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Framework for national groundwater quality reporting technical report

National Groundwater and Contaminated Land Centre
March 2003



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From Phil Humble

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Date 15 August 2003

FRAMEWORK FOR A NATIONAL GROUNDWATER QUALITY REPORTING SYSTEM. FINAL REPORT, MARCH 2003

The above project has recently been completed and has produced a Technical Report. Please find enclosed your copy of the report, but please feel free to pass this on to your colleagues. For queries of a technical nature please contact the Project Manager, Phil Humble on telephone 7-22-4792.

Implementation Statement

The Environment Agency is currently reviewing and extending its National Groundwater Quality Monitoring Network to ensure that it complies with its statutory duties. This will generate significant quantities of data on the hydrochemistry of groundwater in England and Wales. These data represent an information resource for all interested parties in groundwater quality data both within the Environment Agency and externally. The Environment Agency's website represents an effective dissemination system for such information.

The report scopes the issues, requirements and proposes a framework for a web-based groundwater quality information system. It discusses the issues with using such an approach and proposes options for the presentation of certain data. The report aims to discuss issues and make recommendations for the development of a full system, compatible with the Agency's approved computer applications.

Release Status

Internal: Released to Regions
External: Released to Public Domain

Further copies are obtainable from Jeanne Thompson at the National Groundwater and Contaminated Land Centre.

Further work

Further work is planned, which will aim to develop the proposals and recommendations with the National Centre for Environmental Data and Surveillance and CIS.

Cont/d..

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Should you wish any further information or wish to discuss the report or any of it's content please do not hesitate to contact Rob Ward or myself at National Groundwater and Contaminated land Centre. Finally thank you to the project board for their input and recommended improvements to the report.

PHIL HUMBLE

Senior Groundwater Quality Officer

National Groundwater and Contaminated Land Centre

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Our work includes tackling flooding and pollution incidents, reducing industry's impacts on the environment, cleaning up rivers, coastal waters and contaminated land, and improving wildlife habitats.

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Statement of Use:

This document describes a GIS-based template for the reporting of groundwater quality data. The template is intended to guide the construction of an intra and internet based reporting system.

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CONTENTS

Executive Summary	iv
Abbreviations and Glossary	v
1. Introduction	1
1.1 The need for a reporting system	1
1.2 Terms of reference	1
1.3 Objectives	1
1.4 Outputs	2
2. Scoping the Requirements	3
2.1 Available information	3
2.2 The users	4
2.3 The requirement of the system	4
3. GIS Technical Specification	7
3.1 Background	7
3.2 Software	7
3.3 Data sets	7
3.4 Directory structure	8
3.5 Project database	10
3.6 Use of colour and shapes	11
4. GIS Application	12
4.1 Getting started	12
4.2 Main viewing interface	12
4.3 Display of features at different levels	15
4.4 Opening hotlink information	17
5. Conclusion	19
6. Recommendations	20
6.1 Data recommendations	20
6.2 Generation of plots, charts and summary tables	20
6.3 Reporting recommendations	20
6.4 General recommendations for ease of use	20
7. References	22

List of Appendices

Appendix A Specification	23
1. Objective	24
1.1 Introduction	24
1.2 Purpose	24
2. The specification	25
2.1 General features	25
2.2 Software	25
2.3 Data requirements	25
2.4 Directory structure	27
2.5 Display	28
Appendix B Listing of Regional information	31
Appendix C Suggested Groundwater Management Unit report listing	37
Appendix D Example of a Thames Region Groundwater Quality report	38
Appendix E Catalogue available data - batch file listing	42

List of Tables

Table 2.1 Suggested format for tabulated data	6
Table 3.1 Description of the main tables within the database	10

Table 3.2	Description of the main queries within the database	10
Table 4.1	Description of the principal features	14
Table 4.2	Description of search facilities	14
Table 4.3	Different view levels within the GIS	15
Table A.1	Data requirements (mapping)	26
Table A.2	Data requirements (database)	26
Table A.3	Data requirements (linked document)	27
Table A.4	Different view levels within the GIS and data layers visible	29
Table C.1	Summary of hydrochemical data	36

List of Figures

Figure 3.1	Overview of the directory structure	9
Figure 3.2	Macro system within database	11
Figure 4.1	GIS start-up screen	12
Figure 4.2	GIS main user interface screen	13
Figure 4.3	Groundwater quality network - regional view	16
Figure 4.4	Groundwater quality network - local view	16
Figure 4.5	Example of regional hotlinked files	18
Figure 4.6	Example of local hotlinked files	18

Executive Summary

The Environment Agency currently collects and collates groundwater quality data from its own programme, Public Water Supply Companies and a number of specific private abstractions across England and Wales. This information is currently not fully utilised by Agency staff nor is it easily assessable by Agency staff and stakeholders. The Agency has recently carried out work to review regional monitoring activities and to identify further requirements for groundwater quality monitoring to ensure that the Agency's statutory and non-statutory duties are fulfilled for forthcoming and current legislation.

A national groundwater quality reporting system is required by the Environment Agency to provide staff and stakeholders (e.g. water companies, consultants, academics and the wider public) access to groundwater quality information. The long-term objective is to produce a reporting system for the Agency's intranet and internet that will enable interactive interrogation of the groundwater quality data and associated information for England and Wales.

The Environment Agency's website (intranet and internet) represents the most effective dissemination system for such information as it is widely available and has relatively low cost mechanism for documentation. However, the quantity of data that can be displayed by the website will be limited by factors such as file storage, download times and confidentiality of some of the data. It is therefore planned that information will be presented in informative summary form only.

This report describes a template for a reporting system for presenting the summary groundwater quality data from the Agency's groundwater monitoring network.

The reporting system template is GIS-based and uses maps to help users navigate to the area of interest. The building-block of the GIS system is the groundwater management unit. Data are summarised at the level of the groundwater body in linked groundwater quality reports and on charts and tables. In addition to using maps to navigate to areas of interest, the system can also be navigated using searches for place names and groundwater management unit names.

A specification, based on the template, is given for development of an internet/intranet version.

Abbreviations and Glossary

Abbreviations

ArcIMS	ESRI ArcGIS Internet Map Server software. ESRI Software used to manage and display GIS data via the intranet/internet.
GWMU	Groundwater Management Unit.
GIS	Graphic Information System
HTML	Hyper Text Markup Language.
MS DOS	Microsoft Disk Operating System.
NGR	National Grid Reference
NGWQMN	National Groundwater Quality Monitoring Network.
NGWQRS	National Groundwater Quality Reporting System
PASF	Environment Agency - Public Access Search Facility.
PDF	Adobe - Portable Document Format.
PPPG	Policy and Practice for the Protection of Groundwater.
PWS	Public Water Supply.
WFD	Water Framework Directive.
WIMS	Environment Agency - Water Information Management System.

Glossary

Access 97	Microsoft Access 97 industry standard database software.
ArcView project/ APR file	ArcView project file used to store collections of datasets. The file extension for ArcView projects is .APR.
ArcView 3.2	ESRI ArcView GIS software package. Note, the Agency currently use Arc View 3.1.
Batch file	A text file containing a series of MS DOS commands.
Grid file	File format used by ArcView GIS to uniform gridded spatial data.
Hotlink	The use of links between related words, graphics, or documents that allow the user to jump to associated topics or definitions.
Internet Explorer	Microsoft Internet Explorer used to find and display web sites on the internet.
Shapefile	File format used by ArcView GIS to store point, line and areal spatial data. The file extension used by a shapefile is .SHP.

1. INTRODUCTION

1.1 The need for a reporting system

The Environment Agency currently collects groundwater quality data from its network of monitoring boreholes. It also collects data from some, but not all, groundwater public supply wells (PWSs). The number of boreholes sampled and the range of analyses undertaken is, at present, highly variable between Environment Agency regions and even within regions.

The Agency has recently carried out work to review regional monitoring activities and to identify further requirements for groundwater quality monitoring to ensure that the Agency's statutory and non-statutory duties are fulfilled for forthcoming and current legislation.

The extended National Groundwater Quality Monitoring Network (NGWQMN) will generate significant quantities of data on the hydrochemistry of groundwater in England and Wales. The data will be distributed in both time and space. Over time, as more sampling is undertaken, the quantity of data will rapidly expand.

The data represents an information resource for all interested in groundwater quality both within the Environment Agency and external stakeholders (e.g. water companies, consultants, academics and the wider public) and it will be important to ensure that this data source is widely known about and is accessible.

The Environment Agency's website (intranet and internet) represents the most effective dissemination system for such information as it is widely available and has relatively low cost. However, the quantity of data that can be displayed by the website will be limited by factors such as file storage, ensuring realistic download times and confidentiality of some of the data. It is therefore planned that information will be presented in summary form only.

This report describes a reporting system for presenting the summary groundwater quality data from the NGWQMN.

1.2 Terms of reference

The Environment Agency's National Groundwater and Contaminated Land Centre (NGWCLC) provided a brief for undertaking the work. Entec issued a proposal to meet the requirements of the project brief (Reference S05987C022/BAF) and this was accepted by the Environment Agency in their email of 27 September 2001.

The work has been undertaken under the terms of a Call-off Contract between the National Groundwater and Contaminated Land Centre of the Environment Agency and Entec.

The work has been overseen by a project board consisting of Rob Ward (NGWCLC - project executive), Phil Humble (NGWCLC - project manager), Andrea Lancaster (Thames Region), Steve Brown (Midlands Region) and Kate Mason (Southern Region).

1.3 Objectives

The following objectives were set in the project brief:

- Scope the requirements for the development of a tiered framework for the presentation of groundwater quality information.
- Develop a general template and series section titles for regional groundwater quality summaries.
- Produce a detailed specification for the development of a full version of the demonstration system based on the framework and guidance developed in this project.

1.4 Outputs

The principal outputs of this project are:

- this report, including the detailed specification;
- a ArcView GIS-based demonstration version of the proposed framework.

The ArcView GIS-demonstration has been provided separately in electronic format. A brief user guide has been provided with the demonstration version. The GIS-demonstration version illustrates the framework using limited data sets from Midlands, Thames and Southern Regions (as provided by the Environment Agency).

2. SCOPING THE REQUIREMENTS

2.1 Available information

2.1.1 Introduction

A large body of information on hydrochemistry of groundwater is already held by the Environment Agency, but is in a variety of electronic and paper formats and held in a number of different locations.

The existing data are unevenly distributed in time and space. Implementation of the Agency's groundwater monitoring strategy will result in an improved monitoring network across England and Wales leading to greater spatial coverage and information on ground water quality. It is the data from this expanded network that will be used to populate the groundwater quality reporting system described in this report. However, for the purposes of this report, existing information is used to create a demonstration version.

The available information at a regional level was drawn together from the knowledge of the project board. It should be noted that information on hydrochemistry will, in many cases, be superseded once the NGWQMN is in place.

2.1.2 National data

The following, relevant, national data sets are available to the Environment Agency:

- National geology at a scale of 1:625 000;
- Outlines of Environment Agency Regions;
- Local Authority Boundaries (unitary authorities, county councils and district councils);
- Location of towns;
- Location of main rivers;
- 'Road Atlas' style mapping.

2.1.3 Regional data

Following discussion with the Project Board, a variety of regional data sets were provided by representatives of three Environment Agency regions: Midlands, Thames and Southern. The data provided are listed in Appendix A.

The data provided in Appendix A are indicative of the data available at the regional level, rather than an exhaustive search for hydrochemical data. The data available at regional level can be divided into the following groups:

- location of groundwater management units (boundaries). It must be noted that there were considerable differences (in coverage and accuracy) of the three datasets supplied by the test regions (Midlands, Southern and Thames);
- regional appendices of the PPPG;
- data from WIMS (raw hydrochemical data), including location of sampling points and results of chemical analysis. WIMS includes both Environment Agency sampling results and selected water company sampling results;
- groundwater quality reports (Thames Region only);
- plots (Piper diagram and time-series) of hydrochemical data (Midlands only);

- summary tables of hydrochemical data for groundwater management units (Midlands only);
- miscellaneous information on monitoring points (borehole logs, photographs, etc).

At the sub-regional level, data are reported in some regions at the scale of groundwater management units (GWMU).

To comply with the WFD the Environment Agency will divide activities into Groundwater Bodies and it is envisaged that these will be an essential building-block of the reporting system. For the purpose of this report, the existing GWMU has been used in place of groundwater body for illustrative purposes as information already exists at this scale.

2.1.4 Other data

In addition to the information from Environment Agency sources, information exists on groundwater quality in some areas in the form of journal papers and unpublished research. These data sources have not been examined.

2.2 The users

Groundwater hydrochemistry data may be of interest to the following groups:

- Agency staff for the purposes of protecting and managing water resources, ensuring compliance with relevant legislation and answering enquiries; and statutory reporting;
- Water companies: protecting and managing water resources;
- Consultants: information on background water quality, assessing the impact of contamination from contaminated land or landfill;
- Landowners and land managers: may have restrictions imposed on use of say agrochemicals (nitrates and pesticides) and may want to check the original data;
- Public: general interest, quality of raw water entering public supply, rivers and streams (surface water quality data is available elsewhere).

The system is likely to be developed initially to allow access by Agency staff accessing the system through the Agency's intranet. These staff may be interrogating the system to aid with their understanding of a particular area in a general sense, or may be used to provide material to reply to an enquiry or reporting.

At a later date, a public access version of the system will be placed on the Agency's website. The information available on the public access version requires careful consideration to ensure a balance between providing sufficient information to address casual enquiries and most specific enquiries, whilst not overloading the system with data. In addition, information provided to the Agency in confidence (e.g. by water companies) may require complete removal or the removal of confidential material from a public access system.

2.3 The requirement of the system

2.3.1 Introduction

The principal purpose of the National Groundwater Quality Reporting System (NGWQRS) reporting system is to make the large body of groundwater quality data held by the Environment Agency easily available to users. In addition, the NGWQRS should provide a context to permit an understanding of groundwater quality at the scale of a groundwater body (as defined in the WFD) in a way that is meaningful to both specialist users (e.g. internal staff, water company staff and consultants) and non-specialist users (e.g. landowners, the public).

It is not intended that the NGWQRS will report all the Environment Agency's groundwater quality information as this would require resources which are not currently available and would also require additional maintenance to keep it up-to-date.

The requirement for the system is for a ArcView GIS-based system for demo purposes, to permit rapid and effective searching to locate and identify relevant information. The brief identified the need for a series of tiers, such as: national; regional; area; groundwater body, with the groundwater body constituting the base unit. The system was also required to incorporate a search facility to allow the experienced or knowledgeable user to navigate straight to the information that they require. Searching by place name and groundwater management unit has been included in the template to aid rapid navigation. Searching by national grid reference and postcode may be considered for the full scale reporting system.

The template is best explained by reference to the ArcView GIS system that has been developed, this is described in Section 4. In addition a detailed specification for implementing the template is required to allow the Agency to:

- advise Agency staff at regional and area level of the data requirements and formats for inputs;
- provide sufficient information to external contractors to permit an intranet / internet addition to the Agency's website to be developed.

A specification, based on the GIS-based template is given in Appendix B but should be read in conjunction with the Section 3 and Section 4 of this report.

2.3.2 Linked documents

It is intended that a number of relevant documents and charts will be linked through the GIS system to permit access. These documents will include:

- relevant strategy documents;
- regional appendix to the Policy and Practice for the Protection of Groundwater;
- water quality reports;
- Piper diagrams;
- time-series plots;
- other items e.g. borehole logs, photographs, cross-sections.

A number of these documents are already available and simply need to be converted to an appropriate format.

A suggested outline of the contents of the water quality report is given in Appendix C. The suggested content is similar to the 'Thames Groundwater Quality Reports' which are already available on the Environment Agency's website. An example of the Thames Groundwater Quality report is included as Appendix D.

2.3.3 Displaying hydrochemical data

Many methods of plotting hydrochemical data are available and modern software packages such as Aquachem mean that they are simple to produce. However, these methods produce plots which are generally difficult to interpret by non-specialists and present challenges even to specialist interpretation. Probably the best method for plotting hydrochemical data is the Piper Diagram because it is possible to plot large amounts of data on a single diagram and they can be used to illustrate the geochemical evolution of groundwater across an aquifer. Some form of explanatory note or diagram will be necessary to enable non-specialists to understand the data.

Times-series charts will be easier for non-specialists to interpret. Plotting large data sets on times-series charts is likely to reduce the clarity of the data. It is recommended that only nitrate and chloride

are plotted on such diagrams routinely in the reporting system; nitrate as it is indicative of an anthropogenic influence and chloride because it is indicative of a number of potential problems such as saline intrusion, saline water being drawn up from depth or pollution from landfills or sewage disposal.

The use of plots showing contours of equal concentration is not advocated because data are rarely available at sufficient density to permit machine contouring using software such as SURFER and hand contouring is time-consuming, requiring each determinand of interest to be contoured separately and hand-contouring is often a highly subjective exercise.

For external users, hydrochemical plots will be linked to GWMUs rather than individual data points to prevent release of sensitive or confidential information and to permit averaging. It is envisaged that users seeking site-specific information will be directed to the appropriate Environment Agency office.

2.3.4 Tabulated data

Tabulated data should be presented in summary format. A list of determinands that may be of interest is given in Appendix C. The suggested format for the tabulated data is given in Table 2.1.

Additional statistical measures, such as standard deviation, may be included where the quantity and quality of data are sufficient.

Table 2.1 Suggested format for tabulated data

Determinand ¹	Units	Measured values		Mean ⁴	Median	Maximum
		No of samples	Minimum ³			
Chloride	mg/l	30	20.0	35.0	35.0	50.0

Notes:

¹A list of determinands is given in Appendix C

²For many determinands the minimum will be a 'less-than' value

³Mean values should include a consistent method of dealing with 'less than' values, e.g. <0.03µg/l, which is statistically valid to avoid a skewed mean. The treatment of such measurements requires careful consideration and a consistent approach across the Agency, further consideration will be required to determine the most appropriate method.

Chemical data should be displayed with an appropriate number of significant figures (3 is suggested) and columns of numbers should be aligned by decimal point.

3. GIS TECHNICAL SPECIFICATION

3.1 Background

This section details the customised demonstration ArcView GIS which has been developed for this project to assist in the management and analysis of national and regional water quality information held by the Environment Agency. The details presented here also represent the technical specification.

A description of the GIS system is given in Section 4.

3.2 Software

The primary software applications, which have been used are ArcView 3.1 and Access 97. These packages were selected for the following reasons:

- ArcView 3.1 is currently the main GIS software tool used by the Environment Agency;
- Access 97 is a widely available desktop database management packages and can be fully customised to refine the database interface, to produce queries and to permit reporting. Access 97 is the version of Access available to Environment Agency staff via their desktop PCs;
- Data from ArcView 3.1 and Access 97 can be readily extracted to other networked database systems, such as Oracle.

It is anticipated that in subsequent phases of the project, elements of the GIS and database can be integrated into the Public Access Search Facility (PASF) and/or ArcIMS internet systems for wider distribution across the Agency.

3.3 Data sets

This section lists the data sets, which form the basis of the reporting system.

3.3.1 National

The following GIS datasets were supplied to Entec at the start of the project and form the building blocks of the system. The two formats of the data (ArcView shapefiles and grid files) are also outlined below:

- Geology (Grid file)
- Local Authority Boundaries (Shapefile)
- Environment Agency Region boundaries (Shapefile)
- Main towns (Shapefile)
- Main Rivers (Shapefile).

These form the core data for the system and are available to the Environment Agency.

3.3.2 Regional

At the regional scale the following data sets are assumed to be available:

- WIMS locations (in Access database format and converted in ArcView shapefile).

In addition the following documents are assumed to be available:

- Regional appendix of the PPPG;
- Regional groundwater monitoring strategy.

3.3.3 Groundwater unit

The following data sets are included at the GWMU scale

- Water Management Unit boundaries:

As highlighted earlier, the water management boundaries supplied for the project were highly variable in coverage and consistency. The key features of these files are outlined below:

- Midlands - One shapefile containing 142 polygon areas. The file also contains a variety of attribute (i.e. name, sub-zone) fields.
- Thames - Nine individual shapefile containing each individual groundwater area. These files did not contain any additional name or feature descriptions. When these files were merged together, it was also noticeable that the areas had not been digitised cleanly (i.e. overlaps and gaps between adjacent areas).
- Southern - The file supplied contained only internal boundaries, which are not fully joined. Due to the format of the data, there was also attribute fields (i.e. no name to identify each area). A range of further processing had to be performed to enable this dataset to be used.
- Anglian - Entec is currently the framework consultant for groundwater studies for the Anglian region of the Environment Agency. As a consequence, Entec has also included the GIS groundwater management units dataset for this area.

To provide consistency, Entec has merged the various datasets into a combined national dataset of GWMUs. However it must be noted that due to the nature of the original data, the combined dataset still contains (a) some overlaps and gaps in boundaries and (b) a lack of named units, notably those in Southern region.

In addition, the following documents are linked to GWMU:

- Groundwater Quality Reports;
- Plots and charts illustrating spatial and temporal trends in data;
- Summary statistics.

3.4 Directory structure

3.4.1 Introduction

One of the most important steps in the development of the system has been the construction of a directory structure in which to store the various GIS, database and associated 'hotlink' files. It is essential to have a defined file management structure to enable effective management of the data and the subsequent operation of the GIS application. The proposed file structure, used in the demonstration version, is illustrated in Figure 3.1. Maps and views used by Arcview are included in the ArcView subdirectory but other files containing reports, tables, photographs and diagrams are stored within the file structure given in Figure 3.1.

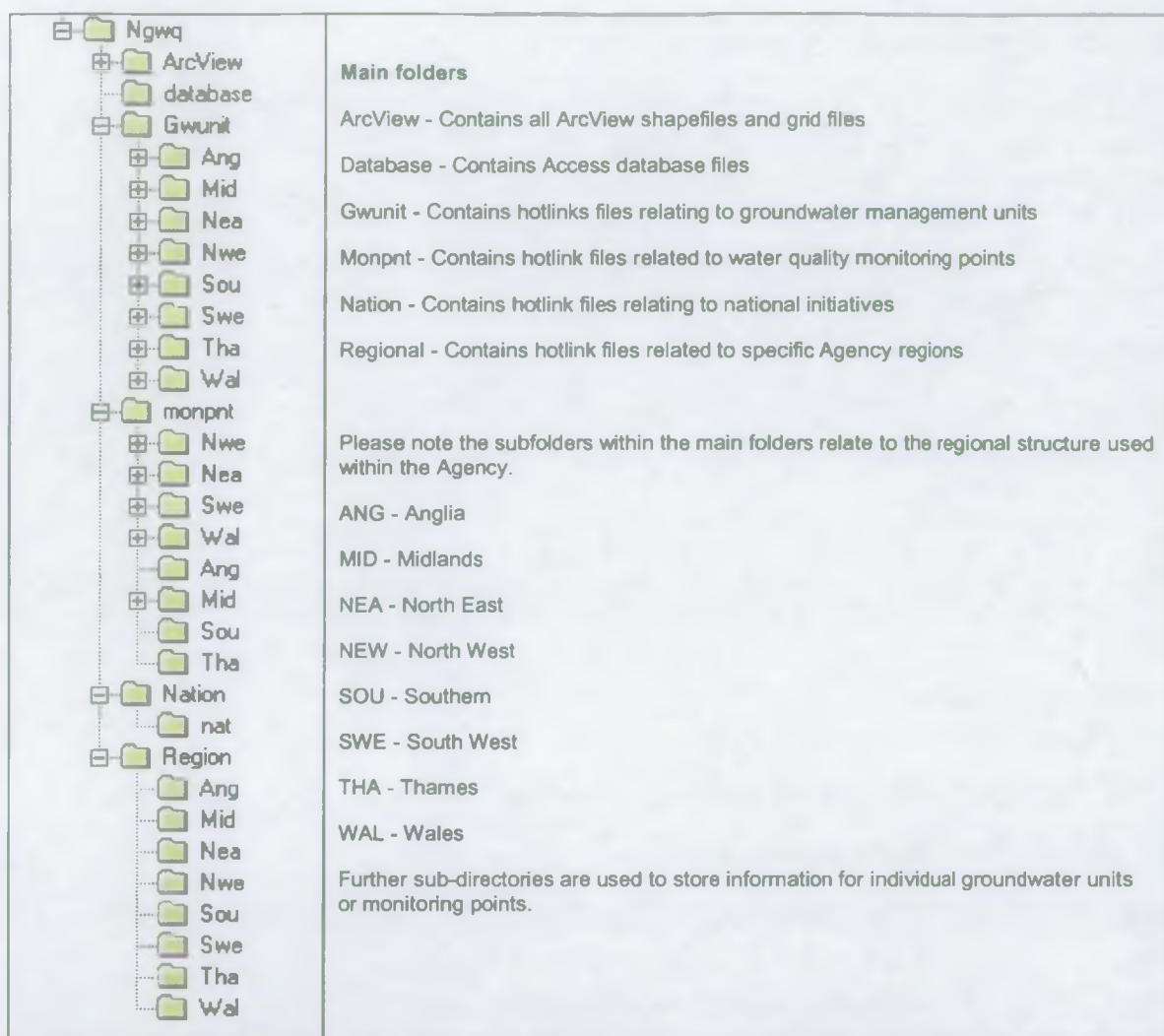


Figure 3.1 Overview of the directory structure

3.4.2 Adding new data

To add new data (reports, diagrams, photographs and tables) to directories within this structure, the following rules should be followed:

- files must be converted into either Adobe Acrobat PDF or HTML Documents (HTML) format to optimise viewing and opening speed within the GIS application;
- The file should be added to the correct sub-directory within the directory framework 'geographical features'. For example:
 - A file belonging to a national data set would be stored under: \Nation\nat\
 - A file related to the Midlands region would be stored under: \Region\mid\
 - A file related to a particular groundwater unit, e.g. the Wombourne groundwater management unit of the Midlands region would be stored under: \Gwunit\mid\wombourne\
 - A file related to a particular WIMS record (e.g. 08888888) within a particular region (e.g. the Midlands region) would be stored under: \monpnt\mid\0888888\

By adopting this structure, data can be correctly related to the appropriate spatial feature and hence queried and opened at the required spatial scale within the GIS application.

3.4.3 An automated directory structure

To assist in the cataloguing of the 'hotlink' files contained in the directory structure, Entec has written a MS-DOS-based batch file (createlinks.bat) to automatically produce a directory listing for the file structure outlined above. The batch file code is given in Appendix E.

This executable file is stored in the top-level directory and performs three main functions:

- it produces individual text listings of all the 'hotlink' files stored under the sub-folders of the various (nation, region, gwunit and monpnt) directories;
- it merges the text files into one file;
- it opens the Access database created for the project (i.e. NGWQ.mdb).

The use of the file listing within the database and the GIS application is discussed in Section 3.4.

3.5 Project database

An important component of the NGWQRS is an Access database used to catalogue the linked files outlined in Section 3.4. The major components of the database are listed in this section.

3.5.1 Database tables

The main tables within the database are outlined in Table 3.1.

Table 3.1 Description of the main tables within the database

Table name	Main purpose
Examples	Listing of files to be used for GIS records which do not have any hotlink
Finaldoc	Table containing directory listing of files
Finaldoc1	Table containing directory listing of files with sub-path delimiters
GWLoc	Table containing monitoring locations. Original data supplied by Environment Agency
Hotlinks	Table containing the final listing of hotlinks in a format compatible with the ArcView GIS application
Lup_reg	Table containing three digit lookup codes for Environment Agency Regions
Template_finaldoc	Blank table to be used as a template for importing the directory listing with any delimiters
Template_indfield	Blank table to be used as a template for importing the directory listing using a "/" delimiter. This is used in the database queries to identify various components of the full directory path

3.5.2 Database queries

The main queries within the database are described in Table 3.2.

Table 3.2 Description of the main queries within the database

Table name	Main purpose
Examples Query	Append query to add the example files to the main hotlink table
Hotlinks_gwunit	Append query to add files linked to groundwater units to the main hotlink table
Hotlinks_monpnt	Make Table query to create structure of the master hotlink table
Hotlinks_natreg	Append query to add files linked to national features to the main hotlink table

3.5.3 Database macros

Using the tables and queries given in Tables 3.1 and 3.2, a macro procedure has been developed within Access to create a structured table of hotlinks to be used in the ArcView GIS. The various commands used in this macro are outlined below in Figure 3.2.

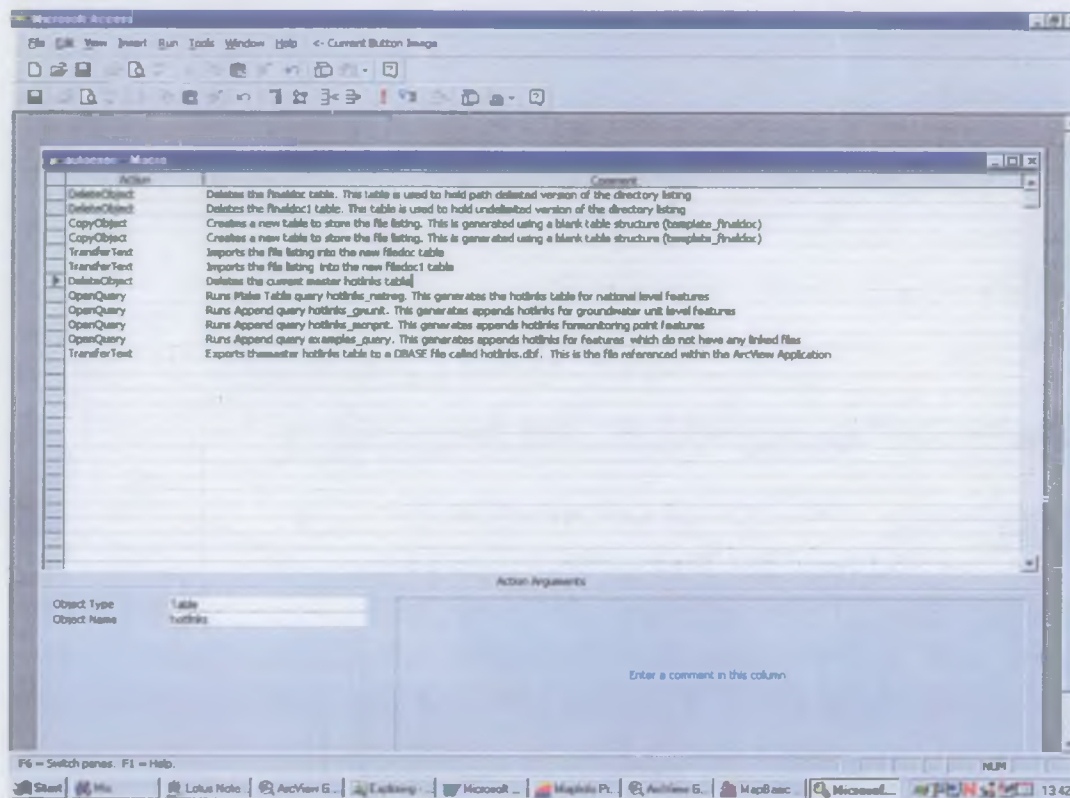


Figure 3.2 Macro system within database

By running this macro, a final table of hotlinks is created. This is used within the GIS application to view and query hotlinks.

3.6 Use of colour and shapes

Extensive use is made of colour in the GIS system. Where applicable (e.g. for geological display) use of standard colours is made. For other parts of the system, colour is used in an **arbitrary fashion** to create a contrast between, for example, adjoining groundwater bodies.

Colour is also used to indicate status of information, for example for monitoring points, i.e. colour (red) is used to indicate whether data are available at an individual WIMS data point.

It should be noted that Groundwater Bodies designated as part of the implementation of the WFD will be colour coded to designate their overall status. The use of colour within the system needs to take account of the WFD colour coding system.

4. GIS APPLICATION

This section outlines the structure of the demonstration ArcView GIS system. This identifies the main components of the GIS application and the structure of the user interface and links to external files.

4.1 Getting started

The demonstration ArcView application has been developed and integrated into a standard ArcView 3.2 project (.apr file) called NGWQ.apr

To open the application, the user follows these steps:

1. *Open the NGWQ.apr project using File-Open Project*

This will open the introduction screen and the demonstration ArcView GIS application, as shown on Figure 4.1.

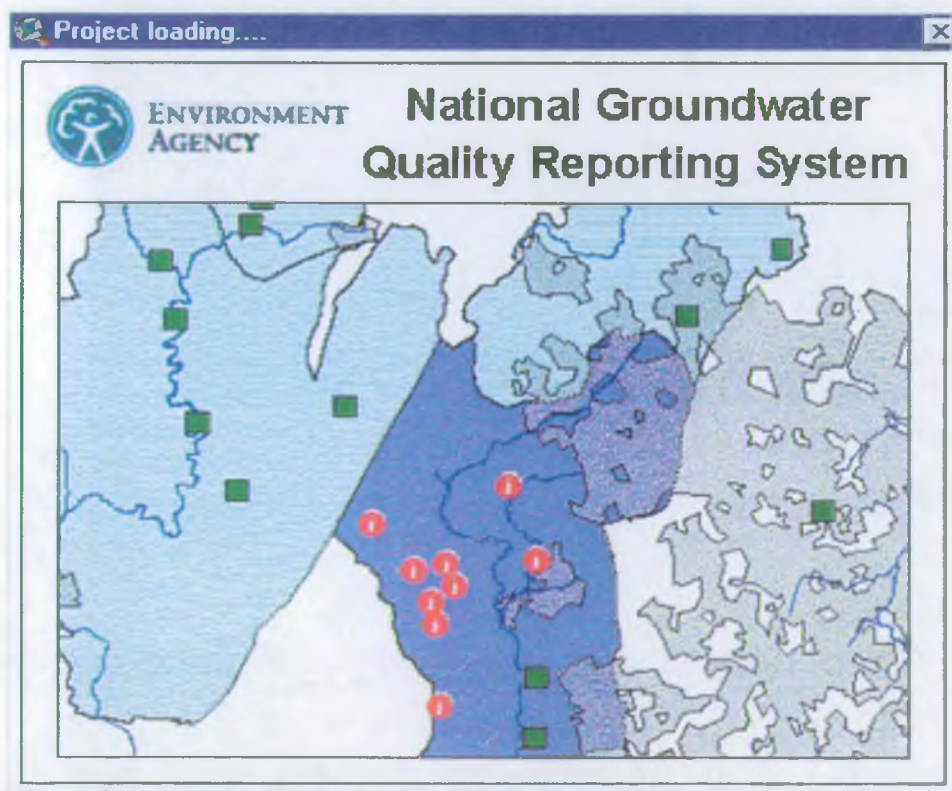


Figure 4.1 GIS start-up screen

4.2 Main viewing interface

On opening the GIS application, the user is presented with a customised user interface to enable the querying and viewing of information relating to a series of spatial levels. The main components of the system are illustrated below in Figure 4.2.

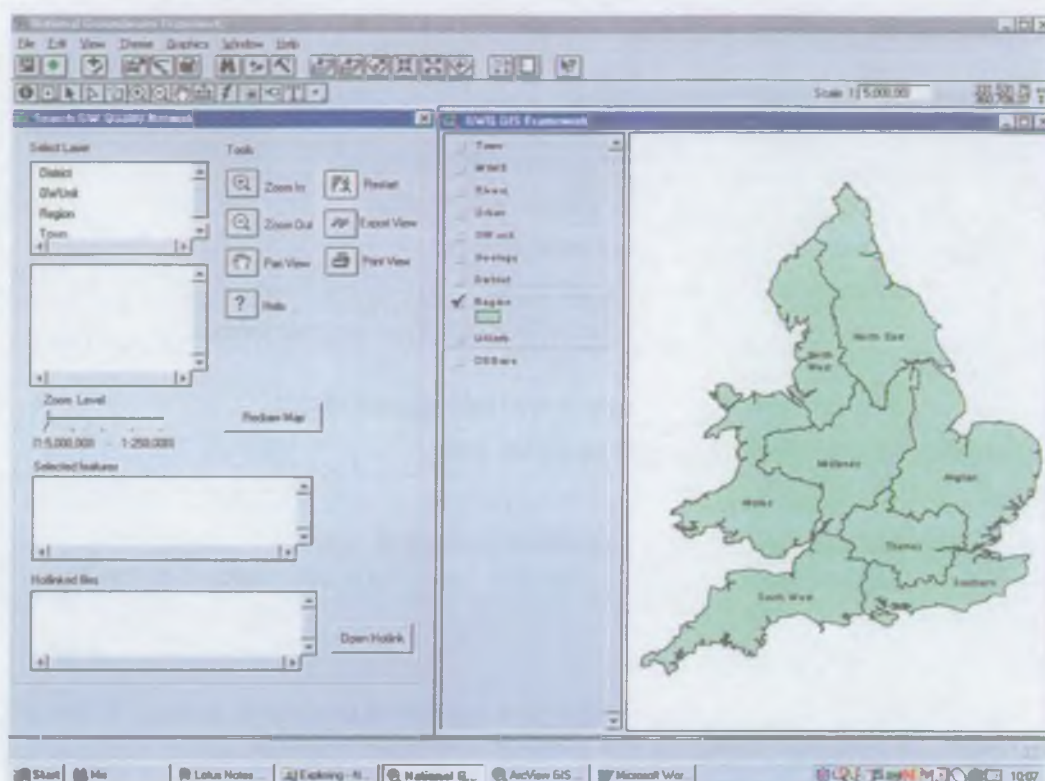


Figure 4.2 GIS main user interface screen

The key features of the interface are:

Select layer

In this dialogue, the user can select a Local Authority, Groundwater Unit, Region or Town from a list-box. By choosing one of these, an associated list-box is populated with a list of available features (Local Authorities etc.) which can be accessed through the 'selected features' box. The user can then select the required name from the list (e.g. "Solihull") and the view will then be automatically re-drawn, centred on the required location at an appropriate scale.

Tools

The functions listed in Table 4.1 are available to the user from the tool buttons in the interface.

Table 4.1 Description of the principal features

Feature	Description
Zoom In	Enables the user to zoom in from the current location
Zoom Out	Enables the user to zoom out from the current location
Pan View	Enables the user to pan the current view window
Restart	Restarts the application at the national level
Export View	Enables the current view to be exported in a variety of graphic formats (i.e. JPG, BMP etc)
Print View	Prints the current view window using a pre-defined print layout
Redraw Map	Updates current view window with new map data

In addition to these features, standard ArcView functions (including Identify Features, Zoom to Previous view and Measure Distances) are available from the main menu and toolbars at the top of the screen.

Zoom level

Using this sliding scale, the user can set the view window to a number of predefined scales. Views of 1:5,000,000; 1:2,000,000; 1:1,000,000; 1:500,000 and 1:250,000 have been preset.

The application does not support the use of a scale bar, but the scale is indicated in a box above the map.

Query map

At view scales below 1:500,000, two tools are provided to assist in the search for information. These are described in Table 4.2.

Table 4.2 Description of search facilities

Search type	Description
By Circle	Enables the user to select a circular area on screen. Features within the circle are then automatically selected and added to the selected features in the interface
By Square	Enables the user to draw a select box on screen. Features within the circle are then automatically selected and added to the selected features in the interface

Selected features

This list-box displays the summary details of features selected. The user can choose one of the selected features and display the associated files in the list-box.

Hotlinked files

Displays the associated hotlink files for the selected features. The user can select the hotlink to be opened (see Section 3). Hotlinked files can be printed from within their application.

Open hotlink

Opens the selected hotlink using its associated application (i.e. Adobe Acrobat for PDF and Internet Explorer for HTML).

4.3 Display of features at different levels

The user interface has also been designed to only display certain datasets at specific spatial scales. This is primarily to optimise system performance and also to ensure that data is viewed at an appropriate scale. The current display settings are shown below in Table 4.3.

Table 4.3 Different view levels within the GIS

View	Scale	Available data layers	Are hotlinks associated with these datasets
National	1:2 000 000 - 1:5 000 000	National boundary	Yes
		Agency boundaries	Yes
Regional	1:500 000 - 1:2 000 000	Geological data	No
		Urban areas	No
Local	< 1:500 000	River network	No
		Monitoring locations	Yes
		Groundwater management units	Yes
		Urban areas	Yes

At each level, the required data is displayed with an appropriate legend and the ability for the user to turn the data layer on or off. Examples of the regional and local zoom levels are shown below in Figures 4.3 and 4.4.

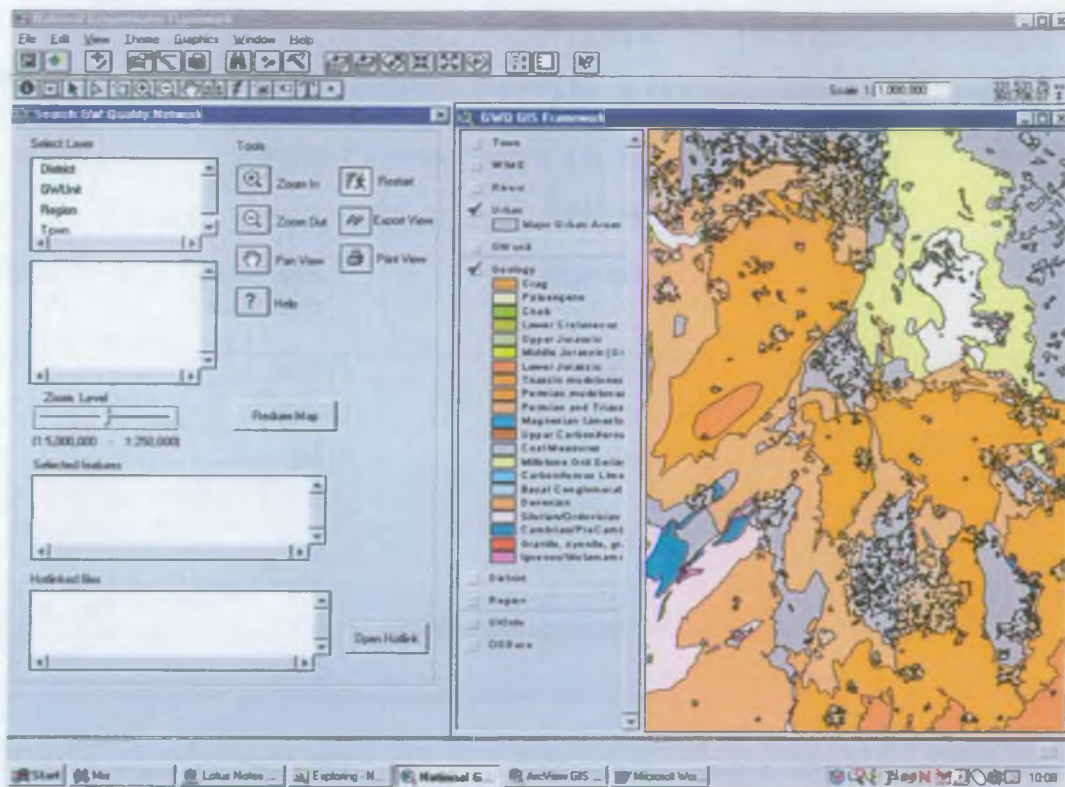


Figure 4.3 Groundwater quality network - regional view

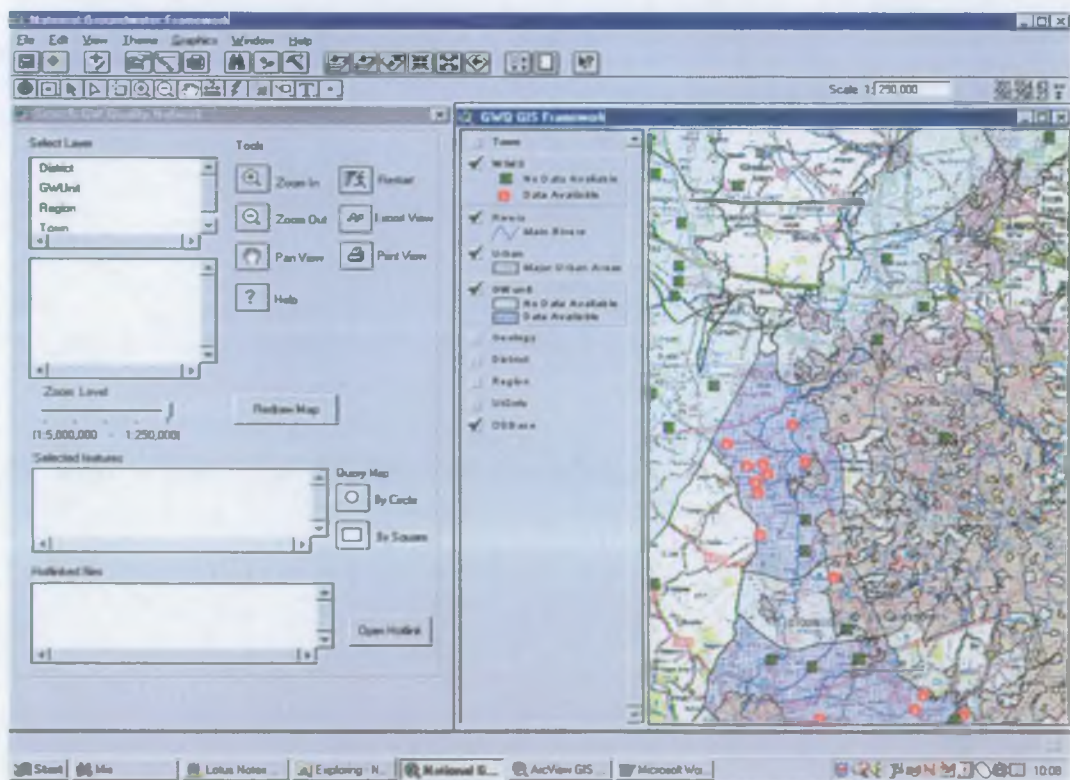


Figure 4.4 Groundwater quality network - local view

4.4 Opening hotlink information

One of the key features of the system is the ability to rapidly navigate to the scale of interest and to query the system for associated information at a variety of geographical levels. There are two main methods for accessing water quality information using the interface and these are described below:

Method 1 - regional and national level

- Select the feature of interest (e. g. 'Region', 'Gwunit') using the dropdown lists;
- Select one of the hotlink files to populate the hotlinks list with the available files;
- Click on the 'open hotlink' button to open the file using its associated application (i.e. Adobe Acrobat for PDF and Internet Explorer for HTML).

Method 2 - local level

- Navigate to the required geographical area.
- Use the 'Map Query' tools, either 'Select by circle' or 'Select by Square', to select a number of features from the view window. This will populate the 'Selected Features' list-box with details of the selected features.
- Select the feature on interest from the list-box to populate the 'Hotlink Files' list-box with the files associated with that feature.
- Select one of the hotlink files.
- Click on the 'Open Hotlink' button to open the file using its associated application (i.e. Adobe Acrobat for PDF and Internet Explorer for HTML). The hotlinked document can then be viewed/printed from within the standard application.

Using either method a wide range of datasets can be accessed using the system. These include:

- Regional level
 - Regional geological and hydrogeological summaries;
 - Regional groundwater quality monitoring plans.
- Groundwater unit level
 - Summary data and statistical information of key parameters;
 - Summary hydrochemical information including; Piper diagram, time-series charts, summary table of groundwater chemistry.
- Individual monitoring sites
 - Photograph of monitoring location;
 - Summary tables of statistics and chemical data for the location;
 - Time series of key chemical parameters.

Examples of the display format from the system are shown below in Figures 4.5 and 4.6.

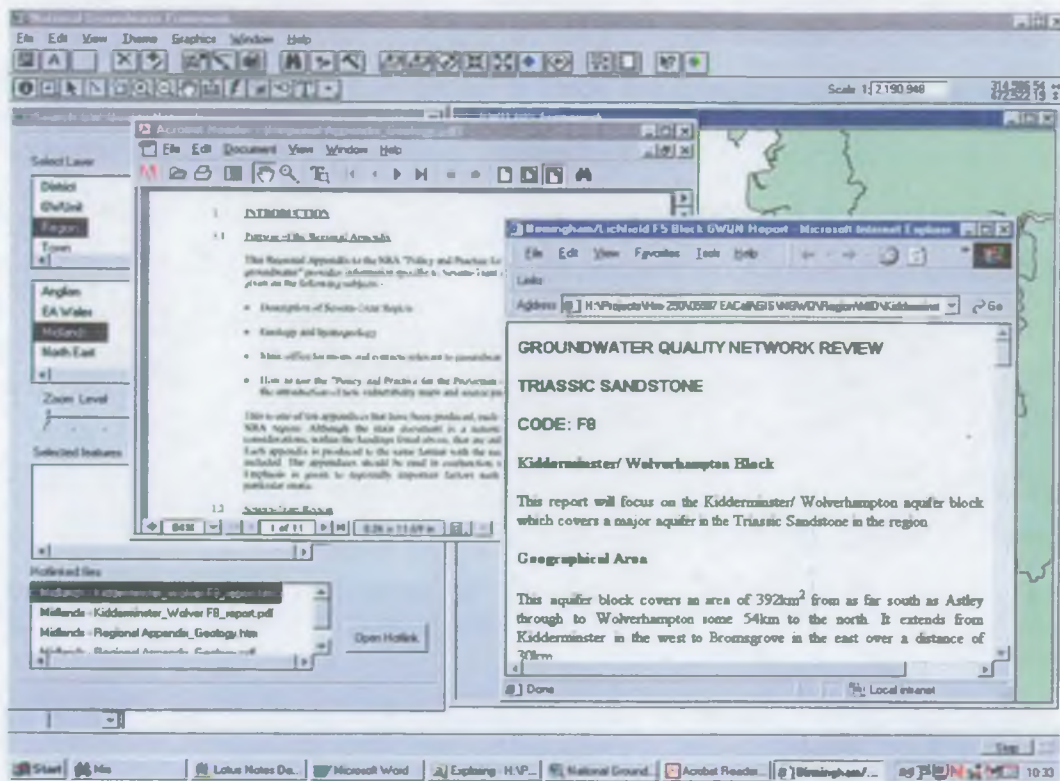


Figure 4.5 Example of regional hotlinked files

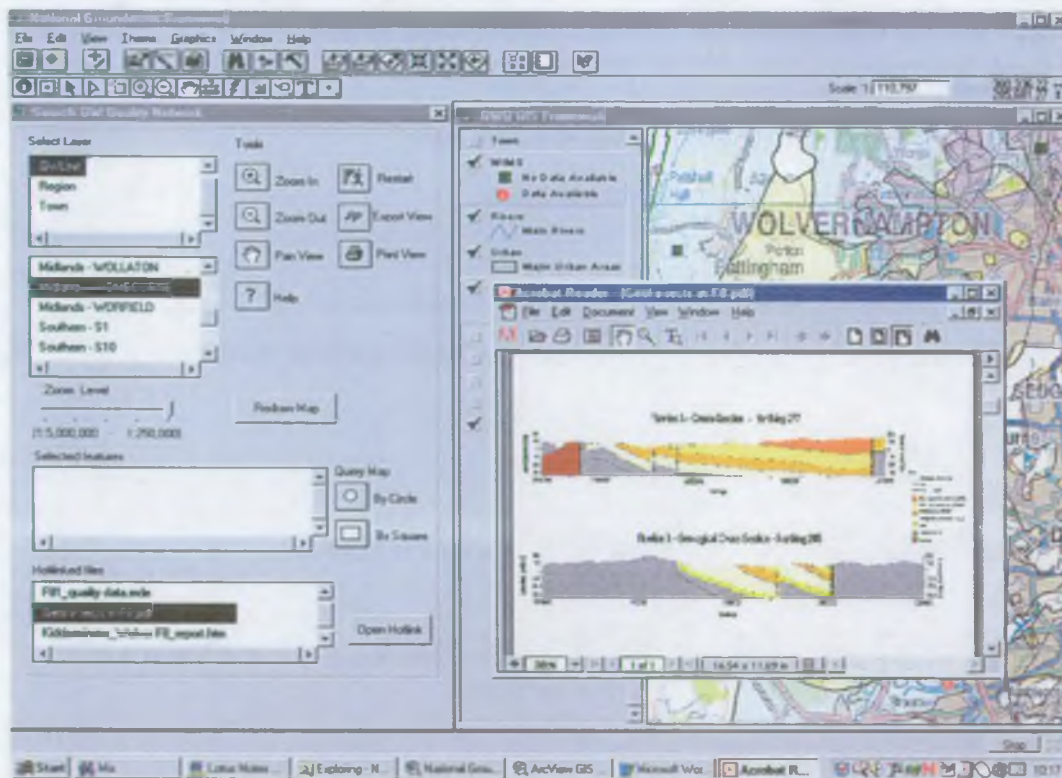


Figure 4.6 Example of local hotlinked files

5. CONCLUSION

The Environment Agency are planning an increase in their groundwater quality monitoring network that will result in the collection of large amounts of hydrochemical data.

To make this data accessible internally, within the Environment Agency and externally to others, it is planned to develop a national groundwater quality reporting system. The reporting system will be intranet and internet based and will summarise the data collected by the national groundwater quality monitoring network. The reporting system will only give access to summary information due to the potentially confidential nature of some of the information and the large quantity of data and frequent updates that a system which contained all the raw data would require.

A demonstration version of a GIS-based national groundwater quality reporting system has been developed and is described in this report. This demonstration version illustrates the way in which a groundwater quality reporting system can be developed which is easy to navigate by both experienced users who wish to go straight to the dataset of interest and by users with a more general interest.

The demonstration version presents summary groundwater quality data in the form of a groundwater quality report on each groundwater management unit, and as charts and tabulated summary of data. The location and spatial density of monitoring points is also indicated.

The building-block of the demonstration version is the groundwater management unit, the current unit at which the Environment Agency manages groundwater resources. With the implementation of the WFD, the basic unit for groundwater will become the groundwater body and it is likely that the full-scale version of the reporting system will be built around the groundwater body.

6. RECOMMENDATIONS

This section makes a number of recommendations for further development of the NGWQRS. These are subdivided into two sections, one covering data requirements and the other detailing reporting requirements.

6.1 Data recommendations

The following data recommendations are essential for the further development of the GIS framework:

- The production of a nationally consistent dataset of groundwater management unit boundaries. This would resolve the inadequacies of the datasets currently available within some of the regions.
- The creation of a standard numbering/naming system for all groundwater units. This framework should be created at national level rather than by individual regions within the Agency. This naming system would be adopted for the creation of the national groundwater boundaries outlined above.
- The digital datasets which will be used by the system should be reviewed to check for consistency prior to their inclusion in any reporting system.

6.2 Generation of plots, charts and summary tables

The generation of plots, charts and summary tables using WIMS data will be a repetitive task and will be best undertaken using a 'macro' or other piece of code to process information for many groundwater management units consecutively. Entec understand that such a code is already used in some regions. Consideration should be given to distributing the code to all regions for their use.

6.3 Reporting recommendations

6.3.1 GIS

The following reporting recommendations are essential for the further development of the GIS framework:

- Any additional information linked to the GIS system should be stored in Adobe Acrobat PDF and/or HTML format.
- Summary statistical tables should be exported from MS Word and/or Excel in HTML format.

6.3.2 Groundwater quality report

A groundwater quality report will be required for each groundwater management unit or groundwater body. These should be standardised as far as possible in terms of headings, content, length and illustrations. A report structure is suggested in Appendix C. A length of 4 to 6 pages is suggested as reasonable.

6.4 General recommendations for ease of use

To ensure that any system that is developed allows the users to access the information stored on the system and the reports it is important that a number of general recommendations are made for ease. The bullet points given below should be considered during the development of any system.

- Provision of a detailed information in the 'help files' to assist the user to navigate and fully utilise the functions of the system.
- The report should use clear, concise and plain English through out. Where ever possible abbreviations should be avoided.

- The functions in the system must be simple and easy to use. Functions such moving between scales, different layers of information and search facilities should simple and clear to the user. There may be more complex and detailed facilities, however the access to these may be restricted to a smaller number of specified users.
- The links between maps and the available supporting information should be clear.
- All printed documents should include a disclaimer. This should detail any data protection issues and state that the reliability of the data cannot be guaranteed by the Agency.

7. REFERENCES

Environment Agency, 1998 (2nd Edition). Policy and Practice for the Protection of Groundwater. Regional Appendix Anglian Region.

Environment Agency, 1998. Policy and Practice for the Protection of Groundwater.

Environment Agency, 2002. Groundwater Quality: A Framework for improving Monitoring

National Rivers Authority, 1992. Policy and Practice for the Protection of Groundwater. Regional Appendix South West Region

National Rivers Authority, 1993. Policy and Practice for the Protection of Groundwater. Regional Appendix Southern Region

National Rivers Authority, 1995. Policy and Practice for the Protection of Groundwater. Regional Appendix Severn-Trent Region

National Rivers Authority, 1995 (2nd Edition). Policy and Practice for the Protection of Groundwater. Regional Appendix North West Region

National Rivers Authority. Policy and Practice for the Protection of Groundwater. Regional Appendix Northumbria Region

National Rivers Authority. Policy and Practice for the Protection of Groundwater. Regional Appendix Thames Region

National Rivers Authority. Policy and Practice for the Protection of Groundwater. Regional Appendix Wessex Region

National Rivers Authority. Policy and Practice for the Protection of Groundwater. Regional Appendix Welsh Region

National Rivers Authority. Policy and Practice for the Protection of Groundwater. Regional Appendix Yorkshire Region

Appendix A

Specification

1. OBJECTIVE

1.1 Introduction

This document forms a specification for implementation of a National Groundwater Quality Reporting System (NGWQRS). The specification sets out, in general terms, the requirements of the system.

The specification should be read in conjunction with Environment Agency Report No. NC/00/24/01 in which a GIS-based template for the (NGWQRS) has been developed to give an example of the intended final product. In addition, the GIS-based system should be consulted 'live' format to further develop an understanding of the requirements.

1.2 Purpose

The Environment Agency currently collects and collates groundwater quality data from its own programme, Public Water Supply Companies and a number of specific private abstractions across England and Wales. This information is currently not fully utilised by Agency staff nor is it easily assessable by Agency staff and stakeholders.

A national groundwater quality reporting system is required by the Environment Agency to provide staff and stakeholders (e.g. water companies, consultants, academics and the wider public) access to the groundwater quality information. The reporting system will be on the Agency's intranet and internet that will enable interactive interrogation of the groundwater quality data and associated information.

The Environment Agency's website (intranet and internet) represents the most effective dissemination system for such information as it is widely available and has relatively low cost. However, the quantity of data that can be displayed by the website will be limited by factors such as file storage, ensuring realistic download times and confidentiality of some of the data. It is therefore planned that information will be presented in summary form only.

2. THE SPECIFICATION

2.1 General features

The system will consist of a search / interrogation system and a map viewer. The search system will contain search facilities (See Section 2.5) and a 'selected features' box / area in which linked documents will be displayed. These various features are specified in more detail in this section.

The interface will need to use, where possible, non-specialist language and terms as it will be used by a wide audience.

For the purposes of managing groundwater resources, the country will be divided into Groundwater Bodies and these will be the base unit of the reporting system. For the purpose of this report, the existing groundwater management units have been used in place of groundwater bodies as this information already exists.

The system needs to be compatible with existing Environment Agency systems and software standards.

2.2 Software

The software requirements are not specified but the software must be capable of meeting the requirements of this specification.

Software will have the capability of displaying map based information linked to databases and in addition to display text and figure based information in PDF or HTML format (or links to applications with that capability).

2.3 Data requirements

The following data are required as part of the groundwater quality system. Data have been grouped by type for ease of reference as:

- spatial (map) data;
- database information;
- documents.

The data requirements are given in more detail in Tables 2.1 to 2.3.

Table A.1 – Data requirements (mapping)

Data requirement	Scale	Source
National 'road map' style map to include towns and cities, major roads and main rivers	National	Various
National geology map	National (1:625 000)	BGS/Environment Agency
Boundaries of Environment Agency Regions	National	Environment Agency
Local Authority Boundaries to include unitary authorities, county councils and district councils.	National	Environment Agency
Main rivers	Regional	Environment Agency
Groundwater management unit (groundwater body) boundaries	Regional	Environment Agency

Table A.2 – Data requirements (database)

Description	Linked to	Source	Comment
Data from WIMS (raw hydrochemical data), including location of sampling points and results of chemical analysis.	GWMU	Environment Agency	Location displayed on the map viewer. Related summary information displayed in the 'selected features'
Place names	Search facility	Not specified	Related to place names displayed on the Road-Map
GWMU / Groundwater body names	Search facility	Environment Agency	

Table A.3 – Data requirements (linked document)

Document	Linked to	Source	Accessed via
Help pages	All	Environment Agency / developer	Help button
Regional appendices of the PPPG	EA Regions	Environment Agency	Selected Features box
Regional groundwater monitoring strategy	EA Regions	Environment Agency	Selected Features box
Groundwater quality reports	GWMU	Environment Agency	Selected Features box
Plots (Piper diagram and time-series) of hydrochemical data ¹	GWMU	Environment Agency	Selected Features box
Summary tables of hydrochemical data for groundwater management units ¹	GWMU	Environment Agency	Selected Features box
Time-series plot ¹	GWMU	Environment Agency	Selected Features box
Miscellaneous information on monitoring points (borehole logs, photographs, etc)	GWMU	Environment Agency	Selected Features box

¹These will require updating on a regular basis as more information is gathered

2.4 Directory structure

2.4.1 Introduction

Data will be structured in a systematic and logical manner to:

- permit rapid understanding of organisational structure;
- permit rapid location of data; enable regular updates to be made in a quick and easily understandable way.

The data organisation system will use logical names that refer to recognisable entities, i.e. Environment Agency regions and groundwater management units. An example database structure is given in the report (NC/00/24/01).

2.4.2 Updates

The system will require updating on a regular basis using data from WIMS. The system will be able to automate the processing of WIMS data into the correct format, including:

- summary tables;
- hydrochemical plots;
- addition of new data points.

Other updates will also occur to linked documents and other information.

2.5 Display

2.5.1 Overview

The system interface will contain the following features:

- a map viewer (including a legend);
- zoom;
- search facilities;
- a help facility;
- a selected features facility (to identify any linked documents).

Each of these is described in more detail below.

2.5.2 Map viewer

This feature will display the map data in a clear and recognisable manner. The size of the viewing window is not specified, but should be larger enough to display a reasonable area without involving excessive download times.

The map viewer will have the following features:

- a scale bar or indicate the displayed scale.
- legend. Map layers will have associated legends. The legend will have the facility to turn on / turn-off the respective layer.
- a 'refresh' button and a 'back' or 'last view' button.
- comments. Items related to groundwater quality should have comments attached -visible when passed over by arrow/cursor.
- zoom. The interface will permit the user to zoom to 4 predefined scales to display the layers given in Table 2.4 at each scale.
- selection. At view scales below 1:500,000, tools will be provided to assist in the search for information. These will enable the user to select an area in the map viewer. Features within the circle will be selected and added to the 'selected features' area of the interface.

Table A.4 Different view levels within the GIS and data layers visible

View	Scale	Available data layers	Are hotlinks associated with these datasets
National	1:5 000 000	National boundary	Yes
		Agency boundaries ¹	Yes
Regional	1:2 000 000	'Road map' style mapping ¹	No
			No
Subregional	1:500 000	Geological data ¹ River network ¹ Groundwater management units ¹	
Local	1:100 000	River network	No
		WIMS monitoring locations	Yes
		Groundwater management units	Yes

¹Present at all levels below this one

2.5.3 Legend

The legend displayed will be specific to the layers visible at a particular zoom level. It will be subdivided into categories related to each of the layers visible.

for the more detailed legend relating to Elements of the legend will be inactivatable, activating a particular aspect of the legend will produce a detailed legend e.g. for geology, the full geological (simplified legend).

Use of colour and shapes and text in the map viewer

Extensive use of colour will be required. Where applicable (e.g. for geological display) use of standard colours must be made. For other parts of the system, colour schemes will be appropriate to distinguish between for example, adjoining groundwater bodies.

Colour should also be used to indicate status, for example for monitoring points, i.e. colour (red) is used to indicate whether data is available at an individual WIMS data point.

Text should be scaled to be legible at the scales displayed.

2.5.4 The search/interrogation interface

Search facilities

The following search facilities will be available:

- search by postcode;
- search by place name;
- search by national grid reference;
- search by groundwater management unit name.

'Help' facilities

The system will include a link to help documents. This will include:

- general introduction to the purpose of the system;

- how to search the system and locate data;
- a glossary of common terms relating to groundwater and hydrochemistry.

In addition, simple comments should be available when moving the mouse cursor over 'buttons' and map features which describe their function (for buttons) or the feature they relate to (for map features).

2.5.5 'Select features' facility

The interface will identify documents linked to various features when they are 'clicked' on the map viewer, or when a particular scale is selected. A list of linked documents will populate a 'selected features' box.

The documents will be text and image based and in the form of PDF or HTML and will be opened by moving to the 'selected features' and double clicking on the feature to open the relevant software and display the document. Each document will require a meaningful name.

Appendix B

Listing of regional information

Midland Region

- Groundwater management unit shape files for Midlands Region;
- piper diagrams for selected groundwater management units;
- hydrochemistry data summaries (as tables);
- relevant photographs;
- borehole logs;
- NVZ shape files;
- Policy and Practice for the Protection of Groundwater: Regional Appendix;
- report on groundwater chemistry.

Southern Region

- Groundwater management unit boundaries (unconnected boundary lines only).

Thames Region

Individual Groundwater Unit Shape files for:

- Colne Valley (chalk);
- Kennet (chalk);
- London Basin (confined chalk);
- Lower Greensand (southern limb);
- North Downs (chalk);
- Oolite southwest unconfined;
- South Reading (confined chalk);
- Southwest Chilterns (chalk);
- Upper Lee Valley.

Groundwater Reports for:

- Chalk-Chilterns;
- Chalk-Marlborough and Berkshire Downs-Figure2.gif;
- Chalk-Chilterns-Figure1.pre;
- Chalk-Chilterns-Table1.

Policy and Practice for the Protection of Groundwater: Regional Appendix.

Appendix C

Suggested Groundwater Quality Management Unit report structure

Groundwater Quality Management Unit report structure

Summary

A brief summary of the contents of the report.

Introduction

The introduction should include:

- purpose of report;
- objectives of groundwater quality monitoring;
- limitations of information in the report.

Geographical area

The area covered by the report should be identified by reference to:

- grid references;
- population centres (towns and cities);
- topographical features (hills, valleys etc);
- nature of the terrain;
- other notable features.

Geology

Geological information should identify:

- major units;
- vertical succession;
- superficial geology;
- structures (anticlines / synclines location of major faults and direction of regional dip.

Hydrogeology

The description of the hydrogeology should include the following:

- identification of aquifers and aquitards;
- aquifer properties (storage, transmissivity);
- flow mechanisms - intergranular Vs fissure;
- direction of flow and hydraulic gradients;
- the location of recharge areas;
- the location of groundwater discharge;
- major groundwater uses e.g. abstractions;
- location of source protection zones.

Hydrology

The hydrology section should identify the major rivers and the nature of river groundwater interaction.

Groundwater quality

The section on groundwater quality should give details of:

- explanation of units and terms; [note a glossary will be required];
- the number of sample sites and type of site (PWS/Agency monitoring borehole/private abstraction);
- the determinands and the frequency at which they are sampled;
- information on data quality, e.g. laboratory accreditation, duplicates, checks;
- the types of groundwater (e.g. sodium-bicarbonate) and their relation to geology and hydrogeology;
- factors which influence groundwater quality, such as saline intrusion/upconing, groundwater interaction with rivers and anthropogenic influences e.g. nitrates, sewage discharges, contaminated land, landfills;
- the purpose and location of nitrate vulnerable zones;
- trends in the data in time and space.

The report should be supported by diagrams showing:

- Piper plots (explanation and key will be required)
- time-series for nitrate and chloride and other relevant determinands.
- Others as determined by the Agency e.g. box and whisker plots
- Indicate parameter plots

In addition data should be summarised in the format given in the summary table (see example below).

Table C.1 Summary of hydrochemical data

Determinand	Units	No of samples	Measured Values		
			Minimum	Mean	Maximum
Indicators					
pH					
Conductivity					
Suspended solids					
Temperature					
Dissolved oxygen					
Major ions					
Chloride					
Sulphate					
Alkalinity (as Bicarbonate)					
Nitrate					
Sodium					
Potassium					
Calcium					
Magnesium					
Minor constituents					
Fluoride					
Orthophosphate					
Iron					
Manganese					
Arsenic					
Mercury					
Cadmium					
Chromium					
Lead					
Copper					
Nickel					
Cobalt					
Zinc					
Total organic carbon					
Boron					
Beryllium					

Note:

Chemical data should be displayed with an appropriate number of significant figures (3 is suggested) and columns of numbers should be aligned by decimal point for ease of reading

Conceptual model

The geology, hydrogeology, hydrology and groundwater quality data should be linked in a conceptual model, preferably illustrated by reference to a cross-section through the GWMU. The conceptual model should indicate the major influences on the hydrochemistry and any evolution of groundwater quality along the direction of flow.

References/further reading

References should be provided to permit further investigation, these will include references which are specific to the GWMU and more general references.

Area specific references

These may include, inter alia:

- Geological Maps;
- Geological Memoirs;
- Groundwater Vulnerability Maps;
- Hydrogeological Maps;
- Journal Papers;
- PhD and MSc Theses;
- 1972 water board reports.

General references

The following are a list of specialist textbooks on the acquisition and interpretation of hydrochemical data:

Appelo C A J and Postma D, 1993. *Geochemistry, Groundwater and Pollution*, Published by A A Balkema, Holland.

Chapman D, 1992. *Water Quality Assessments: A guide to the use of biota, sediments and water in environmental monitoring*. Published on behalf of UNESCO, WHO and UNEP by Chapman & Hall, ISBN 0-412-44840-8. 585pp.

Domenico P A and Schwartz F W, 1990. *Physical and Chemical Hydrogeology*, Published by John Wiley & Sons, ISBN 0-471-50744-X. 824pp.

Freeze R A and Cherry J A, 1979. *Groundwater*. Published by Prentice-Hall, ISBN 0-13-365312-9. 604pp.

Hem J D, 1989. *Study and Interpretation of the Chemical Characteristics of Natural Water*. 3rd Edition. US Geol Surv Water Supply Paper 2254. Published by US Government Printing Office.

Lloyd J W and Heathcote J A, 1985. *Natural inorganic hydrochemistry in relation to groundwater*. An introduction, Published by Clarendon Press [out of print].

Appendix D

Example of a Thames Region groundwater quality report

GROUNDWATER QUALITY IN THE CHILTERNs:

Major and general chemistry for the Chalk aquifer

Summary

Groundwater quality in the Chilterns is monitored using a network of public supply and private abstraction boreholes. The Chalk crops out in a southwest-northeast belt across most of the area, with a small area in the southeast being confined under Tertiary deposits. Pleistocene deposits, namely glacial gravels and boulder clay also cover the Chalk in the east of the area, while clay-with-flints cover some areas of higher ground. Along the valley floors, Chalk is covered by river gravels and alluvium. This report addresses Chalk groundwater quality only.

A number of urban centres lie across the region in the major river valleys. There is little evidence of widespread pollution from urban centres, possibly because the Chalk is protected from infiltration by the glacial and river deposits found in the valleys. Some of the rural abstractions, however, show elevated nitrate concentrations resulting from fertilizer use.

The groundwater chemistry is fairly uniform across the area being of calcium bicarbonate type with low concentrations of other major and minor ions. Boreholes with catchments where there is a significant amount of cover over the Chalk show elevated concentrations of sodium, sulphate, chloride and a number of minor ions, in particular boron and fluoride.

1. Geographical Area

The area covers the Chiltern hills ([Figure 1](#)). The main rivers draining the area are the River Thames, which defines the west and south western boundary, and its tributaries, the rivers Wye, Misbourne, Chess, Bulbourne, Colne, Ver and Mimmshall Brook. These rivers drain south-eastwards away from the crest of the Chilterns. The major towns in the area from east to west are the northern suburbs of Reading, Henley, Maidenhead, High Wycombe, Amersham, Rickmansworth, Hemel Hempstead, Watford, St Albans and the southern part of Dunstable (in the northern corner). There are also a number of smaller towns located across the area.

2. Geology/Hydrogeology

The Chalk crops out across most of the area forming the Chiltern Hills, and dips gently to the south-east under the Tertiary deposits of the London Basin. The Chalk is sub-divided into Lower, Middle and Upper units with the Upper Chalk constituting the majority of exposed Chalk at the surface, while the Middle and Lower Chalk are exposed in the deeper valleys.

In the south-east of the area the Chalk is overlain by the younger Tertiary strata. The main Tertiary units are the Reading Beds and the London Clay. The Reading Beds which consist of a mixture of sands and clays directly overlie the Chalk. The Reading Beds act as a minor aquifer and exhibit varying degrees of hydraulic continuity with the Chalk depending on the proportion and lateral extent of the clay horizons. Overlying the Reading Beds is the near-impermeable London Clay, a non-aquifer, which confines the Chalk and largely prevents water percolating down from the surface.

Pleistocene deposits cover the Chalk with glacial gravels in the south-east between Maidenhead, Rickmansworth and St Albans, and boulder clay around St Albans. Further north the upland areas of Chalk are covered by superficial clay-with-flints or sand. Quaternary river gravels overlie the Chalk and Tertiary strata along the Thames Valley and are also found along other major river valleys. These gravels in turn are overlain by more recent alluvium.

Flow in the saturated Chalk is primarily through fissures and can be very rapid. Slower groundwater flow can occur through pores in the matrix. Groundwater flow is generally toward the south-east, but it can be modified at a local level by the drainage pattern of the rivers.

3. The Quality of Infiltration

The mineralogy of the soils and drift affects the quality of the water as it infiltrates. Soil type appears to correlate with the underlying geology. Where the Chalk crops out the soils are shallow and lime rich and are unlikely to alter the quality of infiltration greatly, either by leaching of the minerals or by inhibiting infiltration of pollutants. Where the Chalk is near the surface, especially along the valleys, the

soil leaching potential is classed as high (H1) as shown on the groundwater vulnerability sheet 39 or sheets 40 and 31 for the extreme west and north of the area, respectively.

The clayey soils which overlie the low permeability drift deposits, such as boulder clay or clay-with-flints are classified as having intermediate leaching potential (I1). These and the clayey strata below have the potential ability to adsorb pollutants as the water infiltrates slowly, and thereby afford some degree of protection to the underlying groundwater.

As groundwater becomes confined under the Tertiary deposits, particularly the London Clay, cation exchange, dissolution and redox processes may affect the balance of minerals in solution.

4. Groundwater Quality

The groundwater quality network in this area (as of September 1997) comprises 48 public supply sites and 12 private sites ([Figure 1](#)). Each sample point reference number relates to an individual borehole. Where several reference numbers are given for one site, this indicates a multiple borehole source, and data are given for each borehole. All boreholes abstract from the Chalk.

4.1 Major ion chemistry

Major ion results are summarised in [Table 1](#). A Piper plot of analyses from the sites is given in [Figure 2](#). Most sites plot close together showing the water is typical of unconfined chalk with groundwater chemistry dominated by calcium and carbonate/bicarbonate ions. The remainder show a trend across the plot indicating relatively higher contents of sodium, chloride and sulphate. Although none of the boreholes in this area have catchments that are completely covered by impermeable strata some have partially confined catchments, especially those on the southern edge of the Chalk around Rickmansworth and Watford (e.g. 0646, 0638, 0639). These sites form the diffuse group nearer the centre of the Piper plots.

The sites with partially covered catchments show a groundwater chemistry similar to that observed from confined Chalk sites elsewhere, with higher concentrations of sodium, potassium, magnesium, chloride, and sulphate ions, but lower calcium. As groundwater moves down gradient the residence time increases and geochemical processes such as cation exchange, reaction with marine clays and dissolution start to occur (Edmunds et al. 1987). This effect becomes more significant in changing groundwater chemistry as cover blocks the recharge from above. Other possible sources of sodium, chloride and sulphate, are from saline connate waters and the breakdown of sulphur rich minerals found in the overlying Tertiary strata. Sites 0646, 0638 and 0639, which abstract water from Chalk partially covered by London Clay, display these trends. The trend of data points across the Piper diagram ([Figure 2](#)) from unconfined to confined indicating increasing residence time is typical for the Chalk elsewhere (Water Resources Board, 1972; Edmunds et al., 1987).

Site 0706 has higher than average sulphate and chloride concentrations but this cationic increase is compensated by a corresponding rise in calcium and magnesium rather than sodium. This site is affected by infiltration through the near-by Water End swallow hole complex which takes all flow of the Mimmshall Brook. The Brook contains run-off from urban areas such as Borehamwood.

There are some anomalous concentrations for major ions that do not conform to this general pattern, such as the high potassium and sulphate at site 0649. This site also has high nitrate indicating pollution from agricultural activities such as fertilizer use. Anomalous results must be treated cautiously, especially if the number of analyses is small.

4.2 Other determinands

A number of the minor ion concentrations also follow the trends observed between unconfined sites and partially covered sites. Fluoride and boron concentrations are higher where the aquifer experiences a degree of cover (e.g. 0638, 0639). This is due to mineral-water reactions. Elevated fluoride concentrations are sometimes attributed to ion exchange with hydroxyl ions in reactions between clay minerals and groundwater. Also a number of sites in the area around Maidenhead have fluoride concentrations above average; a variation in the mineral content of the Chalk or overlying cover may be the cause. Some of these sites (0537, 0564, 0593) also show above average strontium contents for the area.

Sites 0649 and 0613 exceed the UK drinking water standard maximum concentration for nitrate (11.3 mg/l NO₃ as N). Elevated nitrate levels are often due to the use of nitrate fertiliser in agriculture. Both sites are located at farms.

Ammoniacal nitrogen concentrations are generally low (close to detection limits). Sites 0703, 0675 and 0674 show the highest values. These are sites that have a significant portion of their catchment covered by boulder clay which will produce a degree of confinement leading to reducing conditions suitable for elevated ammoniacal nitrogen.

Orthophosphate concentrations are generally low with the highest levels recorded at 0638, 0645, 0682 and 0686. The highest concentrations of Total Organic Carbon (TOC) is found at site 0706. This value may be due to urban pollution or sewage entering the groundwater from runoff to the swallow holes around the Mimmshall Brook.

Environment Agency, Thames Region
September 1997. Data assessed for period January 1985 to September 1997

For further information, contact the Groundwater Quality section at:
Kings Meadow House, Kings Meadow Road, Reading, Berkshire, RG1 8DQ.

Further Information

Data from Table 1 in Excel 97 format

Solid and Drift Geology Sheets 238, 239, 254, 255, 256 and 268 1:50,000 Series - British Geological Survey

Groundwater Vulnerability Sheet 39 (West London), Sheet 38 (Upper Thames and Berkshire Downs), Sheet 31 (Bedfordshire) 1:100,000 Series - Environment Agency

British Geological Survey. 1996. London and the Thames Valley (4th Edition compiled by M G. Sumbler). HMSO.

Edmunds W.M., Cook, J.M., Darling, W.G., Kinniburgh, D.G., Miles, D.L., Bath, A.H., Morgan-Jones, M and Andrews, J.N. 1987. Baseline geochemical conditions in the Chalk Aquifer, Berkshire, UK: a basis for groundwater quality management. Applied Geochemistry Vol. 2 pp 251-274.

Water Resources Board. 1972. The Hydrogeology of the London Basin.

Appendix E

Catalogue available data - batch file listing

File listing for the batch file createlinks.bat

```
cd nation
dir *.* /a:-d /b /s /o:n >c:\temp\natdoc.txt
cd ..
cd region
dir *.* /a:-d /b /s /o:n >c:\temp\regdoc.txt
cd ..
cd gwunit
dir *.* /a:-d /b /s /o:n >c:\temp\gwdoc.txt
cd ..
cd monpnt
dir *.* /a:-d /b /s /o:n >c:\temp\mondoc.txt
c:
cd temp
copy natdoc.txt+regdoc.txt+gwdoc.txt+mondoc.txt finaldoc.txt
copy finaldoc.txt h:\projects\hm-250\05987 EACALL\GIS\NGWQ\
cd /d h:\projects\hm-250\05987 EACALL\GIS\NGWQ\
start NGWQ.mdb
```

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Please note

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