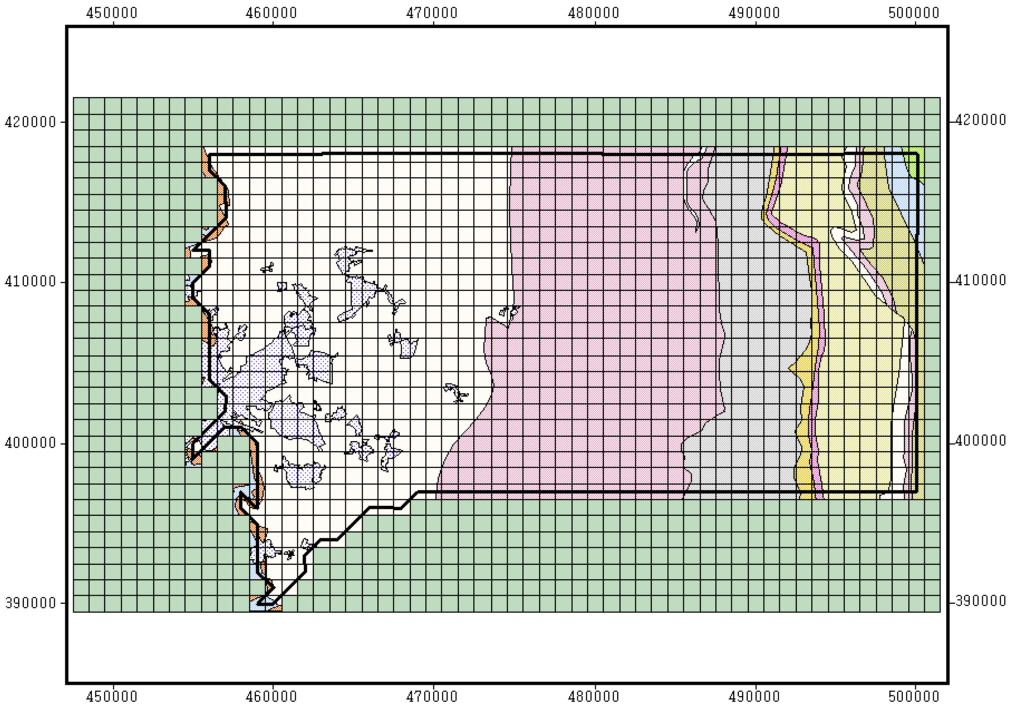
British
Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Translation of the Doncaster Groundwater Model into the MODFLOW code

Groundwater Systems and Water Quality Programme

Commissioned Report CR/03/258N



BRITISH GEOLOGICAL SURVEY

COMMISSIONED REPORT CR/03/258N

Translation of the Doncaster Groundwater Model into the MODFLOW code

I Neumann and A Hughes

Key words

Groundwater, urban, hydrogeology, modelling.

Front cover

The regional Doncaster model area.

Bibliographical reference

NEUMANN I AND HUGHES A. 2003. Translation of the Doncaster Groundwater Model into the MODFLOW code. *British Geological Survey Commissioned Report*, CR/03/258N. 27pp.

Keyworth, Nottingham British Geological Survey 2003

BRITISH GEOLOGICAL SURVEY

The full range of Survey publications is available from the BGS Sales Desks at Nottingham and Edinburgh; see contact details below or shop online at www.thebgs.co.uk

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

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

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

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

Keyworth, Nottingham NG12 5GG
☎ 0115-936 3241 Fax 0115-936 3488
e-mail: sales@bgs.ac.uk
www.bgs.ac.uk
Shop online at: www.thebgs.co.uk

Murchison House, West Mains Road, Edinburgh EH9 3LA
☎ 0131-667 1000 Fax 0131-668 2683
e-mail: scotsales@bgs.ac.uk

London Information Office at the Natural History Museum (Earth Galleries), Exhibition Road, South Kensington, London SW7 2DE
☎ 020-7589 4090 Fax 020-7584 8270
☎ 020-7942 5344/45 email: bgslondon@bgs.ac.uk

Forde House, Park Five Business Centre, Harrier Way, Sowton, Exeter, Devon EX2 7HU
☎ 01392-445271 Fax 01392-445371

Geological Survey of Northern Ireland, 20 College Gardens, Belfast BT9 6BS
☎ 028-9066 6595 Fax 028-9066 2835

Maclean Building, Crowmarsh Gifford, Wallingford, Oxfordshire OX10 8BB
☎ 01491-838800 Fax 01491-692345

Parent Body

Natural Environment Research Council, Polaris House, North Star Avenue, Swindon, Wiltshire SN2 1EU
☎ 01793-411500 Fax 01793-411501
www.nerc.ac.uk

Contents

FIGURES

TABLES

1 Introduction

This report documents the translation of the Doncaster groundwater model, originally developed by the University of Birmingham, into a MODFLOW code (McDonald and Harbaugh, 1988) to be used within the AISUWRS (Assessing and Improving Sustainability of Urban Water Resources and Systems) project (Morris et al., 2003).

The Doncaster model (hereafter referred to as the original model) was established in 1993 by I.T. Brown and K.R. Rushton from the University of Birmingham (Brown and Rushton, 1993). It was extended and slightly modified in 1997 by M. Shepley of the Environment Agency (Shepley, 2000). The original model is regarded as a well-calibrated regional groundwater model, which adequately represents the aquifer conditions in the Doncaster area. It was therefore selected as the basis of the groundwater model to be used within the AISUWRS project. A translation of the original model code into MODFLOW code was deemed necessary in order to simulate both solute transport and groundwater flow. It also provides flexibility to change model input parameters for scenario modelling without recourse to the Environment Agency. A major aim of the AISUWRS project is to simulate various urban water resources management options. The regional MODFLOW model will form the basis for a future sub-regional model, focused on Bessacarr, a suburb of Doncaster, which is the centre of investigations within the AISUWRS project.

The report is written in six sections. Section one presents set up and discretization of both models. Section two describes the representation of aquifer parameters, while section three comments on the representation of external and internal boundaries. Section four discusses initial conditions and section five summarises the discretization of time in both models. The output of the Modflow model and the comparison with the original model outputs is given in section six.

This report details only the conversion of the original model into a MODFLOW equivalent. No detailed description of the original model itself is presented, as this is outside the scope of this report. For an in depth description of the conceptual model behind the original numerical model, the methods used to derive aquifer parameters, the way recharge values were established, etc. the reader is referred to Brown and Rushton (1993) and Shepley (2000).

2 Aquifer parameters, boundaries and recharge

2.1 MODEL SET UP AND DISCRETIZATION

The original model is a two dimensional (2-D) model, representing the groundwater flow conditions within the Sherwood Sandstone aquifer. The low permeability strata above the Sherwood Sandstone are not represented explicitly in the model. The model domain is discretized by a 1km by 1km grid, using a mesh-centred approach. However, model parameters are not always assigned to nodes, but also to areas between nodes. For example, transmissivity values are assigned between nodes, while storage coefficients are assigned to nodes (Figure 1).

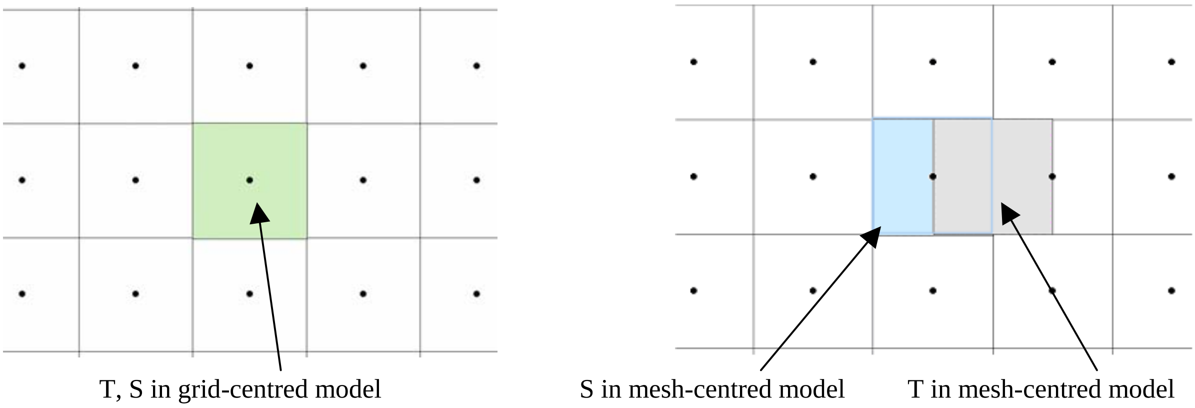
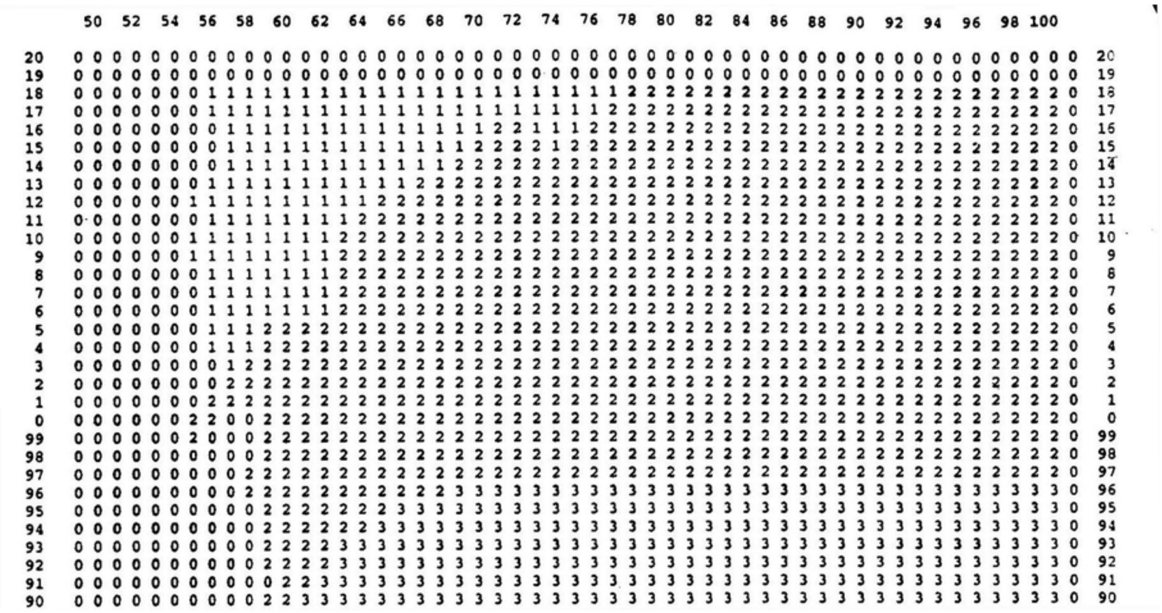


Figure 1 Differences in the assignment of parameters (T = Transmissivity, S = Storativity) in the mesh-centred original model, compared to the block-centred MODFLOW model.

In line with the original model, the MODFLOW equivalent is a 2-D model, using one layer to represent the Sherwood Sandstone aquifer. The model area in the MODFLOW model coincides with the groundwater units 1 and 2 as specified in Shepley (2000) (Figure 2). The model domain has been discretized using a block-centred grid of 1km by 1km. As the original model is nodal based, the block-centred grid covers a model area slightly larger by half a cell size all round compared to the original model area (Figure 4). The grid has been geo-referenced and cell centres coincide with the nodes of the original model (Figure 4). The block-centred approach forces all model parameters to be assigned to grid cells, with cells representing a 1km x 1km area around the nodes of the original model (Figure 1).



		50		52		54		56		58		60		62		64		66		68		70		72		74		76		78		80		82		84		86		88		90		92		94		96		98		100		
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19
18	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	0	18
17	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	0	17
16	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	0	16
15	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	0	15
14	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	0	14
13	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	0	13
12	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	0	12
11	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	0	11
10	0	0	0	0	0	0	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	0	10
9	0	0	0	0	0	0	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	0	9
8	0	0	0	0	0	0	0	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	0	8
7	0	0	0	0	0	0	0	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	0	7
6	0	0	0	0	0	0	0	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	0	6
5	0	0	0	0	0	0	0	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	0	5
4	0	0	0	0	0	0	0	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	0	4
3	0	0	0	0	0	0	0	0	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	0	3
2	0	0	0	0	0	0	0	0	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	0	2
1	0	0	0	0	0	0	0	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	0	1
0	0	0	0	0	0	0	2	2	0	0	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	0	0
99	0	0	0	0	0	0	2	0	0	0	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	0	99
98	0	0	0	0	0	0	0	0	0	0	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	0	98
97	0	0	0	0	0	0	0	0	0	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	0	97
96	0	0	0	0	0	0	0	0	0	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	0	96
95	0	0	0	0	0	0	0	0	0	0	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	0	95
94	0	0	0	0	0	0	0	0	0	0	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	0	94
93	0	0	0	0	0	0	0	0	0	0	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	0	93
92	0	0	0	0	0	0	0	0	0	0	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	0	92
91	0	0	0	0	0	0	0	0	0	0	0	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	0	91
90	0	0	0	0	0	0	0	0	0	0	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	0	90

Figure 2 Node by node map of groundwater units 1 and 2 as specified in Shepley (2000). The eastings and northings are given along the margins.

2.2 AQUIFER PARAMETERS

2.2.1 Transmissivities

The original 2-D model allows for flow through the thickness of the aquifer by the specification of transmissivity rather than hydraulic conductivity and aquifer thickness. Transmissivities do not vary with changes in groundwater head. Transmissivities used in the original model are reproduced in Appendix 2.

The same approach has been followed in the MODFLOW model. However, Groundwater Vistas ©, the user-interface used to create the MODFLOW model, does not allow for direct input of transmissivities, but for aquifer thickness and hydraulic conductivities. By specifying the aquifer as strictly confined, it is ensured that the MODFLOW model uses the product of aquifer thickness and hydraulic conductivity, i.e. transmissivity directly to calculate flow through the aquifer.

The hydraulic conductivity throughout the model is 1/100 of the transmissivities used in the original model. The aquifer thickness is a constant of 100 m. The resulting transmissivities used in the MODFLOW model, which are identical to the original model, are presented in Figure 5. However, due to the mesh-centred approach used in the original model, compared to the block-centred approach used in the MODFLOW code, the area location for the same transmissivity is different by half a cell width between the two models. The MODFLOW model assigns transmissivities to areas 500 m further to the west compared to the original model (Figure 1).

2.2.2 Aquifer storage

The original model specifies the release of water within the confined part of the aquifer by the confined storage coefficient, using a value of 0.0005. Within the unconfined part of the aquifer the water release from storage is specified using a specific yield of 15% where the free water surface is within the Sherwood Sandstone, and 25%, where the free water surface is within the Quaternary sands and gravels. Storage coefficients used in the original model are presented in Appendix 2.

The same storage coefficients have been used in the MODFLOW model, and are presented in Figure 6. Even though the aquifer is specified in the numerical model as fully confined (constant transmissivity and storativity throughout model run), storage coefficients of 15% and 25% respectively have been assigned to represent the water release from storage in the unconfined part of the aquifer.

2.3 BOUNDARY CONDITIONS

2.3.1 Model boundaries

Boundary conditions of the original model have been copied to the MODFLOW model in the case of the western, northern and eastern boundary of the model domain. However, the southern boundary of the original model was set to approximate the southern boundary of the Hatfield groundwater unit. It does not coincide with the actual numerical model boundary, which is the southern boundary of the Notts-Doncaster model (Figure 7). The Notts-Doncaster model is a full model of the Doncaster and Nottingham aquifer, with the model extending as far south as Nottingham. Hence, any flows across the notional southern boundary in the original model are calculated using the full Notts-Doncaster aquifer model. Appendix 2 provides details on the flow across boundaries as applied in the original model.

The southern boundary of the MODFLOW model is the same as the notional southern boundary of the original model, i.e. the southern extent of the Hatfield groundwater unit. The data provided to the BGS by the Environment Agency only included the Doncaster part of the Notts-Doncaster model. Hence, the full Notts-Doncaster model could not be built to simulate the flows over the notional southern model boundary, i.e. the flows between the Hatfield groundwater unit and those further south. Details on the flows across the southern notional boundary were not made available either, to permit the set up of a southern flow boundary. This obliged the authors to use water balance figures from the original model to infer the flows across the boundary. Doing so, the amount and direction of flows could be established, but not the detailed distribution of flow along the southern boundary. The provision of the required data would have been useful, but in the event, the problem has been resolved by approximating the time variant flows along the boundary by evenly distributing the flows to the area mostly affected by abstraction. Flows are represented mathematically using wells.

Figure 8 presents the boundary conditions of the MODFLOW model.

2.3.2 Rivers and drainages

Rivers and drainage channels have been simulated in the original model in similar ways. River or drainage channel cells are contributing or draining water from the aquifer, depending on the head gradient between the river/drainage channels and the aquifer. If the aquifer head drops below the riverbed elevation, a limiting flux is applied. For details on the calculation of river leakage to and from the aquifer see Brown and Rushton (1993). Data input includes the stream bed level, the stream surface elevation and the river coefficient for each river/drainage channel node on the outcrop of the aquifer. The data are reproduced in Appendix 2.

The mathematical representation of river leakage in the original model is similar to the mathematical code within the MODFLOW river package. Hence, river cells can be used to represent the River Torne and drainage channels in the MODFLOW model. The river stage equals thereby the stream surface elevation of the original model, the river bottom elevation equals the stream bed level, while the riverbed conductance equals the river coefficient of the original model. Table 1 gives details of the input data.

Table 1 Details of river package input data in the MODFLOW model

I	J	Hydr. cond.[m/d]	River bottom elevation [mAOD]	Stage of river [mAOD]	Length [m]	Width [m]	Thickness [m]	Nodes
31	13	0.0003	10.5	11.5	1000	1000	1	River Torne
30	12	0.0003	11.6	12.6	1000	1000	1	River Torne
30	13	0.0003	10	11	1000	1000	1	River Torne
30	14	0.0003	9.5	10.5	1000	1000	1	River Torne
29	14	0.0003	9	10	1000	1000	1	River Torne
28	14	0.0003	8.5	9.5	1000	1000	1	River Torne
27	14	0.0003	8	9	1000	1000	1	River Torne
26	14	0.0003	7.5	8.5	1000	1000	1	River Torne
25	14	0.0003	7	8	1000	1000	1	River Torne
25	13	0.0003	6.3	7.3	1000	1000	1	River Torne
24	13	0.00005	5.6	6.6	1000	1000	1	River Torne
23	13	0.00005	5	6	1000	1000	1	River Torne
23	14	0.0005	4.6	5.6	1000	1000	1	River Torne
23	15	0.0005	4.3	5.3	1000	1000	1	River Torne
22	16	0.001	4	5	1000	1000	1	River Torne
21	17	0.0012	3.6	4.6	1000	1000	1	River Torne
20	18	0.0008	3.2	4.2	1000	1000	1	River Torne
20	19	0.0008	2.8	3.8	1000	1000	1	River Torne
11	20	0.00001	2	3	1000	1000	1	Drainage channels
11	21	0.00001	-0.5	0.5	1000	1000	1	Drainage channels
11	22	0.00001	-0.5	0.5	1000	1000	1	Drainage channels
12	21	0.00001	-0.5	0.5	1000	1000	1	Drainage channels
12	22	0.00001	-0.5	0.5	1000	1000	1	Drainage channels
12	23	0.00001	-0.5	0.5	1000	1000	1	Drainage channels
13	23	0.00001	-0.5	0.5	1000	1000	1	Drainage channels
13	24	0.00001	-0.5	0.5	1000	1000	1	Drainage channels
14	21	0.0006	-0.5	0.5	1000	1000	1	Drainage channels
15	17	0.001	-0.5	0.5	1000	1000	1	Drainage channels
15	18	0.001	-0.5	0.5	1000	1000	1	Drainage channels
15	20	0.0005	1	2	1000	1000	1	Drainage channels
16	20	0.0008	1	2	1000	1000	1	Drainage channels
17	19	0.0008	-0.5	0.5	1000	1000	1	Drainage channels
17	20	0.0008	-0.5	0.5	1000	1000	1	Drainage channels
13	22	0.00001	-0.5	0.5	1000	1000	1	Drainage channels
18	21	0.0002	-0.5	0.5	1000	1000	1	Drainage channels
18	22	0.0002	-0.5	0.5	1000	1000	1	Drainage channels
18	23	0.0004	-0.5	0.5	1000	1000	1	Drainage channels
18	24	0.0004	-0.5	0.5	1000	1000	1	Drainage channels
18	25	0.0004	-0.5	0.5	1000	1000	1	Drainage channels
19	20	0.0006	-0.5	0.5	1000	1000	1	Drainage channels
19	21	0.0006	-0.5	0.5	1000	1000	1	Drainage channels
19	22	0.0005	-0.5	0.5	1000	1000	1	Drainage channels
19	23	0.0004	-0.5	0.5	1000	1000	1	Drainage channels
19	24	0.00045	3	4	1000	1000	1	Drainage channels
19	25	0.00045	-0.5	0.5	1000	1000	1	Drainage channels
20	20	0.0004	-0.5	0.5	1000	1000	1	Drainage channels
20	21	0.00055	-0.5	0.5	1000	1000	1	Drainage channels
20	23	0.0005	-0.5	0.5	1000	1000	1	Drainage channels
20	24	0.0004	-0.5	0.5	1000	1000	1	Drainage channels
20	25	0.0004	-0.5	0.5	1000	1000	1	Drainage channels
21	19	0.0007	-0.5	0.5	1000	1000	1	Drainage channels
21	20	0.0007	-0.5	0.5	1000	1000	1	Drainage channels
21	21	0.0007	-0.5	0.5	1000	1000	1	Drainage channels
21	22	0.00045	-0.5	0.5	1000	1000	1	Drainage channels
21	23	0.00045	-0.5	0.5	1000	1000	1	Drainage channels

2.3.3 Leakage through the overlying stratum

The mathematical representation of vertical leakage through an overlying stratum, which includes the Quaternary cover as well as the Mercia Mudstone, is similar to that of the rivers and drainage channels in the original model, although no limited flux is applied. As with the rivers and drainage channels, the original model calculates leakage by the specification of the head gradient between aquifer and overlying stratum, the vertical permeability of the stratum and its thickness. The original input parameters are given in Appendix 2. Some data describing the Quaternary deposits are however conflicting. So are Quaternary deposits assigned to areas, where their thickness is specified as being zero (Figure 9). This apparently is a result of rounding up or down of the original input data; e.g. drift thicknesses were provided as whole numbers of the original thickness, divided by 10, for easier print-out. This led to zero values being assigned to thicknesses smaller than 10 m. The actual thicknesses are not known and could only be established, if the input data provided were the actual data rather than rounded figures.

Leakage through the overlying stratum is best represented in MODFLOW using a General Head Boundary. Thereby the river stage equals the head in the stratum of the original model; the riverbed conductivity equals the stratum permeability and the thickness of the riverbed equals the stratum thickness of the original model. Zero drift thickness in the original input data was adjusted to a 1 m drift thickness in the MODFLOW model. Whether this represents the actual thickness used in the original model will remain uncertain, until the original, un-rounded input data are made available. Figure 10 to Figure 12 represent the input parameters for the MODFLOW model.

2.3.4 Abstraction

The abstraction data used in the original model were not made available to the BGS. Hence, actual abstraction data were sourced from Yorkshire Water for the years 1970 to 1997. Other private abstraction data were sourced from Brown and Rushton (1993) for the years 1970 to 1993. However, no data were available for those abstractions for the years 1994 to 1997. Also no data were available for abstractions added to the model in 1993 following the model update (Shepley, 2000). The original model represented 98% of the total abstraction explicitly (i.e. all abstraction > 0.2Ml/d). The remaining 2% of abstractions were represented implicitly by distributing them evenly over the existing abstractions. As a result, the abstraction data used in the MODFLOW model do differ slightly from the data used in the original model (Figure 14).

2.3.5 Recharge

Recharge to the original model is divided into precipitation recharge and recharge due to urban leakage. Precipitation recharge is applied where the drift cover is thin or absent, while the urban leakage is applied to waste districts (see Brown and Rushton (1993), Table 9, p. 52), which overlap permeable drift or Sherwood Sandstone outcrop. Precipitation recharge is calculated on a daily basis and summarised to provide monthly values, which are input to the model as a specified flow for each nodal point. For details on the procedure of estimation of precipitation and urban leakage see Brown and Rushton (1993).

The recharge input has been translated into MODFLOW using the recharge package. The urban leakage and the precipitation recharge have been combined to give one recharge input value to the model. Due to the fact that the MODFLOW model area is slightly larger by half a cell width due to the mesh centred approach compared to the original model, recharge for boundary cells had to be adjusted according to their cell area outside the original model area, in order to obtain the same recharge input as the original model. Figure 13 presents the distribution of urban leakage in the original and MODFLOW model.

2.4 INITIAL CONDITIONS

Initial conditions for the simulation of the original model are included by enforcing inflows and outflows, which represent the conditions prior to 1970 (Brown and Rushton, 1993). Data on these specified flows were not made available to BGS.

Initial conditions for the MODFLOW model are based on abstractions and cross boundary flows of 1970. Recharge input is based on the average of the years 1970 to 1997. These input values were used for a pre 1970 model run. The pre 1970 model was thereby run for 80 years to ensure that a stable pattern of heads and flows was produced. These then served as the initial conditions for the actual historical model run from 1970 to 1997. The pre 1970 model was run repeatedly, until the resulting heads were similar to the original model heads in 1970 (Figure 3). This was achieved by repeatedly lowering the pre 1970 abstraction rate.

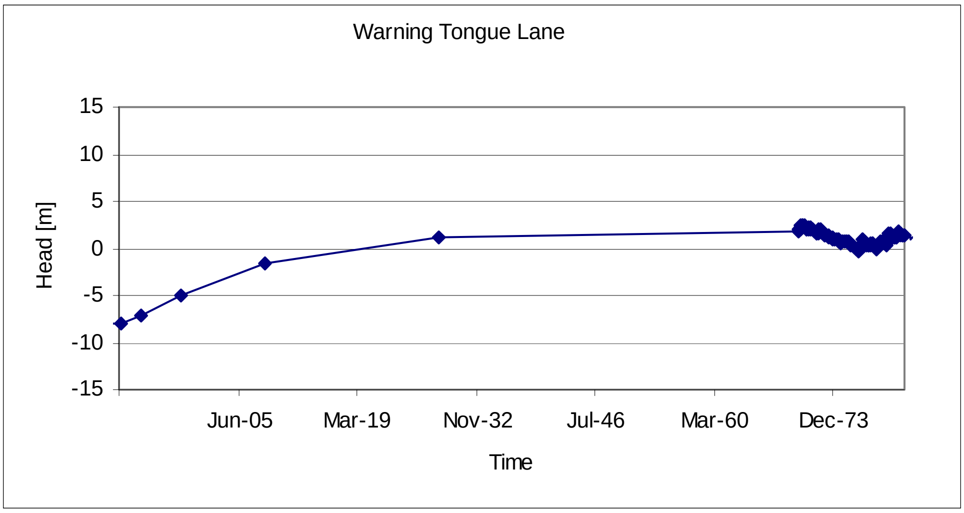


Figure 3 The pre 1970 model was run over 80 years to achieve stable heads and flows, which were similar to the conditions in 1970.

2.5 STRESS PERIODS AND TIME STEPPING

The original model simulates the period from 1970 to 1997 using monthly stress periods with time steps of two-week duration. Time variant boundary conditions are implemented by changing values annually. The notional southern boundary is not the numerical boundary and hence changes in flow correspond to the stress periods used for the model run, i.e. monthly periods. Precipitation recharge is input to the model on a monthly basis.

The MODFLOW model simulates the same period of time using monthly stress periods, which are in turn divided into four time steps, using a time step multiplier of 1.2. Time variant boundary conditions are implemented using yearly stress periods, including the southern boundary. Abstraction data changes on a yearly basis, while recharge is applied using monthly stress periods.

3 Model outputs and comparison with original model

A post-processing program is used to create ASCII files from MODFLOW output to produce time series output. Excel spreadsheets are then used to display the data and compare them with the original model output. The following time series outputs are produced for comparison with the original model data:

- Groundwater heads at observation boreholes
- Abstraction data over time
- Change in storage over time
- Total leakage between aquifer and overlying stratum, including rivers and drainage channels

3.1 WATER BALANCE

WATER LOST AND GAINED THROUGH WELLS

Figure 14 illustrates the abstraction data taken from the MODFLOW and original model output. Abstraction data is thereby all water lost or gained in the model through wells. That includes besides the borehole abstractions, the flow across the northern boundary and the southern boundary. Positive abstraction (flow into the model) reflects mainly the gain over the southern boundary, while water is lost from the aquifer, from flows to the northern boundary and abstraction.

There is good overall agreement between both models, however differences in abstraction can be observed between the MODFLOW and original model in some years (Figure 14). These changes relate to the differences in borehole abstraction values used in both models, while the amount of flow across the northern boundaries are identical in both models. The southern boundary flows are identical in both models in terms of amount of flow. However in the MODFLOW model, where the southern boundary represents the numerical boundary, flows change on an annual basis. The southern boundary flows in the original model meanwhile are not input to the model in form of a boundary condition and change monthly according to the monthly stress periods used in the model.

RECHARGE

Figure 15 shows a comparison between the MODFLOW model and original model recharge data. The recharge is thereby the sum of precipitation recharge and urban leakage. Both models are in good agreement. Urban leakage is input as a constant and accounts for 6.27Ml/d of the total recharge in both models.

LEAKAGE FROM/TO RIVERS AND OVERLYING STRATUM

Figure 16 shows the modelled leakage between rivers/overlying stratum and the aquifer. Both models produce similar results. Slight differences are due to differences in groundwater head, which determine the head gradient between river/overlying stratum and aquifer and which in turn determine the leakage rate. Differences in groundwater heads are discussed in detail in section 3.2. However, differences might also be introduced by possible differences in the thickness of the drift cover in both models (see section 2.3.3). The input data available to BGS specified zero thicknesses for some drift cells, as a result of rounding up or down of the original thicknesses to whole numbers. This was translated into MODFLOW using a 1m thickness instead (Figure 12). The thickness of the drift cover influences its conductance, which in turns influences the amount of leakage from/to the aquifer. Drift thickness could be revised, if the original data were made available.

CHANGE IN STORAGE

Figure 17 demonstrates the change in storage over time for both model runs. The storage change for the original model is the sum of the unconfined and confined storage. The data are in good agreement overall. Slight differences are likely to be the result of different abstraction rates in both models.

3.2 GROUNDWATER HYDROGRAPHS

A full set of groundwater hydrographs comparing MODFLOW modelled output with original model data are found in Appendix 1.

Data from all of the observation boreholes used in the original model have been compared to the MODFLOW model results. The locations of the observation boreholes within the study area are shown in Figure 18. Where possible, sets of hydrographs (original model vs. MODFLOW model) represent the same location within the modelled aquifer, i.e. the grid cell reference in the MODFLOW model corresponds to the nodal point in the original model used to represent the observation well. Several observation boreholes however, have nodal references equivalent to half nodal spacing in the original model (Table 2), which corresponds to grid cell boundaries rather than grid cells in the MODFLOW model. In those cases the nearest grid cell had to be selected in the MODFLOW model to represent the same observation borehole. Table 2 lists the nodal reference of observation boreholes of the original model and the MODFLOW model reference for comparison.

Table 2 Model observation borehole locations

Observation borehole	Original Model (Column/Row)	MODFLOW model (Column/Row)
Armthorpe	16/17	16/17
Bank End	24/22	24/22
Bessaccarr	12.5/21	13/21
Blaxton	22/21	22/21
Boston Park E33	21/18	21/18
Boston Park E33A	21/17	21/17
Branton Tubewell	17/21	17/21
Brier, Holme Carr	21/11.5	21/11
Cantley Towers	15/21	15/21
Cherry Tree	24.5/12	24/12
Cochwood Farm	19/18.5	19/18
Ellerholme Farm	23/18.5	23/18
Four Acres	16.5/19.5	16/19
Glentworth	22/12	22/12
Harworth	14/30	14/30
Holme House Farm	19/16	19/16
Holmewood Grange	18.5/16.5	19/17
Huggin Carr Farm	20.5/16.5	20/16
Lowgate Balne	12/4	13/4
Marshalls Quarry	19/14	19/14
Mill Hill Quarry	20/13	20/13
Partridge Hill	18.5/26	18/26
Pighill Thorne	23/6	23/6
Ponyfield	19/25	19/25
Sandall Beat	14/18	14/18
Sandall Common	16/15	16/15
Sparrington Farm	20/17	20/17
Stainforth Haggs	17/12	17/12
Stone Hill Farm	22/13	22/13
Swinnow Wood	16/28.5	16/28
Sykehouse	16/5	16/5
Thorninghurst Farm	20/7	20/7
Torne Bridge	21/18.5	21/18
Tudworth Hall	22/11	22/11
Tyrham Hall Motel	21/17	21/17
Warning Tongue Lane	17/22	17/22
Woodhouse Grange	21/15	21/15
Pincheon Green	18.5/4.5	18/4

The majority of the groundwater hydrographs show a very good agreement between the original model and the MODFLOW model. Both produce similar groundwater heads as well as the same water level trends over time.

However, some discrepancies exist for a small number of observation boreholes:

- Some hydrographs display differences in groundwater levels in the first few years of the model run (e.g. Cherry Tree, Armthorpe). This is the result of the initial conditions used in the MODFLOW model and original model respectively. The details of how initial conditions were implemented in the original model are unknown and are likely to differ from the initial conditions used in the MODFLOW model (see section 2.4). Identical initial conditions would most likely result in the same groundwater levels in those first few years of the historical model run.
- Boreholes close to the southern boundary exhibit discrepancies (Swinnow Wood, Ponyfield, Bank End). This is due to the fact, that the southern boundary condition is different in both models (see section 2.3.1). The southern boundary of the MODFLOW model is only a notional boundary in the original model. The numerical southern boundary of the original model is the southern boundary of the full Notts-Doncaster model. If the flows across this notional southern boundary could be obtained in terms of amount and location, hydrographs of both models should be the same. However, only the total amount of the flow across the southern boundary was available to BGS, so the location of the flows along the southern boundary had to be approximated.
- Slight differences between hydrographs are due to the different discretization used in both models. This results in some hydrographs representing the time variant head in a grid cell whose location is not identical to the area used in the original model to illustrate the same observation borehole (Table 2).
- The fact that the same transmissivities in both models are assigned to areas 500 m apart, due to different assignments of parameters in mesh-centred compared to grid-centred codes (see section 2.2.1), might influence hydrographs of boreholes which are situated at the border of two transmissivity zones.
- Some observation boreholes are close to abstraction points. As the abstraction input values are not identical in both models (see section 2.3.4) this leads to differences in hydrographs in some cases (Pighill Thorne, Brier Home Carr).

4 Conclusions and recommendations

A MODFLOW model has been built on the basis of the Doncaster model developed by Brown and Rushton (1993) and Shepley (2000). It has been developed to be used within the AISUWRS project. A translation into the MODFLOW code was necessary, in order to facilitate both solute transport modelling and groundwater flow simulations and to allow flexibility in changing input parameters in order to carry out scenario modelling. This regional MODFLOW model is a step, which the project team will use as the basis for a future sub regional model focused on the Doncaster suburb of Bessacarr.

A comparison of model results from the original model and the MODFLOW model led to the following observations:

- The overall agreement between the MODFLOW model and the original model is good, both for hydrographs of observation boreholes and for the water balance of the models.
- The original model domain is discretized using a mesh-centred approach, while the MODFLOW code uses a grid-centred approach. This leads to a model area slightly larger by half a cell width all round compared to the original model domain. Due to the different discretization, observation borehole nodal references used in the original model to produce hydrographs are in some cases not identical to the grid cells used in the MODFLOW model.
- Differences exist in the amount of abstraction from boreholes in both models, as an unavoidable consequence of limited data being made available.
- Differences exist in the numerical representation of the southern boundary of the model area. The southern boundary of the MODFLOW model is only a notional boundary in the original model. The southern boundary of the original model is the southern boundary of the full Notts-Doncaster model. Flows over the notional southern boundary were not supplied to BGS and had to be inferred using water balance figures of the original model. This permitted the correct assignment of the total flow amount, but the location of the flows along the boundary unavoidably had to be inferred.
- Differences may exist between both models in the thickness of the drift cover, which is used to infer a leakage rate to and from the overlying stratum and the aquifer. Original input was supplied with rounded values, which led to the assignment of zero thickness for some drift cells. The actual drift thicknesses for those cells are unknown and were approximated in the MODFLOW model to 1m.

To resolve some of the differences in both models, the following would be required:

- Update with the original abstraction input data, in order to apply the same borehole abstractions in both models.
- Update with the original, un-rounded model parameter input data, to establish the actual thickness of the drift cover in areas where rounding errors led to the assignment of zero values in the data set provided to BGS.
- Obtain data to model flows across the southern boundary more accurately. Either the flows over the southern boundary would be required or data of the Notts-Doncaster

model are needed to establish the flows over the notional southern boundary by running the full Notts-Doncaster model.

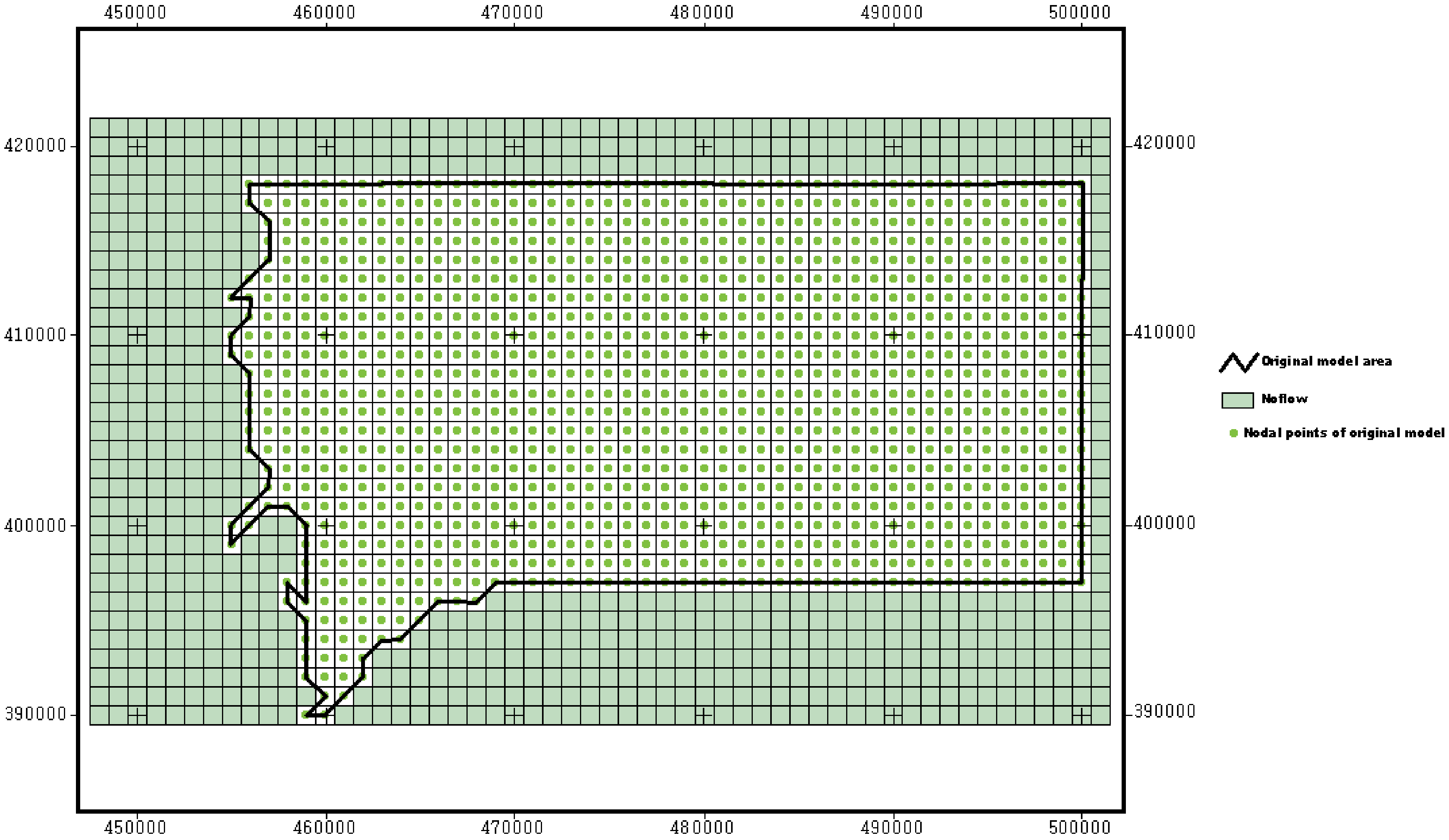


Figure 4 The block-centred grid of the MODFLOW model, overlain by the nodal based original model

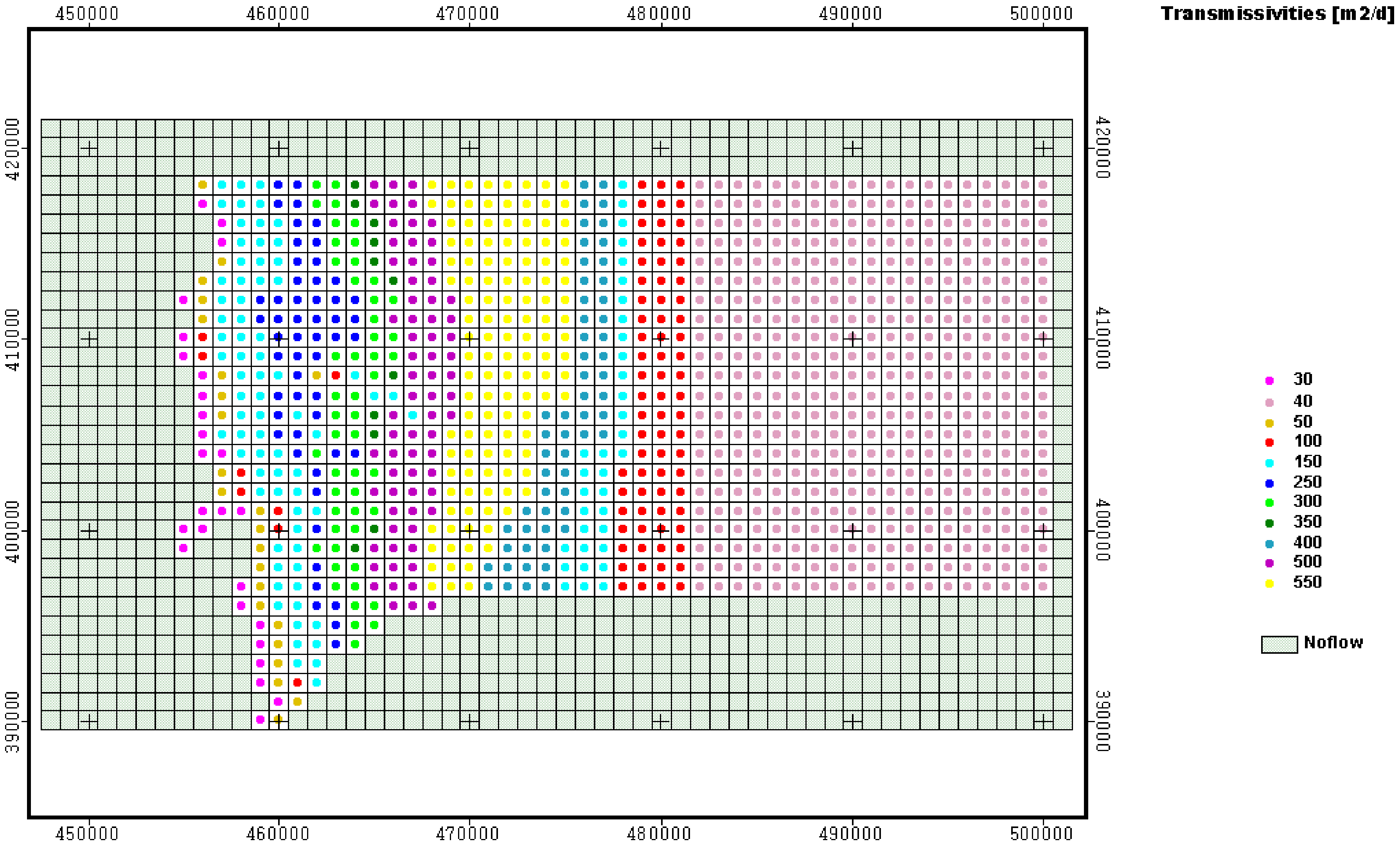


Figure 5 Distribution of transmissivities within the MODFLOW model

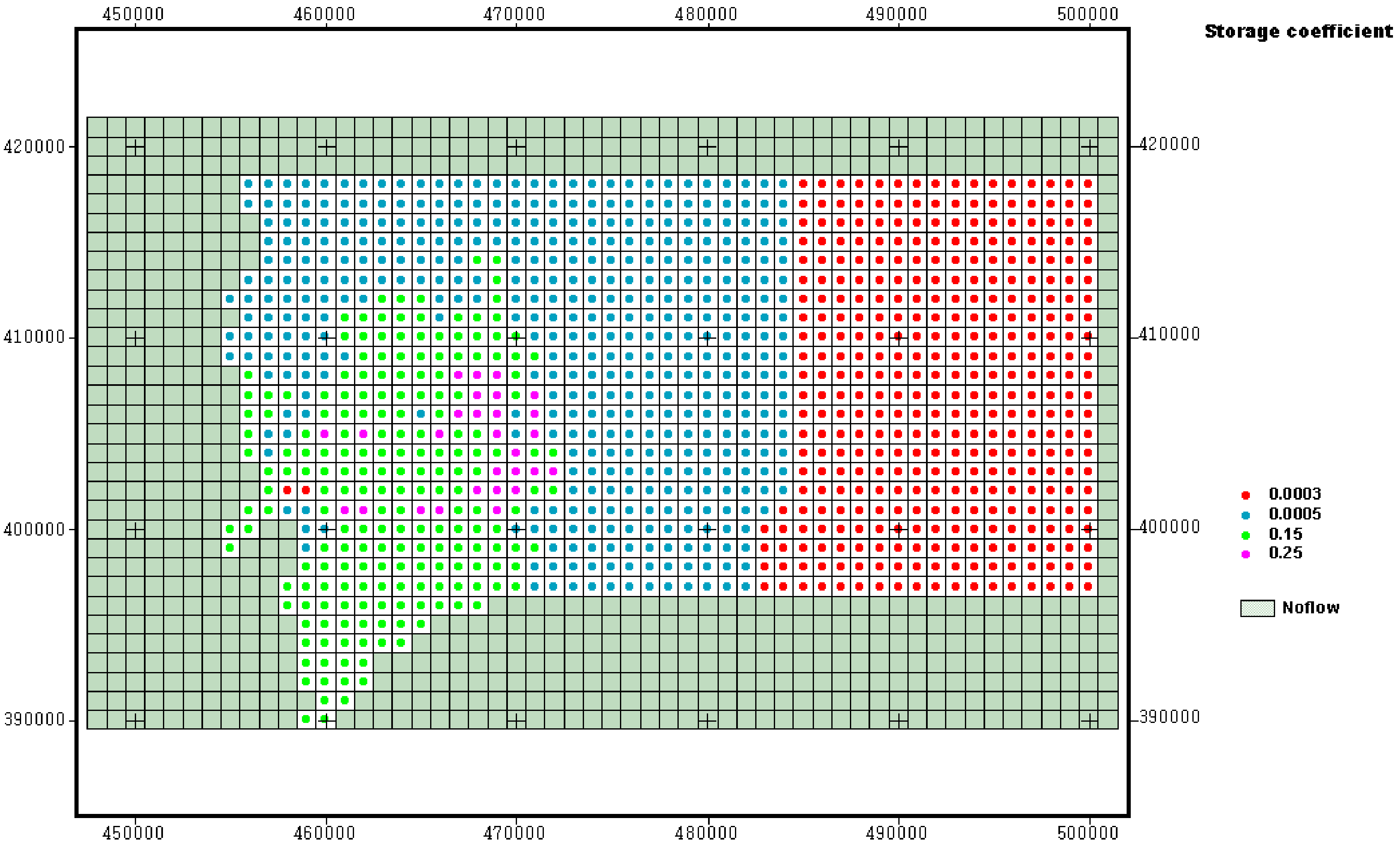


Figure 6 Distribution of storage coefficients within the MODFLOW model

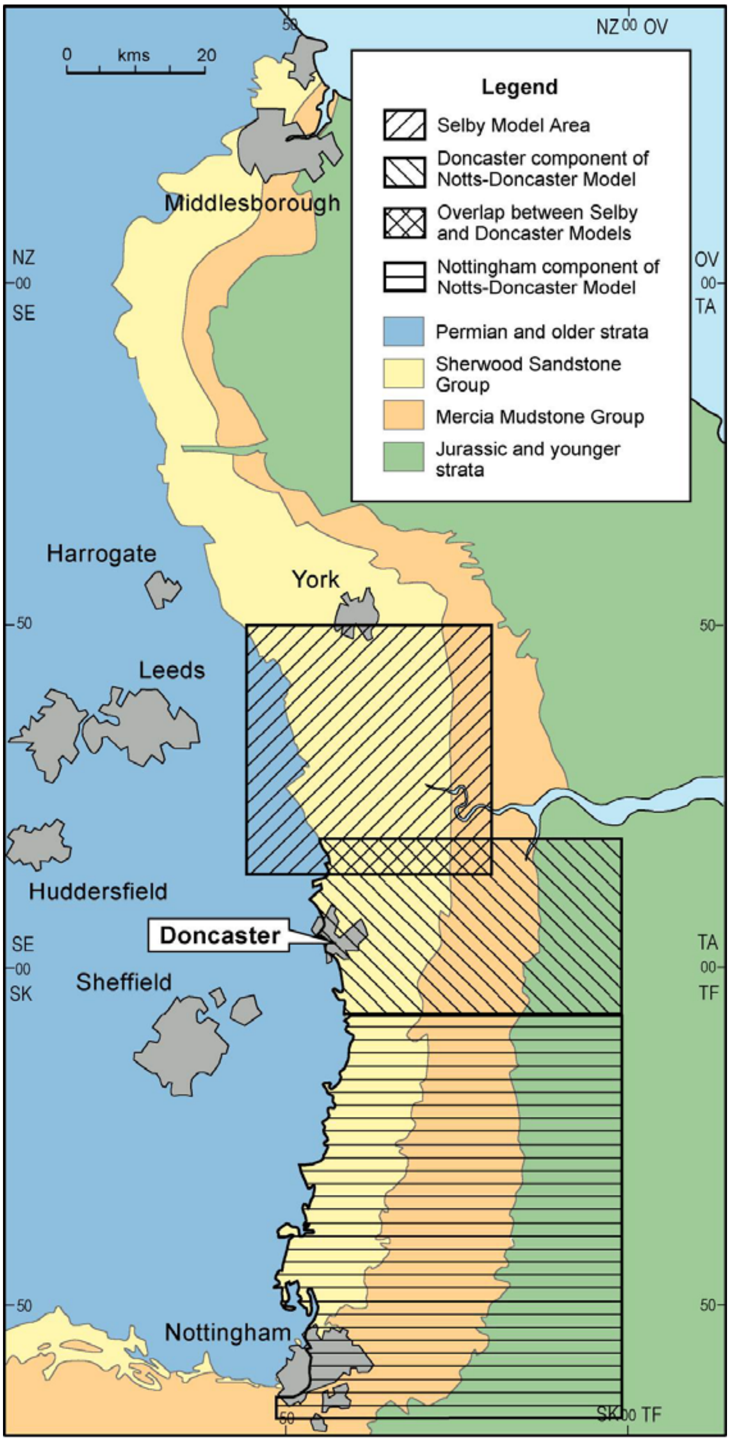


Figure 7 Extent of the Notts-Doncaster model

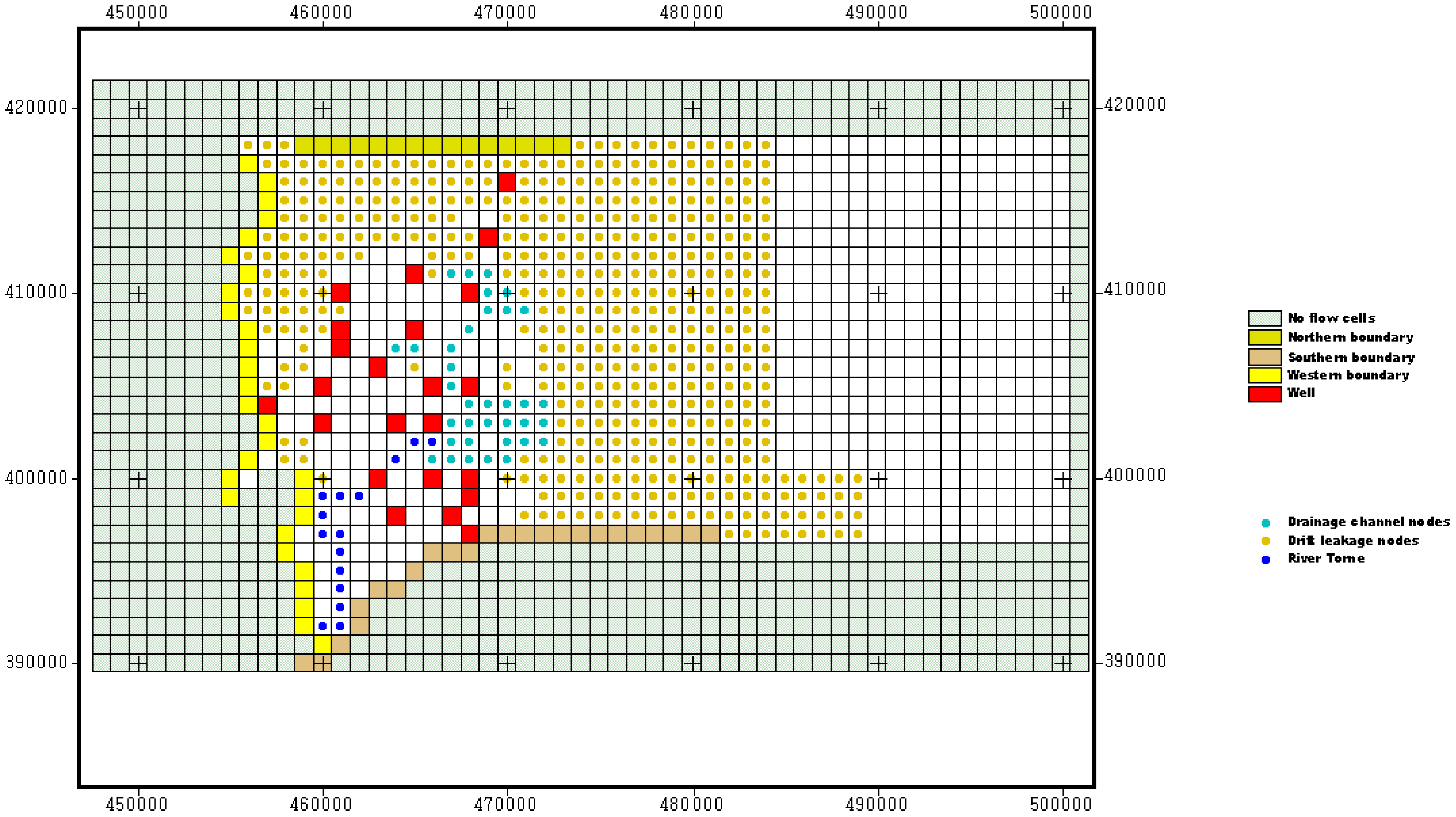


Figure 8 Boundary conditions of the MODFLOW model.

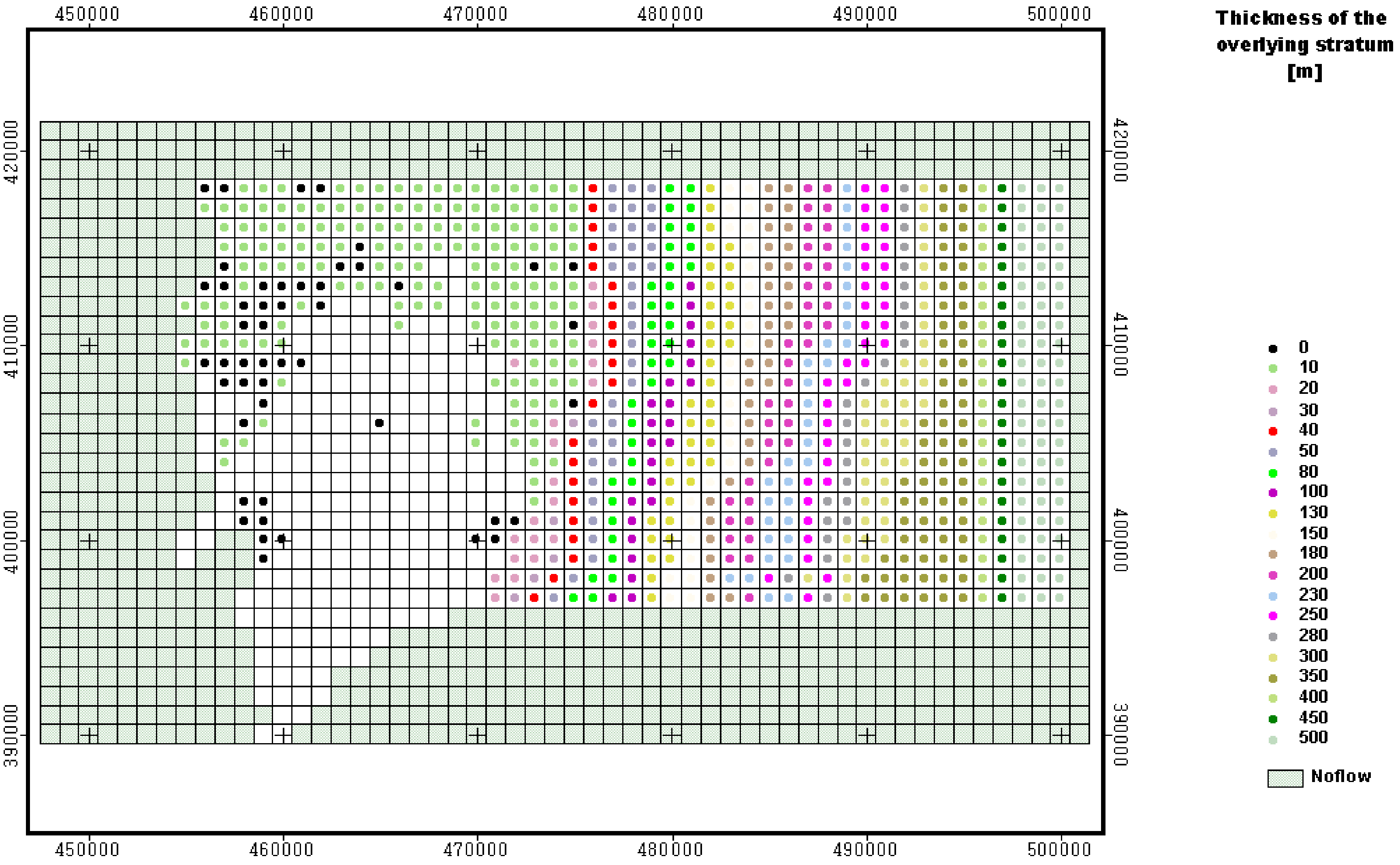


Figure 9 Distribution of the thickness of the overlying stratum (drift deposits and Mercia Mudstone) in the original model.

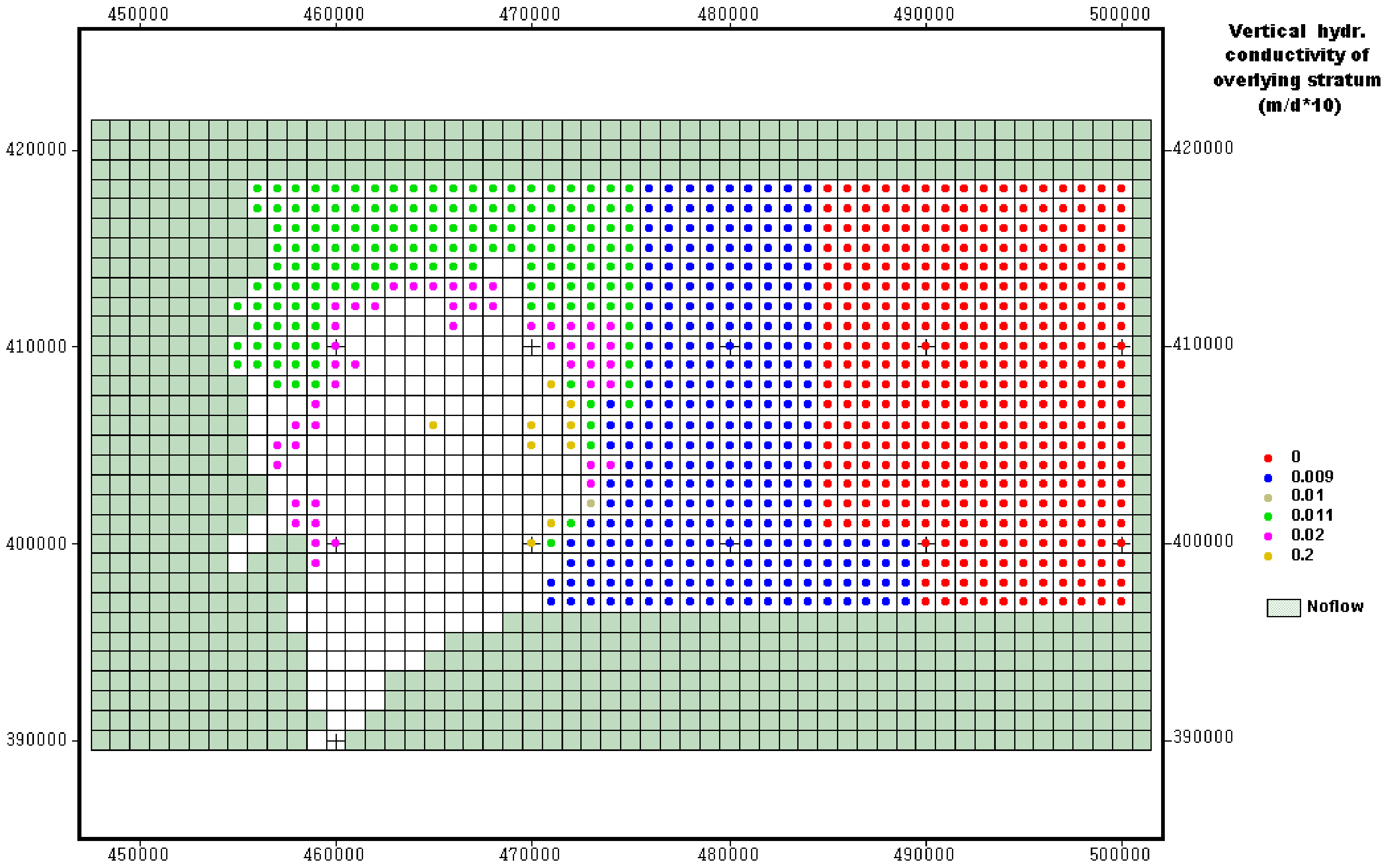


Figure 10 Distribution of vertical hydraulic conductivities in the overlying stratum in the MODFLOW model

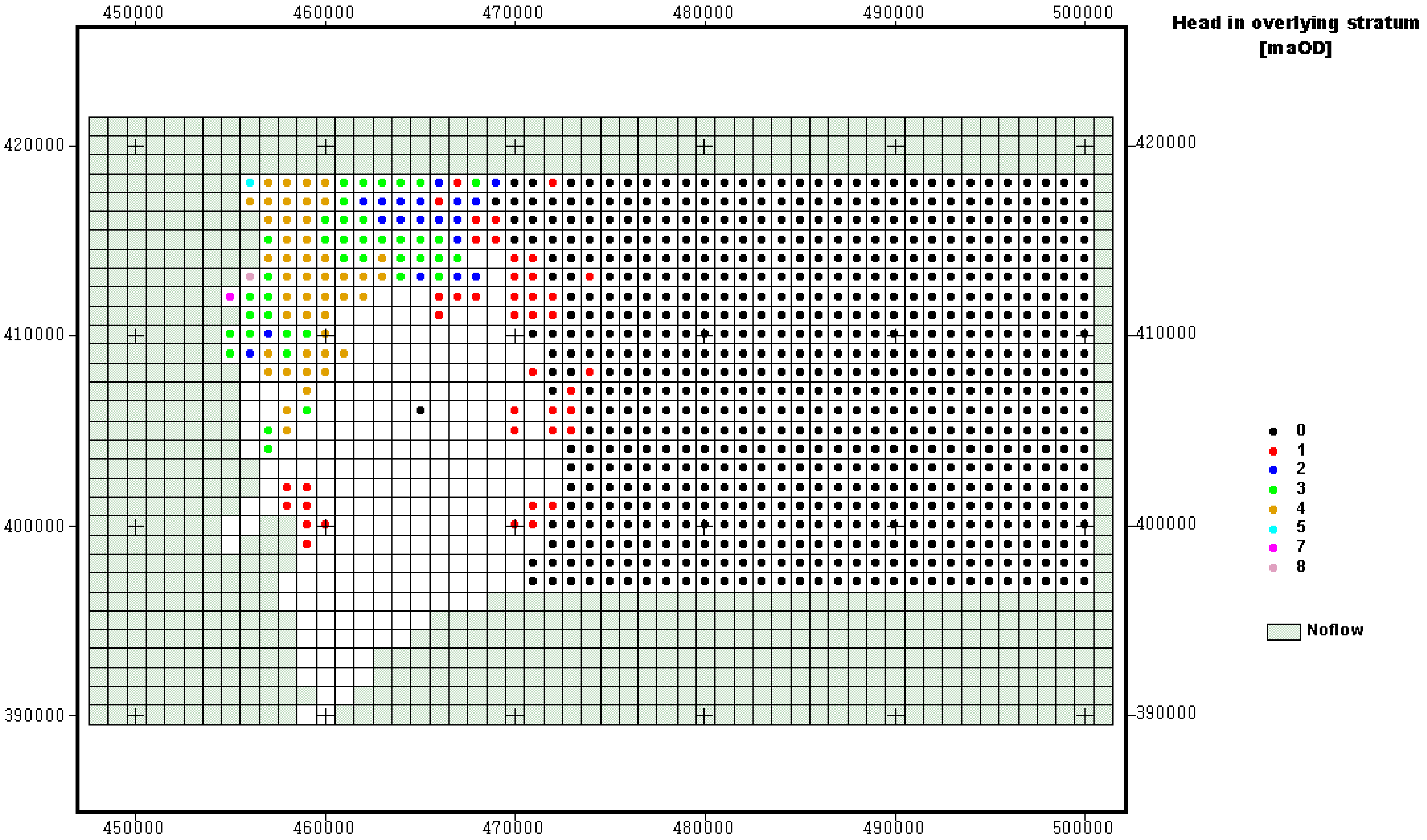


Figure 11 Distribution of hydraulic head in the drift deposits in the MODFLOW model

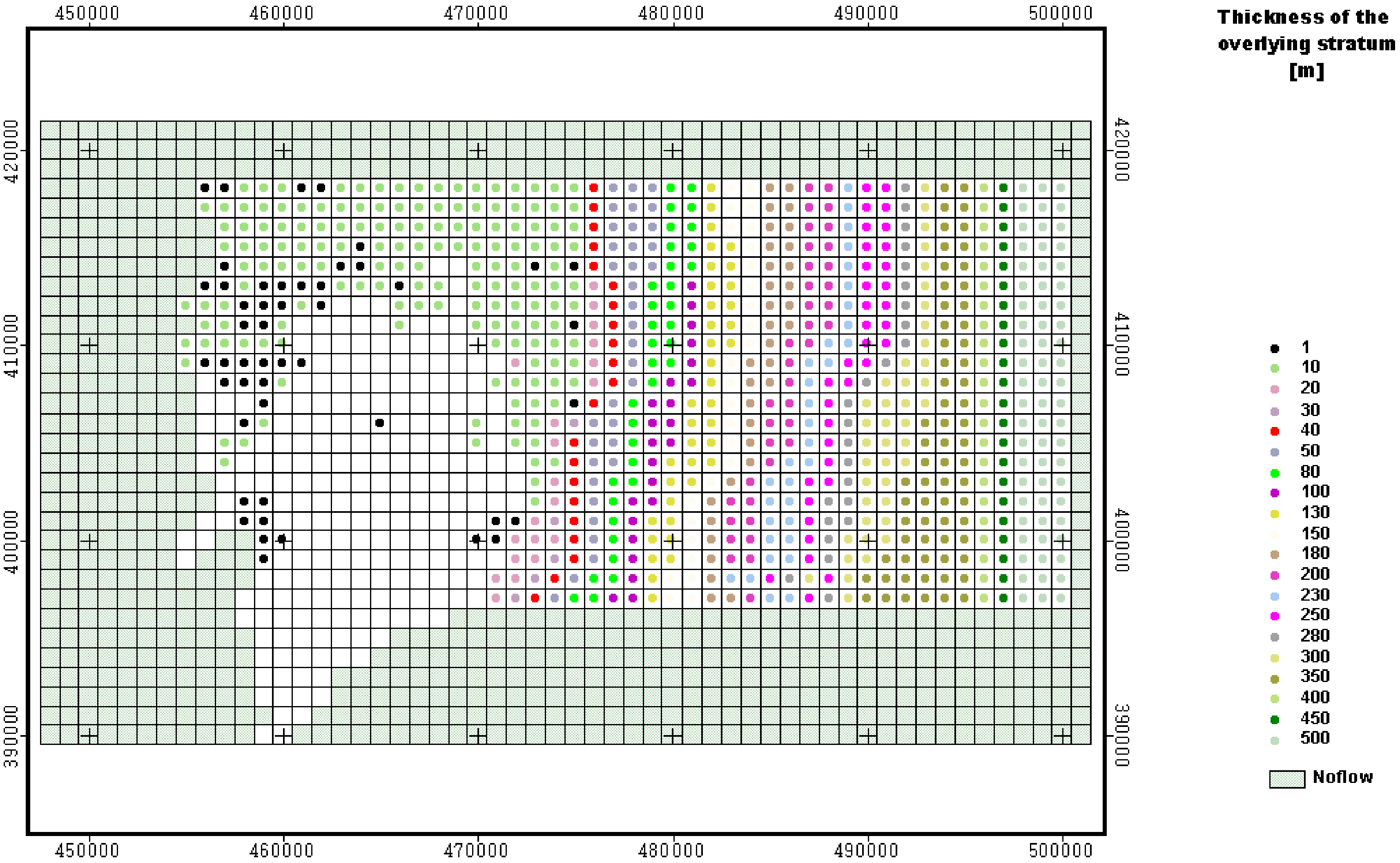


Figure 12 Distribution of thickness of overlying stratum (drift deposits and Mercia Mudstone) in the MODFLOW model

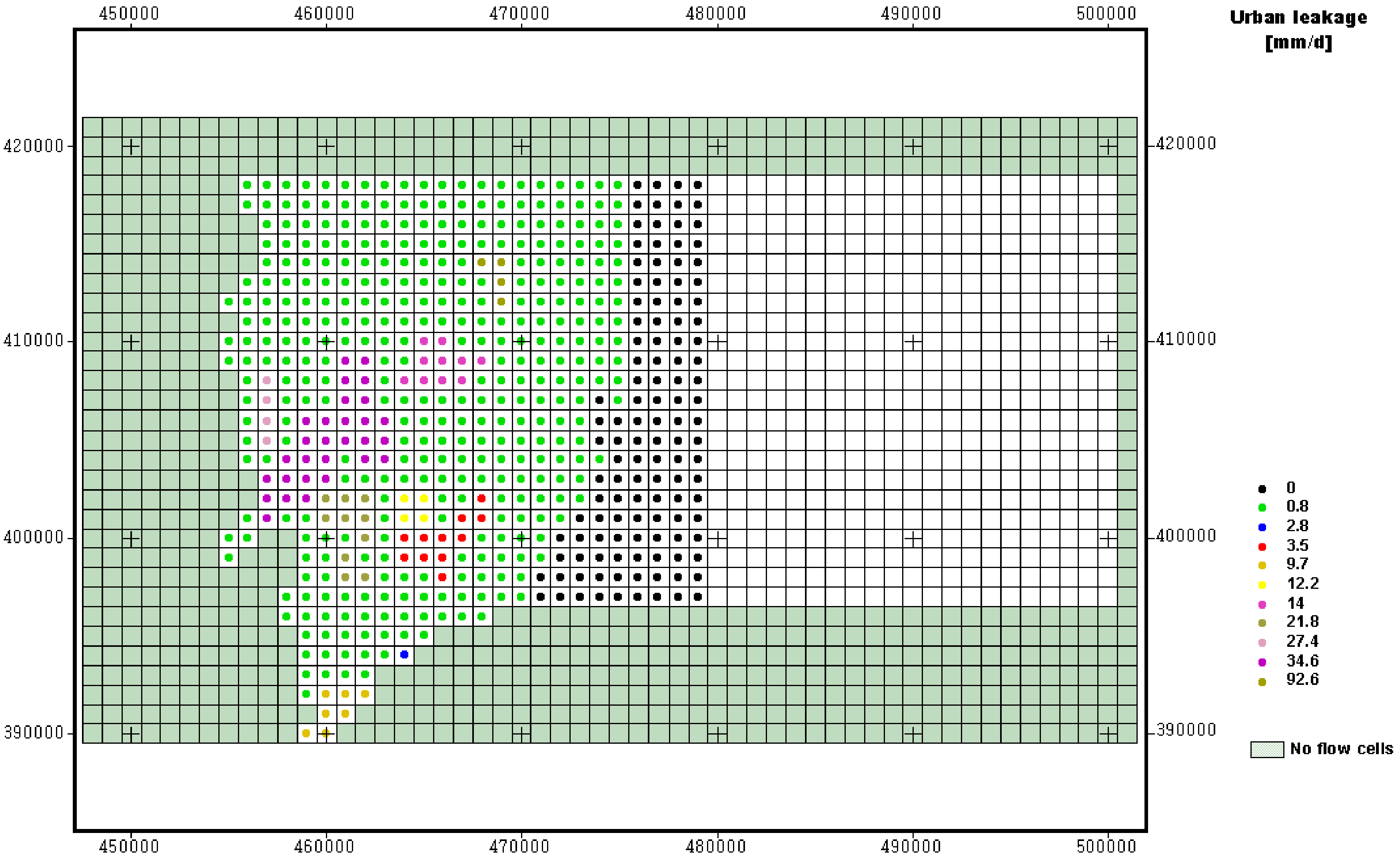


Figure 13 Distribution of urban leakage in the MODFLOW model

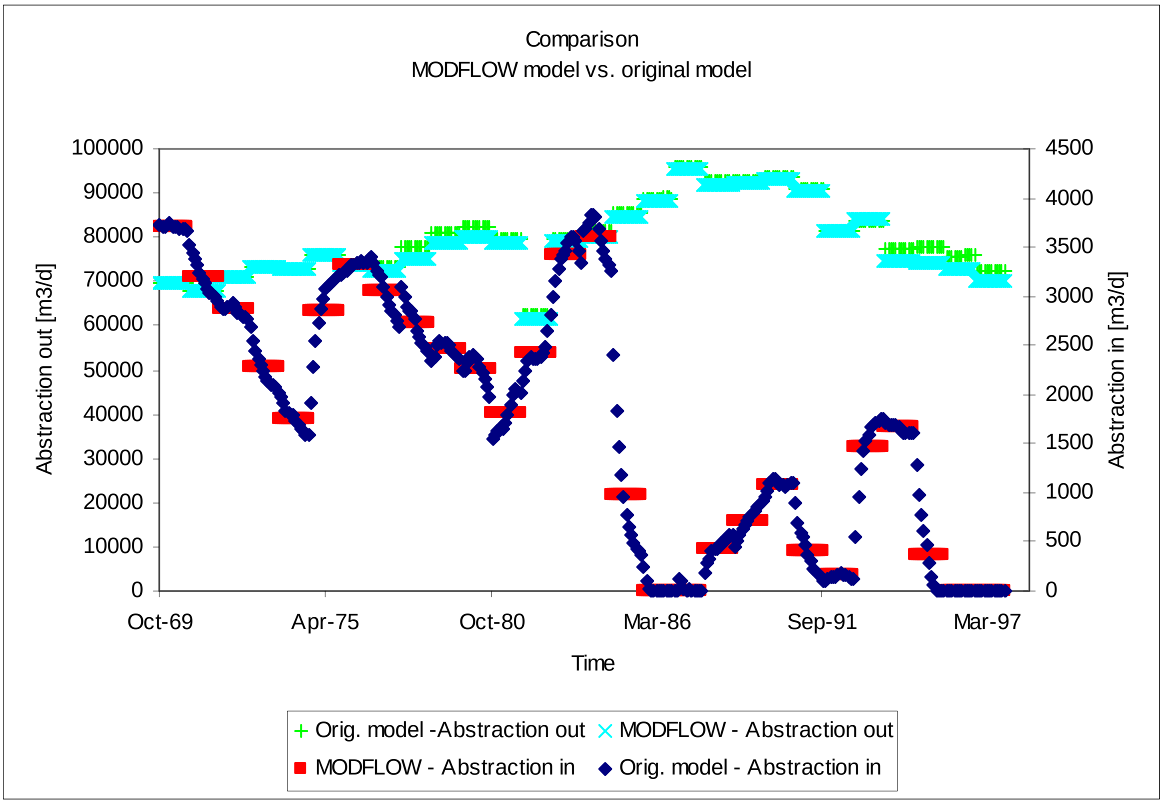


Figure 14 Comparison of abstraction volumes in the MODFLOW and original model

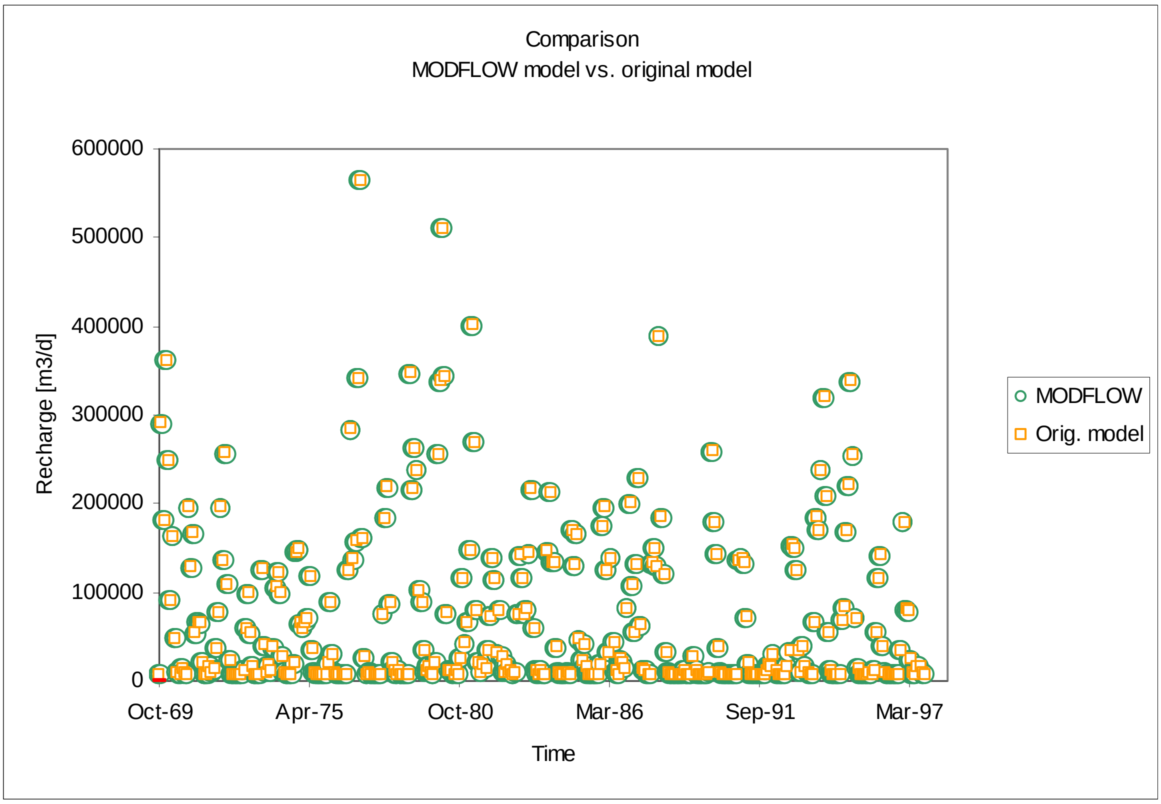


Figure 15 Comparison of recharge volumes in the MODFLOW and original model

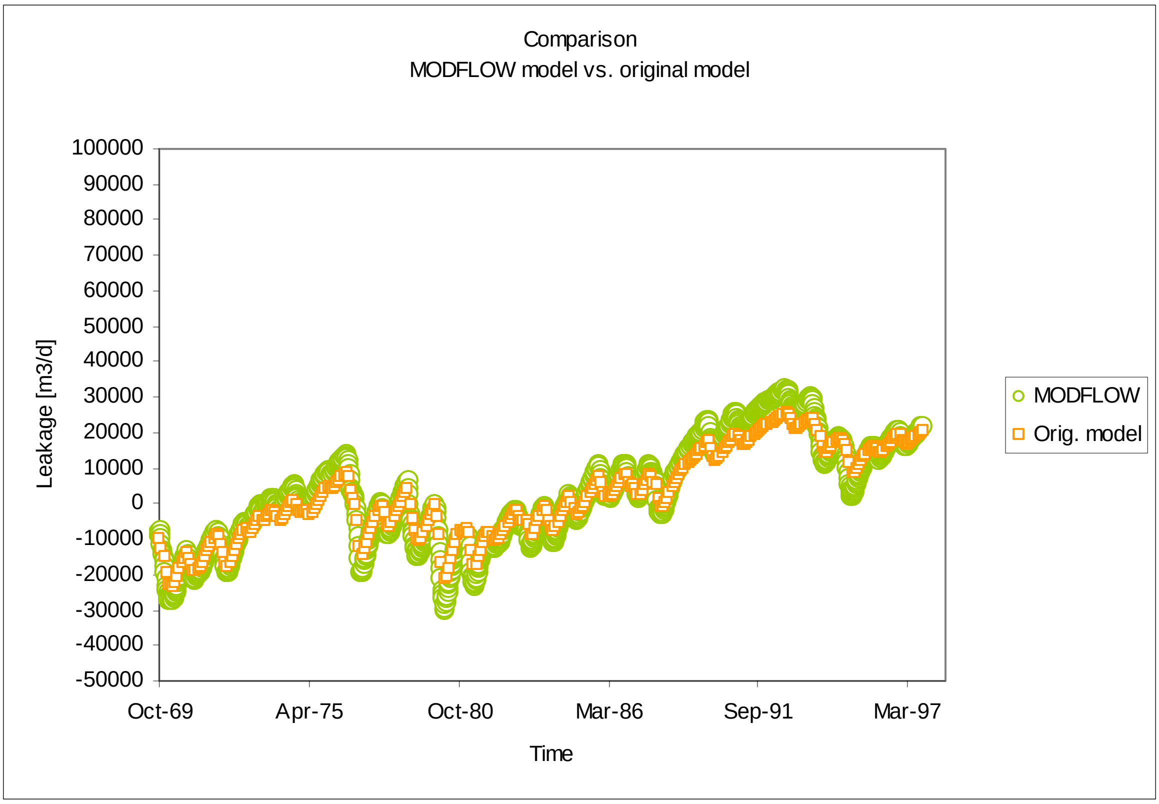


Figure 16 Comparison of leakage from/to rivers and overlying stratum in the MODFLOW and original model

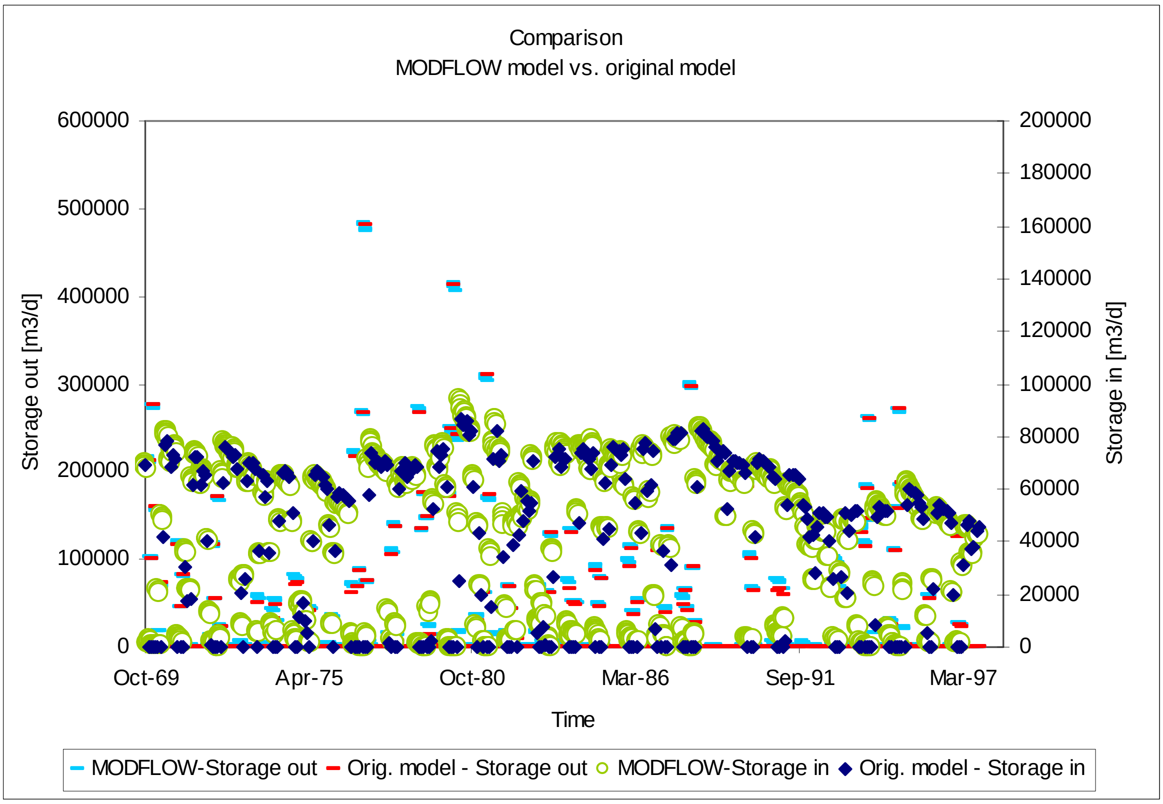


Figure 17 Comparison of change in storage in the MODFLOW and original model

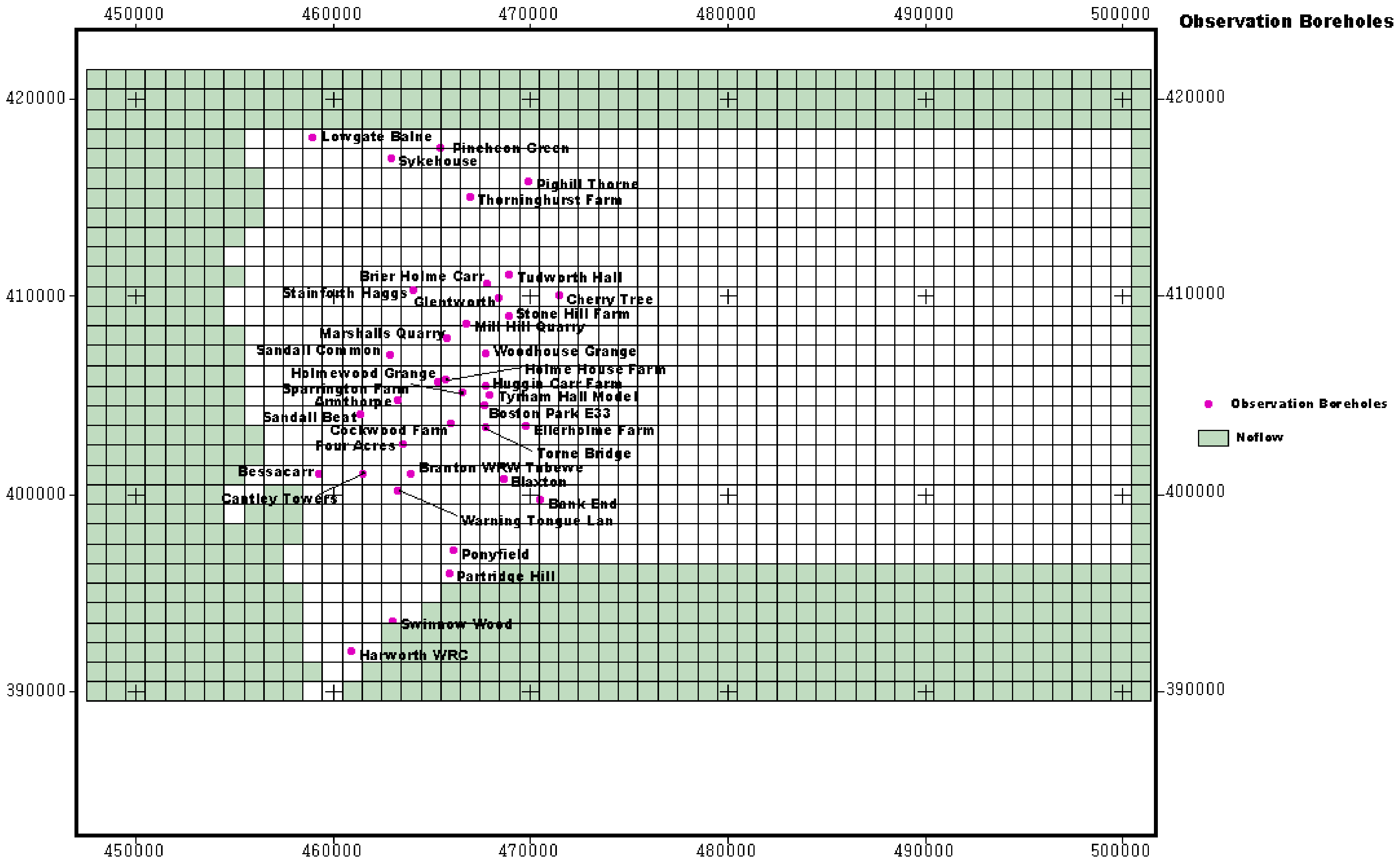


Figure 18 Position of observation boreholes

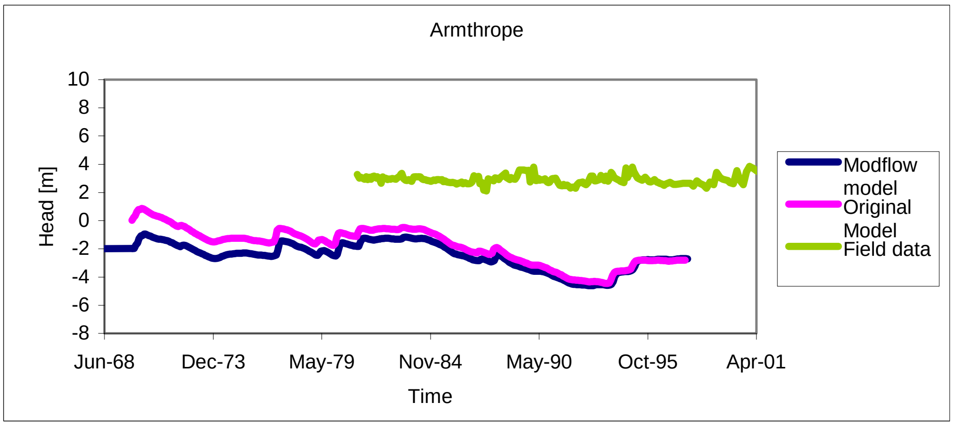
References

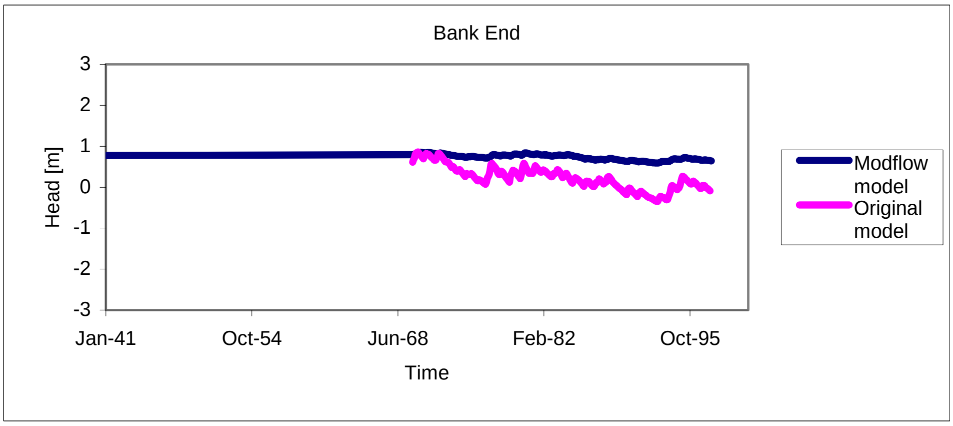
BROWN, I. T, and RUSHTON, K.R. 1993. Modelling of the Doncaster aquifer. Final report. *School of Civil Engineering, University of Birmingham*

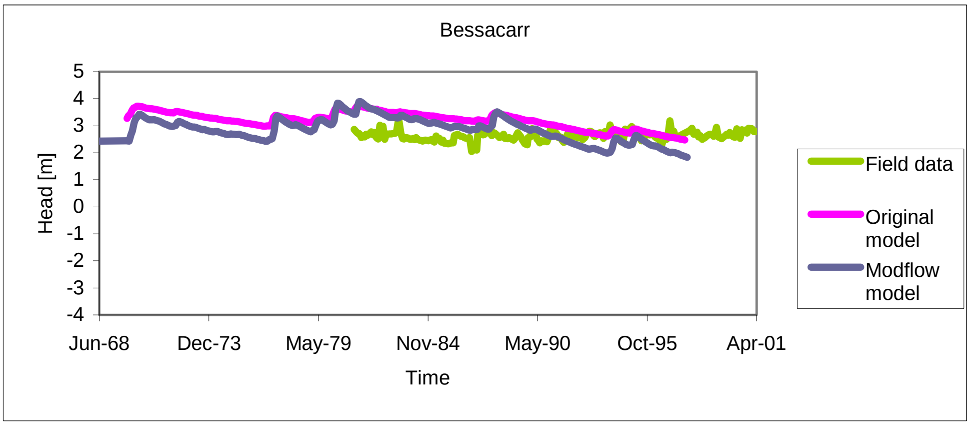
MORRIS, B.L., STUART, M.E. AND CRONIN, A.A. 2003. Assessing and Improving Sustainability of Urban Water Resources and Systems. AISUWRS Work package 1. Background study. *British Geological Survey Commissioned Report*, CR/03/052C.

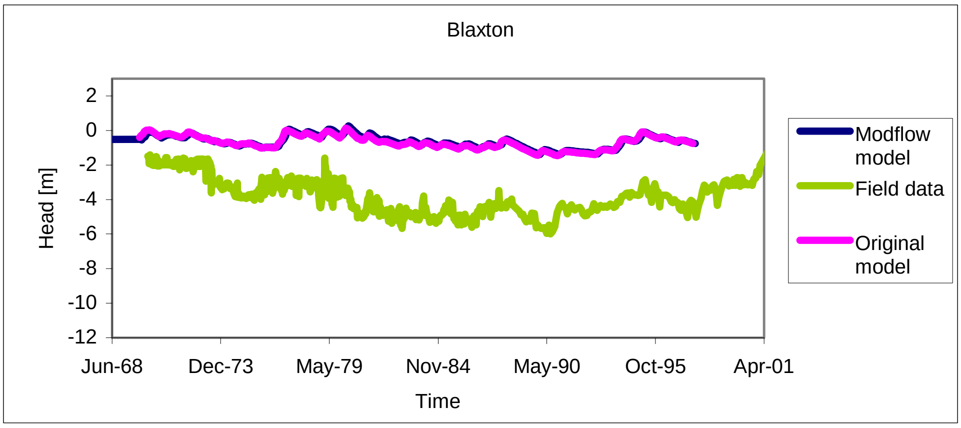
SHEPLEY, M.G. 2000 Notts-Doncaster Sherwood Sandstone Model – 1998 Update. Version 2. Environment Agency, Internal Report

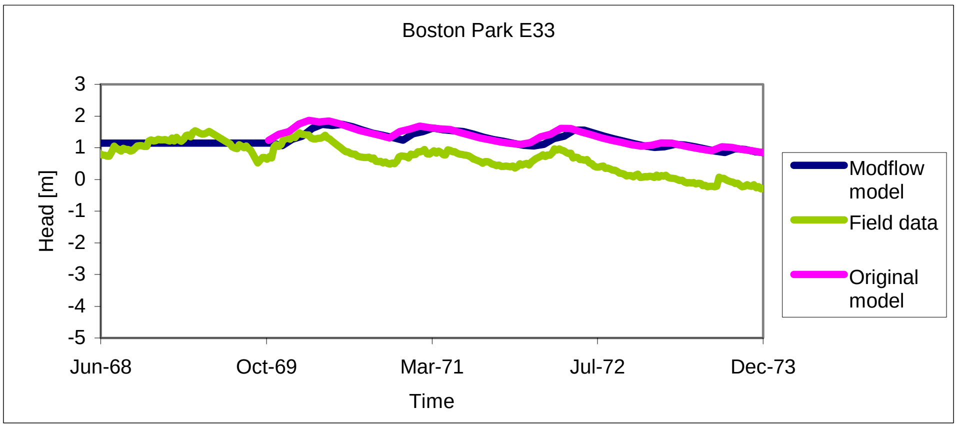
Appendix 1 Comparison of groundwater hydrographs from both models

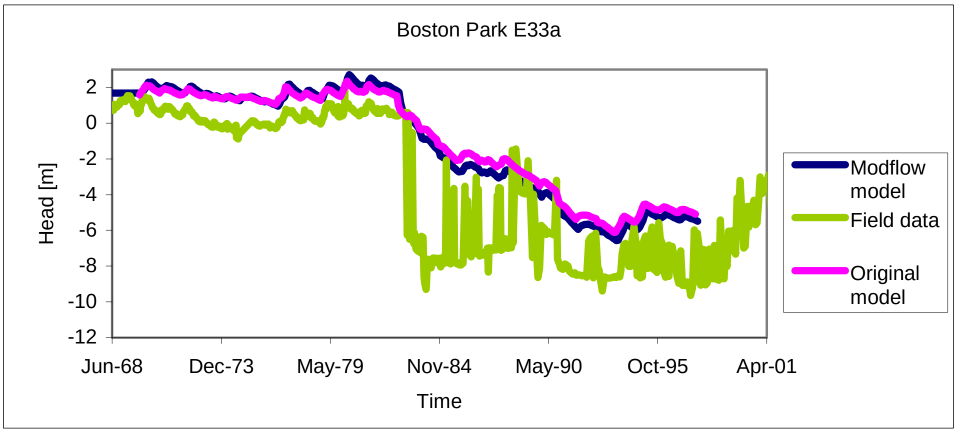

Armthrope
Head [m]
10
8
6
4
2
0
-2
-4
-6
-8
Jun-68
Dec-73
May-79
Nov-84
May-90
Oct-95
Apr-01
Time
Modflow model
Original Model
Field data

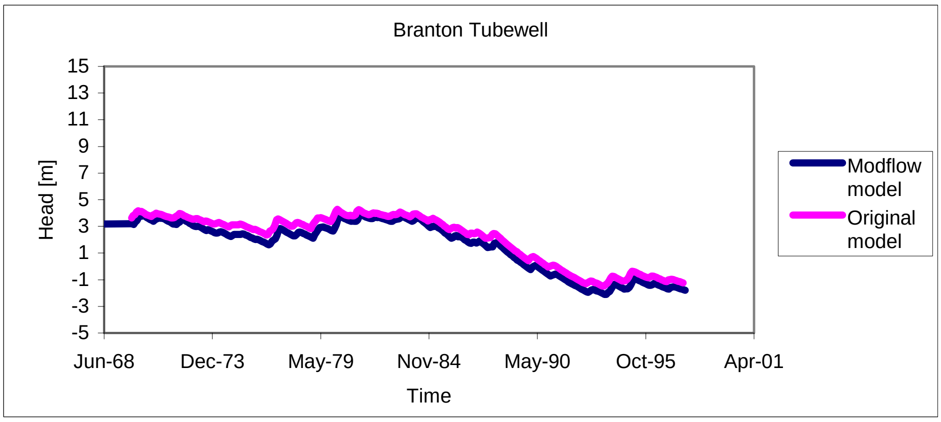

Bank End
Head [m]
3
2
1
0
-1
-2
-3
Jan-41
Oct-54
Jun-68
Feb-82
Oct-95
Time
Modflow model
Original model

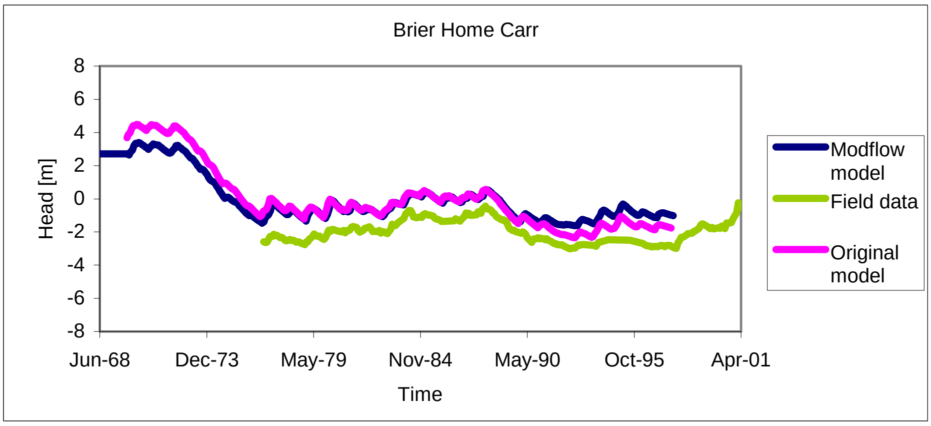

Bessacarr
Head [m]
5
4
3
2
1
0
-1
-2
-3
-4
Jun-68
Dec-73
May-79
Nov-84
May-90
Oct-95
Apr-01
Time
Field data
Original model
Modflow model

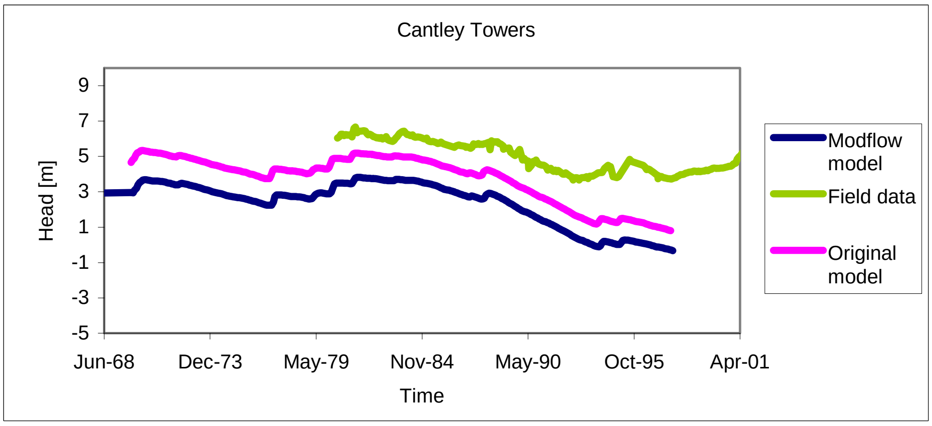

Blaxton
Head [m]
2
0
-2
-4
-6
-8
-10
-12
Jun-68
Dec-73
May-79
Nov-84
May-90
Oct-95
Apr-01
Time
Modflow model
Field data
Original model

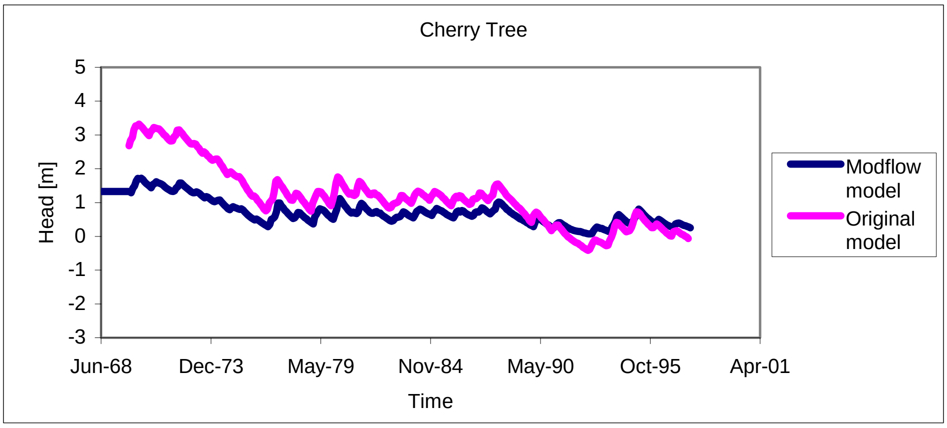

Boston Park E33
Head [m]
3
2
1
0
-1
-2
-3
-4
-5
Jun-68
Oct-69
Mar-71
Jul-72
Dec-73
Time
Modflow model
Field data
Original model

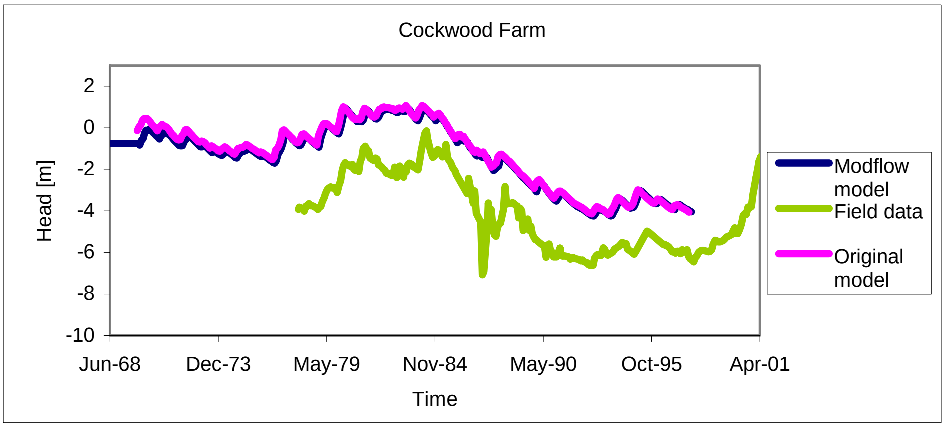

Boston Park E33a
Head [m]
2
0
-2
-4
-6
-8
-10
-12
Jun-68
Dec-73
May-79
Nov-84
May-90
Oct-95
Apr-01
Time
Modflow model
Field data
Original model

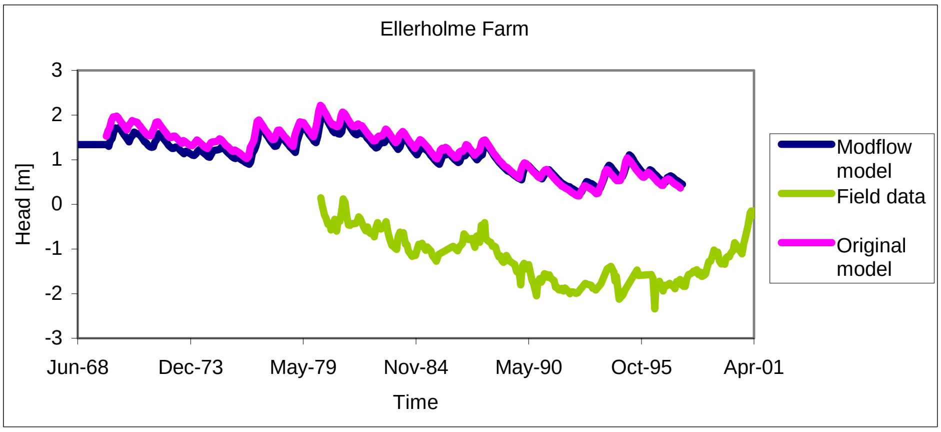

Branton Tubewell
Head [m]
15
13
11
9
7
5
3
1
-1
-3
-5
Jun-68
Dec-73
May-79
Nov-84
May-90
Oct-95
Apr-01
Time
Modflow model
Original model

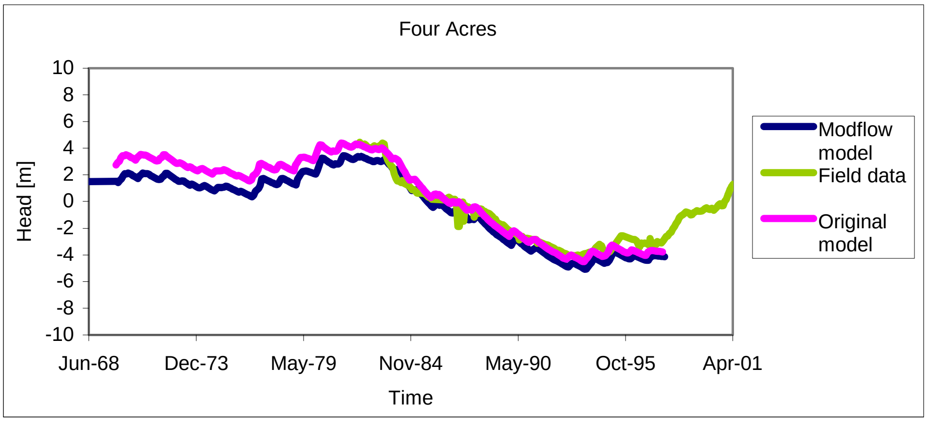

Brier Home Carr
Head [m]
8
6
4
2
0
-2
-4
-6
-8
Jun-68
Dec-73
May-79
Nov-84
May-90
Oct-95
Apr-01
Time
Modflow model
Field data
Original model

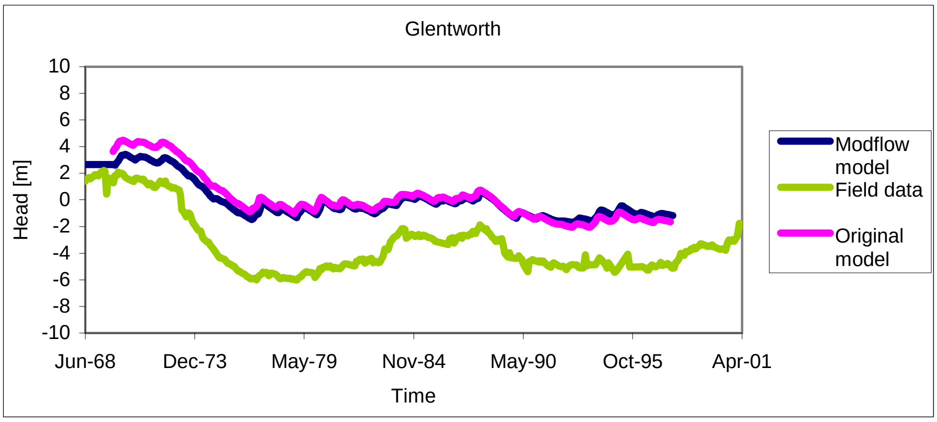

Cantley Towers
Head [m]
9
7
5
3
1
-1
-3
-5
Jun-68
Dec-73
May-79
Nov-84
May-90
Oct-95
Apr-01
Time
Modflow model
Field data
Original model

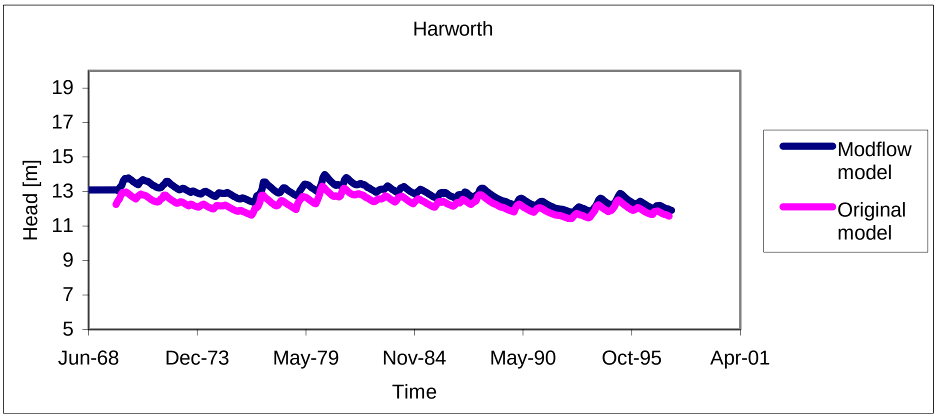

Cherry Tree
Head [m]
5
4
3
2
1
0
-1
-2
-3
Jun-68
Dec-73
May-79
Nov-84
May-90
Oct-95
Apr-01
Time
Modflow model
Original model

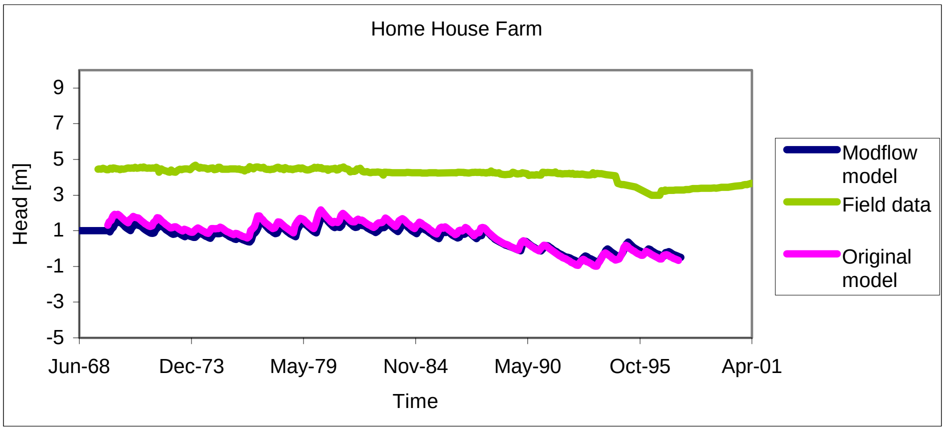

Cockwood Farm
Head [m]
2
0
-2
-4
-6
-8
-10
Jun-68
Dec-73
May-79
Nov-84
May-90
Oct-95
Apr-01
Time
Modflow model
Field data
Original model

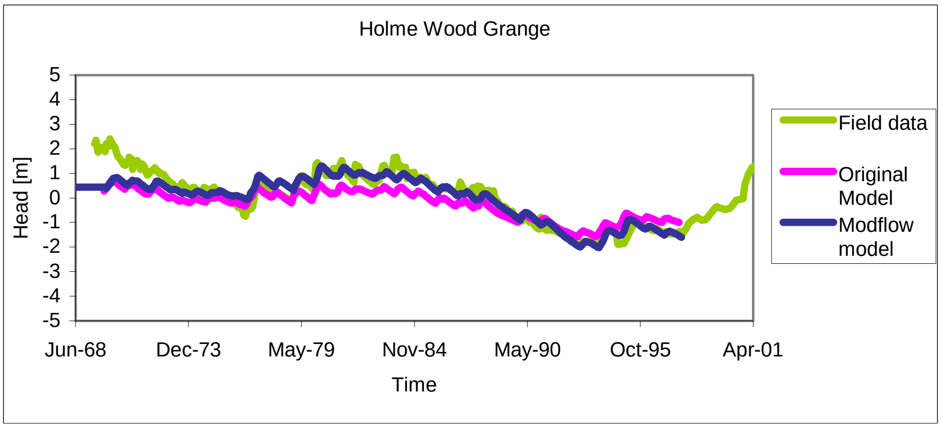

Ellerholme Farm
Head [m]
3
2
1
0
-1
-2
-3
Jun-68
Dec-73
May-79
Nov-84
May-90
Oct-95
Apr-01
Time
Modflow model
Field data
Original model

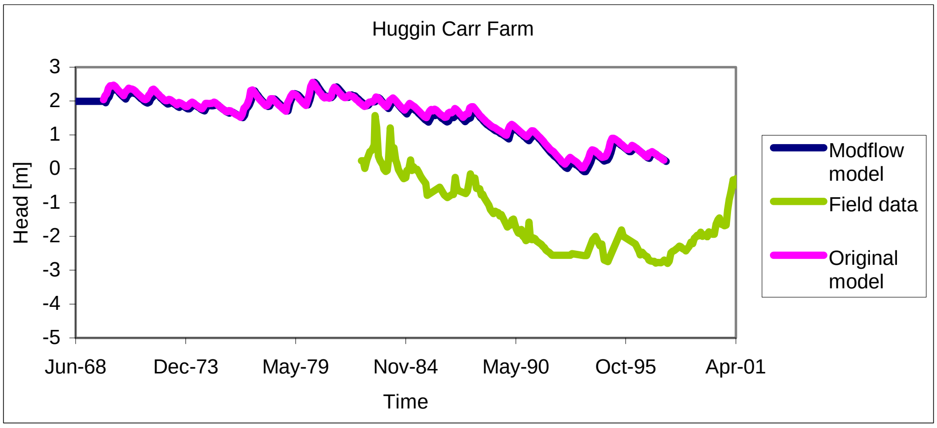

Four Acres
Head [m]
10
8
6
4
2
0
-2
-4
-6
-8
-10
Jun-68
Dec-73
May-79
Nov-84
May-90
Oct-95
Apr-01
Time
Modflow model
Field data
Original model

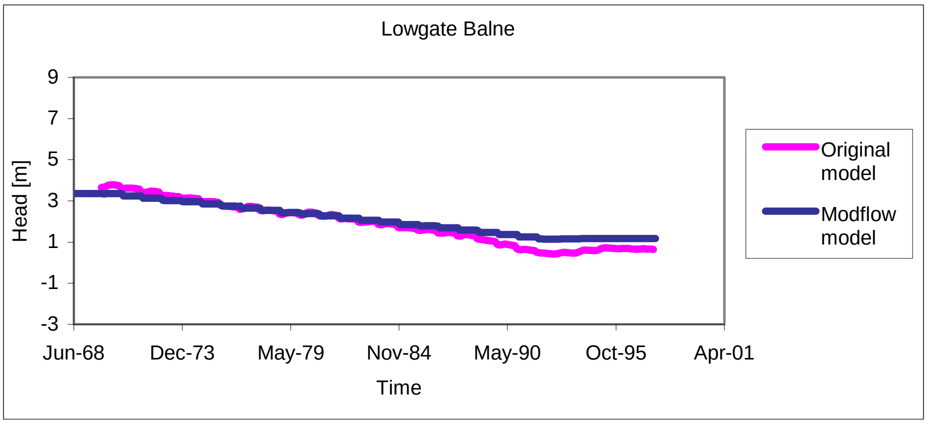

Glentworth
Head [m]
10
8
6
4
2
0
-2
-4
-6
-8
-10
Jun-68
Dec-73
May-79
Nov-84
May-90
Oct-95
Apr-01
Time
Modflow model
Field data
Original model

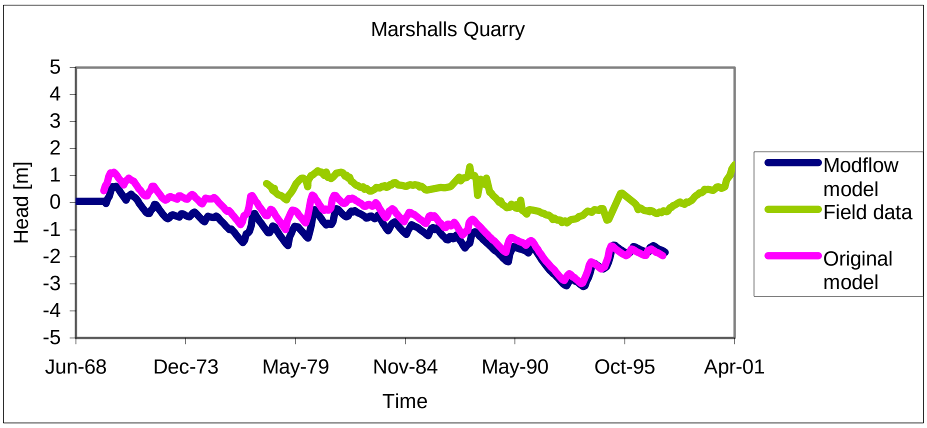

Harworth
Head [m]
19
17
15
13
11
9
7
5
Jun-68
Dec-73
May-79
Nov-84
May-90
Oct-95
Apr-01
Time
Modflow model
Original model

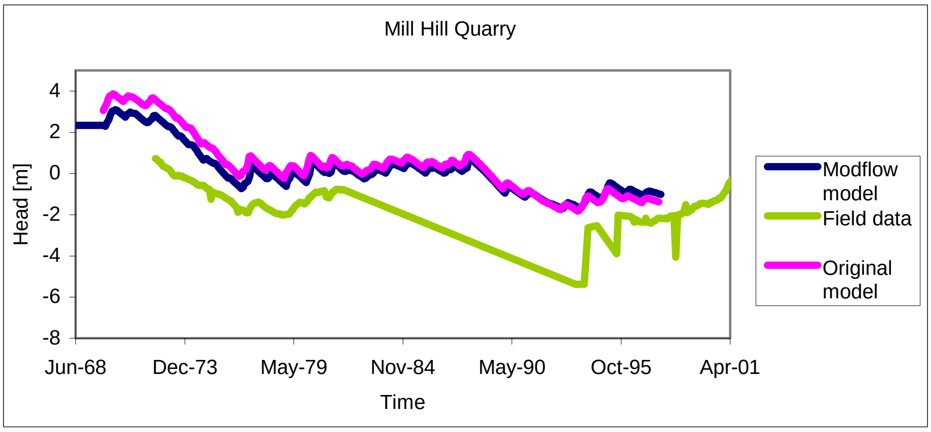

Home House Farm
Head [m]
9
7
5
3
1
-1
-3
-5
Jun-68
Dec-73
May-79
Nov-84
May-90
Oct-95
Apr-01
Time
Modflow model
Field data
Original model

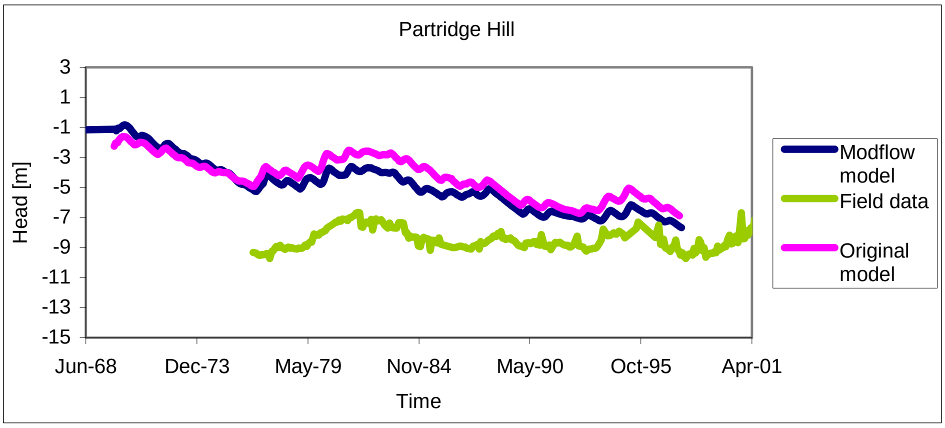

Holme Wood Grange
Head [m]
5
4
3
2
1
0
-1
-2
-3
-4
-5
Jun-68
Dec-73
May-79
Nov-84
May-90
Oct-95
Apr-01
Time
Field data
Original Model
Modflow model

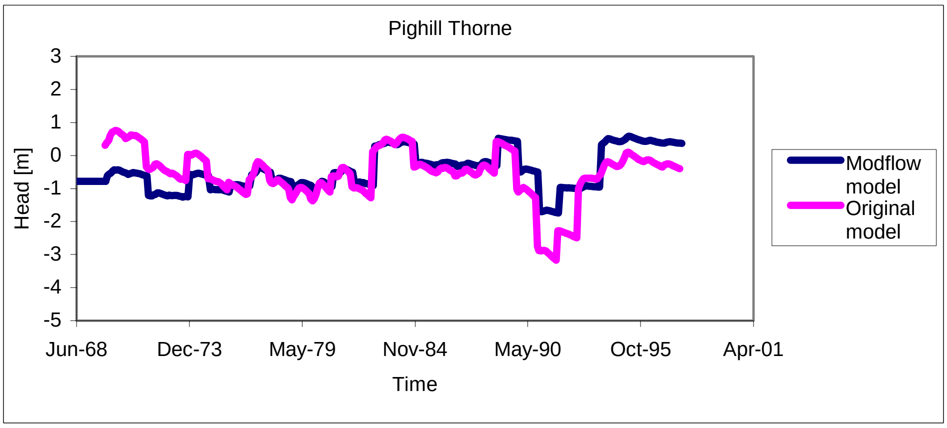

Huggin Carr Farm
Head [m]
3
2
1
0
-1
-2
-3
-4
-5
Jun-68
Dec-73
May-79
Nov-84
May-90
Oct-95
Apr-01
Time
Modflow model
Field data
Original model

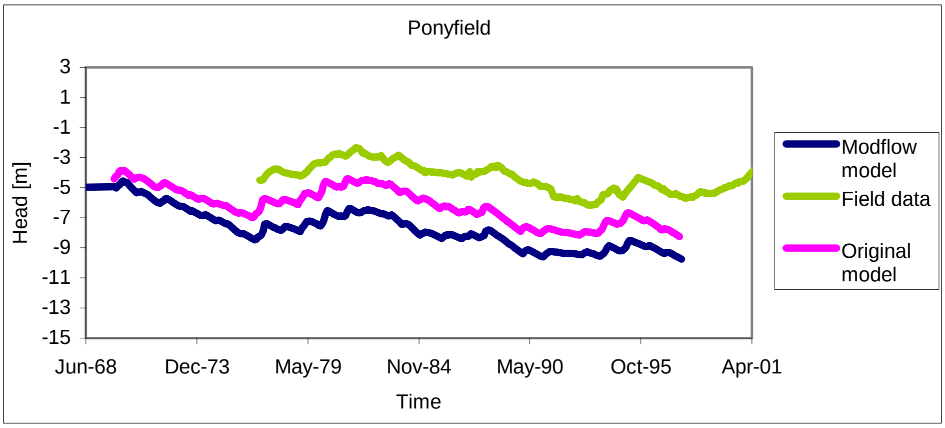

Lowgate Balne
Head [m]
9
7
5
3
1
-1
-3
Jun-68
Dec-73
May-79
Nov-84
May-90
Oct-95
Apr-01
Time
Original model
Modflow model

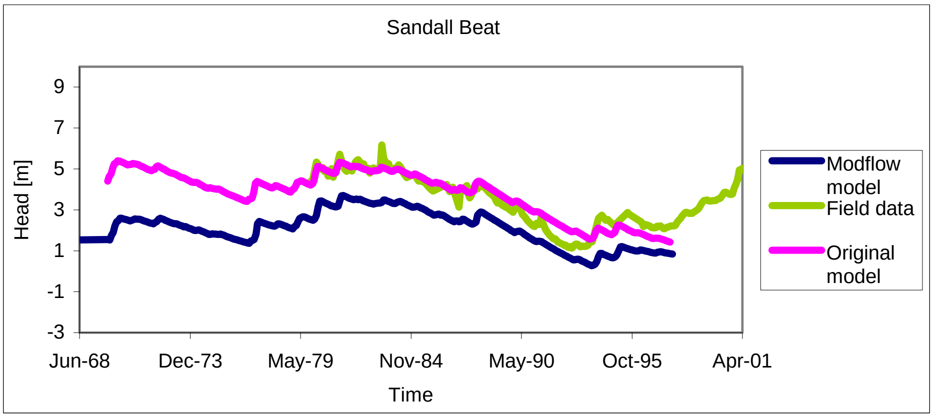

Marshalls Quarry
Head [m]
5
4
3
2
1
0
-1
-2
-3
-4
-5
Jun-68
Dec-73
May-79
Nov-84
May-90
Oct-95
Apr-01
Time
Modflow model
Field data
Original model

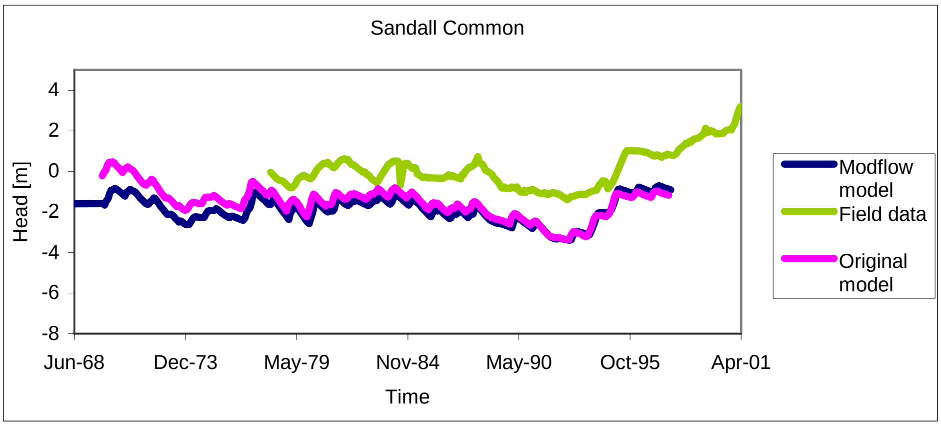

Mill Hill Quarry
Head [m]
4
2
0
-2
-4
-6
-8
Jun-68
Dec-73
May-79
Nov-84
May-90
Oct-95
Apr-01
Time
Modflow model
Field data
Original model

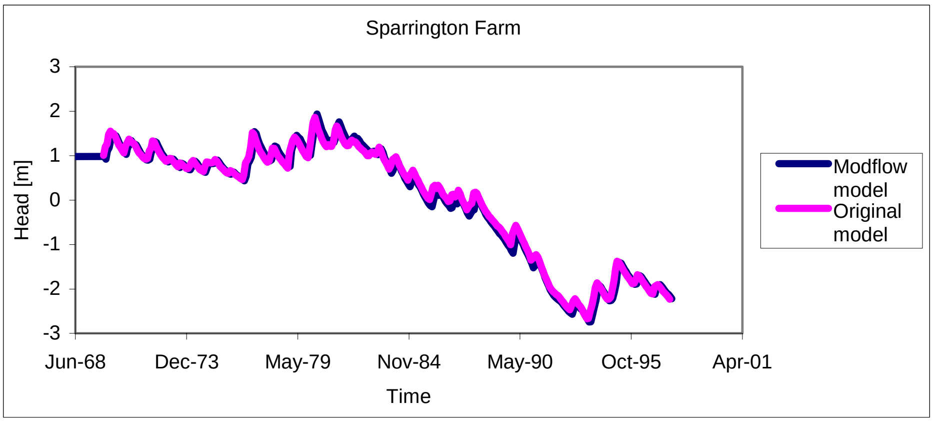

Partridge Hill
Head [m]
3
1
-1
-3
-5
-7
-9
-11
-13
-15
Jun-68
Dec-73
May-79
Nov-84
May-90
Oct-95
Apr-01
Time
Modflow model
Field data
Original model

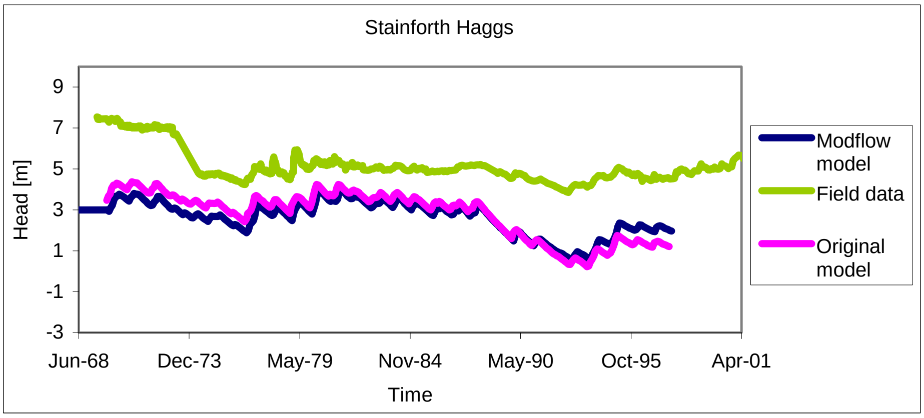

Pighill Thorne
Head [m]
3
2
1
0
-1
-2
-3
-4
-5
Jun-68
Dec-73
May-79
Nov-84
May-90
Oct-95
Apr-01
Time
Modflow model
Original model

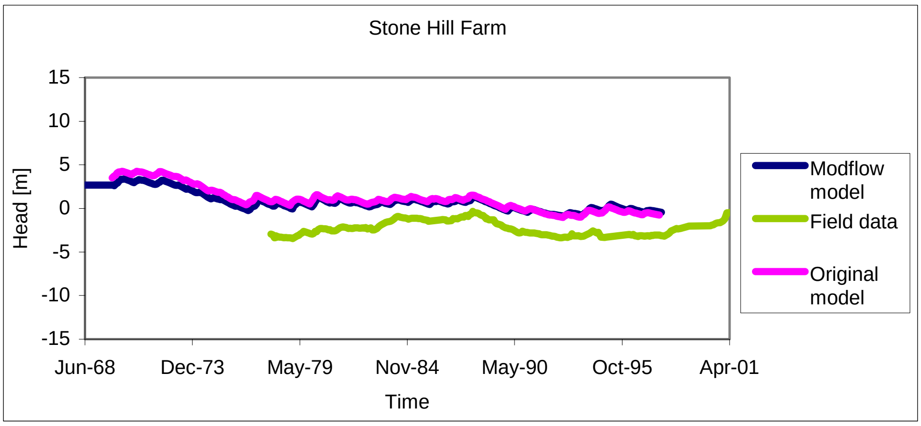

Ponyfield
Head [m]
3
1
-1
-3
-5
-7
-9
-11
-13
-15
Jun-68
Dec-73
May-79
Nov-84
May-90
Oct-95
Apr-01
Time
Modflow model
Field data
Original model

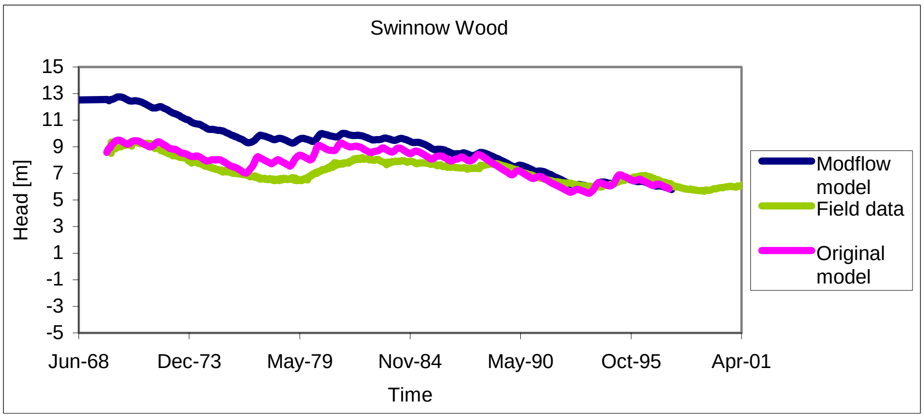

Sandall Beat
Head [m]
9
7
5
3
1
-1
-3
Jun-68
Dec-73
May-79
Nov-84
May-90
Oct-95
Apr-01
Time
Modflow model
Field data
Original model

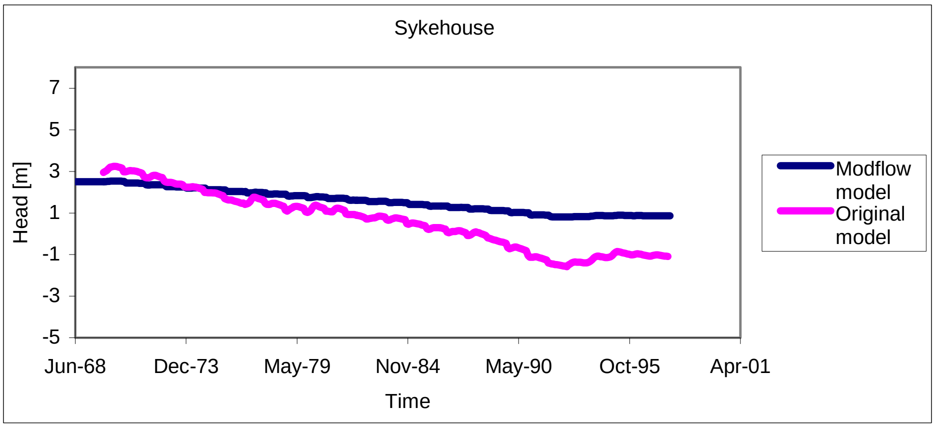

Sandall Common
Head [m]
4
2
0
-2
-4
-6
-8
Jun-68
Dec-73
May-79
Nov-84
May-90
Oct-95
Apr-01
Time
Modflow model
Field data
Original model

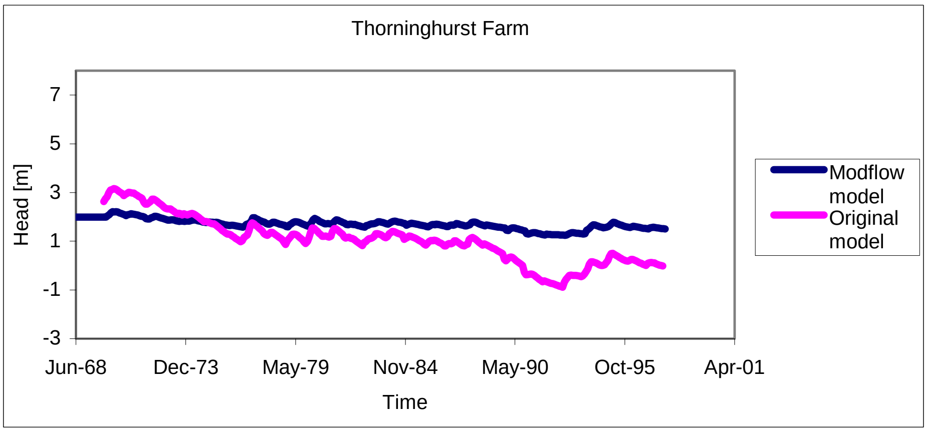

Sparrington Farm
Head [m]
3
2
1
0
-1
-2
-3
Jun-68
Dec-73
May-79
Nov-84
May-90
Oct-95
Apr-01
Time
Modflow model
Original model

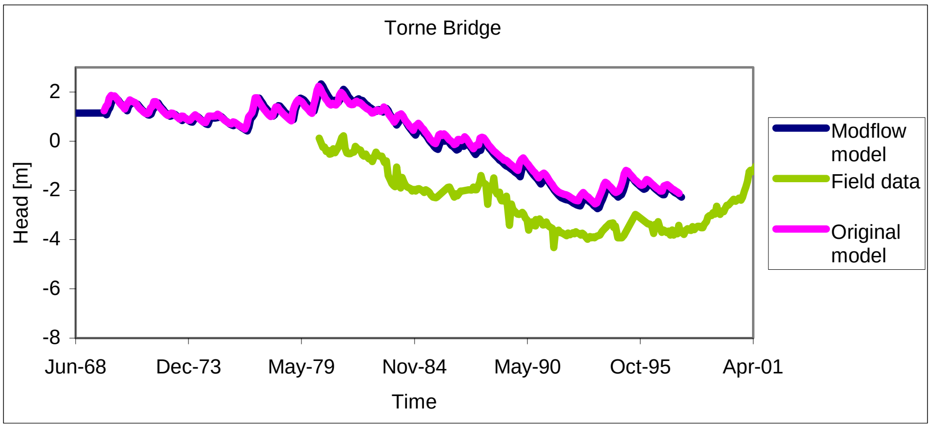

Stainforth Haggs
Head [m]
9
7
5
3
1
-1
-3
Jun-68
Dec-73
May-79
Nov-84
May-90
Oct-95
Apr-01
Time
Modflow model
Field data
Original model

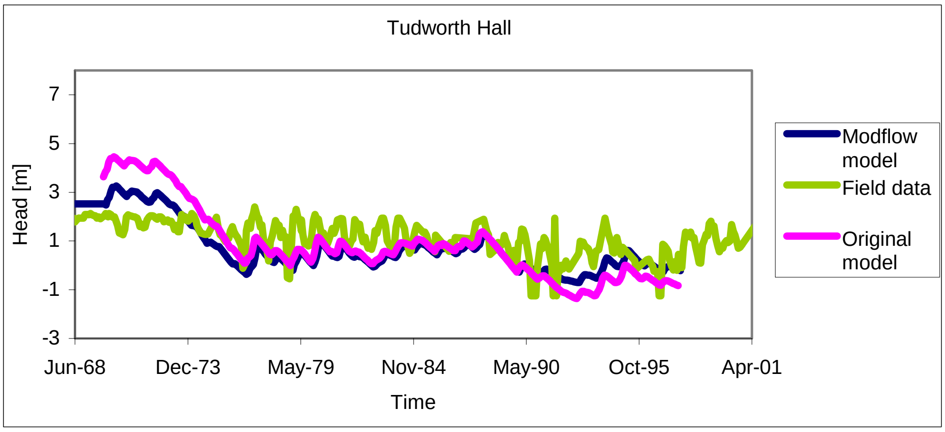

Stone Hill Farm
Head [m]
15
10
5
0
-5
-10
-15
Jun-68
Dec-73
May-79
Nov-84
May-90
Oct-95
Apr-01
Time
Modflow model
Field data
Original model

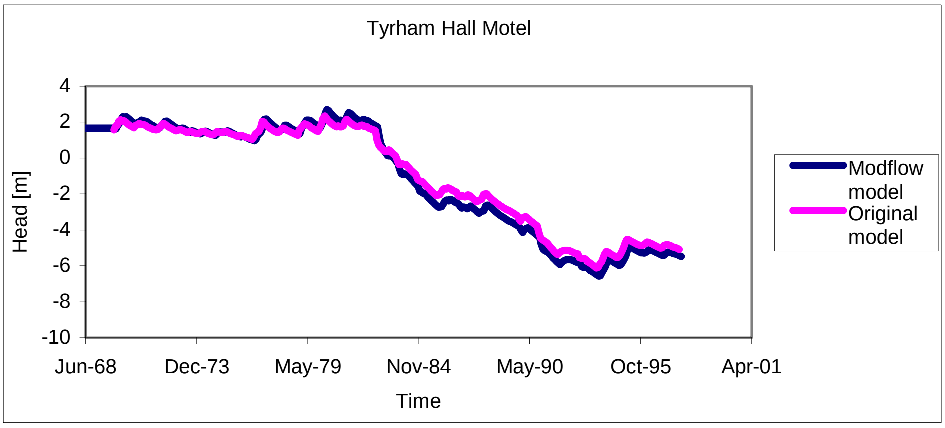

Swinnow Wood
Head [m]
15
13
11
9
7
5
3
1
-1
-3
-5
Jun-68
Dec-73
May-79
Nov-84
May-90
Oct-95
Apr-01
Time
Modflow model
Field data
Original model

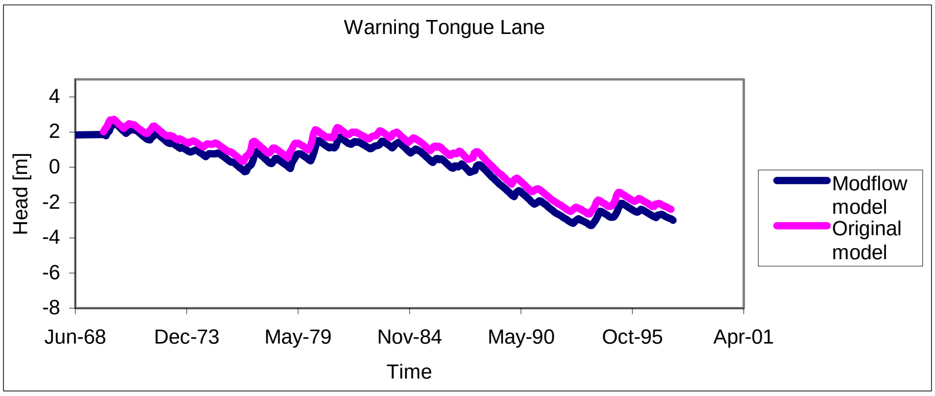

Sykehouse
Head [m]
7
5
3
1
-1
-3
-5
Jun-68
Dec-73
May-79
Nov-84
May-90
Oct-95
Apr-01
Time
Modflow model
Original model

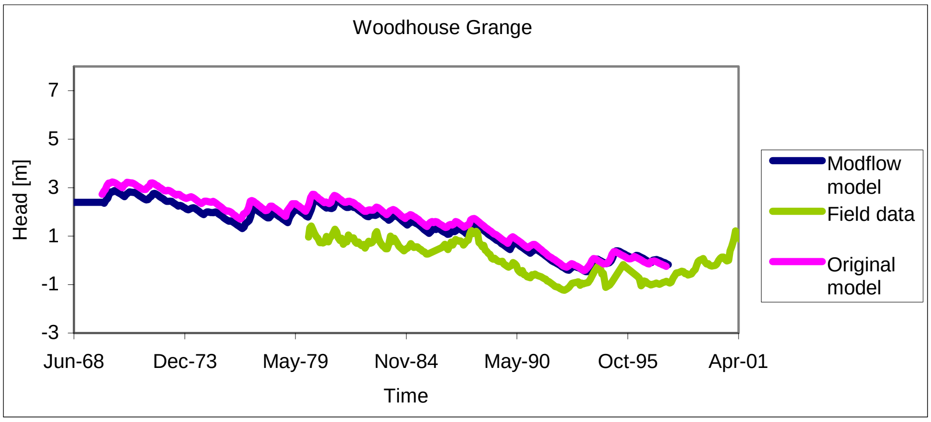

Thorninghurst Farm
Head [m]
7
5
3
1
-1
-3
Jun-68
Dec-73
May-79
Nov-84
May-90
Oct-95
Apr-01
Time
Modflow model
Original model

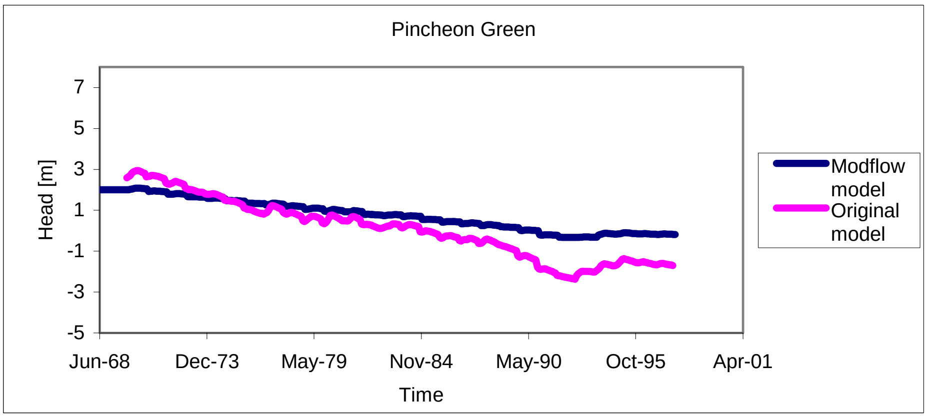

Torne Bridge
Head [m]
2
0
-2
-4
-6
-8
Jun-68
Dec-73
May-79
Nov-84
May-90
Oct-95
Apr-01
Time
Modflow model
Field data
Original model


Tudworth Hall
Head [m]
7
5
3
1
-1
-3
Jun-68
Dec-73
May-79
Nov-84
May-90
Oct-95
Apr-01
Time
Modflow model
Field data
Original model


Tyrham Hall Motel
Head [m]
4
2
0
-2
-4
-6
-8
-10
Jun-68
Dec-73
May-79
Nov-84
May-90
Oct-95
Apr-01
Time
Modflow model
Original model


Warning Tongue Lane
Head [m]
4
2
0
-2
-4
-6
-8
Jun-68
Dec-73
May-79
Nov-84
May-90
Oct-95
Apr-01
Time
Modflow model
Original model


Woodhouse Grange
Head [m]
7
5
3
1
-1
-3
Jun-68
Dec-73
May-79
Nov-84
May-90
Oct-95
Apr-01
Time
Modflow model
Field data
Original model


Pincheon Green
Head [m]
7
5
3
1
-1
-3
-5
Jun-68
Dec-73
May-79
Nov-84
May-90
Oct-95
Apr-01
Time
Modflow model
Original model

Appendix 2 Input data to original model

Storage coefficient (*1000)

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53
4	-99	-99	-99	-99	-99	-99	-99	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	-99	-99	-99	-99	-99	-99	-99	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	-99	-99	-99	-99	-99	-99	-99	-99	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	-99	-99	-99	-99	-99	-99	-99	-99	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	-99	-99	-99	-99	-99	-99	-99	-99	1	1	1	1	1	1	1	1	1	1	1	150	150	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	-99	-99	-99	-99	-99	-99	-99	1	1	1	1	1	1	1	1	1	1	1	1	1	150	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	-99	-99	-99	-99	-99	-99	1	1	1	1	1	1	1	1	150	150	150	1	1	1	150	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	-99	-99	-99	-99	-99	-99	-99	1	1	1	1	1	150	150	150	150	150	1	150	150	150	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	-99	-99	-99	-99	-99	-99	1	1	1	1	1	1	150	150	150	150	150	150	150	150	150	150	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	-99	-99	-99	-99	-99	-99	1	1	1	1	1	1	1	150	150	150	150	150	150	150	150	150	150	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	-99	-99	-99	-99	-99	-99	-99	150	1	1	1	1	150	150	150	150	150	150	250	250	250	150	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	-99	-99	-99	-99	-99	-99	-99	150	150	150	1	150	150	150	150	150	150	150	150	250	250	150	250	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	-99	-99	-99	-99	-99	-99	-99	150	150	1	1	150	150	150	150	150	1	150	250	250	250	1	250	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	-99	-99	-99	-99	-99	-99	-99	150	1	1	150	250	150	250	150	150	150	250	150	150	250	1	250	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	-99	-99	-99	-99	-99	-99	-99	150	1	150	150	150	150	150	150	150	150	150	150	150	150	250	150	150	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	-99	-99	-99	-99	-99	-99	-99	-99	150	150	150	150	150	150	150	150	150	150	150	150	250	250	250	250	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	-99	-99	-99	-99	-99	-99	-99	-99	150	0	0	150	150	150	150	150	150	150	150	250	250	250	150	150	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	-99	-99	-99	-99	-99	-99	-99	150	150	1	1	150	250	250	150	150	250	250	150	150	250	150	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	-99	-99	-99	-99	-99	-99	150	150	-99	-99	1	1	150	150	150	150	150	150	150	150	150	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	-99	-99	-99	-99	-99	-99	150	-99	-99	-99	1	150	150	150	150	150	150	150	150	150	150	150	150	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	150	150	150	150	150	150	150	150	150	150	150	150	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	-99	-99	-99	-99	-99	-99	-99	-99	-99	150	150	150	150	150	150	150	150	150	150	150	150	150	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	-99	-99	-99	-99	-99	-99	-99	-99	-99	150	150	150	150	150	150	150	150	150	150	150	150	150	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	150	150	150	150	150	150	150	150	150	150	150	150	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	150	150	150	150	150	150	150	150	150	150	150	150	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	150	150	150	150	150	150	150	150	150	150	150	150	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	150	150	150	150	150	150	150	150	150	150	150	150	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	150	150	150	150	150	150	150	150	150	150	150	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	150	150	150	150	150	150	150	150	150	150	150	150	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Transmissivity (m2/d/10)

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53
4	-99	-99	-99	-99	-99	-99	-99	5	15	15	15	25	25	30	30	35	50	50	50	55	55	55	55	55	55	55	55	40	40	15	10	10	10	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
5	-99	-99	-99	-99	-99	-99	-99	3	15	15	15	25	25	30	30	35	50	50	50	55	55	55	55	55	55	55	55	40	40	15	10	10	10	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
6	-99	-99	-99	-99	-99	-99	-99	-99	3	15	15	15	25	25	30	30	35	50	50	50	55	55	55	55	55	55	55	40	40	15	10	10	10	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
7	-99	-99	-99	-99	-99	-99	-99	-99	3	15	15	15	25	25	30	30	35	50	50	50	55	55	55	55	55	55	55	40	40	15	10	10	10	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
8	-99	-99	-99	-99	-99	-99	-99	-99	5	15	15	15	25	25	30	30	35	50	50	50	55	55	55	55	55	55	55	40	40	15	10	10	10	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
9	-99	-99	-99	-99	-99	-99	-99	5	15	15	15	15	25	25	25	30	30	35	50	50	55	55	55	55	55	55	55	40	40	15	10	10	10	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
10	-99	-99	-99	-99	-99	-99	3	5	15	15	25	25	25	25	25	25	30	30	50	50	50	55	55	55	55	55	55	40	40	15	10	10	10	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
11	-99	-99	-99	-99	-99	-99	-99	5	15	15	25	25	25	25	25	25	30	50	50	50	50	55	55	55	55	55	55	40	40	15	10	10	10	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
12	-99	-99	-99	-99	-99	-99	3	10	15	15	15	25	25	25	25	25	30	30	50	50	50	55	55	55	55	55	55	40	40	15	10	10	10	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
13	-99	-99	-99	-99	-99	-99	3	10	15	15	15	25	25	25	30	30	30	30	50	50	50	55	55	55	55	55	55	40	40	15	10	10	10	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
14	-99	-99	-99	-99	-99	-99	-99	3	5	15	15	15	25	5	10	15	30	35	50	50	50	55	55	55	55	55	55	40	40	15	10	10	10	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
15	-99	-99	-99	-99	-99	-99	-99	3	5	15	15	25	25	25	30	30	15	15	50	50	50	55	55	55	55	55	55	40	40	15	10	10	10	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
16	-99	-99	-99	-99	-99	-99	-99	3	5	15	15	25	15	25	30	30	35	50	15	50	50	55	55	55	55	40	40	40	40	15	10	10	10	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
17	-99	-99	-99	-99	-99	-99	-99	3	15	15	15	25	25	15	30	30	35	50	50	50	55	55	55	55	55	40	40	40	40	15	10	10	10	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
18	-99	-99	-99	-99	-99	-99	-99	3	3	15	15	15	25	30	25	25	50	50	50	50	55	55	55	55	55	40	40	15	15	15	10	10	10	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
19	-99	-99	-99	-99	-99	-99	-99	-99	5	10	15	15	15	25	30	30	30	50	50	50	55	55	55	55	55	40	40	15	15	10	10	10	10	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
20	-99	-99	-99	-99	-99	-99	-99	-99	5	10	15	15	15	25	30	30	50	50	50	50	55	55	55	55	55	40	40	15	15	10	10	10	10	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
21	-99	-99	-99	-99	-99	-99	-99	3	3	3	5	10	15	15	30	30	30	50	50	50	55	55	55	55	40	40	40	15	15	10	10	10	10	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
22	-99	-99	-99	-99	-99	-99	3	3	-99	-99	5	10	15	25	30	30	35	50	50	55	55	55	55	40	40	40	40	15	15	10	10	10	10	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
23	-99	-99	-99	-99	-99	-99	3	-99	-99	-99	5	15	15	30	30	35	50	50	50	55	55	55	55	40	40	40	15	15	15	10	10	10	10	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
24	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	5	15	15	25	30	30	50	50	50	55	55	55	40	40	40	40	15	15	15	10	10	10	10	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
25	-99	-99	-99	-99	-99	-99	-99	-99	-99	3	5	15	15	25	30	30	50	50	50	55	55	55	40	40	40	40	15	15	15	10	10	10	10	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
26	-99	-99	-99	-99	-99	-99	-99	-99	-99	3	5	15	15	25	25	30	30	50	50	50	55	55	40	40	40	40	15	15	15	10	10	10	10	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
27	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	3	5	15	15	25	30	30	50	50	50	55	55	55	40	40	40	15	15	15	10	10	10	10	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
28	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	3	5	15	15	25	30	30	50	50	50	55	55	55	40	40	40	15	15	15	10	10	10	10	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
29	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	3	5	15	15	25	30	30	50	50	50	55	55	55	40	40	40	15	15	15	10	10	10	10	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
30	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	3	5	10	15	15	25	30	35	50	50	55	55	40	40	40	40	15	15	15	10	10	10	10	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
31	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	3	5	15	15	25	30	35	50	50	55	55	40	40	40	40	15	15	15	10	10	10	10	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
32	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	3	5	10	15	15	25	30	35	50	50	55	55	40	40	40	40	15	15	15	10	10	10	10	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4

Head in overlying stratum for leakage nodes (mAOD)

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53
4	-99	-99	-99	-99	-99	-99	-99	5	4	4	4	4	3	3	3	3	3	2	1	3	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	-99	-99	-99	-99	-99	-99	-99	4	4	4	4	4	3	2	2	2	2	1	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	-99	-99	-99	-99	-99	-99	-99	-99	4	4	4	3	3	3	2	2	2	2	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	-99	-99	-99	-99	-99	-99	-99	-99	3	4	4	3	3	3	3	3	3	3	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	-99	-99	-99	-99	-99	-99	-99	-99	4	4	4	4	3	3	4	3	3	3	3	-88	-88	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	-99	-99	-99	-99	-99	-99	-99	8	3	4	4	4	4	4	4	3	2	3	2	2	-88	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	-99	-99	-99	-99	-99	-99	7	3	3	4	4	4	4	4	-88	-88	-88	1	1	1	-88	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	-99	-99	-99	-99	-99	-99	-99	3	3	4	4	4	-88	-88	-88	-88	-88	1	-88	-88	-88	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	-99	-99	-99	-99	-99	-99	3	3	2	3	3	4	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	-99	-99	-99	-99	-99	-99	3	2	4	3	4	4	4	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	-99	-99	-99	-99	-99	-99	-99	-88	4	4	4	4	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	-99	-99	-99	-99	-99	-99	-99	-88	-88	-88	4	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	-99	-99	-99	-99	-99	-99	-99	-88	-88	4	3	-88	-88	-88	-88	-88	0	-88	-88	-88	-88	1	-88	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	-99	-99	-99	-99	-99	-99	-99	-88	3	4	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	1	-88	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	-99	-99	-99	-99	-99	-99	-99	-88	3	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	-99	-99	-99	-99	-99	-99	-99	-99	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	-99	-99	-99	-99	-99	-99	-99	-99	-88	1	1	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	-99	-99	-99	-99	-99	-99	-99	-88	-88	1	1	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	-99	-99	-99	-99	-99	-99	-88	-88	-99	-99	1	1	-88	-88	-88	-88	-88	-88	-88	-88	-88	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	-99	-99	-99	-99	-99	-99	-88	-99	-99	-99	1	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	-99	-99	-99	-99	-99	-99	-99	-99	-99	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	-99	-99	-99	-99	-99	-99	-99	-99	-99	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
32	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10

Thickness of overlying stratum (m/10)

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53
4	-99	-99	-99	-99	-99	-99	-99	0	0	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	4	5	5	5	8	8	13	15	15	18	18	20	20	23	25	25	28	30	35	35	40	45	50	50	50
5	-99	-99	-99	-99	-99	-99	-99	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	4	5	5	5	8	8	13	15	15	18	18	20	20	23	25	25	28	30	35	35	40	45	50	50	50
6	-99	-99	-99	-99	-99	-99	-99	-99	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	4	5	5	5	8	8	13	15	15	18	18	20	20	23	25	25	28	30	35	35	40	45	50	50	50
7	-99	-99	-99	-99	-99	-99	-99	-99	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	4	5	5	5	8	8	13	13	15	18	18	20	20	23	25	25	28	30	35	35	40	45	50	50	50
8	-99	-99	-99	-99	-99	-99	-99	-99	0	1	1	1	1	1	0	0	1	1	1	-88	-88	1	1	1	0	1	0	4	5	5	5	8	8	13	13	15	18	18	20	20	23	25	25	28	30	35	35	40	45	50	50	50
9	-99	-99	-99	-99	-99	-99	-99	0	0	1	0	0	0	0	1	1	1	0	1	1	-88	1	1	1	1	1	1	2	4	5	8	8	10	13	13	15	18	18	20	20	23	25	25	28	30	35	35	40	45	50	50	50
10	-99	-99	-99	-99	-99	-99	1	1	1	0	0	0	1	0	-88	-88	-88	1	1	1	-88	1	1	1	1	1	1	2	4	5	8	8	10	13	13	15	18	18	20	20	23	25	25	28	30	35	35	40	45	50	50	50
11	-99	-99	-99	-99	-99	-99	-99	1	1	0	0	1	-88	-88	-88	-88	-88	1	-88	-88	-88	1	1	1	1	1	0	2	4	5	8	8	10	13	13	15	18	18	20	20	23	25	25	28	30	35	35	40	45	50	50	50
12	-99	-99	-99	-99	-99	-99	1	1	1	1	1	1	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	1	1	1	1	1	2	4	5	8	8	10	13	13	15	18	20	20	23	23	25	25	28	30	35	35	40	45	50	50	50
13	-99	-99	-99	-99	-99	-99	1	0	0	0	0	0	0	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	2	1	1	1	2	4	5	8	8	10	13	15	18	18	20	23	23	25	25	28	30	30	35	35	40	45	50	50	50
14	-99	-99	-99	-99	-99	-99	-99	-88	0	0	0	1	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	1	1	1	1	1	2	4	5	8	10	10	13	15	18	18	20	23	25	25	28	30	30	30	35	35	40	45	50	50	50
15	-99	-99	-99	-99	-99	-99	-99	-88	-88	-88	0	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	1	1	1	0	4	5	8	10	10	13	13	15	18	20	20	23	25	28	30	30	30	30	35	35	40	45	50	50	50
16	-99	-99	-99	-99	-99	-99	-99	-88	-88	0	1	-88	-88	-88	-88	-88	0	-88	-88	-88	-88	1	-88	1	1	2	3	5	5	8	10	10	13	13	15	18	20	20	23	25	28	30	30	30	35	35	35	40	45	50	50	50
17	-99	-99	-99	-99	-99	-99	-99	-88	1	1	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	1	-88	1	1	2	4	5	5	8	10	10	13	13	15	18	20	20	23	25	28	30	30	30	35	35	35	40	45	50	50	50
18	-99	-99	-99	-99	-99	-99	-99	-88	1	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	1	1	4	5	5	8	10	13	13	13	15	18	20	23	23	25	28	30	30	30	35	35	35	40	45	50	50	50
19	-99	-99	-99	-99	-99	-99	-99	-99	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	1	2	4	5	8	8	10	13	13	15	18	20	23	23	25	25	28	30	30	35	35	35	35	40	45	50	50	50
20	-99	-99	-99	-99	-99	-99	-99	-99	-88	0	0	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	1	2	4	5	8	10	10	13	15	18	20	20	23	23	25	28	28	30	30	35	35	35	35	40	45	50	50	50
21	-99	-99	-99	-99	-99	-99	-99	-88	-88	0	0	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	0	0	2	3	4	5	8	10	13	13	15	18	20	20	23	23	25	28	28	30	30	35	35	35	35	40	45	50	50	50
22	-99	-99	-99	-99	-99	-99	-88	-88	-99	-99	0	0	-88	-88	-88	-88	-88	-88	-88	-88	-88	0	0	2	2	2	4	5	8	10	13	13	15	18	20	20	23	23	25	28	30	30	30	35	35	35	35	40	45	50	50	50
23	-99	-99	-99	-99	-99	-99	-88	-99	-99	-99	0	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	2	2	3	4	5	8	10	13	13	15	18	20	20	23	23	25	28	30	30	35	35	35	35	35	40	45	50	50	50
24	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	2	2	3	4	5	8	8	10	13	15	15	18	23	23	25	28	30	25	30	35	35	35	35	35	35	40	45	50	50	50
25	-99	-99	-99	-99	-99	-99	-99	-99	-99	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	2	3	4	5	8	8	10	10	13	15	15	18	18	20	23	23	25	28	30	35	35	35	35	35	35	40	45	50	50	50
26	-99	-99	-99	-99	-99	-99	-99	-99	-99	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	2	3	4	5	8	8	10	10	13	15	15	18	18	20	23	23	25	28	30	35	35	35	35	35	35	40	45	50	50	50
27	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	1	2	4	5	8	8	10	10	13	15	15	18	18	20	23	23	25	28	30	35	35	35	35	35	35	40	45	50	50	50
28	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	1	2	4	5	8	8	10	10	13	15	15	18	18	20	23	25	25	28	30	35	35	35	35	35	35	40	45	50	50	50
29	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	1	2	4	5	8	8	10	10	13	15	15	18	18	20	23	25	25	28	30	35	35	35	35	35	35	40	45	50	50	50
30	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	2	3	3	5	8	10	13	13	15	15	18	18	20	23	25	25	25	28	30	30	35	35	35	35	35	40	45	50	50	50
31	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	2	2	3	5	10	13	13	13	15	18	18	20	23	23	25	25	28	28	30	30	30	35	35	35	35	40	45	50	50	50
32	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	1	1	3	5	10	13	13	13	15	18	18	20	23	25	25	25	28	28	30	30	30	35	35	35	35	40	45	50	50	50

Leakage - Vertical hydraullic conductivity (m/d*100)

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53
4	-99	-99	-99	-99	-99	-99	-99	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	9	9	9	9	9	9	9	9	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	-99	-99	-99	-99	-99	-99	-99	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	9	9	9	9	9	9	9	9	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	-99	-99	-99	-99	-99	-99	-99	-99	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	9	9	9	9	9	9	9	9	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	-99	-99	-99	-99	-99	-99	-99	-99	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	9	9	9	9	9	9	9	9	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	-99	-99	-99	-99	-99	-99	-99	-99	11	11	11	11	11	11	11	11	11	11	11	-88	-88	11	11	11	11	11	11	9	9	9	9	9	9	9	9	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	-99	-99	-99	-99	-99	-99	-99	11	11	11	11	11	11	11	20	20	20	20	20	20	-88	11	11	11	11	11	11	9	9	9	9	9	9	9	9	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	-99	-99	-99	-99	-99	-99	11	11	11	11	11	20	20	20	-88	-88	-88	20	20	20	-88	11	11	11	11	11	11	9	9	9	9	9	9	9	9	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	-99	-99	-99	-99	-99	-99	-99	11	11	11	11	20	-88	-88	-88	-88	-88	20	-88	-88	-88	20	20	20	20	20	11	9	9	9	9	9	9	9	9	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	-99	-99	-99	-99	-99	-99	11	11	11	11	11	20	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	20	20	20	20	11	9	9	9	9	9	9	9	9	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	-99	-99	-99	-99	-99	-99	11	11	11	11	11	20	20	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	20	20	20	11	9	9	9	9	9	9	9	9	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	-99	-99	-99	-99	-99	-99	-99	-88	11	11	11	20	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	200	11	20	20	11	9	9	9	9	9	9	9	9	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	-99	-99	-99	-99	-99	-99	-99	-88	-88	-88	20	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	200	11	9	11	9	9	9	9	9	9	9	9	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	-99	-99	-99	-99	-99	-99	-99	-88	-88	20	20	-88	-88	-88	-88	-88	200	-88	-88	-88	-88	200	-88	200	11	9	9	9	9	9	9	9	9	9	9	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	-99	-99	-99	-99	-99	-99	-99	-88	20	20	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	200	-88	200	11	9	9	9	9	9	9	9	9	9	9	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	-99	-99	-99	-99	-99	-99	-99	-88	20	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	20	20	9	9	9	9	9	9	9	9	9	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	-99	-99	-99	-99	-99	-99	-99	-99	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	20	9	9	9	9	9	9	9	9	9	9	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	-99	-99	-99	-99	-99	-99	-99	-99	-88	20	20	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	10	9	9	9	9	9	9	9	9	9	9	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	-99	-99	-99	-99	-99	-99	-99	-88	-88	20	20	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	200	11	9	9	9	9	9	9	9	9	9	9	9	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	-99	-99	-99	-99	-99	-99	-88	-88	-99	-99	20	20	-88	-88	-88	-88	-88	-88	-88	-88	-88	200	11	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	0	0	0	0	0	0	0	0	0	0	0
23	-99	-99	-99	-99	-99	-99	-88	-99	-99	-99	20	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	0	0	0	0	0	0	0	0	0	0	0
24	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	0	0	0	0	0	0	0	0	0	0	0
25	-99	-99	-99	-99	-99	-99	-99	-99	-99	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	0	0	0	0	0	0	0	0	0	0	0
26	-99	-99	-99	-99	-99	-99	-99	-99	-99	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	0	0	0	0	0	0	0	0	0	0	0
27	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	20	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	0	0	0	0	0	0	0	0	0	0	0
28	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	20	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	0	0	0	0	0	0	0	0	0	0	0
29	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	20	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	0	0	0	0	0	0	0	0	0	0	0
30	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	0	0	0	0	0	0	0	0	0	0	0
31	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	0	0	0	0	0	0	0	0	0	0	0
32	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	0	0	0	0	0	0	0	0	0	0	0

Cross boundary flows Ml/d

(abstract from water balance)

Time	Northern boundary flow	Western boundary flow	Southern boundary flow
69-70	0.000	0.010	3.704
70-71	-0.240	0.010	3.189
71-72	-0.430	0.010	2.857
72-73	-0.670	0.010	2.264
73-74	-0.850	0.010	1.748
74-75	-1.040	0.010	2.851
75-76	-1.280	0.010	3.310
76-77	-1.520	0.010	3.042
77-78	-1.700	0.010	2.713
78-79	-1.950	0.010	2.454
79-80	-2.120	0.010	2.256
80-81	-2.320	0.010	1.801
81-82	-2.550	0.010	2.410
82-83	-2.790	0.010	3.402
83-84	-2.980	0.010	3.603
84-85	-3.220	0.010	0.963
85-86	-3.400	0.010	-0.148
86-87	-3.590	0.010	-0.016
87-88	-3.830	0.010	0.427
88-89	-4.070	0.010	0.712
89-90	-4.250	0.010	1.080
90-91	-4.500	0.010	0.393
91-92	-4.750	0.010	0.144
92-93	-4.750	0.010	1.467
93-94	-4.750	0.010	1.653
94-95	-4.750	0.010	0.353
95-96	-4.750	0.010	-0.428
96-97	-4.750	0.010	-0.671

Nodal outflows (Ml/d) -ve implies flow out of model domain to the north

GRID	REF	I	J	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
590	180	12	4	0.00	-0.01	-0.02	-0.03	-0.03	-0.04	-0.05	-0.06	-0.07	-0.08	-0.08	-0.09	-0.10	-0.11	-0.12	-0.13	-0.13	-0.14	-0.15	-0.16	-0.17	-0.18	-0.18	-0.18	-0.18	-0.18	-0.18	-0.18
600	180	13	4	0.00	-0.01	-0.02	-0.03	-0.03	-0.04	-0.05	-0.06	-0.07	-0.08	-0.08	-0.09	-0.10	-0.11	-0.12	-0.13	-0.13	-0.14	-0.15	-0.16	-0.17	-0.18	-0.18	-0.18	-0.18	-0.18	-0.18	-0.18
610	180	14	4	0.00	-0.02	-0.03	-0.05	-0.07	-0.08	-0.10	-0.12	-0.13	-0.15	-0.17	-0.18	-0.20	-0.22	-0.23	-0.25	-0.27	-0.28	-0.30	-0.32	-0.33	-0.35	-0.38	-0.38	-0.38	-0.38	-0.38	-0.38
620	180	15	4	0.00	-0.03	-0.07	-0.10	-0.13	-0.17	-0.20	-0.23	-0.27	-0.30	-0.33	-0.37	-0.40	-0.43	-0.47	-0.50	-0.53	-0.57	-0.60	-0.63	-0.67	-0.70	-0.74	-0.74	-0.74	-0.74	-0.74	-0.74
630	180	16	4	0.00	-0.03	-0.05	-0.08	-0.10	-0.13	-0.15	-0.18	-0.20	-0.23	-0.25	-0.28	-0.30	-0.33	-0.35	-0.38	-0.40	-0.43	-0.45	-0.48	-0.50	-0.53	-0.56	-0.56	-0.56	-0.56	-0.56	-0.56
640	180	17	4	0.00	-0.02	-0.03	-0.05	-0.07	-0.08	-0.10	-0.12	-0.13	-0.15	-0.17	-0.18	-0.20	-0.22	-0.23	-0.25	-0.27	-0.28	-0.30	-0.32	-0.33	-0.35	-0.38	-0.38	-0.38	-0.38	-0.38	-0.38
650	180	18	4	0.00	-0.02	-0.03	-0.05	-0.07	-0.08	-0.10	-0.12	-0.13	-0.15	-0.17	-0.18	-0.20	-0.22	-0.23	-0.25	-0.27	-0.28	-0.30	-0.32	-0.33	-0.35	-0.38	-0.38	-0.38	-0.38	-0.38	-0.38
660	180	19	4	0.00	-0.02	-0.03	-0.05	-0.07	-0.08	-0.10	-0.12	-0.13	-0.15	-0.17	-0.18	-0.20	-0.22	-0.23	-0.25	-0.27	-0.28	-0.30	-0.32	-0.33	-0.35	-0.38	-0.38	-0.38	-0.38	-0.38	-0.38
670	180	20	4	0.00	-0.02	-0.03	-0.05	-0.07	-0.08	-0.10	-0.12	-0.13	-0.15	-0.17	-0.18	-0.20	-0.22	-0.23	-0.25	-0.27	-0.28	-0.30	-0.32	-0.33	-0.35	-0.38	-0.38	-0.38	-0.38	-0.38	-0.38
680	180	21	4	0.00	-0.02	-0.03	-0.05	-0.07	-0.08	-0.10	-0.12	-0.13	-0.15	-0.17	-0.18	-0.20	-0.22	-0.23	-0.25	-0.27	-0.28	-0.30	-0.32	-0.33	-0.35	-0.38	-0.38	-0.38	-0.38	-0.38	-0.38
690	180	22	4	0.00	-0.01	-0.02	-0.03	-0.03	-0.04	-0.05	-0.06	-0.07	-0.08	-0.08	-0.09	-0.10	-0.11	-0.12	-0.13	-0.13	-0.14	-0.15	-0.16	-0.17	-0.18	-0.18	-0.18	-0.18	-0.18	-0.18	-0.18
700	180	23	4	0.00	-0.01	-0.02	-0.03	-0.03	-0.04	-0.05	-0.06	-0.07	-0.08	-0.08	-0.09	-0.10	-0.11	-0.12	-0.13	-0.13	-0.14	-0.15	-0.16	-0.17	-0.18	-0.18	-0.18	-0.18	-0.18	-0.18	-0.18
710	180	24	4	0.00	-0.01	-0.02	-0.03	-0.03	-0.04	-0.05	-0.06	-0.07	-0.08	-0.08	-0.09	-0.10	-0.11	-0.12	-0.13	-0.13	-0.14	-0.15	-0.16	-0.17	-0.18	-0.18	-0.18	-0.18	-0.18	-0.18	-0.18
720	180	25	4	0.00	-0.01	-0.02	-0.03	-0.03	-0.04	-0.05	-0.06	-0.07	-0.08	-0.08	-0.09	-0.10	-0.11	-0.12	-0.13	-0.13	-0.14	-0.15	-0.16	-0.17	-0.18	-0.18	-0.18	-0.18	-0.18	-0.18	-0.18
730	180	26	4	0.00	0.00	-0.01	-0.01	-0.02	-0.02	-0.03	-0.03	-0.03	-0.04	-0.04	-0.05	-0.05	-0.05	-0.06	-0.06	-0.07	-0.07	-0.08	-0.08	-0.08	-0.09	-0.09	-0.09	-0.09	-0.09	-0.09	-0.09

Urban Leakage

2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0
5	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0
6	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0
7	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0
8	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	114.4	114.4	1	1	1	1	1	1	0	0	0	0
9	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	114.4	1	1	1	1	1	1	0	0	0	0
10	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	114.4	1	1	1	1	1	1	0	0	0	0
11	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0
12	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	17.3	17.3	1	1	1	1	1	1	1	1	1	0	0	0	0
13	0	0	0	0	0	0	1	1	1	1	1	1	42.8	42.8	1	1	17.3	17.3	17.3	17.3	1	1	1	1	1	1	1	0	0	0	0
14	0	0	0	0	0	0	0	1	33.8	1	1	1	42.8	42.8	1	17.3	17.3	17.3	17.3	1	1	1	1	1	1	1	1	0	0	0	0
15	0	0	0	0	0	0	0	1	33.8	1	1	1	42.8	42.8	1	1	1	1	1	1	1	1	1	1	1	0	1	0	0	0	0
16	0	0	0	0	0	0	0	1	33.8	1	42.8	42.8	42.8	42.8	42.8	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
17	0	0	0	0	0	0	0	1	33.8	1	42.8	42.8	42.8	42.8	42.8	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
18	0	0	0	0	0	0	0	1	1	42.8	42.8	42.8	1	42.8	42.8	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0
19	0	0	0	0	0	0	0	0	42.8	42.8	42.8	42.8	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	42.8	42.8	42.8	26.9	26.9	26.9	1	15.1	15.1	1	1	4.3	1	1	1	1	1	0	0	0	0	0	0
21	0	0	0	0	0	0	0	1	42.8	1	1	26.9	26.9	26.9	1	15.1	15.1	1	4.3	4.3	1	1	1	1	0	0	0	0	0	0	0
22	0	0	0	0	0	0	1	1	0	0	1	1	1	26.9	1	4.3	4.3	4.3	4.3	1	1	1	1	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	1	0	0	0	1	1	26.9	1	1	4.3	4.3	4.3	1	1	1	1	1	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	1	1	26.9	26.9	1	1	1	4.3	1	1	1	1	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	3.5	3.5	1	1	1	1	1	1	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	3.5	3.5	1	1	1	1	1	1	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	1	12	12	12	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	0	0	12	12	12	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	0	12	12	12	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0

Stream parameterisation - see P81, 82 of Brown & Rushton

River	I	J	River coefficient (m3/d/km)	Stream bed level (maod)
Torne	13	31	300	10.5
	12	30	300	11.6
	13	30	300	10
	14	30	300	9.5
	14	29	300	9
	14	28	300	8.5
	14	27	300	8
	14	26	300	7.5
	14	25	300	7
	13	25	300	6.3
	13	24	50	5.6
	13	23	50	5
	14	23	500	4.6
	15	23	500	4.3
	16	22	1000	4
	17	21	1200	3.6
	18	20	800	3.2
	19	20	800	2.8
Doncaster Drainage	20	11	10	2
Channels	21	11	10	-0.5
	22	11	10	-0.5
	21	12	10	-0.5
	22	12	10	-0.5
	23	12	10	-0.5
	23	13	10	-0.5
	24	13	10	-0.5
	21	14	600	-0.5
	17	15	1000	-0.5
	18	15	1000	-0.5
	20	15	500	1
	20	16	800	1
	19	17	800	-0.5
	20	17	800	-0.5
	22	13	10	-0.5
	21	18	200	-0.5
	22	18	200	-0.5
	23	18	400	-0.5
	24	18	400	-0.5
	25	18	400	-0.5
	20	19	600	-0.5
	21	19	600	-0.5
	22	19	500	-0.5
	23	19	400	-0.5
	24	19	450	3
	25	19	450	-0.5
	20	20	400	-0.5
	21	20	550	-0.5
	23	20	500	-0.5
	24	20	400	-0.5
	25	20	400	-0.5
	19	21	700	-0.5
	20	21	700	-0.5
	21	21	700	-0.5
	22	21	450	-0.5
	23	21	450	-0.5

Water balances - EA management units - YEARLY AVERAGE BALANCES in Ml/d

See gwunits.shp for location of Hatfield and Blyth units

	Model area to north of Hatfield unit to northern boundary of model											Hatfield unit										
Time	Prec Rec	Urban Re	Unc Stora	Con Stora	Abstracti	River Torr	Drainage	North Flo	Drift	Mercia M	South Flo	Prec Rech	Urban Re	Unc Storag	Con Stora	Abstractior	River Torr	Drainage	Specified	Drift	Mercia M	CBF
69-70	12.541	1.660	-5.979	-0.037	-5.060	0.000	0.000	0.000	-1.848	-0.010	-1.269	100.032	4.610	-28.404	-0.060	-64.610	-3.121	-6.737	0.010	-6.211	-0.483	4.973
70-71	4.776	1.660	2.083	0.025	-5.280	0.000	0.000	-0.240	-1.713	-0.010	-1.298	50.518	4.610	16.913	0.034	-62.460	-2.613	-4.960	0.010	-6.053	-0.485	4.488
71-72	6.189	1.660	0.711	0.023	-5.700	0.000	0.000	-0.430	-1.298	-0.010	-1.149	60.288	4.610	7.763	0.021	-65.100	-2.090	-3.538	0.010	-5.514	-0.454	4.006
72-73	2.606	1.660	4.476	0.042	-6.060	0.000	0.000	-0.670	-0.690	-0.008	-1.359	27.649	4.610	36.136	0.252	-66.740	-0.870	-0.105	0.010	-4.194	-0.369	3.623
73-74	2.803	1.660	3.258	0.016	-4.840	0.000	0.000	-0.850	-0.375	-0.008	-1.663	29.718	4.610	31.115	0.283	-67.210	-0.238	1.708	0.010	-3.153	-0.251	3.411
74-75	4.796	1.660	1.173	0.035	-5.180	0.000	0.000	-1.040	0.124	0.000	-1.563	50.108	4.610	12.215	0.113	-69.920	-0.235	1.480	0.010	-2.617	-0.175	4.414
75-76	1.769	1.660	3.637	0.040	-4.740	0.000	0.000	-1.280	0.890	0.000	-1.974	18.208	4.610	34.769	0.065	-67.710	0.968	4.960	0.010	-1.049	-0.117	5.284
76-77	14.040	1.660	-7.680	-0.054	-4.590	0.000	0.000	-1.520	0.223	0.000	-2.077	121.920	4.610	-57.488	-0.148	-67.410	-1.318	-1.916	0.010	-3.201	-0.179	5.118
77-78	4.082	1.660	2.203	0.036	-4.530	0.000	0.000	-1.700	0.478	0.000	-2.226	43.103	4.610	21.597	0.203	-71.560	-0.614	0.331	0.010	-2.519	-0.098	4.938
78-79	10.366	1.660	-3.208	-0.008	-4.850	0.000	0.000	-1.950	0.527	0.000	-2.533	94.649	4.610	-24.421	0.020	-74.350	-1.230	-1.480	0.010	-2.723	-0.072	4.988
79-80	13.155	1.660	-5.197	-0.021	-5.150	0.000	0.000	-2.120	0.047	0.000	-2.372	113.947	4.610	-36.145	0.045	-75.290	-3.018	-4.938	0.010	-3.745	-0.098	4.628
80-81	9.585	1.660	-1.677	-0.005	-4.810	0.000	0.000	-2.320	-0.069	0.000	-2.363	84.800	4.610	-9.854	0.060	-72.480	-3.253	-4.248	0.010	-3.717	-0.093	4.164
81-82	3.419	1.660	1.942	0.035	-2.940	0.000	0.000	-2.550	0.167	0.000	-1.729	36.405	4.610	19.441	0.098	-56.790	-2.448	-2.437	0.010	-2.956	-0.072	4.139
82-83	6.547	1.660	0.475	-0.023	-3.500	0.000	0.000	-2.790	0.197	0.000	-2.562	65.708	4.610	2.824	-0.268	-73.520	-1.943	-0.613	0.010	-2.633	-0.136	5.963
83-84	4.663	1.660	1.680	0.011	-2.950	0.000	0.000	-2.980	0.268	0.000	-2.349	48.889	4.610	19.529	0.196	-75.440	-1.683	0.571	0.010	-2.533	-0.097	5.952
84-85	3.985	1.660	2.706	0.041	-3.920	0.000	0.000	-3.220	0.755	0.000	-2.005	41.788	4.610	28.798	0.160	-78.200	-0.902	2.613	0.010	-1.828	-0.018	2.968
85-86	5.171	1.660	1.203	0.013	-3.820	0.000	0.000	-3.400	1.251	0.000	-2.078	54.541	4.610	17.049	0.093	-81.390	-0.523	4.823	0.010	-1.174	0.031	1.930
86-87	6.446	1.660	1.419	0.017	-5.350	0.000	0.000	-3.590	1.517	0.000	-2.119	63.651	4.610	12.694	-0.025	-86.820	-0.688	5.596	0.010	-1.139	0.013	2.103
87-88	9.870	1.660	-2.031	-0.002	-4.820	0.000	0.000	-3.830	1.430	0.000	-2.277	81.222	4.610	-6.484	0.034	-84.060	-1.493	5.139	0.010	-1.703	0.024	2.703
88-89	0.223	1.660	6.071	0.036	-2.890	0.000	0.000	-4.070	1.963	0.000	-2.993	2.797	4.610	64.439	0.056	-85.920	0.340	9.765	0.010	0.152	0.055	3.704
89-90	4.344	1.660	2.823	0.058	-5.180	0.000	0.000	-4.250	3.009	0.000	-2.464	45.696	4.610	18.088	0.071	-84.170	0.633	10.453	0.010	0.963	0.108	3.544
90-91	3.395	1.660	3.491	0.066	-6.370	0.000	0.000	-4.500	4.009	0.004	-1.755	35.689	4.610	22.975	0.134	-79.930	1.068	11.198	0.010	1.921	0.179	2.148
91-92	0.432	1.660	4.700	0.024	-4.650	0.000	0.000	-4.750	4.660	0.010	-2.083	5.065	4.610	41.335	0.135	-71.990	2.222	12.734	0.010	3.409	0.248	2.227
92-93	4.150	1.660	1.135	-0.033	-3.490	0.000	0.000	-4.750	4.473	0.001	-3.148	43.328	4.610	4.380	0.035	-75.430	2.256	12.557	0.010	3.378	0.263	4.614
93-94	10.242	1.660	-6.561	-0.062	-1.160	0.000	0.000	-4.750	3.526	0.000	-2.896	89.870	4.610	-41.164	-0.099	-71.620	0.997	10.846	0.010	1.793	0.212	4.548
94-95	9.016	1.660	-5.274	-0.043	-0.470	0.000	0.000	-4.750	2.620	0.000	-2.763	83.323	4.610	-28.665	-0.063	-72.390	0.234	9.238	0.010	0.448	0.144	3.116
95-96	2.403	1.660	1.347	0.018	-0.440	0.000	0.000	-4.750	2.693	0.000	-2.929	25.456	4.610	24.004	0.100	-70.120	1.271	10.678	0.010	1.308	0.179	2.501
96-97	2.748	1.660	0.871	0.008	-0.450	0.000	0.000	-4.750	2.867	0.000	-2.957	29.514	4.610	14.501	0.052	-66.540	1.917	11.418	0.010	2.013	0.220	2.286
Average	5.849	1.660	0.350	0.009	-4.043	0.000	0.000	-2.779	1.132	-0.001	-2.177	55.281	4.610	7.784	0.057	-72.828	-0.585	3.398	0.010	-1.546	-0.054	3.874