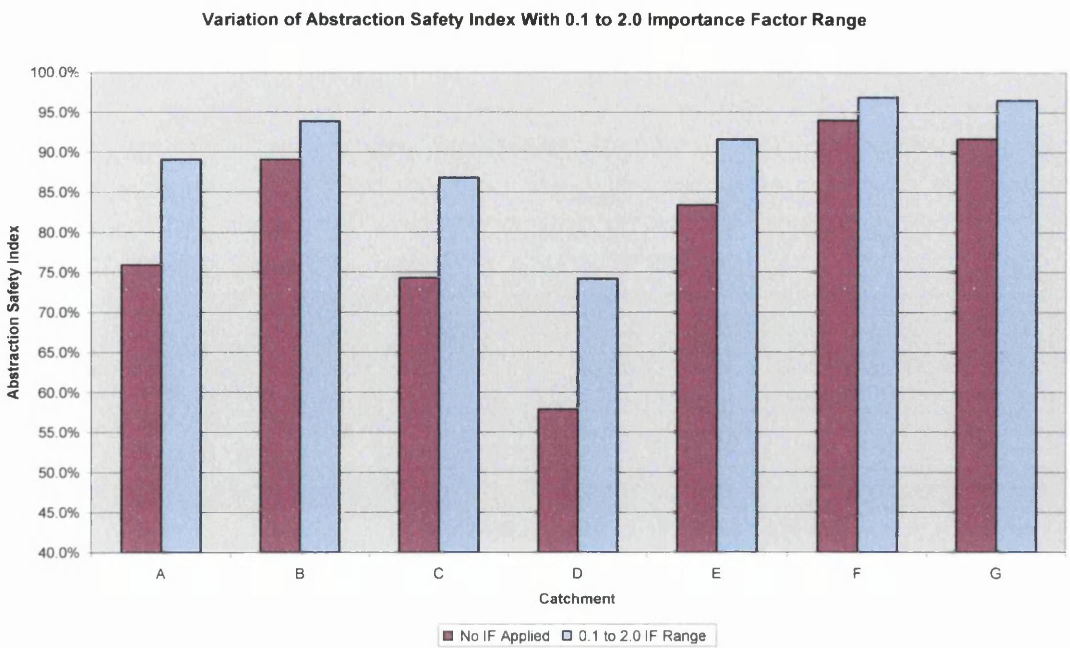


Figure 26: A graphical presentation of some of the data given in Table 26, showing the variation of ASI calculated for each catchment, with a lower Importance Factor of 0.1, and an upper Importance Factor of 2.0

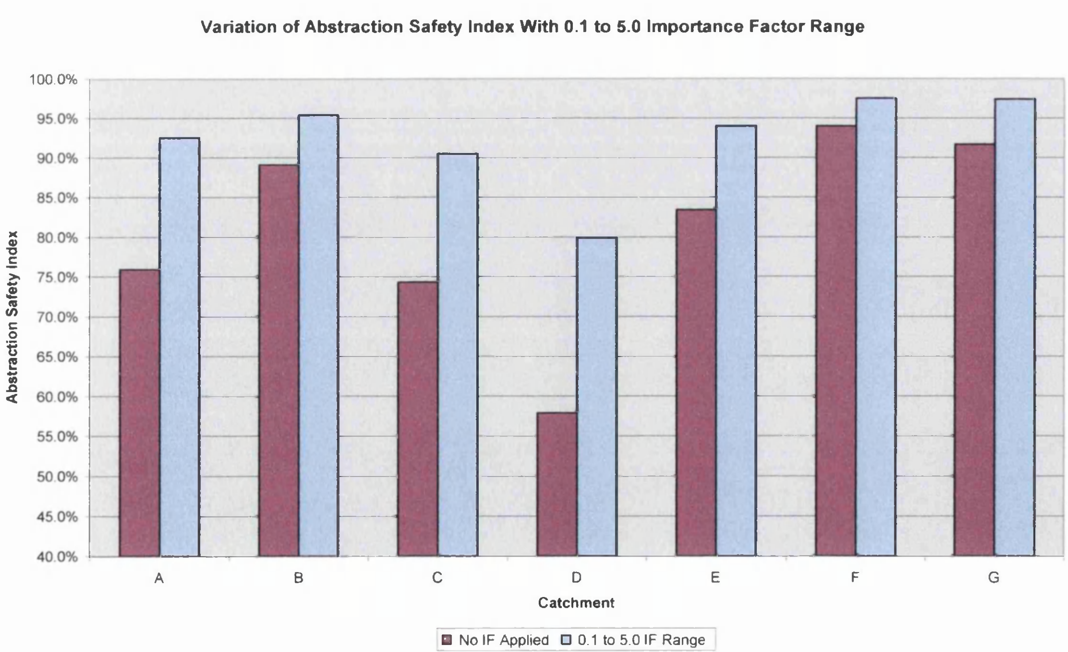


Figure 27: A graphical presentation of some of the data given in Table 26, showing the variation of ASI calculated for each catchment, with a lower Importance Factor of 0.1, and an upper Importance Factor of 5.0

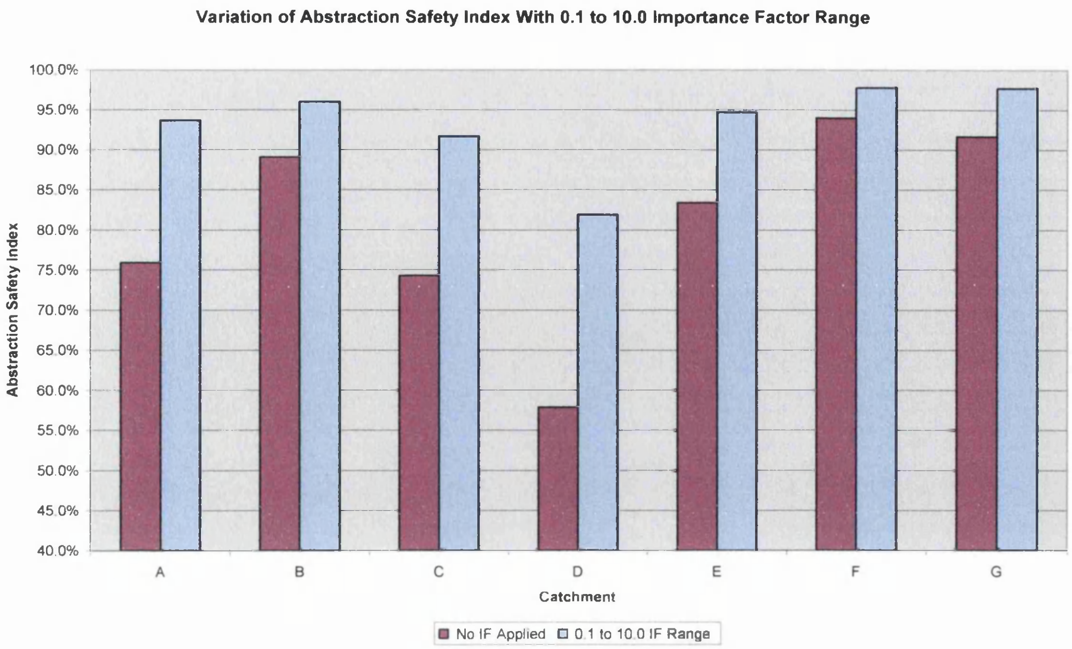


Figure 28: **A graphical presentation of some of the data given in Table 26, showing the variation of ASI calculated for each catchment, with a lower Importance Factor of 0.1, and an upper Importance Factor of 10.0**

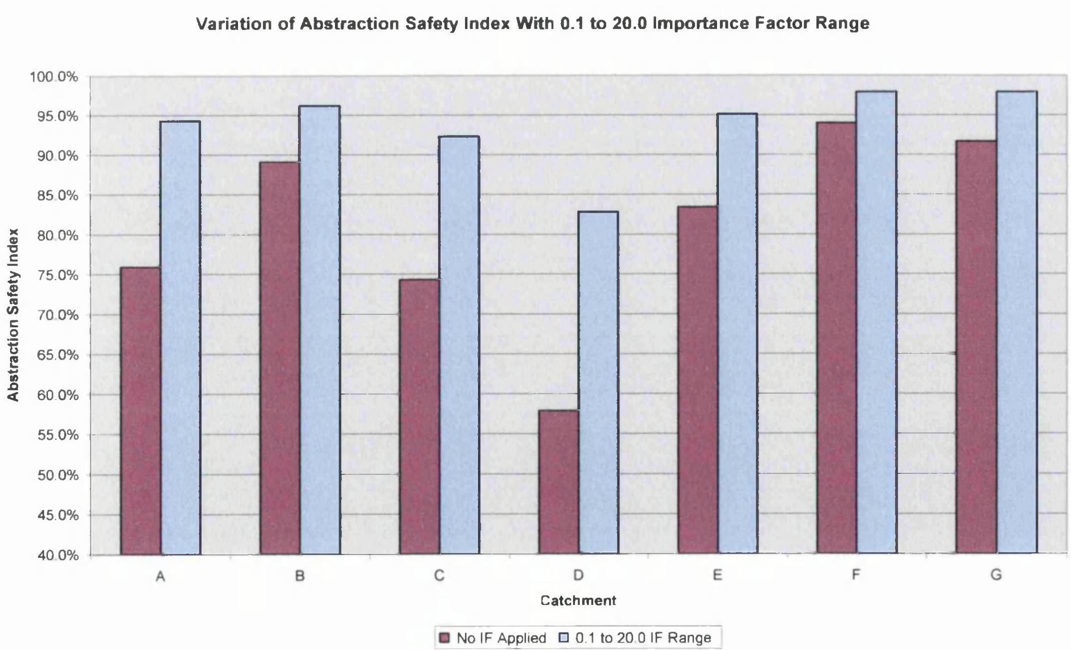


Figure 29: A graphical presentation of some of the data given in Table 26, showing the variation of ASI calculated for each catchment, with a lower Importance Factor of 0.1, and an upper Importance Factor of 20.0

CATCHMENT	NO IF APPLIED	IMPORTANCE FACTOR RANGE			
		0.2 TO 2.0 IF RANGE	0.2 TO 5.0 IF RANGE	0.2 TO 10.0 IF RANGE	0.2 TO 20.0 IF RANGE
A	75.9%	88.5%	92.4%	93.6%	94.2%
B	89.1%	93.7%	95.4%	95.9%	96.2%
C	74.3%	86.4%	90.3%	91.6%	92.3%
D	57.9%	73.9%	79.8%	81.8%	82.8%
E	83.4%	91.4%	93.9%	94.7%	95.1%
F	94.0%	96.6%	97.5%	97.7%	97.9%
G	91.7%	96.2%	97.3%	97.7%	97.9%

Table 27: Variation of ASI calculated for each catchment with differing upper Importance Factors, whilst keeping the lower Importance Factor the same at 0.2 in each case

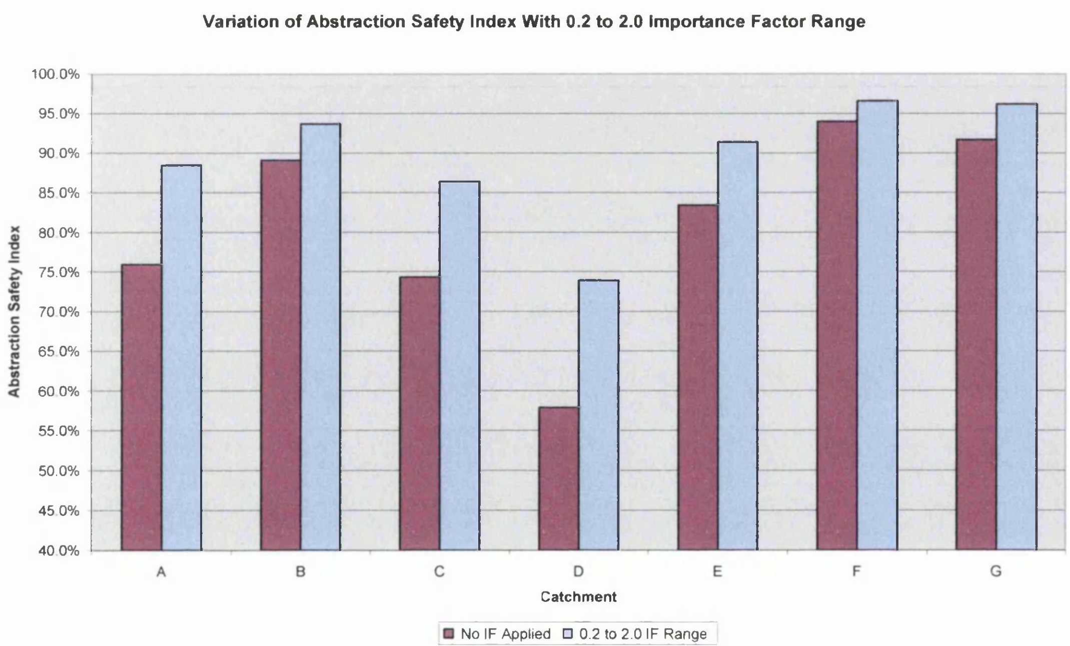


Figure 30: A graphical presentation of some of the data given in Table 27, showing the variation of ASI calculated for each catchment, with a lower Importance Factor of 0.2, and an upper Importance Factor of 2.0

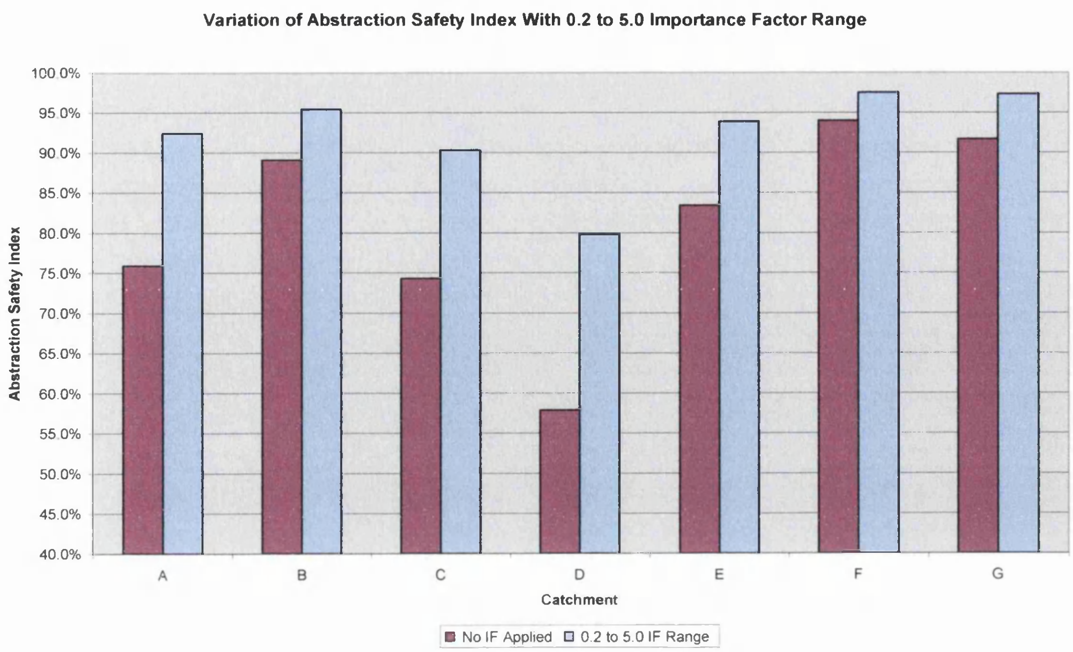


Figure 31: A graphical presentation of some of the data given in Table 27, showing the variation of ASI calculated for each catchment, with a lower Importance Factor of 0.2, and an upper Importance Factor of 5.0

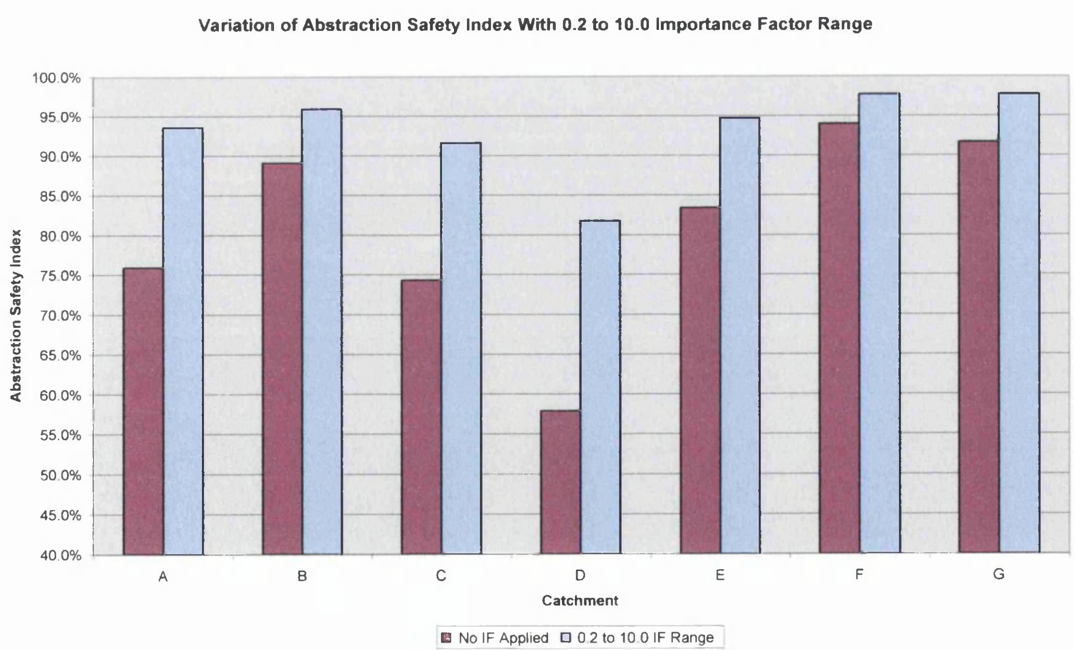


Figure 32: A graphical presentation of some of the data given in Table 27, showing the variation of ASI calculated for each catchment, with a lower Importance Factor of 0.2, and an upper Importance Factor of 10.0

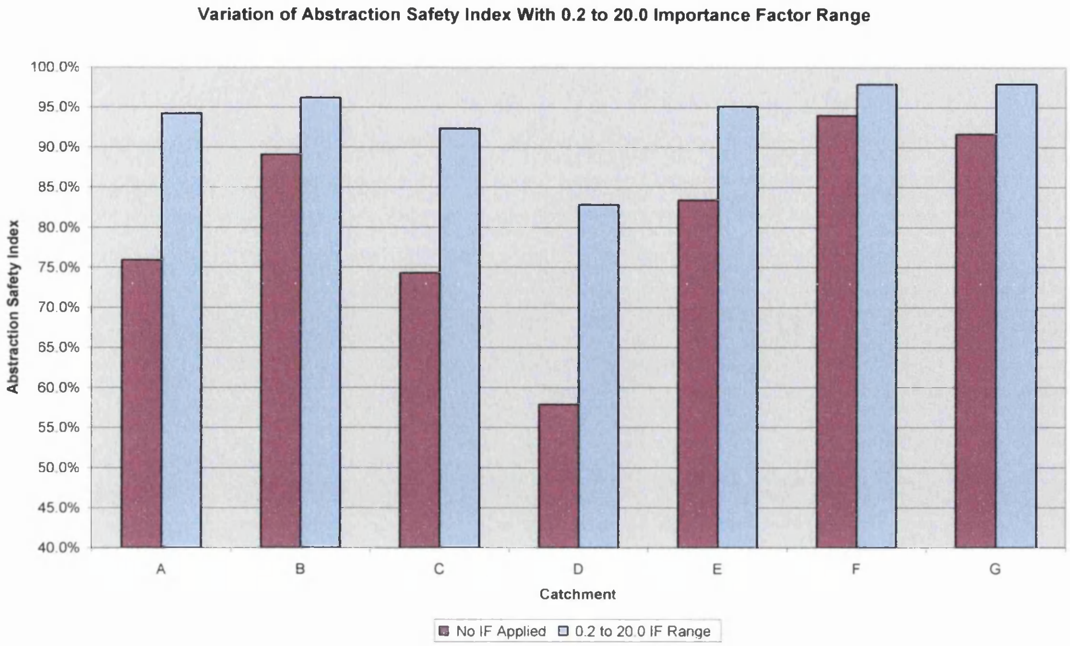


Figure 33: A graphical presentation of some of the data given in Table 27, showing the variation of ASI calculated for each catchment, with a lower Importance Factor of 0.2, and an upper Importance Factor of 20.0

CATCHMENT	NO IF APPLIED	IMPORTANCE FACTOR RANGE			
		0.5 TO 2.0 IF RANGE	0.5 TO 5.0 IF RANGE	0.5 TO 10.0 IF RANGE	0.5 TO 20.0 IF RANGE
A	75.9%	87.2%	91.9%	93.4%	94.1%
B	89.1%	93.3%	95.2%	96.0%	96.2%
C	74.3%	85.2%	89.9%	91.4%	92.2%
D	57.9%	73.2%	79.6%	81.7%	82.7%
E	83.4%	90.6%	93.6%	94.5%	95.0%
F	94.0%	96.4%	97.4%	97.7%	97.8%
G	91.7%	95.7%	97.1%	97.6%	97.8%

Table 28: Variation of ASI calculated for each catchment with differing upper Importance Factors, whilst keeping the lower Importance Factor the same at 0.5 in each case

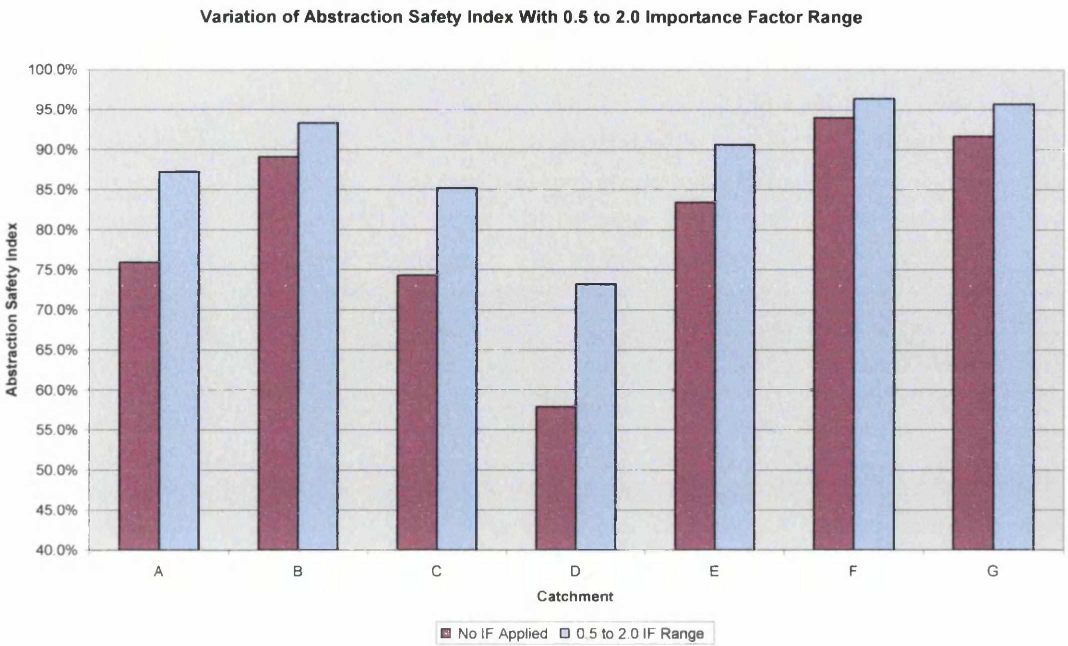


Figure 34: A graphical presentation of some of the data given in Table 28, showing the variation of ASI calculated for each catchment, with a lower Importance Factor of 0.5, and an upper Importance Factor of 2.0

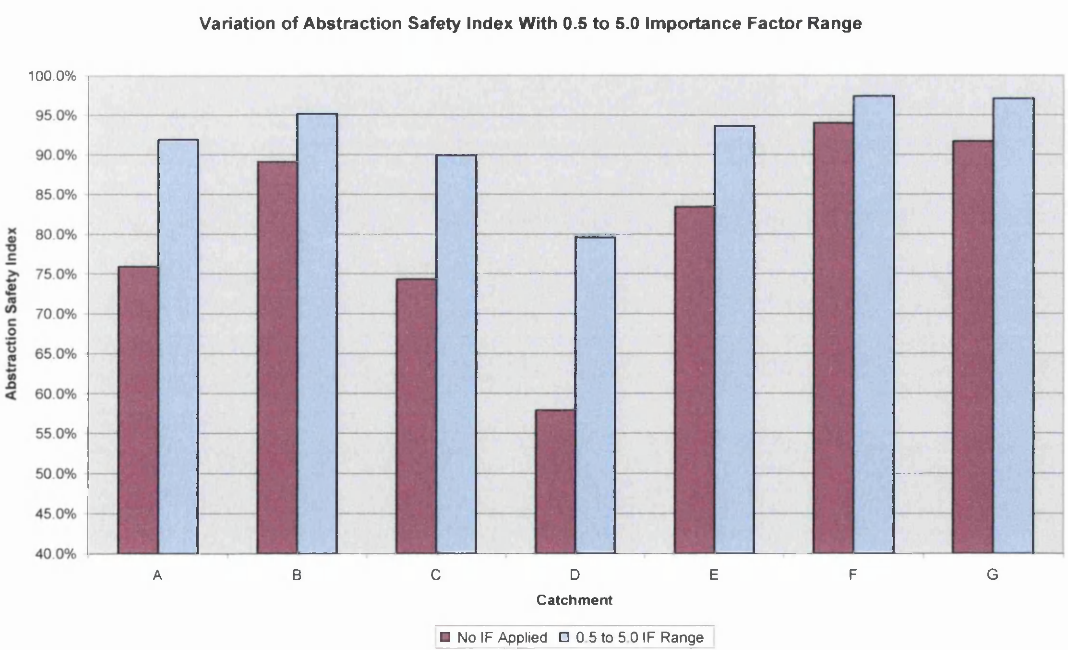


Figure 35: A graphical presentation of some of the data given in Table 28, showing the variation of ASI calculated for each catchment, with a lower Importance Factor of 0.5, and an upper Importance Factor of 5.0

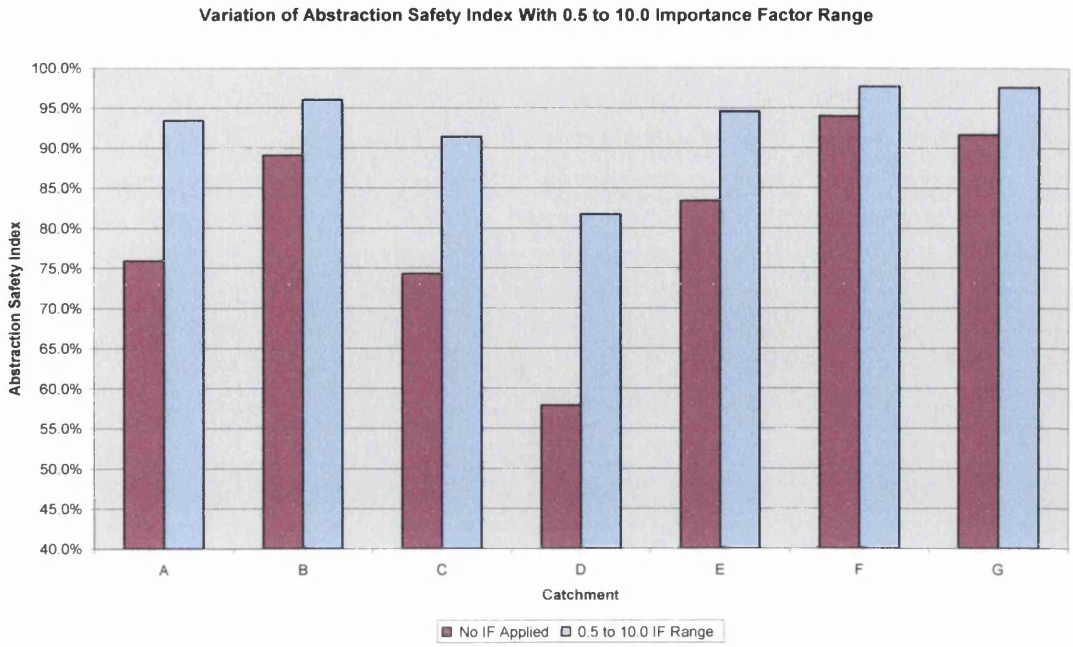


Figure 36: A graphical presentation of some of the data given in Table 28, showing the variation of ASI calculated for each catchment, with a lower Importance Factor of 0.5, and an upper Importance Factor of 10.0

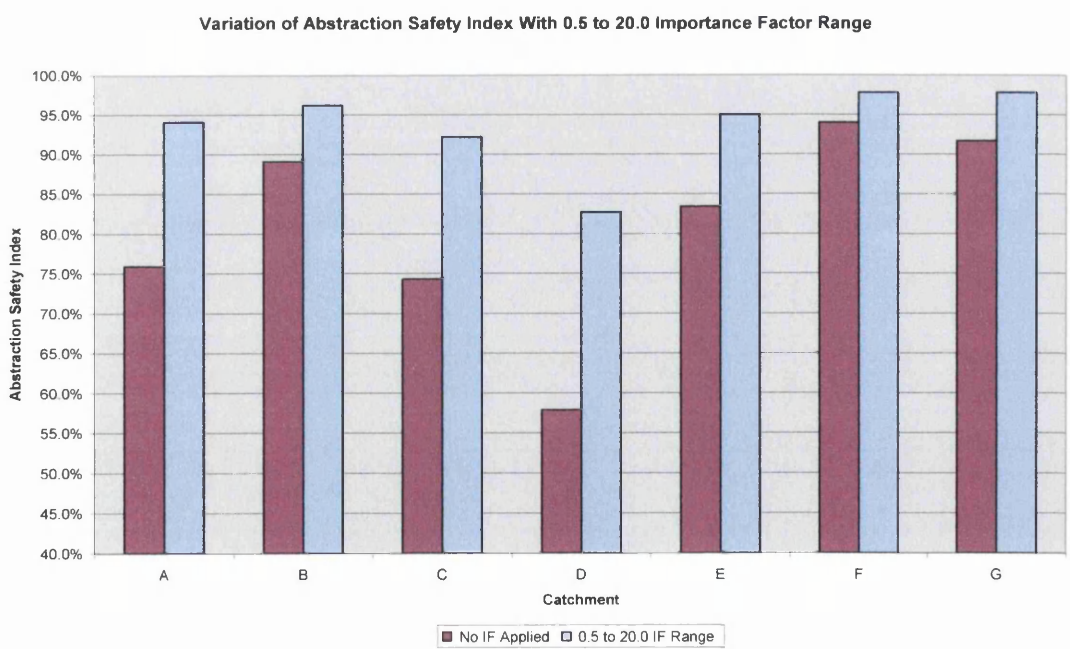


Figure 37: A graphical presentation of some of the data given in Table 28, showing the variation of ASI calculated for each catchment, with a lower Importance Factor of 0.5, and an upper Importance Factor of 20.0

In the following 16 Tables, the data presented in Table 25 to Table 28 inclusive are re-presented to show the percentage variation from the unweighted Abstraction Safety Index of the weighted Abstraction Safety Index for each range of Importance Factor values.

CATCHMENT	NO IF APPLIED	0.05 TO 2.0 IF RANGE	PERCENTAGE VARIATION	INCREASE OR DECREASE?
A	75.9%	89.1%	17.4%	**Increase**
B	89.1%	93.9%	5.5%	**Increase**
C	74.3%	87.0%	17.0%	**Increase**
D	57.9%	73.8%	27.5%	**Increase**
E	83.4%	91.8%	10.0%	**Increase**
F	94.0%	96.8%	3.0%	**Increase**
G	91.7%	96.4%	5.1%	**Increase**

Table 29: Percentage variation from the unweighted Abstraction Safety Index of the weighted Abstraction Safety Index with a lower Importance Factor of 0.05 and an upper Importance Factor of 2.0

CATCHMENT	NO IF APPLIED	0.05 TO 5.0 IF RANGE	PERCENTAGE VARIATION	INCREASE OR DECREASE?
A	75.9%	92.6%	22.0%	**Increase**
B	89.1%	95.5%	7.2%	**Increase**
C	74.3%	90.5%	21.8%	**Increase**
D	57.9%	80.0%	38.2%	**Increase**
E	83.4%	94.0%	12.7%	**Increase**
F	94.0%	97.5%	3.7%	**Increase**
G	91.7%	97.4%	6.2%	**Increase**

Table 30: Percentage variation from the unweighted Abstraction Safety Index of the weighted Abstraction Safety Index with a lower Importance Factor of 0.05 and an upper Importance Factor of 5.0

CATCHMENT	NO IF APPLIED	0.05 TO 10.0 IF RANGE	PERCENTAGE VARIATION	INCREASE OR DECREASE?
A	75.9%	93.7%	23.5%	Increase
B	89.1%	96.0%	7.8%	Increase
C	74.3%	91.7%	23.4%	Increase
D	57.9%	81.9%	41.4%	Increase
E	83.4%	94.8%	13.6%	Increase
F	94.0%	97.8%	4.0%	Increase
G	91.7%	97.7%	6.5%	Increase

Table 31: Percentage variation from the unweighted Abstraction Safety Index of the weighted Abstraction Safety Index with a lower Importance Factor of 0.05 and an upper Importance Factor of 10.0

CATCHMENT	NO IF APPLIED	0.05 TO 20.0 IF RANGE	PERCENTAGE VARIATION	INCREASE OR DECREASE?
A	75.9%	94.3%	24.3%	Increase
B	89.1%	96.2%	8.0%	Increase
C	74.3%	92.3%	24.2%	Increase
D	57.9%	82.8%	43.0%	Increase
E	83.4%	95.1%	14.0%	Increase
F	94.0%	97.9%	4.1%	Increase
G	91.7%	97.9%	6.7%	Increase

Table 32: Percentage variation from the unweighted Abstraction Safety Index of the weighted Abstraction Safety Index with a lower Importance Factor of 0.05 and an upper Importance Factor of 20.0

Catchment	No IF Applied	0.1 to 2.0 IF Range	Percentage Variation	Increase or Decrease?
A	75.9%	89.1%	17.4%	**Increase**
B	89.1%	93.9%	5.4%	**Increase**
C	74.3%	86.8%	16.8%	**Increase**
D	57.9%	74.2%	28.2%	**Increase**
E	83.4%	91.6%	9.8%	**Increase**
F	94.0%	96.9%	3.1%	**Increase**
G	91.7%	96.5%	5.2%	**Increase**

Table 33: Percentage variation from the unweighted Abstraction Safety Index of the weighted Abstraction Safety Index with a lower Importance Factor of 0.1 and an upper Importance Factor of 2.0

Catchment	No IF Applied	0.1 to 5.0 IF Range	Percentage Variation	Increase or Decrease?
A	75.9%	92.5%	21.9%	**Increase**
B	89.1%	95.4%	7.1%	**Increase**
C	74.3%	90.5%	21.7%	**Increase**
D	57.9%	79.9%	38.0%	**Increase**
E	83.4%	94.0%	12.6%	**Increase**
F	94.0%	97.5%	3.7%	**Increase**
G	91.7%	97.4%	6.1%	**Increase**

Table 34: Percentage variation from the unweighted Abstraction Safety Index of the weighted Abstraction Safety Index with a lower Importance Factor of 0.1 and an upper Importance Factor of 5.0

CATCHMENT	NO IF APPLIED	0.1 TO 10.0 IF RANGE	PERCENTAGE VARIATION	INCREASE OR DECREASE?
A	75.9%	93.7%	23.5%	**Increase**
B	89.1%	96.0%	7.7%	**Increase**
C	74.3%	91.7%	23.4%	**Increase**
D	57.9%	81.9%	41.4%	**Increase**
E	83.4%	94.7%	13.6%	**Increase**
F	94.0%	97.8%	4.0%	**Increase**
G	91.7%	97.7%	6.5%	**Increase**

Table 35: Percentage variation from the unweighted Abstraction Safety Index of the weighted Abstraction Safety Index with a lower Importance Factor of 0.1 and an upper Importance Factor of 10.0

CATCHMENT	NO IF APPLIED	0.1 TO 20.0 IF RANGE	PERCENTAGE VARIATION	INCREASE OR DECREASE?
A	75.9%	94.3%	24.2%	**Increase**
B	89.1%	96.2%	8.0%	**Increase**
C	74.3%	92.3%	24.2%	**Increase**
D	57.9%	82.8%	43.0%	**Increase**
E	83.4%	95.1%	14.0%	**Increase**
F	94.0%	97.9%	4.1%	**Increase**
G	91.7%	97.9%	6.7%	**Increase**

Table 36: Percentage variation from the unweighted Abstraction Safety Index of the weighted Abstraction Safety Index with a lower Importance Factor of 0.1 and an upper Importance Factor of 20.0

Catchment	No IF Applied	0.2 to 2.0 IF Range	Percentage Variation	Increase or Decrease?
A	75.9%	88.5%	16.6%	Increase
B	89.1%	93.7%	5.2%	Increase
C	74.3%	86.4%	16.3%	Increase
D	57.9%	73.9%	27.7%	Increase
E	83.4%	91.4%	9.5%	Increase
F	94.0%	96.6%	2.8%	Increase
G	91.7%	96.2%	4.8%	Increase

Table 37: Percentage variation from the unweighted Abstraction Safety Index of the weighted Abstraction Safety Index with a lower Importance Factor of 0.2 and an upper Importance Factor of 2.0

Catchment	No IF Applied	0.2 to 5.0 IF Range	Percentage Variation	Increase or Decrease?
A	75.9%	92.4%	21.7%	Increase
B	89.1%	95.4%	7.1%	Increase
C	74.3%	90.3%	21.5%	Increase
D	57.9%	79.8%	37.9%	Increase
E	83.4%	93.9%	12.5%	Increase
F	94.0%	97.5%	3.7%	Increase
G	91.7%	97.3%	6.1%	Increase

Table 38: Percentage variation from the unweighted Abstraction Safety Index of the weighted Abstraction Safety Index with a lower Importance Factor of 0.2 and an upper Importance Factor of 5.0

Catchment	No IF Applied	0.2 to 10.0 IF Range	Percentage Variation	Increase or Decrease?
A	75.9%	93.6%	23.4%	**Increase**
B	89.1%	95.9%	7.7%	**Increase**
C	74.3%	91.6%	23.3%	**Increase**
D	57.9%	81.8%	41.3%	**Increase**
E	83.4%	94.7%	13.5%	**Increase**
F	94.0%	97.7%	4.0%	**Increase**
G	91.7%	97.7%	6.5%	**Increase**

Table 39: Percentage variation from the unweighted Abstraction Safety Index of the weighted Abstraction Safety Index with a lower Importance Factor of 0.2 and an upper Importance Factor of 10.0

Catchment	No IF Applied	0.2 to 20.0 IF Range	Percentage Variation	Increase or Decrease?
A	75.9%	94.2%	24.2%	**Increase**
B	89.1%	96.2%	8.0%	**Increase**
C	74.3%	92.3%	24.2%	**Increase**
D	57.9%	82.8%	43.0%	**Increase**
E	83.4%	95.1%	14.0%	**Increase**
F	94.0%	97.9%	4.1%	**Increase**
G	91.7%	97.9%	6.8%	**Increase**

Table 40: Percentage variation from the unweighted Abstraction Safety Index of the weighted Abstraction Safety Index with a lower Importance Factor of 0.2 and an upper Importance Factor of 20.0

CATCHMENT	NO IF APPLIED	0.5 TO 2.0 IF RANGE	PERCENTAGE VARIATION	INCREASE OR DECREASE?
A	75.9%	87.2%	14.9%	Increase
B	89.1%	93.3%	4.8%	Increase
C	74.3%	85.2%	14.7%	Increase
D	57.9%	73.2%	26.4%	Increase
E	83.4%	90.6%	8.6%	Increase
F	94.0%	96.4%	2.5%	Increase
G	91.7%	95.7%	4.3%	Increase

Table 41: Percentage variation from the unweighted Abstraction Safety Index of the weighted Abstraction Safety Index with a lower Importance Factor of 0.5 and an upper Importance Factor of 2.0

CATCHMENT	NO IF APPLIED	0.5 TO 5.0 IF RANGE	PERCENTAGE VARIATION	INCREASE OR DECREASE?
A	75.9%	91.9%	21.1%	Increase
B	89.1%	95.2%	6.9%	Increase
C	74.3%	89.9%	20.9%	Increase
D	57.9%	79.6%	37.4%	Increase
E	83.4%	93.6%	12.1%	Increase
F	94.0%	97.4%	3.6%	Increase
G	91.7%	97.1%	5.9%	Increase

Table 42: Percentage variation from the unweighted Abstraction Safety Index of the weighted Abstraction Safety Index with a lower Importance Factor of 0.5 and an upper Importance Factor of 5.0

CATCHMENT	NO IF APPLIED	0.5 TO 10.0 IF RANGE	PERCENTAGE VARIATION	INCREASE OR DECREASE?
A	75.9%	93.4%	23.0%	**Increase**
B	89.1%	96.0%	7.7%	**Increase**
C	74.3%	91.4%	23.0%	**Increase**
D	57.9%	81.7%	41.1%	**Increase**
E	83.4%	94.5%	13.3%	**Increase**
F	94.0%	97.7%	3.9%	**Increase**
G	91.7%	97.6%	6.4%	**Increase**

Table 43: Percentage variation from the unweighted Abstraction Safety Index of the weighted Abstraction Safety Index with a lower Importance Factor of 0.5 and an upper Importance Factor of 10.0

CATCHMENT	NO IF APPLIED	0.5 TO 20.0 IF RANGE	PERCENTAGE VARIATION	INCREASE OR DECREASE?
A	75.9%	94.1%	24.0%	**Increase**
B	89.1%	96.2%	8.0%	**Increase**
C	74.3%	92.2%	24.0%	**Increase**
D	57.9%	82.7%	42.9%	**Increase**
E	83.4%	95.0%	13.9%	**Increase**
F	94.0%	97.8%	4.1%	**Increase**
G	91.7%	97.8%	6.6%	**Increase**

Table 44: Percentage variation from the unweighted Abstraction Safety Index of the weighted Abstraction Safety Index with a lower Importance Factor of 0.5 and an upper Importance Factor of 20.0

24.5 Discussion

After the extensive reviews I had undertaken of regulatory, statutory, management and institutional frameworks (the results of which have been presented in this thesis), I was of the opinion that, in some cases, these frameworks interacted in a positive manner in order to reinforce the protection of catchments, whilst in other cases, protection of the environment was actually being hindered (perhaps because of poor communication between the numerous stakeholders interested in catchment management, coupled with a lack of information). I was therefore expecting the weighted Abstraction Safety Index value to vary from the unweighted values, sometimes quite significantly, and this was borne out in the results obtained using this first methodology.

However, what I was not expecting was that all weighted values would be greater than the respective unweighted values (as demonstrated in Table 29 to Table 44 inclusive); because I was convinced that the methodology should give rise to both increased and reduced Abstraction Safety Index values (compared to the respective unweighted values) once the Importance Factors had been applied, I spent quite some time critically reviewing it, until I realised I had not obtained the results I had anticipated because there was a fundamental flaw in the values assigned to the Importance Factor ranges.

I thought that adopting a figure of 1 for the 'medium' level of Importance Factor was appropriate, and then experimented with values of 'low' and 'high' Importance Factors that were less than and greater than the ''medium' level respectively. However, because all three values in each of the 16 ranges of Importance Factor utilised were positive, in combination they had the effect of simply increasing the overall value of the weighted Abstraction Safety Index, with respect to the unweighted value. Consequently, none of the ranges produced results that complied with the second of the objectives stated in Section 24.3.

Upon reflection, it therefore became obvious that the 'medium' level should be anchored at zero, instead of 1, and that values for 'low' Importance Factors should be negative, whilst values for 'high' Importance Factors should remain positive. With this revised approach in mind, the methodology was revised, and this second methodology is discussed in greater depth in the next Chapter.

25 ABSTRACTION SAFETY INDEX CALCULATIONS USING THE SECOND METHODOLOGY

25.1 Introduction

Following the fundamental revision in the approach taken to assigning values to each of the 16 Importance Factor ranges, the first Abstraction Safety Index methodology was revised, and the second methodology that is presented in this Chapter was constructed.

25.2 Formulae Used to Calculate the Abstraction Safety Index

The following two sub-sections describe how the unweighted, and the weighted, Abstraction Safety Index respectively are calculated.

25.2.1 Calculation of the Unweighted Abstraction Safety Index

The formula used to calculate the unweighted index is identical to the one used for the first methodology, and is described in detail in Section 24.2.1.

25.2.2 Calculation of the Weighted Abstraction Safety Index

As with the first methodology, each of the five Importance Factors has three levels, and these are described in some detail in Section 21.5.2. Each of these levels has been assigned a value, and the value is dependent on which numerical range has been used; further information on the number and magnitude of the ranges used is given in Section 25.3.

The formulae used to calculate the unweighted index is identical to the ones used for the first methodology, and is described in detail in Section 24.2.2.

25.3 Ranges of Importance Factors

As with the first methodology, a total of 16 different ranges of Importance Factors were used for this second methodology, in order to determine the effects different ranges would have on the values for the weighted Abstraction Safety Index; for each range, the median Importance Factor was kept as zero, for the reasons described in Section 24.5. However, the objectives for the investigation of the effects of different ranges of Importance Factors for this second methodology were the same as for the first one (see Section 24.3).

Table 45 to Table 48 inclusive show the variation from the median Importance Factor (i.e. 0.0) with differing upper and lower Importance Factors. In each Table, the lower Importance Factor is kept the same, whilst the upper Importance Factors are varied. The same information is also presented graphically in Figure 38 to Figure 41 inclusive.

Importance Factor Range	**Variation From The Median Importance Factor**	
	Lower IF	**Upper IF**
-2.0 to 2.0	-2	2
-2.0 to 5.0	-2	5
-2.0 to 10.0	-2	10
-2.0 to 20.0	-2	20

Table 45: The variation from the median Importance Factor (i.e. 0.0) with differing upper Importance Factors, whilst keeping the lower Importance Factor the same at 0.05 in each case

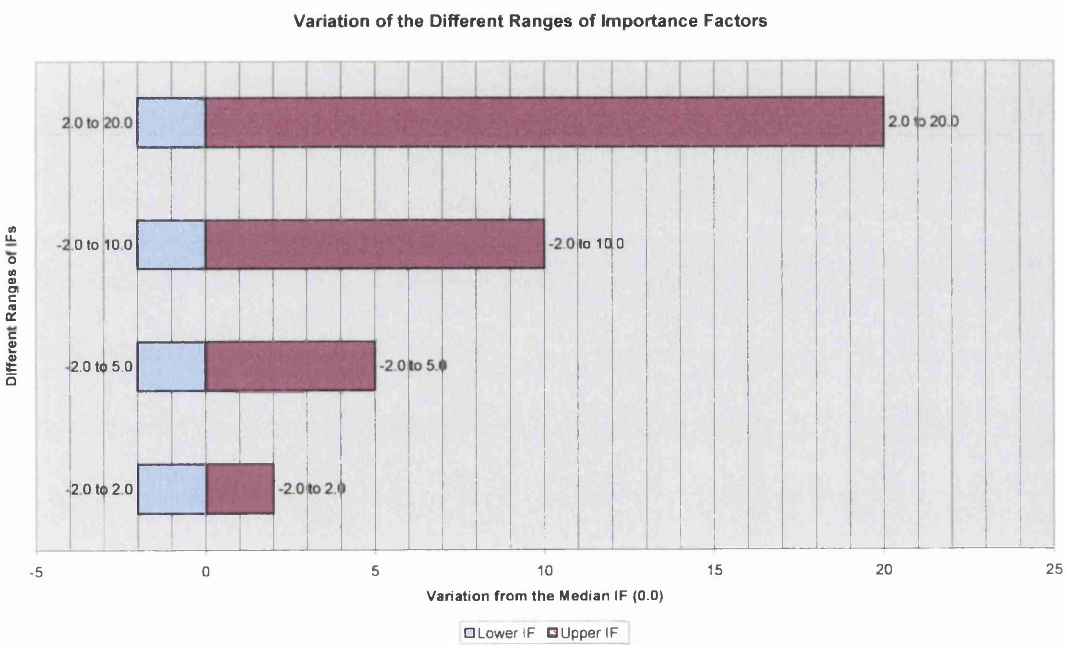


Figure 38: A graphical presentation of the data given in Table 45

Importance Factor Range	Variation From The Median Importance Factor	
	Lower IF	Upper IF
-5.0 to 2.0	-5	2
-5.0 to 5.0	-5	5
-5.0 to 10.0	-5	10
-5.0 to 20.0	-5	20

Table 46: The variation from the median Importance Factor (i.e. 0.0) with differing upper Importance Factors, whilst keeping the lower Importance Factor the same at 0.1 in each case

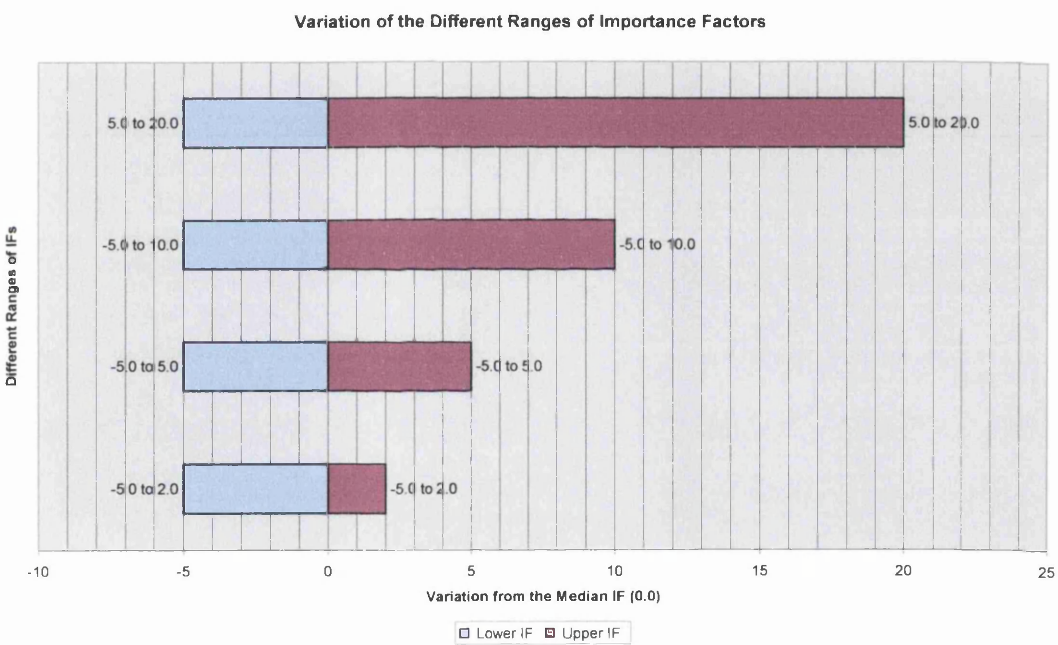


Figure 39: A graphical presentation of the data given in Table 46

IMPORTANCE FACTOR RANGE	VARIATION FROM THE MEDIAN IMPORTANCE FACTOR	
	Lower IF	**Upper IF**
-10.0 to 2.0	-10	2
-10.0 to 5.0	-10	5
-10.0 to 10.0	-10	10
-10.0 to 20.0	-10	20

Table 47: The variation from the median Importance Factor (i.e. 0.0) with differing upper Importance Factors, whilst keeping the lower Importance Factor the same at 0.2 in each case

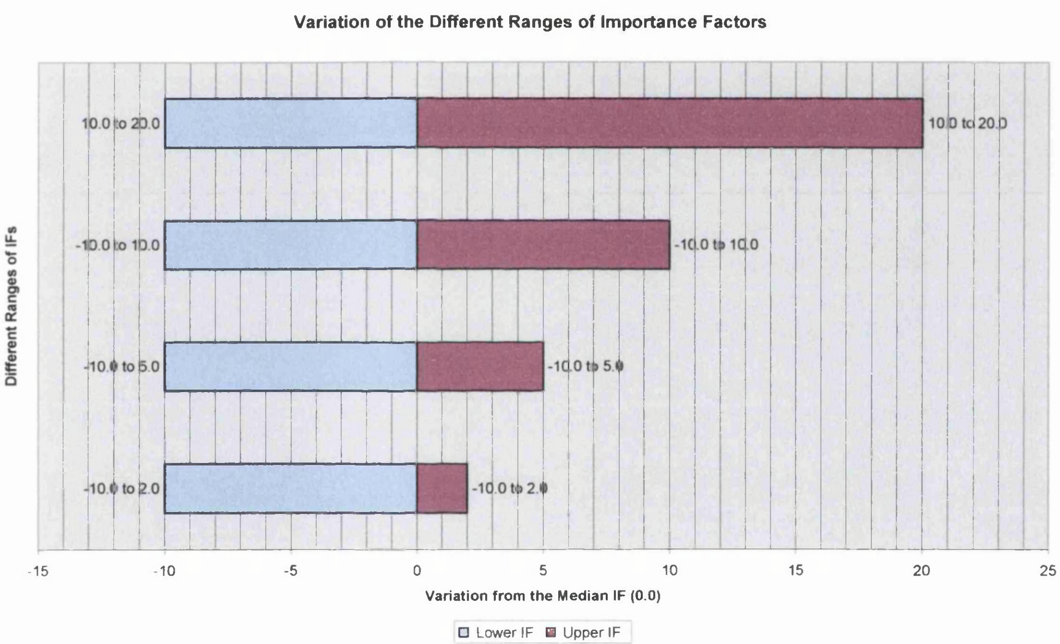


Figure 40: A graphical presentation of the data given in Table 47

IMPORTANCE FACTOR RANGE	VARIATION FROM THE MEDIAN IMPORTANCE FACTOR	
	Lower IF	Upper IF
-20.0 to 2.0	-20	2
-20.0 to 5.0	-20	5
-20.0 to 10.0	-20	10
-20.0 to 20.0	-20	20

Table 48: The variation from the median Importance Factor (i.e. 0.0) with differing upper Importance Factors, whilst keeping the lower Importance Factor the same at 0.5 in each case

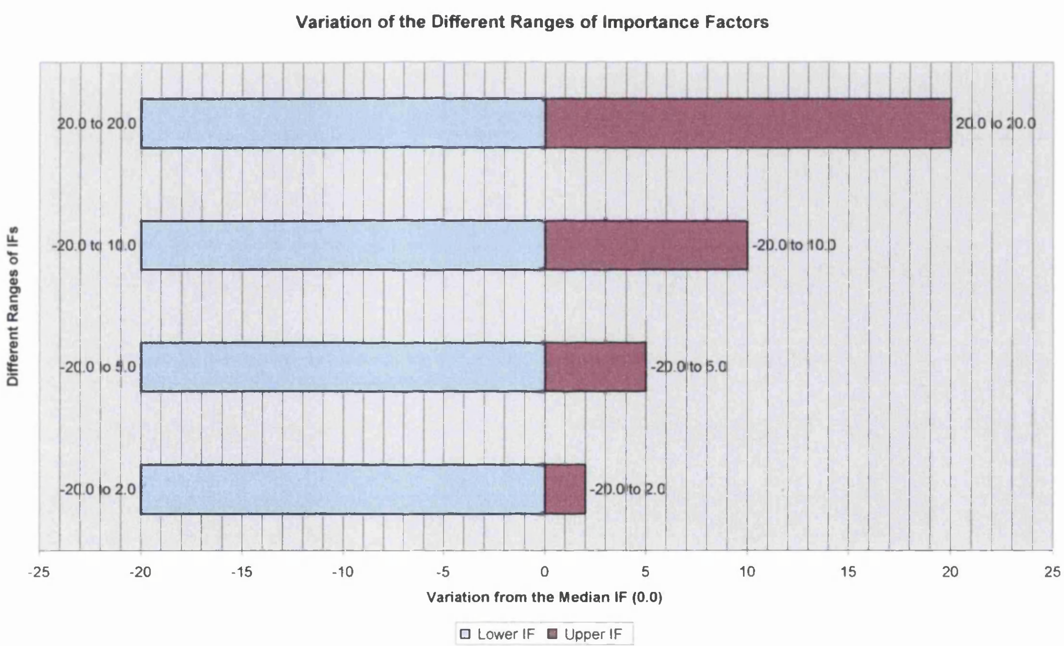


Figure 41: A graphical presentation of the data given in Table 48

25.4 Variation of Calculated ASIs with Different Importance Factor Ranges

All the spreadsheets containing the calculations used to derive the results presented in this Section are contained on a CD-ROM attached to the inside front cover of this thesis. Within these spreadsheets, conditional formatting has been used, the basis of which is exactly the same as that used in the first methodology (see Section 24.4).

The numerical boundaries used for both sets of conditional formatting obviously vary with differing Importance Factor ranges, so the boundaries for each range are given in Table 49.

LOWER IF	UPPER IF	RISK COMPONENT OF EACH IMPORTANCE FACTOR				CUMULATIVE RISK			
		Cell Min	Cell Max	Lower Limit (1/3 of Cell Max)	Upper Limit (2/3 of Cell Max)	Cell Min	Cell Max	Lower Limit (1/3 of Cell Max)	Upper Limit (2/3 of Cell Max)
-2.0	2	-50	50	-16.6	16.6	-250	250	-83.3	83.3
	5	-50	125	8.3	66.6	-250	625	41.6	333.3
	10	-50	250	50.0	150.0	-250	1250	250.0	750.0
	20	-50	500	133.3	316.6	-250	2500	666.6	1583.3
-5.0	2	-125	50	-66.6	-8.3	-625	250	-333.3	-41.6
	5	-125	125	-41.6	41.6	-625	625	-208.3	208.3
	10	-125	250	0.0	125.0	-625	1250	0.0	625.0
	20	-125	500	83.3	291.6	-625	2500	416.6	1458.3
-10.0	2	-250	50	-150.0	-50.0	-1250	250	-750.0	-250.0
	5	-250	125	-125.0	0.0	-1250	625	-625.0	0.0
	10	-250	250	-83.3	83.3	-1250	1250	-416.6	416.6
	20	-250	500	0.0	250.0	-1250	2500	0.0	1250.0
-20.0	2	-500	50	-316.6	-133.3	-2500	250	-1583.3	-666.6
	5	-500	125	-291.6	-83.3	-2500	625	-1458.3	-416.6
	10	-500	250	-250.0	0.0	-2500	1250	-1250.0	0.0
	20	-500	500	-166.6	166.6	-2500	2500	-833.3	833.3

Table 49: Conditional formatting limits used for the range of Importance Factors

The results obtained from using the 16 different ranges of Importance Factor are presented in Table 50 to Table 53 inclusive, whilst the same data are presented graphically in Figure 42 to Figure 57 inclusive.

Catchment	No IF Applied	Importance Factor Range			
		-2.0 to 2.0 IF Range	-2.0 to 5.0 IF Range	-2.0 to 10.0 IF Range	-2.0 to 20.0 IF Range
A	75.9%	78.0%	75.2%	73.2%	72.6%
B	89.1%	88.1%	87.9%	86.4%	86.2%
C	74.3%	74.3%	72.7%	70.1%	69.6%
D	57.9%	49.9%	53.2%	48.0%	47.8%
E	83.4%	83.7%	82.4%	80.5%	80.1%
F	94.0%	93.7%	93.4%	92.4%	92.3%
G	91.7%	92.9%	91.4%	90.6%	90.3%

Table 50: Variation of ASI calculated for each catchment with differing upper Importance Factors, whilst keeping the lower Importance Factor the same at -2.0 in each case

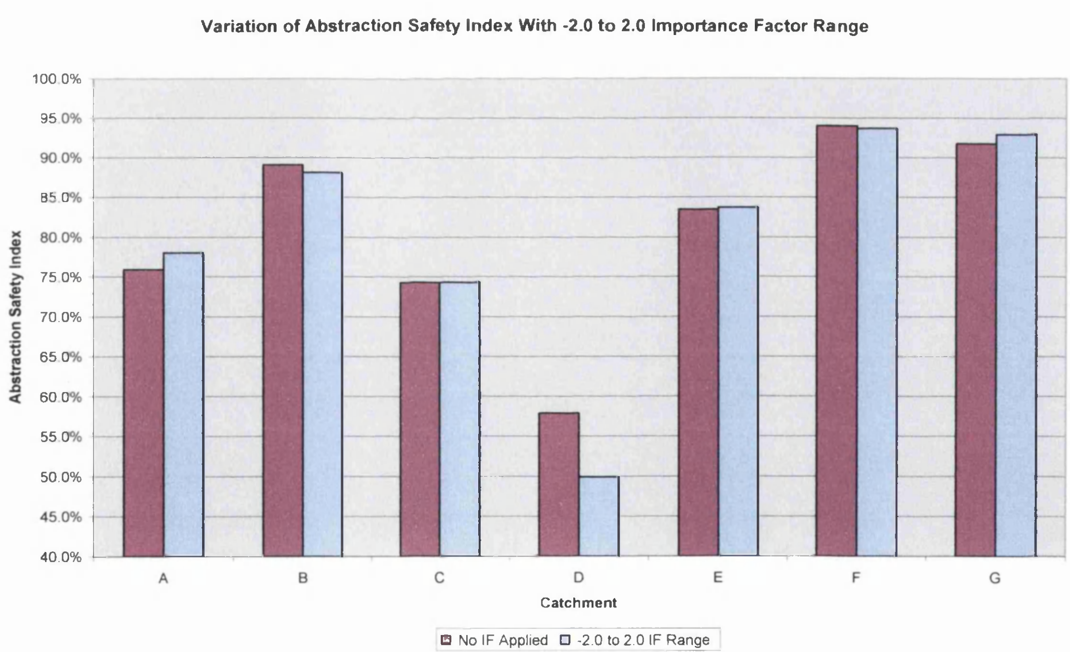


Figure 42: A graphical presentation of some of the data given in Table 50, showing the variation of ASI calculated for each catchment, with a lower Importance Factor of -2.0, and an upper Importance Factor of 2.0

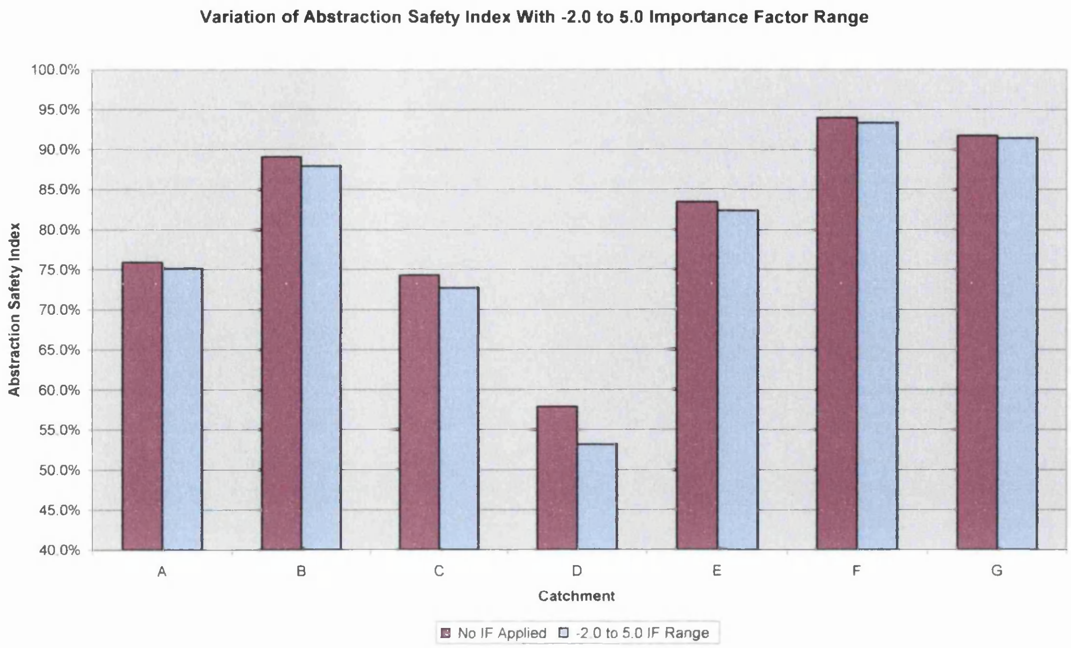


Figure 43: A graphical presentation of some of the data given in Table 50, showing the variation of ASI calculated for each catchment, with a lower Importance Factor of -2.0, and an upper Importance Factor of 5.0

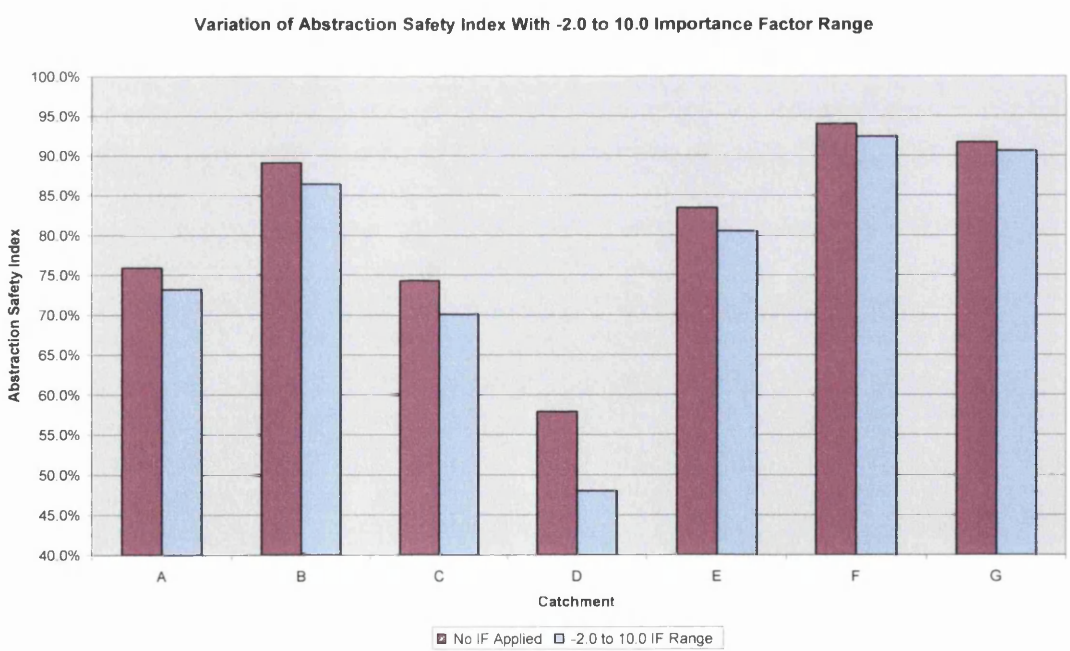


Figure 44: A graphical presentation of some of the data given in Table 50, showing the variation of ASI calculated for each catchment, with a lower Importance Factor of -2.0, and an upper Importance Factor of 10.0

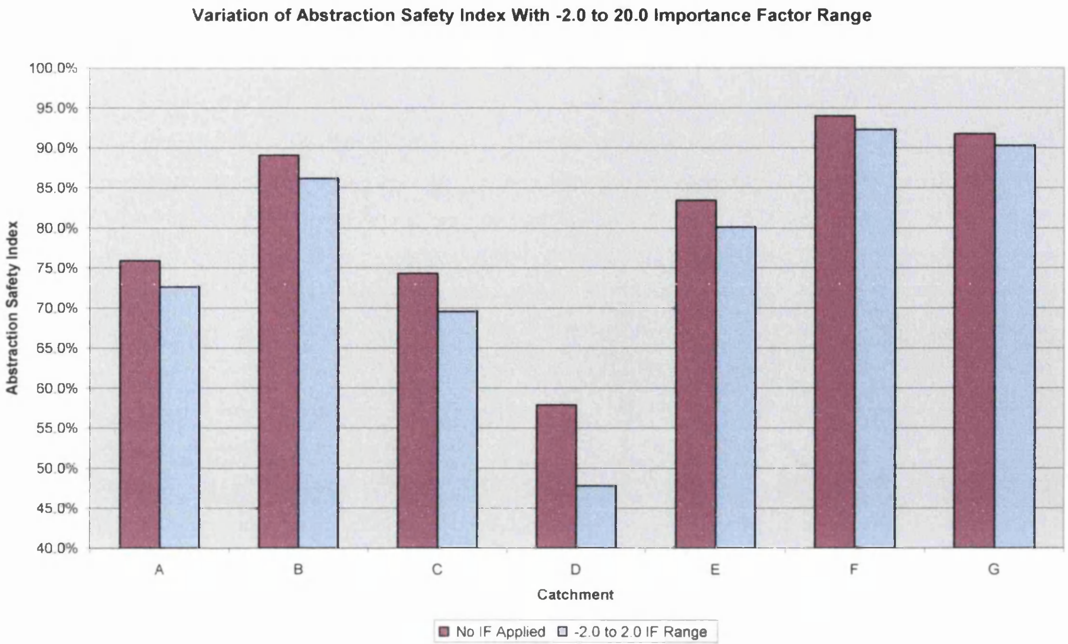


Figure 45: A graphical presentation of some of the data given in Table 50, showing the variation of ASI calculated for each catchment, with a lower Importance Factor of -2.0, and an upper Importance Factor of 20.0

CATCHMENT	NO IF APPLIED	IMPORTANCE FACTOR RANGE			
		-5.0 TO 2.0 IF RANGE	-5.0 TO 5.0 IF RANGE	-5.0 TO 10.0 IF RANGE	-5.0 TO 20.0 IF RANGE
A	75.9%	87.0%	78.0%	75.0%	73.5%
B	89.1%	91.4%	88.1%	87.0%	86.5%
C	74.3%	82.2%	74.3%	71.7%	70.4%
D	57.9%	53.4%	49.9%	48.7%	48.2%
E	83.4%	89.8%	83.7%	81.7%	80.7%
F	94.0%	96.0%	90.9%	92.9%	92.5%
G	91.7%	85.8%	92.9%	91.4%	90.7%

Table 51: Variation of ASI calculated for each catchment with differing upper Importance Factors, whilst keeping the lower Importance Factor the same at -5.0 in each case

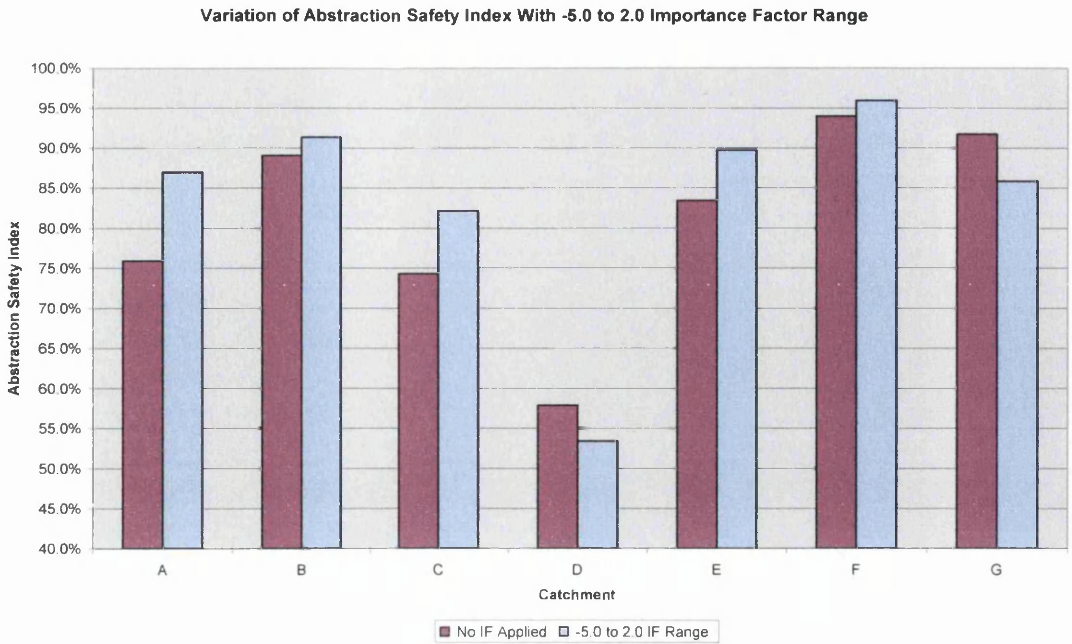


Figure 46: A graphical presentation of some of the data given in Table 51, showing the variation of ASI calculated for each catchment, with a lower Importance Factor of -5.0, and an upper Importance Factor of 2.0

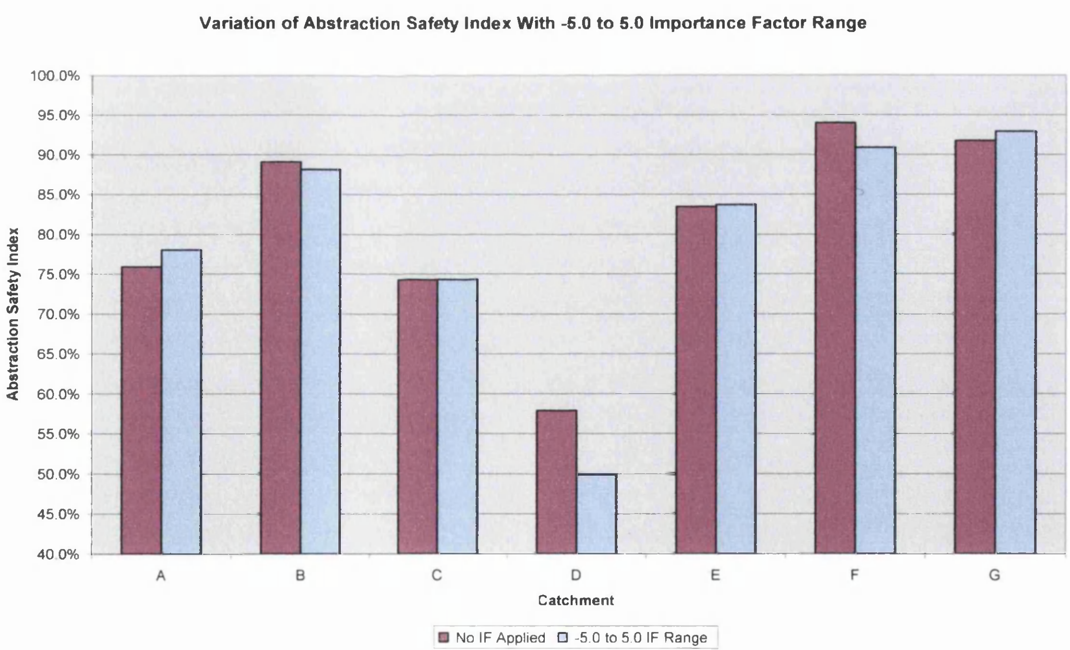


Figure 47: A graphical presentation of some of the data given in Table 51, showing the variation of ASI calculated for each catchment, with a lower Importance Factor of -5.0, and an upper Importance Factor of 5.0

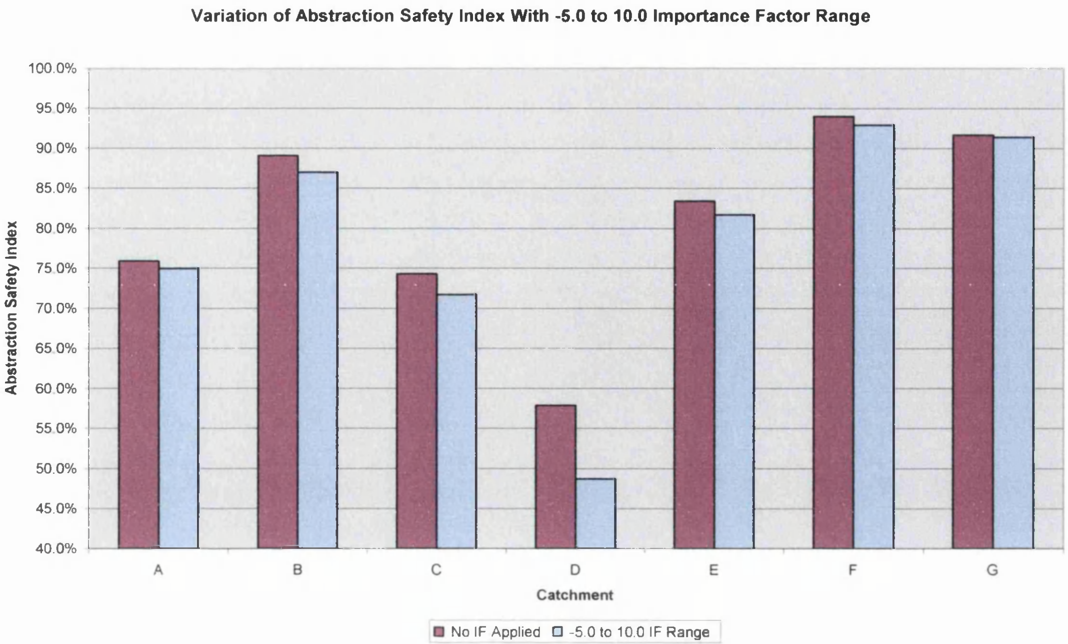


Figure 48: A graphical presentation of some of the data given in Table 51, showing the variation of ASI calculated for each catchment, with a lower Importance Factor of -5.0, and an upper Importance Factor of 10.0

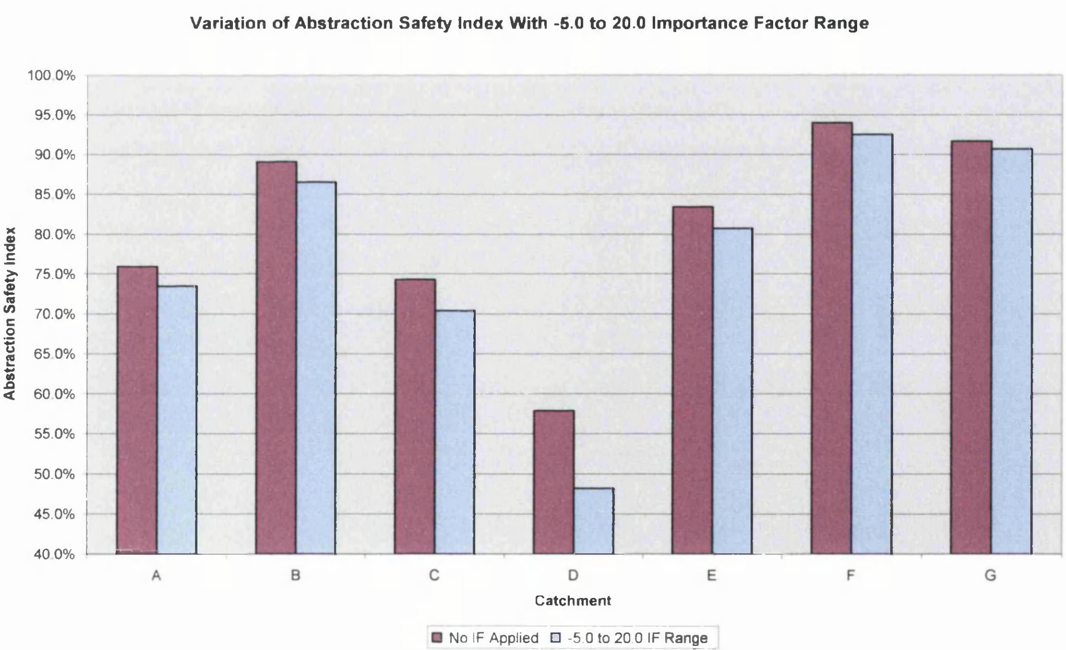


Figure 49: A graphical presentation of some of the data given in Table 51, showing the variation of ASI calculated for each catchment, with a lower Importance Factor of -5.0, and an upper Importance Factor of 20.0

Catchment	No IF Applied	Importance Factor Range			
		-10.0 to 2.0 IF Range	-10.0 to 5.0 IF Range	-10.0 to 10.0 IF Range	-10.0 to 20.0 IF Range
A	75.9%	101.9%	84.0%	78.0%	75.0%
B	89.1%	96.8%	90.3%	88.1%	87.0%
C	74.3%	95.3%	79.5%	74.3%	71.7%
D	57.9%	59.3%	52.3%	49.9%	48.7%
E	83.4%	99.8%	87.7%	83.7%	81.7%
F	94.0%	99.8%	95.2%	92.4%	92.9%
G	91.7%	104.7%	95.9%	92.9%	91.4%

Table 52: Variation of ASI calculated for each catchment with differing upper Importance Factors, whilst keeping the lower Importance Factor the same at -10.0 in each case

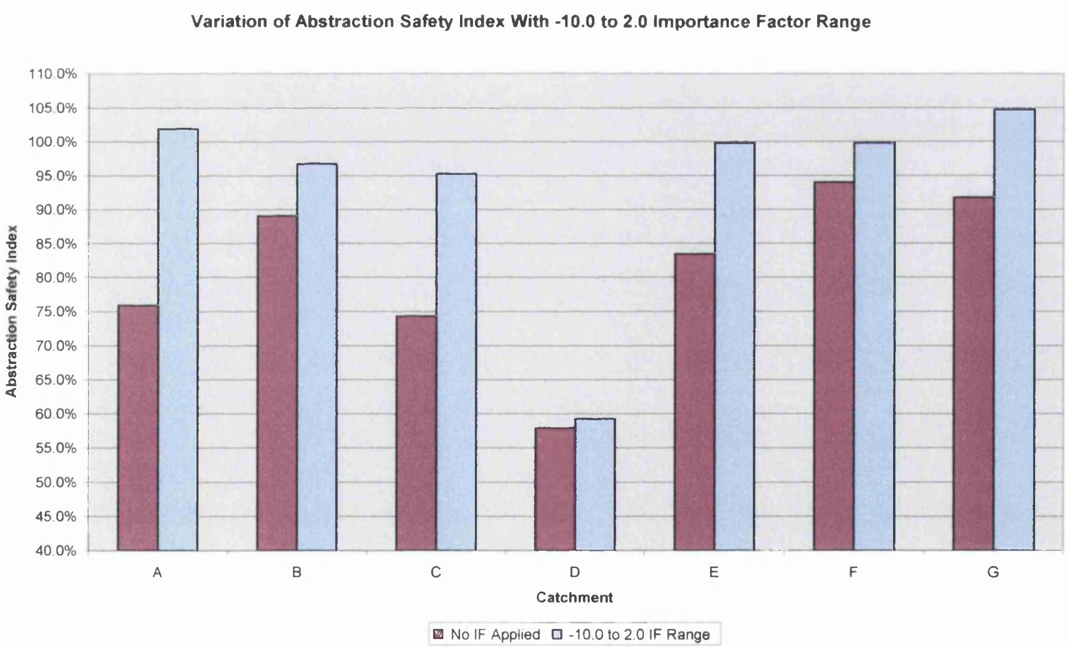


Figure 50: A graphical presentation of some of the data given in Table 52, showing the variation of ASI calculated for each catchment, with a lower Importance Factor of -10.0, and an upper Importance Factor of 2.0

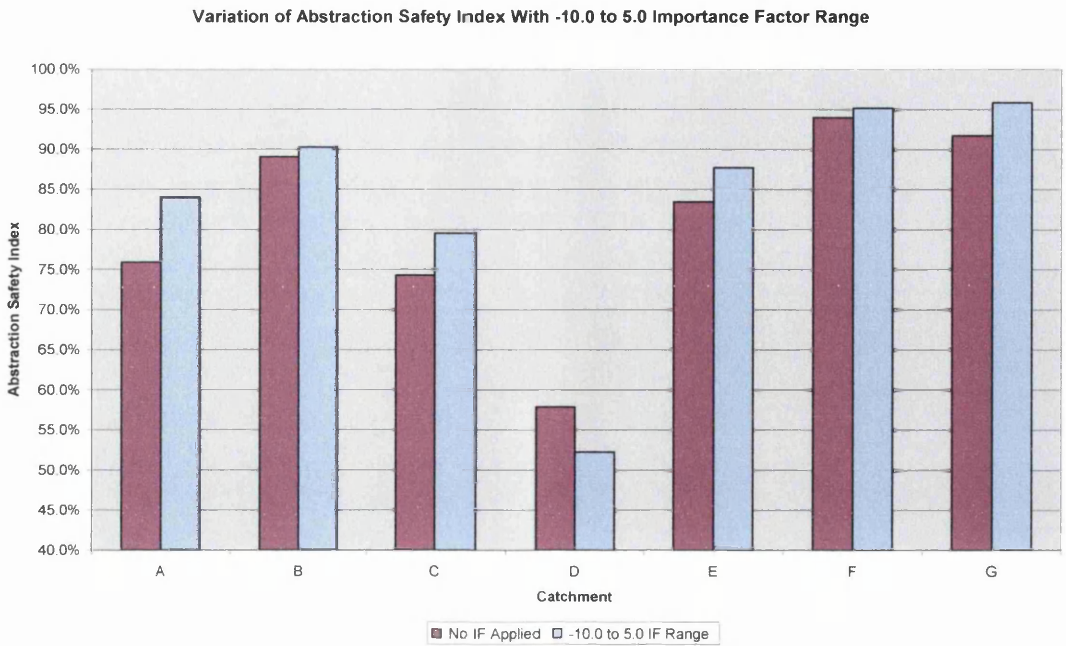


Figure 51: A graphical presentation of some of the data given in Table 52, showing the variation of ASI calculated for each catchment, with a lower Importance Factor of -10.0, and an upper Importance Factor of 5.0

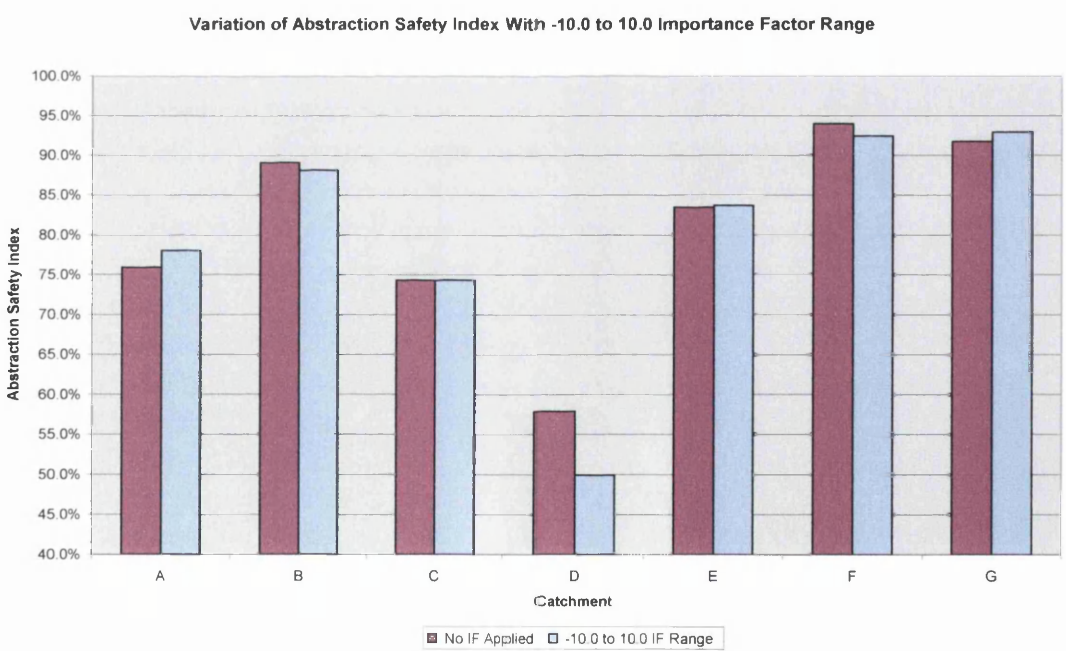


Figure 52: A graphical presentation of some of the data given in Table 52, showing the variation of ASI calculated for each catchment, with a lower Importance Factor of -10.0, and an upper Importance Factor of 10.0

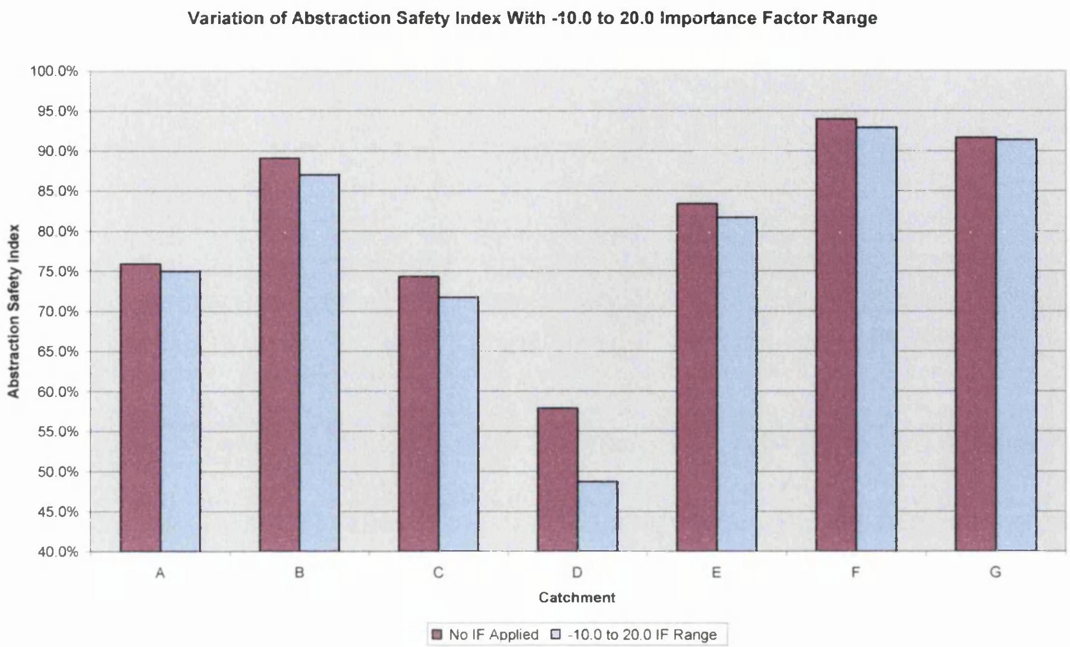


Figure 53: A graphical presentation of some of the data given in Table 52, showing the variation of ASI calculated for each catchment, with a lower Importance Factor of -10.0, and an upper Importance Factor of 20.0

CATCHMENT	NO IF APPLIED	IMPORTANCE FACTOR RANGE			
		-20.0 TO 2.0 IF RANGE	-20.0 TO 5.0 IF RANGE	-20.0 TO 10.0 IF RANGE	-20.0 TO 20.0 IF RANGE
A	75.9%	131.9%	96.0%	84.0%	78.0%
B	89.1%	107.6%	94.6%	90.3%	88.1%
C	74.3%	121.5%	90.0%	79.5%	74.3%
D	57.9%	71.0%	56.9%	52.3%	49.9%
E	83.4%	119.9%	95.8%	87.7%	83.7%
F	94.0%	107.5%	98.3%	95.2%	93.7%
G	91.7%	119.4%	101.8%	95.9%	92.9%

Table 53: Variation of ASI calculated for each catchment with differing upper Importance Factors, whilst keeping the lower Importance Factor the same at -20.0 in each case

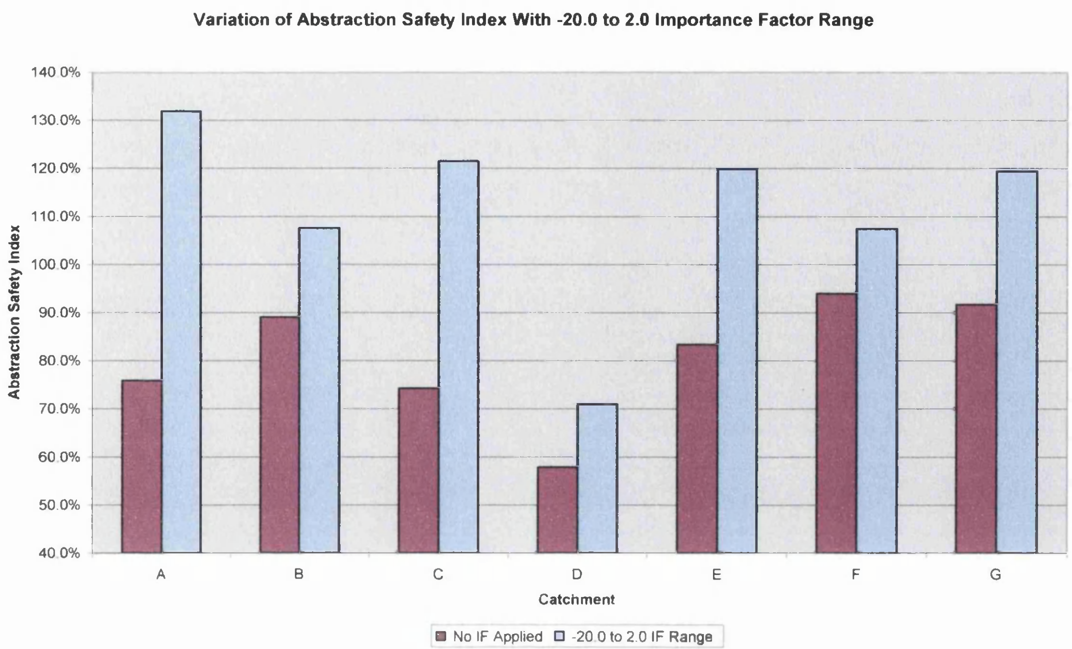


Figure 54: A graphical presentation of some of the data given in Table 53, showing the variation of ASI calculated for each catchment, with a lower Importance Factor of -20.0, and an upper Importance Factor of 2.0

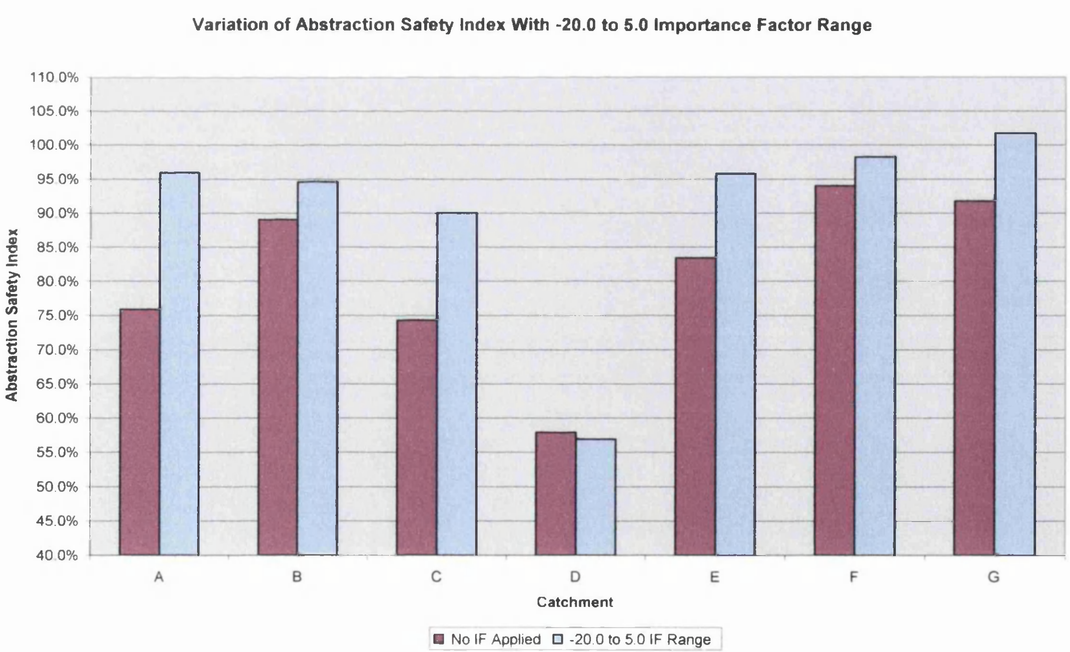


Figure 55: A graphical presentation of some of the data given in Table 53, showing the variation of ASI calculated for each catchment, with a lower Importance Factor of -20.0, and an upper Importance Factor of 5.0

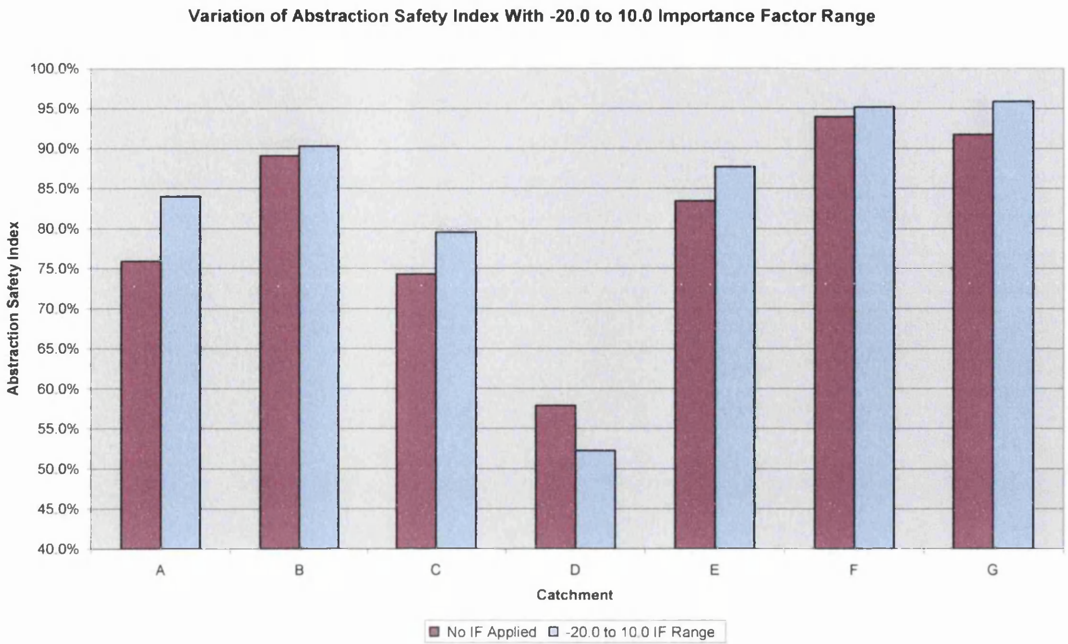


Figure 56: A graphical presentation of some of the data given in Table 53, showing the variation of ASI calculated for each catchment, with a lower Importance Factor of -20.0, and an upper Importance Factor of 10.0

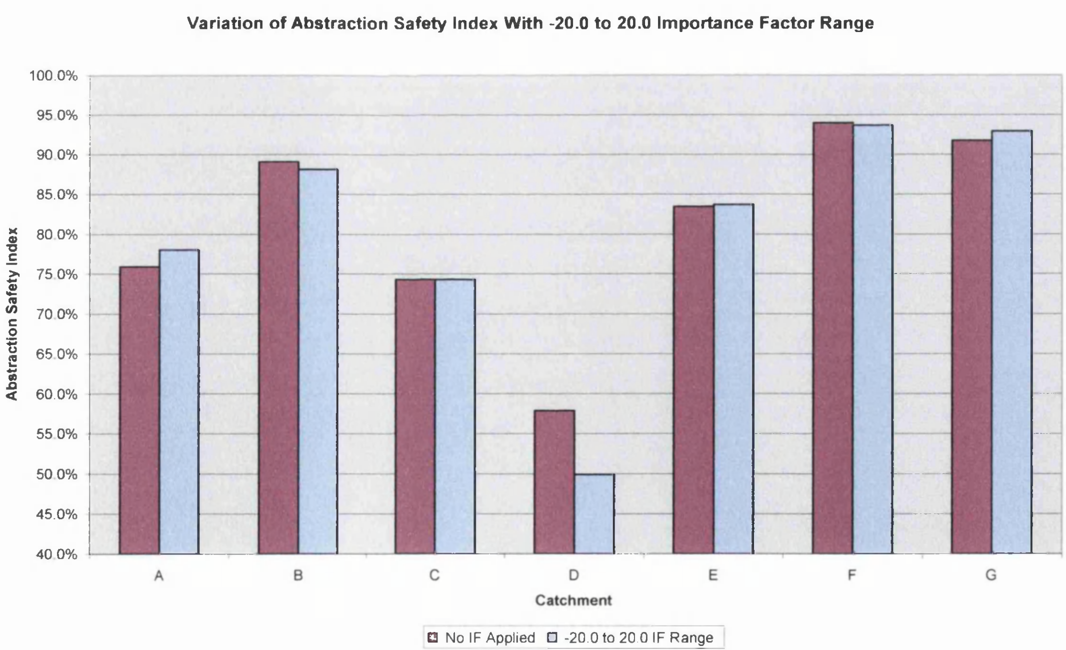


Figure 57: A graphical presentation of some of the data given in Table 53, showing the variation of ASI calculated for each catchment, with a lower Importance Factor of -20.0, and an upper Importance Factor of 20.0

In the following Tables, the data presented in Table 50 to Table 53 inclusive are re-presented to show the percentage variation from the unweighted Abstraction Safety Index of the weighted Abstraction Safety Index for each range of Importance Factor values.

CATCHMENT	NO IF APPLIED	-2.0 TO 2.0 IF RANGE	PERCENTAGE VARIATION	INCREASE OR DECREASE?
A	75.9%	78.0%	2.8%	**Increase**
B	89.1%	88.1%	1.1%	**Decrease**
C	74.3%	74.3%	0.0%	No change
D	57.9%	49.9%	13.8%	**Decrease**
E	83.4%	83.7%	0.3%	**Increase**
F	94.0%	93.7%	0.4%	**Decrease**
G	91.7%	92.9%	1.3%	**Increase**

Table 54: Percentage variation from the unweighted Abstraction Safety Index of the weighted Abstraction Safety Index with a lower Importance Factor of -2.0 and an upper Importance Factor of 2.0

CATCHMENT	NO IF APPLIED	-2.0 TO 5.0 IF RANGE	PERCENTAGE VARIATION	INCREASE OR DECREASE?
A	75.9%	75.2%	1.0%	**Decrease**
B	89.1%	87.9%	1.3%	**Decrease**
C	74.3%	72.7%	2.1%	**Decrease**
D	57.9%	53.2%	8.1%	**Decrease**
E	83.4%	82.4%	1.3%	**Decrease**
F	94.0%	93.4%	0.7%	**Decrease**
G	91.7%	91.4%	0.3%	**Decrease**

Table 55: Percentage variation from the unweighted Abstraction Safety Index of the weighted Abstraction Safety Index with a lower Importance Factor of -2.0 and an upper Importance Factor of 2.0

CATCHMENT	NO IF APPLIED	-2.0 TO 10.0 IF RANGE	PERCENTAGE VARIATION	INCREASE OR DECREASE?
A	75.9%	73.2%	3.5%	**Decrease**
B	89.1%	86.4%	3.0%	**Decrease**
C	74.3%	70.1%	5.7%	**Decrease**
D	57.9%	48.0%	17.0%	**Decrease**
E	83.4%	80.5%	3.5%	**Decrease**
F	94.0%	92.4%	1.7%	**Decrease**
G	91.7%	90.6%	1.3%	**Decrease**

Table 56: Percentage variation from the unweighted Abstraction Safety Index of the weighted Abstraction Safety Index with a lower Importance Factor of -2.0 and an upper Importance Factor of 10.0

CATCHMENT	NO IF APPLIED	-2.0 TO 20.0 IF RANGE	PERCENTAGE VARIATION	INCREASE OR DECREASE?
A	75.9%	72.6%	4.3%	Decrease
B	89.1%	86.2%	3.3%	Decrease
C	74.3%	69.6%	6.4%	Decrease
D	57.9%	47.8%	17.4%	Decrease
E	83.4%	80.1%	4.0%	Decrease
F	94.0%	92.3%	1.8%	Decrease
G	91.7%	90.3%	1.6%	Decrease

Table 57: Percentage variation from the unweighted Abstraction Safety Index of the weighted Abstraction Safety Index with a lower Importance Factor of -2.0 and an upper Importance Factor of 20.0

CATCHMENT	NO IF APPLIED	-5.0 TO 2.0 IF RANGE	PERCENTAGE VARIATION	INCREASE OR DECREASE?
A	75.9%	87.0%	14.6%	**Increase**
B	89.1%	91.4%	2.6%	**Increase**
C	74.3%	82.2%	10.6%	**Increase**
D	57.9%	53.4%	7.7%	**Decrease**
E	83.4%	89.8%	7.6%	**Increase**
F	94.0%	96.0%	2.1%	**Increase**
G	91.7%	85.8%	6.4%	**Decrease**

Table 58: Percentage variation from the unweighted Abstraction Safety Index of the weighted Abstraction Safety Index with a lower Importance Factor of -5.0 and an upper Importance Factor of 2.0

CATCHMENT	NO IF APPLIED	-5.0 TO 5.0 IF RANGE	PERCENTAGE VARIATION	INCREASE OR DECREASE?
A	75.9%	78.0%	2.8%	**Increase**
B	89.1%	88.1%	1.1%	**Decrease**
C	74.3%	74.3%	0.0%	No change
D	57.9%	49.9%	13.8%	**Decrease**
E	83.4%	83.7%	0.3%	**Increase**
F	94.0%	90.9%	3.3%	**Decrease**
G	91.7%	92.9%	1.3%	**Increase**

Table 59: Percentage variation from the unweighted Abstraction Safety Index of the weighted Abstraction Safety Index with a lower Importance Factor of -5.0 and an upper Importance Factor of 5.0

Catchment	No IF Applied	-5.0 to 10.0 IF Range	Percentage Variation	Increase or Decrease?
A	75.9%	75.0%	1.2%	**Decrease**
B	89.1%	87.0%	2.3%	**Decrease**
C	74.3%	71.7%	3.5%	**Decrease**
D	57.9%	48.7%	15.8%	**Decrease**
E	83.4%	81.7%	2.1%	**Decrease**
F	94.0%	92.9%	1.2%	**Decrease**
G	91.7%	91.4%	0.3%	**Decrease**

Table 60: Percentage variation from the unweighted Abstraction Safety Index of the weighted Abstraction Safety Index with a lower Importance Factor of -5.0 and an upper Importance Factor of 10.0

Catchment	No IF Applied	-5.0 to 20.0 IF Range	Percentage Variation	Increase or Decrease?
A	75.9%	73.5%	3.1%	**Decrease**
B	89.1%	86.5%	2.9%	**Decrease**
C	74.3%	70.4%	5.3%	**Decrease**
D	57.9%	48.2%	16.8%	**Decrease**
E	83.4%	80.7%	3.3%	**Decrease**
F	94.0%	92.5%	1.6%	**Decrease**
G	91.7%	90.7%	1.1%	**Decrease**

Table 61: Percentage variation from the unweighted Abstraction Safety Index of the weighted Abstraction Safety Index with a lower Importance Factor of -5.0 and an upper Importance Factor of 20.0

CATCHMENT	NO IF APPLIED	-10.0 TO 2.0 IF RANGE	PERCENTAGE VARIATION	INCREASE OR DECREASE?
A	75.9%	101.9%	34.3%	**Increase**
B	89.1%	96.8%	8.6%	**Increase**
C	74.3%	95.3%	28.2%	**Increase**
D	57.9%	59.3%	2.4%	**Increase**
E	83.4%	99.8%	19.6%	**Increase**
F	94.0%	99.8%	6.2%	**Increase**
G	91.7%	104.7%	14.1%	**Increase**

Table 62: Percentage variation from the unweighted Abstraction Safety Index of the weighted Abstraction Safety Index with a lower Importance Factor of -10.0 and an upper Importance Factor of 2.0

CATCHMENT	NO IF APPLIED	-10.0 TO 5.0 IF RANGE	PERCENTAGE VARIATION	INCREASE OR DECREASE?
A	75.9%	84.0%	10.7%	**Increase**
B	89.1%	90.3%	1.4%	**Increase**
C	74.3%	79.5%	7.0%	**Increase**
D	57.9%	52.3%	9.8%	**Decrease**
E	83.4%	87.7%	5.2%	**Increase**
F	94.0%	95.2%	1.3%	**Increase**
G	91.7%	95.9%	4.5%	**Increase**

Table 63: Percentage variation from the unweighted Abstraction Safety Index of the weighted Abstraction Safety Index with a lower Importance Factor of -10.0 and an upper Importance Factor of 5.0

CATCHMENT	NO IF APPLIED	-10.0 TO 10.0 IF RANGE	PERCENTAGE VARIATION	INCREASE OR DECREASE?
A	75.9%	78.0%	2.8%	**Increase**
B	89.1%	88.1%	1.1%	**Decrease**
C	74.3%	74.3%	0.0%	No change
D	57.9%	49.9%	13.8%	**Decrease**
E	83.4%	83.7%	0.3%	**Increase**
F	94.0%	92.4%	1.7%	**Decrease**
G	91.7%	92.9%	1.3%	**Increase**

Table 64: Percentage variation from the unweighted Abstraction Safety Index of the weighted Abstraction Safety Index with a lower Importance Factor of -10.0 and an upper Importance Factor of 10.0

CATCHMENT	NO IF APPLIED	-10.0 TO 20.0 IF RANGE	PERCENTAGE VARIATION	INCREASE OR DECREASE?
A	75.9%	75.0%	1.2%	**Decrease**
B	89.1%	87.0%	2.3%	**Decrease**
C	74.3%	71.7%	3.5%	**Decrease**
D	57.9%	48.7%	15.8%	**Decrease**
E	83.4%	81.7%	2.1%	**Decrease**
F	94.0%	92.9%	1.2%	**Decrease**
G	91.7%	91.4%	0.3%	**Decrease**

Table 65: Percentage variation from the unweighted Abstraction Safety Index of the weighted Abstraction Safety Index with a lower Importance Factor of -10.0 and an upper Importance Factor of 20.0

CATCHMENT	NO IF APPLIED	-20.0 TO 2.0 IF RANGE	PERCENTAGE VARIATION	INCREASE OR DECREASE?
A	75.9%	131.9%	73.8%	**Increase**
B	89.1%	107.6%	20.8%	**Increase**
C	74.3%	121.5%	63.5%	**Increase**
D	57.9%	71.0%	22.6%	**Increase**
E	83.4%	119.9%	43.7%	**Increase**
F	94.0%	107.5%	14.3%	**Increase**
G	91.7%	119.4%	30.2%	**Increase**

Table 66: Percentage variation from the unweighted Abstraction Safety Index of the weighted Abstraction Safety Index with a lower Importance Factor of -20.0 and an upper Importance Factor of 2.0

CATCHMENT	NO IF APPLIED	-20.0 TO 5.0 IF RANGE	PERCENTAGE VARIATION	INCREASE OR DECREASE?
A	75.9%	96.0%	26.4%	**Increase**
B	89.1%	94.6%	6.2%	**Increase**
C	74.3%	90.0%	21.1%	**Increase**
D	57.9%	56.9%	1.7%	**Decrease**
E	83.4%	95.8%	14.8%	**Increase**
F	94.0%	98.3%	4.5%	**Increase**
G	91.7%	101.8%	10.9%	**Increase**

Table 67: Percentage variation from the unweighted Abstraction Safety Index of the weighted Abstraction Safety Index with a lower Importance Factor of -20.0 and an upper Importance Factor of 5.0

Catchment	No IF Applied	-20.0 to 10.0 IF Range	Percentage Variation	Increase or Decrease?
A	75.9%	84.0%	10.7%	Increase
B	89.1%	90.3%	1.4%	Increase
C	74.3%	79.5%	7.0%	Increase
D	57.9%	52.3%	9.8%	Decrease
E	83.4%	87.7%	5.2%	Increase
F	94.0%	95.2%	1.3%	Increase
G	91.7%	95.9%	4.5%	Increase

Table 68: Percentage variation from the unweighted Abstraction Safety Index of the weighted Abstraction Safety Index with a lower Importance Factor of -20.0 and an upper Importance Factor of 10.0

Catchment	No IF Applied	-20.0 to 20.0 IF Range	Percentage Variation	Increase or Decrease?
A	75.9%	78.0%	2.8%	Increase
B	89.1%	88.1%	1.1%	Decrease
C	74.3%	74.3%	0.0%	No change
D	57.9%	49.9%	13.8%	Decrease
E	83.4%	83.7%	0.3%	Increase
F	94.0%	93.7%	0.4%	Decrease
G	91.7%	92.9%	1.3%	Increase

Table 69: Percentage variation from the unweighted Abstraction Safety Index of the weighted Abstraction Safety Index with a lower Importance Factor of -20.0 and an upper Importance Factor of 20.0

25.5 Discussion

By learning from the fundamental mistake made whilst constructing the first methodology, this second version appears to have worked as expected as, in the majority of cases, the weighted Abstraction Safety Index has either increased or decreased with respect to the unweighted value (in just four instances, both the weighted and unweighted values were the same).

By applying the objectives stated in Section 24.3, it is now possible to discard those ranges of Importance Factors that have produced inappropriate results. With specific reference to the first of these objectives (to ensure that the weighted Abstraction Safety Index values remained within the boundary values of 96.0% and 0.0% respectively), the following ranges can now be discarded, as they gave rise to some weighted values equal to or greater than the upper boundary value of 96.0%:

- -5.0 to 2.0;
- -10.0 to 2.0;
- -20.0 to 2.0; and
- -20.0 to 5.0.

Turning now to the second of the objectives (to ensure application of the Importance Factors did not simply universally increase or decrease the weighted Abstraction Safety Index values; instead, the aim was to demonstrate, in an easily accessible manner, both the positive and negative impacts of the Importance Factors on the final values), the following ranges can now be discarded, as they gave rise to weighted values that were either universally greater or less than the unweighted values:

- -2.0 to 5.0;
- -2.0 to 10.0;
- -2.0 to 20.0;
- -5.0 to 10.0;
- -5.0 to 20.0; and
- -10.0 to 20.0.

Applying the third of the objectives (to accentuate the sometimes subtle impacts of significant qualitative processes, policies and institutional arrangements, on the weighted Abstraction Safety Index) proved to be a little trickier, as this is effectively more of a qualitative objective than a quantitative one. However, I decided to reject the following ranges, as they did not produce a satisfactory 'spread' of changes in weighted values, when compared to the respective unweighted values:

- -10.0 to 5.0; and
- -20.0 to 10.0.

This review of the 16 Importance Factor ranges used resulted in the following four being kept, as they achieved all of the three objectives:

- -2.0 to 2.0;
- -5.0 to 5.0;
- -10 to 10.0; and
- -20.0 to 20.0.

When the results obtained using these three different ranges are compared in Table 59, Table 64 and Table 69 respectively, four interesting points can be made.

Firstly, the application of each of these four different ranges in turn has exactly the same affect on the weighted values of the Abstraction Safety Index (Catchment A – increase; Catchment B – decrease; Catchment C – no change; Catchment D – decrease; Catchment E – increase; Catchment F – decrease; Catchment G – increase). Leading on from this, the second observation is that these four ranges produce the widest 'spread' of changes in weighted values, when compared to the respective unweighted values (three increases, three decreases and one no change).

Thirdly, the greatest percentage variation of weighted value from its unweighted value for all of the seven catchments was consistently greatest with Catchment 'D', which is also the most polluted (in relative terms). However, what is surprising is that a similar relationship between smallest percentage variation and the least polluted catchment (Catchment 'F') is not established; instead, the smallest variation (which for all four ranges was 0% i.e. no change) was actually recorded for the sixth most polluted i.e. Catchment 'C'.

The fourth observation that can be made is that the percentage variation of the weighted value from the respective unweighted value is the same for all catchments with the notable exception of Catchment F. For the -2.0 to 2.0 range the percentage variation is 0.4%, for the -5.0 to 5.0 range the percentage variation is 3.3%, whilst for the -10.0 to 10.0 range it is 1.7%, and for the -20.0 to 20.0 range it is 0.4%. Catchment 'F' is a private water supply derived from a spring source, and was the highest quality out of all seven catchments (with an unweighted Abstraction Safety Index of 94.0%). One possible conclusion from this result is that the -5.0 to 5.0 range is the most sensitive, as it produces the greatest percentage variation of the unweighted value (94.0%) from its weighted value (90.0%). For this reason, I decided to adopt this range when undertaking the investigations detailed in Chapter 27.

26 ABSTRACTION SAFETY INDEX CALCULATIONS USING THE THIRD METHODOLOGY

26.1 Introduction

The third of the Abstraction Safety Index methodologies is presented in this Chapter. This methodology is only a presentational variation of the second one; in this methodology, Abstraction Safety Index values are expressed as a numeral, whilst in the second methodology they are presented as a percentage.

In this methodology, instead of calculating an Abstraction Safety Index of anywhere between 96.0% and 0.0% for a catchment, individual risks are subtracted from a notional value of 10,000; the formulae provide for a reduction in this value in direct proportion to the degradation of environmental water quality.

26.2 Formulae Used to Calculate the Abstraction Safety Index

The following two sub-sections describe how the unweighted, and the weighted, Abstraction Safety Index respectively are calculated.

26.2.1 Calculation of the Unweighted Abstraction Safety Index

The first stage of the calculation of the Abstraction Safety Index derives an unweighted value for the index, and the formula for this stage can be expressed as follows:

$$ASI_{UW} = 10{,}000 - \text{sum of individual risks}$$

where ASI_{UW} = unweighted Abstraction Safety Index

Equation 9: Calculation of the unweighted Abstraction Safety Index

For exactly the same reason as has already been cited for the preceding two methodologies, it is not possible to obtain an Abstraction Safety Index of 10,000 for a catchment; instead, the value will lie anywhere between 9,922 and 8,050.

26.2.2 Calculation of the Weighted Abstraction Safety Index

Each of the five Importance Factors has three levels, and these are described in some detail in Section 21.5.2. Each of these levels has been assigned a value, and the value is dependent on which numerical range has been used; further information on the number and magnitude of the ranges used is given in Section 24.3.

In order to calculate the weighted Abstraction Safety Index, the value for the level of each of the five Importance Factors is multiplied by the magnitude of risk determined from the risk assessment for each individual source of hazard. The following five identical formulae are therefore used to calculate the contribution of risk associated with each of the five Importance Factors for each individual source of hazard:

$$RC_{OA} = IF_{OA} * \text{magnitude of risk}$$
$$RC_{AI} = IF_{AI} * \text{magnitude of risk}$$
$$RC_{LF} = IF_{LF} * \text{magnitude of risk}$$
$$RC_{CP} = IF_{CP} * \text{magnitude of risk}$$
$$RC_{CE} = IF_{CE} * \text{magnitude of risk}$$

where
RC = risk component
IF = Importance Factor
OA = organisational ability
AI = available information
LF = legal framework
CP = codes of practice and other voluntary arrangements
CE = customer expectation

Equation 10: Calculation of the contribution of risk associated with each of the five Importance Factors

The sum of risk components for each individual source of hazard are subsequently accumulated, to give a weighted magnitude of risk for each individual source of hazard, according to the following formula:

$$WMR_{IND} = RC_{OA} + RC_{AI} + RC_{LF} + RC_{CP} + RC_{CE}$$

where WMR_{IND} = weighted magnitude of risk for each individual source of hazard

Equation 11: Calculation of the weighted magnitude of risk for each individual source of hazard

The total of the maximum weighted magnitude of risk for each individual source of hazard is expressed as follows:

$$WMR_{TOTAL} = \Sigma\ WMR_{IND}$$

where WMR_{IND} = actual weighted magnitude of risk for each individual source of hazard

Equation 12: Calculation of the total maximum weighted magnitude of risk for each individual source of hazard

The formula used to calculate the final value of the weighted Abstraction Safety Index is as follows:

$$ASI_W = 10{,}000 - WMR_{TOTAL}$$

where ASI_W = weighted Abstraction Safety Index

Equation 13: Calculation of the weighted Abstraction Safety Index

26.3 Ranges of Importance Factors

As with the first two methodologies, a total of 16 different ranges of Importance Factors were used for this third methodology, in order to determine the effects different ranges would have on the values for the weighted Abstraction Safety Index; for each range, the median Importance Factor was kept as zero.

The 16 different ranges are identical to those used for the second methodology, and further information relating to them is given in Section 25.3.

The second and third of the objectives stated in Section 24.3 could be retained for this third methodology, but the first objective (to ensure that the weighted Abstraction Safety Index values remained within the boundary values of 96.0% and 0.0% i.e. the rule 0% < Abstraction Safety Index < 96.0% must be observed) as the values arising from this third methodology are expressed as numerals, and not percentages. Therefore, this objective can be expressed as follows:

- To ensure that the weighted Abstraction Safety Index values remained within the boundary values of 10,000 and 0 i.e. the rule 0 < Abstraction Safety Index < 10,000 must be observed.

26.4 Variation of Calculated ASIs with Different Importance Factor Ranges

All the spreadsheets containing the calculations used to derive the results presented in this Section are contained on a CD-ROM attached to the inside front cover of this thesis. Within these spreadsheets, the conditional formatting used for this third methodology is identical to that used for the second methodology (see Section 25.4).

The results obtained from using the 16 different ranges of Importance Factor are presented in Table 70 to Table 73 inclusive, whilst the same data are presented graphically in Figure 58 to Figure 73 inclusive.

Catchment	No IF Applied	Importance Factor Range			
		-2.0 to 2.0 IF Range	-2.0 to 5.0 IF Range	-2.0 to 10.0 IF Range	-2.0 to 20.0 IF Range
A	9530	10540	9043	6548	1558
B	9787	9790	8764	7054	3634
C	9499	9996	7926	4476	-2424
D	9179	7310	2093	-6602	-23992
E	9677	10066	8755	6570	2200
F	9883	9930	9348	8378	6438
G	9839	10250	9686	8746	6866

Table 70: Variation of ASI calculated for each catchment with differing upper Importance Factors, whilst keeping the lower Importance Factor the same at -2.0 in each case

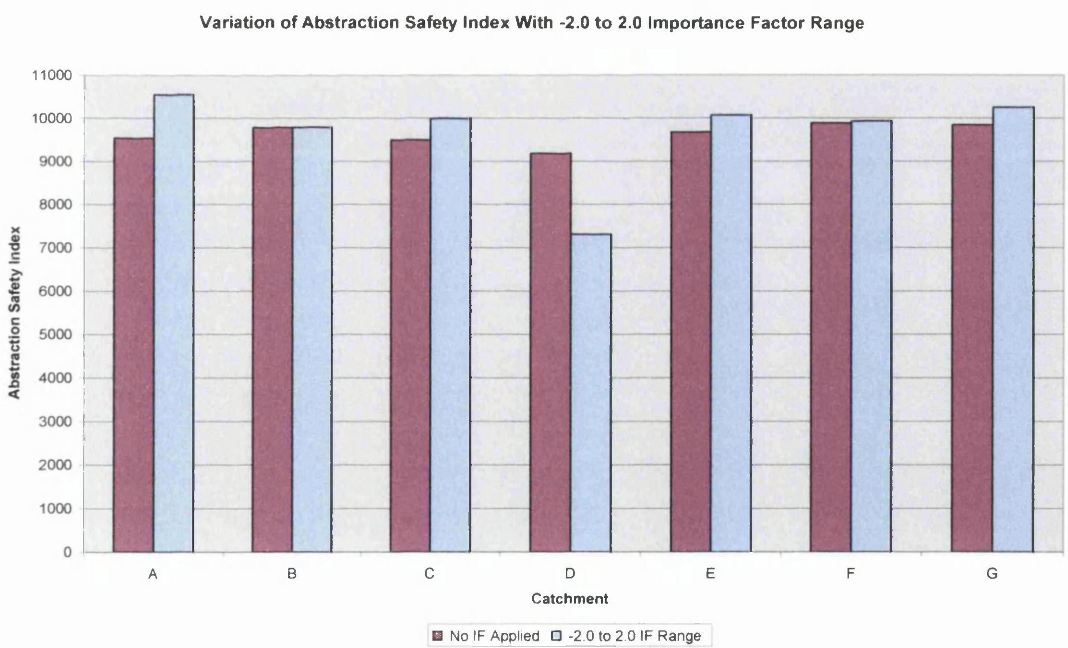


Figure 58: A graphical presentation of some of the data given in Table 70, showing the variation of ASI calculated for each catchment, with a lower Importance Factor of -2.0, and an upper Importance Factor of 2.0

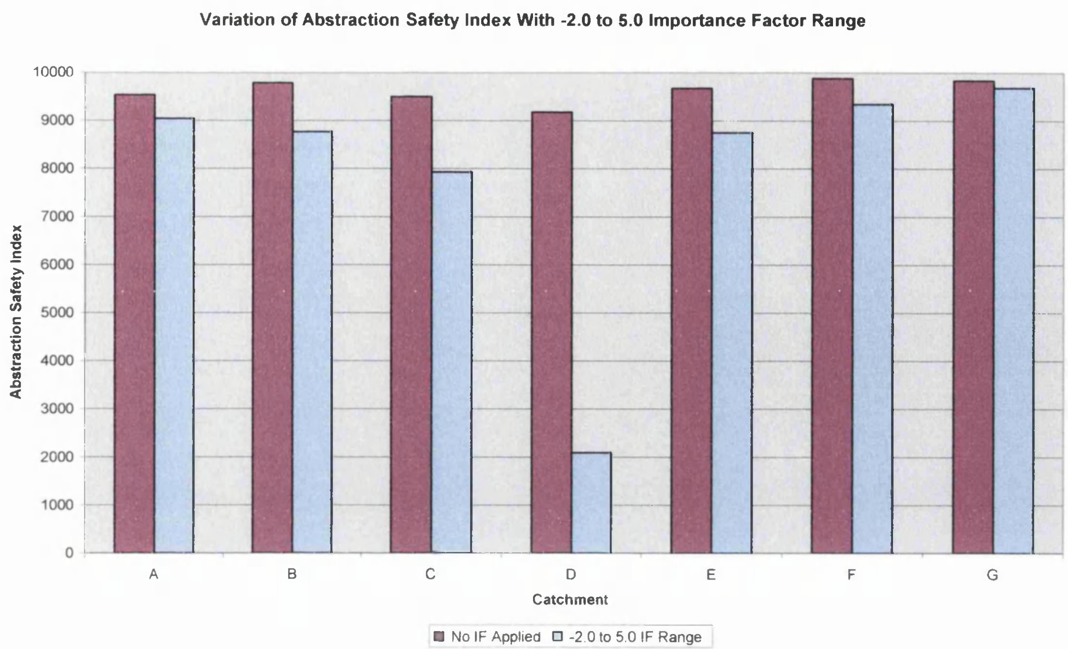


Figure 59: A graphical presentation of some of the data given in Table 50, showing the variation of ASI calculated for each catchment, with a lower Importance Factor of -2.0, and an upper Importance Factor of 5.0

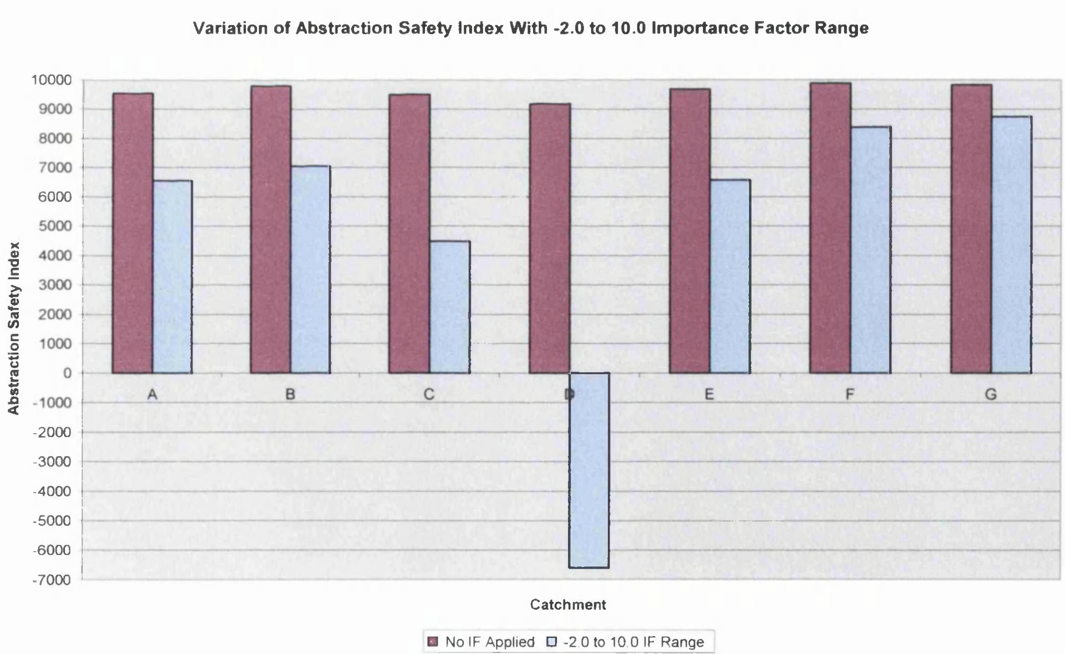


Figure 60: A graphical presentation of some of the data given in Table 50, showing the variation of ASI calculated for each catchment, with a lower Importance Factor of -2.0, and an upper Importance Factor of 10.0

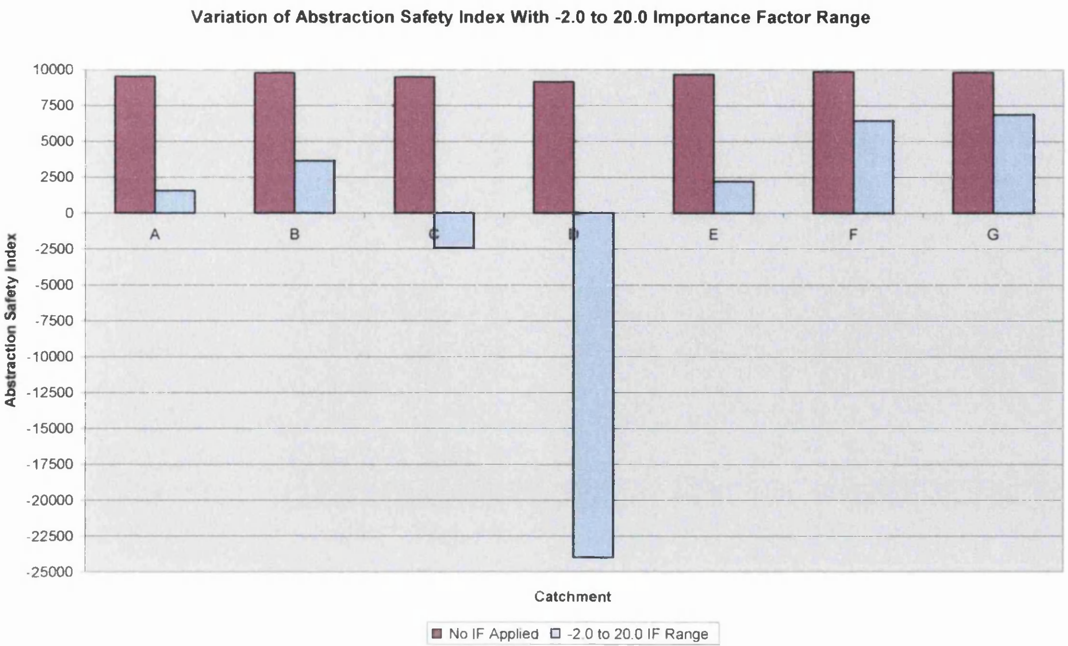


Figure 61: A graphical presentation of some of the data given in Table 50, showing the variation of ASI calculated for each catchment, with a lower Importance Factor of -2.0, and an upper Importance Factor of 20.0

CATCHMENT	NO IF APPLIED	IMPORTANCE FACTOR RANGE			
		-5.0 TO 2.0 IF RANGE	-5.0 TO 5.0 IF RANGE	-5.0 TO 10.0 IF RANGE	-5.0 TO 20.0 IF RANGE
A	9530	12847	11350	8855	3865
B	9787	10501	9475	7765	4345
C	9499	12060	9990	6540	-360
D	9179	8492	3275	-5420	-22810
E	9677	11476	10165	7980	3610
F	9883	10407	8378	8855	6915
G	9839	8746	10625	9685	7805

Table 71: Variation of ASI calculated for each catchment with differing upper Importance Factors, whilst keeping the lower Importance Factor the same at -5.0 in each case

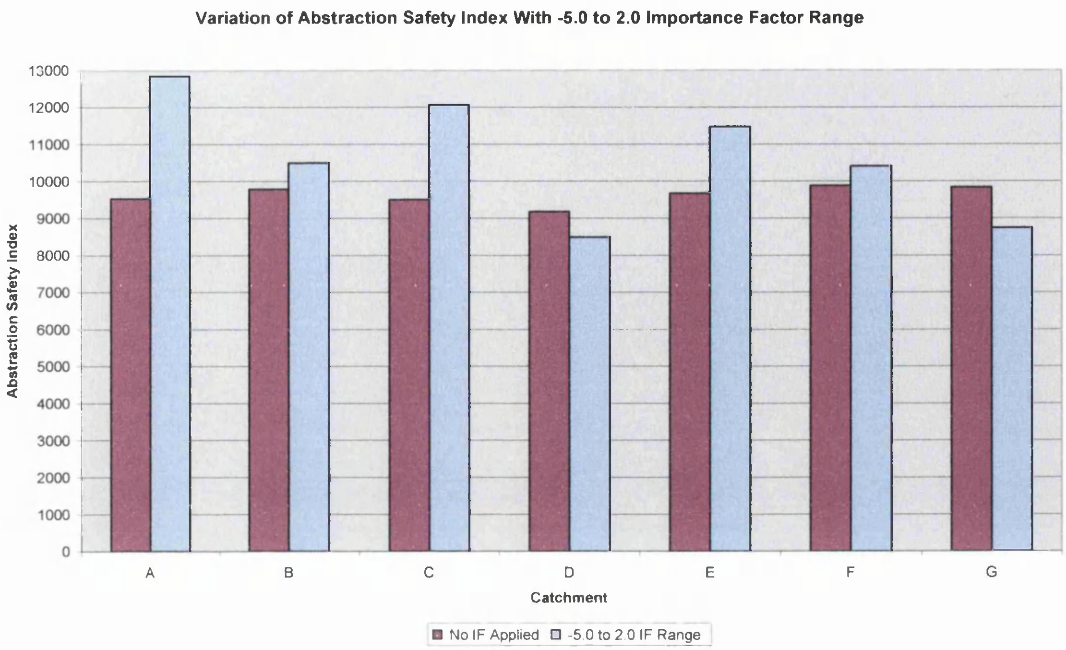


Figure 62: A graphical presentation of some of the data given in Table 51, showing the variation of ASI calculated for each catchment, with a lower Importance Factor of -5.0, and an upper Importance Factor of 2.0

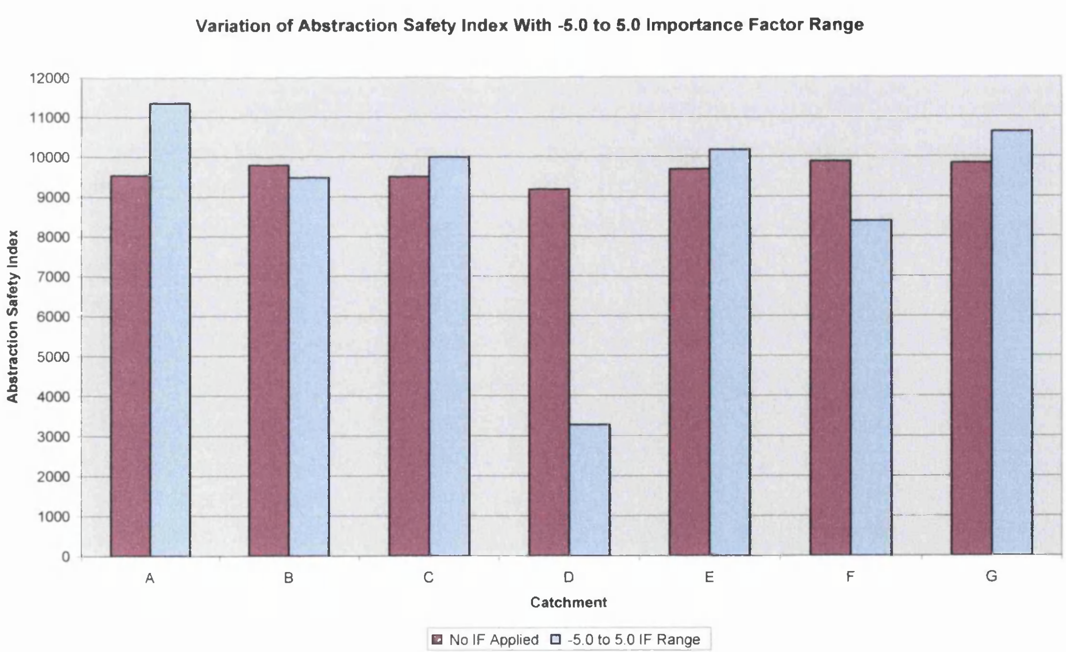


Figure 63: A graphical presentation of some of the data given in Table 51, showing the variation of ASI calculated for each catchment, with a lower Importance Factor of -5.0, and an upper Importance Factor of 5.0

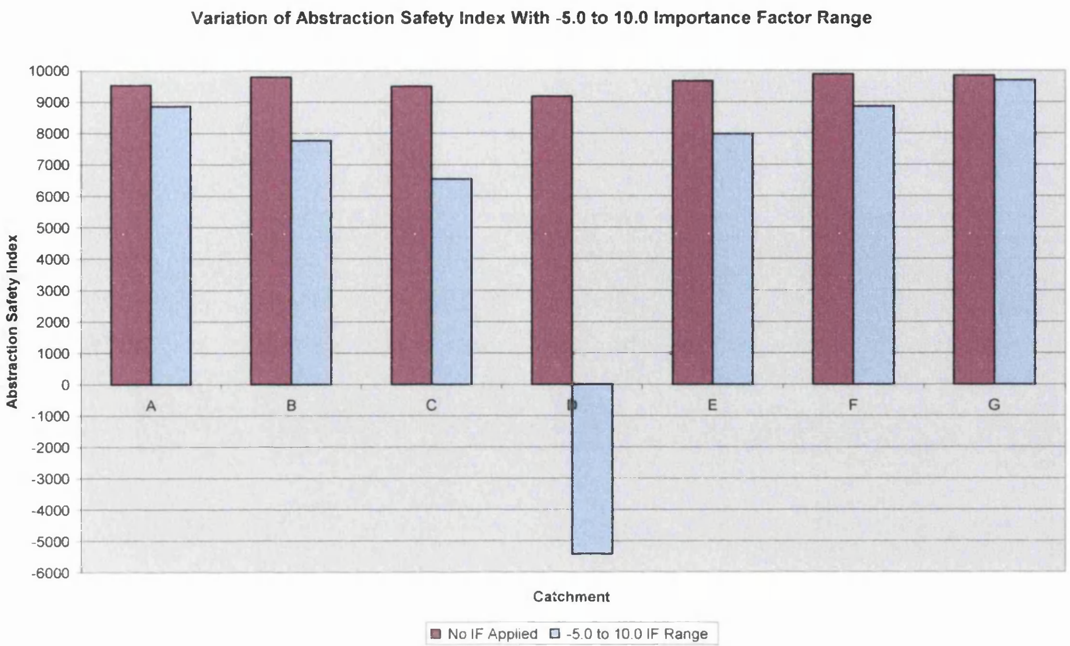


Figure 64: A graphical presentation of some of the data given in Table 51, showing the variation of ASI calculated for each catchment, with a lower Importance Factor of -5.0, and an upper Importance Factor of 10.0

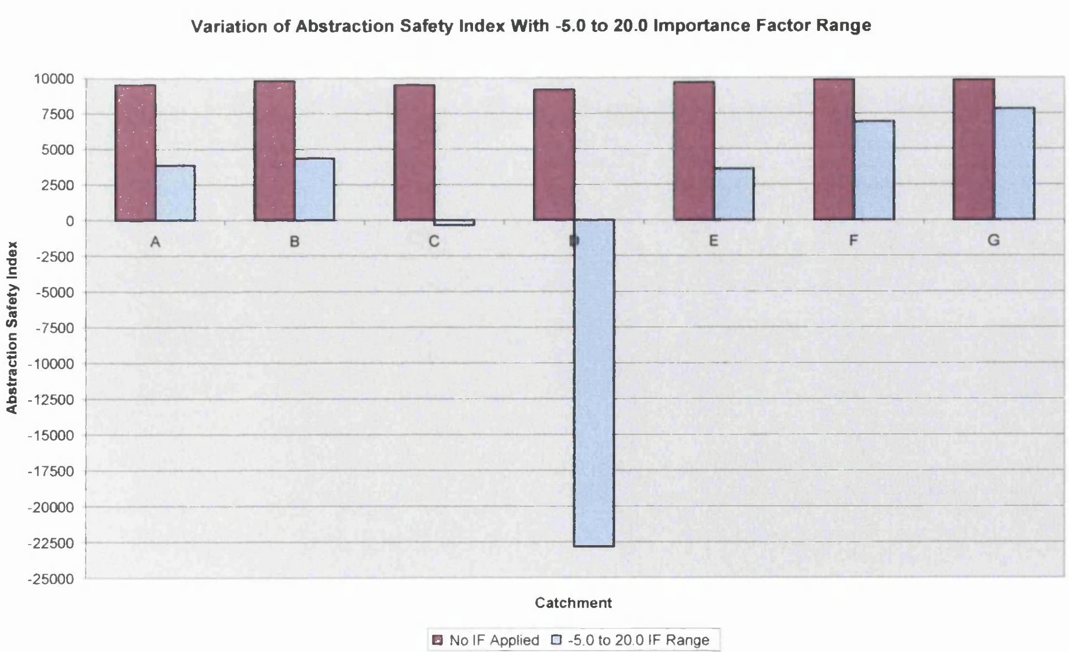


Figure 65: A graphical presentation of some of the data given in Table 51, showing the variation of ASI calculated for each catchment, with a lower Importance Factor of -5.0, and an upper Importance Factor of 20.0

CATCHMENT	NO IF APPLIED	IMPORTANCE FACTOR RANGE			
		-10.0 TO 2.0 IF RANGE	-10.0 TO 5.0 IF RANGE	-10.0 TO 10.0 IF RANGE	-10.0 TO 20.0 IF RANGE
A	9530	16692	15195	12700	7710
B	9787	11686	10660	8950	5530
C	9499	15500	13430	9980	3080
D	9179	10462	5245	-3450	-20840
E	9677	13826	12515	10330	5960
F	9883	11202	10620	8378	7710
G	9839	12754	12190	11250	9370

Table 72: Variation of ASI calculated for each catchment with differing upper Importance Factors, whilst keeping the lower Importance Factor the same at -10.0 in each case

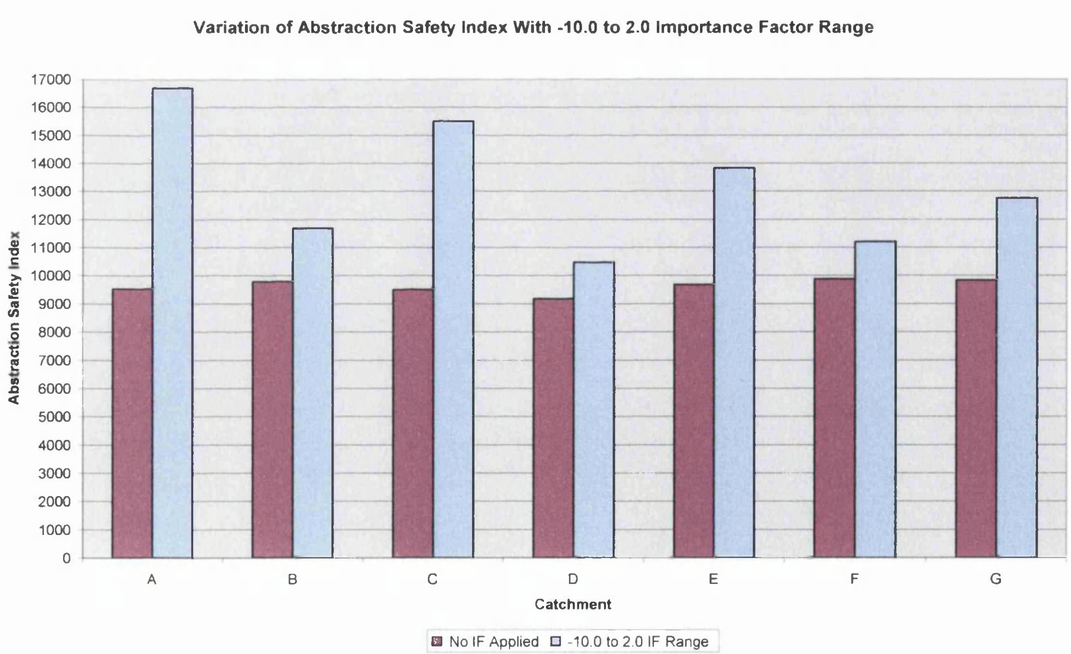


Figure 66: A graphical presentation of some of the data given in Table 52, showing the variation of ASI calculated for each catchment, with a lower Importance Factor of -10.0, and an upper Importance Factor of 2.0

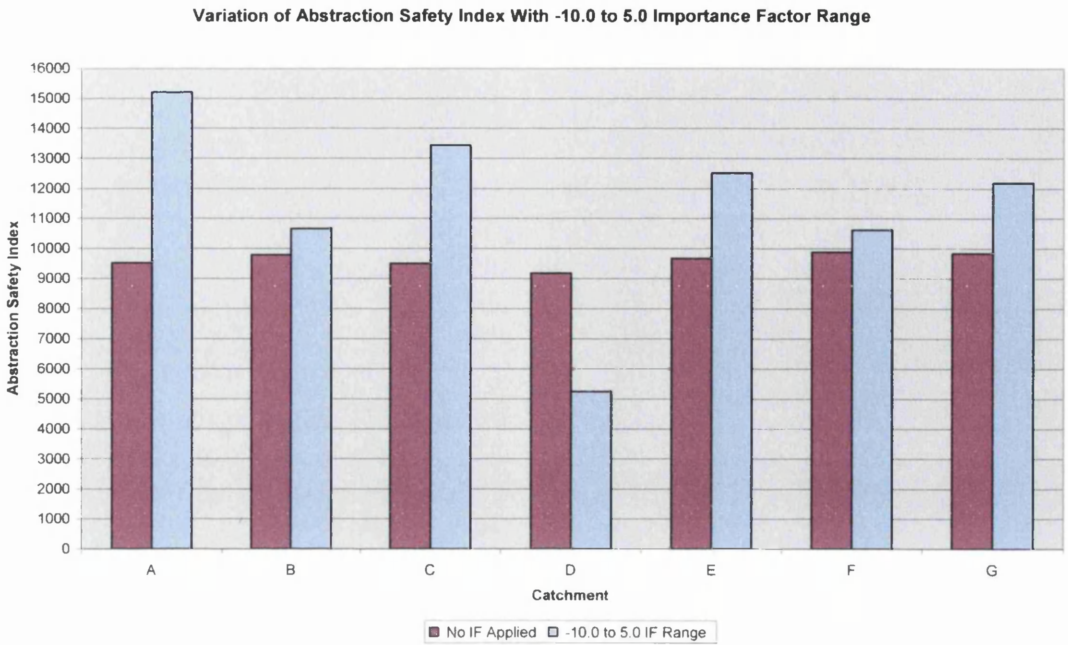


Figure 67: A graphical presentation of some of the data given in Table 52, showing the variation of ASI calculated for each catchment, with a lower Importance Factor of -10.0, and an upper Importance Factor of 5.0

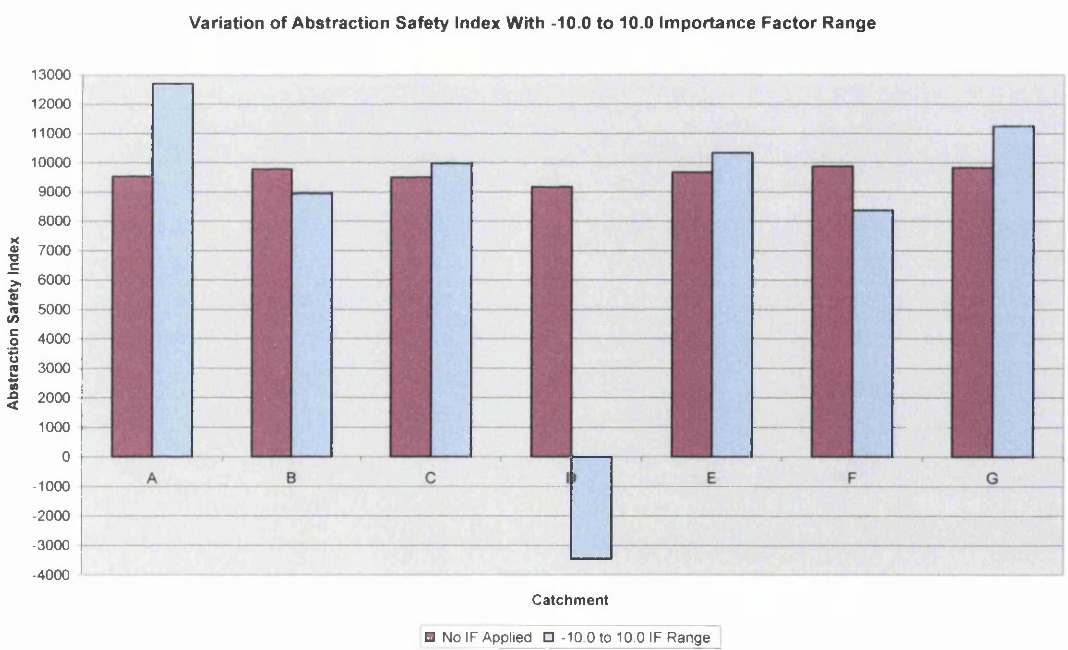


Figure 68: A graphical presentation of some of the data given in Table 52, showing the variation of ASI calculated for each catchment, with a lower Importance Factor of -10.0, and an upper Importance Factor of 10.0

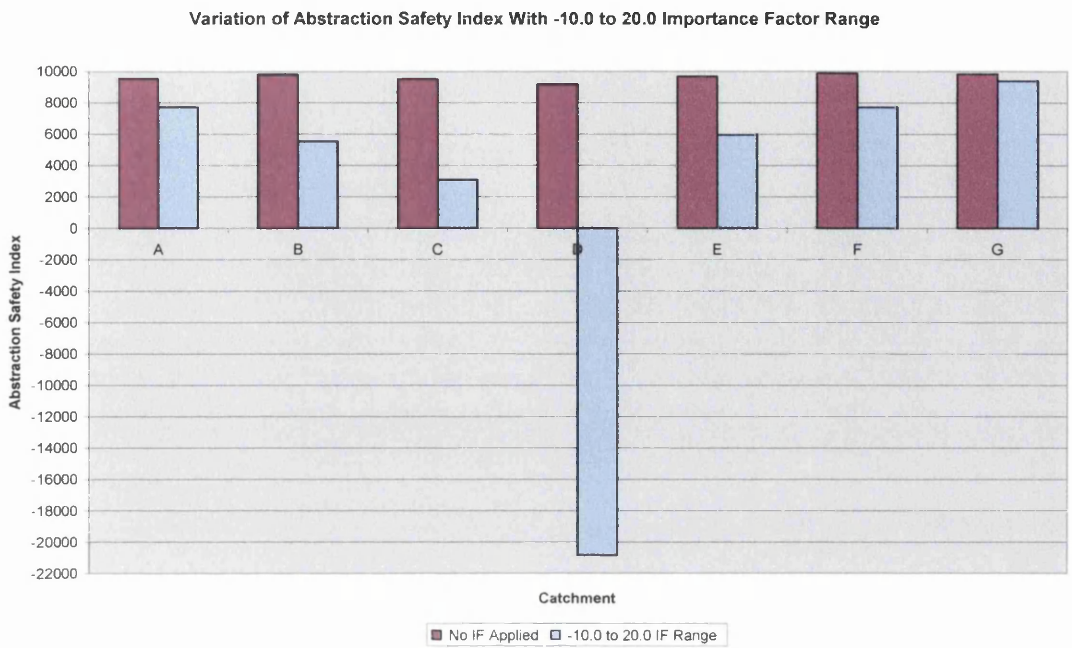


Figure 69: A graphical presentation of some of the data given in Table 52, showing the variation of ASI calculated for each catchment, with a lower Importance Factor of -10.0, and an upper Importance Factor of 20.0

CATCHMENT	NO IF APPLIED	IMPORTANCE FACTOR RANGE			
		-20.0 TO 2.0 IF RANGE	-20.0 TO 5.0 IF RANGE	-20.0 TO 10.0 IF RANGE	-20.0 TO 20.0 IF RANGE
A	9530	24382	22885	20390	15400
B	9787	14056	13030	11320	7900
C	9499	22380	20310	16860	9960
D	9179	14402	9185	490	-16900
E	9677	18526	17215	15030	10660
F	9883	8378	12210	11240	9300
G	9839	15884	15320	8746	12500

Table 73: Variation of ASI calculated for each catchment with differing upper Importance Factors, whilst keeping the lower Importance Factor the same at -20.0 in each case

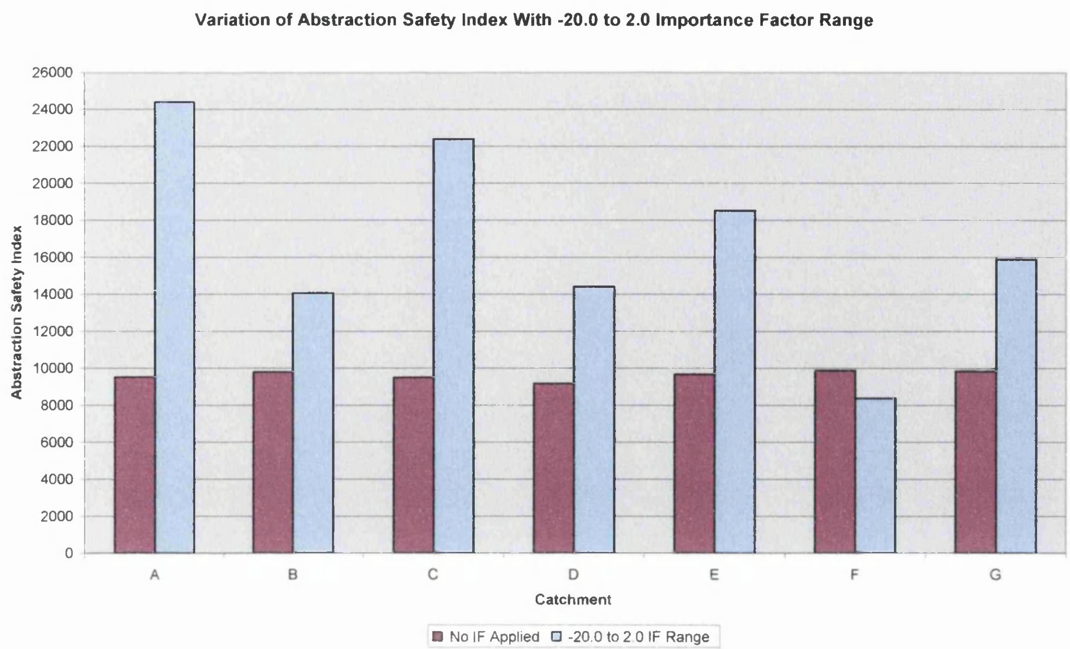


Figure 70: A graphical presentation of some of the data given in Table 53, showing the variation of ASI calculated for each catchment, with a lower Importance Factor of -20.0, and an upper Importance Factor of 2.0

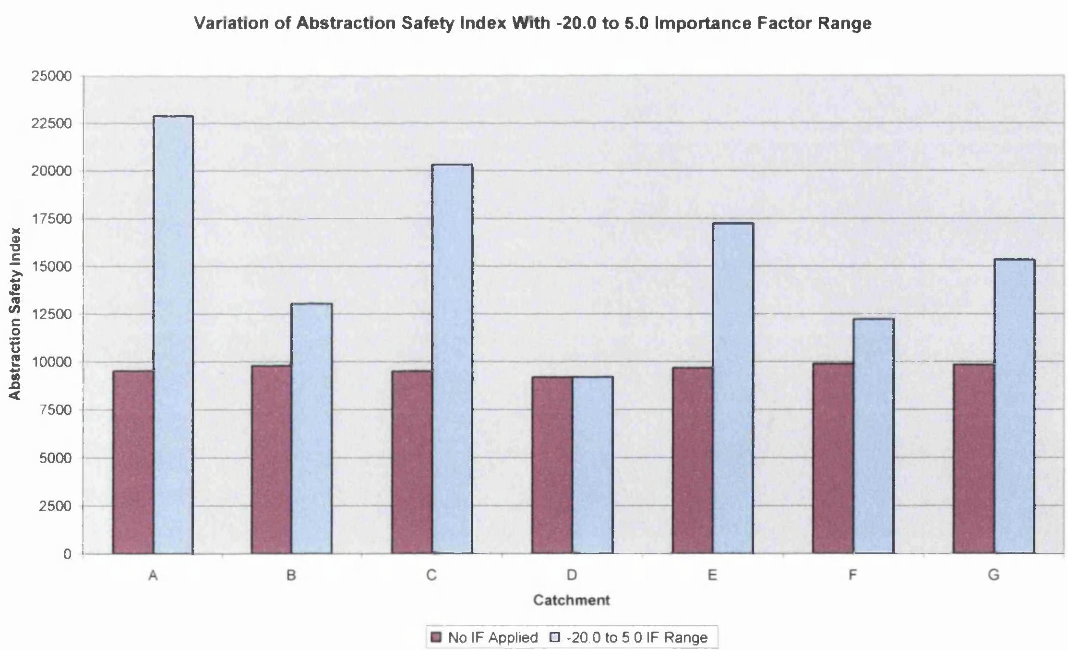


Figure 71: A graphical presentation of some of the data given in Table 53, showing the variation of ASI calculated for each catchment, with a lower Importance Factor of -20.0, and an upper Importance Factor of 5.0

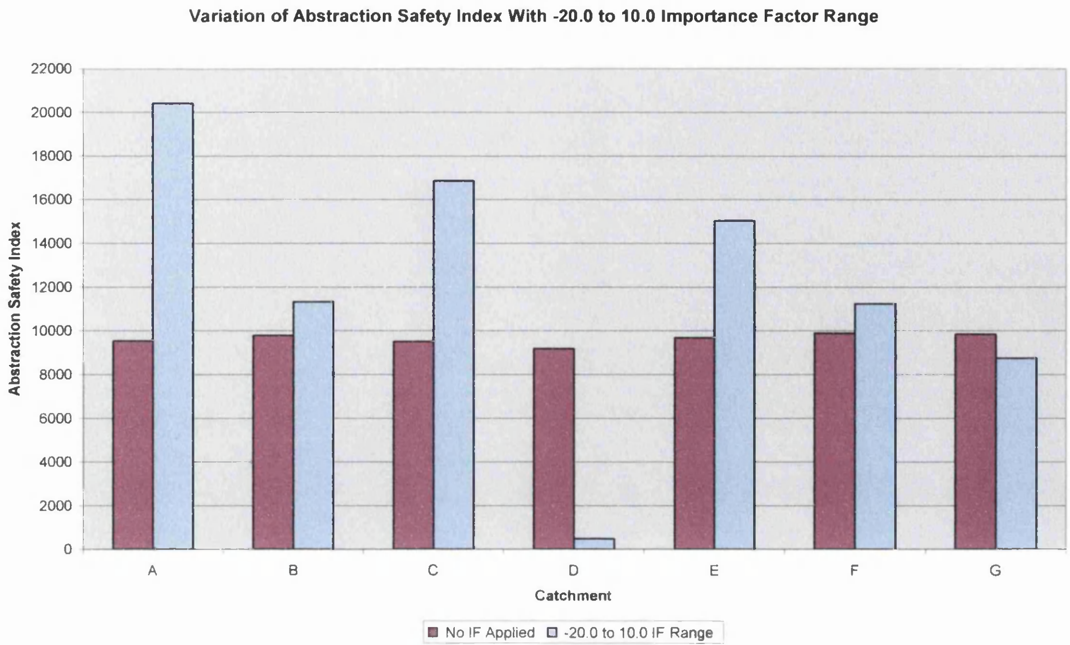


Figure 72: A graphical presentation of some of the data given in Table 53, showing the variation of ASI calculated for each catchment, with a lower Importance Factor of -20.0, and an upper Importance Factor of 10.0

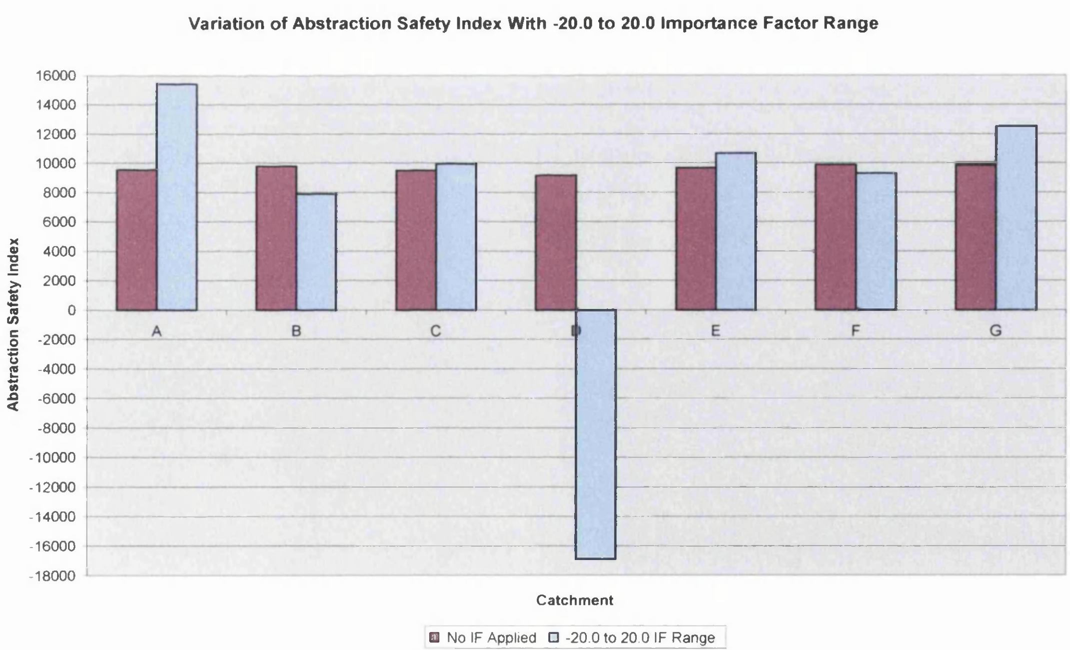


Figure 73: A graphical presentation of some of the data given in Table 53, showing the variation of ASI calculated for each catchment, with a lower Importance Factor of -20.0, and an upper Importance Factor of 20.0

In the following 16 Tables, the data presented in Table 74 to Table 89 inclusive are re-represented to show the percentage variation from the unweighted Abstraction Safety Index of the weighted Abstraction Safety Index for each variation of Importance Factor ranges.

CATCHMENT	NO IF APPLIED	-2.0 TO 2.0 IF RANGE	PERCENTAGE VARIATION	INCREASE OR DECREASE?
A	9530	10540	10.6%	Increase
B	9787	9790	0.0%	No change
C	9499	9996	5.2%	Increase
D	9179	7310	20.4%	Decrease
E	9677	10066	4.0%	Increase
F	9883	9930	0.5%	Increase
G	9839	10250	4.2%	Increase

Table 74: Percentage variation from the median Importance Factor (i.e. 1.0) with a lower Importance Factor of -2.0 and an upper Importance Factor of 2.0

CATCHMENT	NO IF APPLIED	-2.0 TO 5.0 IF RANGE	PERCENTAGE VARIATION	INCREASE OR DECREASE?
A	9530	9043	5.1%	Decrease
B	9787	8764	10.5%	Decrease
C	9499	7926	16.6%	Decrease
D	9179	2093	77.2%	Decrease
E	9677	8755	9.5%	Decrease
F	9883	9348	5.4%	Decrease
G	9839	9686	1.6%	Decrease

Table 75: Percentage variation from the median Importance Factor (i.e. 1.0) with a lower Importance Factor of -2.0 and an upper Importance Factor of 5.0

CATCHMENT	NO IF APPLIED	-2.0 TO 10.0 IF RANGE	PERCENTAGE VARIATION	INCREASE OR DECREASE?
A	9530	6548	31.3%	Decrease
B	9787	7054	27.9%	Decrease
C	9499	4476	52.9%	Decrease
D	9179	-6602	171.9%	Decrease
E	9677	6570	32.1%	Decrease
F	9883	8378	15.2%	Decrease
G	9839	8746	11.1%	Decrease

Table 76: Percentage variation from the median Importance Factor (i.e. 1.0) with a lower Importance Factor of -2.0 and an upper Importance Factor of 10.0

CATCHMENT	NO IF APPLIED	-2.0 TO 20.0 IF RANGE	PERCENTAGE VARIATION	INCREASE OR DECREASE?
A	9530	1558	83.7	Decrease
B	9787	3634	62.9	Decrease
C	9499	-2424	125.5	Decrease
D	9179	-23992	361.4	Decrease
E	9677	2200	77.3	Decrease
F	9883	6438	34.9	Decrease
G	9839	6866	30.2	Decrease

Table 77: Percentage variation from the median Importance Factor (i.e. 1.0) with a lower Importance Factor of -2.0 and an upper Importance Factor of 20.0

Catchment	No IF Applied	-5.0 to 2.0 IF Range	Percentage Variation	Increase or Decrease?
A	9530	12847	34.8%	Increase
B	9787	10501	7.3%	Increase
C	9499	12060	27.0%	Increase
D	9179	8492	7.5%	Decrease
E	9677	11476	18.6%	Increase
F	9883	10407	5.3%	Increase
G	9839	8746	11.1%	Decrease

Table 78: Percentage variation from the median Importance Factor (i.e. 1.0) with a lower Importance Factor of -5.0 and an upper Importance Factor of 2.0

Catchment	No IF Applied	-5.0 to 5.0 IF Range	Percentage Variation	Increase or Decrease?
A	9530	11350	19.1%	Increase
B	9787	9475	3.2%	Decrease
C	9499	9990	5.2%	Increase
D	9179	3275	64.3%	Decrease
E	9677	10165	5.0%	Increase
F	9883	8378	15.2%	Decrease
G	9839	10625	8.0%	Increase

Table 79: Percentage variation from the median Importance Factor (i.e. 1.0) with a lower Importance Factor of -5.0 and an upper Importance Factor of 5.0

CATCHMENT	NO IF APPLIED	-5.0 TO 10.0 IF RANGE	PERCENTAGE VARIATION	INCREASE OR DECREASE?
A	9530	8855	7.1%	Decrease
B	9787	7765	20.7%	Decrease
C	9499	6540	31.2%	Decrease
D	9179	-5420	159.0%	Decrease
E	9677	7980	17.5%	Decrease
F	9883	8855	10.4%	Decrease
G	9839	9685	1.6%	Decrease

Table 80: Percentage variation from the median Importance Factor (i.e. 1.0) with a lower Importance Factor of -5.0 and an upper Importance Factor of 10.0

CATCHMENT	NO IF APPLIED	-5.0 TO 20.0 IF RANGE	PERCENTAGE VARIATION	INCREASE OR DECREASE?
A	9530	3865	59.4%	Decrease
B	9787	4345	55.6%	Decrease
C	9499	-360	103.8%	Decrease
D	9179	-22810	348.5%	Decrease
E	9677	3610	62.7%	Decrease
F	9883	6915	30.0%	Decrease
G	9839	7805	20.7%	Decrease

Table 81: Percentage variation from the median Importance Factor (i.e. 1.0) with a lower Importance Factor of -5.0 and an upper Importance Factor of 20.0

Catchment	No IF Applied	-10.0 to 2.0 IF Range	Percentage Variation	Increase or Decrease?
A	9530	16692	75.2%	Increase
B	9787	11686	19.4%	Increase
C	9499	15500	63.2%	Increase
D	9179	10462	14.0%	Increase
E	9677	13826	42.9%	Increase
F	9883	11202	13.3%	Increase
G	9839	12754	29.6%	Increase

Table 82: Percentage variation from the median Importance Factor (i.e. 1.0) with a lower Importance Factor of -10.0 and an upper Importance Factor of 2.0

Catchment	No IF Applied	-10.0 to 5.0 IF Range	Percentage Variation	Increase or Decrease?
A	9530	15195	59.4%	Increase
B	9787	10660	8.9%	Increase
C	9499	13430	41.4%	Increase
D	9179	5245	42.9%	Decrease
E	9677	12515	29.3%	Increase
F	9883	10620	7.5%	Increase
G	9839	12190	23.9%	Increase

Table 83: Percentage variation from the median Importance Factor (i.e. 1.0) with a lower Importance Factor of -10.0 and an upper Importance Factor of 5.0

Catchment	No IF Applied	-10.0 to 10.0 IF Range	Percentage Variation	Increase or Decrease?
A	9530	12700	33.3%	Increase
B	9787	8950	8.6%	Decrease
C	9499	9980	5.1%	Increase
D	9179	-3450	137.6%	Decrease
E	9677	10330	6.7%	Increase
F	9883	8378	15.2%	Decrease
G	9839	11250	14.3%	Increase

Table 84: Percentage variation from the median Importance Factor (i.e. 1.0) with a lower Importance Factor of -10.0 and an upper Importance Factor of 10.0

Catchment	No IF Applied	-10.0 to 20.0 IF Range	Percentage Variation	Increase or Decrease?
A	9530	7710	19.1%	Decrease
B	9787	5530	43.5%	Decrease
C	9499	3080	67.6%	Decrease
D	9179	-20840	327.0%	Decrease
E	9677	5960	38.4%	Decrease
F	9883	7710	22.0%	Decrease
G	9839	9370	4.8%	Decrease

Table 85: Percentage variation from the median Importance Factor (i.e. 1.0) with a lower Importance Factor of -10.0 and an upper Importance Factor of 20.0

CATCHMENT	NO IF APPLIED	-20.0 TO 2.0 IF RANGE	PERCENTAGE VARIATION	INCREASE OR DECREASE?
A	9530	24382	155.8%	Increase
B	9787	14056	43.6%	Increase
C	9499	22380	135.6%	Increase
D	9179	14402	56.9%	Increase
E	9677	18526	91.4%	Increase
F	9883	8378	15.2%	Decrease
G	9839	15884	61.4%	Increase

Table 86: Percentage variation from the median Importance Factor (i.e. 1.0) with a lower Importance Factor of -20.0 and an upper Importance Factor of 2.0

CATCHMENT	NO IF APPLIED	-20.0 TO 5.0 IF RANGE	PERCENTAGE VARIATION	INCREASE OR DECREASE?
A	9530	22885	140.1%	Increase
B	9787	13030	33.1%	Increase
C	9499	20310	113.8%	Increase
D	9179	9185	0.1%	Increase
E	9677	17215	77.9%	Increase
F	9883	12210	23.5%	Increase
G	9839	15320	55.7%	Increase

Table 87: Percentage variation from the median Importance Factor (i.e. 1.0) with a lower Importance Factor of -20.0 and an upper Importance Factor of 5.0

CATCHMENT	NO IF APPLIED	-20.0 TO 10.0 IF RANGE	PERCENTAGE VARIATION	INCREASE OR DECREASE?
A	9530	20390	114.0%	Increase
B	9787	11320	15.7%	Increase
C	9499	16860	77.5%	Increase
D	9179	490	94.7%	Decrease
E	9677	15030	55.3%	Increase
F	9883	11240	13.7%	Increase
G	9839	8746	11.1%	Decrease

Table 88: Percentage variation from the median Importance Factor (i.e. 1.0) with a lower Importance Factor of -20.0 and an upper Importance Factor of 10.0

CATCHMENT	NO IF APPLIED	-20.0 TO 20.0 IF RANGE	PERCENTAGE VARIATION	INCREASE OR DECREASE?
A	9530	15400	61.6%	Increase
B	9787	7900	19.3%	Decrease
C	9499	9960	4.9%	Increase
D	9179	-16900	284.1%	Decrease
E	9677	10660	10.2%	Increase
F	9883	9300	5.9%	Decrease
G	9839	12500	27.0%	Increase

Table 89: Percentage variation from the median Importance Factor (i.e. 1.0) with a lower Importance Factor of -20.0 and an upper Importance Factor of 20.0

26.5 Discussion

As mentioned in Section 26.1 this third methodology is only a presentational variation of the second one, and this is borne out in the results obtained; all percentage variations of the weighted value from the respective unweighted value for all catchments for all Importance Ranges obtained using both the second and the third methodologies are identical. Therefore, by applying the objectives stated in Section 24.3 and Section 25.3, and by following the same process established in Section 25.5, by discarding those ranges of Importance Factors that have produced inappropriate results, it was that that the same four ranges that were left in Section 25.5 (-2.0 to 2.0, -5.0 to 5.0, -10.0 to 10.0 and -20.0 to 20.0) should also be obtained here.

Therefore, starting with the first of these objectives (to ensure that the weighted Abstraction Safety Index values remained within the boundary values of 10,000 and 0 respectively), the following ranges can now be discarded, as they gave rise to some weighted values greater than the upper boundary value of 10,000, or less than the lower boundary value of 0:

- -2.0 to 2.0;
- -2.0 to 10.0;
- -2.0 to 20.0;
- -5.0 to 2.0;
- -5.0 to 5.0;
- -5.0 to 10.0;
- -5.0 to 20.0;
- -10.0 to 20.0;
- -10.0 to 5.0;
- -10.0 to 10.0;
- -10.0 to 20.0;
- -20.0 to 2.0;
- -20.0 to 5.0;
- -20.0 to 10.0; and
- -20.0 to 20.0.

Consequently, only one range is left after considering this first objective: -2.0 to 5.0. However, when the second of the objectives (to ensure application of the Importance Factors did not simply universally increase or decrease the weighted Abstraction Safety Index values; instead, the aim was to demonstrate, in an easily accessible manner, both the positive and negative impacts of the Importance Factors on the final values), this range must also be discarded, as it gave rise to weighted values that were universally less than the unweighted values.

This result was rather surprising, particularly bearing in mind all percentage variations of the weighted value from the respective unweighted value for all catchments for all Importance Ranges obtained using both the second and the third methodologies are identical. However, when the objectives as stated were applied, the results obtained were significantly different than when they were applied using results obtained from the second methodology; consequently, this means that this third methodology is not fit for purpose and should be abandoned. This is not a huge loss, as only one stakeholder requested that the Abstraction Safety Index should be expressed as a numeral; the vast majority of stakeholders found the expression of weighted values as percentages to be more meaningful and far easier to interpret. Therefore, only the second methodology shall be used when undertaking the investigations detailed in Chapter 27.

27 USING THE ABSTRACTION SAFETY INDEX FOR INVESTIGATIVE PURPOSES

27.1 Introduction

In the previous three Chapters the Abstraction Safety Index was used to evaluate the current environmental water quality of seven catchments, and to express that quality as a single figure, thus enabling these catchments to be ranked, and for capital investment and improvement programmes to be prioritised.

Where the Abstraction Safety Index methodology really comes into its own is that it can also be used for investigative purposes, in order to predict the likely impact of proposed capital investment and improvement programmes, before any money has been spent, or any programmes have been implemented. This is believed to be a first for the UK water industry (or indeed, anywhere else in the world), in that no water company or regulator is using a risk assessment-based methodology to predict the impact of proposed changes within a catchment and, even more significantly, to quantify the impact of those changes.

After the iterations presented in the previous three Chapters, I decided in Section 25.5 that the second methodology only should be used for the purposes of this Chapter, and that only the Importance Factor range -5.0 to 5.0 should be used, as this had proved to be the most sensitive.

27.2 Alternative Scenarios

In order to illustrate the usefulness of this alternative use of the index, in this Chapter the same seven catchments have been used, but their environmental water quality has been assessed against eight alternative conceptual scenarios, each of which are summarised in the following sub-sections; some of these scenarios have been suggested either by stakeholders or myself in the conclusions in the preceding four Parts of this thesis, and they are included here in order to explore the merit of them.

For each scenario, the exact same risk assessment matrix that was used in the previous three methodologies has again been utilised here for consistency, so in each case a risk assessment has been undertaken of all the hazardous events in the 11 hazard (or parameter) groups, by considering the new legal and/or institutional models, and/or the impacts the new scenarios have on the previous values assigned for the 'likelihood' and 'severity' for each hazardous event under the current conditions for each catchment.

Hazard	Source of Hazard	Risk (Before Importance Factors are Applied)		
		Likelihood	Severity	Magnitude of Risk
Herbicides	Spraying of road margins & central reservations	1	2	2
	Spraying of railway margins	2	2	4
	Dumping/flytipping	3	3	9
	Forestry activities	1	2	2
	Domestic use	2	3	6
	Agricultural use	4	2	8
Pesticides & insecticides	Domestic use	2	3	6
	Forestry activities	1	2	2
	Agricultural use	3	2	6
	Dumping/flytipping	3	3	9
	Spraying of agricultural land	3	2	6
Hydrocarbons	Run-off from roads	3	2	6
	Agricultural storage tanks	2	2	4
	Aquatic leisure & tourism activities (eg boating)	1	2	2
	Other storage tanks (local authority etc)	2	2	4
	Building/development sites	4	2	8
	Accidents/spillages	4	4	16

Figure 74: An extract from the Abstraction Safety Index spreadsheet used for the alternative scenarios, showing the turquoise shading utilised to highlight changes in the 'likelihood' and 'severity' values

The construction of the spreadsheet used to calculate the Abstraction Safety Index for each scenario is exactly the same as before, with one slight modification for clarification purposes. For some of the eight alternative scenarios, the previous values assigned for the 'likelihood' and 'severity' for each hazardous event have been revised in order to take into account the changed circumstances of the alternative scenario being considered; in these instances, turquoise shading has been utilised in order to highlight these revisions for ease of reference, as shown in Figure 74.

27.2.1 Wales Organic Strategy

Agriculture and horticulture are devolved matters for the Welsh Assembly Government (see Section 3.2.3), and currently farmers and growers can opt for either the organic route or the alternative traditional fertilizer and pesticide intensive one. What this scenario considers is the imposition by the Welsh Assembly Government of a mandatory blanket policy of an organic-only agricultural and horticultural industry within Wales, using its existing powers, and the impact such a policy would have on environmental water quality. The output of farmers and growers would undoubtedly fall, but organic produce currently attracts a financial premium, so it is possible that the farmers and growers' income would not change appreciably as a result of the adoption of this policy.

No changes to other areas have been considered, so the institutional, legal and voluntary models all remain the same.

27.2.2 Countryside Stewardship Strategy for Wales

This scenario can be viewed as an extreme extension of the previous one; with an organic strategy, agriculture and horticulture is still permitted, but within this scenario it has been banned completely. It has its roots in an anonymous suggestion by a senior manager within a national regulator, which was that agriculturalists and horticulturalists within Wales could stop farming and growing, and instead be paid to care for the land, in the role of countryside stewards. Again, this scenario considers the imposition by the Welsh Assembly Government of such a mandatory blanket policy using its existing powers.

No changes to other areas have been considered, so the institutional, legal and voluntary models all remain the same.

27.2.3 UK-Wide 'Environment Commission'

In Section 5.11 I suggested that the Forestry Commission model could be adapted to deliver environmental policy throughout Great Britain (or even the wider UK). This scenario therefore considers the development of a UK-wide 'Environment Commission', which could ensure that European Directives were implemented consistently and appropriately (and which would help overcome any trans-boundary issues) whilst, for example, 'Environment Wales' and 'Environment England' would deliver the policies of the devolved administrations.

No changes to other institutions have been considered, and the legal and voluntary models both remain the same.

27.2.4 Slimmed-Down Model for the Environment Agency

In Section 5.11.2 I suggested that some of the EA's current operational activities should be passed to other existing bodies – such as the Countryside Council for Wales, Natural England, and British Waterways – so that the resultant slimmed-down EA can focus purely on regulation, and avoid charges of acting as both 'poacher' and 'gamekeeper'; this scenario therefore considers such a change in the structure and areas of responsibility of these organisations.

No changes to other institutions have been considered, and the legal and voluntary models both remain the same.

27.2.5 Replacing the Environment Agency with a National Rivers Authority-Type Regulator

In Section 12.8.1 I reviewed the NRA's Catchment Management Plans, and in Chapter 15 I concluded that protection of catchments had arguably been progressively weakened since the demise of the NRA. I therefore thought it would be useful to consider what effect a modern-day NRA-type regulator would have on environmental quality, hence the inclusion of this scenario.

No changes to other institutions have been considered, and the legal and voluntary models both remain the same.

27.2.6 Water Companies Responsible for Catchment Management

Another anonymous suggestion by a senior manager within a national regulator was that water companies should be made responsible for catchment management, as it would be they who would gain the greatest benefit from this. Controversially, it was suggested that there should be no additional monies made available for this via the Periodic Review, and that water companies should pay for all catchment management initiatives out of their pre-existing operational budgets.

No changes to other areas have been considered, so the institutional, legal and voluntary models all remain the same.

27.2.7 Local Authorities Responsible for Catchment Management

As an alternative to the previous scenario, I then considered whether local authorities instead should be made responsible for catchment management. The advantage here is that local authorities are already responsible for planning control and environmental health, and – more importantly – they also have pre-existing powers of enforcement (which water companies do not, outside of the narrowly focussed Water Supply (Water Fittings) Regulations 1999 (see Section 10.11)); consequently, it would be far easier for local authorities to enforce policies that were sympathetic to the aims of catchment management than water companies. This would also reinforce their current responsibilities for monitoring and protecting the quality of private water supplies.

No changes to other areas have been considered, so the institutional, legal and voluntary models all remain the same.

27.2.8 Catchment Management Strategy for Wales

As a logical progression from the previous scenarios, I then considered whether the implementation of a Wales-wide catchment management strategy (or even a national catchment management strategy, as first suggested in Chapter 15) would be appropriate. Appropriate changes to Acts of Parliament and regulations have been considered as a result, although for the purposes of this scenario it was envisaged that the delivery of such a strategy could be achieved by means of the current institutional and voluntary models.

27.3 Results

The result arising from the consideration of each of the eight alternative scenarios are presented in Table 90 to Table 97 inclusive.

Catchment	No IF Applied (current scenario)	No IF Applied (alternative scenario)	Percentage Variation of Alternative Scenario from Current Scenario (No IF applied)	Increase or Decrease?
A	75.9%	80.5%	6.0%	Increase
B	89.1%	89.1%	0.0%	No change
C	74.3%	78.6%	5.7%	Increase
D	57.9%	60.2%	3.9%	Increase
E	83.4%	86.5%	3.6%	Increase
F	94.0%	94.8%	0.9%	Increase
G	91.7%	94.6%	3.1%	Increase
Catchment	**-5.0 to 5.0 IF Range (current scenario)**	**-5.0 to 5.0 IF Range (alternative scenario)**	**Percentage Variation of Alternative Scenario from Current Scenario (No IF applied)**	**Increase or Decrease?**
A	78.0%	82.3%	5.6%	Increase
B	88.1%	88.1%	0.0%	No change
C	74.3%	78.0%	5.1%	Increase
D	48.9%	52.4%	5.0%	Increase
E	83.7%	86.2%	3.0%	Increase
F	90.9%	92.4%	1.6%	Increase
G	92.9%	94.5%	1.7%	Increase

Table 90: Unweighted and weighted (using the -5.0 to 5.0 Importance Factor range) Abstraction Safety Index values obtained from the second methodology and using the Wales organic strategy scenario

Catchment	No IF Applied (current scenario)	No IF Applied (alternative scenario)	Percentage Variation of Alternative Scenario from Current Scenario (No IF applied)	Increase or Decrease?
A	75.9%	82.6%	8.8%	Increase
B	89.1%	90.6%	1.7%	Increase
C	74.3%	80.5%	8.3%	Increase
D	57.9%	60.6%	4.6%	Increase
E	83.4%	87.6%	5.0%	Increase
F	94.0%	95.3%	1.4%	Increase
G	91.7%	95.1%	3.7%	Increase
Catchment	**-5.0 to 5.0 IF Range (current scenario)**	**-5.0 to 5.0 IF Range (alternative scenario)**	**Percentage Variation of Alternative Scenario from Current Scenario (No IF applied)**	**Increase or Decrease?**
A	78.0%	84.8%	8.7%	Increase
B	88.1%	90.0%	2.1%	Increase
C	74.3%	80.1%	7.9%	Increase
D	49.9%	52.9%	6.1%	Increase
E	83.7%	87.6%	4.6%	Increase
F	90.9%	93.3%	2.6%	Increase
G	92.9%	95.4%	2.7%	Increase

Table 91: Unweighted and weighted (using the -5.0 to 5.0 Importance Factor range) Abstraction Safety Index values obtained from the second methodology and using the countryside stewardship strategy for Wales scenario

Catchment	No IF Applied (current scenario)	No IF Applied (alternative scenario)	Percentage Variation of Alternative Scenario from Current Scenario (no IF applied)	Increase or Decrease?
A	75.9%	75.9%	0.0%	No change
B	89.1%	89.1%	0.0%	No change
C	74.3%	74.3%	0.0%	No change
D	57.9%	57.9%	0.0%	No change
E	83.4%	83.4%	0.0%	No change
F	94.0%	94.0%	0.0%	No change
G	91.7%	91.7%	0.0%	No change
Catchment	-5.0 to 5.0 IF Range (current scenario)	-5.0 to 5.0 IF Range (alternative scenario)	Percentage Variation of Alternative Scenario from Current Scenario (no IF applied)	Increase or Decrease?
A	78.0%	79.9%	2.4%	Increase
B	88.1%	89.1%	1.1%	Increase
C	74.3%	76.5%	2.9%	Increase
D	49.9%	65.9%	32.0%	Increase
E	83.7%	85.4%	2.1%	Increase
F	90.9%	94.5%	4.0%	Increase
G	92.9%	94.0%	1.2%	Increase

Table 92: Unweighted and weighted (using the -5.0 to 5.0 Importance Factor range) Abstraction Safety Index values obtained from the second methodology and using the UK-wide 'Environment Commission' scenario

Catchment	No IF Applied (current scenario)	No IF Applied (alternative scenario)	Percentage Variation of Alternative Scenario from Current Scenario (no IF applied)	Increase or Decrease?
A	75.9%	75.9%	0.0%	No change
B	89.1%	89.1%	0.0%	No change
C	74.3%	74.3%	0.0%	No change
D	57.9%	57.9%	0.0%	No change
E	83.4%	83.4%	0.0%	No change
F	94.0%	94.0%	0.0%	No change
G	91.7%	91.7%	0.0%	No change
Catchment	**-5.0 to 5.0 IF Range (current scenario)**	**-5.0 to 5.0 IF Range (alternative scenario)**	**Percentage Variation of Alternative Scenario from Current Scenario (no IF applied)**	**Increase or Decrease?**
A	78.0%	81.3%	4.3%	Increase
B	88.1%	89.8%	1.9%	Increase
C	74.3%	77.9%	4.8%	Increase
D	49.9%	66.7%	33.6%	Increase
E	83.7%	86.6%	3.4%	Increase
F	90.9%	94.9%	4.4%	Increase
G	92.9%	92.9%	0.0%	No change

Table 93: Unweighted and weighted (using the -5.0 to 5.0 Importance Factor range) Abstraction Safety Index values obtained from the second methodology and using the slimmed-down model for the Environment Agency scenario

Catchment	No IF Applied (current scenario)	No IF Applied (alternative scenario)	Percentage Variation of Alternative Scenario from Current Scenario (no IF applied)	Increase or Decrease?
A	75.9%	75.9%	0.0%	No change
B	89.1%	89.1%	0.0%	No change
C	74.3%	74.3%	0.0%	No change
D	57.9%	57.9%	0.0%	No change
E	83.4%	83.4%	0.0%	No change
F	94.0%	94.0%	0.0%	No change
G	91.7%	91.7%	0.0%	No change
Catchment	-5.0 to 5.0 IF Range (current scenario)	-5.0 to 5.0 IF Range (alternative scenario)	Percentage Variation of Alternative Scenario from Current Scenario (no IF applied)	Increase or Decrease?
A	78.0%	94.9%	21.7%	Increase
B	88.1%	90.1%	2.2%	Increase
C	74.3%	78.4%	5.6%	Increase
D	49.9%	67.4%	35.0%	Increase
E	83.7%	86.5%	3.4%	Increase
F	90.9%	95.0%	4.5%	Increase
G	92.9%	94.9%	2.1%	Increase

Table 94: Unweighted and weighted (using the -5.0 to 5.0 Importance Factor range) Abstraction Safety Index values obtained from the second methodology and using the National Rivers Authority-type regulator scenario

CATCHMENT	NO IF APPLIED (CURRENT SCENARIO)	NO IF APPLIED (ALTERNATIVE SCENARIO)	PERCENTAGE VARIATION OF ALTERNATIVE SCENARIO FROM CURRENT SCENARIO (NO IF APPLIED)	INCREASE OR DECREASE?
A	75.9%	81.1%	6.9%	Increase
B	89.1%	90.2%	1.3%	Increase
C	74.3%	79.9%	7.6%	Increase
D	57.9%	66.3%	14.4%	Increase
E	83.4%	85.6%	2.6%	Increase
F	94.0%	94.6%	0.6%	Increase
G	91.7%	94.4%	2.9%	Increase
CATCHMENT	-5.0 TO 5.0 IF RANGE (CURRENT SCENARIO)	-5.0 TO 5.0 IF RANGE (ALTERNATIVE SCENARIO)	PERCENTAGE VARIATION OF ALTERNATIVE SCENARIO FROM CURRENT SCENARIO (NO IF APPLIED)	INCREASE OR DECREASE?
A	78.0%	84.0%	7.7%	Increase
B	88.1%	89.8%	1.9%	Increase
C	74.3%	80.0%	8.8%	Increase
D	49.9%	71.3%	42.9%	Increase
E	83.7%	86.3%	3.1%	Increase
F	90.9%	94.8%	4.4%	Increase
G	92.9%	94.9%	2.1%	Increase

Table 95: Unweighted and weighted (using the -5.0 to 5.0 Importance Factor range) Abstraction Safety Index values obtained from the second methodology and using the water companies responsible for catchment management scenario

Catchment	No IF Applied (Current Scenario)	No IF Applied (Alternative Scenario)	Percentage Variation of Alternative Scenario from Current Scenario (No IF Applied)	Increase or Decrease?
A	75.9%	79.7%	5.0%	Increase
B	89.1%	89.5%	0.5%	Increase
C	74.3%	77.1%	3.7%	Increase
D	57.9%	63.8%	10.2%	Increase
E	83.4%	85.2%	2.1%	Increase
F	94.0%	94.4%	0.4%	Increase
G	91.7%	93.7%	2.1%	Increase
Catchment	-5.0 to 5.0 IF Range (Current Scenario)	-5.0 to 5.0 IF Range (Alternative Scenario)	Percentage Variation of Alternative Scenario from Current Scenario (No IF Applied)	Increase or Decrease?
A	78.0%	83.9%	7.6%	Increase
B	88.1%	90.0%	2.1%	Increase
C	74.3%	79.9%	7.6%	Increase
D	49.9%	73.3%	46.8%	Increase
E	83.7%	87.2%	4.2%	Increase
F	90.9%	95.2%	4.7%	Increase
G	92.9%	95.1%	2.4%	Increase

Table 96: Unweighted and weighted (using the -5.0 to 5.0 Importance Factor range) Abstraction Safety Index values obtained from the second methodology and using the local authorities responsible for catchment management scenario

Catchment	No IF Applied (current scenario)	No IF Applied (alternative scenario)	Percentage Variation of Alternative Scenario from Current Scenario (No IF applied)	Increase or Decrease?
A	75.9%	79.7%	5.0%	Increase
B	89.1%	89.8%	0.8%	Increase
C	74.3%	77.5%	4.3%	Increase
D	57.9%	70.6%	22.0%	Increase
E	83.4%	85.2%	2.1%	Increase
F	94.0%	94.4%	0.4%	Increase
G	91.7%	93.7%	2.1%	Increase
Catchment	-5.0 to 5.0 IF Range (current scenario)	-5.0 to 5.0 IF Range (alternative scenario)	Percentage Variation of Alternative Scenario from Current Scenario (No IF applied)	Increase or Decrease?
A	78.0%	86.3%	10.6%	Increase
B	88.1%	91.5%	3.9%	Increase
C	74.3%	82.3%	10.8%	Increase
D	49.9%	77.9%	56.0%	Increase
E	83.7%	88.5%	5.7%	Increase
F	90.9%	95.9%	5.5%	Increase
G	92.9%	95.9%	3.2%	Increase

Table 97: Unweighted and weighted (using the -5.0 to 5.0 Importance Factor range) Abstraction Safety Index values obtained from the second methodology and using the catchment management strategy for Wales scenario

27.4 Discussion

Taking each scenario in turn, environmental water quality was at least the same as it would be under current conditions or, in the vast majority of cases, improvements in the Abstraction Safety Index values were recorded.

In the following sub-sections, the impacts on the Abstraction Safety Index values for each scenario are considered in turn.

27.4.1 Wales Organic Strategy

Because the adoption of an organic strategy for Wales would have an effect on the values obtained for both the 'likelihood' and 'severity' elements of the risk assessment for each catchment – with particular reference to those parameters intimately associated with agriculture and horticulture, such as nutrients, pathogens, and suspended solids – modest improvements were recorded in the Abstraction Safety Index for all catchments apart from catchment 'B', before the Importance Factors were applied; broadly comparable improvements in the values were obtained after they were applied.

Rather interestingly, similar increases were obtained for catchments 'A', 'C' and 'D'. The first two of these three catchments are of a similar agriculture nature, whilst catchment 'D' contains a combination of mixed agriculture and is heavily industrialised, and is consequently the most polluted of all the seven catchments being considered. However, these similar increases can be rationalised because the adoption of an organic strategy would have little impact on the industrialised element of a catchment.

What is perhaps more surprising though is that this scenario had no effect on the value for catchment 'B', either before or after the Importance Factors were applied; perhaps this is because the agricultural influence on environmental water quality within this catchment is minimal compared to catchments 'A' and 'D'.

27.4.2 Countryside Stewardship Strategy for Wales

For the same reason as the one noted for the Wales organic strategy scenario, the values obtained for both the 'likelihood' and 'severity' elements of the risk assessment for each catchment – with particular reference the nutrients, pathogens, and suspended solids parameters – are lower, but significantly more so than for the previous scenario because agricultural and horticultural activities have ceased completely; hence the values obtained for the Abstraction Safety Index for all catchments, prior to the application of the Importance Factors, are proportionately higher for this scenario than the previous one. As this scenario is a more extreme version of the previous one, this is as I would have expected.

Again, logic dictates that an improvement should be observed in the values obtained for catchment 'B' as, even though the agricultural impact on environmental water quality was minimal, the impact was still adverse and measurable; this was borne out in practice. The percentage improvements for catchment 'B' are comparable to both the private water supply catchments, catchment 'F' and catchment 'G', where the agricultural impacts are both similarly minimal.

27.4.3 UK-Wide 'Environment Commission'

As this scenario is only concerned with changes to the regulatory model (i.e. a revision of the current structure and responsibilities of the EA), the risk assessment for each catchment remained the same for the alternative scenario, so no changes in the values for the Abstraction Safety Index were either expected, or obtained, prior to the application of the Importance Factors.

Again, modest improvements were obtained for all catchments bar one in the Abstraction Safety Index values after the application of the Importance Factors; the most significant improvement was registered for catchment 'D', which is the most polluted of the seven catchments. It could be interpreted that this result was obtained because the adoption of an approach to environmental regulation along similar lines to the management of our national forestry reserves affords much greater protection over a wide environmental spectrum (i.e. spanning agricultural, horticultural, industrial, commercial and domestic activities) than that of the current structure of the EA.

27.4.4 Slimmed-Down Model for the Environment Agency

For the same reason as that put forward for the previous scenario, no changes in the values for the Abstraction Safety Index were either expected, or obtained, prior to the application of the Importance Factors.

However, after the Importance Factors had been applied, very similar results were obtained for the scenario of a slimmed-down model for the EA as for the previous scenario.

27.4.5 Replacing the Environment Agency with a National Rivers Authority-Type Regulator

Again, this scenario is only considering a change to the regulatory model, and so it has no impact on the risk assessment for each catchment, which is reflected in the unchanged Abstraction Safety Index values, before the Importance Factors are applied, obtained for the current scenario and the alternative scenario.

After the Importance Factors had been applied, very similar results were obtained for this scenario as for the previous two alternative regulatory models, with the exception of catchment ‘A’, where the improvement is particularly extreme. One possible interpretation of the results of these three alternative scenarios is that the current regulatory model is not fit-for-purpose, and a thorough review of the EA’s structure and responsibilities is appropriate.

27.4.6 Water Companies Responsible for Catchment Management

By making water companies responsible for catchment management, this has a similar effect on the values obtained for both the ‘likelihood’ and ‘severity’ elements of the risk assessment for each catchment, as for the first two scenarios considered (the Wales organic strategy, and the countryside stewardship strategy).

The application of the Importance Factors only has a marginal effect on the Abstraction Safety Index values, with two exceptions; the percentage increase in the value for catchment 'F' for this scenario, when compared to the current situation, is approximately seven times greater after the Importance Factors have been applied than before, whilst for catchment 'D', the percentage increase is approximately three times after, than before.

As previously mentioned, catchment 'D' is the most polluted of the seven catchments, so it was to be expected that the most significant percentage variation (42.9%) of the alternative scenario from the current situation – in each case after the Importance Factors had been applied – was achieved for this catchment, as this one has the greatest potential for improvements to be made.

27.4.7 Local Authorities Responsible for Catchment Management

All results obtained for this scenario (both before and after the Importance Factors are applied) and the previous one are broadly the same. Even though the local authorities have greater resources and wider powers of enforcement, it would appear that these advantages are effectively cancelled out by the water companies' much more intimate knowledge and understanding of the workings of the water cycle, and the effects certain contaminants would have on environmental water quality.

27.4.8 Catchment Management Strategy for Wales

For this final scenario, the adoption of a Wales-wide catchment management strategy would have a positive effect on the values obtained for both the 'likelihood' and 'severity' elements of the risk assessment for each catchment, to a very similar extent as for the Wales organic strategy, countryside stewardship strategy, and the two catchment management scenarios.

What is most significant (as far as this Chapter is concerned, and the eight scenarios that have been presented as conceptual alternatives to the current situation) is that, taken as a whole, the percentage variation of the values obtained for the Abstraction Safety Index for each catchment, from the current situation to this alternative scenario, after the Importance Factors have been applied, is the greatest of all the scenarios considered. In particular, the two least polluted catchments – catchment 'F' and catchment 'G' – would be restored to a virtually pristine environment, as they both attain an Abstraction Safety Index of 95.9%, the highest value of any of the catchments considered under these eight alternative scenarios.

Of the eight scenarios considered in this Chapter, it is therefore this last one – the adoption of a catchment management strategy for Wales by the Welsh Assembly Government – that would have the greatest overall positive impact on environmental water quality.

28 CONCLUSIONS FROM PART 5

An introduction to the Abstraction Safety Index concept was presented in the first Chapter of this Part, and an overview of its potential applications to environmental stakeholders was given. Seven catchments were used to refine and calibrate the concept, and an anonymised overview of each one was given, along with a detailed catchment environmental assessment methodology that was constructed in order to obtain information relevant to each one.

Three separate Abstraction Safety Index methodologies were presented here, and subsequently tested using the information obtained for each of the seven catchments. As a result of this extensive calibration process, one methodology and one Importance Factor range were identified as being suitable for testing eight alternative conceptual scenarios.

From this research I have drawn the following conclusions (for ease of reference the Section to which each conclusion relates is given is brackets):

1) The Abstraction Safety Index concept can be used for benchmarking and as a performance indicator (Section 21.6).

2) Not only can the concept be used to enumerate the environmental water quality of catchments, but it is extremely useful in helping to prioritise both capital investment and action programmes (Section 21.6).

3) The catchment environmental assessment methodology has been demonstrated to be a robust tool for the standardised acquisition of data and information relating to the 'health' of catchments (Section 22.7).

4) The Abstraction Safety Index concept can be used to assess prevailing conditions within catchments, as well as being useful for forecasting purposes, as it can predict the likely impact of capital investment or action

programmes before any monies are spent, or any policies enacted (Section 27.1).

5) Using the forecasting capability of the Abstraction Safety Index concept, it has been proven that the adoption of any one of the eight conceptual alternative scenarios would improve the environmental quality of water within catchments in Wales (Section 27.4).

6) Leading on from the previous conclusion, several of the alternative scenarios prove that the current regulatory model is not fit-for-purpose, and a thorough review of the EA's structure and responsibilities is appropriate; such a review could be undertaken by either DEFRA or the Welsh Assembly Government, or by both bodies jointly (Section 27.4).

7) In order to achieve the most significant improvements in environmental water quality within catchments throughout Wales, the Welsh Assembly Government should consider the adoption of a Wales-wide catchment management strategy, using its pre-existing powers (Section 27.4.8).

PART 6 ILLUSTRATIVE EXAMPLES OF THE ABSTRACTION SAFETY INDEX CALCULATIONS

29 CALCULATION OF THE ABSTRACTION SAFETY INDEX FOR CATCHMENT D USING THE FIRST METHODOLOGY

Hazard	Source of Hazard	Risk (Before Importance Factors are Applied)			Importance of Each Factor Influencing the Final Risk Posed by the Hazard				
		Likelihood	Severity	Magnitude of Risk	Organisational Ability	Available Information	Legal Framework	Codes of Practice & Other Voluntary Arrangements	Customer Expectation
Herbicides	Spraying of road margins & central reservations	1	2	2	1	1	1	2	2
	Spraying of railway margins	2	3	6	1	1	1	2	2
	Dumping/flytipping	3	3	9	1	1	1	2	1
	Forestry activities	1	2	2	2	2	1	2	1
	Domestic use	2	3	6	2	2	2	2	1
	Agricultural use	4	3	12	2	2	1	2	1
Pesticides & insecticides	Domestic use	2	3	6	2	2	2	2	1
	Forestry activities	1	2	2	2	2	1	2	1
	Agricultural use	3	2	6	1	1	1	2	0.1
	Dumping/flytipping	3	3	9	1	1	1	2	1
	Spraying of agricultural land	3	2	6	1	1	1	2	0.1
Hydrocarbons	Run-off from roads	3	2	6	1	2	2	2	1
	Agricultural storage tanks	3	2	6	2	2	2	2	1
	Aquatic leisure & tourism activities (eg boating)	1	2	2	2	2	2	2	1
	Other storage tanks (local authority etc)	3	2	6	2	2	2	2	1
	Building/development sites	4	4	16	1	1	1	1	1
	Accidents/spillages	4	4	16	2	2	2	2	1
	Sewage treatment works	4	3	12	1	1	1	1	0.1
	Landfill	4	5	20	2	2	1	2	1
	Dumping/flytipping	3	3	9	1	1	1	2	1
Pathogens	Industrial discharges	4	4	16	1	1	1	2	0.1
	Sewage treatment works	4	4	16	1	0.1	1	1	0.1
	Burial pits	1	2	2	1	2	1	1	1
	Cemetaries	4	2	8	1	1	0.1	1	1
	Agricultural grazing land	3	2	6	2	1	2	2	1
	Agricultural storage of animal waste	2	2	4	2	2	1	2	1
	Muck-spreading	2	2	4	1	1	2	2	1
	Cesspits/soakaways	3	2	6	1	2	1	2	2
	Wildlife	3	3	9	2	2	2	2	2
Chemicals	Industrial discharges	5	5	25	2	1	2	2	0.1
	Sewage treatment works	4	4	16	1	1	1	1	0.1
	Dumping/flytipping	3	3	9	1	1	1	2	1
	Landfill	4	5	20	2	2	1	2	1
	Accidents/spillages	4	5	20	2	1	2	2	0.1
Suspended solids/turbidity	Over-grazing of agricultural land	3	2	6	2	1	1	2	2
	Over-grazing of other land	3	2	6	2	1	1	2	2
	Inadequate stock-proof fencing along waterways	2	2	4	2	2	2	2	2
	Mining activities	4	5	20	2	1	1	2	1
	Geology of the catchment	4	4	16	2	0.1	1	2	1
	Aquatic leisure & tourism activities (eg boating)	1	2	2	2	2	2	2	1
	Forestry activities	1	2	2	2	2	1	2	1
	Innappropriate land management facilitating soil erosion	4	3	12	2	2	1	2	2
	Off-roading facilities	4	3	12	2	2	1	2	2
	Poorly managed public footpaths & by-ways	4	3	12	2	2	1	2	2
	Building/development sites	5	3	15	1	1	1	2	2
	Flooding	5	5	25	1	1	1	2	1
	Dumping/flytipping	3	3	9	1	1	1	2	1
	Run-off from roads	4	2	8	1	1	1	2	2
	Run-off from buildings	4	1	4	1	1	1	2	2
	Industrial/commercial discharges	4	4	16	1	1	1	2	0.1
	General run-off from land	4	2	8	1	1	1	2	2
Heavy Metals	Mining activities	5	5	25	2	1	1	2	0.1
	Geology of the catchment	4	4	16	2	0.1	1	2	1
	Dumping/flytipping	3	3	9	1	1	1	2	1
	Landfill	4	5	20	2	2	1	2	1
	Run-off from roads	4	2	8	2	2	1	2	2
	Industrial discharges	4	5	20	2	1	1	2	1
Taste & Odour	Algal blooms	4	4	16	2	0.1	1	2	0.1
	Reservoir stratification	1	1	1	1	0.1	1	1	0.1
	Geology of the catchment	4	5	20	2	1	2	2	0.1
	Industrial discharges	4	4	16	2	1	1	2	0.1
	Dumping/flytipping	3	3	9	1	1	1	2	0.1
	Landfill	4	5	20	2	2	1	2	0.1
	Agricultural application of pesticides/herbicides	3	2	6	1	1	1	1	0.1
	Accidents/spillages	4	4	16	2	1	2	2	0.1
Radiation	Nuclear power stations	1	1	1	0.1	0.1	0.1	1	0.1
	Industrial/medical uses of radioactive material	4	2	8	0.1	0.1	0.1	1	0.1
Nitrates & phosphates	Industrial discharges	4	4	16	2	1	1	2	1
	Agricultural grazing land	3	2	6	2	1	2	2	1
	Sewage treatment works	4	4	16	1	0.1	1	1	1
	Burial pits	1	2	2	1	2	1	1	1
	Landfill	4	5	20	2	2	1	2	1
	Aeolian deposition	3	2	6	2	2	1	2	2
	Agricultural storage of animal waste	3	2	6	2	2	1	2	1
	Cemetaries	4	2	8	1	1	0.1	1	1
Colour	Industrial discharges	4	4	16	2	1	1	1	0.1
	Accidents/spillages	4	4	16	2	1	2	2	1
	Drainage from peaty areas	1	1	1	2	2	1	1	2
				821					

ABSTRACTION SAFETY INDEX: 57.9%

Risk Component of Each Individual Importance Factor					Cumulative Risk
Organisational Ability	Available Information	Legal Framework	Codes of Practice & Other Voluntary Arrangements	Customer Expectation	
2	2	2	4	4	14
6	6	6	12	12	42
9	9	9	18	9	54
4	4	2	4	2	16
12	12	12	12	6	54
24	24	12	24	12	96
12	12	12	12	6	54
4	4	2	4	2	16
6	6	6	12	0.6	30.6
9	9	9	18	9	54
6	6	6	12	0.6	30.6
6	12	12	12	6	48
12	12	12	12	6	54
4	4	4	4	2	18
12	12	12	12	6	54
16	16	16	16	16	80
32	32	32	32	16	144
12	12	12	12	1.2	49.2
40	40	20	40	20	160
9	9	9	18	9	54
16	16	16	32	1.6	81.6
16	1.6	16	16	1.6	51.2
2	4	2	2	2	12
8	8	0.8	8	8	32.8
12	6	12	12	6	48
8	8	4	8	4	32
4	4	8	8	4	28
6	12	6	12	12	48
18	18	18	18	18	90
50	25	50	50	2.5	177.5
16	16	16	16	1.6	65.6
9	9	9	18	9	54
40	20	40	40	2	142
12	6	6	12	12	48
12	6	6	12	12	48
8	8	8	8	8	40
40	20	20	40	20	140
32	1.6	16	32	16	97.6
4	4	4	4	2	18
4	4	2	4	2	16
24	24	12	24	24	108
24	24	12	24	24	108
24	24	12	24	24	108
	15	15	30	30	90
25	25	25	50	25	150
9	9	9	18	9	54
8	8	8	16	16	56
4	4	4	8	8	28
16	16	16	32	1.6	81.6
8	8	8	16	16	56
50	25	25	50	2.5	152.5
32	1.6	16	32	16	97.6
9	9	9	18	9	54
16	16	8	16	16	72
40	20	20	40	20	140
32	1.6	16	32	1.6	83.2
1	0.1	1	1	0.1	3.2
40	20	40	40	2	142
32	16	16	32	1.6	97.6
9	9	9	18	0.9	45.9
6	6	6	6	0.6	24.6
32	16	32	32	1.6	113.6
0.1	0.1	0.1	1	0.1	1.4
0.8	0.8	0.8	8	0.8	11.2
32	16	16	32	16	112
12	6	12	12	6	48
16	1.6	16	16	16	65.6
2	4	2	2	2	12
40	40	20	40	20	160
12	12	6	12	12	54
12	12	6	12	6	48
8	8	0.8	8	8	32.8
32	16	16	16	1.6	81.6
32	16	32	32	16	128
2	2	1	1	2	8
					5021.1

ABSTRACTION SAFETY INDEX: 74.2%

30 CALCULATION OF THE ABSTRACTION SAFETY INDEX FOR CATCHMENT D USING THE SECOND METHODOLOGY

Hazard	Source of Hazard	Risk (Before Importance Factors are Applied)			Importance of Each Factor Influencing the Final Risk Posed by the Hazard				
		Likelihood	Severity	Magnitude of Risk	Organisational Ability	Available Information	Legal Framework	Codes of Practice & Other Voluntary Arrangements	Customer Expectation
Herbicides	Spraying of road margins & central reservations	1	2	2	0	0	0	2	2
	Spraying of railway margins	2	3	6	0	0	0	2	2
	Dumping/flytipping	3	3	9	0	0	0	2	0
	Forestry activities	1	2	2	2	2	0	2	0
	Domestic use	2	3	6	2	2	2	2	0
	Agricultural use	4	3	12	2	2	0	2	0
Pesticides & insecticides	Domestic use	2	3	6	2	2	2	2	0
	Forestry activities	1	2	2	2	2	0	2	0
	Agricultural use	3	2	6	0	0	0	2	-2
	Dumping/flytipping	3	3	9	0	0	0	2	0
	Spraying of agricultural land	3	2	6	0	0	0	2	-2
Hydrocarbons	Run-off from roads	3	2	6	0	2	2	2	0
	Agricultural storage tanks	3	2	6	2	2	2	2	0
	Aquatic leisure & tourism activities (eg boating)	1	2	2	2	2	2	2	0
	Other storage tanks (local authority etc)	3	2	6	2	2	2	2	0
	Building/development sites	4	4	16	0	0	0	0	0
	Accidents/spillages	4	4	16	2	2	2	2	0
	Sewage treatment works	4	3	12	0	0	0	0	-2
	Landfill	4	5	20	2	2	0	2	0
	Dumping/flytipping	3	3	9	0	0	0	2	0
Pathogens	Industrial discharges	4	4	16	0	0	0	2	-2
	Sewage treatment works	4	4	16	0	-2	0	0	-2
	Burial pits	1	2	2	0	2	0	0	0
	Cemetaries	4	2	8	0	0	-2	0	0
	Agricultural grazing land	3	2	6	2	0	2	2	0
	Agricultural storage of animal waste	2	2	4	2	2	0	2	0
	Muck-spreading	2	2	4	0	0	2	2	0
	Cesspits/soakaways	3	2	6	0	2	0	2	2
	Wildlife	3	3	9	2	2	2	2	2
Chemicals	Industrial discharges	5	5	25	2	0	2	2	-2
	Sewage treatment works	4	4	16	0	0	0	0	-2
	Dumping/flytipping	3	3	9	0	0	0	2	0
	Landfill	4	5	20	2	2	0	2	0
	Accidents/spillages	4	5	20	2	0	2	2	-2
Suspended solids/turbidity	Over-grazing of agricultural land	3	2	6	2	0	0	2	2
	Over-grazing of other land	3	2	6	2	0	0	2	2
	Inadequate stock-proof fencing along waterways	2	2	4	2	2	2	2	2
	Mining activities	4	5	20	2	0	0	2	0
	Geology of the catchment	4	4	16	2	-2	0	2	0
	Aquatic leisure & tourism activities (eg boating)	1	2	2	2	2	2	2	0
	Forestry activities	1	2	2	2	2	0	2	0
	Innappropriate land management facilitating soil erosion	4	3	12	2	2	2	2	2
	Off-roading facilities	4	3	12	2	2	2	2	2
	Poorly managed public footpaths & by-ways	4	3	12	2	2	2	2	2
	Building/development sites	5	3	15	0	0	0	2	2
	Flooding	5	5	25	0	0	0	2	0
	Dumping/flytipping	3	3	9	0	0	0	2	0
	Run-off from roads	4	2	8	0	0	0	2	2
	Run-off from buildings	4	1	4	0	0	0	2	2
	Industrial/commercial discharges	4	4	16	0	0	0	2	-2
	General run-off from land	4	2	8	0	0	0	2	2
Heavy Metals	Mining activities	5	5	25	2	0	0	2	-2
	Geology of the catchment	4	4	16	2	-2	0	2	0
	Dumping/flytipping	3	3	9	0	0	0	2	0
	Landfill	4	5	20	2	2	0	2	0
	Run-off from roads	4	2	8	2	2	0	2	2
	Industrial discharges	4	5	20	2	0	0	2	0
Taste & Odour	Algal blooms	4	4	16	2	-2	0	2	0
	Reservoir stratification	1	1	1	0	-2	0	0	0
	Geology of the catchment	4	5	20	2	0	2	2	-2
	Industrial discharges	4	4	16	2	0	0	2	-2
	Dumping/flytipping	3	3	9	0	0	0	2	-2
	Landfill	4	5	20	2	2	0	2	-2
	Agricultural application of pesticides/herbicides	3	2	6	0	0	0	0	-2
	Accidents/spillages	4	4	16	2	0	2	2	-2
Radiation	Nuclear power stations	1	1	1	-2	-2	-2	0	-2
	Industrial/medical uses of radioactive material	4	2	8	-2	-2	-2	0	-2
Nitrates & phosphates	Industrial discharges	4	4	16	2	0	0	2	0
	Agricultural grazing land	3	2	6	2	0	2	2	0
	Sewage treatment works	4	4	16	0	-2	0	0	0
	Burial pits	1	2	2	0	2	0	0	0
	Landfill	4	5	20	2	2	0	2	0
	Aeolian deposition	3	2	6	2	2	0	2	2
	Agricultural storage of animal waste	3	2	6	2	2	0	2	0
	Cemetaries	4	2	8	0	0	-2	0	0
Colour	Industrial discharges	4	4	16	2	0	0	0	-2
	Accidents/spillages	4	4	16	2	0	2	2	0
	Drainage from peaty areas	1	1	1	2	2	0	0	2
				821					

ABSTRACTION SAFETY INDEX: 57.9%

Risk Component of Each Individual Importance Factor					Cumulative Risk
Organisational Ability	Available Information	Legal Framework	Codes of Practice & Other Voluntary Arrangements	Customer Expectation	
0	0	0	4	4	8
0	0	0	12	12	24
0	0	0	18	0	18
4	4	0	4	0	12
12	12	12	12	0	48
24	24	0	24	0	72
12	12	12	12	0	48
4	4	0	4	0	12
0	0	0	12	-12	0
0	0	0	18	0	18
0	0	0	12	-12	0
0	12	12	12	0	36
12	12	12	12	0	48
4	4	4	4	0	16
12	12	12	12	0	48
0	0	0	0	0	0
32	32	32	32	0	128
0	0	0	0	-24	-24
40	40	0	40	0	120
0	0	0	18	0	18
0	0	0	32	-32	0
0	-32	0	0	-32	-64
0	4	0	0	0	4
0	0	-16	0	0	-16
12	0	12	12	0	36
8	8	0	8	0	24
0	0	8	8	0	16
0	12	0	12	12	36
18	18	18	18	18	90
50	0	50	50	-50	100
0	0	0	0	-32	-32
0	0	0	18	0	18
	40	0	40	0	80
40	0	40	40	-40	80
12	0	0	12	12	36
12	0	0	12	12	36
8	8	8	8	8	40
40	0	0	40	0	80
32	-32	0	32	0	32
4	4	4	4	0	16
4	4	0	4	0	12
24	24	24	24	24	120
24	24	24	24	24	120
24	24	24	24	24	120
	0	0	30	30	60
0	0	0	50	0	50
0	0	0	18	0	18
0	0	0	16	16	32
0	0	0	8	8	16
0	0	0	32	-32	0
0	0	0	16	16	32
50	0	0	50	-50	50
32	-32	0	32	0	32
0	0	0	18	0	18
	40	0	40	0	80
16	16	0	16	16	64
40	0	0	40	0	80
32	-32	0	32	0	32
0	-2	0	0	0	-2
40	0	40	40	-40	80
32	0	0	32	-32	32
0	0	0	18	-18	0
	40	0	40	-40	40
0	0	0	0	-12	-12
32	0	32	32	-32	64
-2	-2	-2	0	-2	-8
-16	-16	-16	0	-16	-64
32	0	0	32	0	64
12	0	12	12	0	36
0	-32	0	0	0	-32
0	4	0	0	0	4
40	40	0	40	0	120
12	12	0	12	12	48
12	12	0	12	0	36
0	0	-16	0	0	-16
32	0	0	0	-32	0
32	0	32	32	0	96
2	2	0	0	2	6
					2690

WEIGHTED ABSTRACTION SAFETY INDEX: 49.9%

31 CALCULATION OF THE ABSTRACTION SAFETY INDEX FOR CATCHMENT D USING THE THIRD METHODOLOGY

Hazard	Source of Hazard	Risk (Before Importance Factors are Applied)			Importance of Each Factor Influencing the Final Risk Posed by the Hazard				
		Likelihood	Severity	Magnitude of Risk	Organisational Ability	Available Information	Legal Framework	Codes of Practice & Other Voluntary Arrangements	Customer Expectation
Herbicides	Spraying of road margins & central reservations	1	2	2	0	0	0	2	2
	Spraying of railway margins	2	3	6	0	0	0	2	2
	Dumping/flytipping	3	3	9	0	0	0	2	0
	Forestry activities	1	2	2	2	2	0	2	0
	Domestic use	2	3	6	2	2	2	2	0
	Agricultural use	4	3	12	2	2	0	2	0
Pesticides & insecticides	Domestic use	2	3	6	2	2	2	2	0
	Forestry activities	1	2	2	2	2	0	2	0
	Agricultural use	3	2	6	0	0	0	2	-2
	Dumping/flytipping	3	3	9	0	0	0	2	0
	Spraying of agricultural land	3	2	6	0	0	0	2	-2
Hydrocarbons	Run-off from roads	3	2	6	0	2	2	2	0
	Agricultural storage tanks	3	2	6	2	2	2	2	0
	Aquatic leisure & tourism activities (eg boating)	1	2	2	2	2	2	2	0
	Other storage tanks (local authority etc)	3	2	6	2	2	2	2	0
	Building/development sites	4	4	16	0	0	0	0	0
	Accidents/spillages	4	4	16	2	2	2	2	0
	Sewage treatment works	4	3	12	0	0	0	0	-2
	Landfill	4	5	20	2	2	0	2	0
	Dumping/flytipping	3	3	9	0	0	0	2	0
Pathogens	Industrial discharges	4	4	16	0	0	0	2	-2
	Sewage treatment works	4	4	16	0	-2	0	0	-2
	Burial pits	1	2	2	0	2	0	0	0
	Cemeteries	4	2	8	0	0	-2	0	0
	Agricultural grazing land	3	2	6	2	0	2	2	0
	Agricultural storage of animal waste	2	2	4	2	2	0	2	0
	Muck-spreading	2	2	4	0	0	2	2	0
	Cesspits/soakaways	3	2	6	0	2	0	2	2
	Wildlife	3	3	9	2	2	2	2	2
Chemicals	Industrial discharges	5	5	25	2	0	2	2	-2
	Sewage treatment works	4	4	16	0	0	0	0	-2
	Dumping/flytipping	3	3	9	0	0	0	2	0
	Landfill	4	5	20	2	2	0	2	0
	Accidents/spillages	4	5	20	2	0	2	2	-2
Suspended solids/turbidity	Over-grazing of agricultural land	3	2	6	2	0	0	2	2
	Over-grazing of other land	3	2	6	2	0	0	2	2
	Inadequate stock-proof fencing along waterways	2	2	4	2	2	2	2	2
	Mining activities	4	5	20	2	0	0	2	0
	Geology of the catchment	4	4	16	2	-2	0	2	0
	Aquatic leisure & tourism activities (eg boating)	1	2	2	2	2	2	2	0
	Forestry activities	1	2	2	2	2	0	2	0
	Innappropriate land management facilitating soil erosion	4	3	12	2	2	2	2	2
	Off-roading facilities	4	3	12	2	2	2	2	2
	Poorly managed public footpaths & by-ways	4	3	12	2	2	2	2	2
	Building/development sites	5	3	15	0	0	0	2	2
	Flooding	5	5	25	0	0	0	2	0
	Dumping/flytipping	3	3	9	0	0	0	2	0
	Run-off from roads	4	2	8	0	0	0	2	2
	Run-off from buildings	4	1	4	0	0	0	2	2
	Industrial/commercial discharges	4	4	16	0	0	0	2	-2
	General run-off from land	4	2	8	0	0	0	2	2
Heavy Metals	Mining activities	5	5	25	2	0	0	2	-2
	Geology of the catchment	4	4	16	2	-2	0	2	0
	Dumping/flytipping	3	3	9	0	0	0	2	0
	Landfill	4	5	20	2	2	0	2	0
	Run-off from roads	4	2	8	2	2	0	2	2
	Industrial discharges	4	5	20	2	0	0	2	0
Taste & Odour	Algal blooms	4	4	16	2	-2	0	2	0
	Reservoir stratification	1	1	1	0	-2	0	0	0
	Geology of the catchment	4	5	20	2	0	2	2	-2
	Industrial discharges	4	4	16	2	0	0	2	-2
	Dumping/flytipping	3	3	9	0	0	0	2	-2
	Landfill	4	5	20	2	2	0	2	-2
	Agricultural application of pesticides/herbicides	3	2	6	0	0	0	0	-2
	Accidents/spillages	4	4	16	2	0	2	2	-2
Radiation	Nuclear power stations	1	1	1	-2	-2	-2	0	-2
	Industrial/medical uses of radioactive material	4	2	8	-2	-2	-2	0	-2
Nitrates & phosphates	Industrial discharges	4	4	16	2	0	0	2	0
	Agricultural grazing land	3	2	6	2	0	2	2	0
	Sewage treatment works	4	4	16	0	-2	0	0	0
	Burial pits	1	2	2	0	2	0	0	0
	Landfill	4	5	20	2	2	0	2	0
	Aeolian deposition	3	2	6	2	2	0	2	2
	Agricultural storage of animal waste	3	2	6	2	2	0	2	0
	Cemeteries	4	2	8	0	0	-2	0	0
Colour	Industrial discharges	4	4	16	2	0	0	0	-2
	Accidents/spillages	4	4	16	2	0	2	2	0
	Drainage from peaty areas	1	1	1	2	2	0	0	2
				821					

ABSTRACTION SAFETY INDEX: 9179

Risk Component of Each Individual Importance Factor					Cumulative Risk
Organisational Ability	Available Information	Legal Framework	Codes of Practice & Other Voluntary Arrangements	Customer Expectation	
0	0	0	4	4	8
0	0	0	12	12	24
0	0	0	18	0	18
4	4	0	4	0	12
12	12	12	12	0	48
24	24	0	24	0	72
12	12	12	12	0	48
4	4	0	4	0	12
0	0	0	12	-12	0
0	0	0	18	0	18
0	0	0	12	-12	0
0	12	12	12	0	36
12	12	12	12	0	48
4	4	4	4	0	16
12	12	12	12	0	48
0	0	0	0	0	0
32	32	32	32	0	128
0	0	0	0	-24	-24
40	40	0	40	0	120
0	0	0	18	0	18
0	0	0	32	-32	0
0	-32	0	0	-32	-64
0	4	0	0	0	4
0	0	-16	0	0	-16
12	0	12	12	0	36
8	8	0	8	0	24
0	0	8	8	0	16
0	12	0	12	12	36
18	18	18	18	18	90
50	0	50	50	-50	100
0	0	0	0	-32	-32
0	0	0	18	0	18
	40	0	40	0	80
40	0	40	40	-40	80
12	0	0	12	12	36
12	0	0	12	12	36
8	8	8	8	8	40
40	0	0	40	0	80
32	-32	0	32	0	32
4	4	4	4	0	16
4	4	0	4	0	12
24	24	24	24	24	120
24	24	24	24	24	120
24	24	24	24	24	120
	0	0	30	30	60
0	0	0	50	0	50
0	0	0	18	0	18
0	0	0	16	16	32
0	0	0	8	8	16
0	0	0	32	-32	0
0	0	0	16	16	32
50	0	0	50	-50	50
32	-32	0	32	0	32
0	0	0	18	0	18
	40	0	40	0	80
16	16	0	16	16	64
40	0	0	40	0	80
32	-32	0	32	0	32
0	-2	0	0	0	-2
40	0	40	40	-40	80
32	0	0	32	-32	32
0	0	0	18	-18	0
	40	0	40	-40	40
0	0	0	0	-12	-12
32	0	32	32	-32	64
-2	-2	-2	0	-2	-8
-16	-16	-16	0	-16	-64
32	0	0	32	0	64
12	0	12	12	0	36
0	-32	0	0	0	-32
0	4	0	0	0	4
40	40	0	40	0	120
12	12	0	12	12	48
12	12	0	12	0	36
0	0	-16	0	0	-16
32	0	0	0	-32	0
32	0	32	32	0	96
2	2	0	0	2	6
					2690

WEIGHTED ABSTRACTION SAFETY INDEX: 7310

PART 7 REFERENCES

ADAS (2006a) Background [online]. ADAS. http://www.whittledene.org/index.php?content=background [accessed 9 October 2006]

ADAS (2006b) Catchment-Scale Management and Stakeholder Engagement [online]. ADAS. http://www.adas.co.uk/water/catchment.html [accessed 9 October 2006]

ADAS (2006c) Climate Change [online]. ADAS. http://www.adas.co.uk/water/climate.html [accessed 9 October 2006]

ADAS (2006d) How Does PSYCHIC Work? [online]. ADAS. http://www.psychic-project.org.uk/index.php?content=how [accessed 1 November 2006]

ADAS (2006e) Introduction [online]. ADAS. http://www.whittledene.org/index.php?content=introduction [accessed 9 October 2006]

ADAS (2006f) Methods [online]. ADAS. http://www.whittledene.org/index.php?content=methods [accessed 9 October 2006]

ADAS (2006g) Phase I: Conclusions [online]. ADAS. http://www.whittledene.org/index.php?content=phase1_conclusions [accessed 9 October 2006]

ADAS (2006h) Phase I: Recommendations [online]. ADAS. http://www.whittledene.org/index.php?content=phase1_recomendations [accessed 9 October 2006]

ADAS (2006i) Project Overview [online]. ADAS. http://www.psychic-project.org.uk/index.php?content=overview [accessed 9 October 2006]

ADAS (2006j) Project Partners [online]. ADAS. http://www.psychic-project.org.uk/index.php?content=partners [accessed 9 October 2006]

ADAS (publication date unknown) The Whittle Dene Catchment Study. ADAS, Wolverhampton.

Ainsworth, R. (2004) Safe Piped Water: Managing Microbial Water Quality in Piped Distribution Systems. *WHO Drinking Water Quality Series.* IWA Publishing, London.

Alegre, H., J. M. Baptista, E. Cabrera, F. Cubillo, P. Duarte, W. Hirner, W. Merkel & R. Parena (2006) *Performance Indicators for Water Supply Services.* IWA Publishing, London.

Altmann, P., J. Cunningham, U. Dhanesha, M. Ballard, J. Thompson & F. Marsh (1999) Disturbance of Cerebral Function in People Exposed to Drinking Water Contaminated with Aluminium Sulphate: Retrospective Study of the Camelford Water Incident. *British Medical Journal,* **319,** 807-811.

Anderson, R. (2003) Opening Address. *In* J. Gray & K. C. Thompson (eds.), *Water Contamination Emergencies: Can We Cope?* RSC Publishing, Le Meridien Hotel, Manchester.

Anonymous (2003) Tackling Diffuse Water Pollution from Agriculture (DWPA) - An Integrated View on Policies, Procedures and Links to Other Catchment Management Issues: A Discussion Paper from English Nature and the Environment Agency. English Nature and the Environment Agency, Bristol & Peterborough.

Anonymous (2007) Welsh Water Fined After Bug Outbreak. *Bangor and Anglesey Mail.* Bangor.

Arnell, N., N. Reynard, R. King, C. Prudhomme & J. Branson (1997) Effects of Climate Change on River Flows and Groundwater Recharge: Guidelines for Resource Assessment. UK Water Industry Research, London.

Arnell, N. W. (2003) Effect of Climate Change on River Flows and Groundwater Recharge: UKCIP02 Scenarios. UK Water Industry Research, London.

Association of Rivers Trusts (2008a) Association of Rivers Trusts [online]. Association of Rivers Trusts. http://www.associationofriverstrusts.org.uk/ [accessed 25 March 2008]

Association of Rivers Trusts (2008b) Rivers Trusts' locations in England, Wales, Ireland and Scotland [online]. Association of Rivers Trusts. http://www.associationofriverstrusts.org.uk/locations/index.htm [accessed 25 March 2008]

Association of Rivers Trusts (2008c) The Rivers Trusts Movement and the Association of Rivers Trusts [online]. Association of Rivers Trusts. http://www.associationofriverstrusts.org.uk/about/art_history_objectives.htm [accessed 25 March 2008]

Australian Government (2004) Australian Drinking Water Guidelines. *National Water Quality Management Strategy.* National Health and Medical Research Council & Natural Resource Management Ministerial Council, Canberra.

Barker, I. (2006) The Future for Water Resources. Environment Agency, Bristol & London.

Barlow, M. & T. Clarke (2002) *Blue Gold: The Battle Against Corporate Theft of the World's Water.* Earthscan Publications Ltd, London.

Barrott, L., T. Darlow, J. LaTrobe-Bateman & S. Smith (2007) Drinking Water Safety Plans Phase IV Project DW02. UK Water Industry Research, London.

Bartram, J., N. Thyssen, A. Gowers, K. Pond & T. Lack (2002) Water and Health in Europe: A Joint Report from the European Environment Agency and the WHO Regional Office for Europe. *Who Regional Publications European Series, No. 93.* World Health Organisation, Geneva.

Batchelor, C. (1999) Improving Water Use Efficiency as Part of Integrated Catchment Management. *Agricultural Water Management,* **40**(2-3), 249-263.

BBC (2007) 'No Barriers' Let Bug Into Water [online]. BBC. http://news.bbc.co.uk/1/hi/wales/north_west/6188764.stm [accessed 10 September 2007]

BBC (2008) Bottled Water [online]. BBC. http://www.bbc.co.uk/dna/h2g2/A13745991 [accessed 8 March 2008]

Bergkamp, G., B. Orlando & I. Burton (2003) Change: Adaptation of Water Management to Climate Change. International Union for Conservation of Nature and Natural Resources, Gland & Cambridge.

Blueprint for Water (2006) Blueprint for Water: 10 Steps to Sustainable Water by 2015. Wildlife and Countryside Link, London.

Blueprint for Water (2007) Blueprint for Water: 2008, A Year of Opportunity. Wildlife and Countryside Link, London.

Blueprint for Water (2008) About the Coalition [online]. Wildlife and Countryside Link. http://www.blueprintforwater.org.uk/about.html [accessed 26 March 2008]

Boon, P. J., P. Calow & G. E. Petts (1992) River Conservation and Management. John Wiley & Sons Ltd, Chichester.

Brandt, M. & M. Wooster (2005) Catchment to Consumer: Water Safety Plans Part 2. UK Water Industry Research, London.

Breach, B. & T. Williams (2006) The Pivotal Role of Water Safety Plans. *Water 21.*

Brecon Beacons National Park Authority (2006a) Welcome to the Brecon Beacons National Park [online]. Brecon Beacons National Park Authority. http://www.breconbeacons.org/ [accessed 12 September 2006]

Brecon Beacons National Park Authority (2006b) Basic Facts about the National Park. Brecon Beacons National Park Authority, Brecon.

British Waterways (2008a) About Us [online]. British Waterways. http://www.britishwaterways.co.uk/about_us/index.html [accessed 27 February 2008]

British Waterways (2008b) Agreements [online]. British Waterways. http://www.britishwaterways.co.uk/about_us/business_activities/agreements.html [accessed 27 February 2008]

British Waterways (2008c) Water [online]. British Waterways. http://www.britishwaterways.co.uk/about_us/business_activities/water.html [accessed 27 February 2008]

British Waterways (2008d) Working in Partnership [online]. British Waterways. http://www.britishwaterways.co.uk/about_us/working_partnership/working_in_partnership.html [accessed 27 February 2008]

Cadw (2008a) About Cadw [online]. Welsh Assembly Government. http://www.cadw.wales.gov.uk/default.asp?id=3&lang=en [accessed 29 February 2008]

Cadw (2008b) Welcome [online]. Welsh Assembly Government. http://www.cadw.wales.gov.uk/ [accessed 29 February 2008]

CAG Consultants & Oxford Brookes University (2004) The Planning Response to Climate Change: Advice on Better Practice. Office of the Deputy Prime Minister, London.

Calder, I. R. (2005) *Blue Revolution: Integrated Land and Water Resource Management.* Earthscan, London.

Cambridge Dictionaries Online (2008) Safe [online]. Cambridge University Press. http://dictionary.cambridge.org/define.asp?key=69396&dict=CALD [accessed 29 January 2008]

Canadian Council of Ministers of the Environment (2002) From Source To Tap: The Multi-Barrier Approach To Safe Drinking Water. Federal-Provincial-Territorial Committee on Environmental and Occupational Health and the Canadian Council of Ministers of the Environment, Winnipeg.

Canadian Council of Ministers of the Environment (2004) From Source To Tap: Guidance On The Multi-Barrier Approach To Safe Drinking Water. Federal-Provincial-Territorial Committee on Environmental and Occupational Health and the Canadian Council of Ministers of the Environment, Winnipeg.

Carter, J. & J. Howe (2006) The Water Framework Directive and the Strategic Environmental Assessment Directive: Exploring the Linkages. *Environmental Impact Assessment Review,* **26**(3)**,** 287-300.

Centre for Ecology & Hydrology (2006a) Hydrological Trends [online]. Centre for Ecology & Hydrology. http://www.ceh.ac.uk/data/nrfa/hydrological_trends.html [accessed 9 October 2006]

Centre for Ecology & Hydrology (2006b) Hydrological Trends - Background [online]. Centre for Ecology & Hydrology. http://www.nerc-wallingford.ac.uk/ih/nrfa/hydrological_trends/hydrological_trends.htm [accessed 9 October 2006]

Centre for Ecology & Hydrology (2006c) The National Groundwater Level Archive [online]. Centre for Ecology & Hydrology. http://www.ceh.ac.uk/data/nrfa/groundwater.html [accessed 9 October 2006]

Centre for Ecology & Hydrology (2006d) The National River Flow Archive [online]. Centre for Ecology & Hydrology. http://www.ceh.ac.uk/data/nrfa/index.html [accessed 9 October 2006]

Centre for Ecology & Hydrology (2006e) National Water Archive [online]. Centre for Ecology & Hydrology. http://www.ceh.ac.uk/data/NWA.htm [accessed 9 October 2006]

Chartered Institution of Water and Environmental Management (2005) Conference Proceedings. *Conference on Water Framework Directive and Agriculture*. Chartered Institution of Water and Environmental Management, SOAS, London.

Chartered Institution of Water and Environmental Management (2006a) About [online]. Chartered Institution of Water and Environmental Management. http://www.ciwem.org/about/mission.asp [accessed 27 June 2006]

Chartered Institution of Water and Environmental Management (2006b) Catchment Management: Land-Use and Water. Chartered Institution of Water and Environmental Management, London.

Chartered Institution of Water and Environmental Management (2006c) CIWEM [online]. Chartered Institution of Water and Environmental Management. http://www.ciwem.org/index.asp [accessed 27 June 2006]

Chartered Institution of Water and Environmental Management (2008) Bottled Drinking Water [online]. Chartered Institution of Water and Environmental Management. http://www.ciwem.org/policy/policies/bottled_water.asp [accessed 9 March 2008]

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

Chilton, P. J., P. Guha, D. W. Peach, M. E. Stuart & E. J. Whitehead (2004) Implications of Changing Groundwater Quality for Water Resources and the UK Water Industry, Phase 3: Financial and Water Resources Impact. UK Water Industry Research, London.

Clapham, D. (2003) Water And Public Health. *In* J. Gray & K. C. Thompson (eds.), *Water Contamination Emergencies: Can We Cope?* RSC Publishing, Le Meridien Hotel, Manchester.

Clayton, B. (1989) Water Pollution at Lowermoor North Cornwall: Report of the Lowermoor Incident Health Advisory Group. HMSO, London.

Clayton, B. (1991) Water Pollution at Lowermoor North Cornwall: Second Report of the Lowermoor Incident Health Advisory Group. HMSO, London.

Committee on Toxicity of Chemicals in Food Consumer Products and the Environment (2005) Subgroup Report on the Lowermoor Water Pollution Incident: Consultation Report. Department for Environment Food and Rural Affairs, London.

Community Research & Development Information Service (2006) Climate Change: More Research Needed, But Time For Action Is Now, Say Experts [online]. Community Research & Development Information Service. http://cordis.europa.eu/search/index.cfm?fuseaction=news.simpledocument&N_RCN=26433&CFID=10832417&CFTOKEN=75810120 [accessed 28 October 2006]

Competition Commission (2009) British Waterways Board: A Report on the Service Provided by the Board [online]. Competition Commission. [accessed 25 January 2009]

Comptroller and Auditor General (2005) Environment Agency: Efficiency in Water Resource Management. *Session 2005-2006.* National Audit Office, London.

Conlan, K. (2003) Effects of Climate Change on River Water Quality, Phase 3: Scoping Study. UK Water Industry Research, London.

Conlan, K., S. Lane, S. Reaney & T. Wade (2006) Effects of Climate Change on River Water Quality. UK Water Industry Research, London.

Consultants in Environmental Sciences Ltd (2001) Diffuse Pollutants in Groundwater: Economic Appraisal. UK Water Industry Research, London.

Consumer Council for Water (2006a) Who We Are And What We Do [online]. http://www2.watervoice.org.uk/aptrix/ofwat/publish.nsf/Content/navigation-watervoice-aboutwatervoice [accessed 27 June 2006]

Consumer Council for Water (2006b) Your Local CCW Committee [online]. http://www2.watervoice.org.uk/aptrix/ofwat/publish.nsf/Content/navigation-watervoice-watervoicecommittees-yourlocalwatervoicecommittee [accessed 27 June 2006]

Cooperative Research Centre for Water Quality and Treatment (2002) Camelford Incident Reviewed [online]. Cooperative Research Centre for Water Quality and Treatment. http://www.waterquality.crc.org.au/hsarch/HS25b.htm [accessed 6 July 2007]

Cortvriend, J. & A. Hulsmann (2006) Europe Paves the Way for Revision of the Drinking Water Directive. *Water 21.*

Council of Europe (2006a) About the Council of Europe [online]. Council of Europe. http://www.coe.int/T/e/Com/about_coe [accessed 3 November 2006]

Council of Europe (2006b) European Landscape Convention. Council of Europe, Strasbourg.

Council of Europe (2006c) European Landscape Convention: CETS No 176 [online]. Council of Europe. http://conventions.coe.int/Treaty/Commun/ChercheSig.asp?NT=176&CM=8&DF=11/12/2006&CL=ENG [accessed 3 November 2006]

Council of Europe (2006d) Explanatory Report [online]. Council of Europe. http://conventions.coe.int/Treaty/en/Reports/Html/176.htm [accessed 3 November 2006]

Council of Europe (2006e) Summary of the European Landscape Convention [online]. Council of Europe. http://conventions.coe.int/Treaty/en/Summaries/Html/176.htm [accessed 3 November 2006]

(1976) Council Directive of 4 May 1976 on Pollution Caused by Certain Dangerous Substances Discharged into the Aquatic Environment of the Community.

(1978) Council Directive 78/659/EEC of 18 July 1978 on the Quality of Fresh Waters Needing Protection or Improvement in Order to Support Fish Life.

(1979) Council Directive 79/923/EEC of 30 October 1979 on the Quality Required of Shellfish Waters.

Countryside Council for Wales (2006) About Us [online]. http://www.ccw.gov.uk/generalinfo/index.cfm?Subject=AboutUs&lang=en [accessed 27 June 2006]

Dabrowski, C., R. Romanowicz, J.-P. Vidal, S. Wade & P. Young (2005) Effect of Climate Change on River Flows and Groundwater Recharge, a Practical Methodology: Trends in UK River Flows 1970-2002. UK Water Industry Research, London.

Dale, M. (2004) Climate Change and the Hydraulic Design of Sewerage Systems Volume 1: Climate Change Effects on Rainfall. UK Water Industry Research, London.

Damikouka, I., A. Katsiri & C. Tzia (2007) Application of HACCP Principles in Drinking Water Treatment. *Desalination,* **210**(1-3)**,** 138-145.

Darlow, T. (2007) Approaches to Risk Assessment. *DW/02 DWSP Phase IV.* UK Water Industry Research, London.

Dartmoor National Park Authority (2008) Agri-Environment Schemes [online]. Dartmoor National Park Authority. http://www.dartmoor-npa.gov.uk/laf-agrienvironmental [accessed 20 March 2008]

Davies, H., T. Osborn, B. Piper & C. Prudhomme (2005) Climate Change Uncertainty in Water Resource Planning. UK Water Industry Research, London.

Davison, A., G. Howard, M. Stevens, P. Callan, L. Fewtrell, D. Deere & J. Bartram (2005) Water Safety Plans: Managing Drinking Water Quality from Catchment to Consumer. World Health Organisation, Geneva.

de Villiers, M. (2001) *Water Wars: Is the World's Water Running Out?* Phoenix Press, London.

DeBarry, P. A. (2004) *Watersheds: Processes, Assessment, and Management.* Wiley, Hoboken, New Jersey.

Dee Valley Water (2006) Annual Report 2006. Dee Valley Water, Wrexham.

Dee Valley Water (Unknown) Annual Water Quality Report 2005. Dee Valley Water, Wrexham.

Deininger, R. A. (2003) Overview Of Handling Emergencies: Some Cautionary Tales. *In* J. Gray & K. C. Thompson (eds.), *Water Contamination Emergencies: Can We Cope?* RSC Publishing, Le Meridien Hotel, Manchester.

Department for Communities and Local Government (2006) The DCLG Remit [online]. http://www.dclg.gov.uk/index.asp?id=1165628 [accessed 17 August 2006]

Department for Environment Food and Rural Affairs (2003) Strategic Review of Diffuse Water Pollution from Agriculture: Discussion Document. Department for Environment Food and Rural Affairs, London.

Department for Environment Food and Rural Affairs (2004a) Delivering the Essentials of Life: Defra's Five Year Strategy. Department of the Environment Food and Rural Affairs, London.

Department for Environment Food and Rural Affairs (2004b) Security and Emergency Measures Direction - Notification and Guidance. Department of the Environment Food and Rural Affairs, London.

Department for Environment Food and Rural Affairs (2004c) Water Quality: A Diffuse Pollution Review - Chapter 1, Introduction. Department for Environment Food and Rural Affairs, London.

Department for Environment Food and Rural Affairs (2005a) Regulatory Impact Assessment: Council of Europe European Landscape Convention. Department for Environment Food and Rural Affairs, London.

Department for Environment Food and Rural Affairs (2005b) Water Quality: A Diffuse Pollution Review - Chapter 3, Sources of Diffuse Water Pollution. Department for Environment Food and Rural Affairs, London.

Department for Environment Food and Rural Affairs (2006a) Catchment-Sensitive Farming Programme: Taking Forward the Strategic Review of Diffuse Water Pollution from Agriculture [online]. Department for Environment Food and Rural Affairs. http://www.defra.gov.uk/environment/water/quality/diffuse/agri/index.htm [accessed 9 May 2006]

Department for Environment Food and Rural Affairs (2006b) Consultation on the Amendment of the Water Supply (Water Quality) Regulations 2000 and the Water Supply (Water Quality) Regulations 2001. Department of the Environment Food and Rural Affairs, London.

Department for Environment Food and Rural Affairs (2006c) Diffuse Pollution of Water from Non-Agricultural Sources [online]. Department for Environment Food and Rural Affairs. http://www.defra.gov.uk/environment/water/quality/diffuse/non-agri/index.htm [accessed 28 October 2006]

Department for Environment Food and Rural Affairs (2006d) Environmental Liability [online]. Department for Environment Food and Rural Affairs. http://www.defra.gov.uk/environment/liability/index.htm [accessed 29 July 2006]

Department for Environment Food and Rural Affairs (2006e) Evidence of the Non-Agricultural Diffuse Pollution of Water [online]. Department for Environment Food and Rural Affairs. http://www.defra.gov.uk/environment/water/quality/diffuse/non-agri/research/index.htm [accessed 28 October 2006]

Department for Environment Food and Rural Affairs (2006f) Landscape Protection [online]. Department for Environment Food and Rural Affairs. http://www.defra.gov.uk/wildlife-countryside/issues/landscap/index.htm [accessed 9 May 2006]

Department for Environment Food and Rural Affairs (2006g) Natural England [online]. Department for Environment Food and Rural Affairs. http://www.defra.gov.uk/rural/ruraldelivery/natural-england.htm [accessed 29 July 2006]

Department for Environment Food and Rural Affairs (2006h) Natural England and Rural Communities Act [online]. Department for Environment Food and Rural Affairs. http://www.defra.gov.uk/rural/ruraldelivery/bill/default.htm [accessed 29 July 2006]

Department for Environment Food and Rural Affairs (2006i) News Release: England Catchment Sensitive Farming Delivery Initiative Announced [online]. Department for Environment Food and Rural Affairs. http://www.defra.gov.uk/news/2005/051219a.htm [accessed 9 May 2006]

Department for Environment Food and Rural Affairs (2006j) Pesticides and the Environment: A Strategy for the Sustainable Use of Plan Protection Products and Strategy Action Plans. Department for Environment Food and Rural Affairs, London.

Department for Environment Food and Rural Affairs (2006k) Remediation of Environmental Damage Under Existing Regimes in the UK [online]. Department for Environment Food and Rural Affairs. http://www.defra.gov.uk/environment/liability/pdf/liability-regimes.pdf [accessed 29 July 2006]

Department for Environment Food and Rural Affairs (2006l) Water Framework Directive [online]. Department for Environment Food and Rural Affairs. http://www.defra.gov.uk/environment/water/wfd/index.htm [accessed 1 August 2006]

Department for Environment Food and Rural Affairs (2006m) What We Do [online]. Department for Environment Food and Rural Affairs. http://www.defra.gov.uk/rds/whatwedo.htm [accessed 11 September 2006]

Department for Environment Food and Rural Affairs (2007a) Explanatory Memorandum To The Water Supply (Water Quality) Regulations 2000 (Amendment) Regulations 2007. Department for Environment Food and Rural Affairs, London.

Department for Environment Food and Rural Affairs (2007b) Taking Forward the UK Climate Change Bill: The Government Response to Pre-Legislative Scrutiny and Public Consultation. *In* Department for Environment Food and Rural Affairs (ed.). The Stationery Office.

Department for Environment Food and Rural Affairs (2008a) Catchment Steering Groups [online]. Department for Environment Food and Rural Affairs. http://www.defra.gov.uk/farm/environment/water/csf/catchments/groups.htm [accessed 2 March 2008]

Department for Environment Food and Rural Affairs (2008b) The England Catchment Sensitive Farming Delivery Initiative (ECSFDI) [online]. Department for Environment Food and Rural Affairs. http://www.defra.gov.uk/farm/environment/water/csf/delivery-initiative.htm [accessed 2 March 2008]

Department for Environment Food and Rural Affairs (2008c) The England Rural Development Programme 2000-2006 [online]. Department of the Environment Food and Rural Affairs. http://www.defra.gov.uk/erdp/default.htm [accessed 28 February 2008]

Department for Environment Food and Rural Affairs (2008d) Environmental Stewardship [online]. Department for Environment Food and Rural Affairs. http://www.defra.gov.uk/erdp/schemes/es/default.htm [accessed 28 February 2008]

Department for Environment Food and Rural Affairs (2008e) The Rural Development Programme for England 2007-2013 [online]. Department of the Environment Food and Rural Affairs. http://www.defra.gov.uk/rural/rdpe/index.htm [accessed 28 February 2008]

Department for Environment Food and Rural Affairs (2008f) Specific Funding for the Uplands [online]. Department for Environment Food and Rural Affairs. http://www.defra.gov.uk/rural/uplands/support.htm [accessed 28 February 2008]

Department for Environment Food and Rural Affairs (2008g) UK Legislation: Taking the Climate Change Bill Forward - Progress [online]. Department for Environment Food and Rural Affairs. http://www.defra.gov.uk/environment/climatechange/uk/legislation/index.htm [accessed 20 March 2008]

Department for Environment Food and Rural Affairs (2008h) Water Quality - EC Bathing Water Directive [online]. Department for Environment Food and Rural Affairs. http://www.defra.gov.uk/ENVIRONMENT/water/quality/bathing/revision.htm [accessed 22 June 2008]

Department for Environment Food and Rural Affairs (date of publication unknown) Catchment Sensitive Farming: A Clear Solution for Farmers. Department for Environment Food and Rural Affairs, London.

Department for Environment Transport and the Regions & Welsh Office (1998) The Review of the Water Abstraction Licensing Scheme In England And Wales. *In* Department for Environment Transport and the Regions & Welsh Office (eds.).

Department for Environment Transport and the Regions & Welsh Office (1999) Taking Water Responsibly: Government Decisions Following Consultations On Changes To The Water Abstraction Licensing Systems In England And Wales. *In* Department for Environment Transport and the Regions & Welsh Office (eds.).

Department of Agriculture and Rural Development (2008) Agri-Environment Schemes [online]. Department of Agriculture and Rural Development. http://www.ruralni.gov.uk/environment/countryside/schemes [accessed 20 March 2008]

Department of Health (1996) Toxicity, Mutagenicity and Carcinogenicity Report 1996 [online]. The Stationery Office. http://www.archive.official-documents.co.uk/document/doh/toxicity/chap-3a.htm [accessed 16 July 2007]

Department of the Environment & Welsh Office (1992) The Water Undertakers (Information) Direction 1992 *Department of the Environment & the Welsh Office.*

Department of the Environment Food and Rural Affairs (2005d) Draft Guidance on the Security and Emergency Measures Direction for Water Supply Licensees. Department of the Environment Food and Rural Affairs.

Department of the Environment Food and Rural Affairs (2006e) About Defra [online]. http://www.defra.gov.uk/corporate/index.asp [accessed 4 June 2006]

Department of the Environment Food and Rural Affairs: Sharon Watkins (2006) *Drinking Water Safety Plans and Catchment Planning. 'personal communication'.*

Department of the Environment Transport and the Regions (1999) Water Supply (Water Fittings) Regulations 1999 (explanatory notes). Department of the Environment, Transport and the Regions.

Department of Water (2006) About Us [online]. Department of Water. http://portal.water.wa.gov.au/portal/page/portal/dow/about [accessed 28 November 2006]

Directgov (2006) Devolved Services in Wales [online]. http://www.direct.gov.uk/Dl1/Directories/DevolvedAdministrations/fs/en?CONTENT_ID=4007266&chk=AsRzer [accessed 4 June 2006]

Downing, T. E., R. E. Butterfield, B. Edmonds, J. Knox, S. Moss, B. Piper & E. Weatherhead (2003) Climate Change and the Demand for Water: Final Report. Stockholm Environment Institute, Oxford.

Drinking Water Chief Inspector (1997) Drinking Water 1997. Drinking Water Inspectorate, London.

Drinking Water Chief Inspector (2001) Drinking Water 2000. Drinking Water Inspectorate, London.

Drinking Water Chief Inspector (2007) Drinking Water 2006. Drinking Water Inspectorate, London.

Drinking Water Inspectorate (1998a) *The 1999 Periodic Review of Prices and AMP3: Further Guidance. 'personal communication'.*

Drinking Water Inspectorate (1998b) *The Periodic Review of Prices and AMP3. 'personal communication'.*

Drinking Water Inspectorate (2001) Inset Appointments [online]. Drinking Water Inspectorate. http://www.dwi.gov.uk/pubs/annrep99/45.htm [accessed 31 July 2006]

Drinking Water Inspectorate (2002) *Distribution Operation and Maintenance Strategies (DOMS) - DWI Requirements and Expectations (Information Letter 15/2002). 'personal communication'.*

Drinking Water Inspectorate (2004) *Microbiological Quality of Water Leaving Treatment Works and in Service Reservoirs: Drinking Water Safety Plans and Regulation (Information Letter 6/2004). 'personal communication'.*

Drinking Water Inspectorate (2005a) A Brief Guide to Drinking Water Safety Plans. London.

Drinking Water Inspectorate (2005b) *Distribution Operation and Maintenance Strategies (DOMS) - Update to DWI Requirements and Expectations (Information Letter 15/2005). 'personal communication'.*

Drinking Water Quality Regulator for Scotland (2005) *Distribution Operation and Maintenance Strategy (DOMS) - Update to DWQR Requirements and Expectations (Information Letter 4/2005). 'personal communication'.*

Drinking Water Quality Regulator for Scotland (2006) Role of the Regulator [online]. Drinking Water Quality Regulator for Scotland. http://www.dwqr.org.uk/role.html [accessed 10 September 2006]

Dufour, A., M. Snozzi, W. Koster, J. Bartram, E. Ronchi & L. Fewtrell (2003) Assessing Microbial Safety of Drinking Water: Improving Approaches and Methods. *WHO Drinking Water Quality Series.* OECD Publishing, Paris.

Dwr Cymru Welsh Water (Unknown) Annual Report of the Quality and Environment Committee: Year Ended 31 March 2005. Dwr Cymru Welsh Water, Nelson.

Dŵr Cymru Welsh Water (2004) Environmental Overview. Dŵr Cymru Welsh Water, Nelson.

Dŵr Cymru Welsh Water (2005) Annual Report of the Quality and Environment Committee: Year Ended 31 March 2005. Dŵr Cymru Welsh Water, Nelson.

Dwyer, J., R. Eaton, A. Farmer, D. Baldock, P. Withers & P. Silcock (2003) Policy Mechanisms for the Control of Diffuse Agricultural Pollution, with Particular Reference to Grant Aid. *English Nature Research Reports.* English Nature, Peterborough.

Environment & Heritage Service (2007) Private Water Supplies [online]. Environment & Heritage Service. http://www.ehsni.gov.uk/water/drinkwater/private_water.htm [accessed 26 July 2007]

Environment Agency (1997) Catchment Management Plan: Anglesey and Menai Strait Action Plan. Environment Agency, Bangor.

Environment Agency (2001a) Managing Water Abstraction: The Catchment Abstraction Management Strategy Process. Environment Agency, Bristol & London.

Environment Agency (2001b) Managing Water Abstraction: Towards A Shared Strategy - Consultation Response. Environment Agency, Bristol & London.

Environment Agency (2001c) Water Resources for the Future: A Strategy for England and Wales. Environment Agency, Bristol & London.

Environment Agency (2001d) Water Resources for the Future: A Summary of the Strategy for Wales. Environment Agency, Bristol & London.

Environment Agency (2005) The Climate is Changing: Time to Get Ready. Environment Agency, Bristol & London.

Environment Agency (2006a) About the RSA Programme [online]. Environment Agency. http://www.environment-agency.gov.uk/subjects/waterres/1341275/564321/449556/449611/?lang=_e [accessed 1 August 2006]

Environment Agency (2006b) Catchment Sensitive Farming [online]. Environment Agency. http://www.environment-agency.gov.uk/business/444304/1224648/1224749/?version=1&lang=_e [accessed 9 October 2006]

Environment Agency (2006c) The Climate is Changing: Time to Get Ready [online]. Environment Agency. http://www.environment-agency.gov.uk/yourenv/639312/641094/642206/642375/1003468/?version=1&lang=_e [accessed 2 October 2006]

Environment Agency (2006d) Diffuse Water Pollution and Agriculture [online]. Environment Agency. http://www.environment-agency.gov.uk/subjects/waterquality/252612/252735/?lang=_e [accessed 19 October 2006]

Environment Agency (2006e) Discharges to Water [online]. Environment Agency. http://www.environment-agency.gov.uk/yourenv/eff/1190084/water/1182267/ [accessed 26 September 2006]

Environment Agency (2006f) Do We Need Large-Scale Water Transfers for South East England? Environment Agency, Bristol & London.

Environment Agency (2006g) Enforcement of the Reservoirs Act 1975 [online]. Environment Agency. http://www.environment-agency.gov.uk/subjects/flood/896276/896368/907848/918900/?lang=_e [accessed 7 June 2006]

Environment Agency (2006h) Environmental Quality Standards [online]. Environment Agency. http://www.environment-agency.gov.uk/subjects/waterquality/252005/?lang=_e [accessed 28 July 2006]

Environment Agency (2006i) Flooding - Explanation of Terms [online]. Environment Agency. http://www.environment-agency.gov.uk/subjects/flood/362926/364792/ [accessed 26 September 2006]

Environment Agency (2006j) Head Office Drought Plan for England and Wales: Draft for Consultation. Environment Agency, Bristol & London.

Environment Agency (2006k) Louth Coastal Catchment Flood Management Plan Summary of Scoping Report. Environment Agency, Peterborough.

Environment Agency (2006l) North West Region - Who Does What? [online]. Environment Agency. http://www.environment-agency.gov.uk/regions/northwest/346910/346928/639778/ [accessed 26 September 2006]

Environment Agency (2006m) Restoring Sustainable Abstraction [online]. Environment Agency. http://www.environment-agency.gov.uk/subjects/waterres/1341275/564321/449556/?version=1&lang=_e [accessed 1 August 2006]

Environment Agency (2006n) River Quality - An Overview [online]. Environment Agency. http://www.environment-agency.gov.uk/yourenv/eff/1190084/water/213902/river_qual/?lang=_e [accessed 26 September 2006]

Environment Agency (2006o) Threats to Water Resources [online]. Environment Agency. http://www.environment-agency.gov.uk/yourenv/639312/641094/642206/642375/642.. [accessed 2 October 2006]

Environment Agency (2006p) Underground, Under Threat: The State of Groundwater in England and Wales. Environment Agency, Bristol.

Environment Agency (2006q) Valuable Underground Resource Under Threat [online]. Environment Agency. http://www.environment-agency.gov.uk/news/1491634 [accessed 19 October 2006]

Environment Agency (2006r) Water Company Drought Plans [online]. Environment Agency. http://www.environment-agency.gov.uk/subjects/waterres/1014767/1370506/1401682/1446113/?version=1&lang=_e [accessed 28 October 2006]

Environment Agency (2006s) Water Demand Management (WDM) [online]. Environment Agency. http://www.environment-agency.gov.uk/subjects/waterres/286587/286599/ [accessed 26 September 2006]

Environment Agency (2006t) Water Resources [online]. Environment Agency. http://www.environment-agency.gov.uk/subjects/waterres/?lang=_e [accessed 26 September 2006]

Environment Agency (2006u) The WFD and Other Directives [online]. Environment Agency. http://www.environment-agency.gov.uk/business/444217/444663/955573/955741/957258/?lang=_e [accessed 1 August 2006]

Environment Agency (2006v) What is the Restoring Sustainable Abstraction (RSA) Programme? [online]. Environment Agency. http://www.environment-agency.gov.uk/subjects/waterres/1341275/564321/449556/449574/?version=1&lang=_e [accessed 1 August 2006]

Environment Agency (2006q) The Climate is Changing: Time to Get Ready [online]. Environment Agency. http://www.environment-agency.gov.uk/yourenv/639312/641094/642206/642375/100.. [accessed 2 October 2006]

Environment Agency (2007a) About Us [online]. Environment Agency. http://www.environment-agency.gov.uk/aboutus/?lang=_e [accessed 9 September 2007]

Environment Agency (2007b) Annual Report and Account: 2006/07. Environment Agency, Bristol.

Environment Agency (2007c) Environmental Liability Directive (2004/35/CE - 21 April 2004) [online]. Environment Agency. http://www.netregs.gov.uk/netregs/legislation/380525/964277/?lang=_e [accessed 15 December 2007]

Environment Agency (2007d) Pollution Incident Categories [online]. Environment Agency. http://www.environment-agency.gov.uk/yourenv/eff/1190084/pollution/296030/296054/297197/ [accessed 13 June 2007]

Environment Agency (2007e) Water Pollution Incidents [online]. Environment Agency. http://www.environment-agency.gov.uk/yourenv/eff/1190084/pollution/296030/298038/?version=1&lang=_e [accessed 6 September 2007]

Environment Agency (2008) Navigation [online]. Environment Agency. http://www.environment-agency.gov.uk/subjects/navigation/?lang=_e [accessed 15 March 2008]

Environment Agency (2009) River Severn Catchment Flood Management Plan (CFMP) [online]. Environment Agency. http://www.environment-agency.gov.uk/cy/ymchwil/cynllunio/33624.aspx [accessed 25 January 2009]

Environment Agency (Unknown) General Quality Assessment of Rivers: Chemistry. Environment Agency, Bristol & London.

Environment Agency, Linking Environment and Farming, National Farmers' Union & Department for Environment Food and Rural Affairs (2007) Waterwise on the Farm: Version 2. Environment Agency, Bristol.

Environment Agency & English Nature (2004) Catchment Sensitive Farming: Delivering Solutions to Diffuse Water Pollution from Agriculture. *Policy Discussion Paper.* Environment Agency & English Nature, Bristol & Peterborough.

Environment Agency: Lucia Susani (2006) *Strategic Environmental Assessment Directive. 'personal communication'.*

Environment and Heritage Service (2006a) About Us [online]. Environment and Heritage Service,. http://www.ehsni.gov.uk/about/about.shtml [accessed 10 September 2006]

Environment and Heritage Service (2006b) Drinking Water Inspectorate [online]. Environment and Heritage Service,. http://www.ehsni.gov.uk/environment/drinkWater/drinkWater.shtml [accessed 10 September 2006]

Environmental Science & Research (2006) *Catchment Management & Drinking Water Safety Plans. 'personal communication'.*

Europa (2006a) Directive 76/464/EEC - Water Pollution by Discharges of Certain Dangerous Substances [online]. http://ec.europa.eu/environment/water/water-dangersub/76_464.htm [accessed 1 August 2006]

Europa (2006b) Environment DG [online]. http://ec.europa.eu/dgs/environment/index_en.htm [accessed 2 June 2006]

Europa (2006c) EU Institutions and Other Bodies [online]. http://europa.eu/institutions/index_en.htm [accessed 1 August 2006]

European Commission (2002) The Water Framework Directive: Tap into it! European Commission, Brussels.

European Commission (2003) Scientific Synthesis Report Drinking Water Seminar: 27 and 28 October 2003. European Commission, Brussels.

European Commission (2007) Environmental Aspects of Enterprise Policy [online]. European Commission. http://ec.europa.eu/enterprise/environment/index_home/ippc/index.htm [accessed 13 November 2007]

European Commission (2008a) Drinking Water Directive: Announcement of Stakeholder Engagement and Consultation [online]. Europa. http://ec.europa.eu/environment/water/water-drink/index_en.html [accessed 4 March 2008]

European Commission (2008b) A New EU Floods Directive [online]. Europa. http://ec.europa.eu/environment/water/flood_risk/index.htm [accessed 9 April 2008]

European Commission (2008c) The new Groundwater Directive (2006/118/EC) [online]. Europa. http://ec.europa.eu/environment/water/water-framework/groundwater/policy/current_framework/new_directive_en.htm [accessed 5 May 2008]

European Commission (2008d) REACH & GHS [online]. Europa. http://ec.europa.eu/enterprise/reach/index_en.htm [accessed 28 February 2008]

(1975) Council Directive 75/440/EEC Concerning the Quality Required of Surface Water Intended for the Abstraction of Water in the Member States.

(1976) Council Directive 76/160/EEC Concerning the Quality of Bathing Water.

(1979) Council Directive 79/869/EEC Concerning the Methods of Measurement and Frequencies of Sampling and Analysis of Surface Water Intended for the Abstraction of Drinking Water in the Member States.

(1980a) Council Directive 80/68/EEC on the Protection of Groundwater against Pollution Caused by Certain Dangerous Substances.

(1980b) Council Directive 80/777/EEC on the Approximation of the Laws of the Member States Relating to the Exploitation and Marketing of Natural Mineral Waters.

(1982) Council Directive 82/176/EEC on Limit Values and Quality Objectives for Mercury Discharges by the Chlor-Alkali Electrolysis Industry.

(1983) Council Directive 83/513/EEC on Limit Values and Quality Objectives for Cadmium Discharges.

(1984a) Council Directive 84/156/EEC on Limit Values and Quality Objectives for Mercury Discharges by Sectors other than the Chlor-Alkali Electrolysis Industry.

(1984b) Council Directive 84/491/EEC on Limit Values and Quality Objectives for Discharges of Hexachlorocyclohexane.

(1985) Council Directive of 27 June 1985 on the Assessment of the Effects of Certain Public and Private Projects on the Environment.

(1986) Council Directive 86/280/EEC on Limit Values and Quality Objectives for Discharges of Certain Dangerous Substances Included in List I of the Annex to Directive 76/464/EEC.

(1988) Council Directive 88/347/EEC amending Annex II to Directive 86/280/EEC on Limit Values and Quality Objectives for Discharges of Certain Dangerous Substances Included in List I of the Annex to Directive 76/464/EEC.

(1991a) Council Directive 91/271/EEC Concerning Urban Waste-Water Treatment.

(1991b) Council Directive 91/676/EEC Concerning the Protection of Waters Against Pollution Caused by Nitrates from Agricultural Sources.

European Parliament (2006a) Legislative Power [online]. http://www.europarl.europa.eu/parliament/public/staticDisplay.do?id=46&pageRank=2&language=EN [accessed 1 August 2006]

European Parliament (2006b) Parliament's Powers and Procedures [online]. http://www.europarl.europa.eu/parliament/public/staticDisplay.do?language=EN&id=46 [accessed 1 August 2006]

European Parliament (2008) Welcome to the European Parliament [online]. http://www.europarl.europa.eu/parliament/public.do?language=en [accessed 15 March 2008]

(1996) Council Directive 96/61/EC Concerning Integrated Pollution Prevention and Control.

(1997) Council Directive 97/11/EC of 3 March 1997 Amending Directive 85/337/EEC on the Assessment of the Effects of Certain Public and Private Projects on the Environment.

(1998) Council Directive 98/83/EC on the Quality of Water Intended for Human Consumption.

(2000) Directive 2000/60/EC Establishing a Framework for Community Action in the Field of Water Policy.

(2001) Directive 2001/42/EC on the Assessment of the Effects of Certain Plans and Programmes on the Environment.

(2004) Directive 2004/35/CE on Environmental Liability with Regard to the Prevention and Remedying of Environment Damage.

(2006a) Directive 2006/7/EC Concerning the Management of Bathing Water Quality and Repealing Directive 76/160/EEC.

(2006b) Directive 2006/11/EC on Pollution Caused by Certain Dangerous Substances Discharged into the Aquatic Environment of the Community.

(2006c) Directive 2006/118/EC of the European Parliament and of the Council of 12 December 2006 on the Protection of Groundwater against Pollution and Deterioration.

E. Union (2006d) Regulation (EC) No 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), establishing a European Chemicals Agency, amending Directive 1999/45/EC and repealing Council Regulation (EEC) No 793/93 and Commission Regulation (EC) No 1488/94 as well as Council Directive 76/769/EEC and Commission Directives 1/155/EEC, 93/67/EEC, 93/105/EC and 2000/21/EC *Official Journal of the European Union.*

Farmers' Union of Wales (2008) About Us [online]. Farmers' Union of Wales. http://www.fuw.org.uk/frameset.htm [accessed 25 March 2008]

Fawell, J., J. Littlejohn & J. Watkins (2005) Development of Drinking Water Safety Plans in Scotland. John Fawell, Independent Consultant, High Wycombe.

Fawell, J. & J. Watkins (2003) Managing Microbial and Chemical Risks from Source to Tap: Report and Toolbox. UK Water Industry Research, London.

Federal Ministry for Environment Nature Conservation and Nuclear Safety (2006) Time to Adapt - Climate Change and the European Water Dimension [online]. Federal Ministry for Environment, Nature Conservation and Nuclear Safety. http://www.climate-water-adaptation-berlin2007.org/ [accessed 5 November 2006]

Food Safety and Inspection Service (2007) HCCP & Pathogen Reduction [online]. Food Safety and Inspection Service. http://www.fsis.usda.gov/Science/Hazard_Analysis_&_Pathogen_Reduction/index.asp [accessed 13 June 2007]

Forestry Commission (2006a) About the Forestry Commission [online]. Forestry Commission. http://www.forestry.gov.uk/forestry/hcou-4u4hzt [accessed 28 July 2006]

Forestry Commission (2006b) The Board of Forestry Commissioners [online]. Forestry Commission. http://www.forestry.gov.uk/forestry/infd-54jehr [accessed 28 July 2006]

Forestry Commission (2008) English Woodland Grant Scheme [online]. Forestry Commission. http://www.forestry.gov.uk/forestry/infd-6dccen [accessed 28 February 2008]

Forestry Commission Wales (2005a) Better Woodlands For A Better Wales: Corporate Plan 2005/06-2007/08. Forestry Commission Wales, Aberystwyth.

Forestry Commission Wales (2005b) Woodlands For Wales: Progress Report 2001-2005. Forestry Commission Wales, Aberystwyth.

Fox, K. R. (2000) Engineering Considerations In The Investigation Of Waterborne Outbreaks, in "Drinking Water And Infectious Disease: Establishing The Links". *In* P. R. Hunter, M. Waite & E. Ronchi (eds.), *Approaches For Establishing Links Between Drinking Water And Infectious Disease*. IWA Publishing, Basingstoke.

Frederick, K. D. (2002) Water Resources and Climate Change. *In* C. W. Howe (ed.), *The Management of Water Resources.* Edward Elgar Publishing Ltd, Gloucester.

Furness, M. (2003) The Wem Incident. *In* J. Gray & K. C. Thompson (eds.), *Water Contamination Emergencies: Can We Cope?* RSC Publishing, Le Meridien Hotel, Manchester.

Galbraith, N. S., N. J. Barrett & R. Stanwell-Smith (1987) Water and Disease After Croydon: A Review of Water-borne and Water-associated Disease in the UK 1937-86. *Water and Environment Journal,* **1**(1)**,** 7-21.

Garbrecht, J. D. & T. C. Piechota (2006) Climate Variations, Climate Change and Water Resources Engineering. American Society of Civil Engineers, Reston.

Gibbons, B. (2006) Cabinet Written Statement: Cryptosporidiosis in North Wales. Welsh Assembly Government, Cardiff.

Gittins, J. (1996) Recreation and Multiple Land Use Catchment Management - Problems and Issues. *In* M. Cresser & K. Pugh (eds.), *Multiple Land Use and Catchment Management*. The Macaulay Land Use Research Institute, Aberdeen.

Glaisher, A. M. (1997) Catchment Management Plans and Local Environment Agency Plans - An Assessment of their Effectiveness in Planning for Nature Conservation. University of Wales, Aberystwyth.

Glas Cymru Cyfyngedig (Unknown) Report and Accounts 2004-05. Glas Cymru Cyfyngedig, Nelson.

Gooddy, D. C., A. G. Hughes, A. T. Williams, A. C. Armstrong, R. J. Nicholson & J. R. Williams (2001) Field and Modelling Studies to Assess the Risk to UK Groundwater from Earth-Based Stores for Livestock Manure. *Soil Use and Management,* **17**(2)**,** 128-137.

Gray, J. & K. C. Thompson (2003) Preface. *In* J. Gray & K. C. Thompson (eds.), *Water Contamination Emergencies: Can We Cope?* RSC Publishing, Le Meridien Hotel, Manchester.

Green Cross International (2007) Access to Water isn't a Privilege... It's a Right [online]. Green Cross International. http://www.watertreaty.org/ [accessed 9 August 2007]

HACCP Now (2006) What is HACCP? [online]. HACCP Now. http://www.haccpnow.co.uk/WhatIsHACCP.asp [accessed 8 October 2006]

Hadley Centre for Climate Change and Prediction (2002) PRECIS - Update 2002: Providing Regional Climates for Impact Studies. Hadley Centre for Climate Change and Prediction, Exeter.

Hadley Centre for Climate Change and Prediction (2004) Uncertainty, Risk and Dangerous Climate Change. Hadley Centre for Climate Change and Prediction, Exeter.

Hadley Centre for Climate Change and Prediction (2005a) Climate Change and the Greenhouse Effect: A Briefing from the Hadley Centre. Hadley Centre for Climate Change and Prediction, Exeter.

Hadley Centre for Climate Change and Prediction (2005b) Climate Change, Rivers and Rainfall. Hadley Centre for Climate Change and Prediction, Exeter.

Halcrow (year unknown) "Catchment Flood Management Plans" leaflet.

Hall, T. (2006) Raising the Stakes. *Water & Environment Magazine.*

Hall, T., P. Hunter, G. Nichols & G. Stanfield (2004) Review of the Microbial Implications of Climate Change for the Water Industry. UK Water Industry Research, London.

Hampton, P. (2005) Reducing Administrative Burdens: Effective Inspection and Enforcement. HM Treasury, London.

Hansard (2006) 12 Jan 2006, column 751W continued - EC Water Framework Directive [online]. UK Parliament. http://www.publications.parliament.uk/pa/cm200506/cmhansrd/cm060112/text/60112w04.htm#60112w04.html_sbhd0 [accessed 22 October 2006]

Haskins, C. (2003) Rural Delivery Review: A Report On The Delivery Of Government Policies In Rural England. Department for Environment, Food and Rural Affairs, London.

Hayes, C., R. Keirle & A. Lobley (2008) The Identification of Xenobiotics in the New Context of Drinking Water Safety Planning and Related Environmental Legislation. *Water, Air & Soil Pollution: Focus,* **8,** 555-564.

Health Protection Agency (2007a) Cryptosporidium [online]. Health Protection Agency,
. http://www.hpa.org.uk/infections/topics_az/crypto/menu.htm [accessed 18 October 2007]

Health Protection Agency (2007b) Giardia [online]. Health Protection Agency,
. http://www.hpa.org.uk/infections/topics_az/giardia/menu.htm [accessed 18 October 2007]

Hendry, K., H. Sambrook, C. Underwood, R. Waterfall & A. Williams (2006) Eutrophication of Tamar Lakes (1975-2003): A Case Study of Land-Use Impacts, Potential Solutions and Fundamental Issues for the Water Framework Directive. *Water and Environment Journal,* **20**(3)**,** 159-168.

Heywood, G. M. & J. P. Lumbers (2006a) DOMS Guidance Manual Volume 1: Non-Technical Overview. UK Water Industry Research, London.

Heywood, G. M. & J. P. Lumbers (2006b) DOMS Guidance Manual Volume 2: Guidance. UK Water Industry Research, London.

Hines, C. (2006) Outbreak of Cryptosporidiosis in North West Wales, 2005: Report of the Outbreak Control Team. National Public Health Service for Wales, Cardiff.

HM Government (2006) Climate Change: The UK Programme 2006. HM Government, London.

Holmes, M. G. R., A. R. Young, T. H. Goodwin & R. Grew (2005) A Catchment-Based Water Resource Decision-Support Tool for the United Kingdom. *Environmental Modelling & Software,* **20**(2)**,** 197-202.

Holt, C. P. (1993) Climate Change and Future Water Resources in Wales. *Institute of Earth Studies.* University of Wales, Aberystwyth.

Horsey, S. (2006) Case Studied Aimed at Reducing Diffuse Water Pollution from Agriculture in England. Department for Environment Food and Rural Affairs, London.

Hossell, J., A. Johnson & J. Wishart (2007) Climate Change, the Aquatic Environment and the Water Framework Directive. UK Water Industry Research, London.

House of Commons (2003a) The Water Framework Directive. *In* Environment Food and Rural Affairs Committee (ed.), *Session 2002-03.* UK Parliament, London.

House of Commons (2003b) The Water Framework Directive: Government Reply. *In* Environment Food and Rural Affairs Committee (ed.), *Session 2002-03.* UK Parliament, London.

House of Commons (2003c) Water Pricing. *In* Environment Food and Rural Affairs Committee (ed.), *Session 2003-04.* UK Parliament, London.

House of Commons (2004a) Climate Change, Water Security and Flooding. *In* Environment Food and Rural Affairs Committee (ed.), *Session 2003-04.* UK Parliament, London.

House of Commons (2004b) Climate Change, Water Security and Flooding: Government Reply to the Committee's Report. *In* Environment Food and Rural Affairs Committee (ed.), *Session 2004-05.* UK Parliament, London.

House of Commons (2004c) Water Pricing: Follow-up. *In* Environment Food and Rural Affairs Committee (ed.), *Session 2003-04.* UK Parliament, London.

House of Commons (2004d) Water Pricing: Government Reply to the Committee's Report. *In* Environment Food and Rural Affairs Committee (ed.), *Session 2003-04.* UK Parliament, London.

House of Commons (2005) Water Pricing: Follow-up: Government Reply to the Committee's Report. *In* Environment Food and Rural Affairs Committee (ed.), *Session 2004-05.* UK Parliament, London.

House of Commons (2006a) The Environment Agency. *In* Environment Food and Rural Affairs Committee (ed.), *Session 2005-06.* UK Parliament, London.

House of Commons (2006b) The Environment Agency: The Government and Environment Response's to the Committee's Seventh Report. *In* Science and Technology Committee (ed.), *Session 2005-06.* UK Parliament, London.

House of Lords (2005a) The Economics of Climate Change. *In* Economic Affairs Committee (ed.), *Session 2005-06.* UK Parliament, London.

House of Lords (2005b) Government Response to the Economics of Climate Change. *In* Science and Technology Committee (ed.). UK Parliament, London.

House of Lords (2005c) House of Lords Briefing: The Science and Technology Committee. *In* Science and Technology Committee (ed.). UK Parliament.

House of Lords (2005d) Press Notice: Lords Inquiry to Examine Water Management [online]. UK Parliament. http://www.parliament.uk/parliamentary_committees/lords_press_notices/pn210705a_sti.cfm [accessed 8 May 2006]

House of Lords (2006a) Government Must Recognise need for Increased Investment in New Water Resources, Warns Lords [online]. UK Parliament. http://www.parliament.uk/parliamentary_committees/lords_press_notices/pn060606sti.cfm [accessed 17 August 2006]

House of Lords (2006b) Minutes of Evidence taken before the Science and Technology Committee (Sub-Committee I). *In* Science and Technology Committee (ed.). UK Parliament, London.

House of Lords (2006c) Water Management, Volume I: Report. *In* Science and Technology Committee (ed.), *Session 2005-06.* UK Parliament, London.

HR Wallingford Ltd (2005a) Climate Change - Impacts and Adaption. *Edge.*

HR Wallingford Ltd (2005b) Effect of Climate Change on Rivers and Groundwater. *Edge.*

Hrudey, S. E. & E. J. Hrudey (2004) *Safe Drinking Water - Lessons from Recent Outbreaks in Affluent Nations.* IWA Publishing, London.

Hulebak, K. L. & W. Schlosser (2002) Hazard Analysis and Critical Control Point (HACCP) History and Conceptual Overview. *Risk Analysis,* **22**(3), 547-552.

Humphrey, N. (2001) Modelling the Effects of Climate Change on Water Quality in Rivers and Reservoirs. UK Water Industry Research, London.

Humphrey, R. L. & M. A. Shepherd (2003) A Review of the UK-ADAPT Project Database. UK Water Industry Research, London.

Hunt, E. C. (2004) *Thirsty Planet: Strategies for Sustainable Water Management.* Zed Books, London.

Hunter, P. R., M. Waite & E. Ronchi (2000a) Appendix, in "Drinking Water And Infectious Disease: Establishing The Links". *In* P. R. Hunter, M. Waite & E. Ronchi (eds.), *Approaches For Establishing Links Between Drinking Water And Infectious Disease*. IWA Publishing, Basingstoke.

Hunter, P. R., M. Waite & E. Ronchi (2000b) Preface, in "Drinking Water And Infectious Disease: Establishing The Links". *In* P. R. Hunter, M. Waite & E. Ronchi (eds.), *Approaches For Establishing Links Between Drinking Water And Infectious Disease*. IWA Publishing, Basingstoke.

Hutton, G. & L. Haller (2004) Evaluation of the Costs and Benefits of Water and Sanitation Improvements at the Global Level. World Health Organisation, Geneva.

Institute of Environment Science University of Wales Bangor, ECOTEC Research and Consulting, Climatic Research Unit University of East Anglia & C. f. E. a. H. Bangor (2000a) Wales: Changing Climate, Challenging Choices - A Scoping Study of Climate Change Impacts in Wales. *In* J. Farrer & P. Vaze (eds.). National Assembly for Wales, Cardiff.

Institute of Environment Science University of Wales Bangor, Institute of Terrestrial Ecology University of Wales Bangor, ECOTEC Research and Consulting & Climatic Research Unit University of East Anglia (2000b) Wales, Changing Climate, Challenging Choices. National Assembly for Wales, Cardiff.

Intergovernmental Panel on Climate Change (2001a) Climate Change 2001: Impacts, Adaptation and Vulnerability - Hydrology and Water Resources. Intergovernmental Panel on Climate Change.

Intergovernmental Panel on Climate Change (2001b) Climate Change 2001: The Scientific Basis. Intergovernmental Panel on Climate Change.

Intergovernmental Panel on Climate Change (2007a) Working Group I: The Physical Basis of Climate Change [online]. IPCC. http://ipcc-wg1.ucar.edu/wg1/wg1-report.html [accessed 8 May 2007]

Intergovernmental Panel on Climate Change (2007b) About IPCC [online]. IPCC. http://www.ipcc.ch/about/about.htm [accessed 8 May 2007]

International Water Association (2004) The Bonn Charter for Safe Drinking Water. International Water Association, London.

Jackson, C. (2003) Problems, Perception and Perfection - The Role Of The Drinking Water Inspectorate In Water Quality Incidents And Emergencies. *In* J. Gray & K. C. Thompson (eds.), *Water Contamination Emergencies: Can We Cope?* RSC Publishing, Le Meridien Hotel, Manchester.

Jones, A. F. (2006) Dipping a Toe into the Great Water Debate. *North Wales Chronicle.* Bangor.

Kallis, G. & D. Butler (2001) The EU Water Framework Directive: Measures and Implications. *Water Policy,* **3**(2), 125-142.

Keirle, R. (2006a) Notes of a Meeting Held at Durleigh WTW, Bridgwater, on 13 July 2006. Swansea University, Bangor.

Keirle, R. (2006b) Notes of a Meeting Held at Environment Agency Wales' Offices, Bangor, on 26 September 2006. Swansea University, Bangor.

Keirle, R. (2006c) Notes of a Telephone Conversation with the Environment Agency Wales on 5 September 2006. Swansea University, Bangor.

Keirle, R. (2008) The Need for Greater Protection for Drinking Water Supplies. *Public Health Network.* Water UK, Birmingham.

Keirle, R. & C. Hayes (2007a) A Review of Catchment Management in the New Context of Drinking Water Safety Plans. *Water and Environment Journal,* **21**(3), 208-216.

Keirle, R. & C. Hayes (2007b) A Review of Climate Change and its Potential Impacts on Water Resources in the UK. *E-WAter,* **2007**(04), 1-18.

Keirle, R. & C. Hayes (2008a) The Need for Greater Protection for Drinking Water Supplies. *E-WAter,* **2008**(05), 1-28.

Keirle, R. & C. Hayes (2008b) UK Experience in Drinking Water Safety Planning: Catchment Risk Assessment and Indexing Methods. *Water Safety Plans: Global Experiences and Future Trends.* International Water Association, Lisbon.

Kellagher, R. (2004) Climate Change and the Hydraulic Design of Sewerage Systems: Summary Report. UK Water Industry Research, London.

Kistemann, T., S. Herbst, F. Dangendorf & M. Exner (2001) GIS-Based Analysis of Drinking-Water Supply Structures: A Module for Microbial Risk Assessment. *International Journal of Hygiene and Environmental Health,* **203**(4)**,** 301-310.

Larsson, M., R. Parena, E. Smeets & I. Troquet (2002) *Process Benchmarking in the Water Industry.* IWA Publishing, London.

LaTrobe-Bateman, J. (2007) Interviews with the DWI and Ofwat. *DW/02 DWSP Phase IV.* UK Water Industry Research, London.

Ministry of Health (2005) *A Framework on How to Prepare and Develop Public Health Risk Management Plans for Drinking-water Supplies* Ministry of Health, Wellington, New Zealand.

Morris, B. & J. Cunningham (2008) Suburbanisation of Important Aquifers in England and Wales: Estimating its Current Extent. *Water and Environment Journal,* **22**(2)**,** 88-99.

(2001a) Tir Gofal (Amendment) (Wales) Regulations 2001 *HMSO.*

(2001b) Water Supply (Water Quality) Regulations 2001 *HMSO.*

National Assembly for Wales (2001c) Woodlands For Wales: The National Assembly For Wales Strategy For Trees And Woodlands. National Assembly For Wales, Cardiff.

(2003a) Action Plan for Nitrate Vulnerable Zones (Amendment) (Wales) Regulations 2003 *HMSO.*

(2003b) Natural Mineral Water, Spring Water and Bottled Drinking Water (Amendment) (Wales) Regulations 2003 *HMSO.*

(2004a) Environmental Assessment of Plans and Programmes (Wales) Regulations 2004 *HMSO.*

(2004b) Natural Mineral Water, Spring Water and Bottled Drinking Water (Amendment) (Wales) Regulations 2004 *HMSO.*

National Assembly for Wales (2006a) Powers and Responsibilities of the Assembly [online]. National Assembly for Wales. http://www.wales.gov.uk/pubinfaboutassembly/content/powers-e.htm [accessed 15 June 2006]

(2006b) Tir Cynnal (Wales) Regulations 2006 *HMSO.*

National Assembly for Wales (2006c) Your Guide to the Assembly. Cardiff.

National Assembly for Wales (2007a) A Guide to the Third Assembly. Cardiff.

National Assembly for Wales (2007b) Legislation [online]. National Assembly for Wales. http://www.wales.gov.uk/pubinfaboutassembly/content/powers-e.htm [accessed 21 December 2007]

National Assembly for Wales (2007c) Legislative Competence Orders [online]. National Assembly for Wales. http://www.wales.gov.uk/pubinfaboutassembly/content/powers-e.htm [accessed 21 December 2007]

National Assembly for Wales (2007d) Measures [online]. National Assembly for Wales. http://www.wales.gov.uk/pubinfaboutassembly/content/powers-e.htm [accessed 21 December 2007]

National Audit Office (2006) About Us: Frequently Asked Questions [online]. National Audit Office. http://www.nao.org.uk/about/faqs.htm#NAOrole [accessed 6 September 2006]

National Farmers' Union (2005) Agriculture and Climate Change. National Farmers' Union, Stoneleigh.

National Farmers' Union (2008a) Environment [online]. National Farmers' Union. http://www.nfuonline.com/x1071.xml [accessed 25 March 2008]

National Farmers' Union (2008b) History [online]. National Farmers' Union. http://www.nfuonline.com/x200.xml [accessed 25 March 2008]

National Farmers' Union (2008c) Structure [online]. National Farmers' Union. http://www.nfuonline.com/x192.xml [accessed 25 March 2008]

National Public Health Service for Wales (2006) Cryptosporidium Outbreak Update (30th January) [online]. http://www.wales.nhs.uk/sites/news.cfm?OrgID=368&ContentID=4383 [accessed 28 June 2006]

National Rivers Authority (1994) Water, Nature's Precious Resource: An Environmentally Sustainable Water Resources Development Strategy for England and Wales. National Rivers Authority, Bristol.

National Rivers Authority (undated) River Conwy Catchment Management Consultation Report Summary. National Rivers Authority, Caernarfon.

Natural Environment Research Council (2006a) Centre for Ecology & Hydrology [online]. Natural Environment Research Council. http://www.nerc.ac.uk/research/sites/research/ceh.asp [accessed 9 October 2006]

Natural Environment Research Council (2006b) NERC Council Statement of Intent - Centre for Ecology and Hydrology [online]. Natural Environment Research Council. http://www.nerc.ac.uk/secretariat-council/ceh [accessed 9 October 2006]

Newson, M. (1997) *Land Water and Development: Sustainable Management of River Basin Systems.* Routledge, London.

NFU Cymru (2008) About NFU Cymru [online]. NFU Cymru. http://www.nfu-cymru.org.uk/about.php [accessed 25 March 2008]

Northern Ireland Authority for Utility Regulation (2007) Utility Regulator - Electricity Gas Water [online]. Northern Ireland Authority for Utility Regulation. http://ofreg.nics.gov.uk/index.html [accessed 22 May 2007]

Northern Ireland Drinking Water Inspectorate (2006) Drinking Water Quality in Northern Ireland, 2006. Environment & Heritage Service, Belfast.

Northern Ireland Water (2007) Facts and Figures [online]. Northern Ireland Water. http://www.niwater.com/factsandfigures.asp [accessed 22 May 2007]

O'Neill, D. (2007) *Drinking Water Safety Plans (DWSP), Distribution Operation and Maintenance Strategies (DOMS) & Private Supplies. 'personal communication'.*

Office of the Deputy Prime Minister (2005) A Practical Guide to the Strategic Environmental Assessment Directive: Practical Guidance on Applying European Directive 2001/42/EC "on the Assessment of the Effects of Certain Plans and Programmes on the Environment". London.

Ofwat (2005) Water Act 2003 Water Supply Licensing: Applying for a Water Supply Licence - Guidance. Ofwat, Birmingham.

Ofwat (2006a) About Us [online]. Ofwat. http://www.ofwat.gov.uk/aptrix/ofwat/publish.nsf/Content/protecting_interests280905 [accessed 27 June 2006]

Ofwat (2006b) The Development of the Water Industry in England and Wales. Ofwat, Birmingham.

Ofwat (2006c) Facts and Figures - May 2006. Ofwat, Birmingham.

Ofwat (2006d) Setting Water and Sewerage Price Limits: Is Five Years Right? Ofwat, Birmingham.

Owen, D. L. (2002) Water Policy Study: A Plaid Cymru - the Party of Wales Discussion Paper. Plaid Cymru, Cardiff.

Parker, J. (2006) Capital Supply. *Water & Environment Magazine.*

Pearce, F. (2006) *When The Rivers Run Dry.* Eden Project Books, London.

Pembrokeshire Coast National Park Authority (2003) National Park Management Plan 2003-2007. Pembrokshire Coast National Park Authority, Haverfordwest.

Persoone, G., K. Wadhia & K. C. Thompson (2003) Rapid Toxkit Microbiotests For Water Contamination Emergencies. *In* J. Gray & K. C. Thompson (eds.), *Water Contamination Emergencies: Can We Cope?* RSC Publishing, Le Meridien Hotel, Manchester.

Randhir, T. O. (2007) *Watershed Management: Issues and Approaches.* IWA Publishing, London.

Rees, B., F. Cessford, R. Connelly, J. Cowan, R. Bowell, E. K. Weatherhead, J. W. Knox, C. L. Twite & J. Morris (2003) Optimum Use of Water for Industry and Agriculture: Phase 3. Environment Agency, Bristol.

Reid, C. & P. Grice (2001) Wildlife Gain From Agri-Environment Schemes: Recommendations From English Nature's Habitat And Species Specialists. English Nature, Peterborough.

Risk & Policy Analysts Ltd (2003) Water Framework Directive - Indicative Costs of Agricultural Measures Assessment: Final Report. Department for Environment Food and Rural Affairs, London.

Rivers Agency (2006) What We Do [online]. Rivers Agency. http://www.riversagencyni.gov.uk/about/whatwedo.htm [accessed 9 October 2006]

Rivers Agency (2007) Rivers in Northern Ireland [online]. Rivers Agency. http://www.riversagencyni.gov.uk/index/rivers-in-northern-ireland.htm [accessed 22 May 2007]

Robinson, R. A. & W. J. Sutherland (2002) Post-War Changes in Arable Farming and Biodiversity in Great Britain. *Journal of Applied Ecology,* **39**(1), 157-176.

Roesch, C. & D. J. Stewart (2006) *Climate Change and Water Resources: A Primer for Municipal Water Providers.* AWWA Research Foundation, Denver, Colorado.

Rouse, M. (1999) Guidance on the Implementation of Paragraph 9(1) of the Water Undertakers (Information) Direction 1998 [online]. Drinking Water Inspectorate. http://www.dwi.gov.uk/regs/infolett/1999/info1399.htm [accessed 24 March 2008]

Rouse, M. (2007) *Institutional Governance and Regulation of Water Services: The Essential Elements.* IWA Publishing, London.

Royal Society for the Protection of Birds (2006a) DEFRA Flood and Coastal Management Strategy [online]. Royal Society for the Protection of Birds. http://www.rspb.org.uk/policy/waterwetlands/lawandpolicy/diffusepollution.asp [accessed 27 June 2006]

Royal Society for the Protection of Birds (2006b) Diffuse Pollution from Agriculture [online]. Royal Society for the Protection of Birds. http://www.rspb.org.uk/policy/waterwetlands/lawandpolicy/diffusepollution.asp [accessed 27 June 2006]

Royal Society for the Protection of Birds (2006c) From Hilltop to Tap [online]. Royal Society for the Protection of Birds. http://www.rspb.org.uk/england/northwest/conservation/hilltoptotap.asp [accessed 27 June 2006]

Royal Society for the Protection of Birds (2006d) Welcome to the RSPB [online]. Royal Society for the Protection of Birds. http://www.rspb.org.uk/ [accessed 27 June 2006]

Royal Society for the Protection of Birds (2008) Agri-Environment Schemes in Wales [online]. Royal Society for the Protection of Birds. http://www.rspb.org.uk/ourwork/farming/policy/policyissues/schemes/wales.asp?view=print [accessed 9 March 2008]

Rural Payments Agency (2008a) About RPA [online]. Rural Payments Agency. http://www.rpa.gov.uk/rpa/index.nsf/UIMenu/F51B6B0D961521A7802570450051BAB9?opendocument [accessed 28 February 2008]

Rural Payments Agency (2008b) England Rural Development Programme [online]. Rural Payments Agency. http://www.rpa.gov.uk/rpa/index.nsf/vContentByTaxonomy/RPA%20Schemes**England%20Rural%20Development%20Programme**?OpenDocument [accessed 28 February 2008]

Samuels, P., B. Woods-Ballard, C. Hutchings, J. Felgate, P. Mobbs, C. Elliott & D. Brook (2006) *Sustainable Water Management in Land-Use Planning.* CIRIA, London.

Science & Environmental Policy Project (2008) About the Project [online]. Science & Environmental Policy Project. http://www.sepp.org/ [accessed 20 March 2008]

Scottish Environment Link (2005) Water Framework Directive and Flooding – Implications for Flooding Policies in Scotland. Scottish Environment Link, Perth.

Scottish Environment Protection Agency (2007) Environmental Liability Directive (ELD): Summary of Requirements [online]. Scottish Environment Protection Agency. http://www.sepa.org.uk/eld/requirements.htm [accessed 15 December 2007]

Scottish Environment Protection Agency (undated) The River Dee: Catchment Management Plan Issues, Consultation Document. Scottish Environment Protection Agency, Aberdeen.

Scottish Executive (2005) Prevention of Environmental Pollution From Agricultural Activity: Code of Good Practice. Scottish Executive, Edinburgh.

Scottish Executive (2006a) Executive Note: The Private Water Supplies (Grants) (Scotland) Regulations 2006 - SSI/2006/210.

Scottish Executive (2006b) Executive Note: The Private Water Supplies (Scotland) Regulations 2006 - SSI/2006/209. Edinburgh.

Scottish Executive (2006c) Final Regulatory Impact Assessment: The Private Water Supplies (Scotland) Regulations 2006. Edinburgh.

(2006d) Private Water Supplies (Notices) (Scotland) Regulations 2006 *HMSO*.

(2006e) Private Water Supplies (Scotland) Regulations 2006 *HMSO*.

Scottish Executive (2006f) Private Water Supplies: Technical Manual. Scottish Executive, Edinburgh.

Scottish Executive & Food Standards Agency (undated) Response to Report of the Task Force on *E coli* O157. Edinburgh.

Scottish Executive Environment Group (2001) Private Water Supply Regulation: A Consultation. Scottish Executive, Edinburgh.

Scottish Executive Environment Group (2002) Private Water Supply Regulation: Consultation Report. Scottish Executive, Edinburgh.

Scottish Executive Environment Group (2005) The Draft Private Water Supplies (Scotland) Regulations 2005 and Proposals for a Private Water Supplies Grant Scheme: A Consultation. Scottish Executive, Edinburgh.

Scottish Executive Environment Group: Drinking Water Quality Division (2003) *Distribution Operation and Maintenance Strategy (DOMS) (Information Letter 5/2003). 'personal communication'.*

Scottish Executive Environment Group: Drinking Water Quality Division (2004) *Microbiological Quality of Water Leaving Treatment Works and in Service*

Reservoirs: Drinking Water Safety Plans and Regulation (Information Letter 3/2004). 'personal communication'.

Scottish Executive Environment Group: Drinking Water Quality Division (2006) *Managing Water Quality from Source to Tap: Drinking Water Safety Plans for Water Supplies in Scotland (Information Letter 1/2006). 'personal communication'.*

(2003) Water Environment and Water Services (Scotland) Act 2003 *HMSO.*

Scottish Water (2006a) About Us [online]. Scottish Water. http://www.scottishwater.co.uk/portal/page?_pageid=225,483511&_dad=portal&_schema=PORTAL [accessed 10 September 2006]

Scottish Water (2006b) Annual Water Quality Report: 2006. Scottish Water, Dunfermline.

Scottish Water (2006c) Our Regulators [online]. Scottish Water. http://www.scottishwater.co.uk/portal/page?_pageid=225,483570&_dad=portal&_schema=PORTAL [accessed 10 September 2006]

Scottish Water (2007) Who We Are [online]. Scottish Water. http://www.scottishwater.co.uk/portal/page?_pageid=225,483516&_dad=portal&_schema=PORTAL [accessed 22 May 2007]

Severn Trent Water (2007a) Mythe - 23 July 2007 [online]. Severn Trent Water. http://www.stwater.co.uk/upload/pdf/Glos_pres_3_Mythe.pdf [accessed 16 October 2007]

Severn Trent Water (2007b) Tap Water Is Safe To Drink [online]. Severn Trent Water. http://www.stwater.co.uk/server.php?show=ConWebDoc.3180 [accessed 16 October 2007]

Severn Trent Water (2007c) Time Line [online]. Severn Trent Water. http://www.stwater.co.uk/upload/pdf/B4815_-_timeline.pdf [accessed 16 October 2007]

Skudder, D. (1998) Adding Insult to Injury [online]. Environmental Assistance. http://www.environmental-assistance.org/conference/papers/skudder_paper.html [accessed 16 July 2007]

Snowdonia National Park Authority (2006) Snowdonia National Park [online]. Snowdonia National Park Authority. http://snowdonia-npa.gov.uk/page/screen.php?nav1=home&nav2=1&nav3=1&nav4=1&nav5=1&level=1&lang=eng [accessed 12 September 2006]

Society for the Environment (2006a) Background to SocEnv [online]. Society for the Environment. http://www.socenv.org.uk/Background.htm [accessed 11 September 2006]

Society for the Environment (2006b) Charter [online]. Society for the Environment. http://www.socenv.org.uk/Royal%20Charter.pdf [accessed 11 September 2006]

Society for the Environment (2006c) Current Constituent Bodies [online]. Society for the Environment. http://www.socenv.org.uk/Constituent%20Bodies.htm [accessed 11 September 2006]

Soil Association (2006a) *Drinking Water Safety Plans and Catchment Planning. 'personal communication'.*

Soil Association (2006b) Who We Are [online]. Soil Association. http://www.soilassociation.org/web/sa/saweb.nsf/Aboutus/Whoarewe.html [accessed 27 June 2006]

Strandberg, P. (2006) Global Warming Greatest Scam in History! [online]. Global Warming and the Climate. http://www.global-warming-and-the-climate.com/arguments-against-global-warming.htm [accessed 22 March 2008]

Sunkin, M., D. M. Ong & R. Wight (1998) *Sourcebook on Environmental Law.* Cavendish Publishing Ltd, London.

Sydney Catchment Authority (2006) About the SCA [online]. Sydney Catchment Authority. http://www.sca.nsw.gov.au/about/index.html [accessed 28 November 2006]

Tané, H. (1996) The Case for Integrated River Catchment Management. *In* M. Cresser & K. Pugh (eds.), *Multiple Land Use and Catchment Management*. The Macaulay Land Use Research Institute, Aberdeen.

Task Force on *E Coli* O157 (2001) Final Report.

The Council of the European Union (2006) Council of the European Union [online]. http://www.consilium.europa.eu/showPage.asp?id=242&lang=en&mode=g [accessed 1 August 2006]

The ENDS Report (1994a) History Repeats Itself in the Worcester Drinking Water Incident. *The Ends Report.*

The ENDS Report (1994b) Worcester Incident Revives Concern Over Drinking Water Safeguards. *The Ends Report.*

The ENDS Report (1995a) Severn Trent Convicted for Worcester Drinking Water Incident. *The Ends Report.*

The ENDS Report (1995b) Torbay's Disease Outbreak Exposes Holes in Drinking Water Safeguards. *The Ends Report.*

The ENDS Report (1995c) Water Company Polluted Own Supply With Cryptosporidium. *The Ends Report.*

The ENDS Report (1995d) Worcester Incident Leads to First Drinking Water Prosecution. *The Ends Report.*

The ENDS Report (1997a) DWI's Crushing Setback Over Torbay Crypto Case. *The Ends Report.*

The ENDS Report (1997b) Lessons from Torbay's Drinking Water Crises. *The Ends Report.*

The ENDS Report (1999a) Camelford: Questions Still Unanswered After Eleven Years. *The Ends Report.*

The ENDS Report (1999b) Waterborne Crypto Comes From Sewage, Studies Show. *The Ends Report.*

The ENDS Report (2007) Welsh Water Faces Crypto Prosecution. *The Ends Report.*

The London School of Economics and Political Science (2008) Department for Environment, Food and Rural Affairs [online]. The London School of Economics and Political Science. http://www.lse.ac.uk/library/govpub/unikin/UK_government_web_defra.htm [accessed 13 March 2008]

The National Trust (2006a) Agriculture and the Trust [online]. The National Trust. http://www.nationaltrust.org.uk/main/w-chl/w-countryside_environment/w-food_farming/w-food_farming-agriculture_overview.htm [accessed 27 June 2006]

The National Trust (2006b) Agriculture Policy [online]. The National Trust. http://www.nationaltrust.org.uk/main/w-chl/w-countryside_environment/w-food_farming/w-food_farming-agriculture_overview/w-food_farming-agriculture-policy.htm [accessed 27 June 2006]

The National Trust (2006c) Farming and the Environment [online]. The National Trust. http://www.nationaltrust.org.uk/main/w-chl/w-countryside_environment/w-food_farming/w-food_farming-agriculture_overview/w-food_farming-agriculture-environment.htm [accessed 27 June 2006]

The National Trust (2006d) Management of the Trust's Agricultural Estates [online]. The National Trust. http://www.nationaltrust.org.uk/main/w-chl/w-countryside_environment/w-food_farming/w-food_farming-agriculture_overview/w-food_farming-agriculture-management.htm [accessed 27 June 2006]

The National Trust (2006e) What We Do [online]. The National Trust. http://www.nationaltrust.org.uk/main/w-trust/w-thecharity/w-what_we_do.htm [accessed 27 June 2006]

The Sunday Herald (2007) SNP Plan to Merge 'Green' Agencies [online]. The Sunday Herald. http://www.sundayherald.com/news/heraldnews/display.var.1201137.0.snp_plan_to_merge_green_agencies.php [accessed 22 May 2007]

The Washington Post (2006) The Tempest [online]. The Washington Post. http://www.washingtonpost.com/wp-dyn/content/article/2006/05/23/AR2006052301305_pf.html [accessed 22 March 2008]

The Wildlife Trusts (2006a) About the Wildlife Trusts [online]. The Wildlife Trusts. http://www.wildlifetrusts.org/index.php?section=about [accessed 25 September 2006]

The Wildlife Trusts (2006b) Water for Wildlife [online]. The Wildlife Trusts. http://www.wildlifetrusts.org/index.php?section=environment:wfw [accessed 25 September 2006]

Thompson, K. C. & J. Gray (2005) Water Contamination Emergencies: Enhancing Our Response. *In* K. C. Thompson & J. Gray (eds.), *Water Contamination Emergencies: Enhancing Our Response*. RSC Publishing, Manchester University.

Three Regions Climate Change Group (2005) Adapting to Climate Change: A Checklist for Development. Greater London Authority.

Twort, A. C., D. D. Ratnayaka & M. J. Brandt (2000) *Water Supply.* Arnold, London.

UK ADAPT (2006) Water Resources Management in Co-operation with Agriculture (WAgriCo) [online]. UK ADAPT. http://www.uk-adapt.org.uk/find/index.html?action=project&id=174 [accessed 15 November 2006]

UK Climate Impacts Programme (2001) REGIS: Regional Climate Change Impact and Response Studies in East Anglia and North West England. *In* I. Holman & P. Loveland (eds.). UK Climate Impacts Programme, Oxford.

UK Climate Impacts Programme (2006) About UKCIP [online]. UK Climate Impacts Programme. http://www.ukcip.org.uk/about/ [accessed 30 September 2006]

(1963) Water Resources Act 1963 *HMSO.*

(1965) Water Resources (Licences) Regulations 1965 *HMSO.*

(1969) Water Resources (Succession to Licences) Regulations 1969 *HMSO.*

(1972) European Communities Act 1972 *HMSO.*

(1975) Reservoirs Act 1975 *HMSO.*

(1985) Food and Environment Protection Act 1985 *HMSO.*

(1989a) Water Act 1989 *HMSO.*

(1989b) Water Supply (Water Quality) (Amendment) Regulations 1989 *HMSO.*

(1989c) Water Supply (Water Quality) Regulations 1989 *HMSO.*

(1990) Environmental Protection Act 1990 *HMSO.*

(1991a) Land Drainage Act 1991 *HMSO.*

(1991b) Private Water Supplies Regulations 1991 *HMSO.*

(1991c) Water Consolidation (Consequential Provisions) Act 1991 *HMSO.*

(1991d) Water Industry Act 1991 *HMSO.*

(1991e) Water Resources Act 1991 *HMSO.*

(1991f) Water Supply (Water Quality) (Amendment) Regulations 1991 *HMSO.*

(1992a) Competition and Service (Utilities) Act 1992 *HMSO.*

(1992b) Private Water Supplies (Scotland) Regulations 1992 *HMSO.*

(1992c) Surface Waters (Dangerous Substances) (Classification) Regulations 1992 *HMSO.*

(1994a) Nitrate Sensitive Areas Regulations 1994 *HMSO.*

(1994b) Surface Waters (River Ecosystem) (Classification) Regulations 1994 *HMSO.*

(1994c) Urban Waste Water Treatment (England and Wales) Regulations 1994 *HMSO.*

(1995) Environment Act 1995 *HMSO.*

(1996a) Protection of Water Against Agricultural Nitrate Pollution (England and Wales) Regulations 1996 *HMSO.*

(1996b) Surface Waters (Abstraction for Drinking Water) (Classification) Regulations 1996 *HMSO.*

(1997a) Surface Waters (Dangerous Substances) (Classification) Regulations 1997 *HMSO.*

(1997b) Surface Waters (Fishlife) (Classification) Regulations 1997 *HMSO.*

(1997c) Surface Waters (Shellfish) (Classification) Regulations 1997 *HMSO.*

(1998a) Action Plan for Nitrate Vulnerable Zones (England and Wales) Regulations 1998 *HMSO.*

(1998b) Government of Wales Act 1998 *HMSO.*

(1998c) Groundwater Regulations 1998 *HMSO.*

(1998d) Private Water Supplies (Scotland) Amendment Regulations 1998 *HMSO.*

(1998e) The Security and Emergency Measures (Water and Sewerage Undertakers) Direction 1998 *Department for the Environment, Transport and the Regions and the Welsh Office.*

(1998f) Surface Waters (Dangerous Substances) (Classification) Regulations 1998 *HMSO.*

(1998g) The Water Undertakers (Information) Direction 1998 *Department for Environment, Food and Rural Affairs.*

(1999a) Land in Care Scheme (Tir Gofal) (Wales) Regulations 1999 *HMSO.*

(1999b) Pollution Prevention and Control Act 1999 *HMSO.*

(1999c) Tir Gofal and Organic Farming (Amendment) (Wales) Regulations 1999 *HMSO.*

(1999d) Water Supply (Water Fittings) (Amendment) Regulations 1999 *HMSO.*

(1999e) Water Supply (Water Fittings) Regulations 1999 *HMSO.*

(1999f) Water Supply (Water Quality) (Amendment) Regulations 1999 *HMSO.*

(2000) Water Supply (Water Quality) Regulations 2000 *HMSO.*

(2001) Water Supply (Water Quality) (Amendment) Regulations 2001 *HMSO.*

(2001a) Water Supply (Water Quality) Regulations 2001 *HMSO.*

(2002) Protection of Water Against Agricultural Nitrate Pollution (Amendment) (Wales) Regulations 2002 *HMSO.*

(2003a) Bathing Waters (Classification) (England) Regulations 2003 *HMSO.*

(2003b) Natural Mineral Water, Spring Water and Bottled Drinking Water (Amendment) (England) Regulations 2003 *HMSO.*

(2003c) Water Act 2003 *HMSO.*

UK Government (2003d) Water Act 2003: Explanatory Notes. *In* Department of the Environment Food and Rural Affairs (ed.).

(2003e) Water Environment (Water Framework Directive) (England and Wales) Regulations 2003 *HMSO.*

(2003f) Water Environment (Water Framework Directive) (Northumbria River Basin District) Regulations 2003 *HMSO.*

(2003g) Water Resources (Environmental Impact Assessment) (England and Wales) Regulations 2003 *HMSO.*

(2004a) Civil Contingencies Act 2004 *HMSO.*

(2004b) Environmental Assessment of Plans and Programmes Regulations 2004 *HMSO.*

(2004c) Natural Mineral Water, Spring Water and Bottled Drinking Water (Amendment) (England) Regulations 2004 *HMSO.*

(2004d) Natural Mineral Water, Spring Water and Bottled Drinking Water (Wales) Regulations 2004 *HMSO.*

(2004e) The Water Undertakers (Information) Direction 2004 *Department for Environment, Food and Rural Affairs.*

(2005a) Drought Plan Regulations 2005 *HMSO.*

UK Government (2005b) Government of Wales Bill. *In* Wales Office (ed.).

UK Government (2005d) Natural Environment and Rural Communities Bill. *In* Department of the Environment Food and Rural Affairs (ed.).

(2006a) Government of Wales Act 2006 *HMSO.*

UK Government (2006b) Government Response to the House of Lords Science and Technology Committee Report on Water Management: 8th Report of Session 2005/06. UK Government, London.

(2006c) Natural Environment and Rural Communities Act 2006 *HMSO.*

(2006d) Protection of Water Against Agricultural Nitrate Pollution (England and Wales) (Amendment) Regulations 2006 *HMSO.*

(2006e) Water Resources (Abstraction and Impounding) Regulations 2006 *HMSO.*

(2006f) Water Resources (Environmental Impact Assessment) (England and Wales) (Amendment) Regulations 2006 *HMSO.*

(2007a) National Assembly for Wales (Legislative Competence) (Amendment of Schedule 7 to the Government of Wales Act 2006) Order 2007 *HMSO.*

(2007b) Natural Mineral Water, Spring Water and Bottled Drinking Water (England) Regulations 2007 *HMSO.*

(2007c) Water Resources Management Plan Regulations 2007 *HMSO.*

(2007d) The Water Supply (Water Quality) Regulations 2000 (Amendment) Regulations 2007 *HMSO.*

UK Technical Advisory Group (2006) About UKTAG [online]. UK Technical Advisory Group,. http://www.wfduk.org/about_tag/ [accessed 11 September 2006]

UK Water Industry Research (2006a) Learning all about DOMS. *UKWIR News.*

UK Water Industry Research (2006b) Projects Underway in: WR/26 - Catchment Issues [online]. UK Water Industry Research. http://www.ukwir.org/content/default.asp?PageId=38247&expanded=73&CatId=131 [accessed 3 November 2006]

UK Water Industry Research (2007) First Workshop: Notes from Afternoon Breakout Sessions. UK Water Industry Research, London.

UKWIR (2006) Learning all about DOMS. *UKWIR News.*

United Nations (2007a) Factsheet on Water and Sanitation [online]. United Nations. http://www.un.org/waterforlifedecade/factsheet.html [accessed 19 June 2007]

United Nations (2007b) The Right to Water [online]. United Nations. http://www.un.org/events/water/TheRighttoWater.pdf [accessed 9 August 2007]

United Utilities (2006a) SCaMP Homepage [online]. United Utilities. http://www.unitedutilities.com/?OBH=3226 [accessed 27 June 2006]

United Utilities (2006b) SCaMP Work Types [online]. United Utilities. http://www.unitedutilities.com/?OBH=3230 [accessed 27 June 2006]

US Census Bureau (2008) Table 094: Midyear Population, by Age and Sex [online]. US Census Bureau. http://www.census.gov/cgi-bin/ipc/idbagg [accessed 2 February 2008]

Vickery, J. A., R. B. Bradbury, I. G. Henderson, M. A. Eaton & P. V. Grice (Unknown) The Role Of Agri-Environment Schemes And Farm Management Practices In Reversing The Decline Of Farmland Birds In England. English Nature, Peterborough.

Vidal, J.-P. & S. Wade (2007) Effects of Climate Change on River Flows and Groundwater Recharge: Guidelines for Resource Assessment and UKWIR06 Scenarios. UK Water Industry Research, London.

Viessman, W. & M. J. Hammer (1993) *Water Supply and Pollution Control.* HarperCollins, New York.

Vuorinen, H. S. (2007) The Medical Identification of New Health Hazards Transmitted by Water. *In* P. S. Juuti, T. S. Katko & H. S. Vuorinen (eds.), *Environmental History of Water.* IWA Publishing, London.

Wade, S., T. Fenn & C. Barnett (2006) Defra Research Contract: Climate Change Impacts and Adaptation - Cross-regional Research Programme (Project C - Water) Draft Final Report. HR Wallingford, Wallingford.

WAgriCo (publication date unknown) Water Resources Management in Cooperation with Agriculture in the United Kingdom. WAgriCo.

Waite, M. & P. Jiggins (2000) *Cryptosporidium* In England And Wales, in "Drinking Water And Infectious Disease: Establishing The Links". *In* P. R. Hunter, M. Waite & E. Ronchi (eds.), *Approaches For Establishing Links Between Drinking Water And Infectious Disease*. IWA Publishing, Basingstoke.

Wales Audit Office (2006) Who We Are [online]. Wales Audit Office. http://www.wao.gov.uk/whoweare/whoweare.asp [accessed 6 September 2006]

Wales Office (2005) Guide to the Government of Wales Bill. Wales Office, London.

Ward, D. R. (2002) *Water Wars: Drought, Flood, Folly and the Politics of Thirst.* Riverhead Books, New York.

Water Committee (1970) Report on Water in Wales. Welsh Council.

Water Industry Commission for Scotland (2005) The Strategic Review of Charges 2006-10: The Final Determination. Water Industry Commission for Scotland, Stirling.

Water Service (2006) About Us/Introduction to Water Service [online]. Water Service. http://www.waterni.gov.uk/home-about.htm [accessed 10 September 2006]

Water Supply and Sanitation Technology Platform (2005a) Strategic Research Agenda, Final Version. Water Supply and Sanitation Technology Platform, Nieuwegein.

Water Supply and Sanitation Technology Platform (2005b) Thematic Working Group 1, Water Management: Vision Document, Final Version. Water Supply and Sanitation Technology Platform, Nieuwegein.

Water UK (2006a) About Water UK [online]. Water UK. http://www.water.org.uk/home/about [accessed 18 August 2006]

Water UK (2006b) Water Services in the UK [online]. Water UK. http://www.water.org.uk/home/resources-and-links/waterfacts-2005/water-services-in-the-uk [accessed 10 September 2006]

Waters, B. (2005) Reservoir Catchment and Impoundment Management. UK Water Industry Research, London.

Watkins, J., C. Francis, D. Kay & L. Lewtrell (2001) Report on the Incidence of *Cryptosporidium* in Private Water Supplies. Drinking Water Inspectorate.

Watson, R. D. (1996) Integrating Catchment Management: The Human Dimension. *In* M. Cresser & K. Pugh (eds.), *Multiple Land Use and Catchment Management*. The Macaulay Land Use Research Institute, Aberdeen.

Watts, G. (2006) Parched. *Water & Environment Magazine.*

Welford, R. & A. Gouldson (1993) *Environmental Management & Business Strategy.* Pitman Publishing, London.

Welsh Assembly Government (2003) A Living And Working Environment For Wales: The State Of The Welsh Environment 2003, Summary Report. Welsh Assembly Government, Cardiff.

Welsh Assembly Government (2005a) Catchment Sensitive Farming Scheme: A Demonstration Project. Welsh Assembly Government, Cardiff.

Welsh Assembly Government (2005b) Our Environment, Our Future, Your Views: Report On The Results Of The Consultation. Welsh Assembly Government, Cardiff.

Welsh Assembly Government (2006a) About The Strategy [online]. Welsh Assembly Government. http://new.wales.gov.uk/topics/environmentcountryside/epq/Environment_strategy_for_wales/About_the_strategy/;jsessionid=9982572238E14AE0204F3BAA177C7194.www2?lang=en [accessed 25 July 2006]

Welsh Assembly Government (2006b) Catchment Sensitive Farming [online]. Welsh Assembly Government. http://new.wales.gov.uk/topics/environmentcountryside/env_cons_management/cs_farming/?lang=en [accessed 9 October 2006]

Welsh Assembly Government (2006c) Catchment Sensitive Farming Scheme Newsletter: June 2006, Issue 1. Welsh Assembly Government, Cardiff.

Welsh Assembly Government (2006d) Environment Strategy For Wales. Welsh Assembly Government, Cardiff.

Welsh Assembly Government (2006e) Tir Cynnal [online]. Welsh Assembly Government. http://new.wales.gov.uk/topics/environmentcountryside/countryside_policy/farming/agri_env_schemes/tircynnal/?lang=en [accessed 9 October 2006]

(2007) The Water Supply (Water Quality) Regulations 2001 (Amendment) Regulations 2007 *HMSO*.

Welsh Assembly Government (2008a) Agri-Environment Schemes [online]. Welsh Assembly Government. http://new.wales.gov.uk/topics/environmentcountryside/farmingandcountryside/farming/agri_env_schemes/?lang=en [accessed 9 March 2008]

Welsh Assembly Government (2008b) Environment, Sustainability and Housing [online]. Welsh Assembly Government. http://new.wales.gov.uk/about/departments/desh/?lang=en [accessed 23 February 2008]

Welsh Assembly Government (2008c) Jane Davidson AM [online]. Welsh Assembly Government. http://www.ecoliinquirywales.org/about/cabinet/cabinetm/janedavidson?lang=en [accessed 23 February 2008]

Welsh Assembly Government (2008d) Local Government [online]. Welsh Assembly Government. http://new.wales.gov.uk/topics/localgovernment/?lang=en [accessed 23 February 2008]

Welsh Assembly Government (2008e) Structure of the Department for Rural Affairs [online]. Welsh Assembly Government. http://new.wales.gov.uk/about/departments/depc/epcstructure/?lang=en [accessed 23 February 2008]

Welsh Assembly Government (2008f) Tir Cynnal Q&A [online]. Welsh Assembly Government. http://new.wales.gov.uk/depc/publications/environmentandcountryside/farmingandcountryside/farmingschemeinformation/agri-env/tircynnal/tcqanda/tircynnalqae.rtf?lang=en [accessed 9 March 2008]

Welsh Assembly Government (2008g) Tir Gofal [online]. Welsh Assembly Government. http://new.wales.gov.uk/topics/environmentcountryside/farmingandcountryside/farming/agri_env_schemes/tirgofal/?lang=en [accessed 9 March 2008]

Welsh Local Government Association (2006) Local Government in Wales [online]. http://www.wlga.gov.uk/content.php?nID=146;lID=1 [accessed 15 June 2006]

Werritty, A. (1995) Integrated Catchment Management: A Review and Evaluation. Scottish Natural Heritage, Perth.

Wescoat, J. L. & G. F. White (2003) *Water for Life: Water Management and Environmental Policy.* Cambridge University Press, Cambridge.

Wessex Water (2007) Water Supply (Water Fittings) Regulations 1999 [online]. Wessex Water. http://www.wessexwater.co.uk/water/sub_water.aspx?id=160 [accessed 6 September 2007]

Wessex Water (date of publication unknown) Wessex Water: A YTL Company. Wessex Water, Bath.

Wessex Water: Ruth Barden (2006) *Drinking Water Safety Plans and Catchment Planning. 'personal communication'.*

WFD UK TAG (2008) When was the Groundwater Daughter Directive finalised? [online]. WFD UK TAG. http://www.wfduk.org/faq/WhenWasTheGroundwaterDaughterDirectiveFinalised [accessed 5 May 2008]

Wilby, R. L., H. G. Orr, M. Hedger, D. Forrow & M. Blackmore (2006a) Risks Posed by Climate Change to the Delivery of Water Framework Directive Objectives in the UK. *Environment International,* **32**(8)**,** 1043-1055.

Wilby, R. L., P. G. Whitehead, A. J. Wade, D. Butterfield, R. J. Davis & G. Watts (2006b) Integrated Modelling of Climate Change Impacts on Water Resources and

Quality in a Lowland Catchment: River Kennet, UK. *Journal of Hydrology,* **330**(1-2), 204-220.

World Health Organisation - Europe Region (2007) Support for the Development of a Framework for the Implementation of Water Safety Plans in the European Union. World Health Organisation, Rome.

World Health Organisation (2003a) Emerging Issues in Water and Infectious Disease. World Health Organisation, Geneva.

World Health Organisation (2003b) The Right to Water. World Health Organisation, Geneva.

World Health Organisation (2004) *Guidelines for Drinking-Water Quality, Third Edition: Volume 1 Recommendations.* World Health Organisation, Geneva.

World Health Organisation (2007) Conservation of Water in Public and Domestic Supply Systems [online]. World Health Organisation. http://www.who.int/water_sanitation_health/hygiene/plumbing18.pdf [accessed 6 September 2007]

World Health Organisation & UNICEF (2005) Water for Life: Making it Happen. World Health Organisation, Geneva.

World Health Organisation & United Nations Children's Fund (2000) Global Water Supply and Sanitation Assessment 2000 Report. World Health Organisation & United Nations Children's Fund, Geneva & New York.

World Health Organisation Regional Office for Europe (2007) Centralized Information System for Infectious Diseases: Cryptosporidiosis - Incidence (Cases per 100,000 Population) [online]. World Health Organisation Regional Office for Europe. http://data.euro.who.int/cisid/?TabID=137595 [accessed 10 August 2007]

WRc (2006) Water Safety Plans and Risk Assessment [online]. http://www.wrcplc.co.uk/default.aspx?item=221 [accessed 12 June 2006]

WWF-UK (2006a) FAQs - Frequently Asked Questions [online]. WWF-UK. http://www.wwf.org.uk/sitehelp/faqs/f_0000000178.asp [accessed 11 September 2006]

WWF-UK (2006b) Freshwater [online]. WWF-UK. http://www.wwf.org.uk/researcher/issues/freshwater/index.asp [accessed 11 September 2006]

WWF-UK (2006c) Natural Rivers - UK [online]. WWF-UK. http://www.wwf.org.uk/researcher/places/0000000251.asp [accessed 11 September 2006]

WWF-UK (2006d) Welcome to WWF-UK [online]. WWF-UK. http://www.wwf.org.uk/core/index.asp [accessed 11 September 2006]