NATIONAL RIVERS AUTHORITY

WATER RESOURCE MANAGERS GROUP

SURVEY OF WATER RESOURCES MODELLING ACTIVITIES

FEBRUARY 1991

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1. Introduction

This report summarises the results of a questionnaire (Appendix 1) to which all Regions responded. The objectives were to identify ;

- the current useage of models (for what, by whom etc.)
- the origin of these models (in-house, bespoke customisation, commercial packages etc.).
- the potential use elsewhere, areas of common ground etc.
- centres of expertise for particular types of modelling (NRA, Universities, Consultants etc).
- perceived shortcomings and requirements for future developments.

The questionnaire was in two parts ;
Part 1 concentrated on general issues and opinions. The responses are summarised in Sections 2 - 5 and 7 - 8.
Part 2 took the form of a sheet to be completed for each model (or group of similar models). These have been listed in Section 6 and reproduced in Appendix 2.

The names of the Regions have been abbreviated in some of the tables.

A	Anglian
N	Northumbrian
NW	North West
S	Southern
ST	Severn Trent
SW	South West
T	Thames
W	Welsh
WX	Wessex
Y	Yorkshire

2. Organisational Structures

This question was to identify, in general terms, where those people doing the modelling fitted into the organisational structures. It seems that most Regions do not have modelling specialists within the Water Resources function. Only Anglian and Thames referred to 'modellers' and no-one utilised in-house expertise outside the Resource Planning sections. In most of the Regions modelling is clearly a DIY activity, making the best use of the staff available and calling for expert help when required.

One related issue is the degree of distinction made between groundwater and surface water investigations. Most Regions (N, NW, ST, T and Y) differentiated very clearly between the two. Only Anglian emphasised the common ground and the need to share staff with the appropriate computing skills.

3. Computing Skills

Table 1 illustrates the wide variation in both the numbers and involvement of staff with computing experience.

Table 1

Modelling expertise	A	N♦	NW	S	ST	SW	T	W	WX	Y♠
Use 'user friendly' models	11	0	5	3	10	1	5	2	4	2½
Edit data files and modify programs.	8		2	3	6	½	4	2	1	1
Develop models and write more advanced programs.	4				4		3	2		
Spend >50% of their time on modelling related activities.	3				1		2			

♦ Northumbrian differentiate between those who can and those who do. They have staff who can !
♠ Yorkshire bemoan the fact that "staff with expertise have left".

It was intended that the numbers in the table indicate how many people are actively involved in water resources modelling. This is not the same thing as the number of staff who have computing skills and could be involved. It is not possible, or indeed necesary, to be too specific and the numbers should be seen in that light.

4. Computer Systems

The portability of models is not helped by the many different types of computer system in use.

Table 2

Type of computer	A	N	NW	S	ST	SW	T	W	WX	Y
ICL Mainframe			x	x			x	x		
IBM Mainframe					x					
Data General								x		
Honeywell Mainframe	x	x								
DEC VAX family	x		x	x	x	x			x	x
DEC PDP/11			x				x			
IBM PCs	x	x	x	x	x	x	x	x	x	x
Hewlett Packard PC							x			
Macintosh PCs			x							
Sun Workstations			x							

There is a growing preference to use PCs (universally IBM compatibles plus Macintosh at North West and HP at Thames), although even now they are not always sufficiently powerful. Software developed on PCs will be easier to share around the Regions.

It is worth noting that 7 Regions use one or other of the VAX series of computers. The proprietary VMS operating system will also help to facilitate software sharing.

North West are the only region using the UNIX operating system (WIS runs on a Sun workstation).

5. Software

Table 3 summarises the returns.

Table 3

Software	A	N	NW	S	ST	SW	T	W	WX	Y
Compilers										
Fortran	x	x	x	x	x		x	x	x	x
Basic					x		x	x	x	x
C					x			x		
Pascal					x					
Clipper (for Dbase)	x		x				x			
Coral			x							
Graphics										
Simpleplot	x									
GINO							x			
Ghost-80				x						
Calcomp							x			
Grapher	x				x		x			x
Surfer	x				x		x			x
Freelance	x			x			x		x	
Harvard					x		x	x		
Spreadsheets										
Supercalc	x			x	x		x	x		
Lotus 1-2-3		x	x	x			x		x	
Smart					x					
Symphony							x			x
Logistix			x							
Databases										
DBase	x			x	x		x		x	
Q&A				x						
Smart					x					
Symphony							x			x
Rapidfile							x			
Dataease	x		x							
Oracle								x		
Stats Packages										
CSS				x						
Aardvark			x							
SPSS	x									

Compilers : Fortran has always been the main language used for programming and its dominance continues, although Basic is still widely used. Interestingly C has not yet made much of an impact.

Graphics : The increasing use of graphics is probably the single biggest development within water resources modelling. The presentation of results is much improved and programs can be made much more user friendly. It is therefore interesting to note the wide range of packages in use. No Fortran graphics library is in use by more than one region. Surfer and Grapher are widely used, particularly amongst Hydrogeologists. Freelance and Harvard are the favourites for 'presentation graphics'. As well as the packages listed it can be assumed that spreadsheet graphicss are commonly used to present model results.

Spreadsheets : Equal preference is shown for Supercalc and Lotus 1-2-3.

Databases : Dbase is marginally the favourite.

6. NRA Modelling Activities

Appendix 2 contains copies of the sheets which describe the models currently in use or available within the NRA. They are listed below in the order in which they are compiled in the Appendix ;

Regional Groundwater Models

A3 London Basin	Thames
A2 Group Pumping Test model	Thames
Cotswolds Limestone	Thames
Kennet Valley (2 models)	Thames
R. Allen groundwater model	Wessex
Central Lincolnshire Limestone (Nitrate)	Anglian
Gipping Chalk	Anglian
Lodes - Granta Chalk	Anglian
L. Mersey Basin and N. Merseyside Saline Groundwater Investigation	North West
Malmesbury Groundwater model	Wessex
Northern and Southern Lincolnshire Chalk	Anglian
North Notts Trias	Severn Trent
Pant Valley Chalk	Anglian
R. Piddle Groundwater study	Wessex
Rhee - Cam Chalk	Anglian
Sherwood Sandstone nitrate model	Yorkshire
Southern Lincolnshire Limestone	Anglian
Spilsby Sandstone	Anglian
Upgrading of distributed groundwater models	Anglian
Yorkshire Chalk	Yorkshire

Other Groundwater Models

AQUA	Anglian, ST, Wessex
FLOWPATH	Anglian
HELP	Anglian
GWFL3D	Anglian
GWTR3D	Anglian
GWPATH	Anglian
MOC	Anglian
MODFLOW	Anglian, Yorkshire
MODPAC (FEPOLL)	Anglian
Multiphase Organic Transport Models	Severn Trent
Nitrate Groundwater model	Yorkshire
Numerical Radial Flow Models	Anglian
PLASM	Anglian
Review of contaminant transport models	National R&D
Wellfield Simulation Model	Anglian, Yorkshire

Catchment Simulation Models / Rainfall - Runoff

Flow generation from rainfall	Thames
Great Ouse Resource Model	Anglian
Hydrological Water Balance	Severn Trent
HYRROM	Anglian, Yorkshire
Lumped recharge / groundwater model	Anglian
Middle Level Model	Anglian
Rainfall - Runoff Model	Severn Trent

River Regulation / Transfer Schemes / Operational

AMORS	North West
Dee simulation	Welsh
Ely Ouse - Essex System Model	Anglian
Flow Forecasting System	Severn Trent
River Severn Regulation System	Severn Trent
Trent - Witham - Ancholme Transfer Scheme	Anglian

Resource Yield Assessment / System Simulation

Control rule program	Anglian
Direct supply reservoir yield analysis	Welsh
Drought Management System	Thames
GENSIM	Southern
Kielder HEP	Northumbrian
Northumbrian Reservoir Simulation	Northumbrian
OSAY	Anglian
Reservoir Simulation	Anglian
Resource Planning Suite	North West, Severn Trent
South East Wales conjunctive use	Welsh
STOMPS	Anglian
STORDET	Severn Trent
Water Resources Model	Thames
Water Resource System Hydrological Models	Severn Trent
Water Resource System Simulation package	Yorkshire (Welsh)

Economic Planning Models

Planning Model	Anglian
RACS	Southern
Regional Resources Allocation Model	Severn Trent

Low Flow Modelling

IH Low Flow System	North West, South West

GIS

WIS	North West
SPANS (Nitrate modelling application)	Severn Trent
SPANS (Recharge application)	Severn Trent

A few contributions which referred to flood hydrology and databases have not been included ;

Southern	FLUCOMP	Hydraulic modelling
North West	ARMA and ISO models	Flood Forecasting
Severn Trent	RAP	Rainfall Analysis Program
Yorkshire	GROWLOG and HYDRODAT	Groundwater databases.

7. The 'Experts'

The following organisations were mentioned as having been used successfuly for consultancy / expert advice on water resources / hydrological issues.

Groundwater modelling

University of Birmingham, Dept of Civil Engineering. (Prof. K.Rushton).	A, ST, Y, T, S
Groundwater Development Consultants. (B. Misstear, W. Bakiewicz)	A, WX
Hydrotechnica (T.Lewis)	WX
K.L. Jones	WX
University of Birmingham, Dept of Geology. (Prof. J. Lloyd)	A, Y
WRC (David Oakes)	A,
C. J. Smith (use of AQUA)	ST
Newcastle University (Water Resource Systems Research Unit - Rae Mackay)	A, N

Low flow analysis / modelling

Institute of Hydrology (A. Bullock, R. Moore)	A, NW, S, SW, T, W, Y
Surrey University (expert system for licensing, with IoH)	S
WRC (David Oakes)	A
Newcastle University (Dept Agriculture & Dept Civil Engineering)	A
Power and Water Consultants	NW

8. The role of a national working group

The following suggestions were made ;

- common requirements.
- common standards of output.
- the evaluation of existing NRA owned 'in-house' software.
- the pooling of experience.
- the interchange of knowledge.
- the generalisation of models to improve portability.
- the transfer of models between Regions.
- the evaluation of existing proprietary modelling software.
- the identification of areas where improved modelling is required, and the commissioning of work on behalf of the NRA nationally.
- consider training requirements.

9. Conclusions

An initial review of water resources modelling activities throughout the NRA has been made. There are differences of approach between the Regions, centering on the level of in-house involvement, but a common belief that sharing experience and expertise would be of benefit to all.

Nigel Fawthrop
NRA Anglian Region
February 1991

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SURVEY OF WATER RESOURCES AND HYDROLOGICAL MODELLING ACTIVITIES

1. Briefly outline the staff structure insofar as it is relevant to water resources / hydrological modelling activities (continue on a separate sheet if necessary).

2. How many water resources staff are there throughout the region who ;

   - use 'user friendly' computer models developed by others. .....
   - use less 'user friendly' models, edit data files, modify programs .....
   - develop models and write more advanced programs. .....
   - spend more than 50% of their time on modelling related activities. .....

3. What types of computer systems do you use?

4. What software do you mostly use?
   - Language compilers. .....
   - Graphics. .....
   - Spreadsheets. .....
   - Databases. .....
   - Stats packages. .....
   - Other (utilities etc.) .....

5. Which organisations have you used successfully for consultation / expert advice on water resources and hydrological modelling issues. Please give the area of expertise and a contact name if appropriate (continue on a separate sheet if necessary).

6. If a national working group on water resources modelling was set up, what topics do you think it ought to consider? (continue on a separate sheet if necessary)

Completed by ..... Position .....

Region ..... Date .....

Region. _____

Model Name or Subject. _____

1. **Area of Application.**

2. **Brief Description.**

3. **Potential Elsewhere.**

4. **Contact name and telephone number.**

Region.	THAMES
Model Name or Subject.	**A3, A2, COTSWOLD, KENNET (LINEAR, NON-LINEAR)**

1. **Area of Application.**

A3 See separate page

A2 Finite element model - general use for modelling group pumping

Cotswold - Finite difference model of the Great Oolite aquifer in the Cotswold

Kennet - Linear and non-linear Finite difference models for the response of the chalk aquifer of the Berkshire Downs

2. **Brief Description.**

A2 - This model is capable of representing situations where the aquifer consists of any number of layers with different hydrogeological properties has been used on a mainframe but not PC - from WRC.

Cotswold - This is a F-D time variant model developed at University of Birmingham (Dept of Civil Engineering).

Kennet - Again developed at Birmingham
Non-linear

Kennet - Predecessor of above using simpler analysis
Linear

3. **Potential Elsewhere.**

A3, Cotswold and Kennet models written for specific areas but A2 can be used anywhere. A2 model will be used on PC but will have to be compiled on a Fortran computer which extends DOS limits (eg. FTN 77/386 from University of Salford) for any large models.

4. **Contact name(s) and telephone number(s).**

Chris Evans 0734 - 535312

Region. THAMES

Model Name or Subject. A3 (LONDON BASIN) GROUNDWATER MODEL

1. **Area of Application.**

Regional groundwater flow model of the chalk aquifer of the London Basin.

2. **Brief Description.**

This is a finite element model and is applied to the London Basin in order to ;
(i) understand groundwater movement both regionally and locally.
(ii) assess operational performance of various groundwater developments.
(iii) predict rising groundwater levels in London.
This model was developed under contract at WRC. The data requirements are very large which include groundwater levels, transmissivities storage coefficients, recharge and abstraction rates, river and spring data. Recharge and abstractions are read in when the model requires then for transient analysis.

3. **Potential Elsewhere.**

The model is specific to the London Basin. But the techniques could be applied elsewhere. The program is written in Fortran and was transferred from an ICL mainframe onto Compaq PC. Documentation consists of a WRC report and a user manual.

4. **Contact name(s) and telephone number(s).**

Chris Evans 0734 - 535312

Region: Wessex

Model Name or Subject River Allen Groundwater Model

1 Area of Application

A linked surface water and groundwater flow model to produce river flows, and ground water levels for the River Allen Catchment, in Dorset.

It will be used to test various management schemes of river compensation and abstraction.

2 Brief Description

The model is currently under development (due for completion Oct 91) by Groundwater Development Consultants, Cambridge. It uses the Stanford Watershed Model for surface water flow and recharge to Groundwater, and the Consultants own groundwater modelling programs, which use the Integrated Finite Difference Method. Uses Morecs data, abstraction data, groundwater level data, continuous flow measurements and specially taken instantaneous flows. Output will be predicted flows, and groundwater levels at appropriate nodes in the model and will be of presentation quality.

3 Potential Elsewhere

The technique could be applied to any other catchment in the country, where the data exists.

The model will run on an IBM compatible micro with 640kb RAM, 20Mb hard disk and a 80386 processor and 80387 co-processor.

Documentation will consist of a report by the Consultants and a User Guide.

4 Contact name and telephone number

Richard Symonds - 0278 457333

Region. ANGLIAN

Model Name or Subject. CENTRAL LINCOLNSHIRE LIMESTONE (NITRATE) MODEL

1. Area of Application.

Distributed regional groundwater flow and nitrate model for the Central Lincolnshire Limestone (CLL).

2. Brief Description.

This is the WRc (David Oakes) nitrate model which was first applied to the CLL in 1984. The model was updated in 1988 and a further contract was let in 1990. It was originally developed to investigate rising levels of nitrate in the Lincolnshire Limestone aquifer. The latest contract is designed to investigate the effect of land use changes within two statutory NSA's on nitrate concentrations in the aquifer.

3. Potential Elsewhere.

This model is specific to the Central Lincolnshire Limestone although the WRc nitrate model has been applied to many other catchments.

4. Contact name and telephone number.

Mark Grout · 0733 371811

Region. ANGLIAN

Model Name or Subject. **GIPPING CHALK MODEL**

1. Area of Application.

Distributed regional groundwater flow model of the Gipping Valley Chalk.

2. Brief Description.

The Gipping Chalk model was developed to help quantify the resources available in the Gipping Valley and to identify the reasons for saline intrusion in the Ipswich area. The model was developed by the Department of Civil Engineering, University of Birmingham for the Norwich Division of Anglian Water Authority. The model is currently being used at the Anglian Region of the NRA to help investigate the effects of increased abstraction under drought conditions.

The groundwater model is accompanied by a relatively detailed recharge routing model.

Input data: Transmissivity, storage, abstraction, recharge, rainfall, potential evapotranspiration and boundary conditions.
Output: Groundwater heads and flows.

3. Potential Elsewhere.

The model is specific to the Gipping Valley although the modelling technique can be applied to other catchments. The understanding which has been achieved with regard to the aquifer flow and recharge mechanisms has been important for helping to identify flow mechanisms in other catchments.
Runs on a Honeywell mainframe computer.

4. Contact name and telephone number.

Mark Grout 0733 371811

Region. ANGLIAN

Model Name or Subject. **LODES-GRANTA GROUNDWATER MODEL**

1. Area of Application.

Regional groundwater flow model of an area of the chalk North-East of Cambridge.

2. Brief Description.

This is the latest of many distributed groundwater flow models which we have had from the Dept. of Civil Engineering at the University of Birmingham. Completed 1988. It has been used to design a groundwater development scheme over 600km^2 comprising new sources for PWS and river support into numerous small streams.

The particualar features of this model are ;

- its relatively complex recharge calculations.
- springflows are head dependant.
- modelling of river-aquifer interaction
- Transmissivity and storage coefficients change with varying head.
- A 1km^2 grid.

Most of the investigations were carried out at Birmingham, but additional runs have subsequently been made in-house

3. Potential Elsewhere.

The model is very specific to the Lodes-Granta area, but the techniques could of course be applied elsewhere. The program is written in Fortran and runs on a Bull mainframe computer. Graphical post processing has been developed in-house using GRAPHER and SURFER.
Documentation consists of the contract Final Report which describes the modelling approach and a program operating manual.

4. Contact name(s) and telephone number(s).

Nigel Fawthrop or Mark Grout 0733-371811

Region.	NORTH WEST
Model Name or Subject.	**L.MERSEY BASIN AND N.MERSEYSIDE SALINE GROUNDWATER INVESTIGATION.**

1. **Area of Application.**

Model to simulate recent history of the Permo-Trias aquifer and provide prediction on response to various future abstraction requirements arising from a more general study of the relationships of various types of fresh and saline waters in a 3-dimensional system.

2. **Brief Description.**

Compilation of this program yielded much useful data on the aquifer characteristics and relationships, all oF which is contained in the final reports issued in 1981 and 1984. These reports contain extensive output from the model. Occasionally use is made of the model for particular local problems. Currently requires Birmingham University to run the model - there is no in-house expertise following the NRA/PLC split.

3. **Potential Elsewhere.**

Specific to the area of study although experience gained in compilation has extensive academic value.

4. **Contact name(s) and telephone number(s).**

M.D. Eggboro 0925 -53999

Region: Wessex

Model Name or Subject: Malmesbury Groundwater Model

1 Area of Application

The model is of the Bristol Avon catchment above Great Somerford. It covers the Great Oolite, modelled with impermeable boundaries, and the Inferior Oolite, parts of which outcrop lie at some distance from the Great Oolite, and which is separated from the Great Oolite by the Fullers Earth.

2 Brief Description

The model was constructed by Hydrotechnica Ltd in 1990. It is based on the USGS MODFLOW program, and has been modified to include features required for the Malmesbury area. The model calculates head distribution over a rectangular grid network representing the aquifer. Inputs such as recharge, and outputs such as flows to rivers and abstractions may be specified. The model produces water level diagrams, and river flows, together with groundwater contours.

3 Potential Elsewhere

The MODFLOW package is commercially available and could be used, with appropriate modifications, in any other catchment where suitable data exists.

4 Contact name and telephone number

David McKay - 0278 457333

Region. ANGLIAN

Model Name or Subject. **NORTHERN AND SOUTHERN LINCOLNSHIRE CHALK MODEL**

1. Area of Application.

Distributed regional groundwater flow model for the northern and southern Lincolnshire Chalk.

2. Brief Description.

The model originally covered the northern Lincolnshire Chalk and was developed to help understand the reasons for increasing salinity in the Grimsby area. This initial work was done in the late 70's but the model was extended to include the southern Lincolnshire Chalk in the mid 80's. The development work has been undertaken by the Department of Civil Engineering, University of Birmingham.

The model has been further developed to allow it to be updated relatively easily on a 3 or 6 monthly basis. The model calibration is generally very good, particularly in the north, and it is probably the only example of a truly operational distributed groundwater model.

Operational planning runs involving liaison with Anglian Water Services Ltd. are currently made at Birmingham, but we aim to take these on in-house by 1992. The model will run on a VAXstation 3100 (see 'Upgrading of distributed groundwater flow models').

3. Potential Elsewhere.

The model is specific to the Lincolnshire Chalk. However, the technique is applicable to other catchments.

4. Contact name and telephone number.

Nigel Fawthrop, Mark Grout or Dave Watling 0733 - 371811
Andy Baxendale 0522 - 513100

Region. SEVERN TRENT

Model Name or Subject. REGIONAL MODEL OF NORTH NOTTS TRIAS

1. **Area of Application.**

Regional Model of Groundwater flow in the North Notts Trias.

2. **Brief Description.**

Finite element model of the confined or unconfined Trias of N. Notts. Just started development. To be used to investigate possible overabstrsction in the light of new licence applications. To be developed in a user friendly form with graphical outputs, and later provision for an extension to transport modelling.

3. **Potential Elsewhere.**

Specific to Severn-Trent Region.

4. **Contact name and telephone number.**

S W Fletcher 021-711-2324 Ext 3056

Region. ANGLIAN

Model Name or Subject. **PANT VALLEY MODEL**

1. **Area of Application.**

Distributed regional groundwater flow model for the Pant Valley, Essex.

2. **Brief Description.**

The model was developed to help estimate catchment resources and identify the reasons for the development of the Braintree Depression. The model was developed by the Department of Civil Engineering, University of Birmingham in the early 80's for the Essex River Division of Anglian Water Authority.

The model was used subsequently by Colchester Division of AWA to model the recovery of the Braintree Depression. The poor fit to the recovery necessitated some additional calibration work.

The model is accompanied by a relatively detailed recharge routing model.

Input Data: Transmissivity, storage, recharge, abstraction, rainfall, potential evapotranspiration and boundary conditions.
Output: Groundwater heads and flows.

3. **Potential Elsewhere.**

The model is specific to the Pant Valley although the modelling techniques can be applied to different catchments. The understanding of the flow mechanism which was achieved has been used to help interpret the behaviour of other catchments.

4. **Contact name and telephone number.**

Mark Grout 0733 371811

Region:	**Wessex**
Model Name or Subject	**River Piddle Groundwater Study**

1 Area of Application

A simulation model of the goundvater and surface water movements within the chalk catchment of the River Piddle in Dorset.

The model has been used to investigate the behaviour of the river flows under various conditions.

2 Brief Description

The model was developed during 1990 by K L Jones, Consultant. The Upper & Middle Chalk have been modelled as a single aquifer, underlain by an aquiclude, and overlain, where appropriate, by a semi-confining layer representing the Tertiary deposits.

The aquifer is not assumed to be isotropic. The model simulates vertical recharge to the aquifer from the surface zone, or by movement through the Tertiary deposits, or by leakage from the river. Depletion of the aquifer may occur due to abstractions or spring flows.

The model produces reasonable river flow estimates during period of low rainfall.

3 Potential Elsewhere

The technique could be applied to any other catchment in the country, where the data exists.

4 Contact name and telephone number

David McKay - 0278 457333

Region. ANGLIAN

Model Name or Subject. **RHEE/CAM MODEL**

1. **Area of Application.**

Distributed regional groundwater flow model of the Rhee and Cam catchments to the south-west of Cambridge.

2. **Brief Description.**

The model was developed to help define the resources of the Rhee/Cam catchment and to assist with operational planning. It has also been used to help site PWS and river support boreholes. The model was used in-house relatively frequently by Cambridge Division of Anglian Water Authority although it is in need of updating and recalibration.

The Rhee/Cam Model was developed by WRc (David Oakes) in the late 70's.

Input Data: Transmissivity, storage, recharge, abstraction, boundary conditions.
Output: Groundwater heads and flows.

3. **Potential Elsewhere.**

The model is specific to the Rhee/Cam catchment.

4. **Contact name and telephone number.**

Mark Grout 0733 37181

Region. YORKSHIRE

Model Name or Subject. **SHERWOOD SANDSTONE NITRATE MODEL**

1. Area of Application.

Nitrate groundwater model.

Used for simulating nitrate response in Sherwood Sandstone in Yorkshire.

2. Brief Description.

- Based on WRC nitrate model
- Finite difference groundwater flow model with nitrate movement superimposed.

Obtained 1988.

Adapted for use on PC also adapted to meet situation in Yorkshire.

3. Potential Elsewhere.

Widely used by WRC.

Fortran on IBM PC.

4. Contact name(s) and telephone number(s).

John Aldrick 0532 - 440191

Region. ANGLIAN

Model Name or Subject. **SOUTHERN LINCOLNSHIRE LIMESTONE MODEL**

1. **Area of Application.**

Distributed regional groundwater flow model for the Southern Lincolnshire Limestone.

2. **Brief Description.**

Developed in the late 70's this was one of the first distributed models to be developed by Prof. Rushton at Birmingham University. It led to a better asessment of available resources through an improved understanding of the aquifer flow mechanisms. It was updated (but not improved) in 1988 and has been used in-house on several occasions recently. (Fortran code - Honeywell mainframe computer). The in-house runs served to highlight some of the models limitations, particularly with respect to the prediction of river flow. It is now being improved and extended to the rest of the Lincolnshire Limestone.

3. **Potential Elsewhere.**

The model is specific to the Lincolnshire Limestone and is now somewhat out of date. The new version will be developed to the new 'standard' and will run on a VAXstation 3100 (see 'Upgrading distributed groundwater models').

4. **Contact name(s) and telephone number(s).**

Nigel Fawthrop or Mark Grout 0733 - 371811

Region. ANGLIAN

Model Name or Subject. **SPILSBY SANDSTONE MODEL**

1. Area of Application.

A distributed regional groundwater flow model of the Spilsby Sandstone (Lincolnshire).

2. Brief Description.

Developed by Groundwater Development Consultants Ltd using their integrated finite difference model. The model has recently been handed over and we are currently carrying out further runs in-house.

The model was developed as part of a hydrogeological study of the aquifer and led to some interesting conclusions about vertical flows between the sandstone and the overlying chalk. The smallest timestep is quarterly, so runs can be carried out on a 386 PC. A Fortran compiler utilising extended DOS (eg. FTN77 from Salford Uny) is required for larger models.

3. Potential Elsewhere.

The GDC model is general purpose and could be applied to any aquifer, including multi-layered situatios involving vertical leakage. Documentation is excellent. To date it has been mostly used overseas and has yet to fully prove itself in UK conditions and karstic aquifers.

4. Contact name(s) and telephone number(s).

Nigel Fawthrop or Mark Grout 0733 - 371811

Region. YORKSHIRE

Model Name or Subject. CHALK GROUNDWATER MODEL

1. Area of Application.

Regional aquifer model of chalk (northern half) in Yorkshire.

2. Brief Description.

Distributed groundwater flow model from Civil Engineering / Geology Departments of Birmingham University 1985.

Features :-

- T and S vary with head - very large variation required to match springflows
- Springflows head dependant
- 1 Km^2 grid

Used for modelling groundwater flows and required for investigations of groundwater development and effects on spring flows.

Probably mainline "Birmingham" type model, but tailored to specification not many runs made in-house.

3. Potential Elsewhere.

Area specific - but technique is not.

Written in Fortram.

Has been adapted to run on IBM compatible PC.

Documentation in Birmingham reports.

4. Contact name(s) and telephone number(s).

John Aldrick 0532 - 440191
Darmindar Chadha 0904 - 636951

Region. ANGLIAN

Model Name or Subject. **UPGRADING OF DISTRIBUTED GROUNDWATER MODELS**

1. **Area of Application.**

Distributed regional groundwater flow models.

2. **Brief Description.**

Many models have been developed over the past 10 years by different Divisions of Anglian Water Authority. NRA Regional HQ staff now support their use and coordinate the development of new models. A contract to 'standardise' and improve many of the old models has recently been let to Birmingham University. This will involve setting them up on a VAXstation 3100 and the development of graphics for the presentation of results. In this way we hope to better utilise the models, particularly for short - medium term operational planing where appropriate.

3. **Potential Elsewhere.**

This work could be extended to other 'Birmingham Models' throughout the NRA.

4. **Contact name(s) and telephone number(s).**

Nigel Fawthrop or Mark Grout. 0733 - 371811

Region. ANGLIAN

Model Name or Subject. **MISCELLANEOUS GROUNDWATER MODELS**

1. **Area of Application.**

A number of commercially available packages for modelling groundwater flow and contaminant transport.

2. **Brief Description.**

MODFLOW	USGS - Groundwater flow (XY with provision for a number of layers).
PLASM	USGS - Groundwater flow (XY with provision for a number of layers).
MOC	USGS - Groundwater flow and contaminant transport.
HELP	USGS - Prediction of landfill leachate volumes
+ other USGS programs	
AQUA	Vatnaskil Consulting Engineers - Groundwater flow and contaminant transport.
FLOWPATH	NWWA Catalogue - Model for delimiting catchments to pumped boreholes.
GWPATH	IGWMC Catalogue - Similar to FLOWPATH.
GWFL3D	Groundwater flow model from WALTON (1989) Numerical Groundwater Modeling
GWTR3D	Groundwater flow and contaminant transport model from WALTON (1989).
WELLFIELD SIMULATION	Earthware. Based on PLASM

None of these have really been used in anger

3. **Potential Elsewhere.**

'Off-the-shelf' models can in principle be applied to most aquifer situations. In practice, however, the code usually needs to be modified to represent specific problems accurately. This could involve a lot of work depending on the complexity of the model and the documentation available. With some models (e.g. AQUA) the code is not supplied.

4. **Contact name and telephone number.**

Mark Grout 0733 371811

Region. SEVERN TRENT

Model Name or Subject. AQUA

1. **Area of Application.**

Contaminant Transport in Groundwater

2. **Brief Description.**

Finite element digital model with pre and post processors. Used infrequently at present but should be used more.

Developed in Iceland and now updated. Requires the usual groundwater model estimates plus the chemical transport parameters, eg diffusivity.

Very poor documentation with the first version.

3. **Potential Elsewhere.**

Other regions have it already but it is useful everywhere. Requires IBM PC 640K coprocessor, colour printer or plotter.

4. **Contact name and telephone number.**

S W Fletcher 021-711-2324 Ext 3056

Region:	Wessex
Model Name or Subject	Aqua

1 Area of Application

A two dimensional groundwater flow and contaminant transport model.

2 Brief Description

Commercially available software, developed by Vatnaskil Consulting Engineers, Iceland. Can deal with seepage, drawdown, recharge with one or several sources, and also contaminant transport. Can provide time-series output in a graphical form.

3 Potential Elsewhere

Limited by its two dimensional modelling ability, but is otherwise applicable to any groundwater catchment.

4 Contact name and telephone number

Richard Symonds - 0278 457333

Region.	YORKSHIRE
Model Name or Subject.	USGS MODFLOW

1. **Area of Application.**

Regional aquifer models.

2. **Brief Description.**

Finite difference groundwater model.

USGS package for IBM - PC.

Obtained 1988.

Used for modelling part of Sherwood Sandstone. Limitations in terms of pumping boreholes.

3. **Potential Elsewhere.**

Probably widespread for groundwater.

4. **Contact name(s) and telephone number(s).**

John Aldrick 0532 - 440191

Region. ANGLIAN

Model Name or Subject. **MODPAC (FEPOLL)**

1. **Area of Application.**

Distributed groundwater flow and contaminant transport model solved by the Finite-Element Method.

2. **Brief Description.**

FEPOLL has been adopted and further developed by the Department of Civil Engineering, Newcastle University. Pre and post-processing facilities allow it to be relatively quickly applied to contaminant transport problems. The pre and post-processing development was partly funded by Anglian Region NRA and the model has been recently taken on. However, only a limited amount of evaluation has been possible so far.

Input data: Transmissivity, storage, abstraction, recharge, boundary conditions.
Output: Groundwater heads and flows, contaminant concentration.

FEPOLL does not allow the detailed representation of aquifer flow and recharge mechanisms which has been achieved with the distributed groundwater flow/resources models. Particular features such as transmissivity and storage coefficient varying with head, complex river-aquifer interaction, dewatering around abstraction sites etc. are not included in the basic model. There is no accompanying recharge model.

3. **Potential Elsewhere.**

FEPOLL can, in principle, be applied to any aquifer situation. The pre and post-processing facilities available within the overall MODPAC package allow it to be relatively quickly set up for different problems.

4. **Contact name and telephone number.**

Mark Grout 0733 371811

Region. SEVERN TRENT

Model Name or Subject. SUITE OF MODELS FROM IGWC

1. Area of Application.

Multiphase Organic Transport Model for investigating the movement of invisible organic compounds in porous media.

2. Brief Description.

Spillvol - calculates volume of spill from thickness in observation wells.

Armos - finite element model produces contours of oil spill in areal plane.

Mofat - 20 vertical or radial model - produces volume of oils, etc, and the concentrations of the oil fractions dissolved in the water.

Air and Venting - used to design venting systems for removing volatile spills.

Analyd - theoretical solution to oil movement.

3. Potential Elsewhere.

Particularly suitable for oil spills in shallow unconfined aquifers eg gravel terraces. I have attended a course on their use but have not used them 'in anger'.

4. Contact name and telephone number.

S W Fletcher 021-711-2324 Ext 3056

Region.	YORKSHIRE
Model Name or Subject.	**NITRATE GROUNDWATER MODEL**

1. **Area of Application.**

Nitrate groundwater model.

2. **Brief Description.**

Finite difference model and particle tracking for solute movement.

Written by Paul Younger (now at Northumbria NRA) for his Ph.D thesis and while at Yorkshire 1990.

3. **Potential Elsewhere.**

Not known.

4. **Contact name(s) and telephone number(s).**

John Aldrick 0532 - 440191

Region. ANGLIAN

Model Name or Subject. **NUMERICAL RADIAL FLOW MODELS**

1. Area of Application.

Numerical radial flow models for interpreting data from pumping tests. A number of models are available. These are based on the original single layer model documented in Rushton and Redshaw (1979). Multi-layer radial flow models are available for aquifer situations where vertical flows are significant.

2. Brief Description.

Numerical radial flow models for pumping test analysis were developed in the mid 70's at the Department of Civil Engineering, University of Birmingham. A further multi-layer radial flow model was developed in the mid 80's by Mark Grout. This model is particularly useful in the many situations where vertical flows are significant. The model has been used to interpret pumping test data from a number of aquifer systems.

Input data: Permeabilities, storages, well radius etc. (The data file is about 10 lines long).
Output: Time-drawdown curves, flows from well storage, distributed aquifer flows.

3. Potential Elsewhere.

The radial flow models can be applied to pumping tests in virtually any aquifer situation. The multi-layer version runs in approximately 5 minutes on a PC (386 machine) with a maths co-processor. Graphical display of model output is currently being developed in-house at Anglian Region.

4. Contact name and telephone number.

Mark Grout 0733 371811

Region.	ANGLIAN
Model Name or Subject.	**REVIEW OF CONTAMINANT TRANSPORT MODELLING TECHNIQUES. (NATIONAL R&D PROJECT)**

1. **Area of Application.**

A national R&D project has been set up to review existing groundwater quality models and to assess their suitability for representing subsurface contaminant transport arising from typical UK pollution problems. The contractor will be BGS and the work will start early in 1991.

2. **Brief Description.**

The project wil review transport and attenuation processes which can occur in the subsurface environment and which are specifically associated with pollution. The work will focus on the major British aquifers and the pollution scenarios most commonly encountered by NRA staff. Both the saturated and unsaturated zones will be considered. Existing groundwater quality models will be thoroughly reviewed and their suitability for representing contaminant transport assessed. It is envisaged that futher, relatively simple transport models including databases and a methodology for use, will be developed.

3. **Potential Elsewhere.**

The results of the review and any transport models developed will be made available nationally.

4. **Contact name(s) and telephone number(s).**

Mark Grout (Project Leader) 0733 - 371811

Region.	YORKSHIRE
Model Name or Subject.	**EARTHWARE WELLFIELD SIMULATION MODEL**

1. **Area of Application.**

Finite - difference groundwater model - (Prickett and Lonnquist) for IBM PC for wellfield simulation and regional aquifer models.

2. **Brief Description.**

Obtained 1990.

Little used to date.

3. **Potential Elsewhere.**

Probably widespread to groundwater.

4. **Contact name(s) and telephone number(s).**

Region. THAMES

Model Name or Subject. **FLOW GENERATION FROM RAINFALL**

1. Area of Application.

Catchment model to produce river flows.

The main application is when used as a daily time step model to produce continuous hydrographs of river flow, possibly over many years, from daily rainfall and monthly potential evaporation. A version of the model operating on an hourly time step is used to generate hydrographs of storm events.

2. Brief Description.

The model consists of two distinct sections representing soil moisture storage and general catchment storage. Generally a number of these soil moisture/catchment storage zones will exist within a catchment eg. aquifer, clay, urban etc.

The model has been developed over a period of about ten years and has been successfully applied to a wide range of rivers in the Thames Region.

Its main use has been in water resources studies and in helping to understand the hydrological processes operating in different catchments.

3. Potential Elsewhere.

The model is completely general and could potentially be applied in other areas.

Versions exist in Fortran 77 on an ICL mainframe and in Basic on an Hewlett Packard micro. data input is specific to local archives.

A document describing the model exists.

4. Contact name(s) and telephone number(s).

Brian Greenfield or Cathy Glenny 0734 - 535320

Region. ANGLIAN

Model Name or Subject. **GREAT OUSE RESOURCE MODEL**

1. Area of Application.

River flow prediction throughout the Great Ouse catchment, incorporating lumped rainfall-runoff/aquifer modelling and taking into account abstractions and discharges.

2. Brief Description.

Used to assess river flow statistics anywhere in the catchment given future growth in abstractions (both surface and groundwater).
Developed under contract at WRC and only recently handed over. Improvements to the user interface are being introduced prior to full evaluation. It looks as though it will be extremely useful.

Inputs are MORECS rainfall and evaporation together with historical abstractions and discharges for every subcatchment for every year. In this case the abstractions and discharges were estimated using catchment wide annual totals and the averaged spatial distribution. Output is basically a 7 day flow duration curve for any of 392 nodes throughout the catchment.

3. Potential Elsewhere.

The code was developed so that it could readily be applied to other catchments. The problem would be collating abstraction and discharge data in the required detail.
The program is written in Fortran and runs on an IBM PC. The user interface (not essential) uses SIMPLEPLOT graphics.
Documentation consists of a WRC report, a user manual and NRA implemention notes.

4. Contact name(s) and telephone number(s).

Nigel Fawthrop 0733-371811

Region. SEVERN TRENT

Model Name or Subject. HYDROLOGICAL WATER BALANCE (WBAL)

1. **Area of Application.**

Assessment of recharge to aquifer from evaporation and rainfall data using Penman Soil moisture budgeting method.

2. **Brief Description.**

Model is used to calculate daily estimates of effective rainfall for any catchment area of groundwater unit.

Input data: daily rainfall, potential evaporation land use distribution

Output data: daily actual evaporation, S.M.D. and effective rainfall

3. **Potential Elsewhere.**

This could be applied to any region. Written in FORTRAN could be easily adapted to run any system with a FORTRAN compiler.

4. **Contact name and telephone number.**

G P Davies 021-711-2324 Ext 3040

Region. ANGLIAN

Model Name or Subject. **HYRROM**

1. Area of Application.

Conceptual rainfall-runoff model packaged for use on PCs by the Institute of Hydrology.

2. Brief Description.

Based on a simple representation of the physical processes which govern water flow in a catchment. Suggested applications are ;

- Infilling missing flow data.
- Quality control of data.
- Extending historical flow records.
- Generating synthetic flow sequences.
- Water resources assessment.

Calibration includes an option for automatic optimisation. Modelled flows may be compared with recorded flows using screen or hard copy graphics. Software links are provided to HYDATA.

There has been only limited use within the Anglian Region. Not surprisingly it seems as though it performs best in 'natural' catchments.

3. Potential Elsewhere.

Developed as a commercial package with general application. Available for purchase from the Institute of Hydrology. Full documentation provided.

4. Contact name(s) and telephone number(s).

Angela Wallis 0733 - 371811

Region. YORKSHIRE

Model Name or Subject. **HYRROM**

1. **Area of Application.**

Rainfall/runoff model.

2. **Brief Description.**

IoH lumped parameter model.

Obtained 1990.

Little experience of using this purchase.

3. **Potential Elsewhere.**

4. **Contact name(s) and telephone number(s).**

Peter Towlson and Phil Proctor 0532 - 440191

Region. ANGLIAN

Model Name or Subject. **LUMPED RECHARGE/GROUNDWATER MODEL**

1. Area of Application.

Two separate models:

1. Recharge Model; Soil moisture balance model for calculating recharge.

2. Groundwater Model; Simple two cell aquifer water balance model. Calculates baseflow which is added to surface runoff to give total river flow. Monthly or daily time step. Accepts output from the Recharge Model.

2. Brief Description.

Developed by Anglian Water Authority in the late 70's. Used for estimating catchment resources and operational planning. Applied to the South Lincolnshire Limestone and the Great Ouse Chalk catchments. Lumped groundwater models for the Great Ouse Chalk form part of the Ely-Ouse to Essex Transfer Model.

The Recharge Model uses rainfall, potential evapotranspiration and land use data. Outputs are: actual evaporation, recharge, surface runoff and evaporation from riparian areas.

The input to the Lumped Groundwater Model is the output from the Recharge Model. Field data (levels, flows and abstractions) are also needed for calibration purposes.

The Recharge Model is useful although it really needs to be used with the Lumped Groundwater Model to allow a more realistic assessment of catchment recharge. The Lumped Groundwater Model is limited by its conceptual simplicity. However, it is useful as an operational planning model.

3. Potential Elsewhere.

The Lumped Recharge/Groundwater Model is probably similar to the Thames Water Authority lumped parameter model. It could, in principle, be used in other regions.

The model runs on a Bull mainframe and a PC. There are, as yet, no accompanying graphics routines for displaying output.

The Recharge Model is relatively well documented. Documentation for the Lumped Groundwater Model is nearly complete.

4. Contact name and telephone number.

Nigel Fawthrop or Mark Grout 0733 371811

Region. ANGLIAN

Model Name or Subject. **MIDDLE LEVEL MODEL**

1. **Area of Application.**

An integrated agro-hydrological plus agro-economic model for the Middle Level of the Fens. Used to improve the understanding of the factors driving the demand for irrigation water, and the availaility and reliability of water resources.

2. **Brief Description.**

Developed by the Department of Agricultural and Environmental Science at the University of Newcastle upon Tyne. There are 3 interlinked but indepenent models ;

- A Water Resources model which carries out a daily simulation of the availability of resources within the area and at key transfer points where water is imported.
- An Agro-Economic model which uses linear programming to project future cropping patterns and irrigation use.
- An Agro-Hydrological model which uses an advanced water balance approach to simulate soil / crop evapotranspiration, sub-surface drainage, sub-surface irrigation and spray irrigation

Analysis has included ;

- The reliability of water resources under various irrigation demand scenarios.
- The impact of changing water resource availability on irrigation use and crop production.

The hydrological models are of prime interest to the NRA. They were handed over on completion of the project (1990) and have been set up and tested on an IBM PC microcomputer. To date there has been no requirement to carry out further analysis in-house.

3. **Potential Elsewhere.**

The programs which we have are customised to the Middle Level, but the approach could be applied to any similar area. Advice would be required from Necastle University. Reports and model documentation is available.

4. **Contact name(s) and telephone number(s).**

Neil Osborne, Steve Cook or Nigel Fawthrop 0733-371811

Region. SEVERN TRENT

Model Name or Subject. RAINFALL/RUNOFF MODEL

1. **Area of Application.**

Anywhere. The model has been calculated for a few locations in the Severn-Trent region.

2. **Brief Description.**

Parameter rainfall/runoff model developed by Severn-Trent Water Authority (1985) used for derivation of reservoir inflow, or river flow values to fill in gaps in data banks, or create new records for input to water resource simulation models.

The model has the facility for optimising parameters for calibration purposes.

3. **Potential Elsewhere.**

The model could be used anywhere, however the simple mechanism used, makes it only appropriate for longer time scale generation (pentads, months) and therefore only for water resource planning purposes. The program is written in FORTRAN 77 and is housed on a MICROVAX minicomputer and on IBM mainframe.

4. **Contact name and telephone number.**

G P Davies 021-711-2324 Ext 3040
T Harrison Ext 3044

Region. NORTH WEST

Model Name or Subject. **AMORS (Advanced Methods of Resource Simulation)**

1. **Area of Application.**

Daily simulation of resources systems to optimise the use of water, taking into account reliability and costs.

2. **Brief Description.**

AMORS is a simulation and optimisation model for water resource systems. The optimisation is done by dynamic programming and takes into account the desired reliability of the system and the costs of power and water treatment. The system description is defined by data input, thus allowing flexibility. Sub-daily pumping routines and power cost schedules can be accommodated .
(Developed by Power and Water Consultants)

3. **Potential Elsewhere.**

The AMORS program comprises of modules which define the components of the model which simulate the system under study. It would be fairly easy to therefore to introduce ammendments and new modules for different needs. Powerful potential for simple and complex systems.

4. **Contact name(s) and telephone number(s).**

J.M. Knowles 0925 - 53999

Region. WELSH

Model Name or Subject. **DEE SIMULATION**

1. **Area of Application.**

Simulates operation of the R. Dee regulation system.

2. **Brief Description.**

Simulation of daily inflows to reservoirs, abstractions and reservoir drawdown.

Program written in Fortram by Binnies over 15 years ago. Very useful program, used at least once per year or more frequently if new options are being examined. No problems.

3. **Potential Elsewhere.**

Limited to Dee System.

4. **Contact name(s) and telephone number(s).**

Richard Streeter 0222 - 770088

Region. THAMES

Model Name or Subject. **DROUGHT MANAGEMENT SYSTEM**

1. **Area of Application.**

Predicting river flows and reservoir levels for periods of up to one year in an actual or potential drought.

2. **Brief Description.**

Used to provide advance warning of the need for special action in drought conditions.

Developed in 1986 by the Institute of Hydrology based on several models developed in-house.

Inputs are recent rainfall and river flow data, current reservoir levels and predicted demands. Outputs are predicted river flows and reservoir levels and anticipated dates when action will be required.

3. **Potential Elsewhere.**

The system is very specific to the particular areas modelled although the methodology could be applied elsewhere.

The system is implemented on a PDP11/73 micro-computer.

Documentation consists of a project report and a user guide.

4. **Contact name(s) and telephone number(s).**

David Elford 0734 - 535322

Region. ANGLIAN

Model Name or Subject. **ELY OUSE - ESSEX SYSTEM MODEL**

1. Area of Application.

A simulation model of a water resources transfer system, incorporating yield analysis and groundwater / surface water interaction.

2. Brief Description.

Based on a general, user configurable, node-link simulation model (see Rutland and Grafham Reservoir simulation models), but it has become specific to the Ely Ouse - Essex system. This is a scheme to transfer raw water from the Ely Ouse (which can be supported by groundwater from the Camridgeshire Chalk to the Essex Rivers and their reservoir intakes.

The system is described through a combination of a parameter data file and hard coding. Model features are ;

- surface / groundwater interaction modelled by 5 lumped parameter groundwater models.
- daily timestep (1932 to date).
- yield calculation by iteration.
- features included or excluded using the node - link structure
- option for nitrate prediction in the rivers and reservoirs.

3. Potential Elsewhere.

Not written in a form which could be readily applied to other catchments. It currently runs on a mainframe computer, but conversion to a PC is underway. Documentation is minimal.

4. Contact name(s) and telephone number(s).

Cameron Thomas or Nigel Fawthrop 0733-371811

Region. SEVERN TRENT

Model Name or Subject. FLOW FORECASTING SYSTEM (FFS II)

1. Area of Application.

Real time system using catchment and flow renting models used to produce forecasts of river flows up to 4 days ahead.

2. Brief Description.

Used primarily for flood forecasting but also used for general water resource management applications such as river regulation. System is fully integrated with an automatic data collection system and facilities to display forecast products to local and remote users.

Modelling and data collection on MICROVAX written in Fortran.

Remote display facilities on IBM micros.

3. Potential Elsewhere.

Could be adapted for use in other regions, eg part of the system is currently used in Southern Region.

4. Contact name and telephone number.

C Dobson 021-711-2324 Ext 5805

Region. SEVERN TRENT

Model Name or Subject RIVER SEVERN REGULATION SYSTEM

1. Area of Application.

Spreadsheet application used to assist in the management of flow regulation of the River Severn.

2. Brief Description.

SMART spreadsheet developed in order to calculate daily regulation release requirement for the River Severn.

Input data: gauged flows
regulation releases
river abstractions
Output : naturalised flows
regulation release requirement

3. Potential Elsewhere.

General principle could be applied elsewhere, but not the specific application.

4. Contact name and telephone number.

R C Cross 021-711-2324 Ext 3038

Region. ANGLIAN

Model Name or Subject. **TRENT - WITHAM - ANCHOLME TRANSFER SCHEME**

1. **Area of Application.**

Simulation model of a bulk raw water transfer scheme.

2. **Brief Description.**

The model simulates operation of the T-W-A scheme with a ½ day timestep. It is basically a series of water balance calculations to ;

- estimate the transfer volumes which are required given a sequence of river flows (at several locations) and a set of demands. The major demand has been for industrial water to Humberside, but future developments may include a potable supply and significant increases for other industrial and agricultural users.
- provide an indication of water quality (in terms of % Trent water) at key points in the system. This is achieved using simple routing calculations.

The program is written in Fortran and uses the Simpleplot graphics library. All parameters are contained in data file. Output may be tabular or graphical, of time series or frequency duration statistics of transfer volumes and river quality.

The model has only recently been developed (in-house) and is currently being evaluated. It will be used to evaluate both water resource / system reliability and water quality issues.

3. **Potential Elsewhere.**

The model is specific to the Trent - Witham - Ancholme system.

4. **Contact name(s) and telephone number(s).**

Steve Cook or Nigel Fawthrop 0733-371811

Region. ANGLIAN

Model Name or Subject. **CONTROL RULE PROGRAM**

1. Area of Application.

Derives control curves for an impounding reservoir (direct supply or pumped storage) designed to maintain supplies through the worst droughts on record. Output to supply is provided by the user. Produces control curves for both refill and drawdown.

2. Brief Description.

A Fortran program which searches through monthly records of historic inflows to the reservoir and finds the worst period of 1 to n months (n is user defined) starting each month of the year. It calculates the volume required in store at the start of the period just to maintain supplies. It also searches through periods of Winter refill to calculate the volumes required in store to guarantee being full at the start of the summer drawdown period.

3. Potential Elsewhere.

A powerful program with widespread use : much potential given the misunderstandings and misconceptions which prevail in the UK Water Industry ! Currently available on mainframe but could be converted easily to run on a PC. There is no documentation but a manual could be written if there is sufficient interest.

4. Contact name(s) and telephone number(s).

Originally written by Gerry Sherriff, but contact Cameron Thomas 0733 - 371811

Region. WELSH

Model Name or Subject. **DIRECT SUPPLY RESERVOIRS**

1. **Area of Application.**

Direct supply reservoir yield analysis.

2. **Brief Description.**

This is perhaps too elementary for inclusion in such a survey, but we have found it a quick and easy tool to use and can be used as a module to larger models such as our conjunctive use model. Model is a simple spreadsheet using monthly runoff data, variable demand and compensation discharges to simulate operational practice. Output is a simple water balance of reservoir contents and summary data of the scenario modelled.

3. **Potential Elsewhere.**

Widespread.

4. **Contact name(s) and telephone number(s).**

Richard Streeter 0222 - 770088

Region. SOUTHERN

Model Name or Subject. GENSIM (General Purpose Resource Simulation)

1. Area of Application.

Design and operation of water resource systems. Used specifically in Southern region to study the Bewl reservoir - R Medway and Broad Oak reservoir systems.

2. Brief Description.

The program was written by the former Water Resources Board. GENSIM was written in Fortran and in Southern Region it is loaded on an ICL 3900 mainframe and run under the VME operating system.

A model has to be configured to a particular resource system. Input data includes details of reservoirs, diversions, transfers, regulation control points and flow and demand data. Output comprises flows and storage at specified components.

3. Potential Elsewhere.

This is a general purpose program suitable for application to a wide range of resource systems. It is not as user friendly as modern software however. The documentation consists of the SWA user manual.

4. Contact name and telephone number.

Geoff Burrow, Paul Shaw - 0903 820692

Region. Northumbria

Model Name or Subject. KIELDER HEP

1. **Area of Application.**

Operational system for determining the weekly program of hydropower releases from Kielder Water which optimises on revenue return based on the statistics of inflow, current reservoir level and time of year.

2. **Brief Description.**

The operational program is the front end of the system. The policy is based on a stochastic dynamic programming algorithm which optimises the policy given the Power Gen tariff structure and flow statistics. The optimisation program has an equivalent simulation model which tests the derived policy for annual revenue. The program is used operationally by Northumbrian Water but the income accrues to the Regional Water Resources account which is held by NRA.

FORTRAN SOURCE the property of NRA (Northumbria) Optimisation has only run on Honeywell mainframe and may be too demanding for a micro.

3. **Potential Elsewhere.**

It has already been used at Selset Reservoir to evaluate the feasibility of power generation at an existing reservoir and could similarly be adapted for other sites. However as it stands it is grossly user-unfriendly and could only be adopted by those involved in its development Documentation only within the program as comment.

4. **Contact name and telephone number.**

D R ARCHER 091 2130266 Ext 2204

Region. Northumbria

Model Name or Subject. NORTHUMBRIA RESERVOIR SIMULATION

1. **Area of Application.**

Development of control rules for filling or emptying of reservoir (single source).
Determination of reliable yield and average draw off when conjunctively used with other more expensive sources.

2. **Brief Description.**

Given as input a historic sequence of weekly or monthly inflows the program simulates various outflows and storages for a sequence of demands and provides a basis for determining probability of emptiness under selected operating policies.

3. **Potential Elsewhere.**

Program not user friendly but has been used for several reservoirs in Northumbria (Font, Scaling). Probably limited potential elsewhere as there are likely to be more user friendly programs of a similar nature in other regions.

4. **Contact name and telephone number.**

D R ARCHER 091 2130266 Ext. 2204

Region. ANGLIAN

Model Name or Subject. **OSAY (OPERATING STRATEGY ASSESSMENT OF YIELD)**

1. Area of Application.

Calculation of resource yield subject to a set of operating rules designed to conserve water during drought compatible with the required level of service.

See 'Reliability of Water Resources', Clarke, Page and Brew, JIWES 34/1 (1980) which describes a more complex predecessor to the current version.

2. Brief Description.

Input to the model are monthly historic inflows to the resource and available storage. Assumptions of savings in PWS demand resulting from measures such as hosepipe bans and publicity campaigns are built in. The user defines a 'plan' and the model calculates a family of control curves. Operation of the resource in accordance with these control curves is simulated and the user presented with simple summary output which includes the frequencies of restrictions on demand. By adjusting the the 'plan' the user can iterate to find the yield corresponding to the required level of service.

3. Potential Elsewhere.

User configurable with simple input. Written in standard Fortran and can be run on a Honeywell mainframe or PC. This is a very powerful technique which deserves more widespread use. Water supply engineers have been reluctant to adopt it because they query the effect of demand restrictions. There is limited up to date documentation.

4. Contact name(s) and telephone number(s).

Cameron Thomas 0733-371811

Region. ANGLIAN

Model Name or Subject. **RESERVOIR SIMULATION**

1. Area of Application.

We have several reservoir simulation models, all customised to a particular job but basically falling into two categories ;

1. The Rutland Water and Grafham Water models, which are based upon a general, user configurable, node - link simulation model (see also the Ely Ouse - Essex model). These are both pumped storage reservoirs. The models incorporate nitrate simulation at the intakes and in the reservoirs.
2. Models of other (smaller) reservoirs. Several are little more than long term water balance calculations.

2. Brief Description.

The Rutland and Grafham models started life as a general resource simulation model (developed in the 70's) and they retain many similarities. The systems are defined in parameter files containing data such as pump / pipeline capacities, storage volumes, demands and runtime information for the program. Over time other, more specific, features such as the nitrate simulation have been incorporated into the program code.

Output comprises daily / monthly / annual series of flows and / or storages. These are imported into spreadsheets for graphical presentation.

Historical flow records are used (1930's to date) are used, with yields derived iteratively and based on the 'worst recorded drought'. (See the OSAY model for a variation upon this). River flow naturalisation is a key preliminary stage.

3. Potential Elsewhere.

The 'general' features of the Rutland and Grafham models unfortunately do not make them easily configurable to other systems. Infact it may be that the attempt to build in generality makes them unnecessarily comlex. If starting from scratch it would be better to write a program specifically for that system.

4. Contact name(s) and telephone number(s).

Nigel Fawthrop 0733-371811

Region. NORTH WEST

Model Name or Subject. **RESOURCE PLANNING SUITE**

1. **Area of Application.**

Water Resource Planning tools, to display, analyse and simulate data sequences.

2. **Brief Description.**

A set of "in-house" Fortran programs for the display, analysis and simulation of monthly and daily data sets for water resource planning purposes.
Routines include ;

- Hydrograph plotting
- Flow Duration analysis
- Double mass analysis
- Tabulation and Summary of data.
- Maximum and minimum event analysis.
- Simulation in a very flexible manner, including storages and transfers.

3. **Potential Elsewhere.**

Flexible set of routines useful for resource planning anywhere.

4. **Contact name(s) and telephone number(s).**

Meg Owens 0925 - 53999

Region. SEVERN TRENT

Model Name or Subject. RP12 & RP23

1. Area of Application.

Anywhere. These two programmes have been applied to many locations in the Severn-Trent region.

2. Brief Description.

These two programs are part of a suite of Resource Planning programs developed by North West Water Authority, and acquired by Severn-Trent Water Authority in 1984. RP12 can be used to analyse return periods of low flow sequences, or rainfall sequences.

RP23 tabulates a yield/storage relationship for a reservoir system, and is also useful in reservoir refill analyses.

3. Potential Elsewhere.

Presumably other regions already use these programs. RP12 in particular has proved to be very useful, and I expect we could make good use of the other programs in the suite.

4. Contact name and telephone number.

G P Davies 021-711-2324 Ext 3040
T Harrison Ext 3044

Region. WELSH

Model Name or Subject. S.E. WALES CONJUNCTIVE USE

1. **Area of Application.**

Allocates resources from a number of direct supply, regulating (and direct supply) reservoirs to demand centres.

2. **Brief Description.**

Model is a larger Supercalc spreadsheet which uses monthly runoff data. Takes into account user defined demand profiles and restrictions such as WTW / pipeline / transfer capacities. It is used to assess surplus/defecit in resources and to generate operating strategies and control curves. Model developed in-house in 1989 for joint use by NRA and Plc to quantify and solve existing problems. Outputs are flexible and include storage tabulations and summary data of scenario being modelled. The model has been extremely useful.

3. **Potential Elsewhere.**

The model is specific to the area studied, but the principle of using spreadsheets for resources work is straight forward and to be commended for this type of analysis. Operates in Supercalc on a PC. Available documentation is specific to the problem, but well worth reading to generate an easy understanding of the possibilities in this approach.

4. **Contact name(s) and telephone number(s).**

Richard Streeter and Terry Spierling 0222 - 770088

Region.	ANGLIAN
Model Name or Subject.	STOMPS (SHORT TERM OPTIMISATION MODEL FOR PUMPING SCHEDULES)

1. Area of Application.

A general purpose optimisation model which can be used to solve the 'transportation problem', specifically oriented towards optimisation of pumping and resource allocation.

2. Brief Description.

STOMPS is written in Fortran using an 'out of kilter' routine originally aimed at deriving pumping schedules for interconnected supply systems comprising sources, treatment works, demand zones, service reservoirs, pumps etc. It uses relatively simple data and gives a true global optimum, handling complex systems within reasonable computation time.

3. Potential Elsewhere.

Great potential within the NRA as a resource allocation tool. Mainframe and PC versions are available. There is a user manual for a mainframe interactive version of the program.

4. Contact name(s) and telephone number(s).

Cameron Thomas 0733-371811

Region. SEVERN TRENT

Model Name or Subject. STORDET

1. Area of Application.

Can be applied to any reservoir inflow sequence. Developed by Severn-Trent Water Authority in 1984.

2. Brief Description.

The program converts a reservoir inflow sequence of a specific probability (derived using RP12) into a set of storages required throughout the year to survive a drought of a predefined duration.

Used to derive direct supply reservoir control rules.

It is a very short and simple program, using monthly data, but could easily be adapted to work on other time scales.

3. Potential Elsewhere.

It is effectively a simpler version of RP23.

Program is written in FORTRAN 77, and resides on an IBM mainframe.

4. Contact name and telephone number.

G P Davies 021-711-2324 Ext 3040
T Harrison Ext 3044

Region.	SEVERN TRENT
Model Name or Subject.	WATER RESOURCE SYSTEM HYDROLOGICAL MODELS

1. **Area of Application.**

Group of about 10 different models covering water resource systems, or local reservoir systems within the Severn-Trent area.

Particular areas covered include:

1 River Avon/Leam Water Resource System
2 North East Derbyshire (Linacre/Barbrook reservoirs)
3 North West Leicestershire (Charnwood reservoirs)
4 River Dove scheme
5 Blithfield reservoir
6 River Derwent resource system

2. **Brief Description.**

Farily simple mass balance surface water hydrological simulation models developed by Severn-Trent Water Authority (1985-87), and used for yield assessment, derivation of operating rules, or for system design purposes. Simulations are considerably more detailed than is included in the Regional Resources Allocation Model, although all use the same pentad (5 day) time step. Some have graphical output.

3. **Potential Elsewhere.**

They are all specific to Severn-Trent region. They are all written in FORTRAN 77, and all reside on either a MICROVAX minicomputer, or on IBM mainframe or both. Documentation is very sparse.

4. **Contact name and telephone number.**

G P Davies 021-711-2324 Ext 3040
T Harrison Ext 3044

Region. THAMES

Model Name or Subject. **WATER RESOURCES MODEL**

1. Area of Application.

Simulation model of the water resources of the Thames Region, incorporating detailed information about how water moves through the catchment.

2. Brief Description.

Used to assist in assessing the reliability of existing resources and understanding the effect of adding to them or using them in a different way.

Developed in-house in the 1970's, the model is currently being reviewed with the intention of bringing it up to date where necessary.

Inputs are projected annual average demands on the system, historical hydrological and meteorological data, and information about any necessary changes to the system. The principal output shows the success of this system in satisfying demands. Further output can be obtained to examine the performance of parts of the system in detail.

3. Potential Elsewhere.

The model is very specific to the Thames Region, although the methodology could be applied elsewhere.

The program is written in Fortran 77 and runs on an ICL Mainframe computer.

Documentation consists of a user guide and a programmer's reference manual.

4. Contact name(s) and telephone number(s).

David Elford 0734 - 535322

Region.	YORKSHIRE
Model Name or Subject.	**WATER RESOURCES SYSTEM SIMULATION PACKAGE**

1. Area of Application.

Water Resources modelling package.

2. Brief Description.

Lumped parameter for reservoirs, groundwater and river sources

from Welsh Water.

Obtained 1990.

Little experience of using this package.

3. Potential Elsewhere.

4. Contact name(s) and telephone number(s).

Peter Towlson and Phil Proctor 0532 - 440191

Region. ANGLIAN

Model Name or Subject. PLANNING MODEL

1. Area of Application.

An economic planning model for the development of water resources. The model analyses complex water resource supply and demand systems to determine the least cost (capital and revenue combined) development program to meet predicted future demands.

2. Brief Description.

The model can be applied to any resource / demand system. Input comprises ;

- demands in each centre to the planning horizon.
- the yields of existing and potential future sources.
- the capacities of existing pipes, pumps etc.
- basic revenue costs and discounting factors.
- potential future mains, pumps etc.
- capital costs for future developments. (If not known these are calculated using TR61 style cost functions).

The model evaluates the most effective development programme to meet future demands on a total discounted cost basis.

3. Potential Elsewhere.

The model is configured through data files and has potential wherever resource / supply systems are too complex for manual analysis. However it is somewhat 'user hostile'. It is a close relative of RACS (see Southern Region's contibution) with which it shares complexity and allocation weaknesses. but unlike RACS has no known errors. It currently runs on Honeywell or ICL mainframe computers. Both simple (overview) and detailed user guides are available.

Anglian Water Services Ltd are currently developing a more user friendly PC version.

4. Contact name(s) and telephone number(s).

Cameron Thomas 0733-371811

Region. SOUTHERN

Model Name or Subject. Resource Allocation and Costing (RACS)

1. Area of Application.

General purpose water resource allocation and costing model used with simplified distribution diagrams to examine possible resource development options.

2. Brief Description.

Developed by the former Central Water Planning Unit in conjunction with Southern Water Authority resource planning staff. Based on the system used by the former Water Resources Board to formulate their regional and national plans.

The model has to be configured to a particular distribution system. Input consists of details of pipelines, pumping stations and reservoirs together with capital, maintenance and running costs and demand forecasts.

Output comprises the least cost allocation of source yields to satisfy the demand centres.

In Southern region the model is loaded on an ICL 3900 mainframe and is run under the VME operating system. The program is written in Fortran.

3. Potential Elsewhere.

This is a general purpose program and so could be set up for any other distribution system. However, it is not 'user friendly'. Documentation consists of a user manual.

4. Contact name and telephone number.

Geoff Burrow, Paul Shaw - 0903 820692

Region. SEVERN TRENT

Model Name or Subject. REGIONAL RESOURCES ALLOCATION MODEL

1. Area of Application.

Covers the whole Severn-Trent Region splitting it into about 25 demand centres.

2. Brief Description.

The model was originally developed about 10 years ago by the Severn-Trent Water Authority, and was recently inherited by the NRA. It is designed to show how the present or projected regionwide water resource system reacts to a wide range of hydrological conditions under varying operational rules. Particular features of the model are:

1 Uses a linear programming solution to allocate resources on a minimum cost basis.
2 Uses a pentad (5 day) time step.
3 Uses a long (50 years) data bank of naturalised and synthesised river and reservoir inflows.
4 Accurately models reservoir and river intakes, but doesn't attempt to model aquifers.

It has been used on most strategic water resource projects throughout the 1980's, including justifying the rebuilding of Carsington Dam. Recently it has been enhanced and is now being used for the River Severn Control Rules projects to model the effect of different control rule scenarios on river flow and residual flows into the estuary.

3. Potential Elsewhere.

The model is specific to the Severn-Trent region. The technique has been applied, elsewhere, since other NRA regions have similar models which use the same and different allocation solutions (ie Quadratic, or Dynamic Programming). The program is written in FORTRAN 77 and is currently housed on MICROVAX minicomputer, and on IBM mainframe. Documentation is being updated, but currently consists of the original STWA User Manual and various notes.

4. Contact name and telephone number.

G P Davies 021-711-2324 Ext 3040
T Harrison Ext 3044

Region. NORTH WEST

Model Name or Subject. **LOW FLOW ESTIMATION**

1. Area of Application.

Low flow estimatiomn to give 95% exceedance flow, mean flow and modal flow at any site in the North West region.

2. Brief Description.

The Institute of Hydrology have produced a system of estimating the natural component of low flows using catchment characteristics. These have been tabulated for defined river stretches which are identified using maps. At present the system is paper based, but there are plans for it to be computerised on a system such as Micro Low Flows.
The artificial influences such as reservoir compensation, abstractions and discharges must be taken into account separately.

3. Potential Elsewhere.

The procedure to give the equations to use catchment characteristics could be used for any region to give a similar set of maps and look up tables for the natural component.

4. Contact name(s) and telephone number(s).

Meg Owens 0925 - 53999

Region. SOUTH WEST

Model Name or Subject. **MICRO LOW FLOWS**

1. **Area of Application.**

Provision of theoretical low flow information for abstraction licensing and discharge consents.

2. **Brief Description.**

Proto type (Beta version) to be supplied by IoH in early January 1990. Provides for approx. 14000 reaches the following theoretical information - catchment area, Q95, ADF, Q50 and note pad facility.

Will provide flow duration curves in future and will allow multiple site access.

Basic GIS type system or an IBM PC.

3. **Potential Elsewhere.**

We are evaluating the software and exploring the possibility of extending the package to calculate budgets with abstraction licensing and discharge consent information.

Needs to be specifically set up for each region.

Not good on groundwater areas or with springs! (not a surprise).

4. **Contact name(s) and telephone number(s).**

Dr Janet Cochrane
Dr Rob Grew 0392-444000

Region.	NORTH WEST
Model Name or Subject.	**WIS (WATER INFORMATION SYSTEM) CATCHMENT CHARACTERISTICS DERIVATION.**

1. Area of Application.

Now : Low flows estimation.
Flood Studies Calculations.
Network Analysis (u/s d/s).

Future : Residual Flows Analysis.
Other hydrological facilities.

2. Brief Description.

Stores measured data (flows, levels, rainfall, abstractions [possibly], discharges, w/q results) together with digitised representations of the river network, SAAR, PE, WRAP, 2DM5.

Will have digital terrain model, SSSI's, admin boundaries and fish surveys.

Supplied by IoH.

3. Potential Elsewhere.

Catchment Planning
QUASAR (Water Quality modelling)

4. Contact name(s) and telephone number(s).

Region. SEVERN TRENT

Model Name or Subject. SPANS MODEL OF NITRATE LEACHING

1. Area of Application.

Nitrate leaching model.

2. Brief Description.

Developed on a SPANS GIS. Used to give areal distribution of nitrate leaching with output straight to a WRc transport model (being developed for the NRA). The SPANS model used all the variables supplied by MAFF. Developed in house and handed over to MAFF for use in other areas particularly in Nitrate Sensitive areas.

3. Potential Elsewhere.

Use everywhere for NSAs. It is presently being extended over the whole ST triassic aquifer using processed LANDSAT images.

4. Contact name and telephone number.

S W Fletcher 021-711-2324 Ext 3056

Region. SEVERN TRENT

Model Name or Subject. GROUNDWATER RESOURCES

1. Area of Application.

Calculations of recharge over outcrop of aquifer.

Under active considerations and preliminary development.

2. Brief Description.

It is proposed to investigate actual recharge using Landsat Imagery to refine calculations of actual evaporation and soil maps to assess run-off infiltration relationships. The model will be written on a SPANS GIS.

3. Potential Elsewhere.

4. Contact name and telephone number.

S W Fletcher 021-711-2324 Ext 3056