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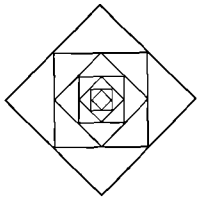

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A time-variant numerical groundwater flow model for the Øvre Romerike aquifer, Southern Norway.

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Using a modified version of the USGS MODFLOW code, coupled with a Penman-Grindley type recharge model, it has been possible to produce a transient, 3-dimensional groundwater flow model of the Øvre Romerike aquifer.

A steady state model has been calibrated against 183 regional water level observation data from autumn 1975 and against the flows in groundwater-fed springs and streams. The distribution of hydraulic conductivity calibrated using the steady state model was then used to simulate water table variations over a period in excess of 30 years at 3 observation wells. The results show a satisfactory fit with real data, allowing for the limited spatial resolution of the model. A seven-month running average filter has been applied to the recharge data to simulate the damping effects of the unsaturated zone on recharge maxima and minima, resulting in an even better fit.

The modelling work has enabled the project's participants to obtain a deeper understanding of the hydraulics of the aquifer, and has also indicated that hydraulic conductivity values obtained from grain size distributions tend to lead to underestimates of aquifer transmissivity. The model provides a framework for further modelling work on contaminant transport at Trandum landfill.

Emneord: Hydrogeologi	Grunnvann	Kornstørrelse
Miljøgeologi	Modellforsøk	Kornfordeling
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TABLE OF CONTENTS

1. Introduction 6
    1.1 Background 6
    1.2 Pollution threats 6
    1.3 Geology 7
    1.4 Hydrology 7
    1.5 Objective of modelling work 7

2. Physical characteristics of the Øvre Romerike aquifer 8
    2.1 The geological model and surface features 8
    2.2 Permeability data 10
    2.3 Storage data 11
    2.4 Recharge model 11
        2.4.1 The basic recharge model 11
        2.4.2 Use of snow data in the recharge model 15
        2.4.3 Results 17

3. Groundwater flow modelling 18
    3.1 MODFLOW 18
    3.2 Data preparation and the Graphical User Interface 18
    3.3 The grid and boundary conditions 19

4 The steady state model 20
    4.1 Calibration of the steady state model 20
    4.2 The permeability model 22

5 The transient model 24
    5.1 Modifications to MODFLOW 24
    5.2 Input to the transient model 25
    5.3 The transient model results and comparison with observations 26

6. Conclusion 27

7. Acknowledgements 28

8. References 29

TABLES

Table 1a - Calculation of recharge from real data from Gardermoen, autumn 1966.. 15

Table 1b - Calculation of infiltration when SMD is approximately equal to the root constant. Example from Rushton (1983). 16

Table 2 - Comparison of recharge model with empirical data. Annual averages for period 1968 - 1974. 17

Table 3 - Outflows from springs; modelled and observed 24

Table 4 - Observation wells with time-series data 26

FIGURES

Text Fig. 1. The assumed recharge model 12

Text Fig. 2. Actual change in soil moisture deficit, as a function of soil moisture content. 13

Fig.1(a) Øvre Romerike area showing Hurdalsjøen, Hersjøen, Transjøen, Dagsjøen, airport, Trandum, the rivers Risa, Leira, Vikka and flow gauging stations on the Risa and Vikka. 33
Fig.1(b) The water table in the Øvre Romerike aquifer, after Østmo (1976) 34

Fig.2(a) Photo of coarse layer at Trandum landfill showing fine and coarse intercalated layers 35
Fig.2(b) An interpretation of the structure of the Romerike delta, after VIAK (1990) 35

Fig.3(a) Contour map of topography 36
Fig.3(b) Contour map of top of fine layer 37
Fig.3(c) Contour map of base of aquifer 38

Fig.4(a) 3D ADVIZE visualisation of topography 39
Fig.4(b) 3D ADVIZE visualisation of top of fine layer 39
Fig.4(c) 3D ADVIZE visualisation of base of aquifer 40

Fig.5(a) Isopach map of the whole aquifer 41
Fig.5(b) Isopach map of the coarse layer 42
Fig.5(c) Isopach map of the fine layer 43

Fig.6 Calibration graph for hydraulic conductivity analysis from grain size samples 44

Fig.7 Polynomial curve, fit to calibration curve 44

Fig.8 Histogram of all hydraulic conductivity estimates (using the Bayer method - from d_{10} and d_{60} grain sizes) 45

Fig.9 Recharge model, (a) monthly data, (b) yearly data 46

Fig.10 Rasterised map example (topography) produced by GENAMAP 47

Fig.11 Example of the graphical user interface screen 48

Fig.12 MODFLOW grid for Øvre Romerike aquifer, with cells defined 49

Fig.13 Map of borehole locations for which measurements of head are available from Nov. 1975 (Østmo 1976). 50

Fig.14 MODFLOW, steady state model: homogeneous layer model - sensitivity of D (average error) to variation in hydraulic conductivity of coarse and fine layers. . . . 51

Fig.15 Histograms of discrepancies between steady state model and borehole data for: (a) homogeneous layer model, (b) calibrated hydraulic conductivity model 52

Fig.16 Resulting hydraulic conductivity field for fine layer after calibration with borehole data. 53

Fig.17 (a) MODFLOW steady state results for head. 54
Fig.17 (b) simplification of Østmo's (1976) map for comparison 55
Fig.17 (c) 3D ADVIZE picture of modelled water table with base of aquifer 56

Fig.18 Transient MODFLOW results, with steady state heads in fig.17(a) (i.e. recharge = $1.27*10^{-8}$ m/s) as initial heads: (a) using monthly recharge 57
(b) using running averages of monthly recharge over 7 month intervals 58

Fig.19 Transient MODFLOW results with steady state heads generated using calibrated hydraulic conductivity field (Fig.16) and recharge of $8.239*10^{-9}$ m/sec:
(a) using monthly recharge 59
(b) using running averages of monthly recharge over 7 month intervals 60

APPENDICES

APPENDIX 1 - Input files (basic package and block-centred flow package) for MODFLOW, steady state model 61

APPENDIX 2 - Input file (block-centred flow package) for MODFLOW, transient model 70

APPENDIX 3 - Elevations of drains, rivers and constant head cells. 79

APPENDIX 4 - Head difference between vertically adjacent cells in the two aquifer layers (steady state) 83

APPENDIX 5 - Deviations of modelled head (modelled - observed) in each cell 85

APPENDIX 6 - Output files from MODFLOW, flow to drains, rivers and constant head cells 90

APPENDIX 7 - Listing of recharge model 94

1. Introduction

1.1 Background

The Øvre Romerike aquifer is the largest discrete aquifer in Norway; in fact, one of the few areally extensive Quaternary aquifers in the country, covering an area of approximately 105 km^2 (Fig.1a). Due to increasingly stringent requirements as regards the quality of drinking water (SIFF 1987), and the corresponding recognition of the unsatisfactory quality of many surface waters, there is a growing interest in groundwater resources in Norway (Ellingsen & Banks 1992). NGU has recently completed both a nationwide survey of groundwater resources in the country (Ellingsen 1992) and a nationwide survey of landfills and contaminated ground (Misund et al. 1991a,b). The latter survey uncovered several contaminated sites which come into conflict with the groundwater resources of the Øvre Romerike aquifer (Morland et al. 1990). Many of the sites registered in this latter survey have been, or will be, followed up with detailed investigations of their impact on groundwater quality (Storrø & Banks 1992, Sæther et al. 1992, Omejer et al. 1992).

1.2 Pollution threats

Situated some 40 km north of Oslo, the proximity of the Øvre Romerike aquifer to Norway's most populated and industrialised region has led to increased interest in the aquifer as a potential source of water. At present, however, the aquifer is utilized to only a few percent of its potential (Bryn 1992), supplying several military bases situated on the aquifer, and some small local communities. Nevertheless, there has already been considerable controversy arising from the conflicting interests of industry/the military and those who wish to preserve groundwater quality. Authorities have placed emphasis on protecting the quality of the groundwater in the aquifer from "potentially polluting activities", as it represents a possible future water resource for municipalities in the Romerike area (Østlandskonsult et al. 1991) with a potential exploitable capacity of up to 570 l/s (Snekkerbakken 1992).

Most of the area is either forest or farmland. A limited degree of "urbanisation" (villages, airport) is concentrated on the southern part of the aquifer. Substantial areas of the aquifer are also occupied by military bases and training grounds.

Known sources of pollution to date on the Øvre Romerike aquifer include various military activities, a military and civil airport at Gardermoen (Davidsen 1991), two known leakages from oil storage tanks (Storrø & Banks 1992) and several landfill sites (Sæther et al. 1992, Omejer et al. 1992). Perhaps the greatest controversy surrounds the proposed removal of Oslo's main international airport (currently siuated at Fornebu, west of Oslo) to Gardermoen, on the aquifer (Englund & Moseid 1992, Solnørdal 1992).

1.3 Geology

The geology of the area is described in detail by Longva (1987). The Romerike aquifer consists of a ca. 105 km^2 expanse of Quaternary ice-marginal delta sediments built up to, and in some locations above, the marine limit. The upper part of the aquifer consists of dominantly glaciofluvial sand and gravel deposits, with areas of aeolian sand and glaciolacustrine sands and silts. These are underlain by glaciomarine/marine silts and clays. The upper, coarser part of the deposit exceeds 30-40 m thickness in some areas, while the total depth to bedrock (including marine silts and clays) may be as much as 100 m (Østmo 1976, Jørgensen & Østmo 1990).

The aquifer is bounded below by bedrocks of Precambrian age and to the south and west by marine clay sediments which have very low hydraulic conductivities. The delta top is relatively flat, lying at an altitude of around 200m above sea level and is surrounded by hills of outcropping basement rocks, except to the south and south west where the marine sediments form a lower lying plane at an altitude of around 150m. The Romerike deposit is believed to contain 150-200 million m^3 of good quality sand and gravel (Wolden & Erichsen 1990) and a number of pits have been excavated for this purpose throughout the area.

1.4 Hydrology

The main surface water drainage of the aquifer consists of the northwards-flowing River Risa and Hersjøen Lake. The river and lake are almost entirely groundwater-fed (Jørgensen & Østmo 1990, Hongve 1992).

There has been intense hydrogeological and hydrochemical investigation of the aquifer due to its selection as a study area for the International Hydrological Decade (Falkenmark 1972, Norwegian National Committee for IHD 1973, 1975). This has resulted in the publication of a hydrogeological map (Østmo 1976), and descriptions of the hydrogeology (Jørgensen & Østmo 1990) and hydrochemistry (Jørgensen et al. 1991). The aquifer is entirely fed by recharge from precipitation. Østmo's (1976) map (Fig.1b) indicates that the major central part of the aquifer drains towards Hersjøen and the River Risa. The average discharge in the River Risa (in the period 1967-74) was 0.85 m^3/s (Jørgensen & Østmo 1990). The marginal parts of the aquifer drain outwards towards springs in the periphery of the delta. Hydraulic and hydrochemical balances for the aquifer have been calculated. The permeability within the aquifer is believed to range between 5 m/d for coarse sands to 0.06 m/d for silts on the basis of particle-size distributions (Jørgensen & Østmo 1990).

1.5 Objective of modelling work

Groundwater flow modelling provides a quantitative tool that, when sufficient effort is invested in model calibration and verification, can be used to predict the short and long term effects of

varying recharge and groundwater abstraction. It can also provide a basis for further modelling of groundwater pollution incidents and their remediation, and can help in planning preventive action to maintain groundwater quality.

Modelling techniques are in common use in many countries that rely heavily on groundwater to supply domestic and industrial needs (e.g. Netherlands, Denmark, U.S.A.). Until relatively recently, water requirements in Norway were met almost solely from surface supplies, and as a result, competence in the area of groundwater modelling is at a rather low level compared with many other European countries and America.

Part of the aim of the project reported here has therefore been to help build modelling competence at the two participating institutions (Bergen Environmental Sciences and Solutions Centre [IBM/BSC] and the Geological Survey of Norway [NGU]).

The more concrete objective of the project has been to develop a three dimensional (or "2½ dimensional", since vertical discretization is limited to only two layers), time-dependent model of groundwater flow in the Øvre Romerike aquifer. This model has been constructed as a basis for a more detailed modelling study of the impact of a landfill site at Trandum, near the centre of the aquifer, on groundwater quality. The Trandum site lies in relatively close proximity to the Military's abstraction wells, has been investigated in detail by NGU (Misund & Sæther 1991, Sæther et al. 1992) and has produced an excellent set of hydrochemical data which lends itself to a more detailed hydro-chemical/-dynamic modelling attempt. This attempt will form the basis for a project application to the Norwegian Research Council, to be submitted in Spring 1993.

2. Physical characteristics of the Øvre Romerike aquifer

2.1 The geological model and surface features

NGU possesses large amounts of both geological and geophysical data from the Øvre Romerike area which have been used in the study. The main sources of data used to construct the geological model are:

i) Borehole data collected during the International Hydrological Decade (IHD). These data have been published by Misund & Banks (1993).

ii) Borehole data from groundwater contamination investigations at Trandum and Sessvollmoen (Storrø 1991, Banks 1991, Misund & Sæther 1991, Storrø & Banks 1992 and Sæther et al. 1992).

iii) Data collected in connection with the proposed Gardermoen main airport (NGI 1991).

iv) Seismic profiles run during the IHD; summarised on Østmo's (1976) map and by Longva (1987).

It is widely accepted that, although complex, the Romerike deposit is a generally fining-downwards glacio-fluvial and glacio-marine sequence (Longva 1987). In some boreholes, and most seismic profiles, it is possible to distinguish at least two distinct subdivisions or "layers"; an upper layer of medium-to-coarse sands and gravels and a lower layer of fine sand and silt grading down into clay. It must be pointed out that this is a considerable oversimplification; in the upper coarse section, wedges of fine sands and silt occur (Fig.2). In the silty layer recent investigations have indicated that several discrete sand horizons can be detected in the Gardermoen area, possibly associated with marginal spring horizons (Sønsterudbråten 1992).

VIAK (1990) have also constructed 3-D block diagrams which, even though they are based on a mixture of "enlightened guesswork" and real data, do illustrate the aquifer's considerable complexity (Fig.2b). However, because of the limited available data and the resolution possible in a numerical model, the aquifer structure chosen for modelling is simplified to two layers; a coarse-grained (high conductivity) upper layer and a finer (lower conductivity) lower layer.

The topography, rivers, roads and other prominent features were derived from 1:50 000 topographical maps of the Romerike area. The topography is taken to represent the top of the upper aquifer layer. Contour maps of the interface between the two layers and the aquifer base (top of bedrock or, where present, very low permeability marine clays/till) have been constructed, primarily from the seismic profiles and some borehole data, and thereafter digitised. Contour maps of the three layer interfaces are presented in Fig.3. Three-dimensional views of the geological model are shown in Fig.4.

The map of the aquifer base (Fig.3c) shows a deep channel lying under Hersjøen and the bed of the Risa river, and a deep basin in the south created by a channel in the bedrocks against which the marine sediments abut. The sediments of the aquifer essentially fill in this topography to produce the flat-lying topography of the delta top (Fig.3(a)). Isopach maps of the aquifer as a whole (Fig.5(a)) show that it is thickest where it fills in the deep basin in the south of the area (150m) and under Hersjøen (100m), and thinnest in the north, near Hurdalsjøen. Fig.5(b) and (c) show that the majority of the aquifer, as modelled, is composed primarily of the finer sediments with a relatively thin layer of coarse sediments laid on top. The coarse sediments

(Fig.5b) are thickest in the region of Hersjøen (up to 50m)[1] and virtually absent in the north-west of the area close to Hurdalsjøen.

2.2 Permeability data.

Using samples from the boreholes from sources i) to iii) above, grain size distributions have been analyzed at NGU. These distributions have been used to estimate hydraulic conductivity using the Bayer method (Langguth and Voigt 1980). In this method, the 10% and 60% (d_{10} and d_{60}) grain size fractions are used to estimate hydraulic conductivity, porosity and effective porosity from three calibration graphs (Fig.6a). These graphs can be described very adequately by 5th- to 7th-order polynomials. For example, for hydraulic conductivity, K:

$$C = a + b\log_{10}U + c(\log_{10}U)^2 + d(\log_{10}U)^3 + e(\log_{10}U)^4 + f(\log_{10}U)^5$$

: where $U = d_{60}/d_{10}$ and $K = C.d_{10}^2$ in m/s

A	1	0.120108904410752941E-01
B	2	-0.584932336100109015E-02
C	3	-0.511800227510852306E-03
D	4	0.515919309987529929E-02
E	5	-0.443467400175974902E-02
F	6	0.116482360824580501E-02

The fit of these polynomials to the calibration curves is shown in Fig.7. The polynomials have been entered into a spreadsheet to allow automatic calculation of the hydraulic parameters (Misund & Banks 1993).

In using these estimates of hydraulic conductivity, the limitations of the method and the quality of the data must be considered. The samples from the boreholes are of varying quality. The data from i) above are largely from sediment samples which have been rinsed up with drilling water, or pumped up through a slotted pipe, and are hence likely to be depleted in both fines and the coarsest fraction. Samples from ii) and iii) above are likely to be more representative. Boreholes under investigations ii) were sampled using a "throughflow" sampling device. Many of these considerations indicate that the estimations of hydraulic conductivity using this method are probably incorrect. However, they provide a useful starting point for modelling work, under the expectation that they will need to be adjusted during calibration. All hydraulic conductivity data were plotted on a histogram (Fig.8), and four main maxima were identified corresponding to clay, silt, fine sand and course sand/gravel.

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[1] Due to the relatively sparse input data, the structure contour maps include some smoothing of surfaces, thus excluding local variations. Due to the coarse grid-size used in the numerical model (500 x 500 m), the loss of information this represents is not regarded as problematic. In reality, however, greater thicknesses of coarse aquifer material have been penetrated in narrow zones near Transjøen and Hersjøen (Misund & Banks 1993) than are indicated by the geological model.

2.3 Storage data

Very few pumping tests have been carried out in the Øvre Romerike aquifer which have yielded reliable values of storage coefficients. The following values have thus been used, as indicated by Fetter (1988)

Course layer $S_Y = 0.25$, $S_s = 0.0003\ m^{-1}$

Fine layer $S_Y = 0.20$ $S_s = 0.0003\ m^{-1}$

2.4 Recharge model

2.4.1 The basic recharge model

There are several methods which can be used to assess recharge to an aquifer from precipitation. Two of the simpler methods which are often used are:

i) to assume that a fixed percentage (e.g. 30%-50%) of precipitation percolates down to the water table.
ii) calculation of soil moisture balance

"The soil moisture model" considers the soil zone as a reservoir which contains a certain amount of water (soil moisture). This quantity is typically quoted in mm (i.e. $m^3/1000\ m^2$).

The model assumes that percolation of water from the soil down to the water table only occurs if the soil is at "field capacity". If the soil is undersaturated with respect to field capacity, percolation will not occur. The degree of undersaturation with respect to field capacity is called the "soil moisture deficit" (SMD), and is expressed in mm.

In addition the model assumes the following scenario, illustrated in text figure 1.

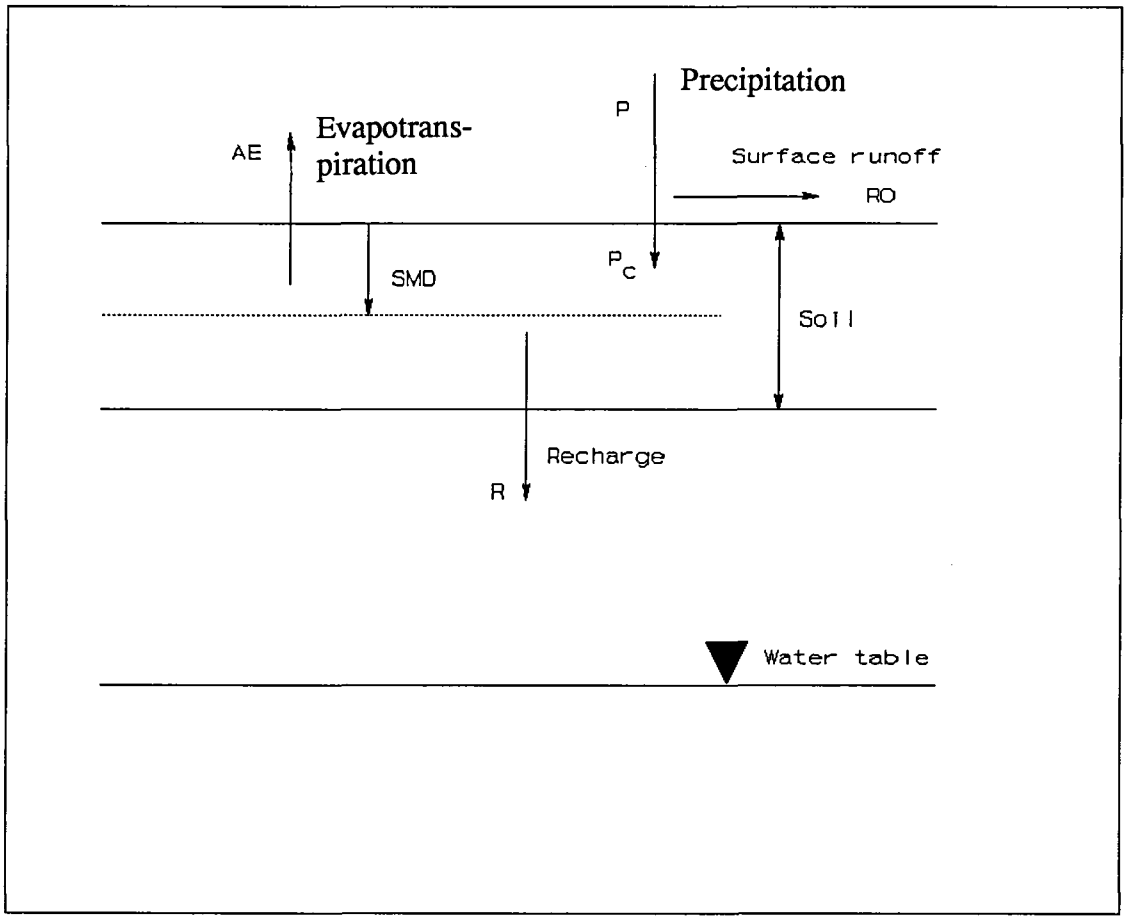
For any given day:

$$AS = -(P - RO - AE)$$

Where AS = actual change in soil moisture deficit (ΔSMD - R)
P = precipitation
RO = surface run-off
AE = actual evapotranspiration
R = recharge to groundwater

R = 0 if SMD > 0.

All values are quoted in mm.



Text Fig. 1. The assumed recharge model

Surface run-off depends on natural conditions such as e.g. topographical gradient, soil type etc. It is often simply calculated as a fixed percentage of P. In the Øvre Romerike model, surface run-off was assumed to be negligible, due to the porous sediment material, the flat delta surface and the observed lack of surface watercourses on the aquifer.

P_c = precipitation corrected for surface run-off = (P - RO)

P is often available from meteorological institues as daily data, as are values of potential evapotranspiration (PE). PE is the amount of evapotranspiration which can occur under ideal conditions. In reality, AE will often be less than PE, especially if the soil moisture deficit is high. If such is the case, plants cannot suck up as much water as they "want to" because the soil is too dry.

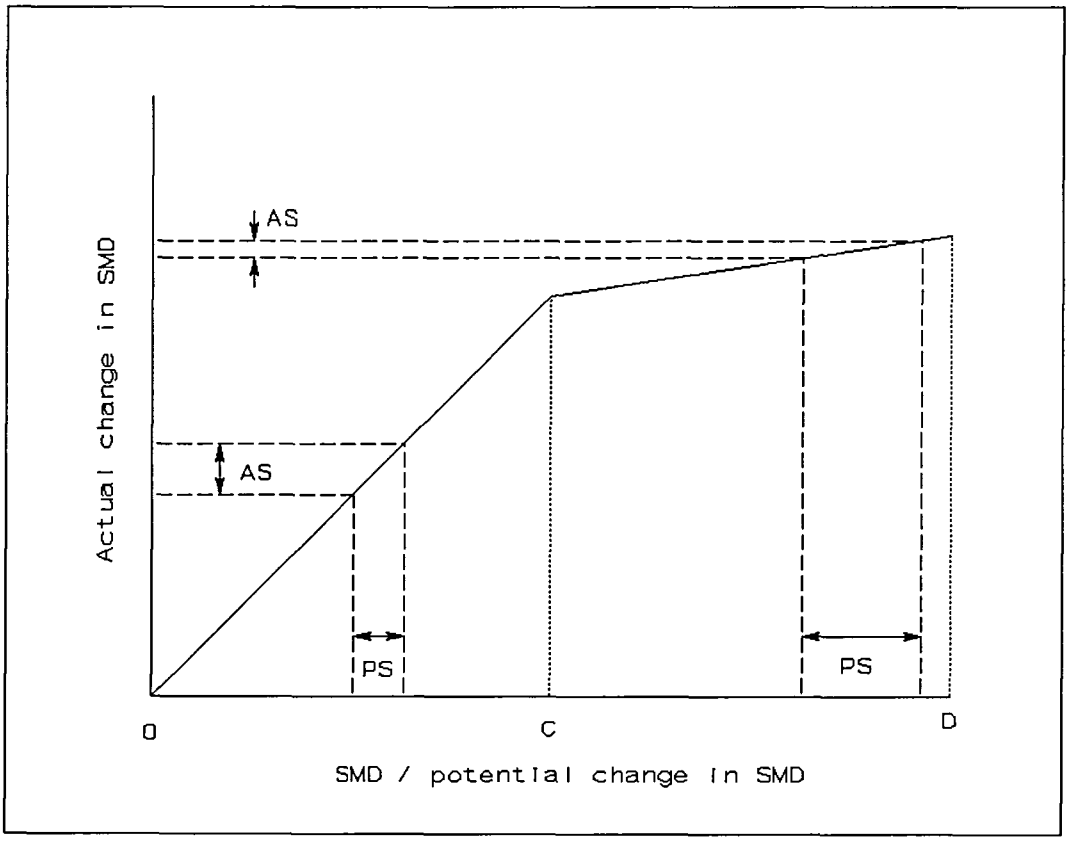
Therefore, in order to solve for recharge, it is necessary to calculate AE and SMD.

The model assumes:

$$PS = -(P - RO - PE) = PE - P_c$$

Where PS = potential change in soil moisture deficit

If the soil is wet, and enough water is available, evapotranspiration occurs at its potential level (AE = PE). AS is therefore equal to PS. According to the model, this occurs until the SMD reaches a level called the **root constant** (C). At this point, the soil is so dry that the extent of AE is reduced. The model assumes that if SMD > C, then AS = PS/10 (Text Fig. 2). If the soil becomes even drier, and SMD reaches **wilting point** (D), the plants die and evapotranspiration ceases. Reality is of course more complex. There is not found a sharp break-point at C or D, only a gradual reduction in AE/PE with increasingly dry soil. The 10 %-factor on exceeding the root constant is also rather arbitrary. Nevertheless, experience has shown that such a model can give sensible results in most situations. It is normally called the "Penman/-Grindley method" (see e.g. Rushton & Redshaw 1979).



Text Fig. 2. Actual change in soil moisture deficit, as a function of soil moisture content.

PS is calculated on a daily basis. Calculations based on periods longer than one day will give misleading results. Every day, one "tests" whether PS is positive or negative. The SMD at the end of the n^{th} day is termed SMD_n.

If PS is negative:

effective precipitation (P_c) is greater than PE. There is therefore a lot of available water in the soil for evapotranspiration, and:

$AE = PE$

To begin with, one assumes that $R = 0$:

$SMD_n = AS + SMD_{(n-1)} = SMD_{(n-1)} -(P_c - AE)$

If $SMD_n > 0$ then $R = 0$

If $SMD_n \leq 0$ then $R = -SMD_n$, and SMD_n is reset to 0.

If PS is positive:

there are two possibilities:

i) If $SMD_{(n-1)} < C$
then $AS = PS$
$AE = PE$
$SMD_n = AS + SMD_{(n-1)} = SMD_{(n-1)}-(P_c - AE)$

ii) If $SMD_{(n-1)} > C$
then $AS = 10\% \times PS$
$SMD_n = AS + SMD_{(n-1)} = SMD_{(n-1)}-[0.1*(P_c - PE)]$
$AE = P_c + AS$

Example

As examples of the use of this model, the following data from Øvre Romerike (Gardermoen meteorological station - Table 1a) are shown, together with an example from Rushton (1983) (Table 1b).

Table 1a: Calculation of recharge from real data from Gardermoen, autumn 1966. "Root constant" = 175 mm, and is therefore not reached. Recharge only occurs when SMD = 0. Surface run-off = 0. All values in mm.

Year	Day	Precipitation P	Potential evapotran-spiration PE	Potential change in SMD PS	Soil moisture deficit SMD	Actual change in SMD AS	Actual evapotran-spiration AE	Recharge to groundwater R
1966	237	0.000E+00	3.200E+00	3.200E+00	1.260E+01	3.200E+00	3.200E+00	0.000E+00
1966	238	0.000E+00	3.100E+00	3.100E+00	1.570E+01	3.100E+00	3.100E+00	0.000E+00
1966	239	0.000E+00	3.200E+00	3.200E+00	1.890E+01	3.200E+00	3.200E+00	0.000E+00
1966	240	0.000E+00	3.000E+00	3.000E+00	2.190E+01	3.000E+00	3.000E+00	0.000E+00
1966	241	0.000E+00	2.600E+00	2.600E+00	2.450E+01	2.600E+00	2.600E+00	0.000E+00
1966	242	0.000E+00	1.800E+00	1.800E+00	2.630E+01	1.800E+00	1.800E+00	0.000E+00
1966	243	0.000E+00	5.000E-01	5.000E-01	2.680E+01	5.000E-01	5.000E-01	0.000E+00
1966	244	1.030E+01	0.000E+00	-1.030E+01	1.650E+01	-1.030E+01	0.000E+00	0.000E+00
1966	245	4.000E-01	1.000E-01	-3.000E-01	1.620E+01	-3.000E-01	1.000E-01	0.000E+00
1966	246	9.400E+00	2.000E-01	-9.200E+00	7.000E+00	-9.200E+00	2.000E-01	0.000E+00
1966	247	5.100E+00	3.000E-01	-4.800E+00	2.200E+00	-4.800E+00	3.000E-01	0.000E+00
1966	248	6.500E+00	2.100E+00	-4.400E+00	0.000E+00	-4.400E+00	2.100E+00	2.200E+00
1966	249	2.000E-01	4.000E-01	2.000E-01	2.000E-01	2.000E-01	4.000E-01	0.000E+00
1966	250	3.400E+00	2.200E+00	-1.200E+00	0.000E+00	-1.200E+00	2.200E+00	1.000E+00
1966	251	0.000E+00	1.500E+00	1.500E+00	1.500E+00	1.500E+00	1.500E+00	0.000E+00
1966	252	0.000E+00	5.000E-01	5.000E-01	2.000E+00	5.000E-01	5.000E-01	0.000E+00
1966	253	0.000E+00	1.000E-01	1.000E-01	2.100E+00	1.000E-01	1.000E-01	0.000E+00
1966	254	6.000E-01	7.000E-01	1.000E-01	2.200E+00	1.000E-01	7.000E-01	0.000E+00
1966	255	1.900E+00	1.000E+00	-9.000E-01	1.300E+00	-9.000E-01	1.000E+00	0.000E+00
1966	256	1.590E+01	1.200E+00	-1.470E+01	0.000E+00	-1.470E+01	1.200E+00	1.340E+01
1966	257	2.600E+00	6.000E-01	-2.000E+00	0.000E+00	-2.000E+00	6.000E-01	2.000E+00
1966	258	7.000E+00	1.000E+00	-6.000E+00	0.000E+00	-6.000E+00	1.000E+00	6.000E+00
1966	259	0.000E+00	1.100E+00	1.100E+00	1.100E+00	1.100E+00	1.100E+00	0.000E+00
1966	260	0.000E+00	1.300E+00	1.300E+00	2.400E+00	1.300E+00	1.300E+00	0.000E+00

2.4.2 Use of snow data in the recharge model

The most common versions of such a model treat snow exactly as rain, i.e. that snow infiltrates directly into the ground. In Scandinavia, this is not satisfactory, as during winter a store of precipitation is built up in a long-lasting snow cover, without significant amounts being recharged to the soil and further to the water table. In Norway, the winter is the period when groundwater levels recede to their lowest levels (Kirkhusmo & Sønsterud 1988, Nordberg 1980), in contrast to e.g. England, where the majority of recharge occurs in winter. Unfortunately there is no simple relationship between the amount of water (in mm) which is stored in the snow cover, and its thickness, as the snow becomes steadily more compacted during winter

Table 1b: Calculation of infiltration when SMD is approximately equal to the root constant (C 100 mm). All values are in mm. Example from Rushton (1983).

Day	Precip-itation P	Surface run-off RO	Potential evapotrans-piration PE	Potential change in SMD PS	Actual change in SMD AS	Soil moisture deficit SMD	Actual evapotrans-piration AE	Recharge to ground-water R
179						96,0		
180	0,0	0,0	3,3	3,3	3,3	99,3	3,3	0,0
181	0,0	0,0	3,7	3,7	3,7	103,0	3,7	0,0
182	8,3	1,4	2,7	-4,2	-4,2	98,8	2,7	0,0
183	2,3	0,2	3,2	1,1	1,1	99,9	3,2	0,0
184	0,5	0,1	3,8	3,4	3,4	103,3	3,8	0,0
185	0,0	0,0	3,7	3,7	0,37	103,67	0,37	0,0
186	2,1	0,4	3,4	1,7	0,17	103,84	1,87	0,0
187	15,6	3,6	2,5	-9,5	-9,5	94,34	2,5	0,0
188	0,0	0,0	3,6	3,6	3,6	97,94	3,6	0,0
189	0,0	0,0	3,8	3,8	3,8	101,74	3,8	0,0
190	0,7	0,1	3,6	3,0	0,30	102,04	0,90	0,0

(Nor.Nat.Comm. I.H.D. 1975). One cannot therefore use changes in snow depth to assess whether accumulation or melting of the snow cover is occurring. In NGU/IBM's model it has been chosen to use a simplified model. Data from the Meteorological Institute contain daily measurements of precipitation, snow depth and degree of snow coverage (S) from 0 (no cover) to 4 (100 % cover). The IBM/NGU model considers 3 different modes of treatment of snow data:

i) When $S \leq 1$, the model functions as the normal summertime model.

ii) When $S > 1$, the model switches to "accumulation mode". No precipitation seeps into the soil layer; it is all stored in the snow layer. Evapotranspiration of existing soil moisture is allowed, such that the SMD steadily increases during this period, and no groundwater recharge occurs.

iii) When the snow cover begins to decrease ($S_n < S_{n-1}$), the model switches again to "melting mode". New precipitation is allowed to enter the soil zone and all precipitation which is stored in the snow layer is allowed to melt and seep into the soil, where it is treated by the model as normal rainfall. The melting occurs as follows:

$$\text{Daily amount of meltwater} = \frac{\text{precipitation stored in snow during accumulation}}{\text{duration of melting period}}$$

During the melting period, relatively large amounts of meltwater seep into the ground, and the SMD is quickly satisfied, allowing recharge to the water table.

The melting period finishes when S reaches 0 again (and the model returns to "normal mode"), or when S begins to rise again (and the model returns to mode ii).

It should be mentioned that the model does not take into account changing run-off due to frozen ground conditions.

2.4.3 Results

The recharge model was run for the period 1968-1974 (Fig. 9), using a root constant of 175 mm, and assuming surface run-off = 0, due to the flat and permeable nature of the aquifer surface. The results were found to correspond very well to empirical estimates calculated from the hydrological balance of the aquifer by Jørgensen & Østmo (1990) for the same period (Table 2). The results of the model also give the typical two recharge peaks every year, one at snow melt and one in late summer, a typical pattern for inland Norway (Nordberg 1980).

Table 2. Comparison of recharge model with empirical data. Annual averages for period 1968 - 1974. (In model run-off = 0, root constant = 175 mm). The recharge models with and without the snow package yield similar average results for the period in question, but the snow package radically improves the distribution of recharge within a given year. In the third column, recharge is not exactly equal to precipitation - evapotranspiration due to end effects of snow storage at the beginning and end of the simulation period)

	Empirical (Jørgensen & Østmo 1990)	Recharge model without snow package (snow treated as rain)	Recharge model (with snow package)
Precipitation mm	794	844	843
Evapotranspiration mm	400	445	447
Recharge mm	394	399	407

3. Groundwater flow modelling

3.1 MODFLOW

To model groundwater flow, the numerical model MODFLOW, written by the USGS, was chosen (McDonald & Harbaugh 1988). This is a finite difference model which is widely used throughout America and Europe and thus has the advantage of being well tested, with clear instructions for its use. MODFLOW can only simulate flow in the saturated zone (below the water table) but this has not been a serious disadvantage for the present project since the data required to model flow in the unsaturated zone are not available for the sediments of the Øvre Romerike area. Both steady state and transient simulations can be performed.

MODFLOW requires a geological model defined on a grid (dimensions and size chosen by the user) as well as arrays defining the cell type, horizontal and vertical hydraulic conductivities, and storage coefficients (for transient simulations) for each grid block in each layer. In addition, files describing the properties and location of rivers, drains, wells and areas of constant head must be provided by the user. In many cases, these files of data must be compatible with each other. Much of the work involved in using MODFLOW lies in the creation of these files. At BSC, time was invested in building a GUI (graphical user interface) to automatically perform as much of this work as possible.

3.2 Data preparation and the Graphical User Interface

The contour maps of the geological model (Fig.3) were automatically digitised using the data capture software developed at IBM/BSC in Bergen. The prepared maps were scanned and the resulting images vectorised to give the contours as a series of points. Each contour was then assigned a height value using the AUTOCAD package. These digitized contour maps were then rasterized using the commercial GIS package GENAMAP (GENYSIS). This procedure results in maps consisting of small square regions (pixels) each of which has a height associated with it. Each pixel represents a region of 50 by 50 m. These rasterized maps provided the basic input for the graphical user interface and an example is shown in Fig.10. The graphical user interface can display the input maps together with information on the location of rivers and roads to help the user define the MODFLOW grid. MODFLOW requires a grid that is uniform and right-angled (i.e. squares or rectangles) when viewed from above. This grid is generated interactively by entering the number of rows and columns in the X-Y grid plane and locating the bottom left hand and top right hand corners of the grid on the map displayed by the GUI using a mouse. The interface then automatically determines the heights of the grid nodes at the top and bottom of each geological layer, using the rasterized maps. Once a satisfactory grid has been generated it may be saved and recalled on later applications of the user interface. The cell type may be altered to "no flow" or "constant head" and properties, such as height of constant

head cells and horizontal hydraulic conductivities may be assigned interactively. Cells containing rivers are automatically detected using the input digitized information on river locations. An example of the interface screen with the windows displayed is shown in Fig.11. The interface then uses this information to create the necessary input files for MODFLOW, checking for internal consistency. At present, files containing information on recharge, drains and output control flags must created separately. The interface makes possible the rapid generation and modification of the input required for MODFLOW, thus relieving the user of much time-consuming and tedious work. This enables the modeller to run the model many times and allows him/her to concentrate most effort on the generation of a hydrogeologically good model.

3.3 The grid and boundary conditions

A grid of 36 by 24 square blocks (Fig.12), covering almost the entire areal extent of the Øvre Romerike aquifer was generated using the user interface. The whole area covered by the grid is 18 by 12 km and each grid block represents an area of 500 by 500 m. Boundary conditions are defined so as to represent external influences on the groundwater system. As much as possible, natural features were used to determine conditions around the model perimeter. The crystalline bedrock underlying the aquifer and the clay-rich marine sediments in the southwest are assumed to be impermeable, and grid cells representing these lithologies are defined as "no-flow" cells. The lakes Hurdalsjøen and Hersjøen were modelled as constant head cells (constant water level throughout the simulation). This seems reasonable since the level of these lakes varies very little with time and they are believed to be in some degree of hydraulic continuity with the aquifer. These no-flow and constant head cells fix conditions on a large proportion of the model's boundary.

The Risa river, the smaller stream from Transjøen to Hersjøen and the small eastern tributary of the Risa were modelled using the river package in MODFLOW. Here rivers are assumed to be continually active and are either influent or effluent with respect to the aquifer depending on the relative heights of the river bottom and the water table. It has been assumed that the river beds represent no significant barrier to water exchange between the aquifer and the river, i.e. that the sediments in the river bed have the same hydraulic conductivity as the aquifer at this level.

Springs which occur along the west and the southwest margins of the aquifer, near the boundary with the underlying marine sediments, are modelled using the drain package of MODFLOW. Here only flow from the aquifer to the spring-fed stream is possible. The springs are only active when the water table is higher than the drain level, and flow is proportional to the water table height above the spring elevation. This allows the simulation of streams or springs which can go dry, and prevents influent (recharge) conditions occurring.

The remaining small portions of the model's outer boundary, which cannot be defined as no-flow cells or drains, are assigned a reasonable value of constant head derived from Østmo's (1976) map. The water level in these cells should strictly be variable, but since there are only a small number of them and they are situated in regions where the aquifer is relatively thin, holding their water levels constant has only minor effects on the rest of the model.

The boundary conditions and allocation of cell types in the model are shown in Fig.12. Recharge is assumed to be constant over the whole region. MODFLOW was used in the mode that adds recharge to the top of the uppermost active cell. No account is therefore taken of the time taken for water to travel through the unsaturated region. Rain falling on bedrock areas is neglected, except in the east where it is, in part, represented by the small eastern tributary of the Risa which rises from a small bedrock outcrop.

The task of modelling the groundwater flow in the Øvre Romerike aquifer was divided into two sections:

(1) generation and calibration of the hydraulic conductivity model under steady state conditions,
(2) transient modelling and comparison with the available time series data on water table levels in three observation boreholes.

4 The steady state model

4.1 Calibration of the steady state model

The aim of the steady state modelling was to generate a hydraulic conductivity model for the two aquifer layers that produces water table levels and water fluxes in rivers and springs in acceptable agreement with observations. A total of 183 water levels measured in boreholes, largely in the period 5-7 November 1975, from Østmo's map (1976) were used in model calibration. They cover most of the region but are especially concentrated in the region surrounding Hersjøen, Fig.13. Two parameters were used to test the fit of the model results to these borehole measurements. To test the fit of the model results to the observations on the scale of the whole model, the average discrepancy, D, was calculated:

$$D = \frac{\Sigma (h_m - h_o)}{n}$$

where h_m and h_o are the modelled and observed water table levels, respectively, and n is the number of grid blocks where borehole observations are available. To test the fit of model results to the observations on the scale of one grid block, the root mean square of the discrepancies, rmsD, was used:

$$rmsD = \sqrt{\frac{\sum (h_m - h_o)^2}{n}}$$

The best fit is obtained when D and rmsD are minimized, although as individual deviations can be positive or negative, more emphasis was laid on minimising rmsD than D itself. Since the borehole observations are point measurements, they reflect a wide range of frequencies of spatial variations in the water table, and several boreholes in a single grid block can exhibit considerably different water levels. In the simulation however, one grid block is allowed a single water level and only variations in water table on the scale of a single grid block or larger can be modelled. Thus, in calibration, an exact fit (i.e. values of rmsD approaching zero) should not be expected.

Other available methods of calibrating the model are to compare the fluxes in rivers and springs. Data are available for the water flux in the Risa river at Risabru (Fig.1a), at the north end of Hersjøen. The flow in the Risa (Jørgensen & Østmo 1990, Norweg. Nat. Comm. IHD 1973, 1975) varies little throughout the year and has an average value of around 0.7 m^3/sec. In MODFLOW, the flux in rivers is not directly calculated, only the exchange rates between rivers and the aquifer. However, an estimate may be made by considering the upstream influences on flow rates at Risabru (the NVE gauging station on the Risa, at Grid.Ref.^{6}203 ^{66}801). An estimate of this flow rate from the simulation was obtained by summing the fluxes from the aquifer to:

1) constant head cells representing Hersjøen,
2) cells representing the stream from Transjøen to Hersjøen,
3) the drain cells representing the springs at Dagsjøen
4) cells representing the Risa river upstream of Risabru

This sum is likely to overestimate the flow at Risabru as it does not include the effects of evaporation from Herjøen or possible losses to the aquifer between Dagsjøen and Hersjøen.

Water flowing from the springs along the southwest margin of the aquifer provides the main input to the Leira and Vikka rivers which are situated on the marine sediments and flow parallel to the aquifer's margin (Fig.1a). Sporadic data is available on flux in the Vikka river (at UTM ^{6}154 ^{66}722) for the period 1989 to 1991 (NVE 1991), giving an average of 0.089 m^3/sec. From this a rough estimate can be made of the flux from all the springs along the southwest margin. From the map, approximately one quarter of the southwestern marginal springs feed the Vikka upstream of the measuring station. Assuming that the outflow from each of the springs is roughly comparable along this margin of the aquifer, an estimate of the flux from all springs is therefore given by four times the measured flux in the Vikka. Since the Vikka is partially fed by runoff from the low-permeability marine sediments, this represents an upper boundary. The springs are likely to provide at least half of the influx to the Vikka, so that one half of this

estimated flux provides a lower boundary. The total flux from the springs along the south-western margin is therefore estimated to lie between 0.36 and 0.18 m^3/sec.

4.2 The permeability model

The major variables still to be determined in the model are grid block hydraulic conductivities (both within and between the two layers) and the recharge rate. For a given recharge rate, there are many possible hydraulic conductivity models that can satisfy the calibration data outlined above. It is therefore not possible to arrive at a unique solution to the hydraulic conductivity field, but by using the available data on hydraulic conductivity and recharge as a guide, a likely solution can be obtained. Time-dependent data indicate that the water table lies at approximately its average level for the year of 1975 during the month of November, although recharge is normally below average in this month. This discrepancy is due to the delaying action of the unsaturated zone on recharge arrival at the water table, and to the fact that November lies on the decaying limb of the previous hydrograph peak of earlier autumn. For the purposes of the steady state model, where the aim is to reproduce the water table levels in November 1975, the average recharge rate for 1975 (1.27×10^{-8} m/s) was used, rather than the November value for this year (c. 1×10^{-8} m/s). *[All recharges generated using root constant = 175 mm and run-off = 0].*

In reality, both the coarse upper and fine lower layers of the aquifer model are composed of intercalated layers and lenses of coarse and fine sediment, the difference being the relative proportions of sediment grain size fractions. The grain size samples (Misund & Banks 1993) from which hydraulic conductivities are estimated therefore reflect this intermixture of layers and lenses, rather than the overall hydraulic conductivity of the coarse and fine layers. This means that it has not been practical to conclusively identify the boundary between the two modelled layers using the hydraulic conductivity estimates from borehole samples or to assign a grain size sample to a specific layer. However, the histogram of all available hydraulic conductivity estimates (Fig.8), based on d_{60} and d_{10} data, shows several peaks which are typical for coarse, fine and clay-rich sediments. This histogram was used as a guide to the likely average hydraulic conductivity values of the two modelled layers, which were thus estimated at 2.0×10^{-4}m/s (coarse layer) and 7.0×10^{-6}m/s (fine layer), corresponding to the "coarse sand" and "fine sand" peaks on the histogram. These conductivities were used as a starting point for model calibration.

To determine the most probable average hydraulic conductivities for each layer, MODFLOW was first run using two spatially homogeneous layers. A hydraulic conductivity of the fine layer of 7.0×10^{-6}m/sec (the value suggested by the histogram in Fig.8) was found to be too low, yielding water table levels which were too high regardless of the hydraulic conductivity assigned to the coarse layer.

In order to develop a strategy for modelling the hydraulic conductivity, the sensitivity of the homogeneous layer model to variations in hydraulic conductivity was tested by holding the hydraulic conductivity of one layer constant, varying the other and recording the change in the average error, D, as a measure in net change in the water table level. The results, shown in Fig.14, show that the water table level is many times more sensitive to variation in the hydraulic conductivity of the lower fine layer than the coarse upper layer. This is consistent with the observation that the water table tends to be situated close to the interface between the two layers over large areas of the aquifer, indicating that water table levels are largely controlled by properties of the fine layer.

A hydraulic conductivity of 7.2×10^{-4} m/sec was assigned to the coarse layer, a near maximum value. The hydraulic conductivity of the fine layer that minimized the total error, D, was then found. This resulted in a hydraulic conductivity value of 3.2×10^{-5}m/sec for the fine layer, which is somewhat higher than the initial estimate based on the histogram in Fig.8. The modelled results were discovered to be extremely insensitive to the hydraulic conductivity of the coarse layer.

There are two justifications for the discrepancy between the modelled conductivities for the fine layer and those derived from grain size analysis. Firstly, it is probable that the estimates of hydraulic conductivity from grain size samples are rather inaccurate and contain systematic errors due to the sampling and /or analytical procedure. Secondly, the fine layer is composed of intercalated fine and coarser layers, whereas the 'fine sand' histogram peak probably represents primarily the finer grained portions of the layer and thus leads to an underestimation of the layer's average hydraulic conductivity.

The modelled estimates of the 'average' hydraulic conductivity of each layer (i.e. 7.2×10^{-4} and 3.2×10^{-5} m/s) were considered a satisfactory intermediate point in the development of a hydraulic conductivity model for the Øvre Romerike aquifer. The homogeneous layer model described above, although miminizing the average error, D, gave a high value of rmsD (5.86m), see Fig.15(a). To improve the fit of modelled to observed water levels, the hydraulic conductivity field within each layer was allowed to vary horizontally. The fit of the modelled to observed data was improved as much as possible by modifying the spatial distribution of hydraulic conductivity within the fine layer, this layer's hydraulic characteristics being the most important for determining the water table level.

Using this approach, rmsD values were improved to 3.4m while maintaining a low value of average error, D (0.22 m). In most grid cells where observations were available, the discrepancy between the simulated and observed data was 5m or less and frequency histograms of the errors for the homogeneous layer and modified layer models are shown in Fig.15. Although the 5 m error may sound large, it must be remembered (as previously explained) that one is comparing the average water table within a 500 x 500 m grid block, with the observed data

from a single point within the block, often in areas with high water table gradients. The "final" hydraulic conductivity field for the fine layer is shown in Fig.16, and the simulated water table level, compared to Østmo's (1976) map in Fig.17b. A three dimensional view of the aquifer base and the modelled water table are shown in Fig. 17c. Values of flux at Risabru, calculated in the manner described above, and flux from the springs along the southwest margin of the aquifer were acceptably close to the observed values, and are listed in Table 3.

Table 3 - Outflows from springs; modelled and observed

Location	Modelled flow m^3/s	Observed flow m^3/s
R.Risa at Risabru	0,82	0,7
Springs in SW	0,29	0,18 - 0,36

By comparing the groundwater head values in the upper and lower layers, one can identify vertical head gradients and areas where upward or downward flow is occurring. This has been done, the results being presented in Appendix 4. The 2-layer model is clearly not adequate to satisfactorily model vertical head gradients, but in general downward head differentials are observed in the area corresponding to the main watershed (i.e. recharge area), while upward differentials are observed along the River Risa (discharge area).

5 The transient model

5.1 Modifications to MODFLOW

The version of MODFLOW received from the USGS is designed to model situations in which the water table is, in general falling, e.g. the development of drawdown cones due to pumping. The model is so written that if a model cell goes dry, it is redefined as a "no flow" cell and remains inactive for the remainder of the simulation. With this code it is therefore not possible to model the behaviour of a water table which is expected to rise over the boundary between two layers. Since, in a significant part of the Øvre Romerike area, the water table is known to lie close to the boundary between the coarse and fine sediment layers, varying recharge is expected to cause the water table to cross this boundary many times in the 31 year period for which time series data is available. Thus, this feature of MODFLOW was a serious drawback for modelling transient behaviour and it was necessary to modify the code.

In order to allow a water table to rise significantly during a single simulation, an additional subroutine was added to MODFLOW to check and, if necessary, modify the conditions at cells which have gone dry at some point during the simulation. When the head in the cell below is

higher than the base of the dry cell (indicating a rising water table), the dry cell is reactivated and its head set to that of the cell below. Cells in the bottom layer and cells underlain by inactive (no flow) cells are reactivated when a minimum of one immediate neighbour has a head greater than the base of the dry cell (indicating potential flow into the dry cell) and their heads set to a value slightly higher (10 cm) than the cell base. Since the subroutine is called between time steps, care must be taken that time steps are small enough to sufficiently resolve upwards movements in the water table, i.e., that changes in head within a single time step are small compared to the average grid height.

5.2 Input to the transient model

As a test of MODFLOW in transient mode, a simulation with the average recharge for 1975 (1.27×10^{-8} m/sec) was run for 16 stress periods of 1 year, with 4 timesteps per stress period and an initial water table at the aquifer top (i.e. topography). The model converged to a solution which lay to within a few centimeters of the steady state model results after some 25 stress periods, confirming the results of steady state modelling.

The transient model was also run with the initial head set below the top of the fine layer. This also converged to the steady state solution, proving that the modifications to MODFLOW, made to allow resaturation of dry cells, function satisfactorily.

For transient simulations using time-dependent recharge data (derived from the recharge model), the length of stress period (i.e. time over which external stress conditions such as recharge are constant) was set to 1 month, the maximum time interval between successive measurements in the observed data. Two time steps of equal length per stress period were found to be sufficient to resolve movements of the water table and no significant difference in the results was obtained by increasing the number of timesteps. Recharge data was calculated for monthly intervals from the meterological data as described in section 2.4, for the time period from May 1960 to June 1991, giving a total of 374 stress periods.

The hydraulic conductivity field and boundary conditions as determined in the steady state model were used in the transient model. The water table levels in May 1965 (when time-series data for observation wells commences), which should be used as initial levels in the transient modelling, are unknown. The increasing trend in the recharge for the period 1960 to 1965, suggest that the water table was probably at lower than average level in 1960. Two initial water table levels were used in the model to investigate the effect of initial water table levels on the model results at the three observation wells, Hauerseter, Sand and Nordmoen. These two initial conditions were generated by using the calibrated, spatially variable, hydraulic conductivity model and running MODFLOW in steady state mode with recharge values corresponding to:

(1) the average value for 1975 (1.27×10^{-8}m/sec - as used in the calibration of the hydraulic

conductivity model)

(2) 8.293 x 10^{-9}m/sec representing approximately the minimum annual recharge for the time period 1965 to 1990.

5.3 The transient model results and comparison with observations.

The model results are compared with observed time series data from the three observation wells at Hauerseter, Sand and Nordmoen (Kirkhusmo & Sønsterud 1988) for the period from May 1967 to September 1991. Information and model input parameters at the locations of the three wells are listed in Table 4 (UTM, height, cell number, thickness of layers, layer hydraulic conductivities).

Table 4 - Observation wells with time-series data (Kirkhusmo & Sønsterud 1988)

Location	UTM coordinates	Elavation, m above sea level	Cell in MODFLOW (col,row)	Elevation of top of fine layer in model	Elevation of base of aquifer in model
Hauerseter	219 745	c.215	(18,25)	196,19	132,63
Sand	191 706	c.200	(13,33)	186,50	123,12
Nordmoen	168 816	c.200	(8,12)	192,96	132,13

The transient model run with the best-fit steady state model heads as initial conditions (i.e. recharge = 1.27 x 10^{-8} m/s) is shown in Fig.18(a). The model shows similar trends to the real data, but with the absolute elevation of the model results too high for Hauerseter by some 3-4m, and an overall good fit for Nordmoen and Sand. All three model trends show much greater seasonal variations that the observed data. This is due to the 'damping' effect of the unsaturated zone (i.e. the "smearing out" of major recharge peaks) which is not included in the model. It was found that this "smearing" effect could be simulated by taking running averages of the recharge data over 7-monthly periods, and the results are shown in Fig.18(b). This modified model produces results which show very similar variations to the observed data, but with the modelled results lagging some months behind the model data. The magnitude of this lag varies from 1 to 10 months and is roughly correlated with the thickness of the unsaturated zone. This correlation is also seen in the nature of the trends of observed data. The data from Nordmoen, where the thickness of the unsaturated zone is 1 to 3 m, are more jagged, indicating more rapid water-table fluctuations than at Hauerseter and Sand, where the unsaturated zone is between 10 and 20 m thick. This illustrates the "smearing" or "damping" effect of the unsaturated zone, which tends to smooth out the high frequency variations in recharge.

The time lags between observed and modelled data, and the respective unsaturated zone thicknesses, indicate a range of filtration velocities between 1 and 12 cm/day. These results are low compared with estimations from field observations by Jørgensen and Østmo (1990) of around 17 - 20 cm/day during the spring of 1966 at Nordmoen. Filtration velocities are dependent not only on the nature of the sediments, but also on their degree of saturation (hydraulic conductivity decreases markedly with decreasing saturation). Jørgensen and Østmo's observations were made during snow melt when saturation levels were high. In addition, the unsaturated zone was thin (1.35 to 2.65 m) so that high saturation levels throughout the thickness of the unsaturated zone are more easily reached during periods of high recharge.

The modelled trends all show a similar type of deviation from the observed data in that they fall less sharply in the time period from 1967 to 1976 and rise quicker in the time period 1976 to 1991. However the change in discrepancies between modelled and observed water levels in the observation wells over this 26 year period are small (2.5m for Hauerseter, 2.2m for Nordmoen and 1.7m for Sand). These discrepancies are of the same magnitude, or smaller, than the discrepancies between the steady state model and observed water table levels for November 1975.

However, the nature of the water table at the start of transient simulations (May 1960) is unknown and so to test the possible influence of the initial heads on the modelled trends, a further simulation was run with a lower initial water table generated as described above (the steady state solution with a recharge of 8.293×10^{-9} m/sec) and the results are shown in Fig.19.

Comparison of Figures 18(b) and 19(b) show that the lower initial head condition results in a slightly improved fit at Hauerseter. The two trends resulting from the different initial head conditions converge, however, and become indistinguishable after some 160 months. At Sand and Nordmoen, the effect of different initial water tables is less marked and the two trends become indistinguishable after some 90 months. The model trend resulting from the lower initial head condition shows a better fit to the real data trends, with the variations in deviation between the modelled and observed data from 1965 to 1991 reduced to around 1m for all three observation wells.

6. Conclusion

Using the U.S.G.S MODFLOW code, coupled with a Penman-Grindley type recharge model, it has been possible to produce a transient, 3-dimensional groundwater flow model of the Øvre Romerike aquifer. It was, however, found necessary to modify the MODFLOW code to allow the water table to rise across the boundary of aquifer layers, and to modify the recharge model to take into account snow effects during winter.

A steady state model has been calibrated against 183 regional water level observation data from autumn 1975 and against the flows in groundwater fed springs and streams. Allowing for the limited resolution attainable using 500 x 500 m grid blocks in areas of high water table gradient, the fit achieved was highly satisfactory. The distribution of hydraulic conductivity calibrated using the steady state model was then used to simulate water table variations over a period in excess of 30 years. Calibration data at 3 observation wells showed satisfactory fits with modelled data, again allowing for the limited spatial resolution of the model, and the uncertain elevations of the real data points. A seven-month running average filter has been applied to the data to simulate the damping effects of the unsaturated zone on recharge maxima and minima, resulting in an even better fit. The seasonal variations in water table level appear to lag the modelled water level data by 1 to 10 months, indicating a considerable delay period in the unsaturated zone.The delay seems to vary with the thickness of the unsaturated zone and indicates filtration velocities between 1 and 12 cm/day. In comparison, Jørgensen & Østmo (1990) calculated an "unsaturated zone delay" of only some 8 - 12 days at Nordmoen, with an unsaturated zone of ca. 2 m.

The modelling work has enabled the project's participants to obtain a deeper understanding of the hydraulics of the aquifer, and has also indicated that hydraulic conductivity values obtained from grain size distributions tend to lead to underestimates of aquifer transmissivity. The model provides a framework for further modelling work on contaminant transport at Trandum landfill. It is debatable, however, whether the model can be used for contaminant modelling in its present form. It is believed that a significantly more detailed geological base model (e.g. more layers) will be needed before attempting contaminant modelling. Experience has shown that, even though a model may yield satisfactory results as regards groundwater flow, it may not be satisfactory for contaminant transport (Guerin & Billaux 1993). Much detailed data is, however, available at the Trandum landfill site, and the prospects appear very hopeful for a fruitful attempt at contaminant and hydrogeochemical modelling at that locality in the future. The present model could, however, be used to estimate the large-scale effects of water abstraction on the Øvre Romerike aquifer.

7. Acknowledgements

At IBM/BSC, Arne Harvorsen did much of the work in programming the interface. Børre Johnson and Brit-Gunn Ersland worked on the automatic digitizing of the geological model and on the design of the graphical user interface.

At NGU, Ola Sæther and Gaute Storrø were of great assistance in processing grain-size data in order to arrive at the permeability histogram.

The modelling work has been financially supported by the Norsk Hydrologisk Komité (a part of Norges Almenvitenskapelige Forskningsråd - NAVF), as well as by the authors' host institutions, IBM/BSC and NGU.

Copies of input files and further results from the model can be obtained by contacting the authors.

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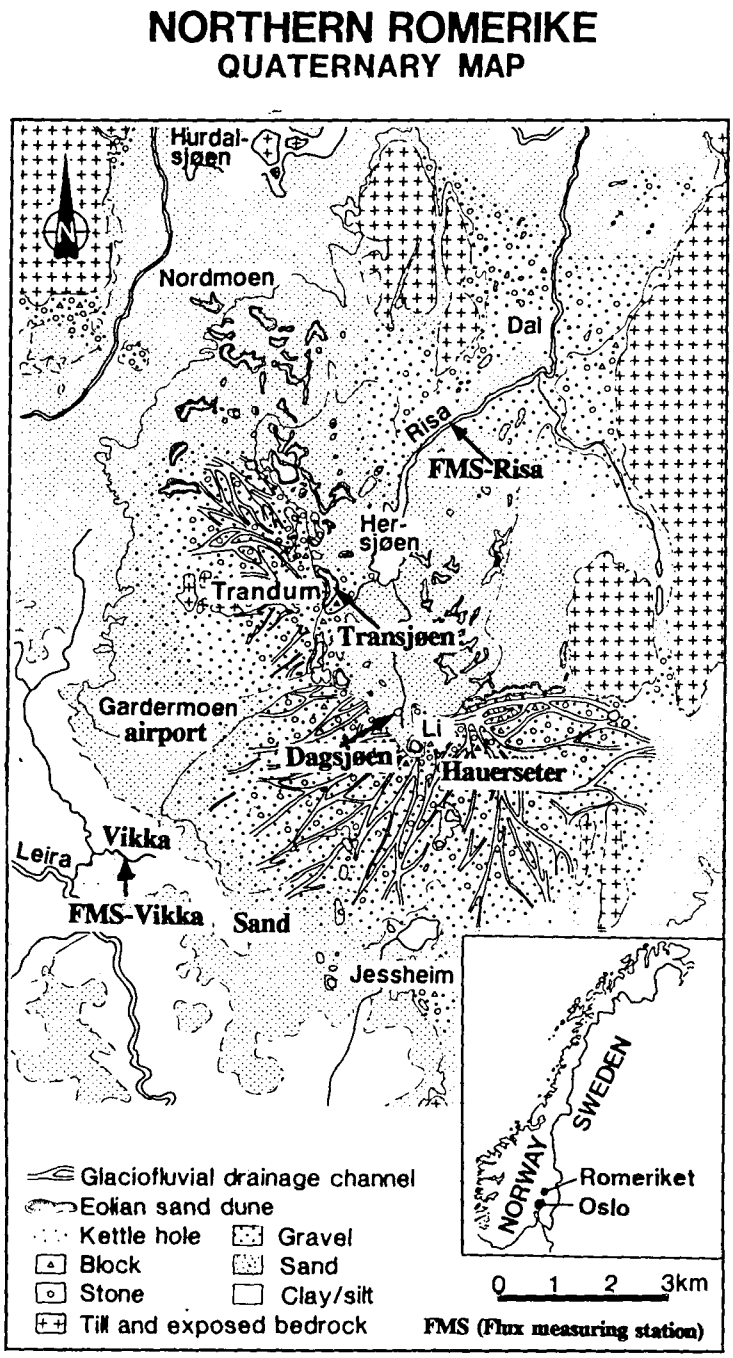


Fig.1(a) Øvre Romerike area showing Hurdalsjoen, Hersjoen, Transjoen, Dagsjoen, airport, Trandum, the rivers Risa, Leira, Vikka and flow gauging stations on the Risa and Vikka.

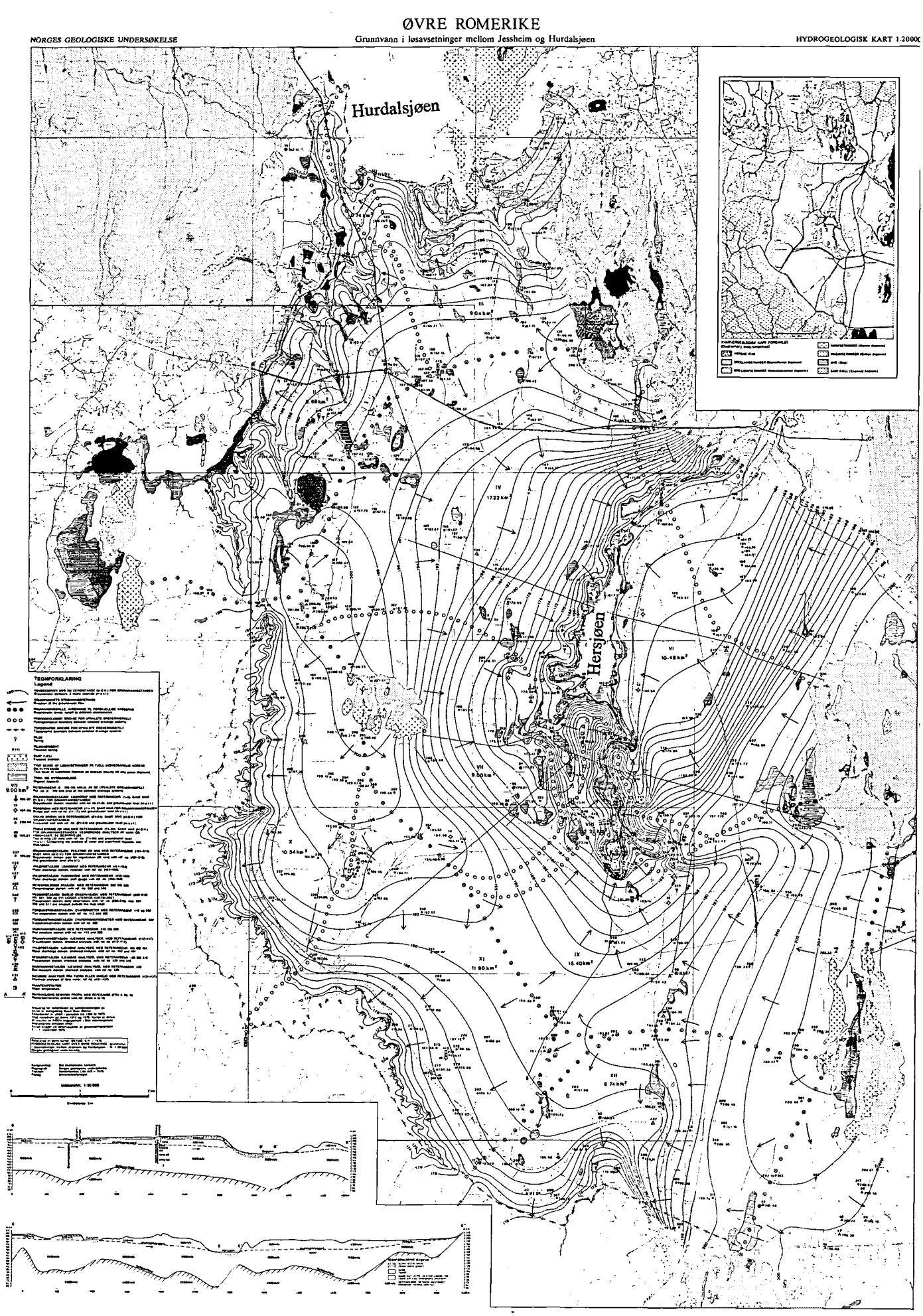


Fig.1(b) The water table in the Øvre Romerike aquifer , Østmo (1976). Contours show water table (2 m intervals). Arrows show groundwater flow.

Fig.2(a) Photo of coarse layer at Trandum landfill showing fine and coarse intercalated layers

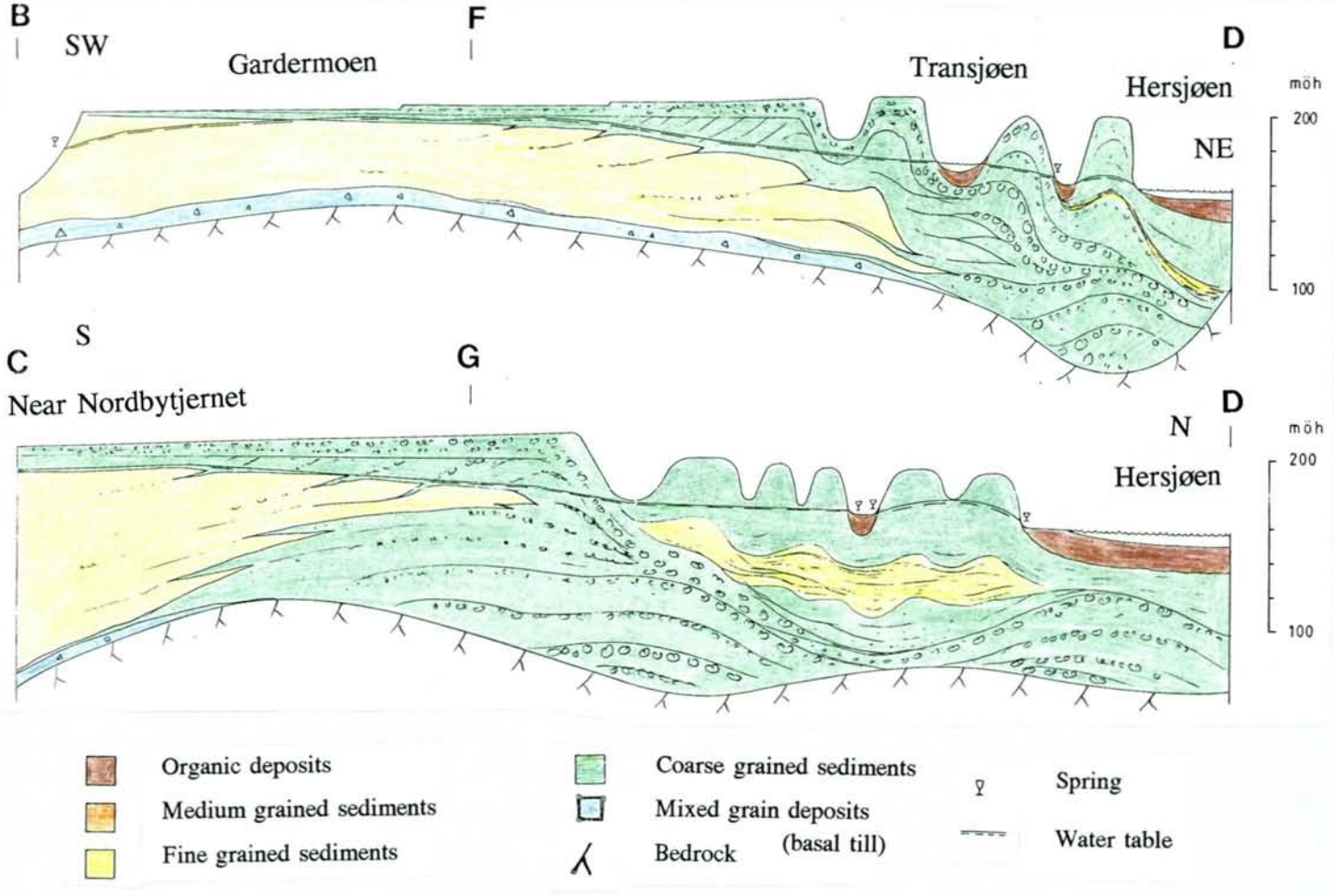


Fig.2(b) An interpretation of the structure of the Romerike delta, after VIAK (1990)

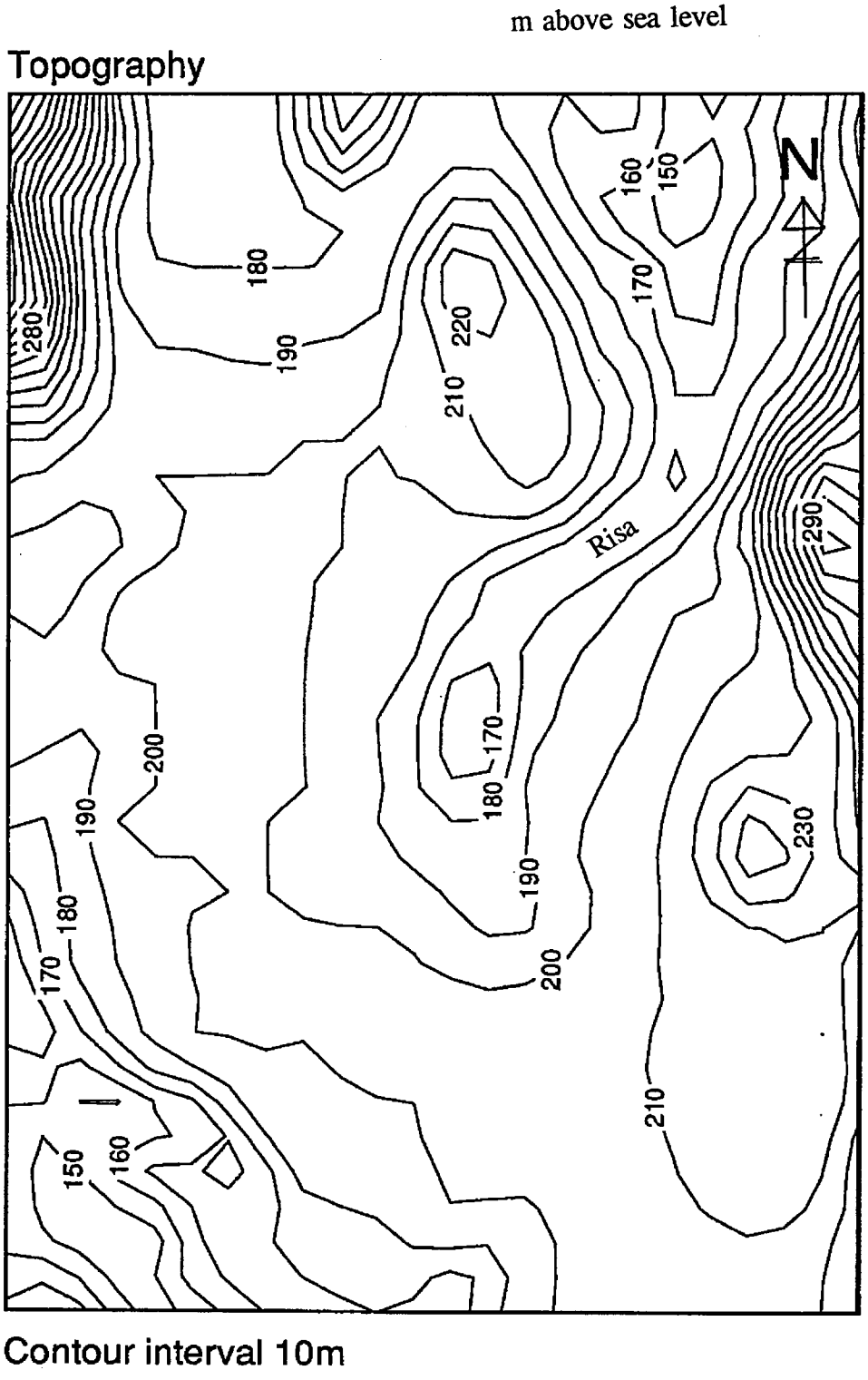


Fig.3(a) Contour map of topography

m above sea level

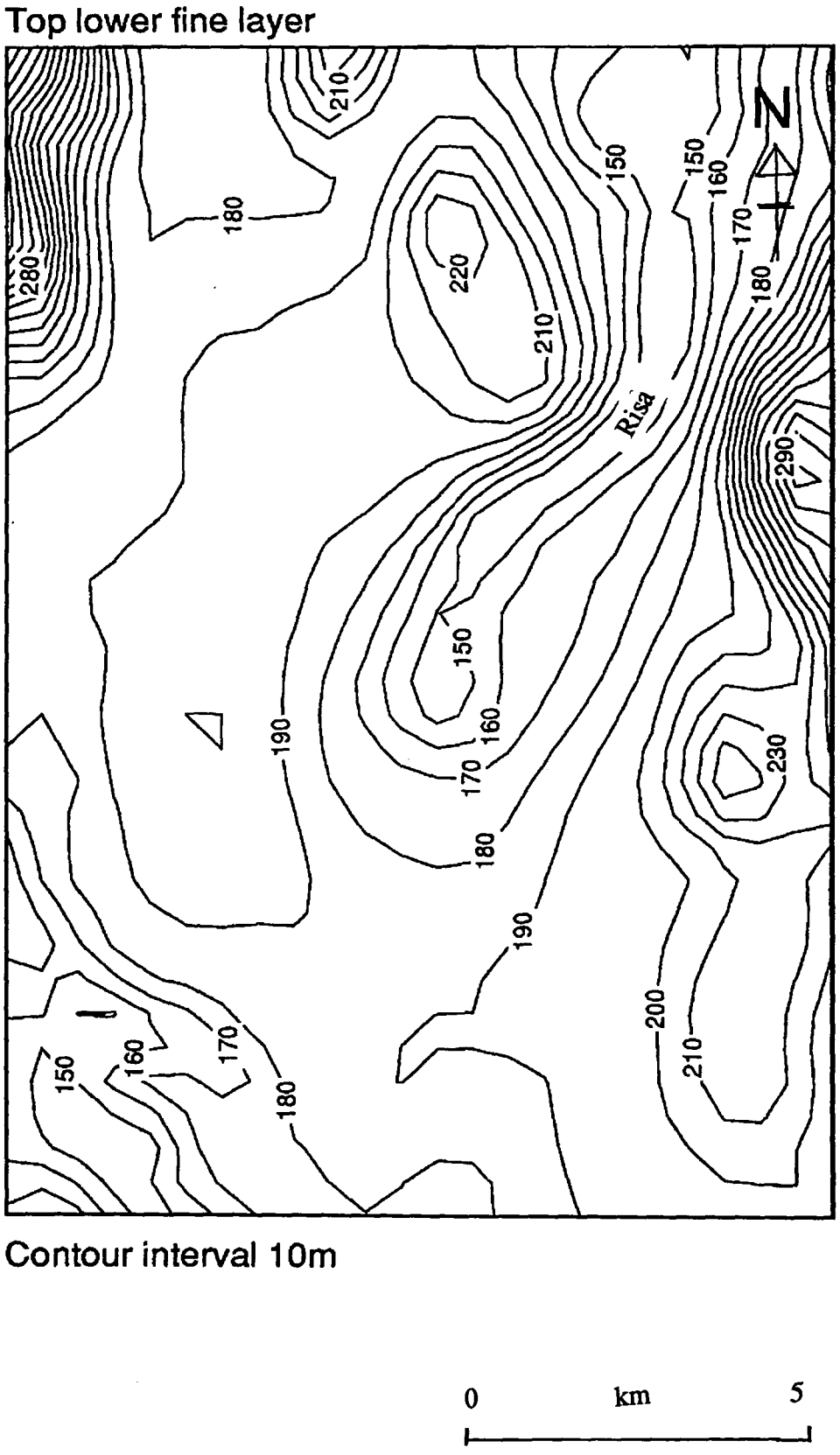


Fig.3(b) Contour map of top of fine layer

m above sea level

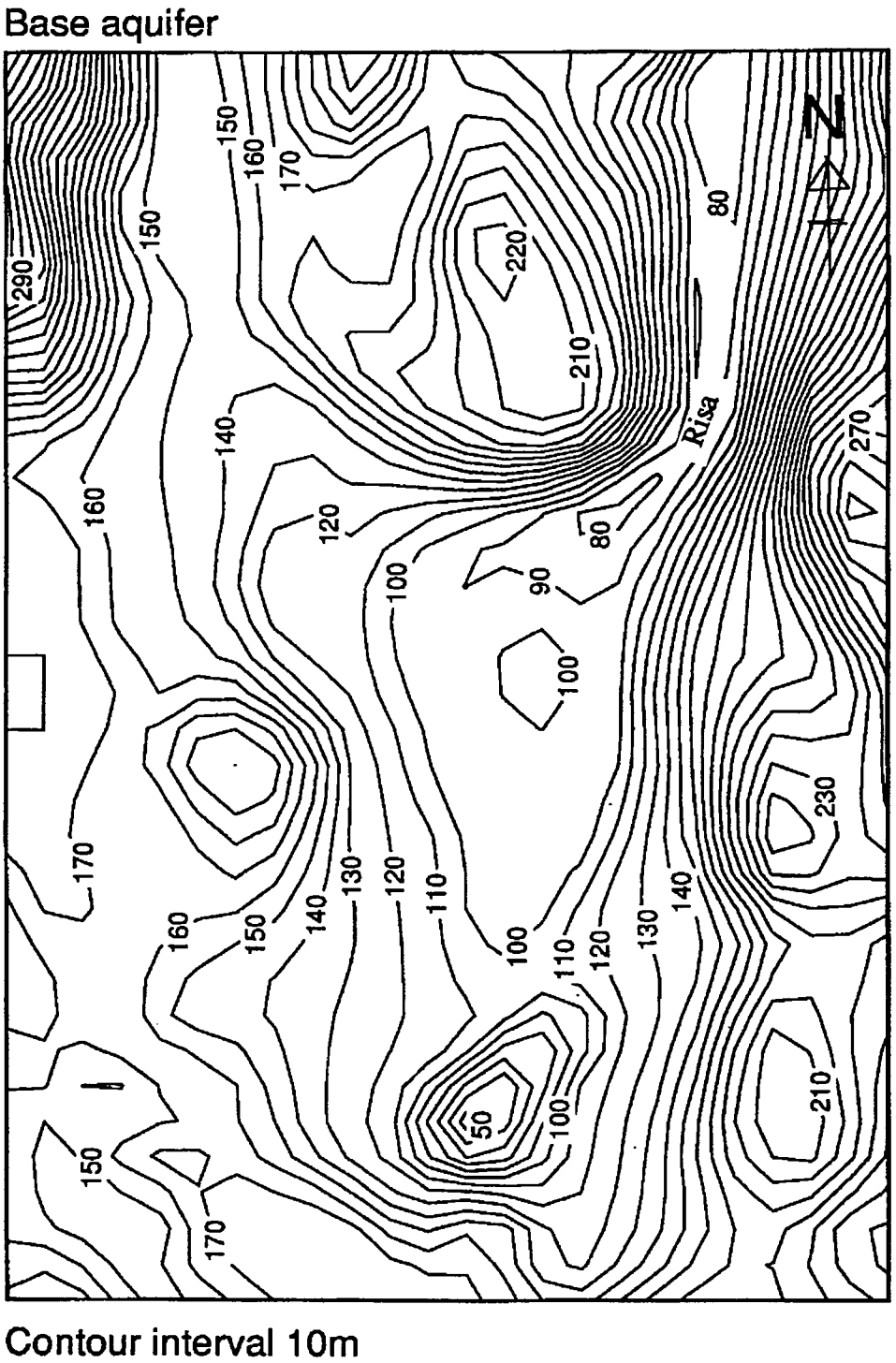


Fig.3(c) Contour map of base of aquifer

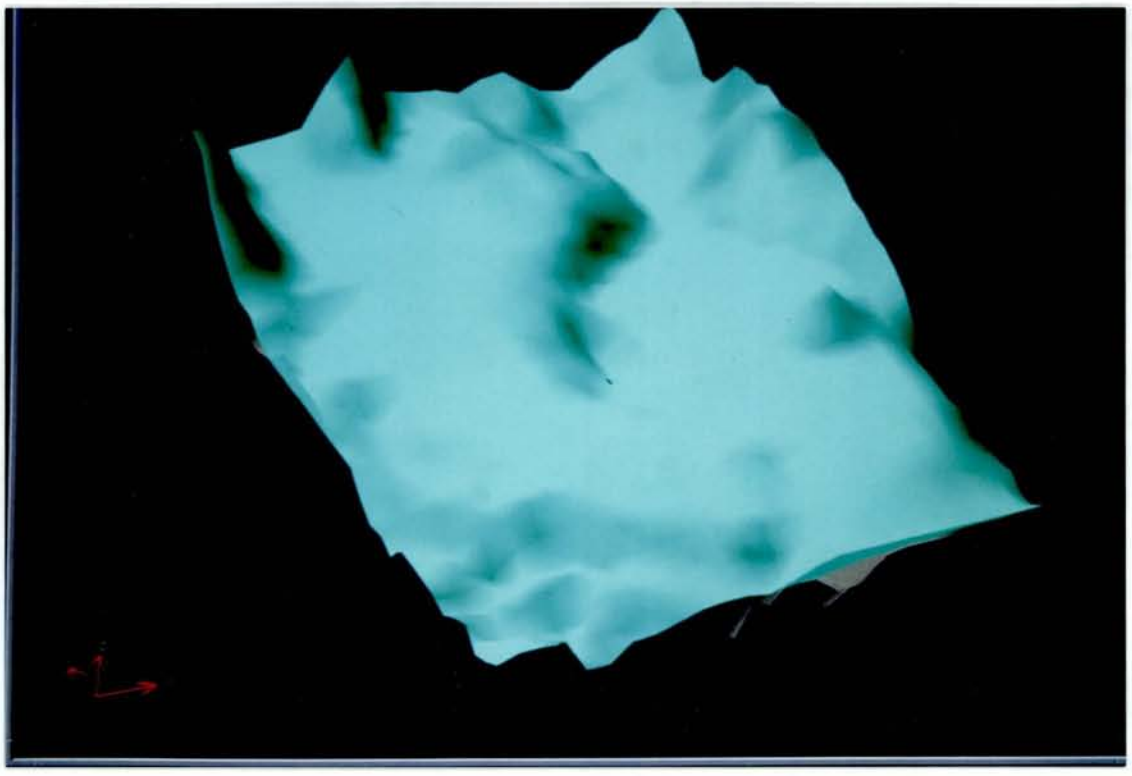


Fig.4(a) 3D ADVIZE visualisation of topography

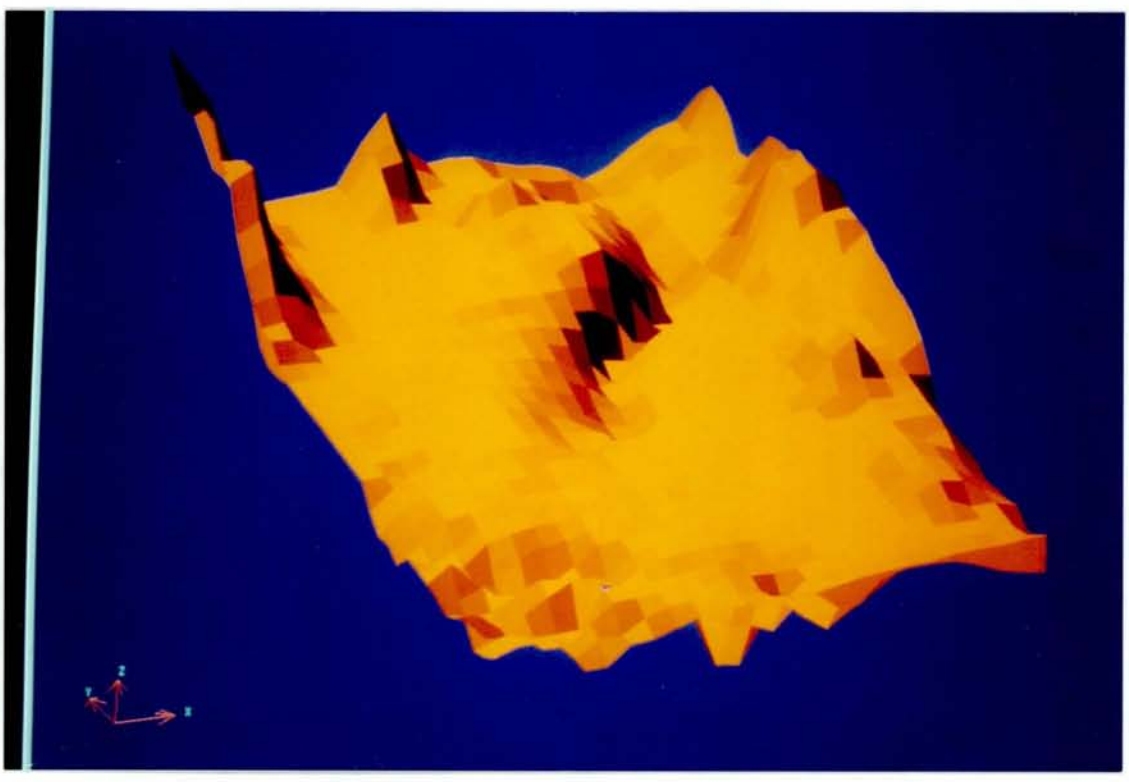


Fig.4(b) 3D ADVIZE visualisation of top of fine layer

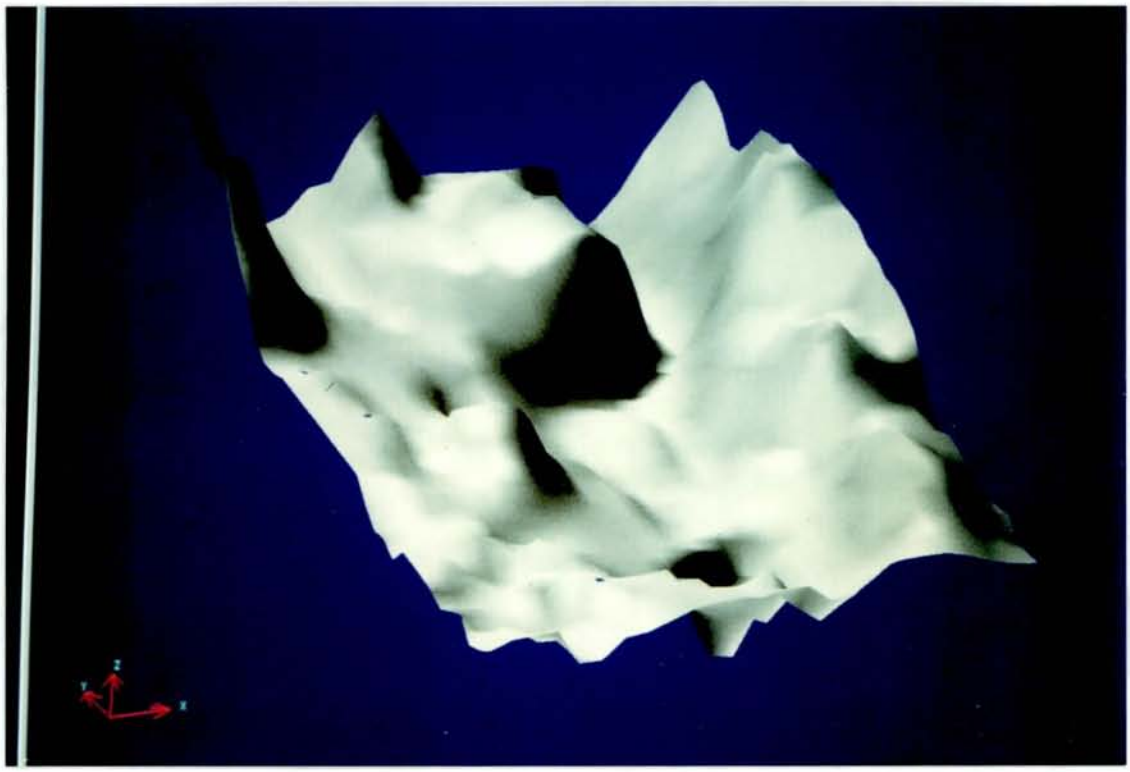


Fig.4(c) 3D ADVIZE visualisation of base of aquifer

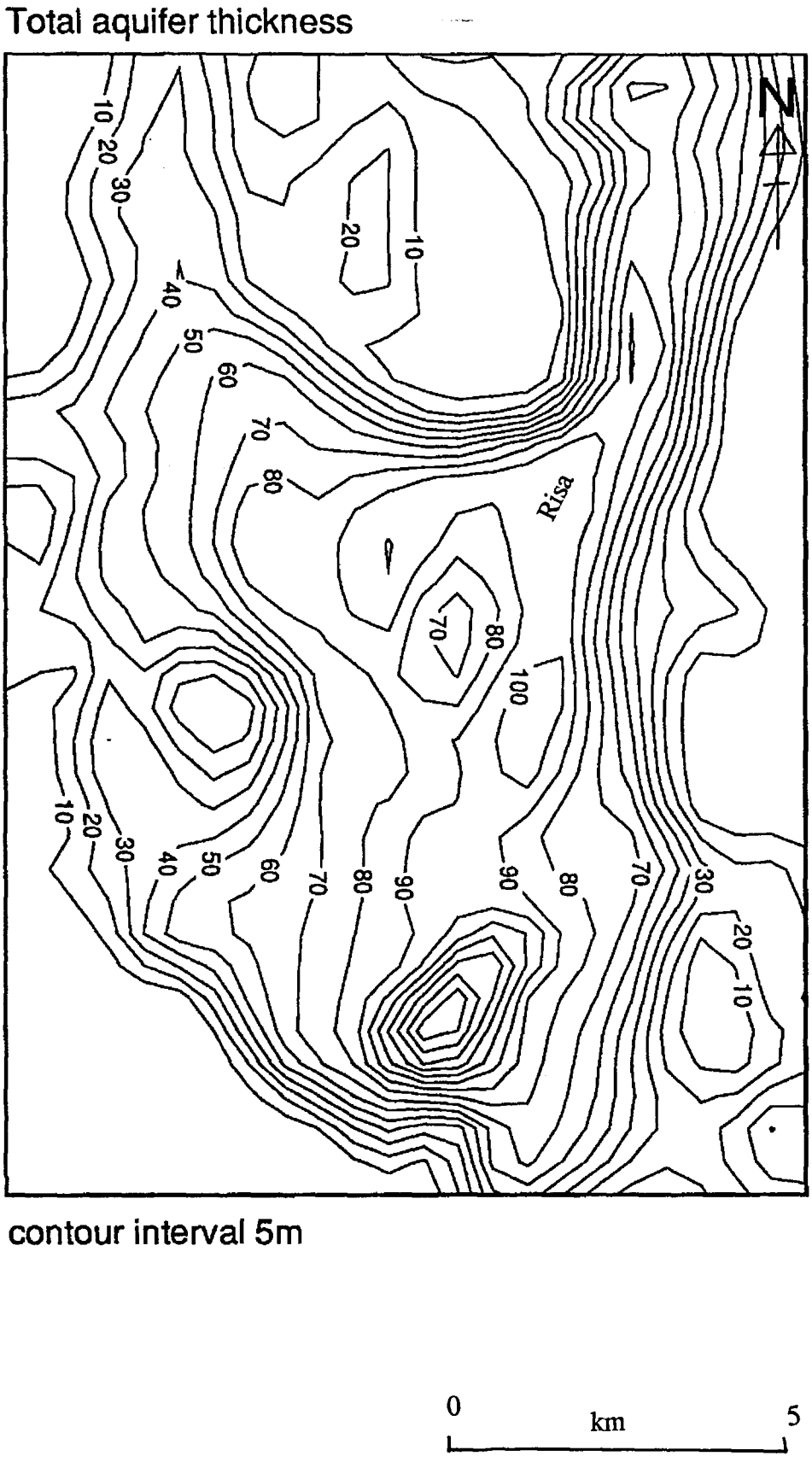


Fig.5(a) Isopach map of the whole aquifer

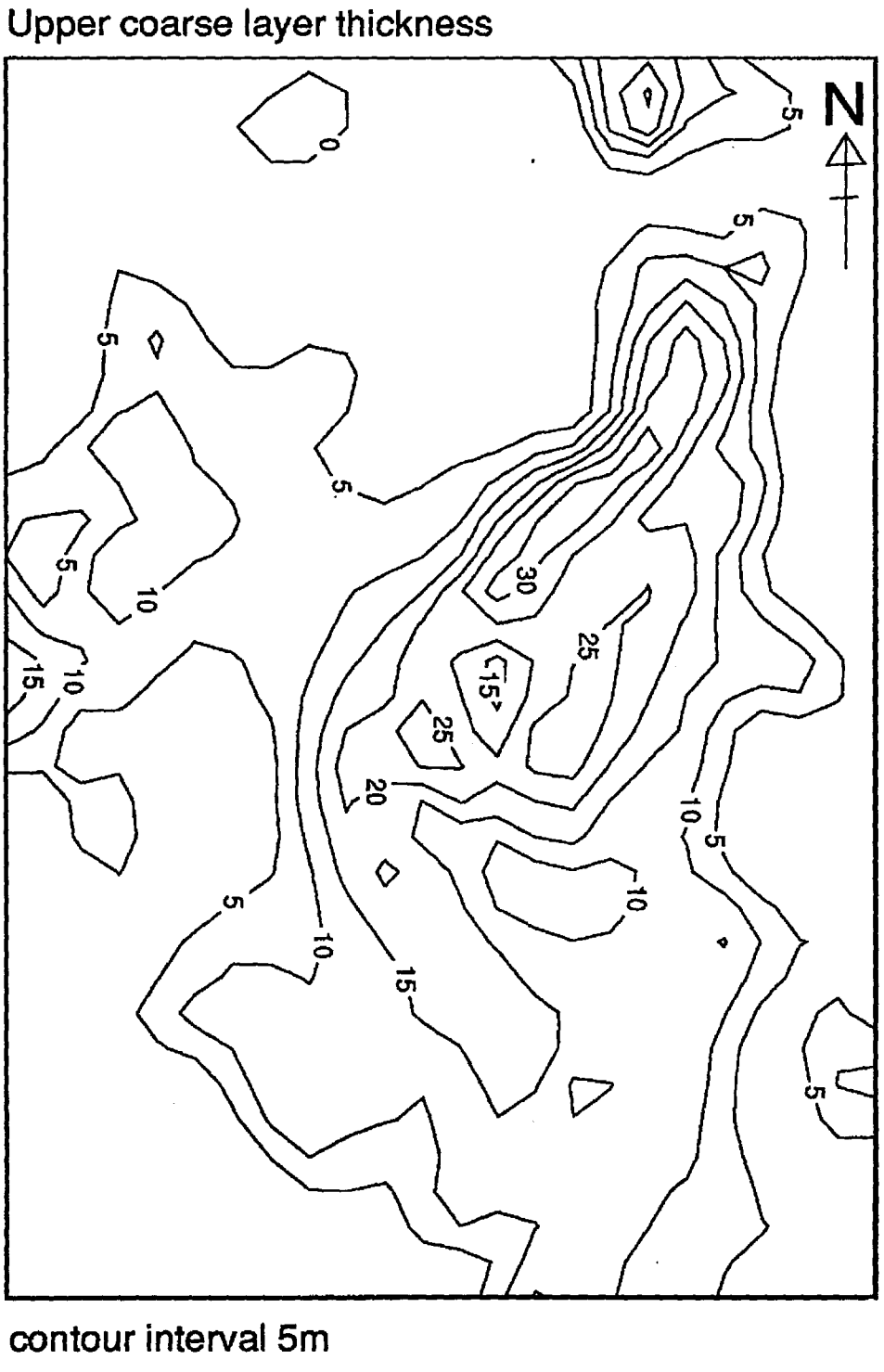


Fig.5(b) Isopach map of the coarse layer

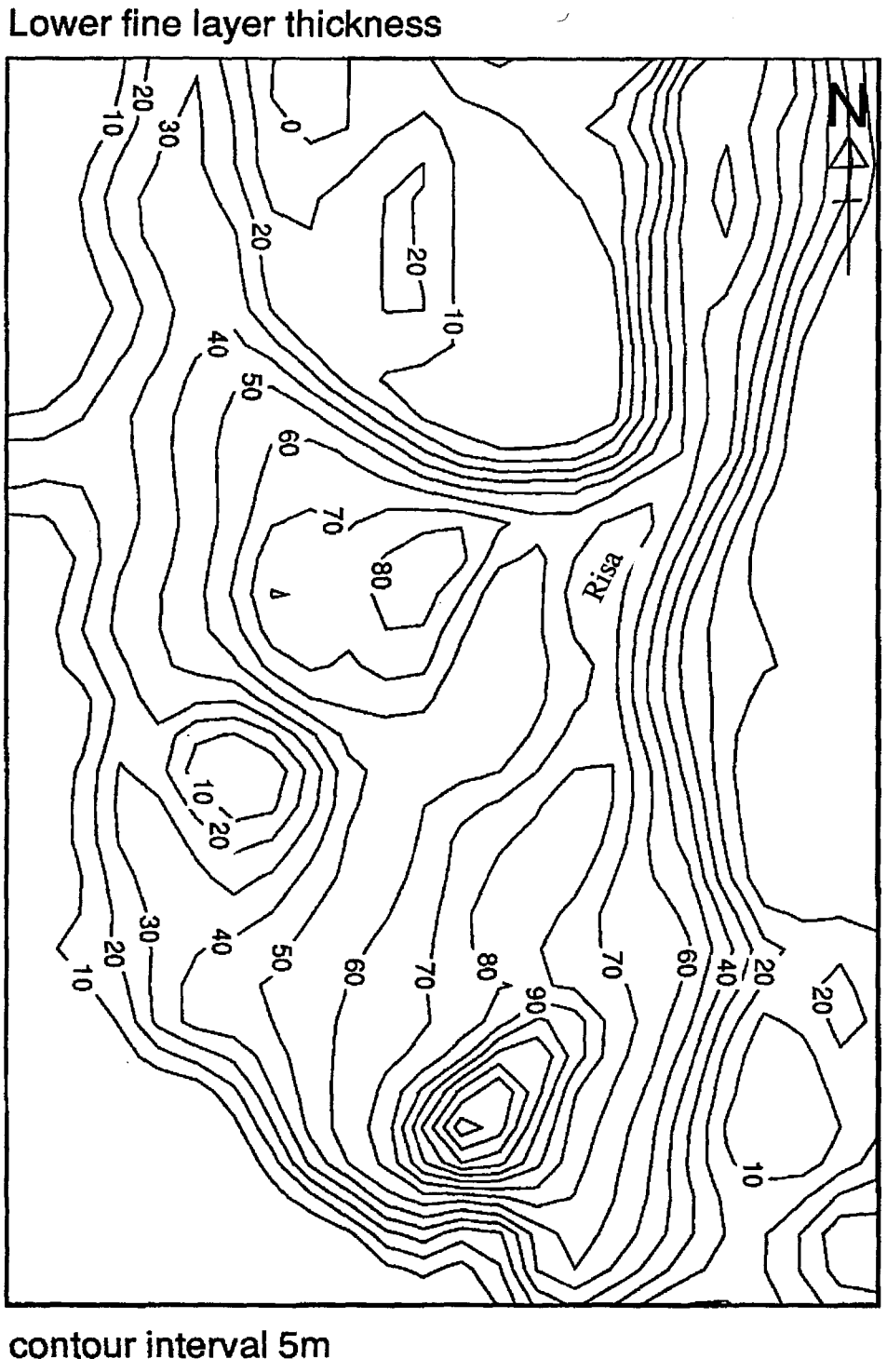


Fig.5(c) Isopach map of the fine layer

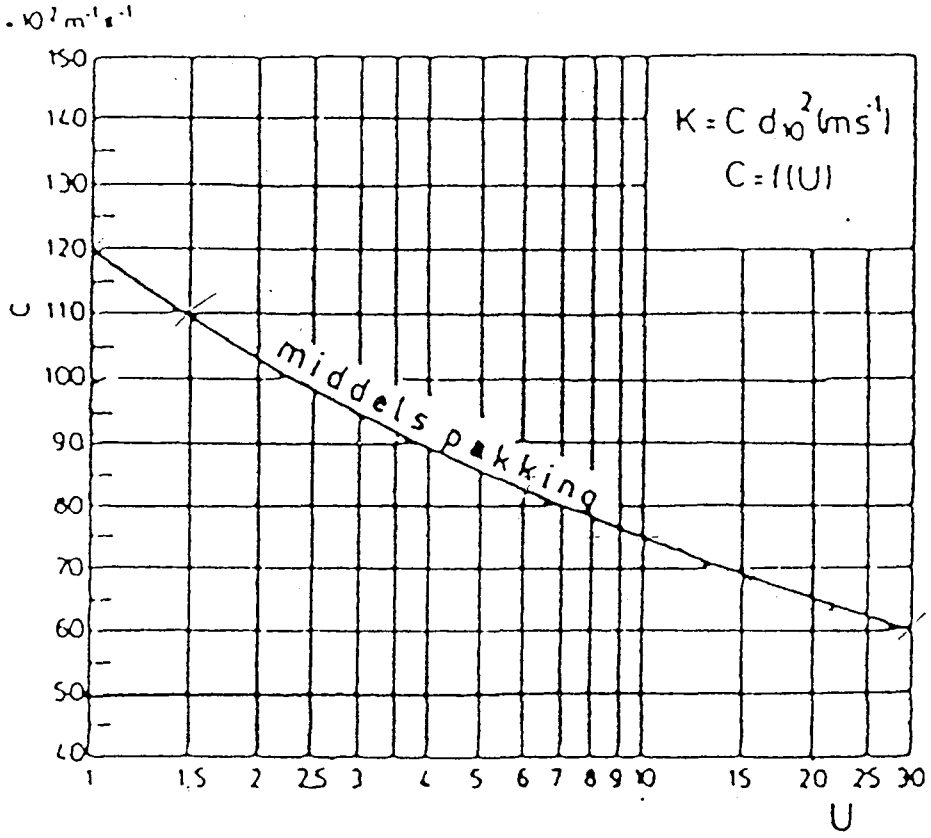


Fig.6 Calibration graph for hydraulic conductivity analysis from grain size samples (Bayer method - after Langguth & Voigt)

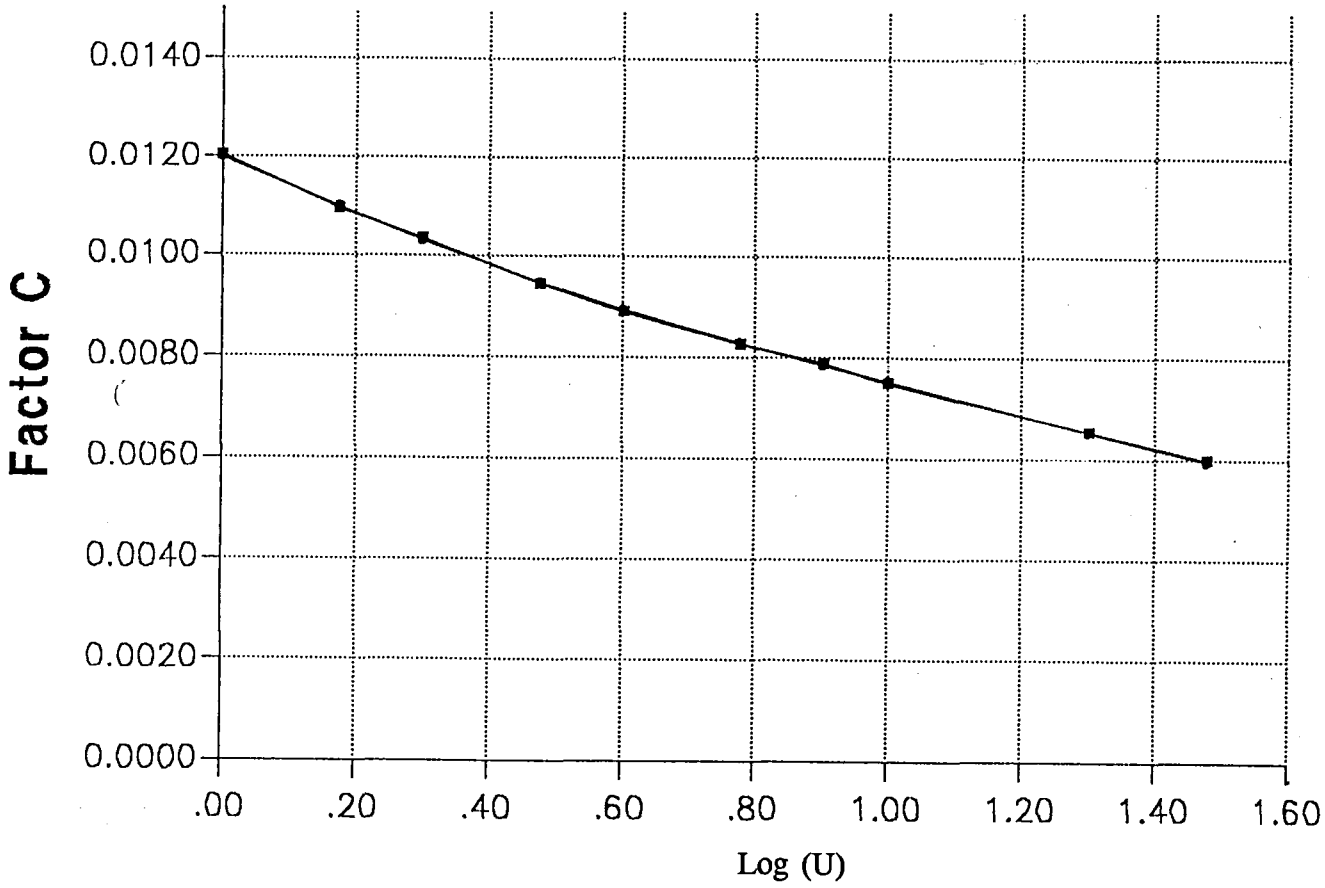


Fig.7 Polynomial curve, fit to calibration curve (the two curves are exactly coincident !)

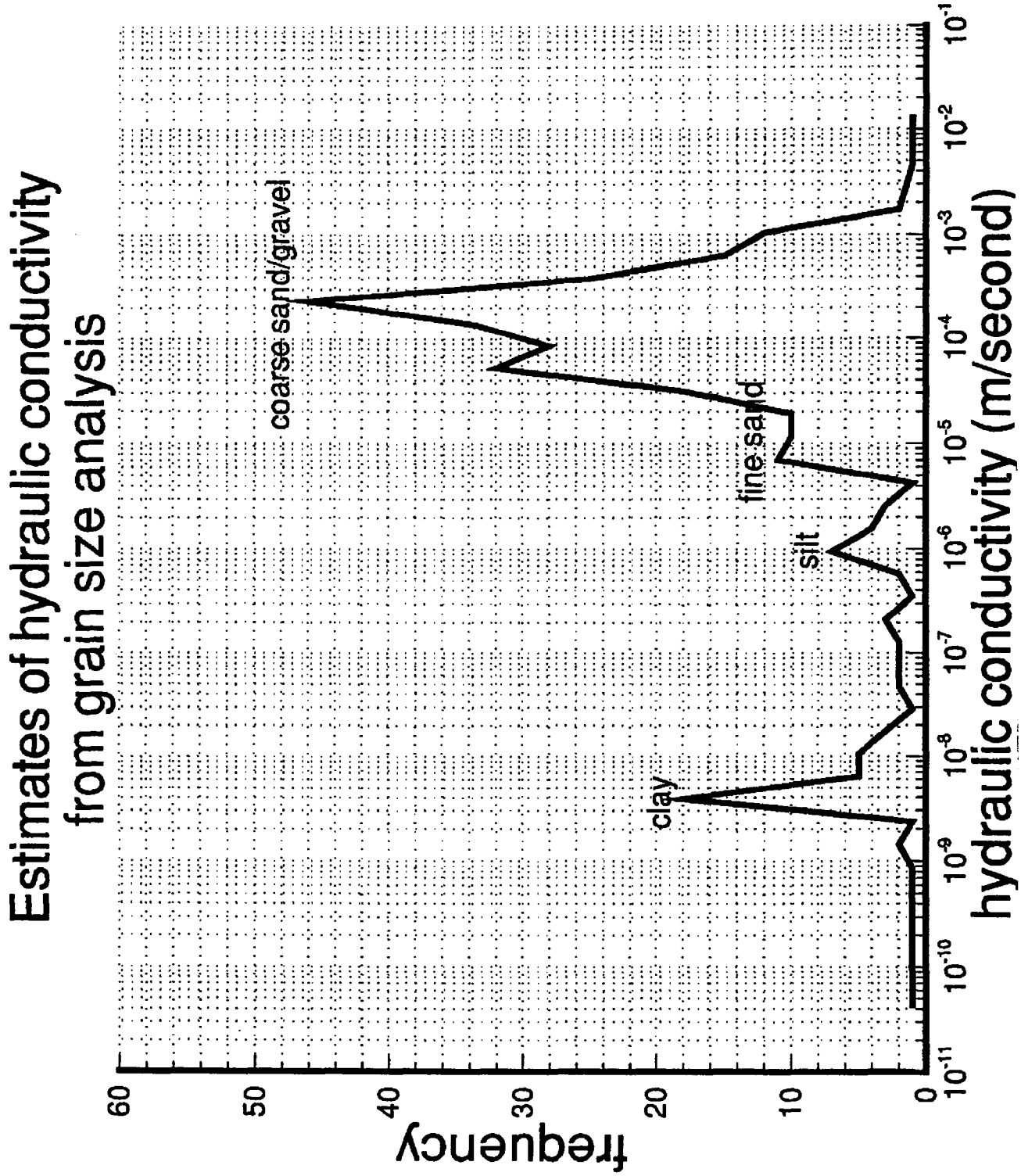
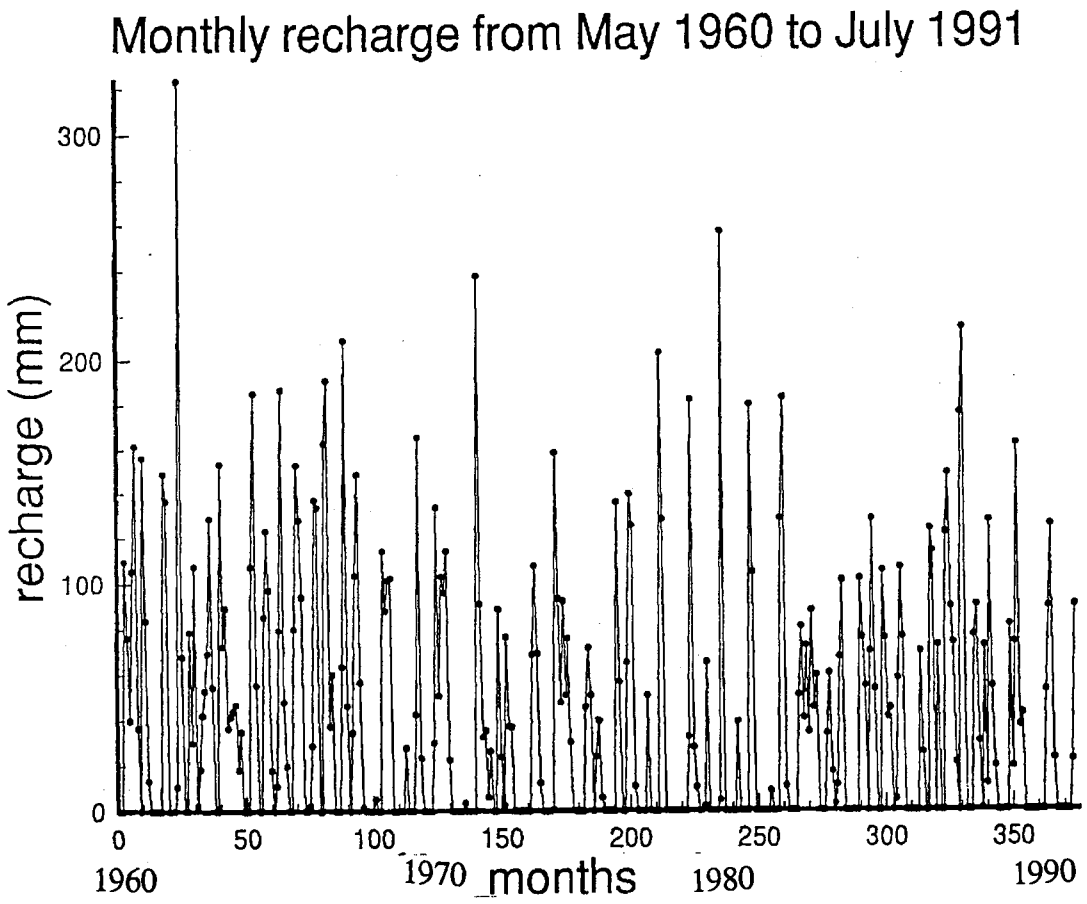


Fig.8 Histogram of all hydraulic conductivity estimates (using the Bayer method - from d_{10} and d_{∞} grain sizes)



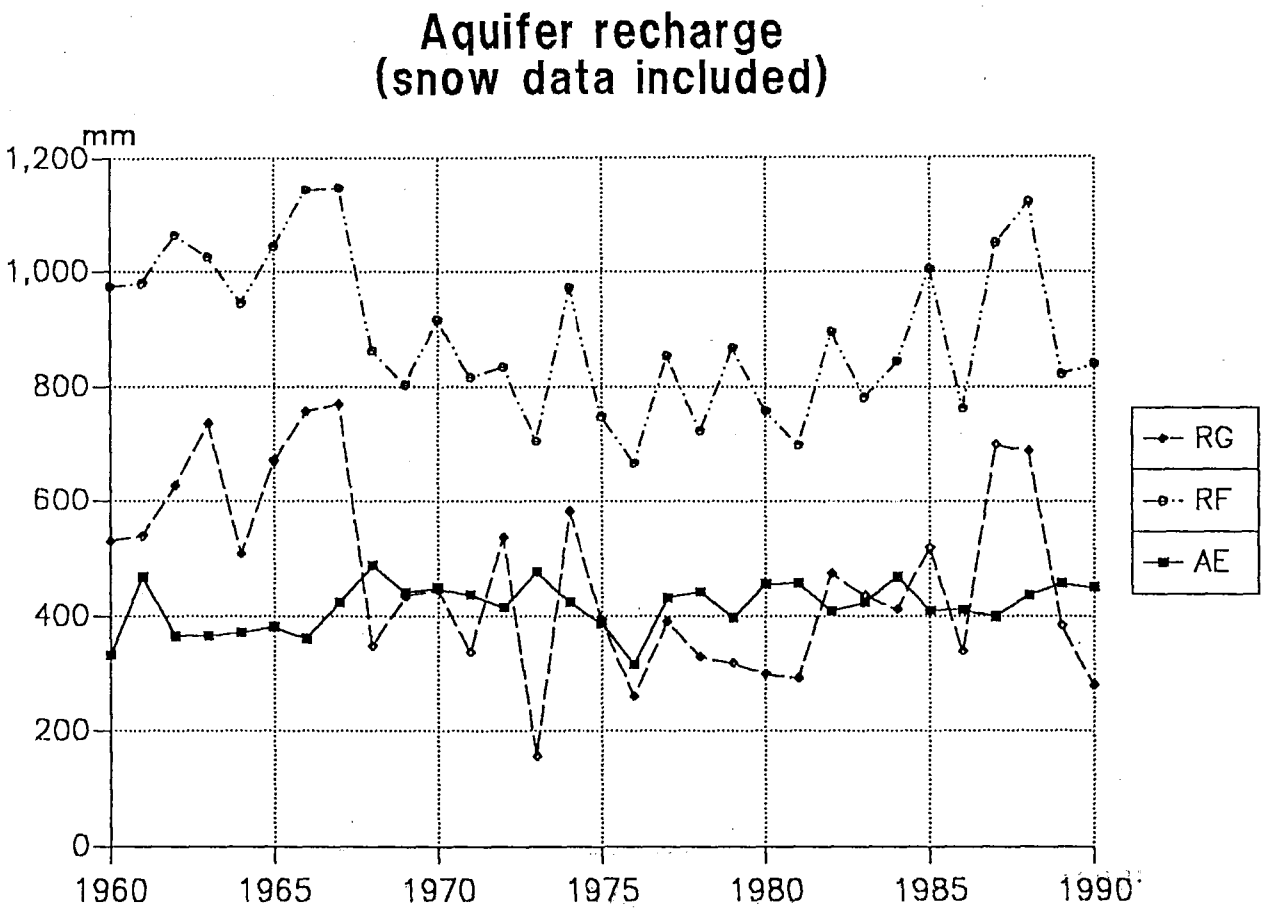


Fig.9 Recharge model, (a) monthly data, (b) yearly data

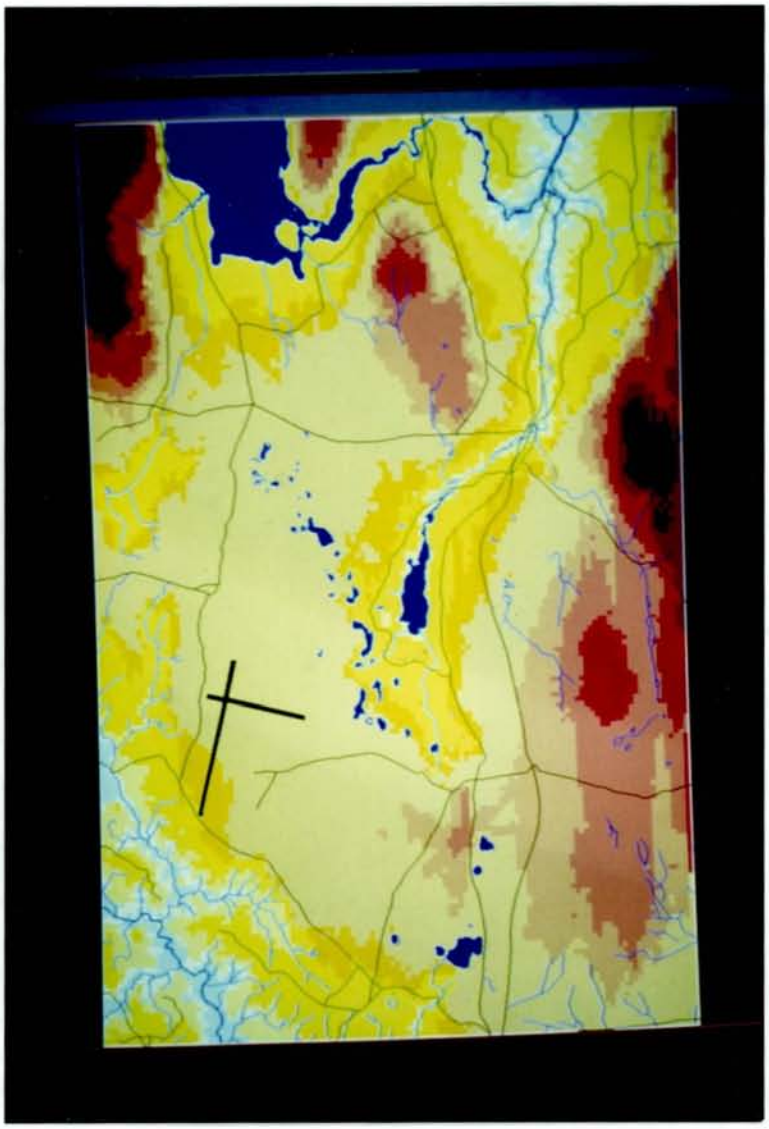


Fig.10 Rasterised map example (topography) produced by GENAMAP

Windows (from top)

Groundwater Workstation
GridOprDialog

GIVE HEAD

GIVE TRANS

Fig.11 Example of the graphical user interface to MODFLOW. The grid has been defined and is displayed, together with roads, rivers and topography, in the right hand window. On the left are windows that enable the user to (a) modify the grid (GridOprDialog window), (b) define constant head cells (GIVE_HEAD window) and (c) define hydraulic conductivity in individual cells (GIVE_TRANS window).

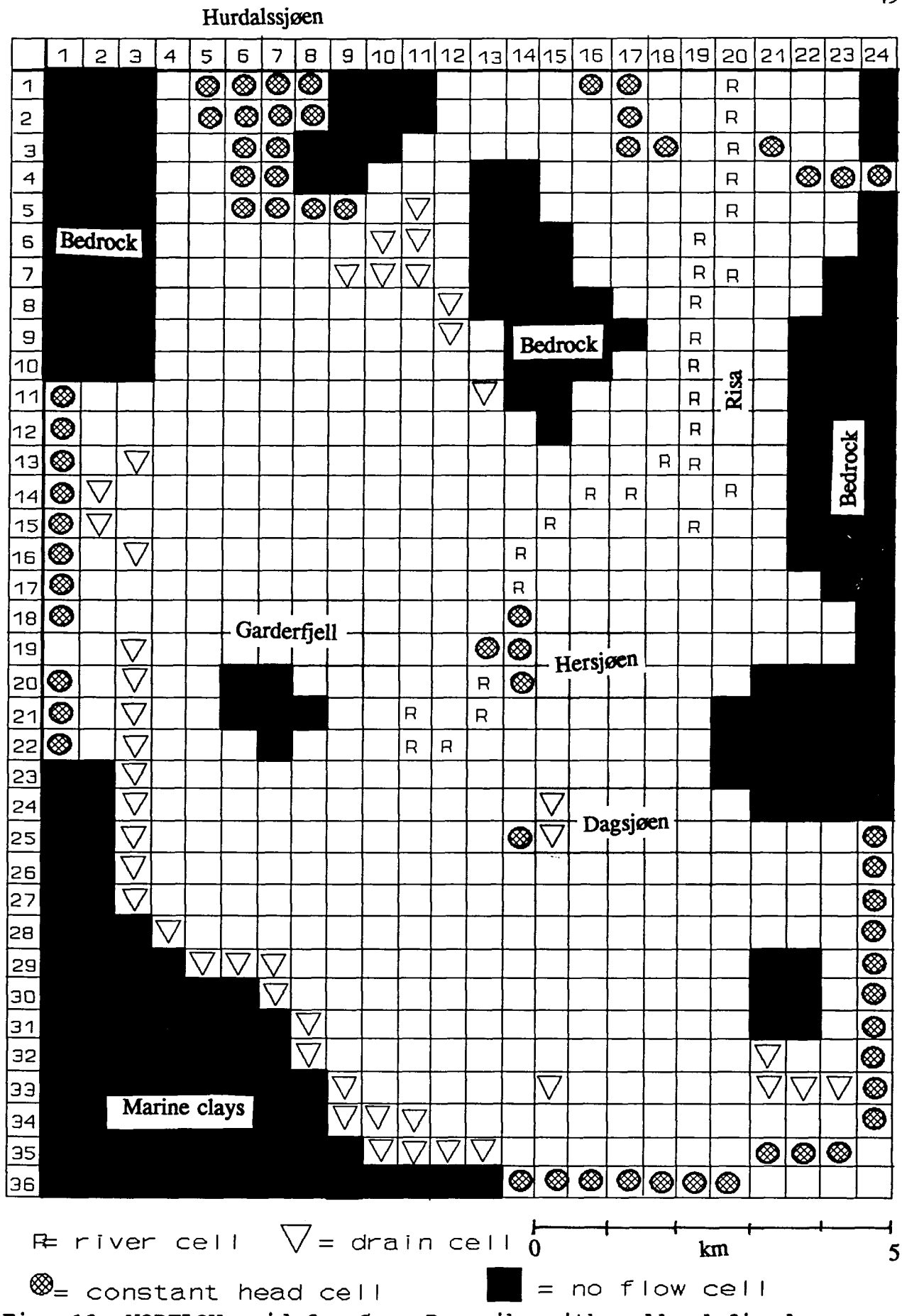


Fig. 12. MODFLOW grid for Øvre Romerike with cells defined

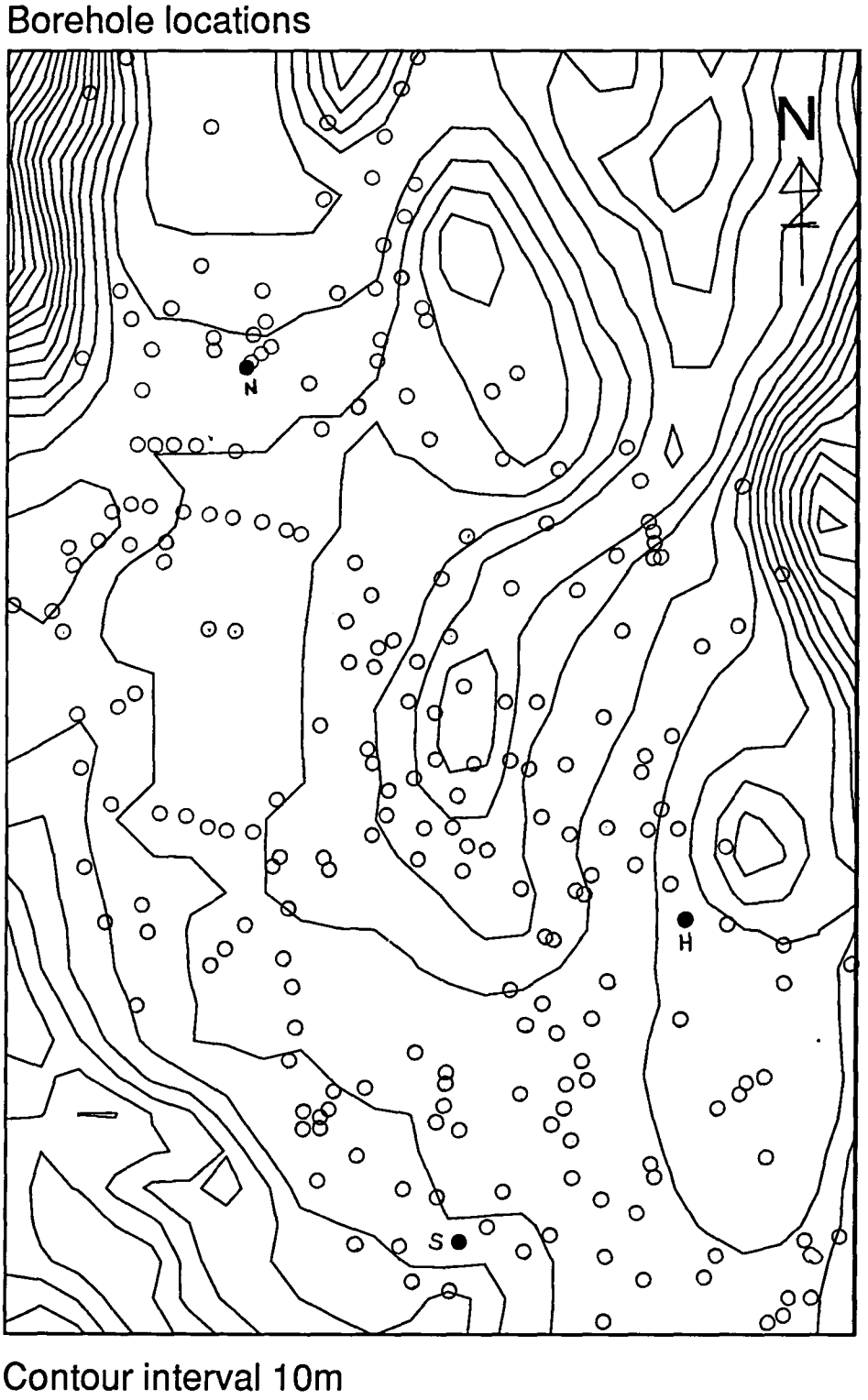


Fig.13 Map of borehole locations for which measurements of head are available from Nov. 1975 (Østmo 1976). S = Sand, H = Hauerseter, N = Nordmoen

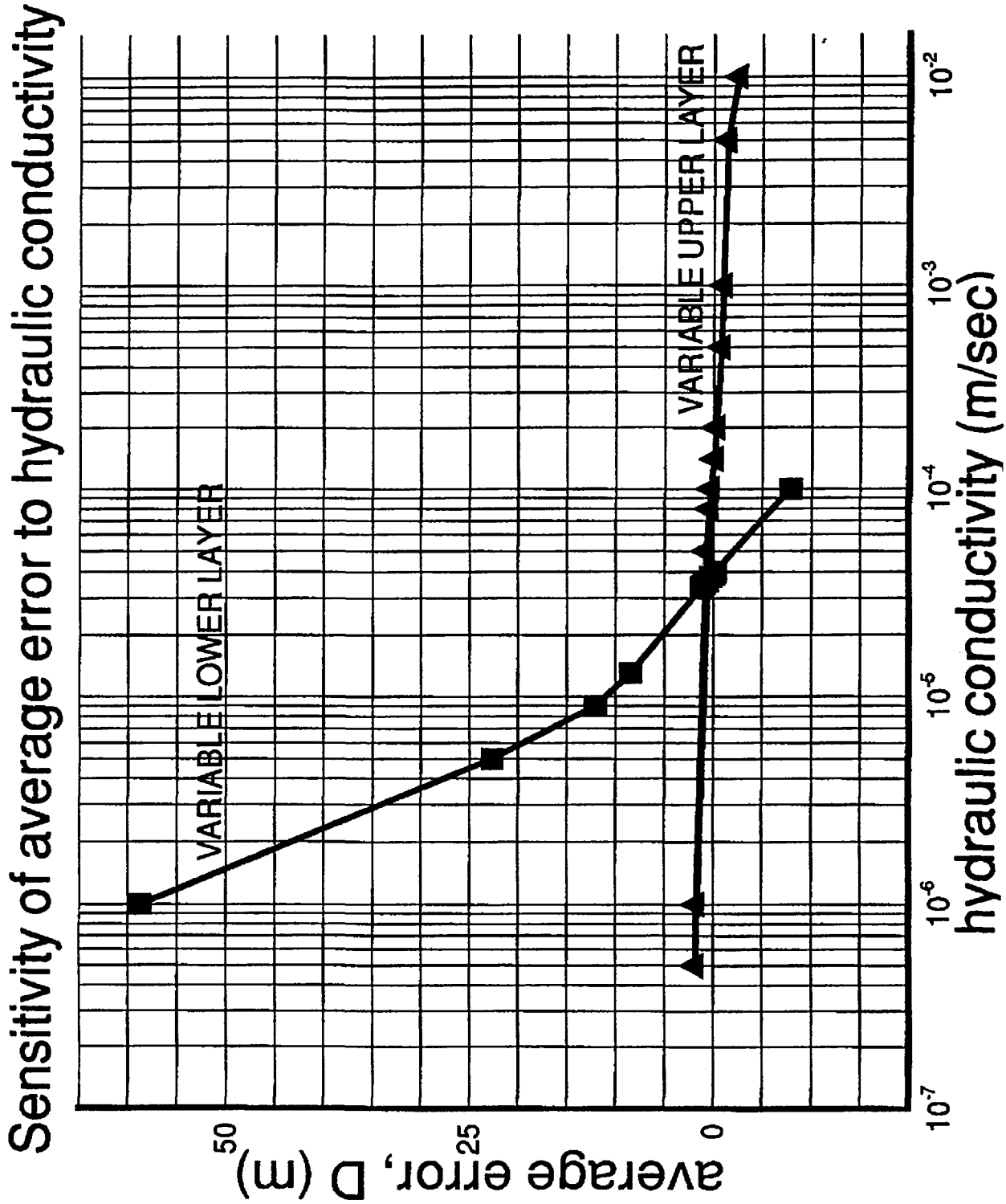


Fig.14 MODFLOW, steady state model: homogeneous layer model - sensitivity of D (average error) to variation in hydraulic conductivity of coarse and fine layers.

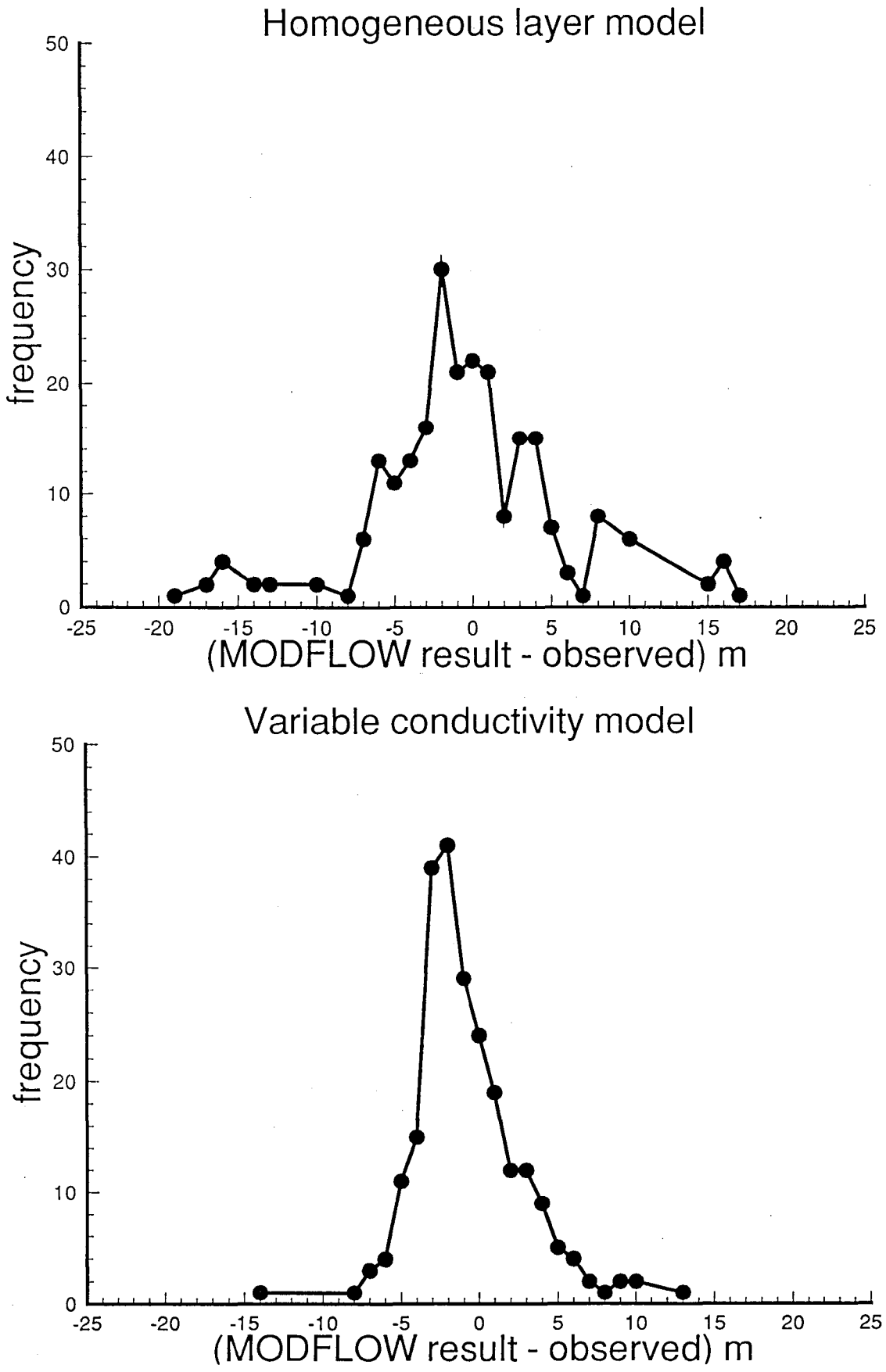


Fig.15 Histograms of discrepancies between steady state model and borehole data for:
(a) homogeneous layer model
(b) calibrated hydraulic conductivity model

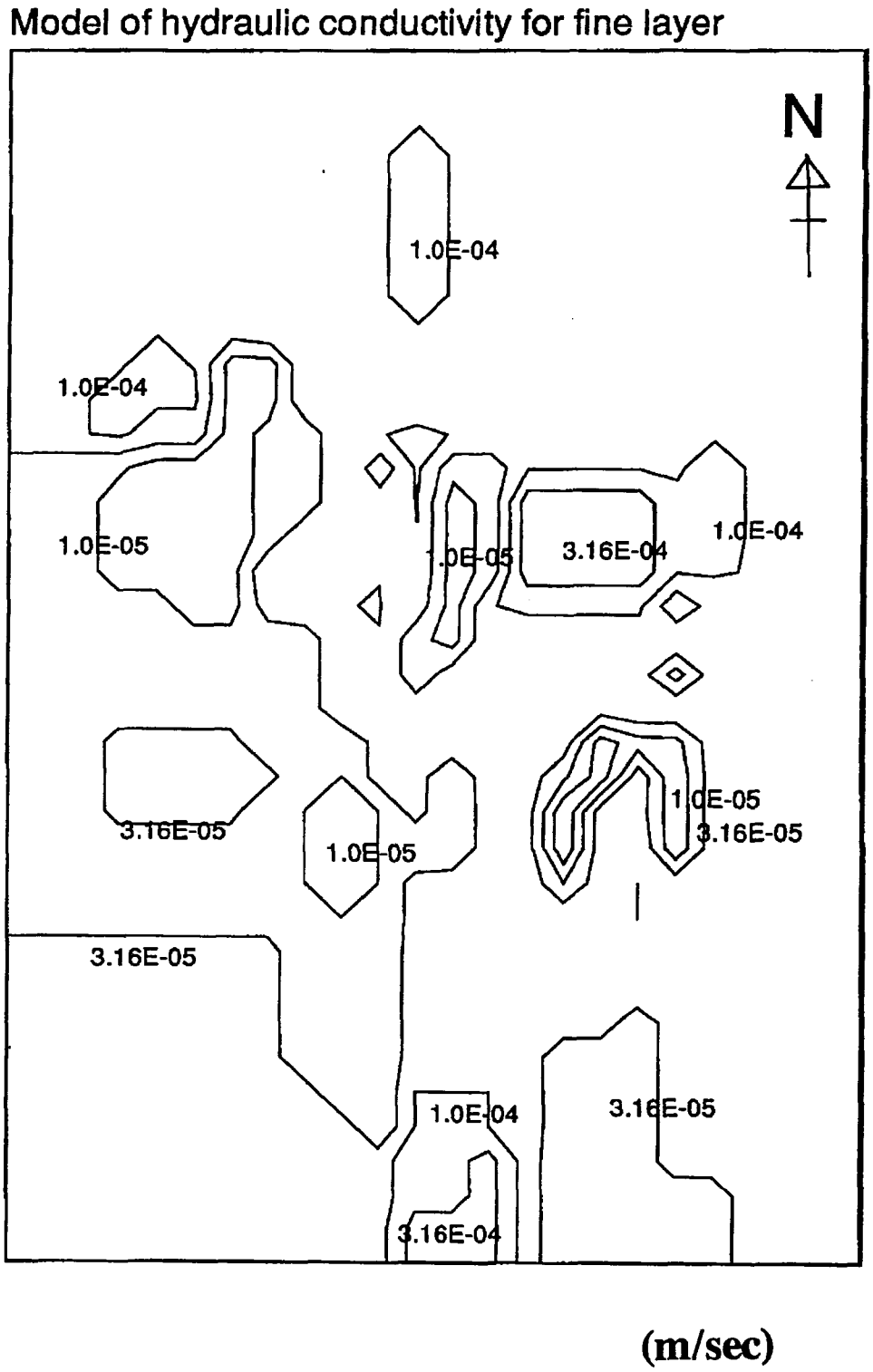


Fig.16 Resulting hydraulic conductivity field for fine layer after calibration with borehole data.

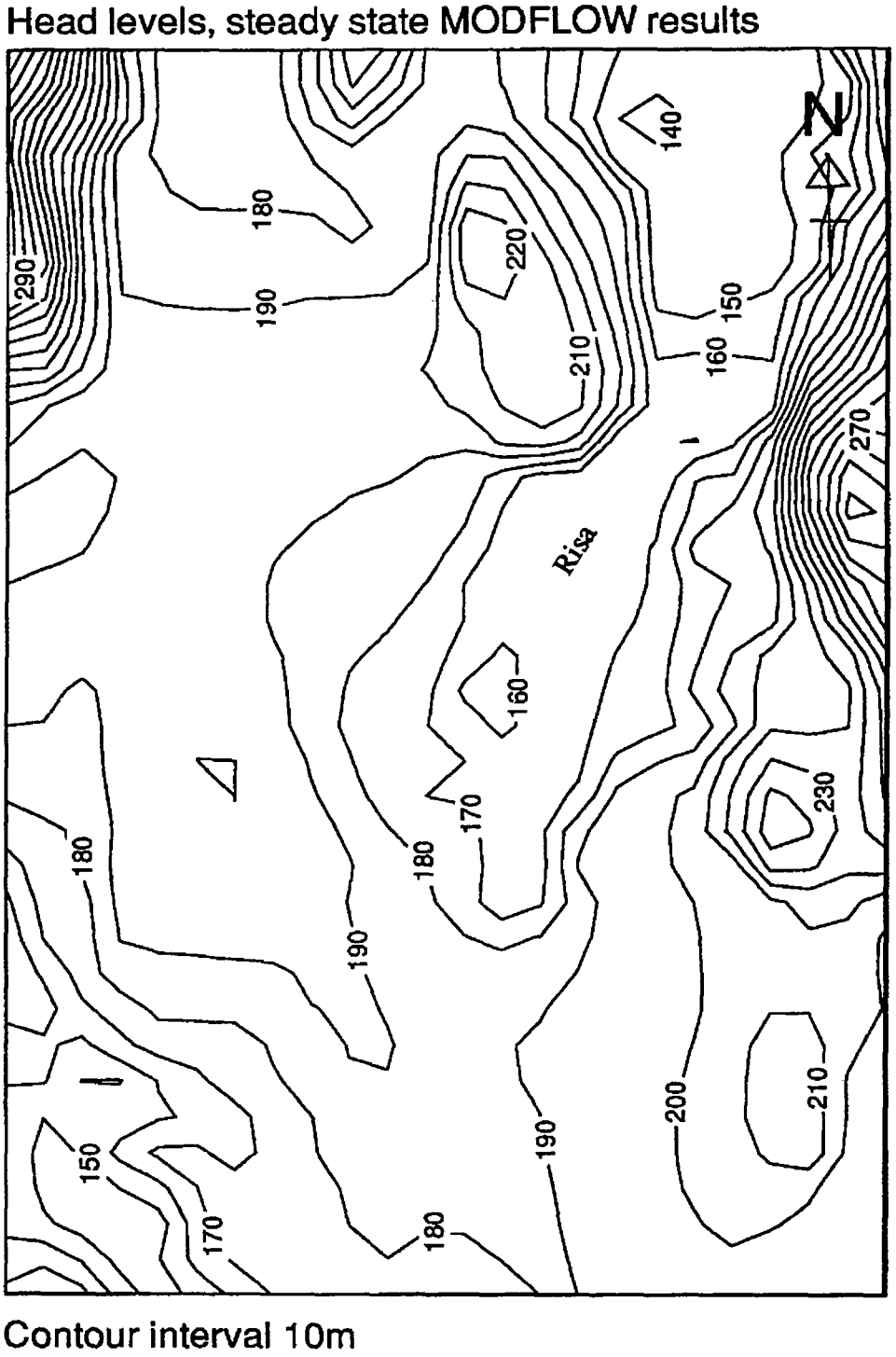
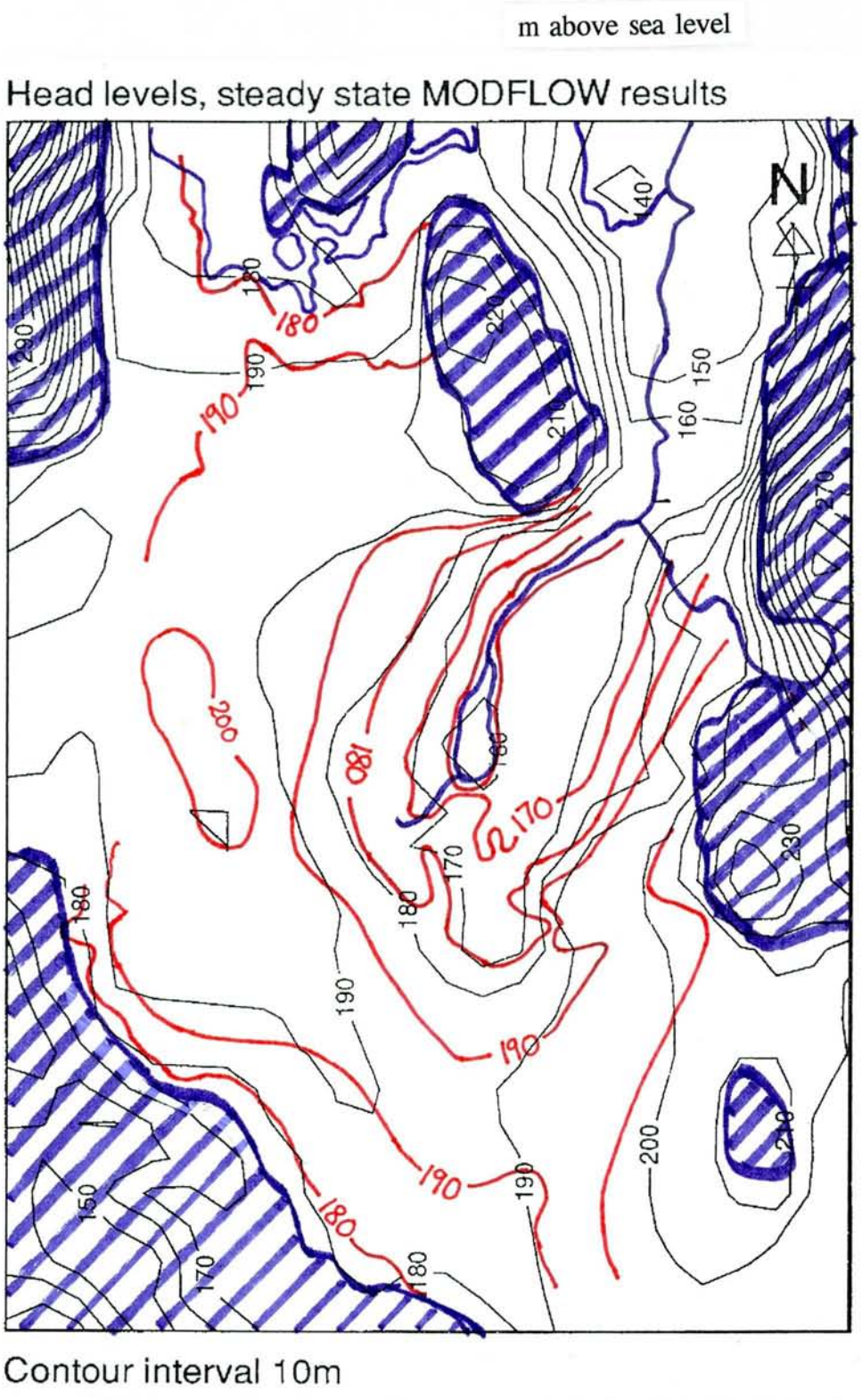


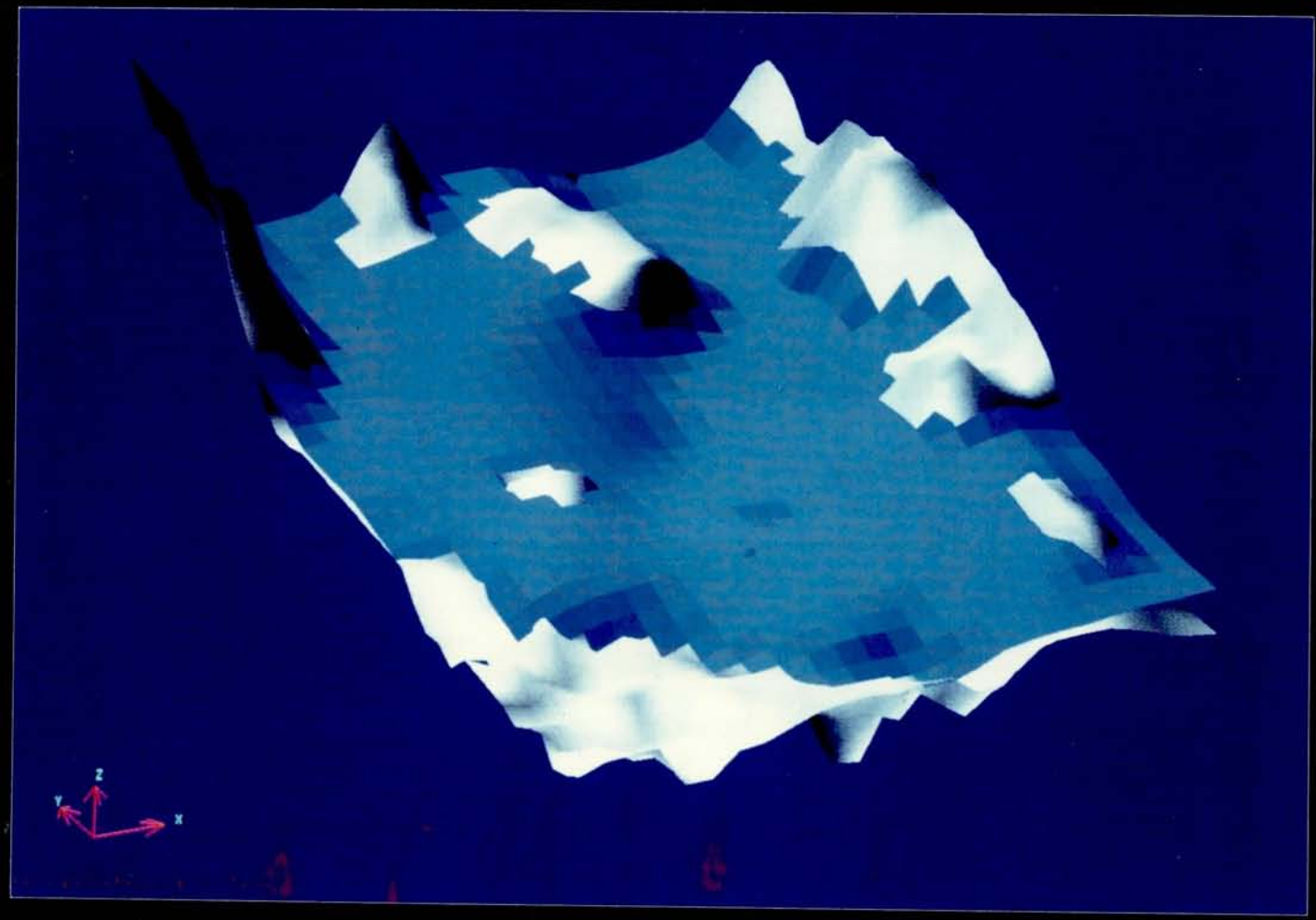
Fig.17 (a) MODFLOW steady state results for head.



Red = Østmo's (1976) contours, Blue = rivers, lakes, Blue striping = no-flow areas

Fig.17 (b) simplification of Østmo's (1976) map for comparison

ØVRE ROMERIKE AQUIFER
GROUNDWATER FLOW MODELLING



Bergen Environmental Sciences IBM - ADVIZE

Fig.17 (c) 3D ADVIZE picture of modelled water table (blue) with base of aquifer (grey)

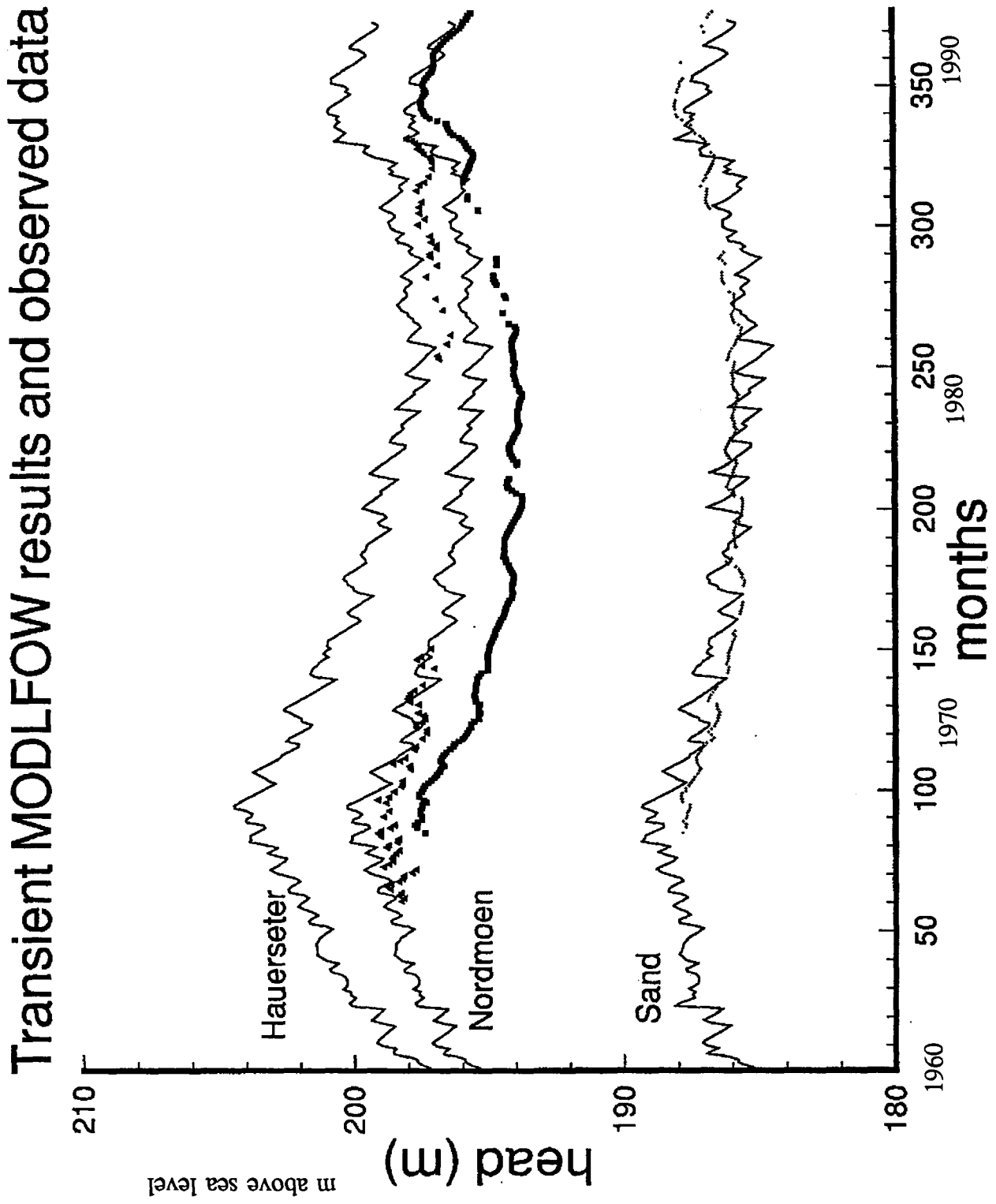


Fig.18 Transient MODFLOW results, with steady state heads in fig.17(a) (i.e. recharge = 1.27×10^{-8} m/s) as initial heads:
(a) using monthly recharge

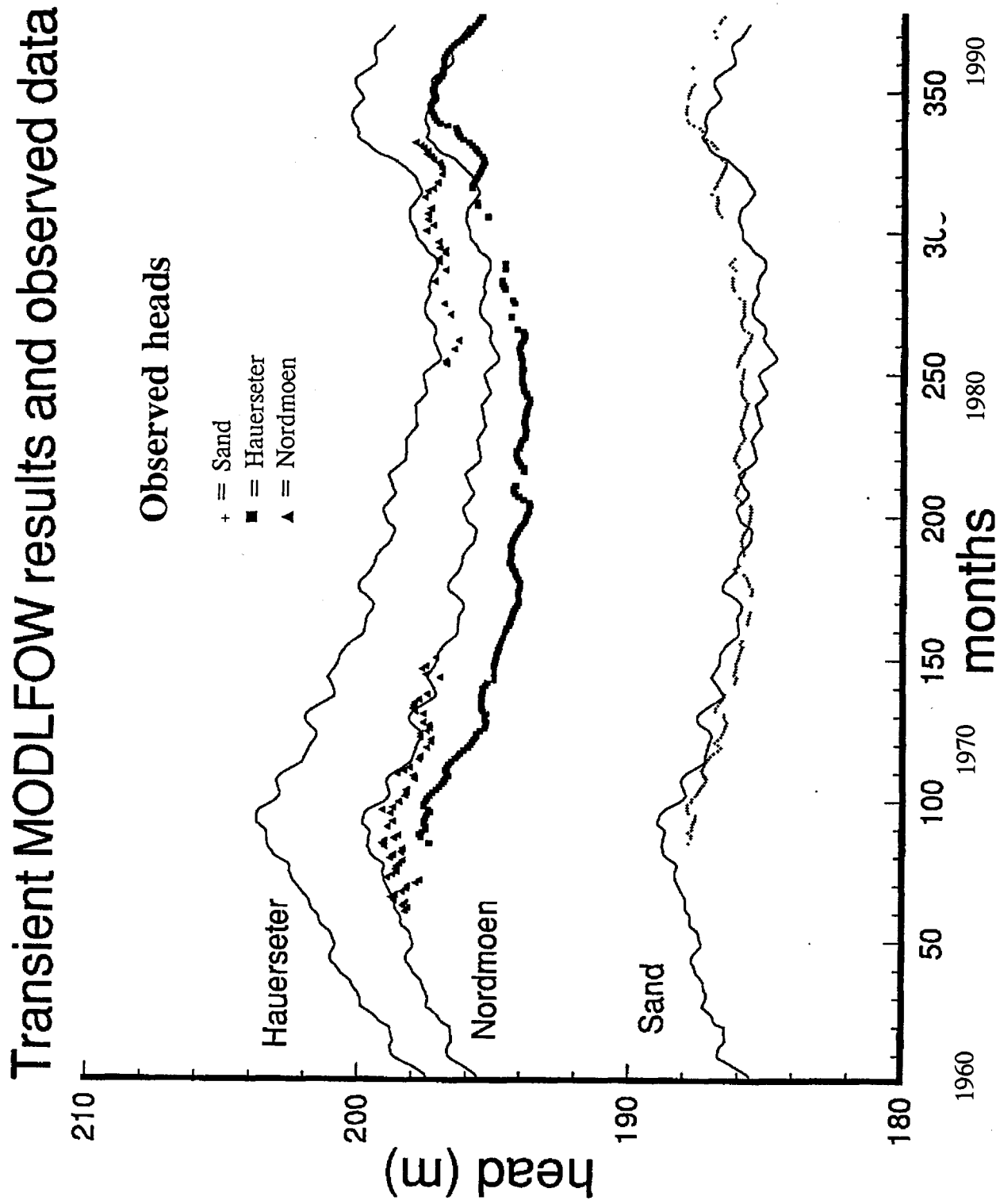


Fig.18 Transient MODFLOW results, with steady state heads in fig.17(a) (i.e. recharge = 1.27×10^{-8} m/s) as initial heads:
(b) using running averages of monthly recharge over 7 month intervals

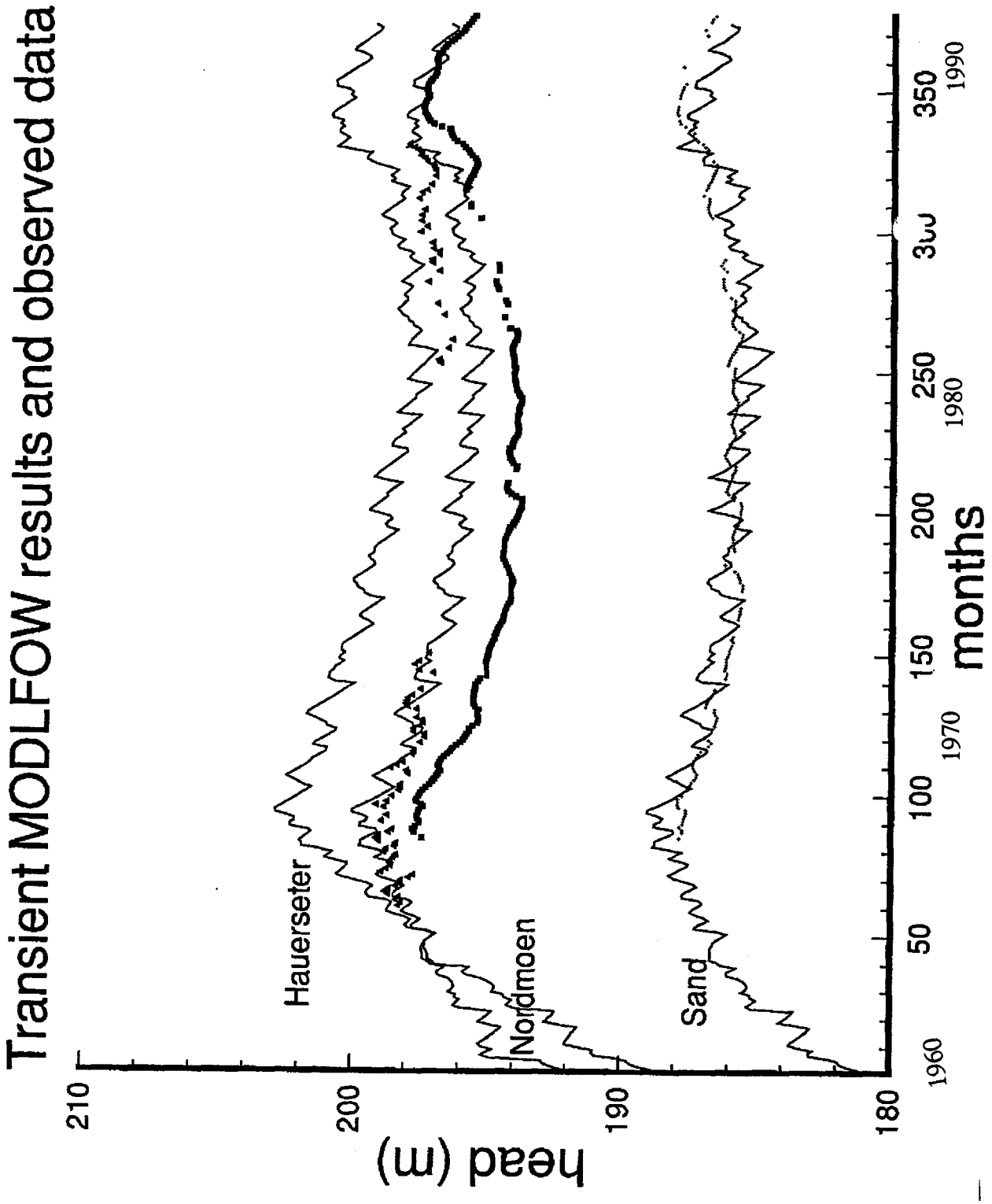


Fig.19 Transient MODFLOW results with steady state heads generated using calibrated hydraulic conductivity field (Fig.16) and minimum recharge of 8.239E-09 m/sec:
(a) using monthly recharge

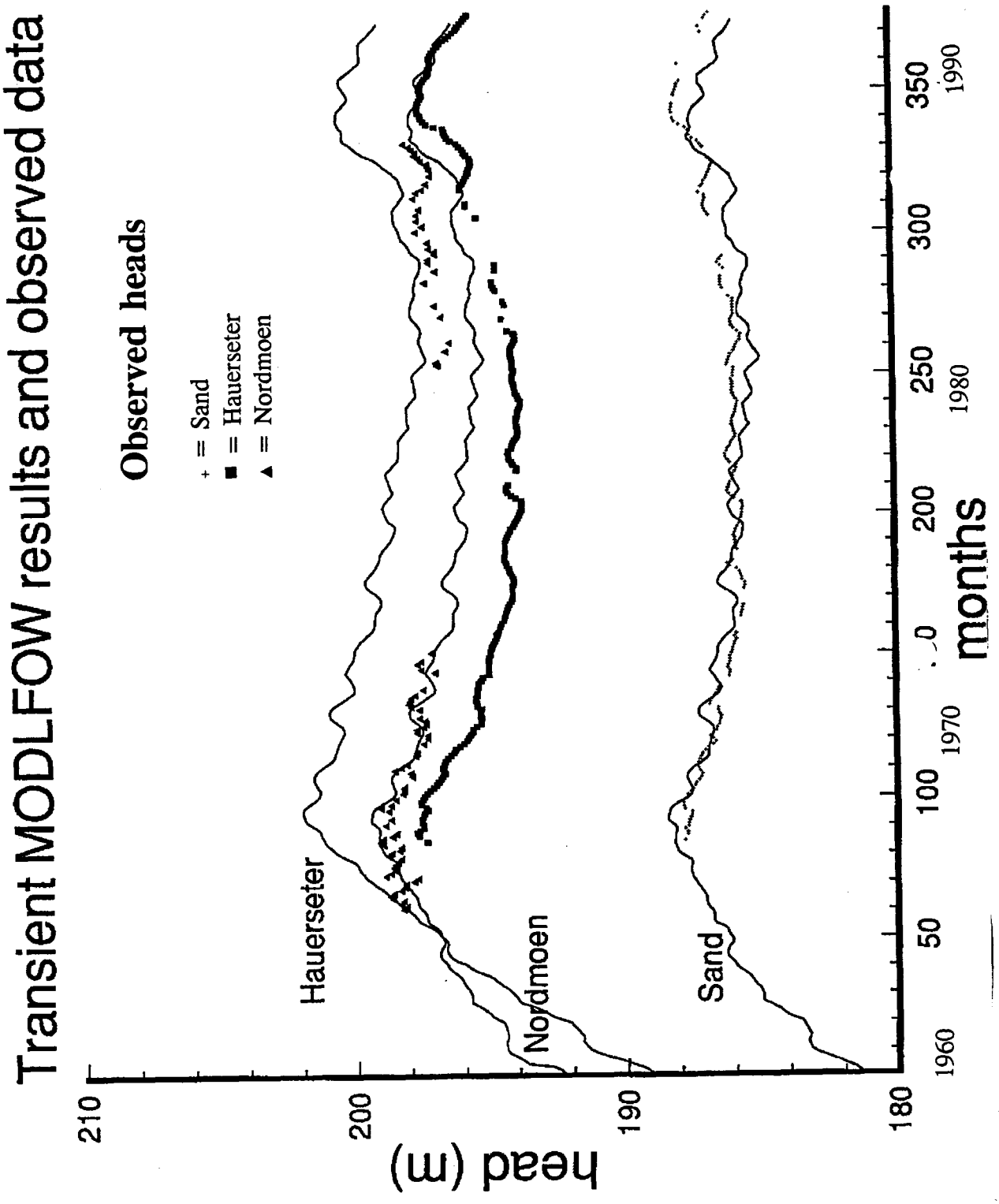


Fig.19 Transient MODFLOW results with steady state heads generated using calibrated hydraulic conductivity field (Fig.16) and minimum recharge of 8.239E-09 m/sec:
(b) using running averages of monthly recharge over 7 month intervals

APPENDIX 1 - Input files (basic package and block-centred flow package) for MODFLOW, steady state model

```
SAMPLE----1 LAYER, ; STEADY STATE
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
          2         36         24         50         1
11  0 13 14  0  0 17 18 19  0  0 22
          0         1
          1         1(50I3)                          3    IBOUND-1
  0  0  0  1 -1 -1 -1 -1  0  0  0  1  1  1  1 -1 -1  1  1  1  1  1  1  0
  0  0  0  1 -1 -1 -1 -1  0  0  0  1  1  1  1  1 -1  1  1  1  1  1  1  0
  0  0  0  1  1 -1 -1  0  0  0  1  1  1  1  1  1 -1 -1  1  1 -1  1  1  0
  0  0  0  1  1 -1 -1  0  0  1  1  1  0  0  1  1  1  1  1  1  1 -1 -1 -1
  0  0  0  1  1 -1 -1 -1 -1  1  1  1  0  0  1  1  1  1  1  1  1  1  1  0
  0  0  0  1  1  1  1  1  1  1  1  1  0  0  0  1  1  1  1  1  1  1  1  0
  0  0  0  1  1  1  1  1  1  1  1  1  0  0  0  1  1  1  1  1  1  1  0  0
  0  0  0  1  1  1  1  1  1  1  1  1  0  0  0  1  1  1  1  1  1  0  0  0
  0  0  0  1  1  1  1  1  1  1  1  1  1  0  0  0  1  1  1  1  1  0  0  0
  0  0  0  1  1  1  1  1  1  1  1  1  1  0  0  0  0  1  1  1  1  1  0  0
 -1  1  1  1  1  1  1  1  1  1  1  1  1  0  0  0  1  1  1  1  1  0  0  0
 -1  1  1  1  1  1  1  1  1  1  1  1  1  1  0  1  1  1  1  1  1  0  0  0
 -1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  0  0  0
 -1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  0  0  0
 -1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  0  0  0
 -1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  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  1  0
  1  1  1  1  1  1  1  1  1  1  1 -1 -1  1  1  1  1  1  1  1  1  1  1  0
 -1  1  1  1  1  0  0  1  1  1  1  1  1 -1  1  1  1  1  1  1  0  0  0  0
 -1  1  1  1  1  0  0  0  1  1  1  1  1  1  1  1  1  1  1  1  0  0  0  0
 -1  1  1  1  1  1  0  1  1  1  1  1  1  1  1  1  1  1  1  1  0  0  0  0
  0  0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  0  0  0  0
  0  0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  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
  0  0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1 -1
  0  0  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  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  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  0  0  1 -1
  0  0  0  0  0  0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  0  0  1 -1
  0  0  0  0  0  0  0  1  1  1  1  1  1  1  1  1  1  1  1  1  0  0  1 -1
  0  0  0  0  0  0  0  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  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  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  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 -1 -1 -1 -1 -1 -1 -1  1  1  1  1
          1         1(50I3)                          3    IBOUND-1
  0  0  0  1 -1 -1 -1 -1  0  0  0  1  1  1  1 -1 -1  1  1  1  1  1  1  0
  0  0  0  1 -1 -1 -1 -1  0  0  0  1  1  1  1  1 -1  1  1  1  1  1  1  0
  0  0  0  1  1 -1 -1  0  0  0  1  1  1  1  1  1 -1 -1  1  1 -1  1  1  0
  0  0  0  1  1 -1 -1  0  0  1  1  1  0  0  1  1  1  1  1  1  1 -1 -1 -1
  0  0  0  1  1 -1 -1 -1 -1  1  1  1  0  0  1  1  1  1  1  1  1  1  1  0
  0  0  0  1  1  1  1  1  1  1  1  1  0  0  0  1  1  1  1  1  1  1  1  0
  0  0  0  1  1  1  1  1  1  1  1  1  0  0  0  1  1  1  1  1  1  1  0  0
  0  0  0  1  1  1  1  1  1  1  1  1  0  0  0  0  1  1  1  1  1  1  0  0
  0  0  0  1  1  1  1  1  1  1  1  1  1  0  0  0  1  1  1  1  1  0  0  0
  0  0  0  1  1  1  1  1  1  1  1  1  1  0  0  0  0  1  1  1  1  1  0  0
 -1  1  1  1  1  1  1  1  1  1  1  1  1  0  0  0  1  1  1  1  1  0  0  0
 -1  1  1  1  1  1  1  1  1  1  1  1  1  1  0  1  1  1  1  1  1  0  0  0
 -1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  0  0  0
 -1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  0  0  0
 -1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  0  0  0
 -1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  0  0  0
 -1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  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  1  0
  1  1  1  1  1  1  1  1  1  1  1 -1 -1  1  1  1  1  1  1  1  1  1  1  0
 -1  1  1  1  1  0  0  1  1  1  1  1  1 -1  1  1  1  1  1  1  0  0  0  0
 -1  1  1  1  1  0  0  0  1  1  1  1  1  1  1  1  1  1  1  1  0  0  0  0
 -1  1  1  1  1  1  0  1  1  1  1  1  1  1  1  1  1  1  1  1  0  0  0  0
  0  0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  0  0  0  0
  0  0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  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
  0  0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1 -1
  0  0  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  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  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  0  0  1 -1
  0  0  0  0  0  0  1  1  1  1  1  1  1  1  1  1  1  1  1  0  0  1 -1
  0  0  0  0  0  0  0  1  1  1  1  1  1  1  1  1  1  1  1  0  0  1 -1
  0  0  0  0  0  0  0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1 -1
  0  0  0  0  0  0  0  0  1  1  1  1  1  1  1  1  1  1  1  1  1  1 -1
  0  0  0  0  0  0  0  0  1  1  1  1  1  1  1  1  1  1  1  1  1  1 -1
  0  0  0  0  0  0  0  0  0  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 -1 -1 -1 -1 -1 -1 -1  1  1  1  1
   999.990
        1          1(50f7.2)                          3    HEADs
999.99 999.99 999.99 197.98 177.00 177.00 177.00 177.00 999.99 999.99 999.99 188.98 181.00 180.29 171.67 160.00 150.00 151.16 141.79 139.47 152.95 168.90 177.88 999.99
999.99 999.99 999.99 203.42 177.00 177.00 177.00 177.00 999.99 999.99 999.99 183.91 182.08 182.02 172.99 162.07 145.00 144.13 140.96 140.79 152.41 170.78 179.69 999.99
999.99 999.99 999.99 203.39 176.00 177.00 177.00 999.99 999.99 999.99 191.26 183.34 188.60 188.20 179.93 167.00 140.00 137.00 141.39 140.66 140.00 167.78 177.99 999.99
999.99 999.99 999.99 192.65 176.00 177.00 177.00 999.99 999.99 186.40 181.86 187.95 999.99 999.99 187.38 172.94 153.85 144.64 142.47 145.96 157.06 160.00 170.00 180.00
999.99 999.99 999.99 185.71 177.93 176.60 176.60 176.60 176.60 180.00 181.34 194.56 999.99 999.99 193.81 180.19 167.01 155.05 145.29 150.21 162.61 172.63 180.37 999.99
999.99 999.99 999.99 183.93 179.93 179.85 179.85 179.85 179.93 180.31 184.26 204.20 999.99 999.99 999.99 186.62 174.98 164.96 149.09 150.68 165.46 174.43 182.64 999.99
999.99 999.99 999.99 186.43 180.00 180.98 181.88 181.74 182.78 182.99 188.34 207.15 999.99 999.99 999.99 194.66 176.64 165.04 145.49 147.94 165.53 174.53 999.99 999.99
999.99 999.99 999.99 189.02 180.61 183.74 185.53 185.50 187.70 188.39 192.56 204.36 999.99 999.99 999.99 999.99 180.21 164.85 142.39 146.18 166.40 176.24 999.99 999.99
999.99 999.99 999.99 189.29 182.49 186.92 188.70 188.92 190.59 192.43 195.72 202.55 211.53 999.99 999.99 999.99 186.90 165.09 141.19 146.90 169.17 999.99 999.99 999.99
999.99 999.99 999.99 188.47 185.57 189.08 190.57 191.11 191.22 193.82 197.27 200.48 206.83 999.99 999.99 999.99 999.99 165.65 142.79 149.62 175.49 999.99 999.99 999.99
208.90 208.75 196.58 186.05 187.49 190.05 191.11 192.15 192.44 194.91 197.38 198.87 202.65 999.99 999.99 999.99 189.25 160.29 143.38 155.47 184.79 999.99 999.99 999.99
200.90 195.13 186.18 182.88 186.84 190.42 191.48 192.96 194.63 196.77 197.57 197.38 198.49 202.34 999.99 196.60 171.92 146.73 145.80 164.55 194.79 999.99 999.99 999.99
195.00 185.23 180.00 180.55 185.55 190.45 191.43 192.88 193.99 195.46 195.98 194.58 192.69 190.46 183.85 165.79 148.51 146.70 157.85 173.58 203.69 999.99 999.99 999.99
185.00 180.95 180.05 180.79 185.75 190.37 191.66 192.96 192.40 192.85 192.88 190.25 185.49 172.05 155.13 144.90 148.14 159.91 169.10 180.03 205.81 999.99 999.99 999.99
185.00 180.07 181.48 184.55 188.89 191.63 192.43 193.09 191.95 191.31 189.95 185.23 174.36 151.03 140.11 150.77 160.37 166.22 173.66 184.85 201.47 999.99 999.99 999.99
190.00 181.72 185.61 189.00 191.84 193.66 193.19 192.69 191.76 189.56 185.52 177.49 160.66 143.21 148.59 161.52 165.08 169.34 177.87 188.57 197.71 999.99 999.99 999.99
198.00 184.87 189.42 191.13 193.05 195.17 194.48 193.20 191.68 187.60 180.67 169.75 153.21 147.79 157.03 163.51 167.59 173.28 182.50 191.66 196.97 210.79 999.99 999.99
198.00 185.21 188.96 191.63 194.07 195.99 195.46 193.65 190.88 184.85 175.91 163.13 149.84 158.00 161.60 165.03 169.08 176.38 186.27 194.12 198.62 203.98 224.65 999.99
181.80 182.53 185.22 191.17 196.17 197.97 196.86 193.96 189.23 181.63 171.18 156.68 158.00 158.00 162.21 166.39 171.13 179.82 190.31 201.09 207.77 208.25 215.35 999.99
190.00 180.55 183.49 192.00 198.51 999.99 999.99 195.60 187.80 178.27 166.96 152.69 142.93 158.00 162.26 168.03 174.56 184.36 194.06 208.51 999.99 999.99 999.99 999.99
185.00 180.00 184.05 193.16 199.11 999.99 999.99 999.99 186.99 177.20 168.50 155.89 146.74 152.18 164.04 171.95 180.39 189.23 198.09 999.99 999.99 999.99 999.99 999.99
181.00 178.11 181.72 192.60 198.98 200.00 999.99 196.39 186.77 178.17 173.26 166.21 160.04 162.00 169.31 177.55 186.10 192.90 201.87 999.99 999.99 999.99 999.99 999.99
999.99 999.99 179.79 190.87 198.29 200.00 199.79 196.77 188.23 180.09 175.90 173.20 171.25 170.92 174.90 182.71 189.56 194.42 203.41 999.99 999.99 999.99 999.99 999.99
999.99 999.99 180.97 188.88 196.08 198.74 198.08 195.38 190.31 182.91 178.03 176.19 174.54 174.90 179.20 186.29 192.05 195.91 201.59 215.42 999.99 999.99 999.99 999.99
999.99 999.99 182.12 187.97 194.28 196.96 195.55 193.43 191.35 186.26 181.38 179.19 177.77 163.00 182.58 188.42 192.92 196.19 198.75 203.48 213.31 218.16 218.03 204.50
999.99 999.99 182.13 187.11 192.53 194.51 193.04 191.97 191.16 188.65 185.02 182.15 181.19 181.88 185.29 189.85 193.21 195.72 197.93 199.95 207.83 213.60 214.84 198.50
999.99 999.99 175.92 184.55 189.08 191.29 191.00 190.47 190.38 189.30 187.54 185.13 183.08 184.58 187.97 190.74 193.52 195.89 197.88 201.03 209.66 215.33 215.56 198.50
999.99 999.99 999.99 181.23 185.68 188.12 188.84 189.06 189.42 188.97 188.40 186.63 185.09 187.56 189.98 191.40 193.66 195.95 198.12 204.24 213.75 215.47 213.88 199.50
999.99 999.99 999.99 999.99 178.83 182.41 184.59 187.54 188.96 188.48 188.45 188.32 188.42 189.76 190.56 191.62 193.67 195.94 198.29 208.01 999.99 999.99 209.72 197.00
999.99 999.99 999.99 999.99 999.99 999.99 177.99 185.84 188.07 188.14 188.74 189.77 190.00 190.01 190.56 191.57 193.46 195.93 198.44 209.69 999.99 999.99 207.51 191.50
999.99 999.99 999.99 999.99 999.99 999.99 999.99 178.35 186.48 188.31 189.38 190.00 190.00 189.98 190.25 191.00 192.87 195.68 198.48 208.84 999.99 999.99 206.82 190.00
999.99 999.99 999.99 999.99 999.99 999.99 999.99 171.43 184.36 188.10 189.88 189.99 189.36 189.17 189.40 189.84 192.07 195.22 198.46 206.33 216.09 217.42 207.59 191.50
999.99 999.99 999.99 999.99 999.99 999.99 999.99 999.99 180.99 184.68 187.91 188.39 186.50 186.66 188.43 189.50 191.62 194.66 197.91 202.79 210.56 211.28 203.76 194.00
999.99 999.99 999.99 999.99 999.99 999.99 999.99 999.99 179.57 180.91 183.63 184.35 182.38 182.58 185.66 189.05 191.29 193.87 196.79 199.73 203.40 202.67 200.00 193.00
999.99 999.99 999.99 999.99 999.99 999.99 999.99 999.99 999.99 180.00 180.60 180.17 174.95 175.99 183.57 188.07 190.91 193.01 195.43 197.77 197.00 197.00 197.00 190.74
999.99 999.99 999.99 999.99 999.99 999.99 999.99 999.99 999.99 999.99 999.99 999.99 999.99 172.00 180.00 190.00 190.00 197.00 197.00 197.00 198.02 198.68 199.30 195.59
        1          1(50f7.2)                          3    HEADs
999.99 999.99 999.99 197.98 177.00 177.00 177.00 177.00 999.99 999.99 999.99 188.98 181.00 180.29 171.67 160.00 150.00 151.16 141.79 139.47 152.95 168.90 177.88 999.99
999.99 999.99 999.99 203.42 177.00 177.00 177.00 177.00 999.99 999.99 999.99 183.91 182.08 182.02 172.99 162.07 145.00 144.13 140.96 140.79 152.41 170.78 179.69 999.99
999.99 999.99 999.99 203.39 176.00 177.00 177.00 999.99 999.99 999.99 191.26 183.34 188.60 188.20 179.93 167.00 140.00 137.00 141.39 140.66 140.00 167.78 177.99 999.99
999.99 999.99 999.99 192.65 176.00 177.00 177.00 999.99 999.99 186.40 181.86 187.95 999.99 999.99 187.38 172.94 153.85 144.64 142.47 145.96 157.06 160.00 170.00 180.00
999.99 999.99 999.99 185.71 177.93 176.60 176.60 176.60 176.60 180.00 181.34 194.56 999.99 999.99 193.81 180.19 167.01 155.05 145.29 150.21 162.61 172.63 180.37 999.99
999.99 999.99 999.99 183.93 179.93 179.85 179.85 179.85 179.93 180.31 184.26 204.20 999.99 999.99 999.99 186.62 174.98 164.96 149.09 150.68 165.46 174.43 182.64 999.99
999.99 999.99 999.99 186.43 180.00 180.98 181.88 181.74 182.78 182.99 188.34 207.15 999.99 999.99 999.99 194.66 176.64 165.04 145.49 147.94 165.53 174.53 999.99 999.99
999.99 999.99 999.99 189.02 180.61 183.74 185.53 185.50 187.70 188.39 192.56 204.36 999.99 999.99 999.99 999.99 180.21 164.85 142.39 146.18 166.40 176.24 999.99 999.99
999.99 999.99 999.99 189.29 182.49 186.92 188.70 188.92 190.59 192.43 195.72 202.55 211.53 999.99 999.99 999.99 186.90 165.09 141.19 146.90 169.17 999.99 999.99 999.99
999.99 999.99 999.99 188.47 185.57 189.08 190.57 191.11 191.22 193.82 197.27 200.48 206.83 999.99 999.99 999.99 999.99 165.65 142.79 149.62 175.49 999.99 999.99 999.99
208.90 208.75 196.58 186.05 187.49 190.05 191.11 192.15 192.44 194.91 197.38 198.87 202.65 999.99 999.99 999.99 189.25 160.29 143.38 155.47 184.79 999.99 999.99 999.99
200.90 195.13 186.18 182.88 186.84 190.42 191.48 192.96 194.63 196.77 197.57 197.38 198.49 202.34 999.99 196.60 171.92 146.73 145.80 164.55 194.79 999.99 999.99 999.99
195.00 185.23 180.00 180.55 185.55 190.45 191.43 192.88 193.99 195.46 195.98 194.58 192.69 190.46 183.85 165.79 148.51 146.70 157.85 173.58 203.69 999.99 999.99 999.99
185.00 180.95 180.05 180.79 185.75 190.37 191.66 192.96 192.40 192.85 192.88 190.25 185.49 172.05 155.13 144.90 148.14 159.91 169.10 180.03 205.81 999.99 999.99 999.99
185.00 180.07 181.48 184.55 188.89 191.63 192.43 193.09 191.95 191.31 189.95 185.23 174.36 151.03 140.11 150.77 160.37 166.22 173.66 184.85 201.47 999.99 999.99 999.99
190.00 181.72 185.61 189.00 191.84 193.66 193.19 192.69 191.76 189.56 185.52 177.49 160.66 143.21 148.59 161.52 165.08 169.34 177.87 188.57 197.71 999.99 999.99 999.99
198.00 184.87 189.42 191.13 193.05 195.17 194.48 193.20 191.68 187.60 180.67 169.75 153.21 147.79 157.03 163.51 167.59 173.28 182.50 191.66 196.97 210.79 999.99 999.99
198.00 185.21 188.96 191.63 194.07 195.99 195.46 193.65 190.88 184.85 175.91 163.13 149.84 158.00 161.60 165.03 169.08 176.38 186.27 194.12 198.62 203.98 224.65 999.99
181.80 182.53 185.22 191.17 196.17 197.97 196.86 193.96 189.23 181.63 171.18 156.68 158.00 158.00 162.21 166.39 171.13 179.82 190.31 201.09 207.77 208.25 215.35 999.99
190.00 180.55 183.49 192.00 198.51 999.99 999.99 195.60 187.80 178.27 166.96 152.69 142.93 158.00 162.26 168.03 174.56 184.36 194.06 208.51 999.99 999.99 999.99 999.99
185.00 180.00 184.05 193.16 199.11 999.99 999.99 999.99 186.99 177.20 168.50 155.89 146.74 152.18 164.04 171.95 180.39 189.23 198.09 999.99 999.99 999.99 999.99 999.99
181.00 178.11 181.72 192.60 198.98 200.00 999.99 196.39 186.77 178.17 173.26 166.21 160.04 162.00 169.31 177.55 186.10 192.90 201.87 999.99 999.99 999.99 999.99 999.99
999.99 999.99 179.79 190.87 198.29 200.00 199.79 196.77 188.23 180.09 175.90 173.20 171.25 170.92 174.90 182.71 189.56 194.42 203.41 999.99 999.99 999.99 999.99 999.99
999.99 999.99 180.97 188.88 196.08 198.74 198.08 195.38 190.31 182.91 178.03 176.19 174.54 174.90 179.20 186.29 192.05 195.91 201.59 215.42 999.99 999.99 999.99 999.99
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 999.99 999.99 175.92 184.55 189.08 191.29 191.00 190.47 190.38 189.30 187.54 185.13 183.08 184.58 187.97 190.74 193.52 195.89 197.88 201.03 209.66 215.33 215.56 198.50
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 1 3
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  1.0  1.0
        11      .000            (50f7.2)         0              delr
491.21 491.21 491.21 491.21 491.21 491.21 491.21 491.21 491.21 491.21 491.22 491.21 491.21 491.21 491.21 491.21 491.21 491.21 491.21 491.21 491.21 491.20 491.20 491.20
        11      .000            (50f7.2)         0              delc
497.10 497.10 497.09 497.10 497.10 497.10 497.09 497.10 497.10 497.09 497.10 497.10 497.10 497.09 497.10 497.10 497.09 497.10 497.10 497.06 497.10 497.10 497.10 497.10 497.10 497.10
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5.754E-07 7.934E-07 1.721E-06 2.998E-06 3.159E-06 7.525E-06 4.799E-06 3.491E-06 3.125E-06
      11        1.(50(1pe12.3))                    3    HHCOND
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      11        1.(50f7.2)                          3   ZBOT
343.16 310.90 256.95 189.69 147.71 142.84 158.08 173.53 200.81 228.55 217.86 180.61 162.32 158.38 154.34 148.73 145.84 132.70  89.82  70.39  92.25 122.43 157.30 196.10
326.66 296.60 251.66 192.79 147.47 141.03 154.65 174.60 200.02 221.19 203.74 177.33 171.05 166.76 158.49 145.32 134.10 108.04  72.85  70.96  94.05 122.55 155.98 200.84
307.43 270.60 238.99 189.00 146.87 140.00 152.38 171.54 193.13 205.20 183.12 170.26 182.29 181.18 167.07 148.14 126.22 100.80  73.54  72.37  97.18 125.30 154.15 195.26
305.03 254.09 214.69 170.71 145.42 140.00 151.77 169.25 178.56 178.59 165.04 167.69 192.32 196.57 178.92 158.51 136.94 113.22  80.29  74.16 101.80 128.78 152.65 184.12
315.13 259.85 205.04 159.17 144.20 140.00 150.34 167.24 169.10 164.46 160.84 174.49 205.65 210.18 191.07 171.03 152.90 122.10  81.60  76.50 104.70 133.36 157.91 183.14
317.94 273.11 207.52 160.26 145.44 140.00 148.64 165.81 169.37 164.46 163.52 184.19 219.44 221.77 202.37 182.51 161.52 124.76  82.63  80.61 109.84 140.30 168.55 197.49
315.62 281.67 213.85 169.28 150.73 142.38 148.64 166.63 172.19 167.19 167.59 187.14 218.11 224.53 213.67 193.62 167.53 124.98  80.92  83.92 115.95 149.99 180.87 216.41
291.71 269.86 218.21 176.93 155.10 147.46 149.26 166.19 176.00 172.89 172.06 184.28 208.57 220.03 219.46 202.02 174.66 123.87  78.80  89.17 123.04 160.83 194.52 232.63
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171.07 166.18 159.94 155.37 150.32 144.90 137.78 128.75 127.23 131.13 132.51 136.47 142.52 144.51 136.97 118.93  91.41  77.77  96.73 134.13 190.39 263.49 297.42 284.20
175.91 172.83 164.01 155.32 150.90 145.96 137.24 123.45 120.32 123.70 118.95 112.74 105.89 100.15  90.56  79.19  76.38  88.57 116.16 153.79 199.63 260.62 302.89 298.65
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175.00 176.76 166.76 160.00 161.52 172.34 182.55 175.91 152.71 128.92 119.98 112.33  98.15  92.14  92.10  93.18 113.02 135.56 157.15 205.03 246.36 241.31 225.37 235.39
164.33 176.26 170.96 162.85 160.19 166.19 171.73 163.61 146.81 130.03 120.76 113.75 100.04  92.52  93.33 102.33 121.48 135.12 149.49 191.99 232.39 232.08 222.19 224.41
157.53 170.76 171.64 165.39 161.28 162.02 161.28 152.92 141.66 130.90 121.86 114.15 100.06  91.84  97.09 112.02 126.28 132.63 140.21 167.39 200.44 209.94 209.04 202.88
152.94 163.23 167.08 165.50 160.63 155.37 149.86 144.30 138.12 130.75 122.58 114.81 103.01  97.75 104.60 115.85 125.00 130.95 137.15 156.32 184.53 196.68 196.43 185.33
152.15 157.13 167.56 167.67 155.70 147.34 142.96 139.56 135.13 129.22 122.51 115.61 107.67 105.10 106.79 112.41 121.38 129.34 139.70 164.28 191.29 197.26 193.36 183.66
157.25 155.55 168.08 169.85 152.79 143.87 142.55 139.02 133.43 127.15 121.62 117.33 112.19 102.78  88.20  96.10 117.55 129.43 146.02 178.19 206.09 202.62 190.50 182.13
164.36 161.60 157.51 163.09 163.37 158.41 151.88 142.01 132.94 125.80 120.06 116.46 101.48  75.47  70.95  95.98 119.39 133.12 154.25 190.45 216.46 209.28 190.90 177.69
161.62 160.95 149.90 149.46 160.42 165.10 160.29 146.16 132.81 124.34 116.78  97.47  67.20  50.77  76.72 110.86 123.89 138.24 161.82 196.82 218.12 213.29 193.97 173.01
150.68 150.10 152.31 154.50 158.96 161.18 160.58 149.82 133.48 123.17 115.12  78.88  44.12  54.92  89.24 114.79 127.07 142.74 167.89 199.77 217.78 216.11 196.96 171.53
154.90 148.01 150.35 163.00 172.05 171.94 165.01 156.13 142.27 127.84 117.29  91.39  69.58  76.12  97.42 116.69 129.22 145.03 169.58 195.26 210.11 212.39 192.68 167.58
160.62 147.24 144.07 150.24 156.82 169.63 174.91 170.01 164.85 150.16 132.03 122.87 123.12 118.13 113.62 120.13 131.24 145.95 166.01 185.49 195.95 192.50 171.60 157.92
157.90 151.85 145.82 140.67 145.07 164.77 179.70 179.57 179.37 173.41 156.57 148.87 158.58 154.48 131.57 124.04 134.22 148.18 165.38 180.15 184.04 171.74 152.14 148.22
163.60 167.85 158.93 146.49 149.44 163.23 171.34 177.45 179.93 179.61 173.46 167.53 168.68 157.23 132.99 128.28 141.70 156.81 172.71 181.47 179.74 168.96 155.40 147.72
172.95 177.47 173.48 156.04 144.44 153.44 162.01 170.23 176.41 179.17 179.49 177.78 173.61 165.06 150.24 145.52 159.96 175.43 184.20 186.66 182.31 173.83 164.99 157.20
       11       1.(50f7.2)                          3    ZTOP
343.16 310.90 256.95 197.83 171.86 171.80 171.84 173.73 197.03 228.55 217.86 188.98 181.00 180.09 171.67 161.79 156.67 151.16 141.79 139.47 152.95 168.90 177.68 198.85
326.66 296.60 251.76 203.28 173.86 171.80 172.27 174.08 197.75 221.19 205.31 183.84 181.88 181.82 172.99 162.07 152.65 144.13 140.96 140.79 152.41 170.78 179.69 203.95
307.43 270.60 240.25 203.19 175.80 171.80 172.23 173.81 191.52 205.26 191.26 183.34 188.40 188.00 179.73 166.96 148.88 141.08 141.39 140.66 151.44 167.78 177.99 201.14
305.03 254.09 222.05 192.45 175.80 171.80 171.80 172.00 180.98 186.20 181.81 187.89 199.65 199.06 187.18 172.74 153.85 144.64 142.47 145.96 157.06 168.20 177.81 192.40
315.13 259.85 215.78 185.71 177.73 175.65 175.65 175.65 177.73 179.81 181.15 194.36 212.97 210.38 193.81 180.19 167.01 155.05 145.29 150.21 162.61 172.63 180.17 188.77
317.94 273.11 216.62 183.93 179.93 179.66 179.65 179.65 179.73 180.11 184.06 204.00 226.76 221.77 202.64 186.62 174.98 164.96 149.09 150.68 165.46 174.43 182.64 198.88
315.62 281.67 219.35 186.43 180.00 180.98 181.88 181.54 182.66 182.87 188.22 207.03 225.43 224.53 213.68 194.66 176.64 165.04 145.49 147.94 165.53 174.53 187.27 216.41
291.71 269.86 220.16 189.02 180.61 183.74 185.53 185.42 187.70 188.39 192.56 204.36 215.90 220.03 219.46 202.34 180.21 164.85 142.39 146.18 166.40 176.24 195.74 232.63
256.54 249.33 216.93 189.29 182.49 186.92 188.71 188.92 190.59 192.43 195.72 202.55 211.53 217.77 219.82 207.68 186.90 165.09 141.19 146.90 169.17 184.04 209.65 243.62
230.21 229.13 208.42 188.47 185.57 189.08 190.58 191.11 191.22 193.82 197.26 200.48 206.83 214.61 219.28 211.63 191.70 165.65 142.79 149.62 175.49 202.64 228.38 253.10
208.85 208.55 196.58 186.05 187.49 190.05 191.11 192.15 192.44 194.91 197.38 198.87 202.65 210.56 218.15 211.30 189.25 160.29 143.38 155.47 184.79 227.37 254.14 264.17
199.99 195.13 186.18 182.88 186.84 190.42 191.48 192.96 194.63 196.77 197.57 197.38 198.49 202.34 205.37 196.60 171.92 146.73 145.80 164.55 194.79 251.02 280.39 271.02
191.65 185.23 180.00 180.55 185.55 190.45 191.43 192.88 193.99 195.46 195.98 194.58 192.69 190.46 183.85 165.79 148.51 146.70 157.85 173.58 203.69 263.49 297.42 284.20
182.37 180.95 180.05 180.79 185.75 190.37 191.66 192.96 192.40 192.85 192.88 190.25 185.49 172.05 155.13 144.90 148.14 159.91 169.10 180.03 205.81 260.62 302.89 298.65
180.00 180.07 181.48 184.55 188.90 191.64 192.43 193.09 191.95 191.31 189.95 185.23 174.36 151.03 140.11 150.77 160.37 166.22 173.66 184.85 201.47 245.06 286.15 289.97
180.00 181.72 185.61 189.00 191.84 193.67 193.19 192.69 191.76 189.55 185.52 177.49 160.66 143.21 148.59 161.52 165.08 169.34 177.87 188.57 197.71 224.87 264.06 280.27
181.28 184.87 189.43 191.14 193.05 195.17 194.48 193.20 191.68 187.59 180.67 169.75 153.21 147.79 157.03 163.52 167.60 173.28 182.50 191.66 196.97 210.79 246.68 275.32
182.53 185.21 188.97 191.63 194.07 195.99 195.46 193.65 190.88 184.85 175.91 163.13 149.84 152.27 161.60 165.05 169.09 176.38 186.27 194.12 198.62 203.98 224.65 257.92
181.80 182.53 185.22 191.17 196.17 197.97 196.86 193.96 189.23 181.63 171.18 156.68 145.61 151.69 162.21 166.40 171.14 179.82 190.31 201.09 207.77 208.25 215.35 245.47
180.55 180.55 183.49 192.00 198.51 199.90 199.01 195.60 187.80 178.27 166.96 152.69 142.93 149.47 162.26 168.03 174.56 184.36 194.06 208.51 218.67 217.69 219.77 243.53
180.00 180.00 184.05 193.16 199.11 200.00 200.00 196.60 186.99 177.21 168.51 155.89 146.74 152.18 164.04 171.95 180.39 189.23 198.09 215.35 230.47 226.83 223.03 243.01
180.00 178.11 181.72 192.60 198.98 199.80 200.00 196.40 186.77 178.17 173.26 166.21 160.04 162.00 169.31 177.55 186.10 192.89 201.87 221.55 242.42 236.60 224.80 241.42
175.00 177.20 179.79 190.87 198.29 199.80 199.79 196.77 188.23 180.09 175.90 173.20 171.25 170.92 174.90 182.71 189.56 194.42 203.41 223.16 246.36 241.31 225.37 235.39
164.33 176.96 180.97 188.88 196.08 198.74 198.08 195.38 190.31 182.91 178.02 176.18 174.54 174.90 179.20 186.29 192.05 195.91 201.59 215.42 233.26 232.08 222.19 224.41
157.53 173.70 182.11 187.97 194.28 196.96 195.55 193.43 191.35 186.26 181.37 179.19 177.78 178.30 182.58 188.42 192.92 196.19 198.75 203.48 213.30 218.15 218.03 209.32
152.94 170.51 182.12 187.11 192.53 194.51 193.04 191.97 191.16 188.65 185.02 182.15 181.19 181.88 185.29 189.85 193.21 195.72 197.93 199.95 207.82 213.59 214.84 199.08
152.15 161.73 175.91 184.54 189.08 191.29 191.00 190.47 190.38 189.30 187.54 185.13 183.08 184.58 187.97 190.76 193.53 195.89 197.88 201.03 209.65 215.32 215.56 199.28
157.25 155.55 168.33 181.22 185.68 188.12 188.84 189.06 189.42 188.97 188.40 186.63 185.09 187.56 189.98 191.42 193.68 195.97 198.14 204.24 213.75 215.46 213.88 200.55
164.36 161.60 157.51 167.76 178.82 182.41 184.59 187.54 188.96 188.48 188.45 188.32 188.42 189.76 190.58 191.64 193.67 195.96 198.30 208.01 218.10 215.28 209.72 197.37
161.62 160.95 149.90 149.46 160.42 168.18 177.99 185.85 188.08 188.14 188.74 189.77 190.00 190.01 190.57 191.59 193.46 195.95 198.46 209.69 219.75 216.51 207.51 192.03
150.68 150.10 152.31 154.50 158.96 161.18 167.00 178.36 186.50 188.31 189.38 190.00 190.00 189.98 190.25 190.99 192.87 195.70 198.49 208.84 218.87 216.80 206.82 190.31
154.90 148.01 150.35 163.00 172.05 172.21 165.28 171.43 184.36 188.10 189.88 189.99 189.36 189.17 189.40 189.84 192.07 195.22 198.46 206.33 216.09 217.42 207.59 192.11
160.62 147.24 144.07 150.24 156.82 169.90 175.18 175.00 180.99 184.68 187.91 188.39 186.50 186.66 188.43 189.50 191.62 194.64 197.89 202.79 210.56 211.28 203.76 194.46
157.90 151.85 145.82 140.67 145.07 164.77 179.70 179.57 179.57 180.91 183.63 184.35 182.38 182.58 185.68 189.07 191.29 193.85 196.77 199.73 203.40 202.67 200.00 193.20
163.60 167.85 158.93 146.49 149.44 163.23 171.34 177.45 179.93 180.00 180.60 180.17 174.95 175.99 183.58 188.09 190.91 193.01 195.43 197.77 199.55 200.00 200.00 190.74
172.95 177.47 173.48 156.04 144.44 153.44 162.01 170.23 176.41 179.17 179.89 178.18 173.68 175.87 182.82 187.01 190.04 192.00 193.68 195.69 198.02 198.68 199.30 195.40
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APPENDIX 2 - Input file (block-centred flow package) for MODFLOW, transient model

```
         0        31
 1 3
        11        1.           (50f5.1)         0               trpy
  1.0  1.0
        11      .000           (50f7.2)         0               delr
 491.21 491.21 491.21 491.21 491.21 491.21 491.21 491.21 491.21 491.21 491.22 491.21 491.21 491.21 491.21 491.21 491.21 491.21 491.21 491.21 491.21 491.20 491.20 491.20
        11      .000           (50f7.2)         0               delc
 497.10 497.10 497.09 497.10 497.10 497.10 497.09 497.10 497.10 497.09 497.10 497.10 497.10 497.09 497.10 497.10 497.09 497.10 497.10 497.06 497.10 497.10 497.10 497.10 497.10 497.10
 497.10 497.10 497.10 497.10 497.10 497.10 497.10 497.10 497.10 497.10
        11        1.(50(1pe12.3))                 3   SF1
   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01
 2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01
   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01
 2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01
   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01
 2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01
   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01
 2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01
   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01
 2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01
   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01
 2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01
   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01
 2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01
   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01
 2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01
   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01
 2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01
   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01
 2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01
   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01
 2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01
   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01
 2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01
   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01
 2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01
   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01
 2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01
   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01
 2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01
   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01
 2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01
   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01
 2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01
   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01
 2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01
   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01
 2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01
   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01
 2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01
   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01
 2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01
   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01
 2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01
   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01
 2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01
   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01
 2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01   2.500E-01
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     11        1.(50f7.2)                          3   ZBOT
343.16 310.90 256.95 197.83 171.86 171.80 171.84 173.73 197.03 228.55 217.86 188.98 181.00 180.09 171.67 161.79 156.67 151.16 141.79 139.47 152.95 168.90 177.68 198.85
326.66 296.60 251.76 203.28 173.86 171.80 172.27 174.08 197.75 221.19 205.31 183.84 181.88 181.82 172.99 162.07 152.65 144.13 140.96 140.79 152.41 170.78 179.69 203.95
307.43 270.60 240.25 203.19 175.80 171.80 172.23 173.81 191.52 205.26 191.26 183.34 188.40 188.00 179.73 166.96 148.88 141.08 141.39 140.66 151.44 167.78 177.99 201.14
305.03 254.09 222.05 192.45 175.80 171.80 171.80 172.00 180.98 186.20 181.81 187.89 199.65 199.06 187.18 172.74 153.85 144.64 142.47 145.96 157.06 168.20 177.81 192.40
315.13 259.85 215.78 185.71 177.73 175.65 175.65 175.65 177.73 179.81 181.15 194.36 212.97 210.38 193.81 180.19 167.01 155.05 145.29 150.21 162.61 172.63 180.17 188.77
317.94 273.11 216.62 183.93 179.93 179.66 179.65 179.65 179.73 180.11 184.06 204.00 226.76 221.77 202.64 186.62 174.98 164.96 149.09 150.68 165.46 174.43 182.64 198.88
315.62 281.67 219.35 186.43 180.00 180.98 181.88 181.54 182.66 182.87 188.22 207.03 225.43 224.53 213.68 194.66 176.64 165.04 145.49 147.94 165.53 174.53 187.27 216.41
291.71 269.86 220.16 189.02 180.61 183.74 185.53 185.42 187.70 188.39 192.56 204.36 215.90 220.03 219.46 202.34 180.21 164.85 142.39 146.18 166.40 176.24 195.74 232.63
256.54 249.33 216.93 189.29 182.49 186.92 188.71 188.92 190.59 192.43 195.72 202.55 211.53 217.77 219.82 207.68 186.90 165.09 141.19 146.90 169.17 184.04 209.65 243.62
230.21 229.13 208.42 188.47 185.57 189.08 190.58 191.11 191.22 193.82 197.26 200.48 206.83 214.61 219.28 211.63 191.70 165.65 142.79 149.62 175.49 202.64 228.38 253.10
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199.99 195.13 186.18 182.88 186.84 190.42 191.48 192.96 194.63 196.77 197.57 197.38 198.49 202.34 205.37 196.60 171.92 146.73 145.80 164.55 194.79 251.02 280.39 271.02
191.65 185.23 180.00 180.55 185.55 190.45 191.43 192.88 193.99 195.46 195.98 194.58 192.69 190.46 183.85 165.79 148.51 146.70 157.85 173.58 203.69 263.49 297.42 284.20
182.37 180.95 180.05 180.79 185.75 190.37 191.66 192.96 192.40 192.85 192.88 190.25 185.49 172.05 155.13 144.90 148.14 159.91 169.10 180.03 205.81 260.62 302.89 298.65
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181.28 184.87 189.43 191.14 193.05 195.17 194.48 193.20 191.68 187.59 180.67 169.75 153.21 147.79 157.03 163.52 167.60 173.28 182.50 191.66 196.97 210.79 246.68 275.32
182.53 185.21 188.97 191.63 194.07 195.99 195.46 193.65 190.88 184.85 175.91 163.13 149.84 152.27 161.60 165.05 169.09 176.38 186.27 194.12 198.62 203.98 224.65 257.92
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175.00 177.20 179.79 190.87 198.29 199.80 199.79 196.77 188.23 180.09 175.90 173.20 171.25 170.92 174.90 182.71 189.56 194.42 203.41 223.16 246.36 241.31 225.37 235.39
164.33 176.96 180.97 188.88 196.08 198.74 198.08 195.38 190.31 182.91 178.02 176.18 174.54 174.90 179.20 186.29 192.05 195.91 201.59 215.42 233.26 232.08 222.19 224.41
157.53 173.70 182.11 187.97 194.28 196.96 195.55 193.43 191.35 186.26 181.37 179.19 177.78 178.30 182.58 188.42 192.92 196.19 198.75 203.48 213.30 218.15 218.03 209.32
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152.15 161.73 175.91 184.54 189.08 191.29 191.00 190.47 190.38 189.30 187.54 185.13 183.08 184.58 187.97 190.76 193.53 195.89 197.88 201.03 209.65 215.32 215.56 199.28
157.25 155.55 168.33 181.22 185.68 188.12 188.84 189.06 189.42 188.97 188.40 186.63 185.09 187.56 189.98 191.42 193.68 195.97 198.14 204.24 213.75 215.46 213.88 200.55
164.36 161.60 157.51 167.76 178.82 182.41 184.59 187.54 188.96 188.48 188.45 188.32 188.42 189.76 190.58 191.64 193.67 195.96 198.30 208.01 218.10 215.28 209.72 197.37
161.62 160.95 149.90 149.46 160.42 168.18 177.99 185.85 188.08 188.14 188.74 189.77 190.00 190.01 190.57 191.59 193.46 195.95 198.46 209.69 219.75 216.51 207.51 192.03
150.68 150.10 152.31 154.50 158.96 161.18 167.00 178.36 186.50 188.31 189.38 190.00 190.00 189.98 190.25 190.99 192.87 195.70 198.49 208.84 218.87 216.80 206.82 190.31
154.90 148.01 150.35 163.00 172.05 172.21 165.28 171.43 184.36 188.10 189.88 189.99 189.36 189.17 189.40 189.84 192.07 195.22 198.46 206.33 216.09 217.42 207.59 192.11
160.62 147.24 144.07 150.24 156.82 169.90 175.18 175.00 180.99 184.68 187.91 188.39 186.50 186.66 188.43 189.50 191.62 194.64 197.89 202.79 210.56 211.28 203.76 194.46
157.90 151.85 145.82 140.67 145.07 164.77 179.70 179.57 179.57 180.91 183.63 184.35 182.38 182.58 185.68 189.07 191.29 193.85 196.77 199.73 203.40 202.67 200.00 193.20
163.60 167.85 158.93 146.49 149.44 163.23 171.34 177.45 179.93 180.00 180.60 180.17 174.95 175.99 183.58 188.09 190.91 193.01 195.43 197.77 199.55 200.00 200.00 190.74
172.95 177.47 173.48 156.04 144.44 153.44 162.01 170.23 176.41 179.17 179.89 178.18 173.68 175.87 182.82 187.01 190.04 192.00 193.68 195.69 198.02 198.68 199.30 195.40
     11        1.(50(1pe12.3))                     3   VHCOND
  1.694E-03   1.694E-03   1.694E-03   2.311E-05   7.899E-06   6.581E-06   1.378E-05   9.861E-04   1.015E-03   1.694E-03   1.694E-03   2.211E-05   1.011E-05   8.761E-06   1.083E-05
1.356E-05   1.445E-05   9.149E-06   3.572E-06   2.740E-06   3.148E-06   4.106E-06   9.323E-06   6.933E-05
  1.694E-03   1.694E-03   1.656E-03   1.804E-05   7.233E-06   6.196E-06   1.087E-05   4.770E-04   1.694E-03   1.694E-03   1.209E-04   2.911E-05   1.738E-05   1.257E-05   1.290E-05
1.112E-05   9.164E-06   4.857E-06   2.744E-06   2.696E-06   3.225E-06   3.940E-06   8.071E-06   6.052E-05
  1.694E-03   1.694E-03   1.506E-04   1.333E-05   6.588E-06   5.997E-06   9.635E-06   8.394E-05   1.694E-03   1.694E-03   2.347E-05   1.464E-05   3.037E-05   2.728E-05   1.491E-05
1.017E-05   7.741E-06   4.421E-06   2.780E-06   2.776E-06   3.477E-06   4.460E-06   7.932E-06   3.226E-05
  1.694E-03   1.694E-03   2.603E-05   8.745E-06   6.275E-06   5.997E-06   9.484E-06   6.942E-05   7.870E-05   2.456E-05   1.140E-05   1.183E-05   2.611E-05   7.683E-05   2.266E-05
1.329E-05   1.084E-05   5.918E-06   3.063E-06   2.663E-06   3.465E-06   4.818E-06   7.545E-06   2.281E-05
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2.069E-05   1.353E-05   5.818E-06   3.007E-06   2.600E-06   3.290E-06   4.835E-06   8.542E-06   3.399E-05
  1.694E-03   1.694E-03   2.005E-05   7.923E-06   5.552E-06   4.816E-06   6.149E-06   1.366E-05   1.817E-05   1.211E-05   9.250E-06   1.198E-05   2.617E-05   1.694E-03   5.403E-04
4.479E-05   1.397E-05   4.683E-06   2.859E-06   2.719E-06   3.382E-06   5.501E-06   1.356E-05   1.376E-04
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1.418E-04   1.952E-05   4.617E-06   2.899E-06   2.939E-06   3.762E-06   7.585E-06   2.966E-05   1.694E-03
  1.694E-03   1.694E-03   9.296E-05   1.486E-05   7.228E-06   3.277E-06   3.297E-06   9.936E-06   1.623E-05   1.222E-05   9.289E-06   1.190E-05   2.617E-05   1.694E-03   1.694E-03
2.541E-04   3.022E-05   4.494E-06   2.895E-06   3.254E-06   4.310E-06   1.203E-05   1.549E-04   1.694E-03
  1.694E-03   1.694E-03   3.009E-05   1.073E-05   6.664E-06   3.110E-06   2.794E-06   5.719E-06   1.051E-05   1.601E-05   1.284E-05   1.250E-05   2.201E-05   7.639E-05   1.694E-03
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11 1.(50(1pe12.3)) 3 SF1
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3.917E-04 3.249E-04 5.537E-04 1.559E-03 2.072E-03 1.821E-03 1.394E-03 6.114E-04 8.268E-05
0.000E+00 0.000E+00 3.078E-06 3.147E-04 7.916E-04 9.232E-04 5.286E-04 0.000E+00 0.000E+00 0.000E+00 4.713E-05 1.953E-04 3.251E-04 4.517E-04 4.349E-04
5.024E-04 5.564E-04 1.083E-03 2.043E-03 2.095E-03 1.751E-03 1.447E-03 7.115E-04 9.322E-05
0.000E+00 0.000E+00 3.786E-05 4.258E-04 8.679E-04 9.541E-04 5.957E-04 6.822E-05 0.000E+00 1.575E-06 2.443E-04 3.924E-04 1.833E-04 2.047E-04 3.799E-04
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4.271E-04 5.074E-04 9.426E-04 1.866E-03 2.154E-03 1.658E-03 1.183E-03 7.546E-04 2.486E-04
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0.000E+00 0.000E+00 5.859E-05 3.626E-04 7.653E-04 1.089E-03 1.088E-03 5.768E-04 3.510E-04 4.650E-04 6.150E-04 6.022E-04 2.197E-04 0.000E+00 0.000E+00
9.678E-06 1.664E-04 1.229E-03 1.908E-03 1.711E-03 1.301E-03 4.621E-04 3.678E-05 0.000E+00
0.000E+00 0.000E+00 1.878E-04 5.068E-04 8.217E-04 1.141E-03 1.282E-03 9.990E-04 5.306E-04 3.421E-04 4.364E-04 4.545E-04 2.599E-04 7.500E-05 0.000E+00
0.000E+00 5.981E-05 1.097E-03 1.876E-03 1.679E-03 1.122E-03 2.817E-04 0.000E+00 0.000E+00

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1.406E-03  1.713E-03  2.068E-03  1.834E-03  1.184E-03  3.988E-04  0.000E+00  0.000E+00  0.000E+00
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1.971E-03  2.153E-03  2.140E-03  1.588E-03  7.872E-04  1.852E-04  0.000E+00  0.000E+00  0.000E+00
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2.013E-03  2.188E-03  1.443E-03  7.349E-04  4.925E-04  3.288E-04  2.391E-04  7.734E-05  0.000E+00
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2.055E-03  2.214E-03  1.433E-03  7.983E-04  4.815E-04  1.856E-04  1.578E-04  5.103E-05  0.000E+00
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2.203E-03  2.316E-03  1.627E-03  9.165E-04  4.066E-04  2.082E-05  2.573E-05  4.914E-06  0.000E+00
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2.411E-03  2.416E-03  1.812E-03  1.055E-03  3.817E-04  0.000E+00  0.000E+00  0.000E+00  0.000E+00
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2.686E-03  2.296E-03  1.766E-03  1.388E-03  5.438E-04  0.000E+00  0.000E+00  0.000E+00  0.000E+00
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2.519E-03  2.117E-03  1.824E-03  1.563E-03  7.029E-04  2.603E-05  0.000E+00  0.000E+00  0.000E+00
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2.350E-03  2.165E-03  1.997E-03  1.745E-03  1.102E-03  5.507E-04  5.420E-04  6.663E-04  4.689E-04
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 0.000E+00  0.000E+00  0.000E+00  0.000E+00  0.000E+00  0.000E+00  1.926E-04  8.562E-04  1.590E-03  1.954E-03  2.228E-03  3.333E-03  4.376E-03  4.052E-03  3.030E-03
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1.200E-05  1.200E-05  1.440E-05  1.440E-05  1.440E-05  6.000E-05  6.000E-05  6.000E-05  6.000E-05
      11       1.(50f7.2)                    3   ZBOT
343.16 310.90 256.95 189.69 147.71 142.84 158.08 173.53 200.81 228.55 217.86 180.61 162.32 158.38 154.34 148.73 145.84 132.70  89.82  70.39  92.25 122.43 157.30 196.10
326.66 296.60 251.66 192.79 147.47 141.03 154.65 174.60 200.02 221.19 203.74 177.33 171.05 166.76 158.49 145.32 134.10 108.04  72.85  70.96  94.05 122.55 155.98 200.84
307.43 270.60 238.99 189.00 146.87 140.00 152.38 171.54 193.13 205.20 183.12 170.26 182.29 181.18 167.07 148.14 126.22 100.80  73.54  72.37  97.18 125.30 154.15 195.26
305.03 254.09 214.69 170.71 145.42 140.00 151.77 169.25 178.56 178.59 165.04 167.69 192.32 196.57 178.92 158.51 136.94 113.22  80.29  74.16 101.80 128.78 152.65 184.12
315.13 259.85 205.04 159.17 144.20 140.00 150.34 167.24 169.10 164.46 160.84 174.49 205.65 210.18 191.07 171.03 152.90 122.10  81.60  76.50 104.70 133.36 157.91 183.14
317.94 273.11 207.52 160.26 145.44 140.00 148.64 165.81 169.37 164.46 163.52 184.19 219.44 221.77 202.37 182.51 161.52 124.76  82.63  80.61 109.84 140.30 168.55 197.49
315.62 281.67 213.85 169.28 150.73 142.38 148.64 166.63 172.19 167.19 167.59 187.14 218.11 224.53 213.67 193.62 167.53 124.98  80.92  83.92 115.95 149.99 180.87 216.41
291.71 269.86 218.21 176.93 155.10 147.46 149.26 166.19 176.00 172.89 172.06 184.28 208.57 220.03 219.46 202.02 174.66 123.87  78.80  89.17 123.04 160.83 194.52 232.63
256.54 249.33 210.67 172.40 155.10 148.87 145.96 155.62 172.91 181.03 181.17 187.40 202.87 215.27 219.82 207.68 184.91 128.50  78.67  90.95 131.76 174.65 209.65 243.62
230.21 229.13 197.04 164.10 153.47 146.04 141.36 142.28 156.41 177.16 188.55 194.67 201.83 212.11 219.28 211.63 189.07 131.06  79.91  92.33 144.30 197.80 228.38 253.10
198.69 195.86 176.79 158.54 151.55 144.23 139.27 135.50 138.81 154.99 174.47 190.13 200.30 210.34 218.15 211.30 182.94 123.88  80.36  98.29 159.13 225.96 254.14 264.17
175.26 171.07 163.00 156.20 150.42 144.14 138.13 132.13 131.50 137.97 150.25 166.35 181.06 191.33 194.22 182.79 145.10  97.37  83.36 111.57 173.46 251.02 280.39 271.02
171.07 166.18 159.94 155.37 150.32 144.90 137.78 128.75 127.23 131.13 132.51 136.47 142.52 144.51 136.97 118.93  91.41  77.77  96.73 134.13 190.39 263.49 297.42 284.20
175.91 172.83 164.01 155.32 150.90 145.96 137.24 123.45 120.32 123.70 118.95 112.74 105.89 100.15  90.56  79.19  76.38  88.57 116.16 153.79 199.63 260.62 302.89 298.65
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179.50 179.50 169.19 156.17 151.78 146.63 133.50 115.68 114.04 117.58 108.95  98.30  91.54  87.93  82.98  80.62  84.53 101.12 132.52 166.16 196.83 245.06 286.15 289.97
179.50 179.50 169.27 156.84 152.44 146.84 131.63 112.28 112.36 115.17 102.06  91.89  89.89  92.22  91.33  87.24  90.38 111.79 146.33 173.32 190.67 222.82 264.06 280.27
179.75 179.75 169.58 157.79 153.44 148.53 137.49 117.92 113.59 115.02 100.74  90.69  91.48  97.10  98.67  92.73  94.29 121.57 156.61 176.74 186.94 205.17 245.64 275.32
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179.80 179.80 171.99 161.99 175.10 195.10 200.00 194.20 164.39 129.87 115.68 101.17  90.19  92.67  94.24  91.57  99.86 128.82 162.92 202.63 230.47 226.83 223.03 243.01
179.80 177.91 168.11 160.00 166.60 183.59 194.84 188.62 160.49 129.79 118.29 106.36  93.14  90.07  90.17  90.22 106.22 132.08 160.47 206.89 242.42 236.60 224.80 241.42
175.00 176.76 166.76 160.00 161.52 172.34 182.55 175.91 152.71 128.92 119.98 112.33  98.15  92.14  92.10  93.18 113.02 135.56 157.15 205.03 246.36 241.31 225.37 235.39
164.33 176.26 170.96 162.85 160.19 166.19 171.73 163.61 146.81 130.03 120.76 113.75 100.04  92.52  93.33 102.33 121.48 135.12 149.49 191.99 232.39 232.08 222.19 224.41
157.53 170.76 171.64 165.39 161.28 162.02 161.28 152.92 141.66 130.90 121.86 114.15 100.06  91.84  97.09 112.02 126.28 132.63 140.21 167.39 200.44 209.94 209.04 202.88
152.94 163.23 167.08 165.50 160.63 155.37 149.86 144.30 138.12 130.75 122.58 114.81 103.01  97.75 104.60 115.85 125.00 130.95 137.15 156.32 184.53 196.68 196.43 185.33
152.15 157.13 167.56 167.67 155.70 147.34 142.96 139.56 135.13 129.22 122.51 115.61 107.67 105.10 106.79 112.41 121.38 129.34 139.70 164.28 191.29 197.26 193.36 183.66
157.25 155.55 168.08 169.85 152.79 143.87 142.55 139.02 133.43 127.15 121.62 117.33 112.19 102.78  88.20  96.10 117.55 129.43 146.02 178.19 206.09 202.62 190.50 182.13
164.36 161.60 157.51 163.09 163.37 158.41 151.88 142.01 132.94 125.80 120.06 116.46 101.48  75.47  70.95  95.98 119.39 133.12 154.25 190.45 216.46 209.28 190.90 177.69
161.62 160.95 149.90 149.46 160.42 165.10 160.29 146.16 132.81 124.34 116.78  97.47  67.20  50.77  76.72 110.86 123.89 138.24 161.82 196.82 218.12 213.29 193.97 173.01
150.68 150.10 152.31 154.50 158.96 161.18 160.58 149.82 133.48 123.17 115.12  78.88  44.12  54.92  89.24 114.79 127.07 142.74 167.89 199.77 217.78 216.11 196.96 171.53
154.90 148.01 150.35 163.00 172.05 171.94 165.01 156.13 142.27 127.84 117.29  91.39  69.58  76.12  97.42 116.69 129.22 145.03 169.58 195.26 210.11 212.39 192.68 167.58
160.62 147.24 144.07 150.24 156.82 169.63 174.91 170.01 164.85 150.16 132.03 122.87 123.12 118.13 113.62 120.13 131.24 145.95 166.01 185.49 195.95 192.50 171.60 157.92
157.90 151.85 145.82 140.67 145.07 164.77 179.70 179.57 179.37 173.41 156.57 148.87 158.58 154.48 131.57 124.04 134.22 148.18 165.38 180.15 184.04 171.74 152.14 148.22
163.60 167.85 158.93 146.49 149.44 163.23 171.34 177.45 179.93 179.61 173.46 167.53 168.68 157.23 132.99 128.28 141.70 156.81 172.71 181.47 179.74 168.96 155.40 147.72
172.95 177.47 173.48 156.04 144.44 153.44 162.01 170.23 176.41 179.17 179.49 177.78 173.61 165.06 150.24 145.52 159.96 175.43 184.20 186.66 182.31 173.83 164.99 157.20
    11        1.(50(1pe12.3))                    3   SF2
  2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01
2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01
  2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01
2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01
  2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01
2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01
  2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01
2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01
  2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01
2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01
  2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01
2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01
  2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01
2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01
  2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01
2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01
  2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01
2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01
  2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01
2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01
  2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01
2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01
  2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01
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  2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01
2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01
  2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01
2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01
  2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01
2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01
  2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01
2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01 2.000E-01
  2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01
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  2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01
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  2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01
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  2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01
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  2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01
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  2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01
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  2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01
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  2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01
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  2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01
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2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01
  2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01
2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01
  2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01
2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01
  2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01
2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01
  2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01
2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01
  2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01
2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01
  2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01
2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01
  2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01
2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01
  2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01
2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01
  2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01
2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01   2.000E-01
       11        1.(50f7.2)                          3    ZTOP
343.16 310.90 256.95 197.83 171.86 171.80 171.84 173.73 197.03 228.55 217.86 188.98 181.00 180.09 171.67 161.79 156.67 151.16 141.79 139.47 152.95 168.90 177.68 198.85
326.66 296.60 251.76 203.28 173.86 171.80 172.27 174.08 197.75 221.19 205.31 183.84 181.88 181.82 172.99 162.07 152.65 144.13 140.96 140.79 152.41 170.78 179.69 203.95
307.43 270.60 240.25 203.19 175.80 171.80 172.23 173.81 191.52 205.26 191.26 183.34 188.40 188.00 179.73 166.96 148.88 141.08 141.39 140.66 151.44 167.78 177.99 201.14
305.03 254.09 222.05 192.45 175.80 171.80 171.80 172.00 180.98 186.20 181.81 187.89 199.65 199.06 187.18 172.74 153.85 144.64 142.47 145.96 157.06 168.20 177.81 192.40
315.13 259.85 215.78 185.71 177.73 175.65 175.65 175.65 177.73 179.81 181.15 194.36 212.97 210.38 193.81 180.19 167.01 155.05 145.29 150.21 162.61 172.63 180.17 188.77
317.94 273.11 216.62 183.93 179.93 179.66 179.65 179.65 179.73 180.11 184.06 204.00 226.76 221.77 202.64 186.62 174.98 164.96 149.09 150.68 165.46 174.43 182.64 198.88
315.62 281.67 219.35 186.43 180.00 180.98 181.88 181.54 182.66 182.87 188.22 207.03 225.43 224.53 213.68 194.66 176.64 165.04 145.49 147.94 165.53 174.53 187.27 216.41
291.71 269.86 220.16 189.02 180.61 183.74 185.53 185.42 187.70 188.39 192.56 204.36 215.90 220.03 219.46 202.34 180.21 164.85 142.39 146.18 166.40 176.24 195.74 232.63
256.54 249.33 216.93 189.29 182.49 186.92 188.71 188.92 190.59 192.43 195.72 202.55 211.53 217.77 219.82 207.68 186.90 165.09 141.19 146.90 169.17 184.04 209.65 243.62
230.21 229.13 208.42 188.47 185.57 189.08 190.58 191.11 191.22 193.82 197.26 200.48 206.83 214.61 219.28 211.63 191.70 165.65 142.79 149.62 175.49 202.64 228.38 253.10
208.85 208.55 196.58 186.05 187.49 190.05 191.11 192.15 192.44 194.91 197.38 198.87 202.65 210.56 218.15 211.30 189.25 160.29 143.38 155.47 184.79 227.37 254.14 264.17
199.99 195.13 186.18 182.88 186.84 190.42 191.48 192.96 194.63 196.77 197.57 197.38 198.49 202.34 205.37 196.60 171.92 146.73 145.80 164.55 194.79 251.02 280.39 271.02
191.65 185.23 180.00 180.55 185.55 190.45 191.43 192.88 193.99 195.46 195.98 194.58 192.69 190.46 183.85 165.79 148.51 146.70 157.85 173.58 203.69 263.49 297.42 284.20
182.37 180.95 180.05 180.79 185.75 190.37 191.66 192.96 192.40 192.85 192.88 190.25 185.49 172.05 155.13 144.90 148.14 159.91 169.10 180.03 205.81 260.62 302.89 298.65
180.00 180.07 181.48 184.55 188.90 191.64 192.43 193.09 191.95 191.31 189.95 185.23 174.36 151.03 140.11 150.77 160.37 166.22 173.66 184.85 201.47 245.06 286.15 289.97
180.00 181.72 185.61 189.00 191.84 193.67 193.19 192.69 191.76 189.55 185.52 177.49 160.66 143.21 148.59 161.52 165.08 169.34 177.87 188.57 197.71 224.87 264.06 280.27
181.28 184.87 189.43 191.14 193.05 195.17 194.48 193.20 191.68 187.59 180.67 169.75 153.21 147.79 157.03 163.52 167.60 173.28 182.50 191.66 196.97 210.79 246.68 275.32
182.53 185.21 188.97 191.63 194.07 195.99 195.46 193.65 190.88 184.85 175.91 163.13 149.84 152.27 161.60 165.05 169.09 176.38 186.27 194.12 198.62 203.98 224.65 257.92
181.80 182.53 185.22 191.17 196.17 197.97 196.86 193.96 189.23 181.63 171.18 156.68 145.61 151.69 162.21 166.40 171.14 179.82 190.31 201.09 207.77 208.25 215.35 245.47
180.55 180.55 183.49 192.00 198.51 199.90 199.01 195.60 187.80 178.27 166.96 152.69 142.93 149.47 162.26 168.03 174.56 184.36 194.06 208.51 218.67 217.69 219.77 243.53
180.00 180.00 184.05 193.16 199.11 200.00 200.00 196.60 186.99 177.21 168.51 155.89 146.74 152.18 164.04 171.95 180.39 189.23 198.09 215.35 230.47 226.83 223.03 243.01
180.00 178.11 181.72 192.60 198.98 199.80 200.00 196.40 186.77 178.17 173.26 166.21 160.04 162.00 169.31 177.55 186.10 192.89 201.87 221.55 242.42 236.60 224.80 241.42
175.00 177.20 179.79 190.87 198.29 199.80 199.79 196.77 188.23 180.09 175.90 173.20 171.25 170.92 174.90 182.71 189.56 194.42 203.41 223.16 246.36 241.31 225.37 235.39
164.33 176.96 180.97 188.88 196.08 198.74 198.08 195.38 190.31 182.91 178.02 176.18 174.54 174.90 179.20 186.29 192.05 195.91 201.59 215.42 233.26 232.08 222.19 224.41
157.53 173.70 182.11 187.97 194.28 196.96 195.55 193.43 191.35 186.26 181.37 179.19 177.78 178.30 182.58 188.42 192.92 196.19 198.75 203.48 213.30 218.15 218.03 209.32
152.94 170.51 182.12 187.11 192.53 194.51 193.04 191.97 191.16 188.65 185.02 182.15 181.19 181.88 185.29 189.85 193.21 195.72 197.93 199.95 207.82 213.59 214.84 199.08
152.15 161.73 175.91 184.54 189.08 191.29 191.00 190.47 190.38 189.30 187.54 185.13 183.08 184.58 187.97 190.76 193.53 195.89 197.88 201.03 209.65 215.32 215.56 199.28
157.25 155.55 168.33 181.22 185.68 188.12 188.84 189.06 189.42 188.97 188.40 186.63 185.09 187.56 189.98 191.42 193.68 195.97 198.14 204.24 213.75 215.46 213.88 200.55
164.36 161.60 157.51 167.76 178.82 182.41 184.59 187.54 188.96 188.48 188.45 188.32 188.42 189.76 190.58 191.64 193.67 195.96 198.30 208.01 218.10 215.28 209.72 197.37
161.62 160.95 149.90 149.46 160.42 168.18 177.99 185.85 188.08 188.14 188.74 189.77 190.00 190.01 190.57 191.59 193.46 195.95 198.46 209.69 219.75 216.51 207.51 192.03
150.68 150.10 152.31 154.50 158.96 161.18 167.00 178.36 186.50 188.31 189.38 190.00 190.00 189.98 190.25 190.99 192.87 195.70 198.49 208.84 218.87 216.80 206.82 190.31
154.90 148.01 150.35 163.00 172.05 172.21 165.28 171.43 184.36 188.10 189.88 189.99 189.36 189.17 189.40 189.84 192.07 195.22 198.46 206.33 216.09 217.42 207.59 192.11
160.62 147.24 144.07 150.24 156.82 169.90 175.18 175.00 180.99 184.68 187.91 188.39 186.50 186.66 188.43 189.50 191.62 194.64 197.89 202.79 210.56 211.28 203.76 194.46
157.90 151.85 145.82 140.67 145.07 164.77 179.70 179.57 179.57 180.91 183.63 184.35 182.38 182.58 185.68 189.07 191.29 193.85 196.77 199.73 203.40 202.67 200.00 193.20
163.60 167.85 158.93 146.49 149.44 163.23 171.34 177.45 179.93 180.00 180.60 180.17 174.95 175.99 183.58 188.09 190.91 193.01 195.43 197.77 199.55 200.00 200.00 190.74
172.95 177.47 173.48 156.04 144.44 153.44 162.01 170.23 176.41 179.17 179.89 178.18 173.68 175.87 182.82 187.01 190.04 192.00 193.68 195.69 198.02 198.68 199.30 195.40
```

APPENDIX 3 - Elevations of drains, rivers and constant head cells.

```
   45        41 spring cells modelled as drains
   45
    2        33        15   1.875E+02   2.600E+00     South and
    2        35        13   1.720E+02   2.600E+00     east sides
    2        35        12   1.720E+02   2.600E+00
    2        35        11   1.800E+02   2.600E+00
    2        34        11   1.830E+02   2.600E+00
    2        34        10   1.800E+02   2.600E+00
    2        34         9   1.795E+02   2.600E+00
    2        35        10   1.798E+02   2.600E+00
    2        33         9   1.730E+02   2.600E+00
    1        32         8   1.740E+02   2.600E+00
    2        31         8   1.740E+02   2.600E+00
    2        30         7   1.740E+02   2.600E+00
    2        29         7   1.740E+02   2.600E+00
    2        29         6   1.740E+02   2.600E+00
    2        29         5   1.740E+02   2.600E+00
    2        28         4   1.740E+02   2.600E+00
    2        27         3   1.740E+02   2.600E+00
    2        26         3   1.750E+02   2.600E+00
    2        25         3   1.760E+02   2.600E+00
    1        24         3   1.810E+02   2.600E+00
    1        23         3   1.820E+02   2.600E+00
    1        22         3   1.840E+02   2.600E+00
    1        21         3   1.860E+02   2.600E+00
    1        20         3   1.870E+02   2.600E+00
    1        19         3   1.880E+02   2.600E+00
    1        16         3   1.920E+02   1.400E+00  western
    1        15         2   1.880E+02   1.400E+00  boundary
    1        14         2   1.840E+02   1.400E+00
    1        13         3   1.820E+02   1.400E+00
    2         5        11   1.810E+02   2.600E-01  small streams
    2         6        11   1.824E+02   2.600E-01  SE of Hurdalsjoen
    2         7        11   1.829E+02   2.600E-01
    2         8        12   1.963E+02   2.600E-01
    2         9        12   2.022E+02   2.600E-01
    2         6        10   1.778E+02   2.600E-01
    2         7        10   1.828E+02   2.600E-01
    2         7         9   1.827E+02   2.600E-01
    2        25        15   1.680E+02   7.800E-02  Dagsjoen
    2        24        15   1.660E+02   7.800E-02
    2        11        13   1.990E+02   2.600E-02  S of bedrock nr. Rissa bru
    2         9        17   1.930E+02   2.600E-02
    1        33        21   2.108E+02   2.600E+00  S of bedrock in SE corner
    1        32        21   2.080E+02   2.600E-01  S of bedrock in SE corner
    1        33        22   2.130E+02   2.600E-01
    1        33        23   2.060E+02   2.600E-01
   -1
   -1
```

Drains

```
 31       51
 31
  1       17       14   1.638E+02   5.754E+01   1.633E+02
  1       16       14   1.654E+02   1.497E+02   1.649E+02
  1       15       15   1.636E+02   1.732E+02   1.631E+02
  1       14       16   1.647E+02   1.385E+02   1.642E+02
  1       14       17   1.636E+02   1.600E+02   1.631E+02
  1       13       18   1.603E+02   1.801E+02   1.598E+02
  1       12       19   1.596E+02   1.688E+02   1.591E+02
  1       11       19   1.671E+02   3.725E+01   1.666E+02
  1       10       19   1.639E+02   1.704E+02   1.634E+02
  1        9       19   1.553E+02   1.684E+02   1.548E+02
  2        8       19   1.426E+02   1.438E+02   1.421E+02
  2        7       20   1.435E+02   6.835E+01   1.430E+02
  2        7       19   1.406E+02   1.082E+02   1.401E+02
  2        6       19   1.420E+02   7.270E+01   1.415E+02
  2        5       20   1.449E+02   1.681E+02   1.444E+02
  2        4       20   1.420E+02   1.732E+02   1.415E+02
  1        3       20   1.420E+02   1.081E+02   1.415E+02
  2        2       20   1.413E+02   1.851E+02   1.408E+02
  1        1       20   1.424E+02   7.616E+01   1.419E+02
  1       20       13   1.645E+02   6.869E+00   1.640E+02
  1       21       13   1.700E+02   3.181E+01   1.695E+02
  1       22       12   1.700E+02   5.340E+00   1.695E+02
  1       22       11   1.700E+02   7.149E+00   1.695E+02
  1       21       11   1.700E+02   9.768E+00   1.695E+02
  1       13       19   1.795E+02   1.214E+02   1.790E+02
  1       14       20   1.929E+02   1.709E+02   1.924E+02
  1       15       19   1.930E+02   4.175E+01   1.925E+02
  1       15       20   1.965E+02   3.097E+01   1.960E+02
  1       15       21   2.086E+02   5.770E+02   2.081E+02
  1       17       22   2.186E+02   4.469E+02   2.181E+02
  1       19       23   2.186E+02   1.620E+01   2.181E+02
 -1
 -1
```

Rivers

```
   62        31              CONSTANT HEAD CELLS
   62
    1        11         1   2.089E+02   2.600E-04 western boundary
    1        12         1   2.009E+02   2.600E-04
    1        13         1   1.950E+02   2.600E-04
    1        14         1   1.850E+02   2.600E-04
    1        15         1   1.850E+02   2.600E-04
    1        16         1   1.900E+02   2.600E-04
    1        17         1   1.980E+02   2.600E-04
    1        18         1   1.980E+02   2.600E-04
    1        20         1   1.900E+02   2.600E-04
    1        21         1   1.850E+02   2.600E-04
    1        22         1   1.810E+02   2.600E-04
    2        25        24   2.045E+02   2.600E-06  southeastern boundary
    2        26        24   1.985E+02   2.600E-06
    2        27        24   1.985E+02   2.600E-06
    2        28        24   1.995E+02   2.600E-06
    2        29        24   1.970E+02   2.600E-06
    2        30        24   1.915E+02   2.600E-06
    2        31        24   1.900E+02   2.600E-06
    2        32        24   1.915E+02   2.600E-06
    2        33        24   1.940E+02   2.600E-06
    2        34        24   1.930E+02   2.600E-06
    2        35        23   1.970E+02   2.600E-06
    2        35        22   1.970E+02   2.600E-06
    2        35        21   1.970E+02   2.600E-06
    1        36        20   1.970E+02   1.400E-04
    1        36        19   1.970E+02   1.400E-04
    2        36        14   1.720E+02   1.400E-04
    2        36        15   1.800E+02   1.400E-04
    1        36        16   1.900E+02   1.400E-04
    1        36        17   1.900E+02   1.400E-04
    1        36        18   1.970E+02   1.400E-04
    1         1         5   1.770E+02   2.600E-04  Start Hurdalsjoen
    1         1         6   1.770E+02   2.600E-04
    1         1         7   1.770E+02   2.600E-04
    1         1         8   1.770E+02   2.600E-04
    1         2         5   1.770E+02   2.600E-04
    1         2         6   1.770E+02   2.600E-04
    1         2         7   1.770E+02   2.600E-04
    1         2         8   1.770E+02   2.600E-04
    1         3         6   1.770E+02   2.600E-04
    1         3         7   1.770E+02   2.600E-04
    1         4         6   1.770E+02   2.600E-04
    1         4         7   1.770E+02   2.600E-04
    1         4         9   1.770E+02   2.600E-04
    2         5         6   1.766E+02   2.600E-04
    2         5         7   1.766E+02   2.600E-04
    2         5         8   1.766E+02   2.600E-04    End Hurdalsjoen
    2         5         9   1.766E+02   2.600E-06
    2         1        16   1.600E+02   2.600E-06
    2         1        17   1.500E+02   2.600E-06
    2         2        17   1.450E+02   2.600E-06
    2         3        17   1.400E+02   2.600E-06
    2         3        18   1.370E+02   2.600E-06
    2         3        21   1.400E+02   2.600E-06
    2         4        22   1.600E+02   2.600E-06
    2         4        23   1.700E+02   2.600E-06
    2         4        24   1.800E+02   2.600E-06
    1        18        14   1.580E+02   1.400E-04     Herjoen
    1        19        13   1.580E+02   1.400E-04
    1        19        14   1.580E+02   1.400E-04
    1        20        14   1.580E+02   1.400E-04
    2        25        14   1.630E+02   2.600E-06      Dagsjoen
   -1
   -1
```

Constant head cells

APPENDIX 4 - head difference between vertically adjacent cells in the two aquifer layers (steady state)

HEAD DIFFERENCES

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
1	9.99	9.99	9.99	9.99	.00	.00	.00	.00	9.99	9.99	9.99	9.99	.00	9.99	9.99	9.99	9.99	9.99	.00	.00	9.99	9.99	9.99	9.99
2	9.99	9.99	9.99	9.99	.00	.00	.00	****	9.99	9.99	9.99	.00	.00	9.99	9.99	9.99	9.99	9.99	-.01	-.01	9.99	9.99	9.99	9.99
3	9.99	9.99	9.99	9.99	.00	.00	.00	9.99	9.99	9.99	9.99	.00	9.99	9.99	9.99	9.99	9.99	9.99	9.99	-.03	9.99	9.99	9.99	9.99
4	9.99	9.99	9.99	9.99	.00	.00	.00	9.99	9.99	9.99	.00	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99
5	9.99	9.99	9.99	9.99	.00	.00	.00	.00	9.99	.00	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99
6	9.99	9.99	9.99	.00	-.01	.00	.00	.00	.00	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99
7	9.99	9.99	9.99	.00	.00	-.01	.00	.00	.00	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99
8	9.99	9.99	9.99	.00	.00	-.01	.00	.00	.00	.00	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	-.01	-.03	9.99	9.99	9.99	9.99
9	9.99	9.99	9.99	.00	.00	.00	-.01	.00	.00	.00	.00	9.99	9.99	9.99	9.99	9.99	9.99	9.99	-.02	-.02	9.99	9.99	9.99	9.99
10	9.99	9.99	9.99	.00	.00	.00	-.01	-.01	.00	.00	.00	.00	9.99	9.99	9.99	9.99	9.99	9.99	-.07	-.01	9.99	9.99	9.99	9.99
11	.00	9.99	9.99	.00	.00	.00	-.01	-.01	.00	.00	9.99	9.99	9.99	9.99	9.99	9.99	9.99	.00	-.12	.00	9.99	9.99	9.99	9.99
12	.00	.00	.01	.00	.00	.00	-.01	-.01	-.03	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	.01	.29	.00	9.99	9.99	9.99	9.99
13	.00	.01	.04	-.01	.00	.00	.00	-.02	-.05	9.99	9.99	9.99	9.99	9.99	9.99	9.99	.01	.33	-.27	-.02	9.99	9.99	9.99	9.99
14	.00	.00	.00	.00	.00	-.01	-.03	-.04	9.99	9.99	9.99	9.99	9.99	9.99	.00	-.01	.11	-.01	-.08	-.04	9.99	9.99	9.99	9.99
15	.00	.00	.00	.00	-.01	-.01	-.07	9.99	9.99	9.99	9.99	9.99	9.99	.09	.04	.00	.00	-.03	-.22	.00	9.99	9.99	9.99	9.99
16	.00	.00	.00	.00	-.01	-.02	-.10	9.99	9.99	9.99	9.99	.05	.22	.00	.00	.00	.00	-.01	-.03	.00	9.99	9.99	9.99	9.99
17	.00	.00	.00	.00	.00	-.01	-.10	9.99	9.99	9.99	9.99	.07	-.01	-.02	.00	.00	.00	9.99	-.03	.00	.00	9.99	9.99	9.99
18	.00	.00	.00	.00	.00	-.01	-.03	9.99	9.99	9.99	.02	.06	-.07	.00	.00	.00	.00	9.99	9.99	9.99	.00	.00	9.99	9.99
19	.00	.00	.00	.00	.00	-.01	-.01	9.99	9.99	9.99	.02	-.12	.00	.00	.00	.00	9.99	9.99	9.99	9.99	9.99	.00	9.99	9.99
20	.00	.00	.00	.01	9.99	9.99	9.99	9.99	9.99	9.99	.00	-.01	-.02	.00	.01	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99
21	.00	.00	.00	9.99	9.99	9.99	9.99	9.99	9.99	9.99	.08	.00	-.11	.01	.01	9.99	-.33	9.99	9.99	9.99	9.99	9.99	9.99	9.99
22	.00	.00	.01	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	.05	.00	.02	9.99	9.99	-.40	-.01	-.06	9.99	9.99	9.99	9.99	9.99
23	9.99	9.99	.01	.01	9.99	9.99	9.99	9.99	-.02	9.99	9.99	9.99	9.99	9.99	9.99	-.79	.00	-.01	-.05	9.99	9.99	9.99	9.99	9.99
24	9.99	9.99	.00	-.01	.00	9.99	.00	.00	-.02	-.04	9.99	9.99	9.99	9.99	9.99	-.75	.00	-.01	-.04	9.99	9.99	9.99	9.99	9.99
25	9.99	9.99	9.99	-.01	.00	-.01	-.01	-.01	-.01	-.01	-.09	9.99	9.99	9.99	9.99	-.22	-.01	.00	-.03	.00	9.99	9.99	9.99	9.99
26	9.99	9.99	9.99	-.01	9.99	9.99	-.03	-.03	-.03	-.03	.00	-.02	9.99	9.99	9.99	-.03	-.01	.00	-.01	.00	9.99	9.99	9.99	9.99
27	9.99	9.99	9.99	-.01	9.99	9.99	9.99	9.99	9.99	9.99	-.01	-.01	-.03	-.03	-.02	-.01	-.01	-.01	-.01	.00	9.99	9.99	9.99	9.99
28	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	-.01	-.01	.00	.00	-.01	-.01	-.01	-.01	.00	9.99	9.99	9.99	9.99	9.99
29	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	-.01	-.01	.00	-.01	-.01	-.02	-.01	-.01	.00	9.99	9.99	9.99	9.99	9.99
30	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	-.01	-.01	-.01	-.01	-.03	-.04	-.01	.00	.00	9.99	9.99	9.99	9.99	9.99
31	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	-.01	-.01	-.03	-.05	-.02	-.01	.00	.00	9.99	9.99	9.99	9.99	9.99
32	9.99	9.99	9.99	9.99	9.99	9.99	9.99	.01	9.99	9.99	9.99	-.01	-.01	-.01	-.10	-.01	-.01	.00	.00	9.99	9.99	9.99	9.99	9.99
33	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	.00	9.99	-.01	.00	.00	-.96	-.08	-.01	.00	.00	.00	9.99	9.99	9.99	9.99
34	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	-.01	.00	.00	-.03	-.01	.00	.00	.00	.00	9.99	9.99	9.99	9.99
35	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	-.01	-.04	-.01	-.02	.00	.00	.00	9.99	9.99	9.99	.00
36	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	.00	9.99	.00	.00	.00	9.99	9.99	9.99	9.99
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	

Head difference (m)
(negative = downwards gradient,
positive = upwards gradient,
9,99 = one of the two layers not saturated)

APPENDIX 5 - deviations of modelled head (modelled - observed) in each cell

Steady state. Recharge = $1.27 * 10^{-8}$ m/s

no data points = 183
parameters least squares fit: aa (intercept) = 13.77385139 bb (slope) = 0.9282963872
variance = 14.27121449
redidual sum on squares = 2583.108887
WATER TABLE COMPARISONS
MAP

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
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
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
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
4	.0	.0	.0	.0	4.5	.0	.0	.0	.0	.0	.0	7.4	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
5	.0	.0	.0	2.9	.0	.0	.0	.0	.0	.0	.0	6.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
6	.0	.0	.0	.0	.0	.0	7.9	.0	.0	.1	-.4	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
7	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.2	2.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
8	.0	.0	.0	.0	.0	.0	.0	.0	.0	2.9	.0	6.9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
9	.0	.0	.0	.0	.0	.0	3.8	.0	.0	.0	3.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
10	.0	.0	.0	.0	11.2	1.9	.0	-.4	.0	-1.2	.2	2.3	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
11	.0	.0	.0	.0	6.1	8.0	-1.0	-1.0	.0	.0	-1.6	-1.5	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
12	.0	.0	.0	10.4	2.1	.0	.0	.7	-.5	.0	-2.8	.0	.0	-6.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
13	.0	.0	.0	.0	.0	.0	.0	.0	.0	-2.4	.0	-4.3	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
14	.0	.0	.0	.0	-1.6	-.1	-.1	-1.9	.0	.0	.0	.8	.0	-2.2	6.1	.0	8.7	.0	.0	.0	.0	.0	.0	.0
15	.0	.0	.0	.0	-.5	.5	.2	-4.3	.0	.0	.0	.0	.0	.0	.0	.0	4.2	.0	.0	14.0	.0	.0	.0	.0
16	.0	.0	.0	-2.8	-2.5	-1.2	.0	-3.8	-4.2	.0	.0	.0	-3.2	.0	2.1	.0	3.1	5.7	.0	.0	.0	.0	.0	.0
17	.0	.0	.0	.1	.0	-2.4	.0	.0	.0	-4.7	1.6	.0	-2.6	2.6	.0	1.0	.0	.0	.0	.0	2.8	.0	.0	.0
18	.0	-2.6	2.5	.0	.0	.0	-1.7	-6.6	.0	-2.0	.0	.0	.4	.0	.0	.0	2.2	.0	.0	.1	.0	.0	.0	.0
19	.0	.0	.0	.0	.0	.0	.0	.0	.0	-2.3	-2.9	2.9	.0	.0	.0	.0	.0	.0	-1.6	.0	.0	.0	.0	.0
20	.0	.0	.0	1.2	.3	.0	.0	.0	.0	.0	.0	2.3	4.7	-1.0	-1.2	-2.0	.0	.0	.0	.0	.0	.0	.0	.0
21	.0	.0	.0	.0	.0	.0	.0	.0	.0	-7.1	-4.9	1.0	.0	3.8	.0	.0	-13.5	-8.1	.0	.0	.0	.0	.0	.0
22	.0	.0	.0	4.4	.7	.0	.0	.0	-3.4	.0	-4.3	-3.4	-6.2	.0	.7	-5.1	-.9	.0	.0	.0	.0	.0	.0	.0
23	.0	.0	.0	.0	.0	.5	.2	-1.3	.0	.0	-5.4	-4.2	-2.2	.0	-4.3	-1.9	1.3	1.7	1.0	.0	.0	.0	.0	.0
24	.0	.0	.0	1.2	.0	.0	.0	.0	-3.9	-10.3	.0	-3.9	-5.8	-3.9	.0	.3	1.6	6.7	.0	.0	.0	.0	.0	.0
25	.0	.0	.0	.0	-.4	.0	.0	.3	-2.4	.0	.0	.0	.0	.0	.0	3.3	.0	3.6	4.7	.0	.0	.0	.0	.0
26	.0	.0	.0	.0	-2.5	.0	.3	.0	-.7	.0	.0	.0	.0	.0	-.1	.0	.0	.0	.0	.0	2.0	3.8	.0	.0
27	.0	.0	.0	.0	-.5	.0	.0	.0	-.9	.0	.0	.0	.0	-.7	-1.1	2.5	.0	.0	.0	.0	2.3	.0	.0	.0
28	.0	.0	.0	.0	.0	.0	.0	.0	-.8	.0	.0	-1.9	.0	.0	.4	1.1	.0	-.1	.0	.0	.0	.0	.0	.0
29	.0	.0	.0	.0	.0	.0	.0	.0	.5	1.3	.7	.0	-.7	-1.2	.0	.7	.0	.0	.0	-.3	.0	.0	.0	.0
30	.0	.0	.0	.0	.0	.0	.0	.0	.7	2.0	.0	-.6	.2	.0	-.1	1.9	.0	.0	-2.2	.0	.0	.0	.0	.0
31	.0	.0	.0	.0	.0	.0	.0	.0	.0	.3	.0	.0	.0	.0	.0	5.3	-2.5	-1.3	.0	2.0	.0	.0	.0	.0
32	.0	.0	.0	.0	.0	.0	.0	.0	.0	2.6	.0	2.0	1.9	2.2	.0	-.3	-3.0	.0	.0	.0	.0	.0	.0	.0
33	.0	.0	.0	.0	.0	.0	.0	.0	.0	1.1	.0	2.9	3.6	14.9	-.6	-1.1	.0	.0	-1.3	.0	3.4	.8	.0	.0
34	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	5.8	8.9	.0	.0	.0	-3.1	.0	-1.6	.0	1.3	.0	.0	.0
35	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	-4.7	.0	.0	.0	2.7	-2.4	.0	.0	.0
36	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24

no.	borehole	MODFLOW	Discrepancy	col.	row
1	175.7400055	180.1999969	4.459991455	5	4
2	182.1100006	185.0000000	2.889999390	4	5
3	175.8300018	183.6999969	7.869995117	7	6
4	179.6699982	187.1000061	7.430007935	12	4
5	179.4400024	185.3999939	5.959991455	12	5
6	177.7700043	177.8999939	0.1299896240	10	6
7	182.4100037	182.0000000	-0.4100036621	11	6
8	182.8300018	183.0000000	0.1699981689	11	7
9	188.5399933	191.3999939	2.860000610	10	8
10	188.3399963	190.3999939	2.059997559	12	7
11	187.9900055	194.8999939	6.909988403	12	8
12	192.6600037	195.8999939	3.239990234	11	9
13	190.3800049	194.1999969	3.819992065	7	9
14	183.5299988	194.6999969	11.16999817	5	10
15	193.1199951	195.0000000	1.880004883	6	10
16	188.7500000	194.8999939	6.149993896	5	11
17	183.4400024	193.8000031	10.36000061	4	12
18	187.3999939	195.3999939	8.000000000	6	11
19	197.0950012	196.1000061	-0.9949951172	7	11
20	197.0950012	196.1000061	-0.9949951172	7	11
21	196.2100067	195.8000031	-0.4100036621	8	10
22	197.1000061	195.8999939	-1.200012207	10	10
23	197.1699982	197.3999939	0.2299957275	11	10
24	197.1699982	197.3999939	0.2299957275	11	10

25	198.4600067	200.8000031	2.339996338	12	10
26	198.5899963	197.1000061	-1.489990234	12	11
27	197.2533417	196.3000031	-0.9533386230	8	11
28	197.2533417	196.3000031	-0.9533386230	8	11
29	197.2533417	196.3000031	-0.9533386230	8	11
30	195.7533417	196.5000000	0.7466583252	8	12
31	195.7533417	196.5000000	0.7466583252	8	12
32	195.7533417	196.5000000	0.7466583252	8	12
33	192.6000061	194.6999969	2.099990845	5	12
34	196.3699951	195.8999939	-0.4700012207	9	12
35	194.2749939	191.8999939	-2.375000000	10	13
36	197.2700043	195.6999969	-1.570007324	11	11
37	196.4499969	193.6000061	-2.849990845	11	12
38	192.9700012	188.6999969	-4.270004272	12	13
39	197.5449982	191.3000031	-6.244995117	14	12
40	197.5449982	191.3000031	-6.244995117	14	12
41	197.2500000	195.6999969	-1.550003052	5	14
42	197.3349915	197.1999969	-0.1349945068	6	14
43	197.3349915	197.1999969	-0.1349945068	6	14
44	197.2700043	197.1999969	-0.7000732422E-01	7	14
45	196.6199951	194.6999969	-1.919998169	8	14
46	194.2749939	191.8999939	-2.375000000	10	13
47	185.3699951	186.1999969	0.8300018311	12	14
48	171.5299988	169.3000031	-2.229995728	14	14
49	158.3000031	164.3999939	6.099990845	15	14
50	154.8699951	163.6000061	8.730010986	17	14
51	162.5500031	166.8000031	4.250000000	17	15
52	178.9900055	193.0000000	14.00999451	20	15
53	164.6450043	167.6999969	3.054992676	17	16
54	164.9349976	170.6000061	5.665008545	18	16
55	164.9349976	170.6000061	5.665008545	18	16
56	164.9349976	170.6000061	5.665008545	18	16
57	164.6450043	167.6999969	3.054992676	17	16
58	162.8399963	164.8999939	2.059997559	15	16
59	172.7599945	169.6000061	-3.159988403	13	16
60	191.2900085	187.1000061	-4.190002441	9	16
61	191.2900085	187.1000061	-4.190002441	9	16
62	192.4700012	188.6999969	-3.770004272	8	16
63	195.3000031	191.0000000	-4.300003052	8	15
64	197.1300049	197.3000031	0.1699981689	7	15
65	197.7200012	198.1999969	0.4799957275	6	15
66	197.5433350	197.0000000	-0.5433349609	5	15
67	197.5433350	197.0000000	-0.5433349609	5	15
68	197.5433350	197.0000000	-0.5433349609	5	15
69	200.3399963	197.8000031	-2.539993286	5	16
70	199.8399963	198.6000061	-1.239990234	6	16
71	200.4400024	198.0000000	-2.440002441	6	17
72	198.2135010	195.3999939	-2.813507080	4	16
73	198.2135010	195.3999939	-2.813507080	4	16
74	198.2100067	195.6000061	-2.610000610	2	18
75	195.9900055	196.1000061	0.1100006104	4	17
76	191.8099976	194.3000031	2.490005493	3	18
77	191.8099976	194.3000031	2.490005493	3	18
78	199.1000061	197.3999939	-1.700012207	7	18
79	197.6100006	191.0000000	-6.610000610	8	18
80	187.8399963	183.1000061	-4.739990234	10	17
81	182.3399963	180.3000031	-2.039993286	10	18
82	178.8899994	180.5000000	1.610000610	11	17
83	182.3399963	180.3000031	-2.039993286	10	18
84	172.3300018	169.6999969	-2.630004883	13	17
85	178.3766632	175.5000000	-2.876663208	11	19
86	165.1799927	165.6000061	0.4200134277	13	18
87	161.2299957	163.8000031	2.570007324	14	17
88	165.3699951	166.3999939	1.029998779	16	17
89	167.3300018	169.5000000	2.169998169	17	18
90	164.9349976	170.6000061	5.665008545	18	16
91	193.0599976	193.1999969	0.1399993896	20	18
92	197.6399994	200.3999939	2.759994507	21	17
93	191.9900055	193.1999969	1.209991455	4	20
94	198.6350098	198.8999939	0.2649841309	5	20
95	198.6350098	198.8999939	0.2649841309	5	20

96	180.2100067	177.8999939	-2.310012817	10	19
97	178.3766632	175.5000000	-2.876663208	11	19
98	178.3766632	175.5000000	-2.876663208	11	19
99	169.0299988	171.8999939	2.869995117	12	19
100	167.5899963	169.8999939	2.309997559	12	20
101	167.5899963	169.8999939	2.309997559	12	20
102	159.8099976	164.5000000	4.690002441	13	20
103	159.0099945	158.0000000	-1.009994507	14	20
104	164.6000061	163.3999939	-1.200012207	15	20
105	169.8999939	167.8999939	-2.000000000	16	20
106	187.5899963	186.0000000	-1.589996338	19	19
107	190.9700012	195.3999939	4.429992676	4	22
108	181.2200012	174.1000061	-7.119995117	10	21
109	174.9049988	170.0000000	-4.904998779	11	21
110	174.9049988	170.0000000	-4.904998779	11	21
111	176.9499969	172.6000061	-4.349990845	11	22
112	173.4100037	170.0000000	-3.410003662	12	22
113	169.1499939	170.1000061	0.9500122070	12	21
114	175.7999878	169.6000061	-6.199981689	13	22
115	160.7500000	164.5000000	3.750000000	14	21
116	167.1000061	167.8000031	0.6999969482	15	22
117	176.8600006	171.8000031	-5.059997559	16	22
118	194.8999939	194.0000000	-0.8999938965	17	22
119	195.7200012	182.1999969	-13.52000427	17	21
120	196.8800049	188.8000031	-8.080001831	18	21
121	197.3899994	198.1000061	0.7100067139	5	22
122	199.2399902	199.6999969	0.4600067139	6	23
123	199.2399902	199.6999969	0.4600067139	6	23
124	199.4949951	199.6999969	0.2050018311	7	23
125	199.4949951	199.6999969	0.2050018311	7	23
126	198.4799957	197.1999969	-1.279998779	8	23
127	195.7850037	191.8999939	-3.885009766	9	24
128	195.7850037	191.8999939	-3.885009766	9	24
129	194.2550049	184.0000000	-10.25500488	10	24
130	194.2550049	184.0000000	-10.25500488	10	24
131	180.0050049	174.6000061	-5.404998779	11	23
132	180.0050049	174.6000061	-5.404998779	11	23
133	177.0500031	172.8000031	-4.250000000	12	23
134	178.8099976	174.8999939	-3.910003662	12	24
135	189.6900024	186.3000031	-3.389999390	9	22
136	175.7999878	169.6000061	-6.199981689	13	22
137	173.2050018	171.0000000	-2.205001831	13	23
138	173.2050018	171.0000000	-2.205001831	13	23
139	171.5899963	167.6999969	-3.889999390	14	24
140	177.7799988	172.0000000	-5.779998779	13	24
141	172.4900055	168.1999969	-4.290008545	15	23
142	191.6300049	189.6999969	-1.930007935	16	23
143	191.6300049	189.6999969	-1.930007935	16	23
144	197.4700012	199.1000061	1.630004883	17	24
145	197.7700043	199.1000061	1.330001831	17	23
146	198.0299988	199.6999969	1.669998169	18	23
147	198.0299988	199.6999969	1.669998169	18	23
148	203.6999969	204.6999969	1.000000000	19	23
149	192.2899933	193.5000000	1.210006714	4	24
150	195.8950043	195.5000000	-0.3950042725	5	25
151	195.8950043	195.5000000	-0.3950042725	5	25
152	194.8600006	192.3999939	-2.460006714	5	26
153	194.7100067	195.0000000	0.2899932861	8	25
154	193.1250000	193.3999939	0.2749938965	7	26
155	194.3999939	192.0000000	-2.399993896	9	25
156	171.5899963	167.6999969	-3.889999390	14	24
157	182.0549927	182.0000000	-0.5499267578E-01	15	26
158	182.0549927	182.0000000	-0.5499267578E-01	15	26
159	185.3399963	188.6000061	3.260009766	16	25
160	193.3899994	193.6999969	0.3099975586	16	24
161	185.3399963	188.6000061	3.260009766	16	25
162	193.2400055	199.8999939	6.659988403	18	24
163	196.0700073	199.6999969	3.629989624	18	25
164	198.4499969	203.1000061	4.650009155	19	25
165	205.5299988	207.5000000	1.970001221	21	26
166	205.8999939	209.6999969	3.800003052	22	26

167	205.2299957	207.5000000	2.270004272	21	27
168	199.2899933	199.1999969	-0.8999633789E-01	18	28
169	190.4900055	193.0000000	2.509994507	16	27
170	193.2200012	194.3000031	1.080001831	16	28
171	189.9900055	188.8999939	-1.090011597	15	27
172	191.4700012	191.8999939	0.4299926758	15	28
173	187.2400055	186.5000000	-0.7400054932	14	27
174	192.2200012	191.5000000	-0.7200012207	9	26
175	189.9700012	189.1000061	-0.8699951172	9	27
176	188.7400055	187.8999939	-0.8400115967	9	28
177	193.1250000	193.3999939	0.2749938965	7	26
178	187.2599945	186.8000031	-0.4599914551	5	27
179	186.0000000	186.5000000	0.5000000000	9	29
180	184.3699951	185.1000061	0.7300109863	9	30
181	187.1199951	188.3999939	1.279998779	10	29
182	185.8033447	187.8000031	1.996658325	10	30
183	185.8033447	187.8000031	1.996658325	10	30
184	188.8399963	189.5000000	0.6600036621	11	29
185	190.6799927	188.8000031	-1.879989624	12	28
186	191.5299988	190.8000031	-0.7299957275	13	29
187	191.5299988	190.8000031	-0.7299957275	13	29
188	191.2949982	191.5000000	0.2050018311	13	30
189	193.0200043	191.8000031	-1.220001221	14	29
190	191.4700012	191.8999939	0.4299926758	15	28
191	194.2600098	195.0000000	0.7399902344	16	29
192	194.2600098	195.0000000	0.7399902344	16	29
193	194.2600098	195.0000000	0.7399902344	16	29
194	193.9199982	195.8000031	1.880004883	16	30
195	203.4700012	201.3000031	-2.169998169	19	30
196	204.1633301	203.8999939	-0.2633361816	20	29
197	204.1633301	203.8999939	-0.2633361816	20	29
198	204.1633301	203.8999939	-0.2633361816	20	29
199	184.3699951	185.1000061	0.7300109863	9	30
200	185.8033447	187.8000031	1.996658325	10	30
201	186.6699982	187.0000000	0.3300018311	10	31
202	183.6300049	186.1999969	2.569992065	10	32
203	191.2100067	190.6000061	-0.6100006104	12	30
204	191.2949982	191.5000000	0.2050018311	13	30
205	193.7299957	193.6000061	-0.1299896240	15	30
206	190.8950043	196.1999969	5.304992676	16	31
207	190.8950043	196.1999969	5.304992676	16	31
208	200.4900055	198.0000000	-2.490005493	17	31
209	201.1000061	199.8000031	-1.300003052	18	31
210	203.6199951	205.6000061	1.980010986	20	31
211	188.1699982	190.1999969	2.029998779	12	32
212	189.2299957	191.1000061	1.870010376	13	32
213	183.7899933	184.8999939	1.110000610	10	33
214	186.4100037	189.3000031	2.889999390	12	33
215	186.6799927	190.3000031	3.620010376	13	33
216	175.8000031	190.6999969	14.89999390	14	33
217	189.5099945	191.6999969	2.190002441	14	32
218	196.2599945	196.0000000	-0.2599945068	16	32
219	200.8000031	197.8000031	-3.000000000	17	32
220	175.8000031	190.6999969	14.89999390	14	33
221	189.1100006	188.5000000	-0.6100006104	15	33
222	196.8000031	195.6999969	-1.100006104	16	33
223	202.1499939	200.8000031	-1.349990845	19	33
224	200.0700073	200.8999939	0.8299865723	22	33
225	200.7399902	204.1000061	3.360015869	21	33
226	200.7399902	204.1000061	3.360015869	21	33
227	182.0000000	187.8000031	5.800003052	12	34
228	180.2500000	189.1999969	8.949996948	13	34
229	197.6699982	193.0000000	-4.669998169	16	35
230	201.4900055	199.8999939	-1.590011597	19	34
231	199.7500000	196.6999969	-3.050003052	17	34
232	199.1950073	200.5000000	1.304992676	21	34
233	199.1950073	200.5000000	1.304992676	21	34
234	199.3800049	197.0000000	-2.380004883	21	35
235	196.6900024	199.3999939	2.709991455	20	35

average of discrepancies = 0.2033738196
root mean square discrepancy 3.835682631

APPENDIX 6 - output files from MODFLOW, flow to drains, rivers and constant head cells.

Net cell-by-cell flow terms for drain cells
flow rates in l**3/t
negative values - net flow into cell, postive values - net flow out of cell
kstp,kper,icol,irow,ilay 1 1 24 36 2
Number of darin cells is 45

layer	row	col	flow rate
2	33	15	-0.3189697117E-01
2	35	13	-0.2011413500E-01
2	35	12	-0.1210021973E-01
2	35	11	-0.2499389462E-02
2	34	11	-0.2027282678E-01
2	34	10	-0.8291625418E-02
2	34	9	-0.2975463867E-02
2	35	10	-0.3094482236E-02
2	33	9	-0.1924133301E-01
1	32	8	-0.1368713286E-01
2	32	8	0.0000000000E+00
2	31	8	-0.3213500977E-01
2	30	7	-0.1098937914E-01
2	29	7	-0.3495177999E-01
2	29	6	-0.1503601018E-01
2	29	5	-0.1091003418E-01
2	28	4	-0.1158447191E-01
2	27	3	-0.1011657715E-01
2	26	3	-0.5435180385E-02
2	25	3	-0.4998778924E-02
1	24	3	-0.5792235956E-02
2	24	3	0.0000000000E+00
1	23	3	-0.2150268480E-01
2	23	3	0.0000000000E+00
1	22	3	-0.1487731840E-01
2	22	3	0.0000000000E+00
1	21	3	-0.6982421502E-02
2	21	3	0.0000000000E+00
1	20	3	-0.1701965183E-01
2	20	3	0.0000000000E+00
1	19	3	-0.4284667969E-01
2	19	3	0.0000000000E+00
1	16	3	-0.1805114746E-01
2	16	3	0.0000000000E+00
1	15	2	-0.3717040876E-02
2	15	2	0.0000000000E+00
1	14	2	-0.3138122335E-01
2	14	2	0.0000000000E+00
1	13	3	-0.8536376804E-01
2	13	3	0.0000000000E+00
2	5	11	-0.1996734552E-01
2	6	11	0.0000000000E+00
2	7	11	-0.2153442241E-01
2	8	12	-0.3491210809E-03
2	9	12	0.0000000000E+00
2	6	10	-0.2133209072E-01
2	7	10	-0.1040618867E-01
2	7	9	-0.1948333718E-01
2	25	15	-0.4514016956E-01
2	24	15	-0.3114596568E-01
2	11	13	0.0000000000E+00
2	9	17	0.0000000000E+00
1	33	21	0.0000000000E+00
2	33	21	0.0000000000E+00
1	32	21	0.0000000000E+00
2	32	21	0.0000000000E+00
1	33	22	0.0000000000E+00
2	33	22	0.0000000000E+00
1	33	23	0.0000000000E+00
2	33	23	0.0000000000E+00

total sum of flows = -0.9484448433
Flow rates for springs in SE =-0.2712432742

Net cell-by-cell flow terms for river cells
flow rates in l**3/t
negative values - net flow into cell, postive values - net flow out of cell
kstp,kper,icol,irow,ilay 1 1 24 36 2
Number of river cells is 27

layer	row	col	flow rate
1	17	14	0.8779907366E-03
2	17	14	0.0000000000E+00
1	16	14	-0.1827392541E-01
2	16	14	0.0000000000E+00
1	15	15	-0.1823547333
2	15	15	0.0000000000E+00
1	14	16	0.2747344971E-01
2	14	16	0.0000000000E+00
1	14	17	-0.3662109375
2	14	17	0.0000000000E+00
1	13	18	-0.4342010617
2	13	18	0.0000000000E+00
1	12	19	-0.4790771604
2	12	19	0.0000000000E+00
1	11	19	0.2068939209
2	11	19	0.0000000000E+00
1	10	19	0.9620361030E-01
2	10	19	0.0000000000E+00
1	9	19	-0.8222655952E-01
2	9	19	0.0000000000E+00
2	8	19	-0.1075164825
2	7	20	-0.3441696241E-01
2	7	19	-0.4127502441E-01
2	6	19	-0.1885833591E-01
2	5	20	0.7695007604E-02
2	4	20	-0.3964233398E-01
1	3	20	0.1319580059E-01
2	3	20	0.0000000000E+00
2	2	20	-0.2259521559E-01
1	1	20	-0.3486328293E-02
2	1	20	0.0000000000E+00
1	20	13	0.8804259822E-02
2	20	13	0.0000000000E+00
1	21	13	0.5290664732E-01
2	21	13	0.0000000000E+00
1	22	12	-0.3577056900E-01
2	22	12	0.0000000000E+00
1	22	11	0.0000000000E+00
2	22	11	0.0000000000E+00
1	21	11	-0.5350817740E-01
2	21	11	0.0000000000E+00
1	13	19	0.4834808409
2	13	19	0.0000000000E+00
1	14	20	0.2164413333
2	14	20	0.0000000000E+00
1	15	19	0.4561309814
2	15	19	0.0000000000E+00

total sum of flows = -0.4420106411
Flow rates for Rissa river = -1.921705842
Flow rates Hersjoen to Rissabru =-0.1997506618
Flow rates for Transjoen-Hersjoen river =-0.2756783925E-01

Net cell-by-cell flow terms for constant head cells
flow rates in l**3/t
negative values - net flow into cell, postive values - net flow out of cell
kstp,kper,icol,irow,ilay 1 1 24 36 2
Number of constant head cells is 62

layer	row	col	flow rate
1	11	1	0.0000000000E+00
2	11	1	0.4324987531E-02
1	12	1	0.2512730192E-02
2	12	1	0.8855989203E-02
1	13	1	0.1239921525E-01
2	13	1	0.1288261614E-02
1	14	1	0.1682206406E-02
2	14	1	0.8524260920E-04
1	15	1	-0.3599552670E-02
2	15	1	-0.1942480412E-04
1	16	1	-0.5583088845E-02
2	16	1	-0.2489967665E-04
1	17	1	0.1149423700E-01
2	17	1	0.5191951277E-04
1	18	1	0.4847203568E-01
2	18	1	0.1889392006E-03
1	20	1	-0.2773019113E-01
2	20	1	-0.4310255099E-04
1	21	1	-0.8594832383E-02
2	21	1	-0.6443018719E-05
1	22	1	-0.3477390390E-02
2	22	1	-0.1185233850E-04
2	25	24	-0.1210805494E-02
2	26	24	-0.6170213223E-02
2	27	24	-0.5846171640E-02
2	28	24	-0.4919835832E-02
2	29	24	-0.4075833596E-02
2	30	24	-0.4045531619E-02
2	31	24	-0.2740506083E-02
2	32	24	-0.3100136993E-02
2	33	24	-0.5296288058E-02
2	34	24	-0.1633769646E-01
2	35	23	-0.1834069612E-02
2	35	22	-0.5808800925E-02
2	35	21	-0.6674275268E-02
1	36	20	-0.3035686444E-02
2	36	20	-0.9319806122E-03
1	36	19	-0.5015324336E-02
2	36	19	-0.3730241733E-03
2	36	14	-0.1455520932E-01
2	36	15	-0.5459354725E-02
1	36	16	-0.9869552217E-02
2	36	16	-0.2006976400E-02
1	36	17	0.0000000000E+00
2	36	17	-0.2497273264E-02
1	36	18	-0.4121921025E-02
2	36	18	-0.3625699319E-03
1	1	5	0.0000000000E+00
2	1	5	0.0000000000E+00
1	1	6	0.0000000000E+00
2	1	6	0.0000000000E+00
1	1	7	0.0000000000E+00
2	1	7	0.0000000000E+00
1	1	8	0.0000000000E+00
2	1	8	0.0000000000E+00
1	2	5	-0.1986759598E-03
2	2	5	-0.3651133738E-02
1	2	6	0.0000000000E+00
2	2	6	0.0000000000E+00
1	2	7	0.0000000000E+00
2	2	7	0.0000000000E+00
1	2	8	0.0000000000E+00
2	2	8	0.0000000000E+00
1	3	6	-0.2034629724E-03
2	3	6	-0.4104258027E-02

1	3	7	0.0000000000E+00
2	3	7	0.0000000000E+00
1	4	6	-0.4531591258E-03
2	4	6	-0.9382458404E-02
1	4	7	0.0000000000E+00
2	4	7	0.0000000000E+00
1	4	9	0.0000000000E+00
2	4	9	0.0000000000E+00
2	5	6	-0.4391283542E-01
2	5	7	-0.1777783968E-01
2	5	8	-0.6254647393E-02
2	5	9	-0.6991866976E-02
2	1	16	-0.1350457128E-01
2	1	17	0.2879552310E-02
2	2	17	-0.9807439521E-02
2	3	17	-0.1468977984E-01
2	3	18	-0.3901800513E-01
2	3	21	-0.6850904226E-01
2	4	22	0.6989737600E-01
2	4	23	0.1115912944E-01
2	4	24	0.0000000000E+00
1	18	14	-0.5093380809E-01
2	18	14	-0.4603963345E-01
1	19	13	-0.3443370014E-01
2	19	13	-0.4001548141E-01
1	19	14	-0.5595716182E-02
2	19	14	-0.1793069951E-01
1	20	14	-0.6344031543E-01
2	20	14	-0.7425953448E-01
2	25	14	-0.1506618261

total sum of flows = -0.6747183800
Flow rates for Hersjoen = -0.3326489031
Flow rates for Hurdalsjoen = -0.9660165012E-01
sum of positive flows in buff 0.1752918065
sum of negative flows in buff-0.8908209205

93

APPENDIX 7 - listing of recharge model

```
c      PROGRAM RECHARGE
c
c Calculates aquifer recharge from meteorological data
c using the Penman-Grindley model (Rushton and Redshaw, 1979,
c 'Seepage and Groundwater Flow') with modifications to
c include effects of accumulating snow cover and snow melt.
c
c
c Written by Noelle Odling (BSC) and David Banks (NGU)
c at IBM Bergen Environmental Sciences and Solution Centre (BSC),
c Bergen Norway.
c
c 9th April 1992
c
c.....................................................................
c Variable definitions:
c
c rg - recharge (mm)
c pe - potential evapotransiration
c ro - runoff (fraction of precipitation)
c rf - precipitation
c rc - root constant
c sm - soil moisture deficit
c ps - potential change in soil moisture
c as - actual      #     # #      #
c ae - actual evapotransiration
c.....................................................................
c
       PARAMETER (NUM=20000)
       real*4 sm(num), ps(num),as(num),ae(num),pe(num),rg(num)
       real*4 rf(num)
       integer*4 dat(2,num),snod(num),ntyp(num),sdur(6,num),maxs(num)
       character*20 title
c
       data sm(121) / 0.0 /
       data rc      / 175.0 /
c
c read rainfall, pot.evap. data set
c
       read (77,8) title
 8     format (a20)
       ndata = 0
       nyear = 0
       do 10 i = 1,num
       read (77,*,end=11) ndum, dat(1,i), dat(2,i), pe(i), rf(i),
     #                    snod(i),ntyp(i)
        if (pe(i).lt.0.0) then
        rf(i) = rf(i) - pe(i)
        pe(i) = 0.0
        end if
       ndata = ndata + 1
        if (dat(2,i).eq.200) nyear = nyear + 1
 10    continue
 11    continue
c---------------------------------------------------------------------
c find periods of significant snow cover and day max snow depth
c
       nper = 0
       do 50 i = 1,ndata
       if (i.eq.1) nprev = 1
       if (i.gt.1) nprev = ntyp(i-1)
c detect snow cover start
        if (nprev.lt.2) then
         if (ntyp(i).ge.2) then
         nper = nper + 1
          if (nper.gt.num) write (6,*)'array bounds exceeded'
         maxs(nper) = 0
         nflag1 = 1
         sdur(1,nper) = dat(1,i)
         sdur(2,nper) = dat(2,i)
         end if
```



```
        end if
c
c find day with max snow cover depth
c
        if (nflag1.eq.1) then
         if (snod(i).gt.maxs(nper)) sdur(5,nper) = dat(1,i)
         if (snod(i).gt.maxs(nper)) sdur(6,nper) = dat(2,i)
         if (snod(i).gt.maxs(nper)) maxs(nper) = snod(i)
        end if
c
c detect snow cover finish - day after last ntyp=2
c
        if (nflag1.eq.1) then
        if (nprev.ge.2) then
         if (ntyp(i).lt.2) then
         nflag1 = 0
          sdur(3,nper) = dat(1,i)
          sdur(4,nper) = dat(2,i) + 1
c check for end of year and leap years
           if (mod(dat(1,i),4).eq.0) then
            if (dat(2,i).eq.366) then
             sdur(3,nper) = dat(1,i)
             sdur(4,nper) = dat(2,i) + 1
            end if
            else
             if (dat(2,i).eq.365) then
              sdur (3,nper) = dat(1,i) + 1
              sdur(4,nper) = 1
             end if
            end if
c
           end if
         end if
        end if
 50    continue
c
c---------------------------------------------------------------------
c CALCULATE RECHARGE PER DAY
c---------------------------------------------------------------------
c
       nflag = 0
       kflag = 0
       nper1 = 0
       nper2 = 0
       nper3 = 0
       DO 100 I = 122,ndata
c
c detect start, finish and time of max snow cover
c nflag=1: snow cover, kflag=1: snow melting period
c start period
       do 101 j = 1,nper
         if (dat(1,i).eq.sdur(1,j)) then
          if (dat(2,i).eq.sdur(2,j)) then
          nflag = 1
          storrf = 0.0
          nper1 = nper1 + 1
          end if
         end if
c
c start melting period
c
        if (nflag.eq.1) then
         if (dat(1,i).eq.sdur(5,j)) then
          if (dat(2,i).eq.sdur(6,j)) then
          nper2 = nper2 + 1
          kflag = 1
c
c no days over which melting takes place
c
           if (sdur(3,j).eq.sdur(5,j)) then
           meltd = sdur(4,j) - sdur(6,j)
```

```
           else
           meltd = 365 - sdur(6,j) + sdur(4,j)
            if (mod(dat(1,i),4).eq.0) meltd = meltd + 1
           end if
          end if
         end if
       end if
c
c finish period
c
         if (dat(1,i).eq.sdur(3,j)) then
          if (dat(2,i).eq.sdur(4,j)) then
          nflag = 0
          kflag = 0
          nper3 = nper3 + 1
          end if
         end if
c
  101   continue
c
c calculate precitation storage in form of snow during snow buildup
c
        if (nflag.eq.1) then
        if (kflag.eq.0) then
        storrf = storrf + rf(i)
        end if
        end if
c.....................................................................
c calculate ps, potential change in soil moisture
c 1) when zero snow cover
       ps(i) = pe(i) - (1-ro)*rf(i)
c 2) when snow is accumulating
       if (nflag.eq.1) then
        if (kflag.eq.0) then
         ps(i) = pe(i)
c 3) when snow is melting
        else if (kflag.eq.1) then
         ps(i) = pe(i) - (1-ro)*rf(i) - (storrf/float(meltd))
        end if
       end if
c
       if (sm(i-1).lt.rc) then
        as(i) = ps(i)
        ae(i) = pe(i)
       end if
c
       if (ps(i).gt.0.0) then
        if (sm(i-1).ge.rc) then
        as(i) = 0.1*ps(i)
        ae(i) = rf(i)*(1-ro) + as(i)
        end if
       else
        if (sm(i-1).ge.rc) then
        as(i) = ps(i)
        ae(i) = pe(i)
        end if
       end if
c
c calculate present sm and rg
c
       sm(i) = sm(i-1) + as(i)
       if (sm(i).lt.0.0) then
        rg(i) = -sm(i)
        sm(i) = 0.0
       else
        rg(i) = 0.0
       end if
c
 100   continue
c
c calculate yearly averages
```



```
c
      write (55,*) 'Year       recharge     rainfall      actual evapo
     #transiration'
        sumae = 0.0
        sumrf = 0.0
        sumrg = 0.0
       do 150 i = 122,ndata
        if (dat(2,i).eq.1) then
         avae = sumae / dat(2,i-1)
         avrf = sumrf / dat(2,i-1)
         avrg = sumrg / dat(2,i-1)
        write (55,151) dat(1,i-1),sumrg,sumrf,sumae
 151    format (i4,2x,3(1pe12.3))
        sumae = 0.0
        sumrf = 0.0
        sumrg = 0.0
        end if
         sumae = sumae + ae(i)
         sumrf = sumrf + rf(i)
         sumrg = sumrg + rg(i)
 150    continue
c
c calculate monthly averages
c
      call month (dat,rg,rf,ae,122,ndata,nyear)
c
c write output data
c
      write (66,*)'year   day         rf            pe            ps
     #      sm            as           ae           rg '
       do 200 i = 122,ndata
       write (66,210) dat(1,i),dat(2,i),rf(i),pe(i),ps(i),sm(i),as(i),
     # ae(i),rg(i)
 210   format (2(i4,1x),7(1pe12.3))
 200   continue
c
      stop
      end
c**********************************************************************
c
      subroutine month (dat,rg,rf,ae,nstart,ndata,nyear)
c
c calculate monthly averages of recharge, rainfall, actual evapo-
c transpiration.
c
      parameter (NUM=20000)
      real*4 rg(num),rf(num),ae(num)
      integer*4 dat(2,num)
c
c header for output file
c
      write (88,*) 'Gardemoen meterological station - monthly values'
      write (88,*) '                year  month  recharge       rainfall
     #       actual evapotransiration'
c
      i = nstart
      jmon = 0
      do 50  iyear = 1,nyear
      do 100 imonth = 1,12
      jmon = jmon + 1
c
c for first year, start in May
c
      nflag = 0
      if (iyear.eq.1) then
       if (imonth.lt.5) nflag = 1
      end if
      if (nflag.eq.1) go to 100
c
c determine no days in present month
c
```

```
      if (mod(dat(1,i),4).eq.1) then
       if (dat(2,i).eq.335) nday = 31
       if (dat(2,i).eq.305) nday = 30
       if (dat(2,i).eq.274) nday = 31
       if (dat(2,i).eq.244) nday = 30
       if (dat(2,i).eq.213) nday = 31
       if (dat(2,i).eq.182) nday = 31
       if (dat(2,i).eq.152) nday = 30
       if (dat(2,i).eq.121) nday = 31
       if (dat(2,i).eq.91) nday = 30
       if (dat(2,i).eq.60) nday = 31
       if (dat(2,i).eq.32) nday = 28
       if (dat(2,i).eq.1) nday = 31
      else if (mod(dat(1,i),4).eq.0) then
       if (dat(2,i).eq.336) nday = 31
       if (dat(2,i).eq.306) nday = 30
       if (dat(2,i).eq.275) nday = 31
       if (dat(2,i).eq.245) nday = 30
       if (dat(2,i).eq.214) nday = 31
       if (dat(2,i).eq.183) nday = 31
       if (dat(2,i).eq.153) nday = 30
       if (dat(2,i).eq.122) nday = 31
       if (dat(2,i).eq.92) nday = 30
       if (dat(2,i).eq.61) nday = 31
       if (dat(2,i).eq.32) nday = 29
       if (dat(2,i).eq.1) nday = 31
      end if
c
c averages for month
c
      sumrg = 0.0
      sumrf = 0.0
      sumae = 0.0
c
      do 200 j = 1,nday
       sumrg = sumrg + rg(i)
       sumrf = sumrf + rf(i)
       sumae = sumae + ae(i)
       i = i + 1
 200  continue
c
c write to output file
c
      npyear = dat(1,1) + iyear - 1
      write (88,201) jmon, npyear, imonth, sumrg, sumrf, sumae
 201  format (3(i4,2x),2x,3(1pe12.3))
c
100   continue
 50   continue
c
      return
      end
```