RISING GROUNDWATER LEVELS IN THE

CHALK - BASAL SANDS AQUIFER

OF THE CENTRAL LONDON BASIN

Progress Report - February 1992

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RISING GROUNDWATER LEVELS IN THE CHALK-BASAL SANDS AOUIFER

OF THE CENTRAL LONDON BASIN

PROGRESS REPORT - FEBRUARY 1992

SUMMARY

The London Basin computer model was extensively re-configured to a desktop computer environment with high quality graphics output (3). Many scenarios involving extensive pumping of chalk groundwater have now been modelled for a 50 year period into the future (1990-2040) and a possible scenario for controlling groundwater level has been identified producing up to 36Ml/d of extra water resource. It depends heavily on Thames Water Utilities Limited (TWUL) maximising those existing licences which are considerably under used in some areas plus using rising groundwater as an additional resource. The location of additional pumping sites is a critical factor in the optimum scenario.

Over 20 additional groundwater monitoring sites will have been added to the network by April 1992. Considerable success has been achieved in continuing to locate and modify disused boreholes for monitoring purposes and over £100K will have been spent by the NRA in drilling 7 new boreholes by May 1992.

Groundwater level and rate of rise contour maps have been produced for January 1st 1992 and these show no slowing down of the recovery of levels, with rates of rise in excess of 2 metres per year in small areas.

RISING GROUNDWATER LEVELS UNDER LONDON

Progress Report - February 1992

1. INTRODUCTION

Following the publication of the CIRIA Special Publication 69 (1) in 1989 the NRA Thames Region was instructed by the Department of the Environment to ensure adequate monitoring of groundwater levels in the London Area and to consider options for controlling their rise. This report covers further progress in improving the monitoring network, an update of trends in groundwater levels and modelling to investigate control options. The report is mainly concerned with the confined chalk aquifer of the Central London Basin but does extend NW and SE to include areas of the unconfined chalk aquifer in the SW Chilterns and N Downs. The area covers 300 km^2 from Harlow in the north to Croydon in the South and along the Thames from Staines in the west to Dartford in the east (TL 01 to TL 61 and TQ 06 to TQ 66). An interim report with groundwater level maps was produced in 1990 (2).

2. IMPROVEMENTS TO THE LONDON BASIN GROUNDWATER MONITORING NETWORK

The regional groundwater monitoring network in the London area as of January 1991 is shown in Figure 1. Some of these boreholes were drilled in the period 1985-89. It can be seen, however, that the distribution of monitoring boreholes in the London Basin is far from uniform (4).

There are several reasons for this: historically, some observation boreholes have been former abstraction boreholes and some have been drilled to monitor specific projects such as the TWUL artificial recharge scheme and so are not uniformly distributed. Also, there are many physical constraints to the location of new boreholes in the urban areas of London. Consequently, there are many areas, several kilometres square, where there are no observation boreholes. Since 1990 several projects have been carried out or are still in progress to improve the situation.

2.1 Private Borehole Search

In January 1991, the National Rivers Authority (NRA) Thames Region commissioned Scott Wilson Kirkpatrick (SWK) Consulting Engineers, to undertake a four month search of the Greater London area to identify existing private boreholes penetrating the chalk aquifer which could be potentially incorporated within the NRA monitoring network.

Search areas were located, based on the critical area of Central London where groundwater levels are rising as identified in the CIRIA report and where monitoring points were either unevenly distributed or where a greater density of sites was required.

The search for additional boreholes began with database searches followed up by site visits. In some cases, small remedial works were necessary to enable the borehole to be monitored.

On completion of the contract, ten boreholes were suitable for incorporation within the monitoring network. (One has since been found not to penetrate the chalk aquifer and has been abandoned as an observation borehole). A further fourteen possible sites were found and negotiations continued by NRA staff. Of these fourteen, two are now part of the network and one is to be pursued in 1992 when development of the site is planned. The remaining ten have not been successful due to no response or non co-operation by the owners, expense of remedial works or it has been found that the boreholes are no longer in existence.

Work is ongoing to locate other disused chalk boreholes as sites come up for redevelopment and several are under investigation at present.

2.2 Thames Water Utilities New Observation Boreholes

As part of their current investigations in to the hydrogeology of the London Basin, TWUL have test pumped seven disused, underused, or emergency licensed pumping stations. Prior to these tests, an observation boreholes was drilled at each of the seven sites. The existing wells at five of the sites are already monitored by the NRA on a monthly basis, but at the other two sites, Streatham and East Ham, the two additional observation boreholes are available for incorporation in the monitoring network.

In 1992/93 TWU are planning to drill new observation boreholes at 5 further under utilised pumping stations at E Wickham, Eltham, Ravensbourne, Wanstead and Shortlands.

Five regional observation boreholes are planned in the western area at Dollis Hill, Ealing, Kew, Hammersmith and Putney Heath. These will be test pumped for yield, groundwater quality and aquifer parameter assessment.

In connection with the completion of the North London Recharge scheme, a further 24 observation boreholes will be drilled in 1992/93 along the line of the New River. Approximately 13 of these will be into the Chalk. All will be associated with 14 new abstraction/recharge sites.

2.3 NRA Drilling Contracts

Towards the end of the SWK borehole search contract, a review of the Central London groundwater level monitoring network was carried out by the NRA (4).

Nine areas were identified where large gaps still remained in the network where extensive interpolation of the groundwater contours was required and similarly where the rate of rise of water level is particularly high.

The priority area for the drilling of new monitoring boreholes, however, was to the east of Easting 30, covering the critical area of rising groundwater levels defined in the CIRIA report. To the west, where the chalk is deeply confined and aquifer parameters are low, new abstractions are unlikely to be attractive due to poor yield. To the east, however, the chalk is less deeply confined and the parameters are higher. It is in this area where abstraction could be encouraged to help control rising groundwater levels that monitoring of the changing water level is particularly important.

A search of NRA property holdings in East London was carried out resulting in one suitable site alongside the River Roding in Chigwell (TQ 413 905), not within the CIRIA critical area but in an area where existing data is very sparse.

TWUL had recently completed a property search of Central London and provided the NRA with a list of a number of TWUL owned sites, generally disused pumping stations, sewage treatment works, reservoir sites and depots. As it would have been extremely difficult to acquire land in Central London for drilling purposes the TWUL owned sites were considered as realistically the only other possible sites for new observation holes.

Thanks to good co-operation from TWUL four sites were identified as suitable, two north of the Thames, at Redbridge Sewage Treatment Works (TQ 419 870) and Mile End Depot (TQ 361 823) and two south of the river at Earl Pumping Station (TQ 361 788) and Kidbrook Reservoir (TQ 414 766).

A contract has been let to drill these five boreholes beginning in late January 1992. They should be complete and become part of the monitoring network by April 1992.

Two further TWUL sites have been identified, one within the critical area at Store Road (TQ 431 798) and one further west at Western Road Pumping Station (TQ 287 780) where the groundwater gradient appears to be particularly steep. These boreholes should be complete by May 1992.

2.4 Summary

Since January 1991, fourteen boreholes have been added to the monitoring network in Central London. Seven more are currently being drilled and will be completed by May 1992, generally in East London, and discussions are in progress for the use of a further five existing private wells in Greater London. TWUL plan to drill approximately 23 boreholes into the Chalk in 1992/93. The updated monitoring network for May 1992 is shown in Figure 2.

3. GROUNDWATER LEVEL AND RATE OF RISE

Groundwater levels are continuing to rise in response to the long term decline in abstraction from the confined chalk aquifer. Groundwater data are collected from all the observation boreholes within the Central London basin. To present a picture of the latest conditions these data have been used to draw two maps;

(i) Groundwater levels in January 1992.

(ii) Rate of rise December 1989 to December 1991.

3.1 Chalk Groundwater Levels January 1992

This map, shown in Figure 3 indicates the general groundwater level situation which occurs presently in the Central London Basin. As can be seen, the centre of the cone of depression occurs under the very central part of London, and then the levels increase out towards the north and north-west and to the south and south-east. The current level in the cone of depression recorded by the observation borehole TQ 28/119 at Trafalgar Square, is -51.32 m OD. This compares with -88m OD in 1967.

Towards the east, a shallow depression also exists in south Essex, to the north and south of grid line 90, where the groundwater levels are in the region of -20 m OD. This is being maintained by a number of Water Company pumping stations.

In several locations along the Lee Valley and in the adjacent Enfield-Haringey area there are readings of current groundwater levels which deviate from the general pattern given by the contours. This is due to abstraction from the Lee Valley Artificial Recharge Scheme sites during December 1991 which will lead to non-representative readings.

When this map is compared to the one drawn in January 1990 (Figure 4) it can be seen that the overall pattern of groundwater levels is fairly similar. During the two years however, there has been a general rise in level which will be discussed in the following section.

3.2 Average Rate of Rise Map

The average rate of rise which has occurred in the chalk groundwater levels over the period December 1989 - December 1991 is shown in Fig. 5. The contours have been drawn at intervals of 0.5 m/yr and it can be seen that in the centre of the cone of depression, an average rate of rise of +2 m/yr around TQ28/119 (Trafalgar Square) and +2.5 m/yr at TQ38/390A (Lloyds Bank Cornhill) have been recorded. Figure 6 is a hydrograph of the groundwater level at Trafalgar Square since 1966.

In general the amount of rise decreases out from the centre of the cone of depression, although not uniformly. As can be seen the contour lines to the east of the centre of the cone, near TQ38/390A decrease rapidly whereas to the west they are spaced further apart. There is also a rise in the Essex area cone of +0.5 m/yr.

When this latest average rate of rise map is compared to that drawn for the period December 1987 - December 1989 (Figure 7) it can be seen that in general the situation in the central cone of depression is very similar, ie. continuing to rise at a similar rate, whereas there appear to be differences along the Lee Valley and Enfield-Haringey area. Figure 8 shows the hydrograph of the observation borehole TQ 39/55A, Brimsdown Power Station, where the groundwater levels have obviously been affected by pumping of the Lee Valley artificial recharge scheme during 1990; a similar response has occurred at other sites in the general area, particularly in the grid-square TQ39. Plotting rate of rise in this area for December 1989 to 1991 would be meaningless (see Fig. 5).

There is a very local sharp rate of rise occurring in the vicinity of TQ 38/466 (see Figs. 5 and 9) which was not seen on Figure 7. This is probably due to an approximate reduction of 80,000m^3/year in the abstraction from this area recently.

These maps indicate the changing nature of the groundwater level in the chalk of the London Basin. The continuing rate of rise has been shown in Figure 5 and the way in which the pumping regime can affect these levels has also been discussed.

4. MODELLING OF THE LONDON BASIN

The CIRIA report suggested that one solution to the problem of rising groundwater levels was to increase abstractions from the London Basin. Using the improved London Basin Finite Element model inherited from Thames Water Authority, the NRA has run and analysed various scenarios (5) which could control rising groundwater levels in the "critical" areas as defined by the CIRIA Report.

4.1 Baseline Conditions

To enable comparison between various control scenarios certain baseline conditions were first modelled. These were:

a:- to assume that natural recharge will be at a rate equivalent to that of the average of the last 14 years.

b:- to assume that the quantity of abstraction will continue at the 1990 rate throughout the 50 year run.

The predicted groundwater level map produced for the year 2040 (Figure 10) indicates that the centre of the cone of depression will have risen to -20m OD from the current position indicating a rise of 30m which is equivalent to 0.6m/year. The average rate of rise has slowed down from the current 2m/year because of the rise of the groundwater levels through the Lower London Tertiary Strata where different aquifer parameters exist. A hydrograph at the model node nearest Trafalgar Square (Figure 11) indicates the groundwater level situation in the centre of the cone.

From the licence returns it is evident that there are several licences in the outer London area, in particular the large public water supply abstractions for TWUL, which have either lapsed or are not being fully utilized. It was therefore felt important to model a condition which would maximise TWUL's currently licensed abstractions. This produced a limit on the groundwater level rate of rise in that the predicted level in the cone of depression would be -30m OD in 2040, ie. a rise equivalent to 0.4m/year (Figure 12) and 10m lower than the continuation of the present regime.

Other preliminary scenarios included modelling the effects of proposed water resource developments such as the Artificial Recharge Schemes in both North and South London and new sources which are being test-pumped as part of TWUL's initial investigations into utilising rising levels.

4.2 Possible Future Scenarios

The main emphasis of the modelling work was then directed towards attempting to control the rising levels by placing additional abstractions around the London Basin. Various locations and quantities for the abstractions were modelled to attempt to define an "acceptable" situation, but it must be emphasised that all abstractions are at hypothetical locations. From the various scenarios, it would appear on resources grounds that the London Basin could support an increased abstraction of 36Ml/d above the present licensed amount depending upon the location of these abstractions. This report looks selectively at certain scenarios. Work will continue and options will be revised particularly in the light of the results of investigations by TWUL.

The main objective of the modelling work was to produce conditions whereby groundwater levels in the chalk outside the main cone of depression stabilise a few metres above the top of the Chalk aquifer ie. by preventing the otherwise uncontrolled rise, but without inducing significant drawdowns. The main cone would continue to recover slowly before stabilising a few metres above the fully saturated Chalk aquifer. It can be seen that for large areas outside the cone of depression there is scope for additional drawdown.

4.2.1 Unacceptable Condition

An example of an "unacceptable" condition is shown in Figure 13., where it was assumed that all the existing TWUL sites were abstracting at their full licensed quantity, the artificial recharge sites were included, and a number of hypothetical sites, each abstracting at 1Ml/d, were placed in a ring, completely encircling the cone of depression. The total additional abstraction amounted to 39Ml/d, but as can been seen, the trend of rising groundwater levels was completely reversed so that the cone of depression deepened to -80m AOD. The hydrograph of the trend at Trafalgar Square indicates this, reversing the rising trend dramatically (Figure 14).

4.2.2 Controlled Conditions

It became evident from further modelling that due to differences in the properties of transmissivity and storativity, the aquifer in the chalk to the east of national grid Easting 30 could support far more of the additional abstractions without producing unacceptable drawdowns than could the aquifer west of Easting 30 which produced high drawdowns for little yield.

The predicted groundwater level contour map at 2040 shown in Figure 15. indicates a similar situation to that of the current map but with additional abstraction, biased towards the east. As can be seen in Figure 16, the hydrograph for Trafalgar Square indicates that the chalk groundwater level is only varying by approximately 1m over the modelled time period. In this scenario the additional abstractions were located in the following way: 29Ml/d was abstracted from sites (at approximately 4Ml/d from each site) east of Easting 30, 5Ml/d was abstracted (at 1Ml/d each) from sites on the north-west of the depression and 2Ml/d (at 1Ml/d each) was abstracted from the southern fringes. As in previous scenarios, all the existing TWUL sites were assumed to be abstracting at their full licensed quantity and the artificial recharge sites were also operating. In this scenario, the London Basin is supporting an additional abstraction of approximately 70Ml/d, made up from 34Ml/d by maximising existing TWUL licences and 36Ml/d from new sources using rising groundwater.

Although this option produces an effective solution for the control of rising groundwater levels, in practice it is unlikely that an abstraction of 4Ml/d per site could be guaranteed due to the confined nature of the strata. Therefore alternative variants were examined whereby the quantity of 29Ml/d being abstracted from the area east of Easting 30 was distributed at different rates. In one case where there were 29 sites each abstracting at approximately 1Ml/d, and in another 14 sites abstracting at approximately 2Ml/d per site. However these different abstraction rates did not seem to have a significant effect on the resulting groundwater levels, producing very similar groundwater level maps for 2040. Figure 17 shows the current London Basin groundwater map with the optimum area for controlled pumping producing 36Ml/d highlighted.

4.3 Summary

The modelling work has indicated the possible additional abstraction which could be supported by the London Basin in controlling the rising groundwater levels. It would be acceptable to concentrate much of the abstraction east of Easting 30, up to approximately 29Ml/d in addition to the full water company licences. Some small additional abstractions on the north-west and southern fringes of the cone of depression could also occur increasing the total additional abstraction to approximately 36Ml/d.

Many other scenarios remain to the modelled, involving different abstraction rates and patterns. One option yet to be investigated is the use of some sites as "drought only sites", in conjunction with the base load sites.

It must be emphasized that all of those sites for additional abstractions have been hypothetical, and that, having defined areas where abstractions would be most beneficial, the NRA can now encourage water users to apply for licences within the preferred areas.

The potential effect on groundwater level of all new chalk groundwater abstractions within the London Basin can now be examined with a reasonable degree of realism using a reliable model.

5. THAMES WATER UTILITIES RESOURCE INVESTIGATIONS

Thames Water have commenced a comprehensive program to investigate the use of rising groundwater as a potable resource. In the second half of 1991 7 under utilised or disused sites were each test pumped for 4 weeks. Observation boreholes were drilled where necessary (Section 2.2).

A completely new site at Battersea, comprising a large diameter abstraction borehole and existing OBH has recently been drilled and test pumped with promising results.

Test pumping at upto a further 2 existing under utilised sites is planned this year and upto 5 observation boreholes will also be drilled and test pumped at a range of sites on TWUL land.

In addition to these operations, the completion of the North London Recharge/Abstraction scheme (Section 2.2) in the next 18 months will add considerably to the knowledge of the London Basin.

6. WATER QUALITY

One restriction on utilising the Chalk groundwater for public water supply is the zone of high ionic concentration extending up the tidal Thames as far as Wapping. Recent dewatering of construction sites for the Jubilee line extension at TQ 38,80 yielded Chalk water of conductivities in excess of 4000 micro siemens, clearly not potable groundwater.

Away from this area, initial exploration and test pumping by TWUL indicates few areas of very poor water quality. However, water abstracted from the Chalk in this area will require treatment, mainly to reduce the level of mineralisation. The feasibility and costs of this treatment are presently under investigation by TWUL.

7. CONCLUSIONS

1) A likely policy for controlling and stabilising rising groundwater levels under London has been established utilising the London Basin Computer model.

2) Up to 36Ml/d of abstraction beyond that which is already licensed could be available, mostly east of Easting 30.

3) The area for the most effective abstraction has been identified (Figure 17) and approximately 15 sites would give sufficient versatility for fine tuning the long term control of rising levels. The geographical distribution of abstraction is very important for controlling levels efficiently and avoiding unacceptable drawdowns.

4) The NRA will seek to bring together organisations most likely to benefit from control of levels, particularly London Underground and TWUL, to establish sites of mutual benefit.

5) Control of rising groundwater in the high conductivity areas of the Thames Tideway would require pumping to waste if the use by TWUL of the potable resource was insufficient to control levels over the entire area.

6) Although NRA Thames Region is unlikely to drill any new observation boreholes in the near future in inner London, additional groundwater level information will become available as TWUL investigations proceed. It is planned that future groundwater level maps will be produced on an annual basis and become more accurate.

7) As the results from TWUL investigations become available, amendments to the aquifer model and to patterns of additional control abstractions may arise.

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Fig. 1.

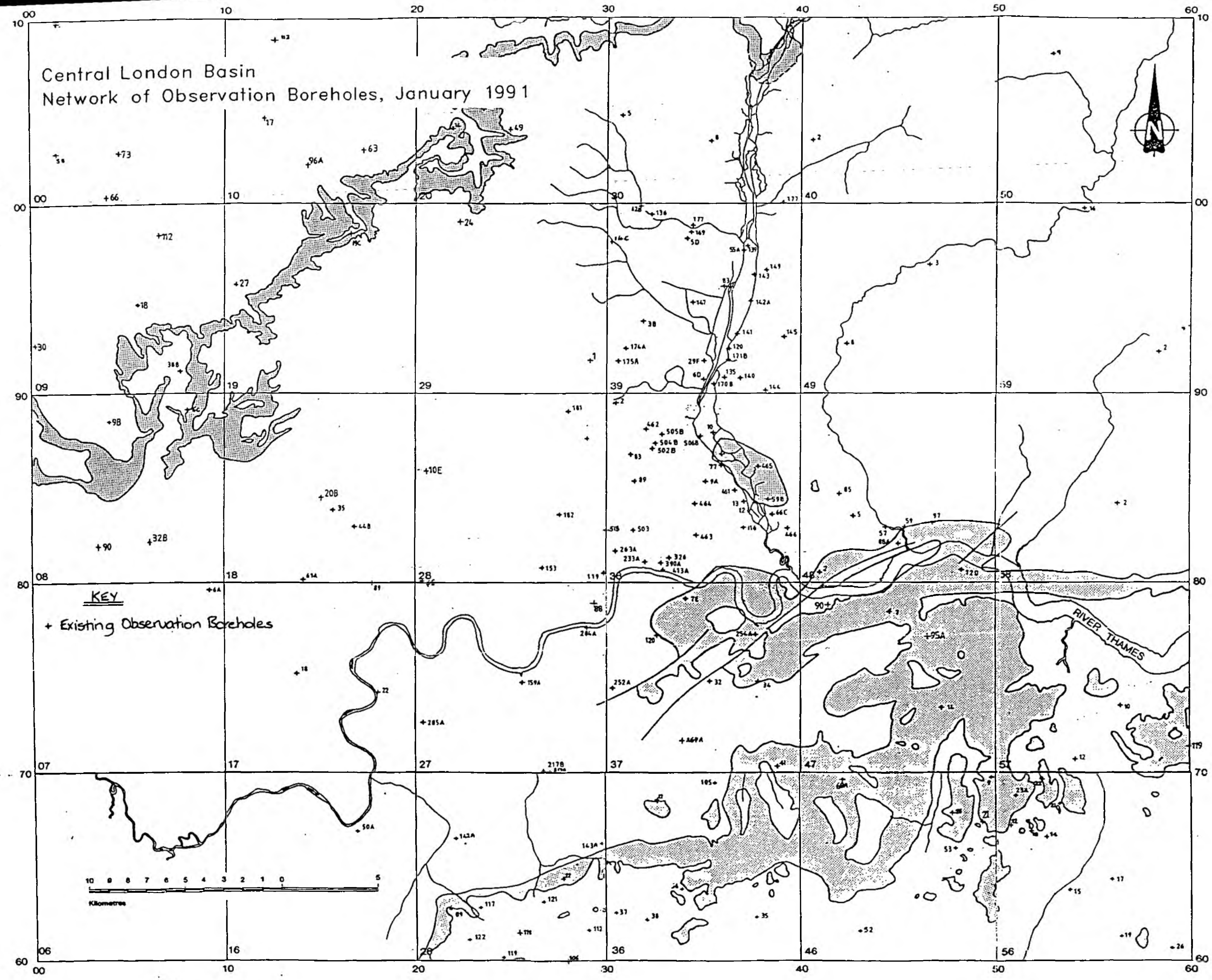
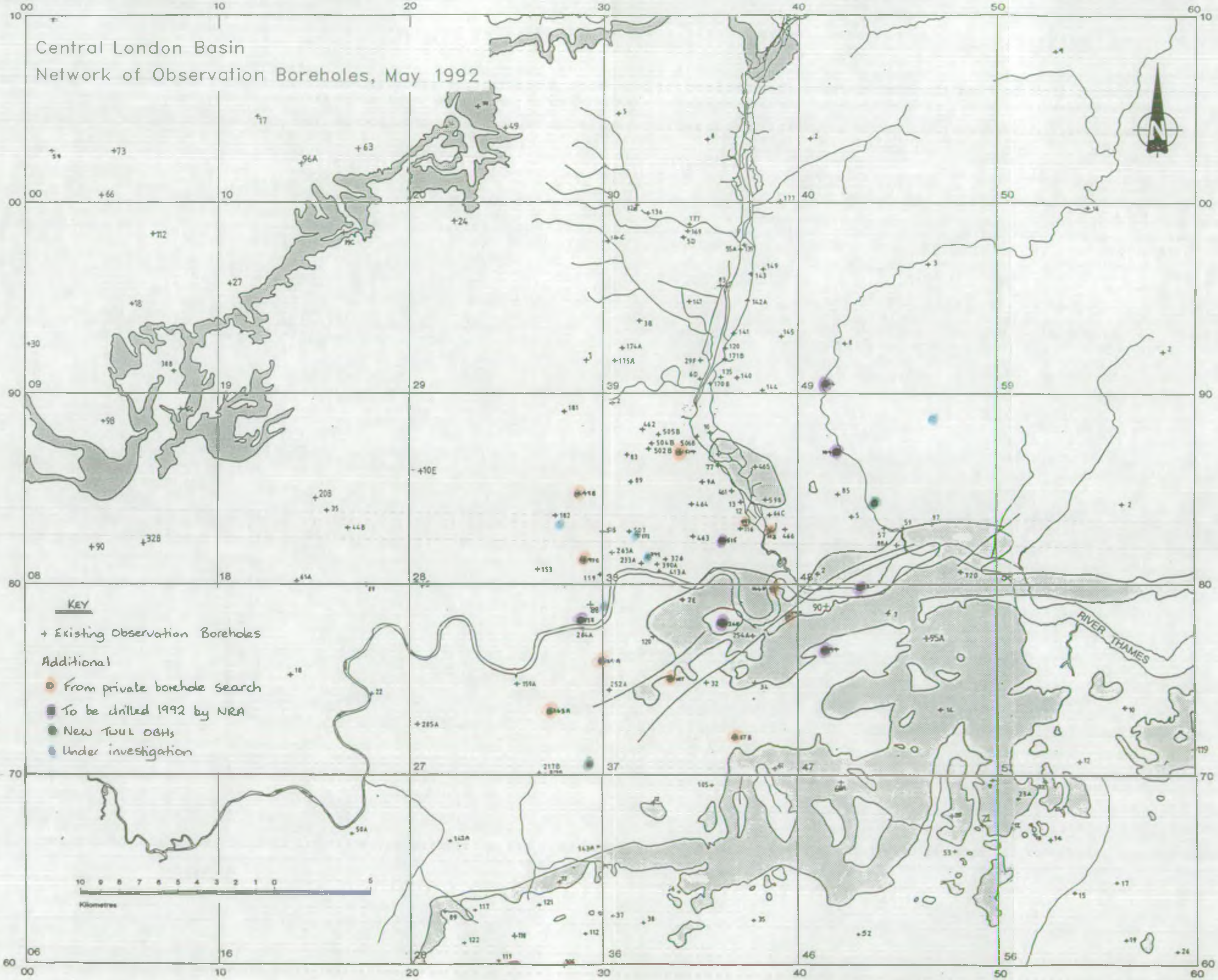

Central London Basin
Network of Observation Boreholes, January 1991
KEY
+ Existing Observation Boreholes
RIVER THAMES
Kilometres
NRA
National Rivers Authority
Thames Region

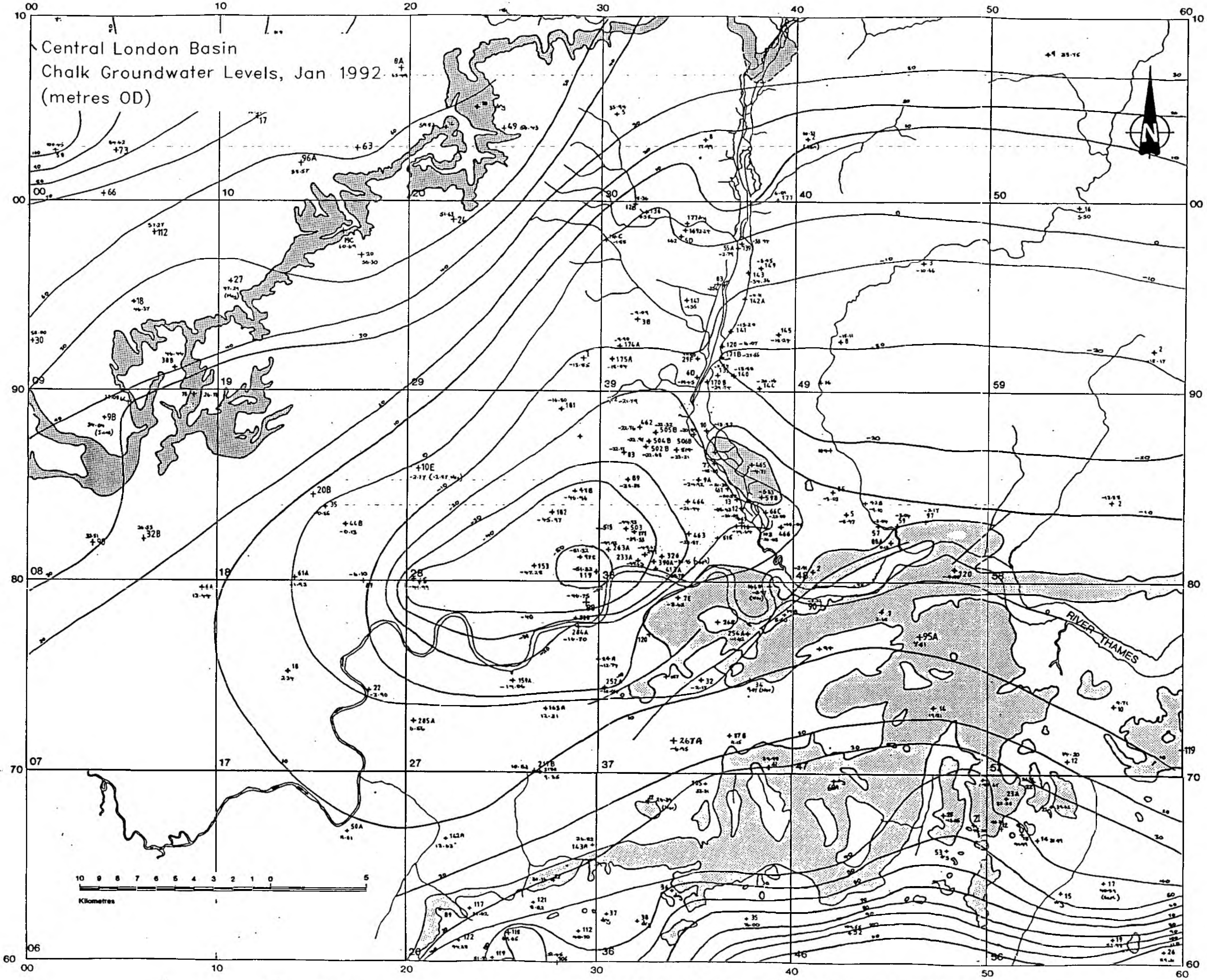
Fig. 2.



NRA

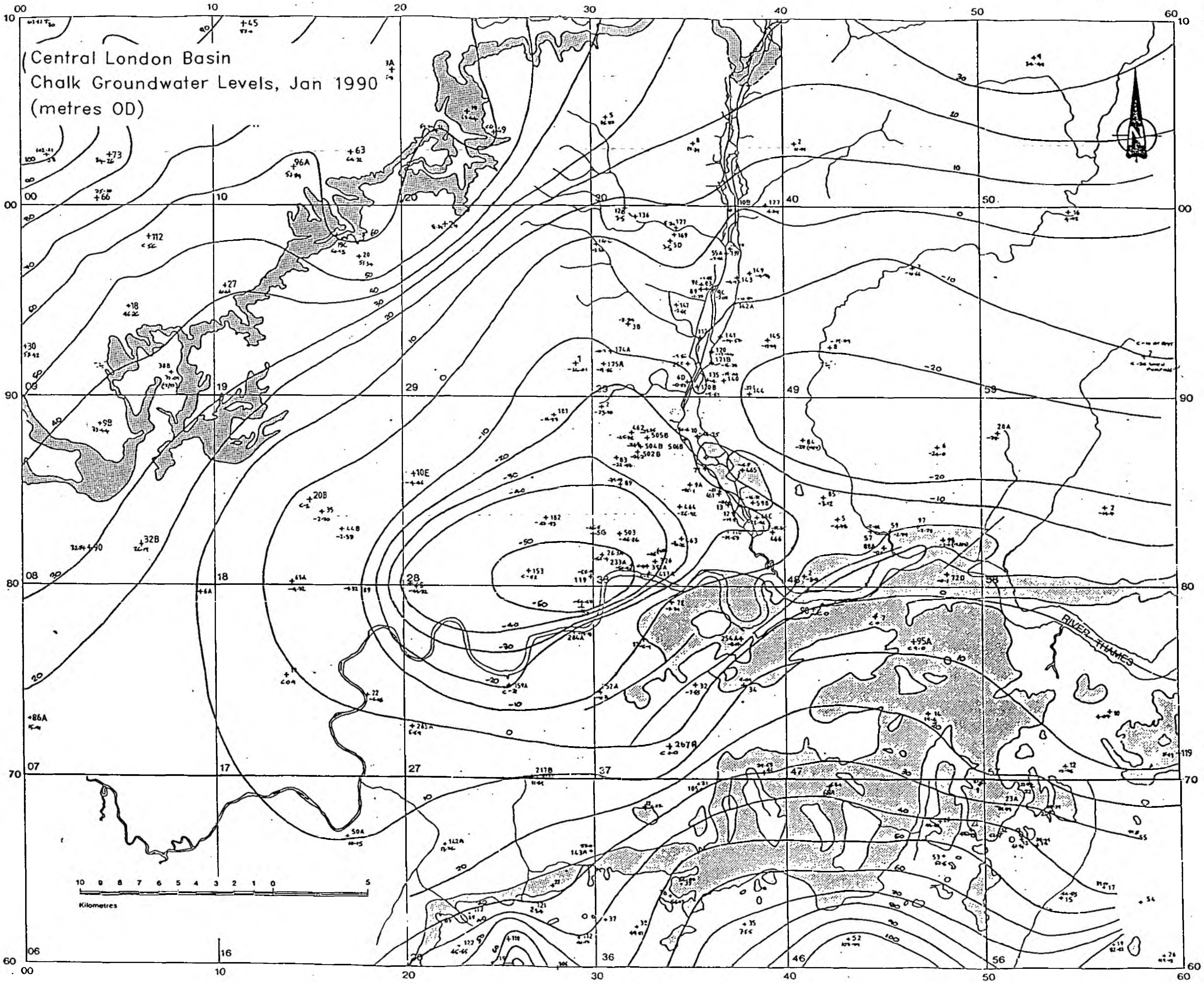
National Rivers Authority
Thames Region

FIG 3



NRA
National Rivers Authority
Thames Region

FIG 4



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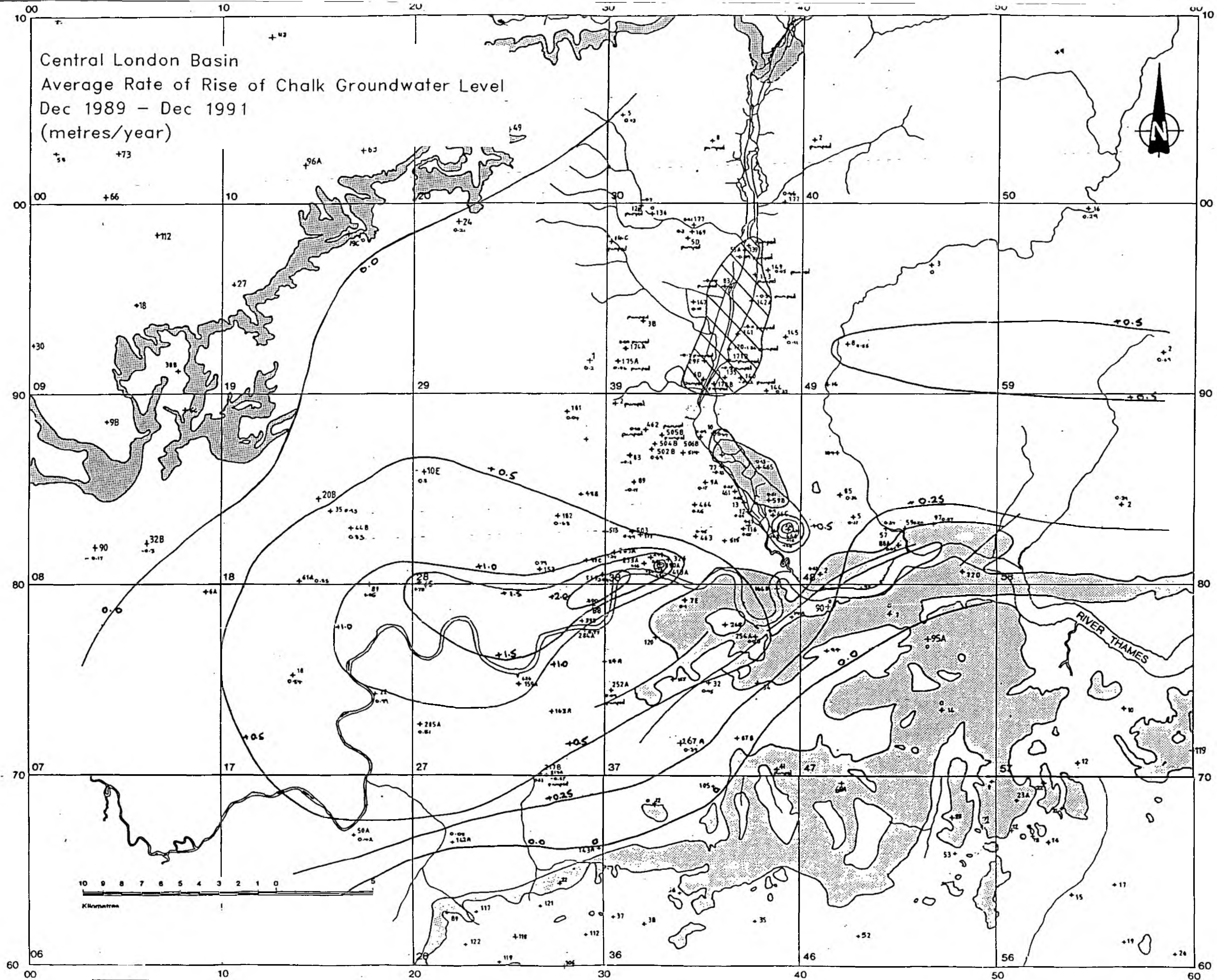
National Rivers Authority
Thames Region

FIG 5



Area affected by exceptional pumping (see text)

NRA

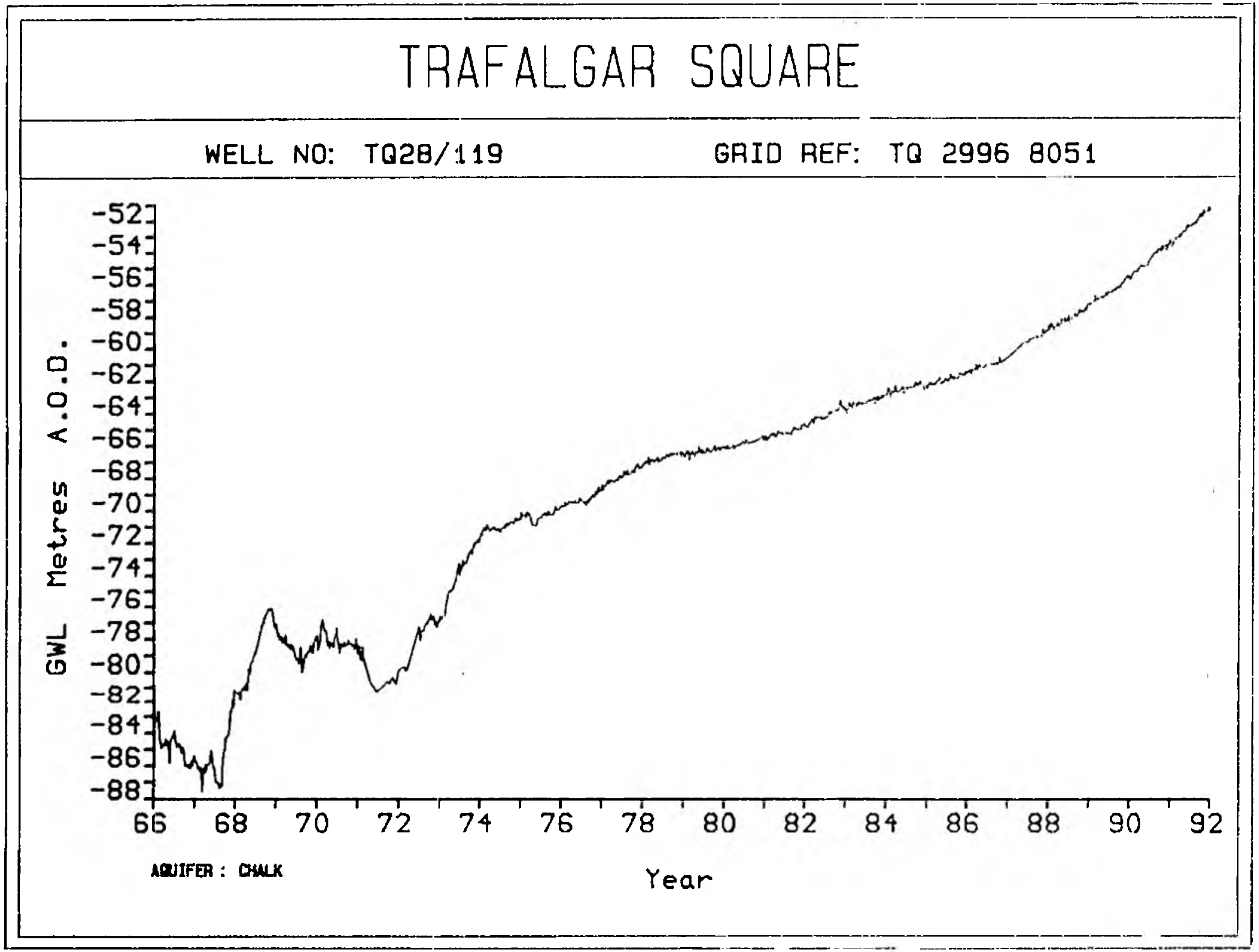
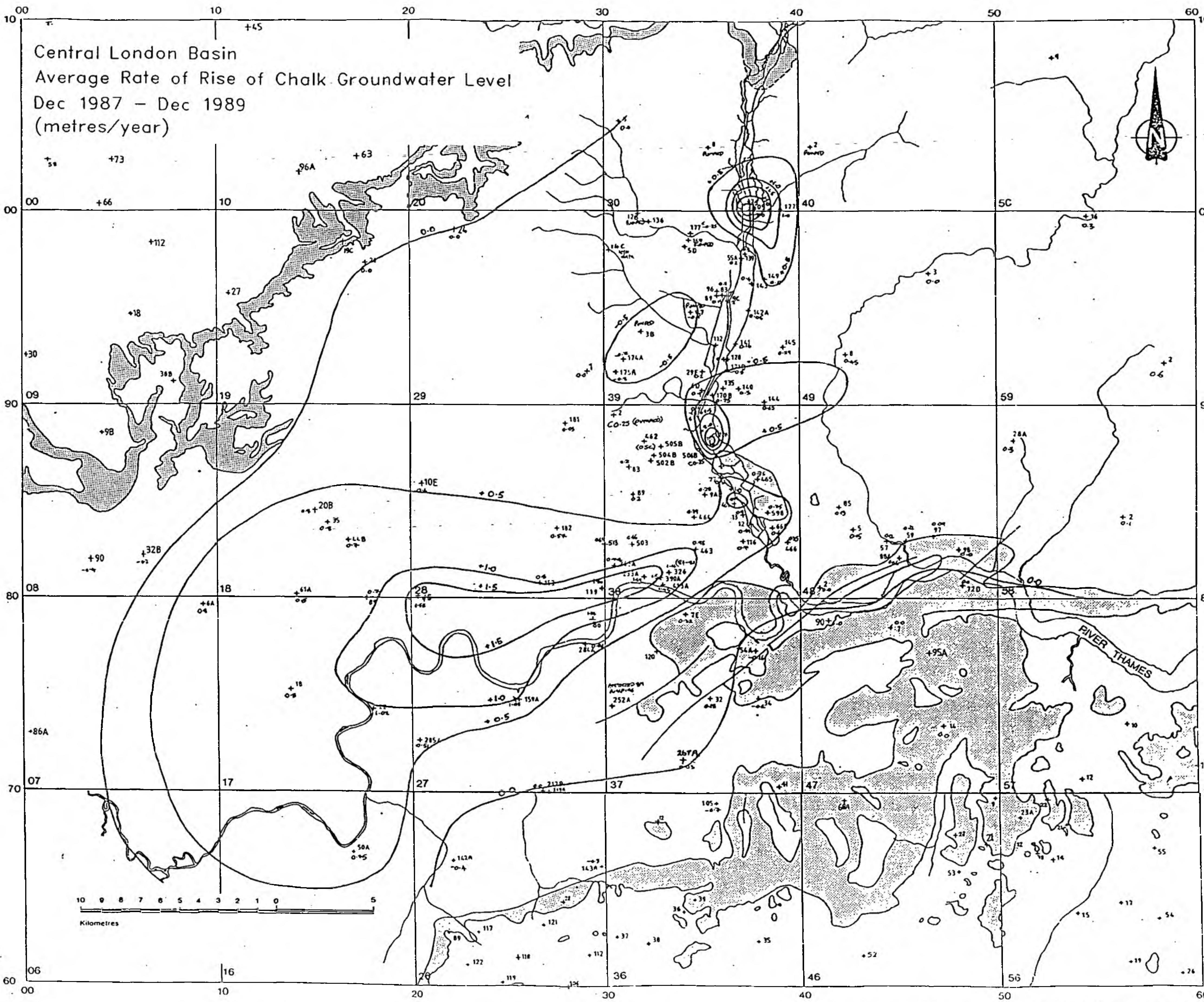


FIG 6. HYDROGRAPH AT TRAFALGAR SQUARE (1966 - 1992)

FIG 7



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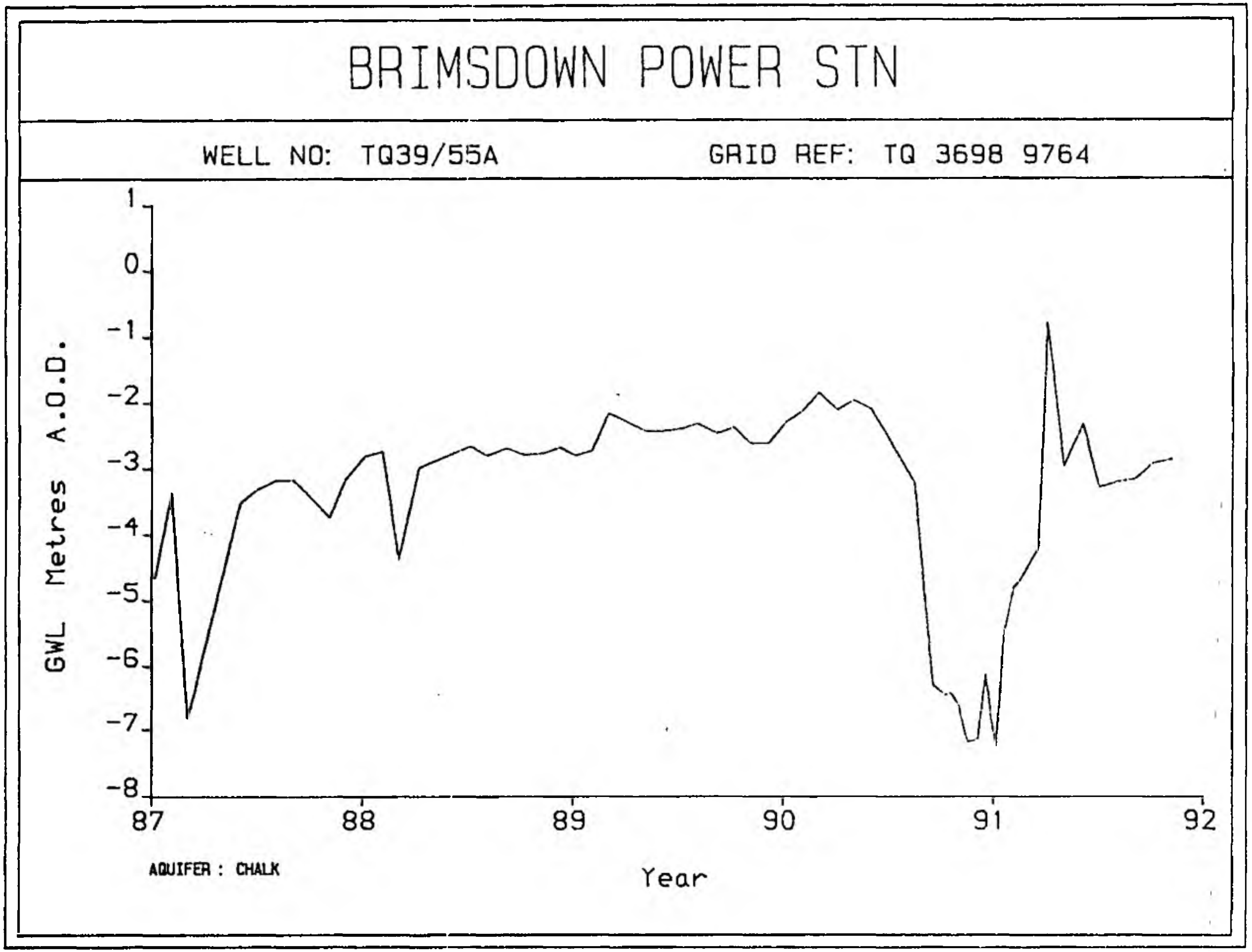


FIG 8. HYDROGRAPH AT BRIMSDOWN POWER STATION (1987 - 1992)

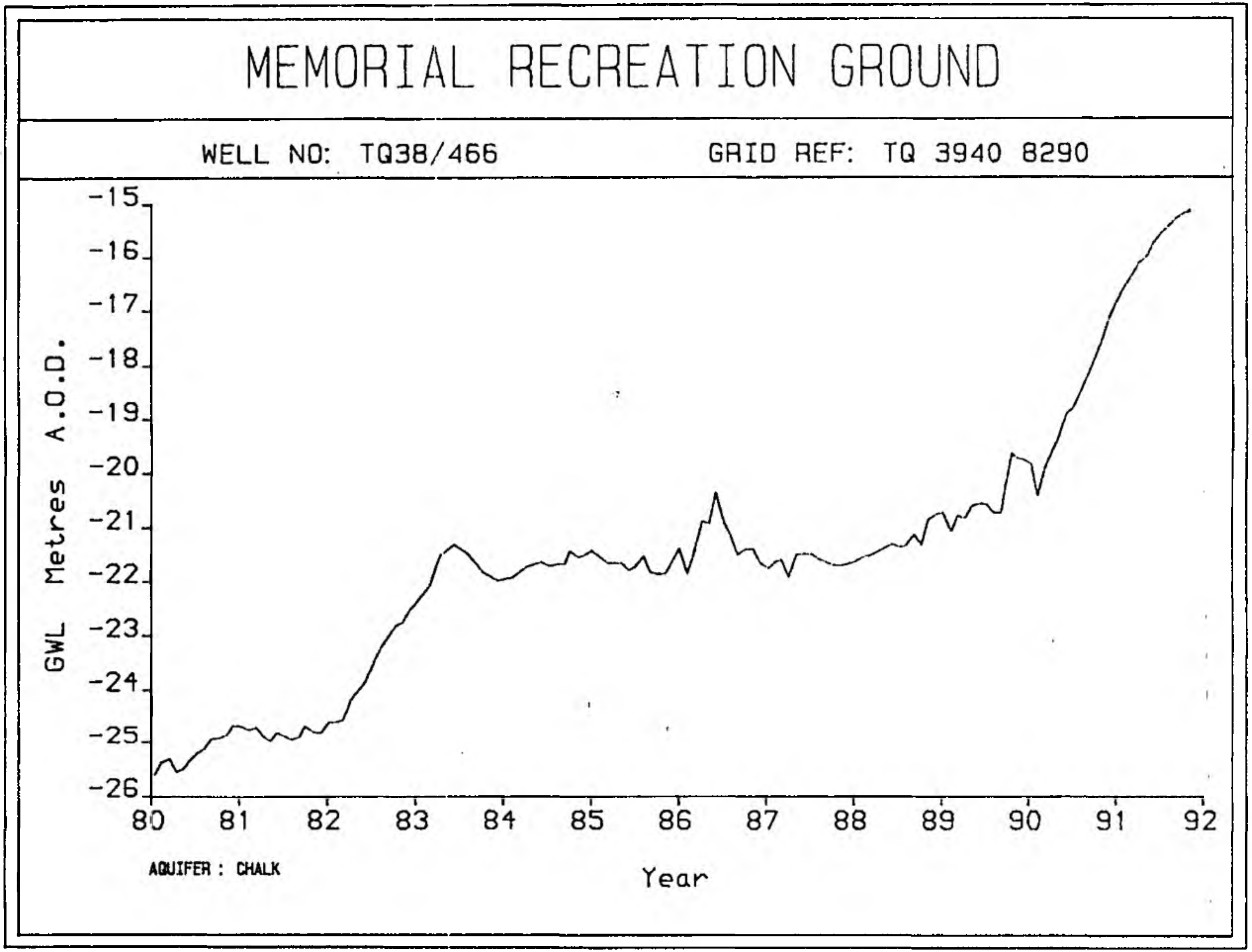


FIG 9. HYDROGRAPH AT THE MEMORIAL RECREATION GROUND (1987 - 1992)

FIG 10. PREDICTED GROUNDWATER LEVEL MAP FOR THE YEAR 2040, ABSTRACTIONS CONTINUING AT 1990 RATES.

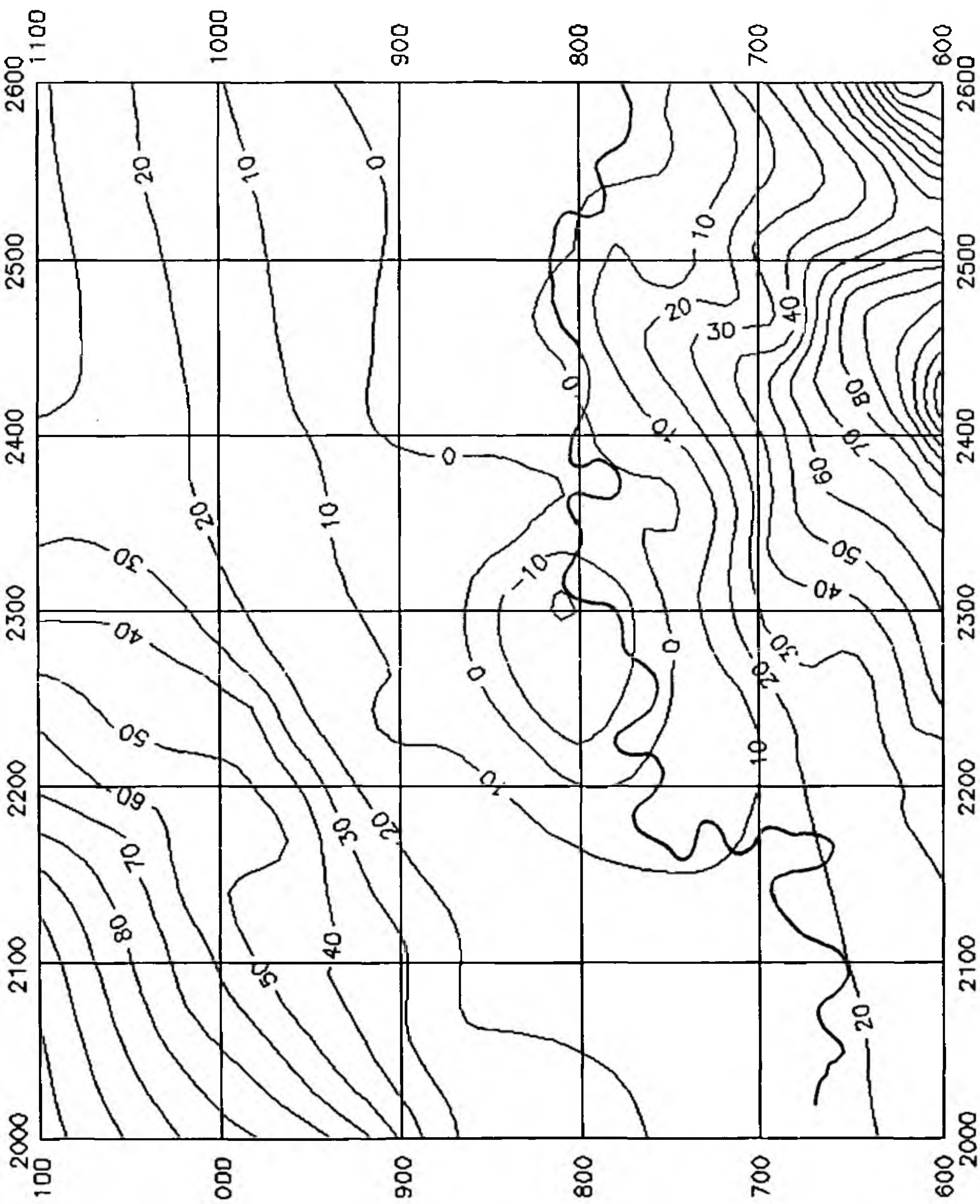


FIG 11. HYDROGRAPH AT THE MODEL NODE NEAREST TRAFALGAR SQUARE IN THE SCENARIO SHOWN IN FIG 10.

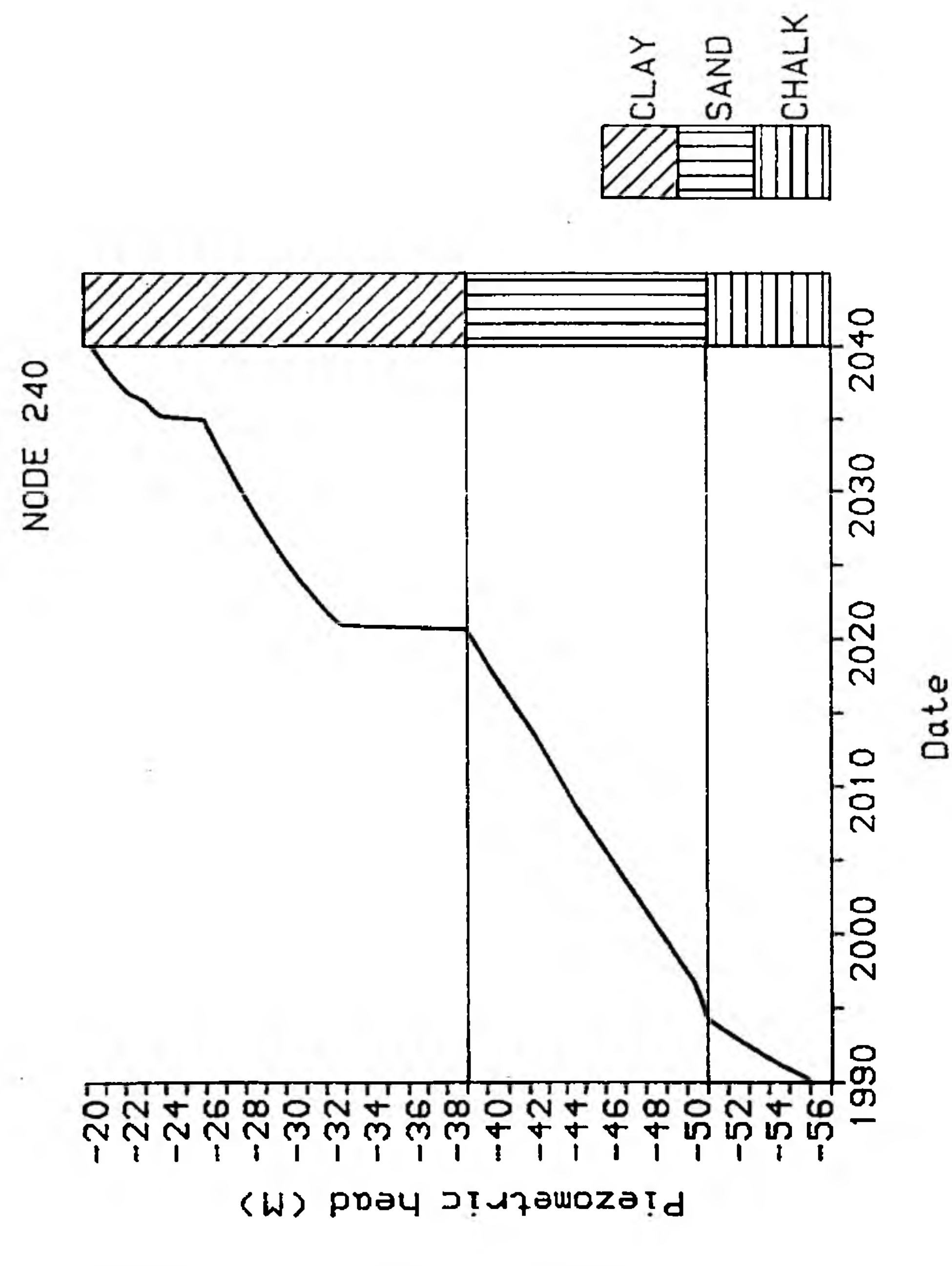


FIG 12. PREDICTED GROUNDWATER LEVEL MAP FOR THE YEAR 2040, MAXIMIZING TWUL LICENCED QUANTITIES.

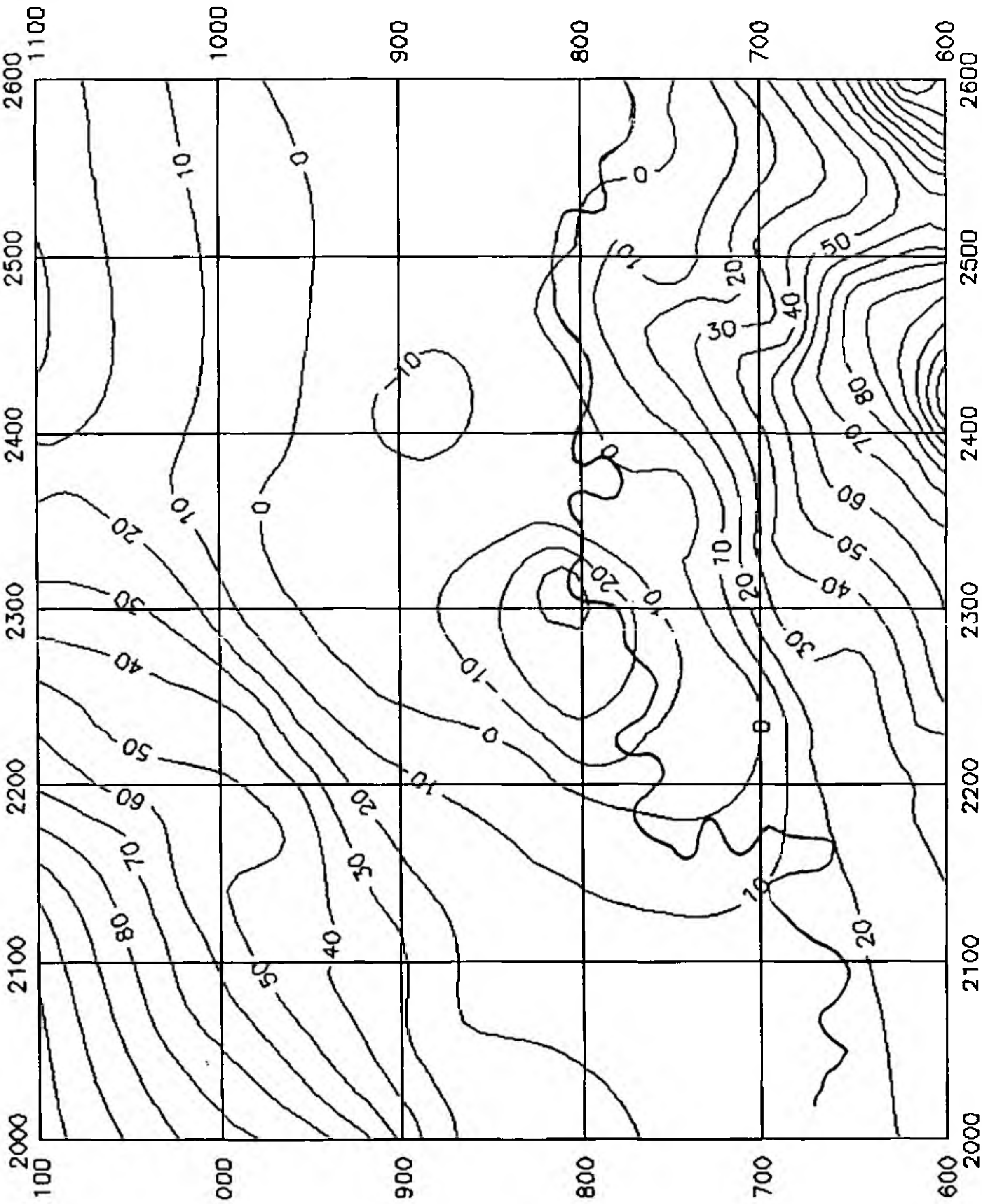


FIG 13. PREDICTED GROUNDWATER LEVEL MAP FOR THE YEAR 2040, WTTH ADDITIONAL ABSTRACTIONS PLACED IN A RING AROUND THE CONE OF DEPRESSION, RESULTING IN AN UNACCEPTABLE INCREASE IN DRAWDOWN.

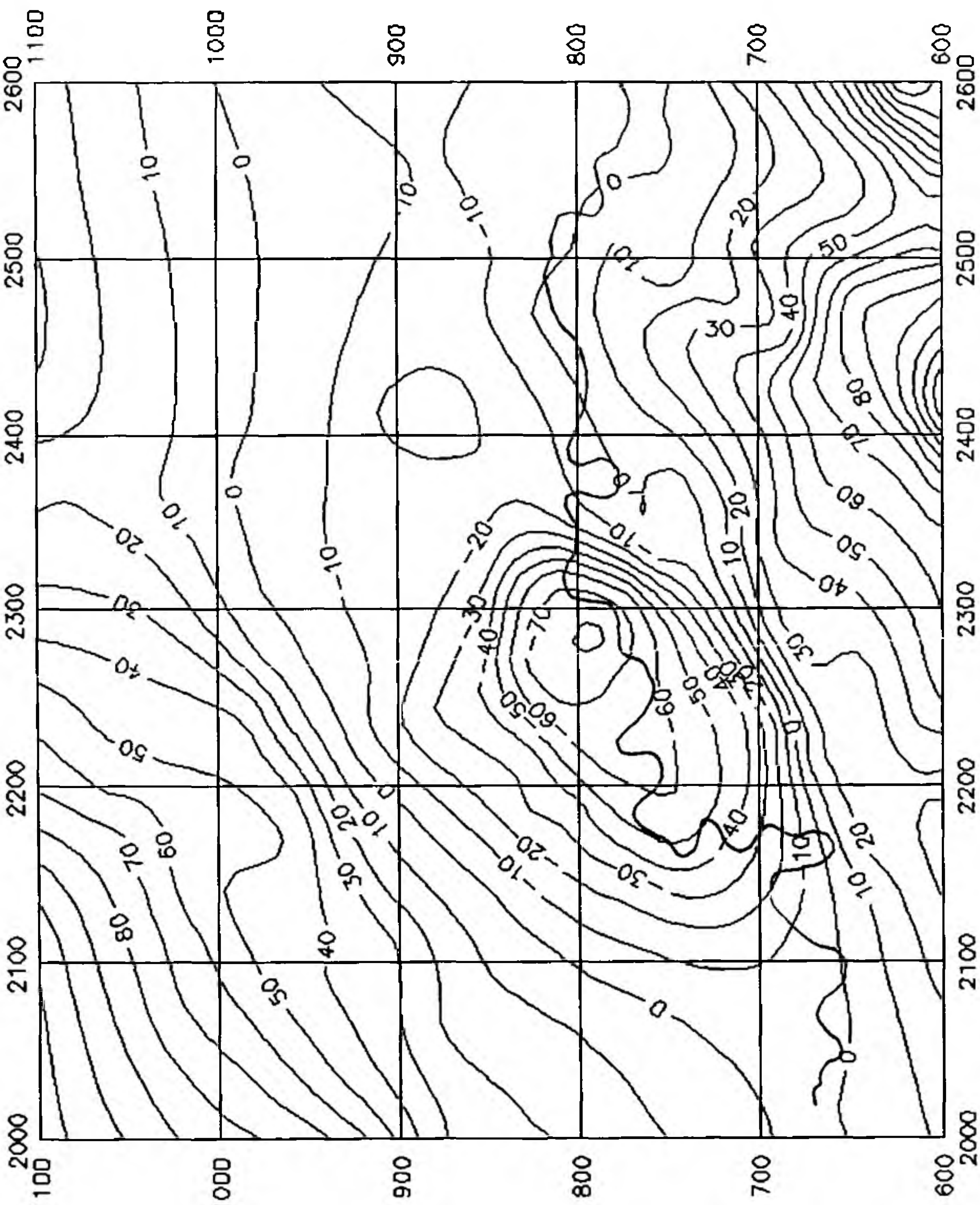


FIG 14. HYDROGRAPH AT THE MODEL NODE NEAREST TRAFALGAR SQUARE IN THE SCENARIO SHOWN IN FIG 13.

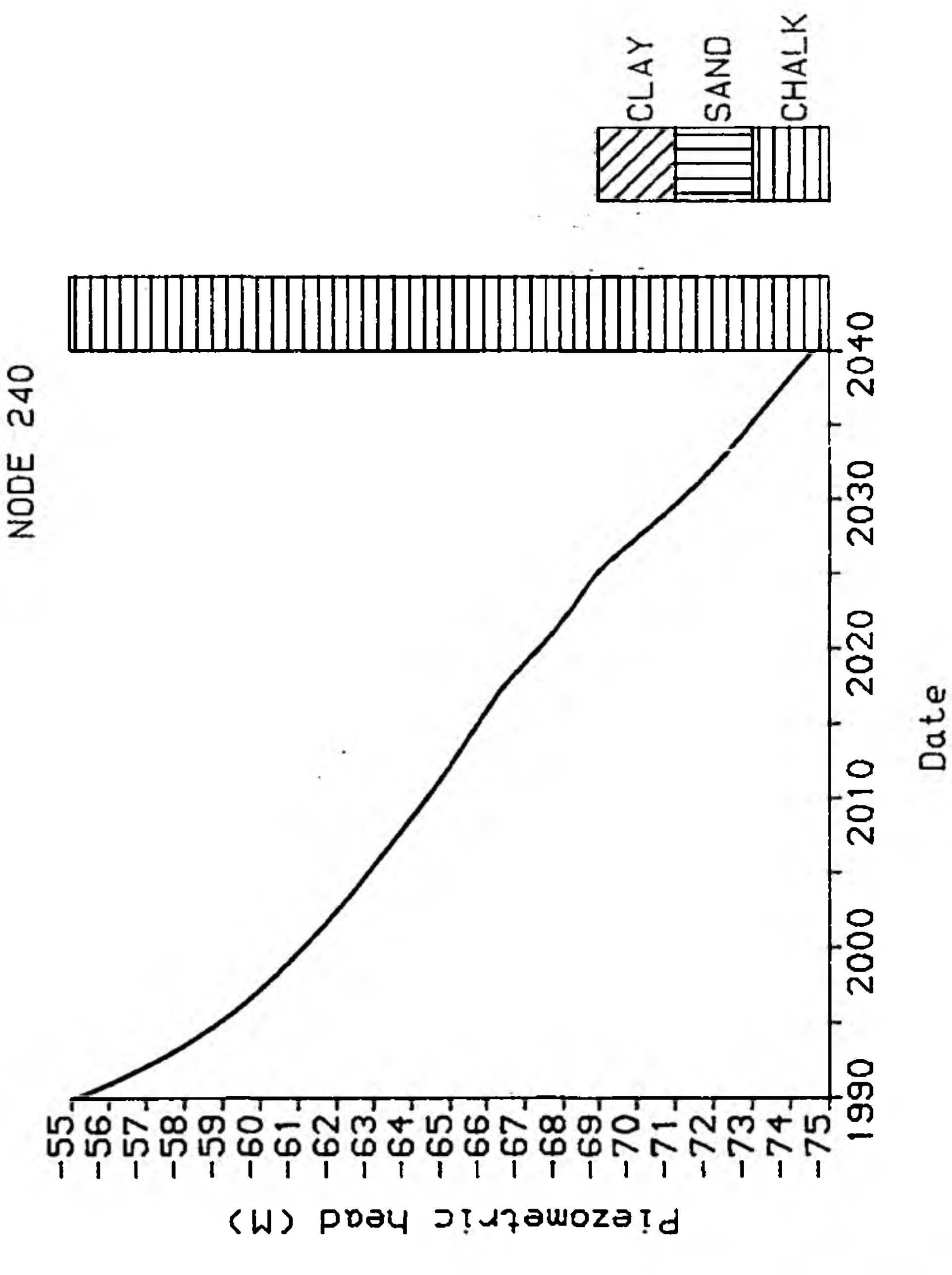


FIG.15. PREDICTED GROUNDWATER LEVEL MAP FOR THE YEAR 2040 WITH MOST OF THE ADDITIONAL ABSTRACTIONS PLACED EAST OF EASTING 30.

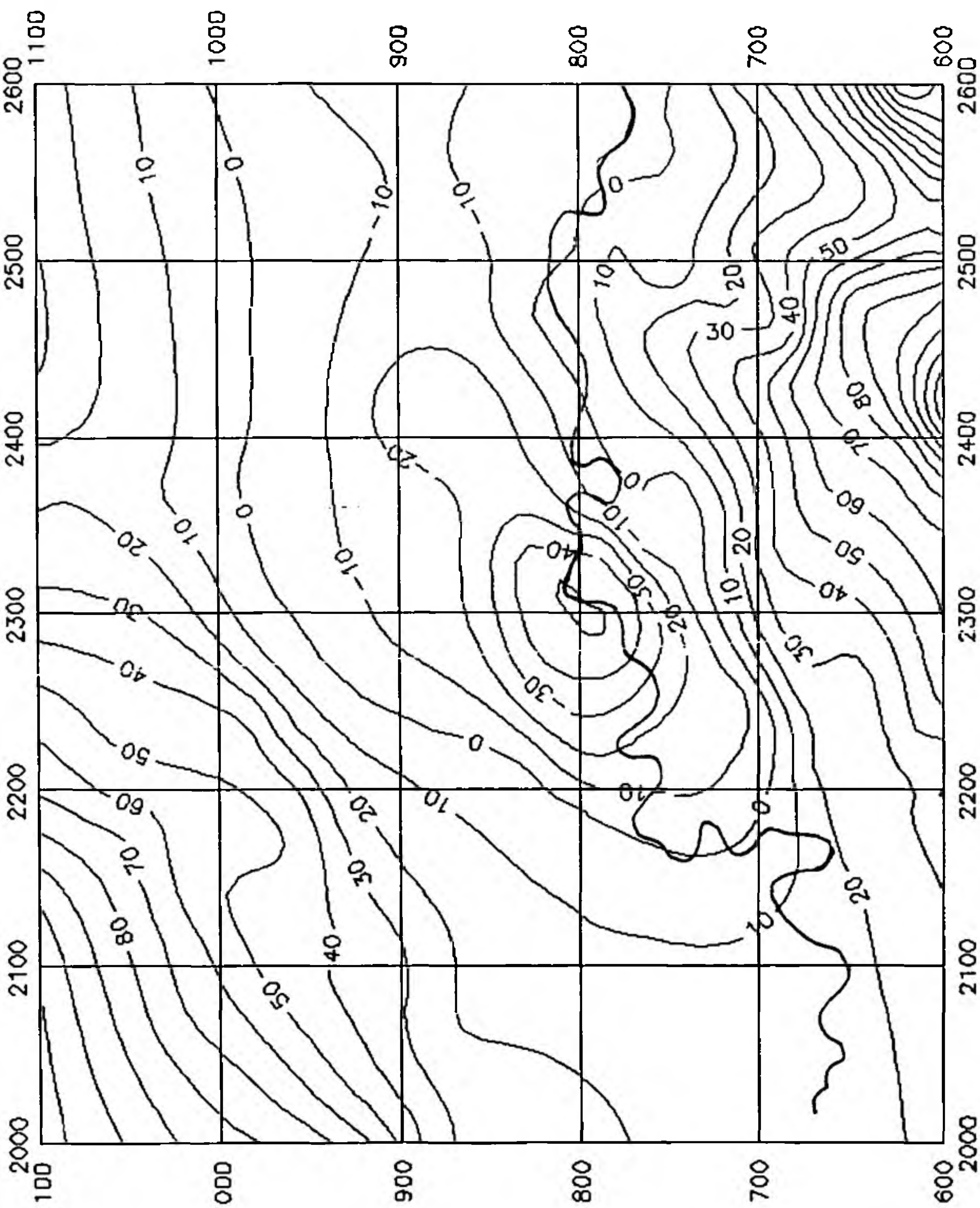
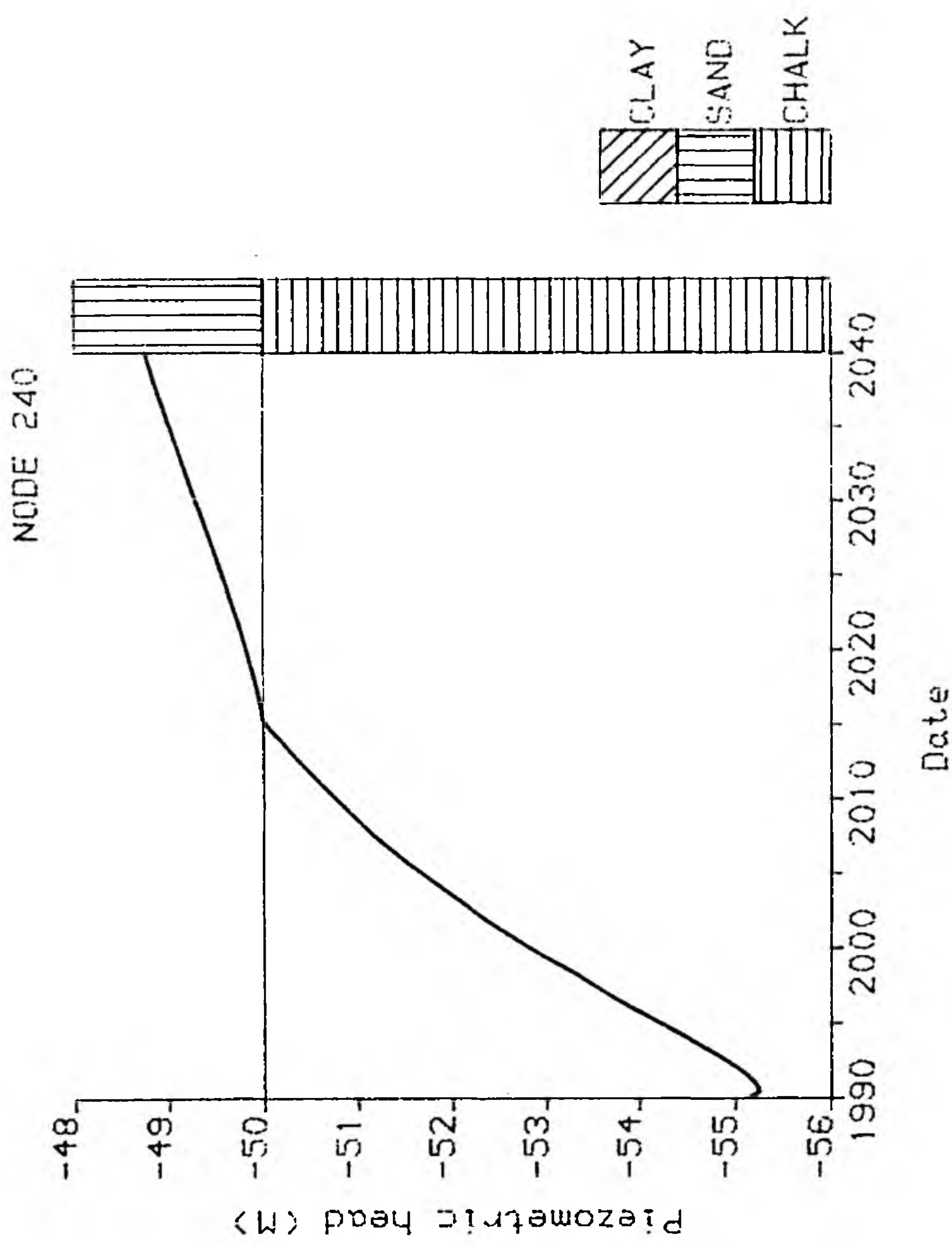


FIG 16. HYDROGRAPH AT THE MODEL NODE NEAREST TRAFALGAR SQUARE IN THE SCENARIO SHOWN IN FIG. 15



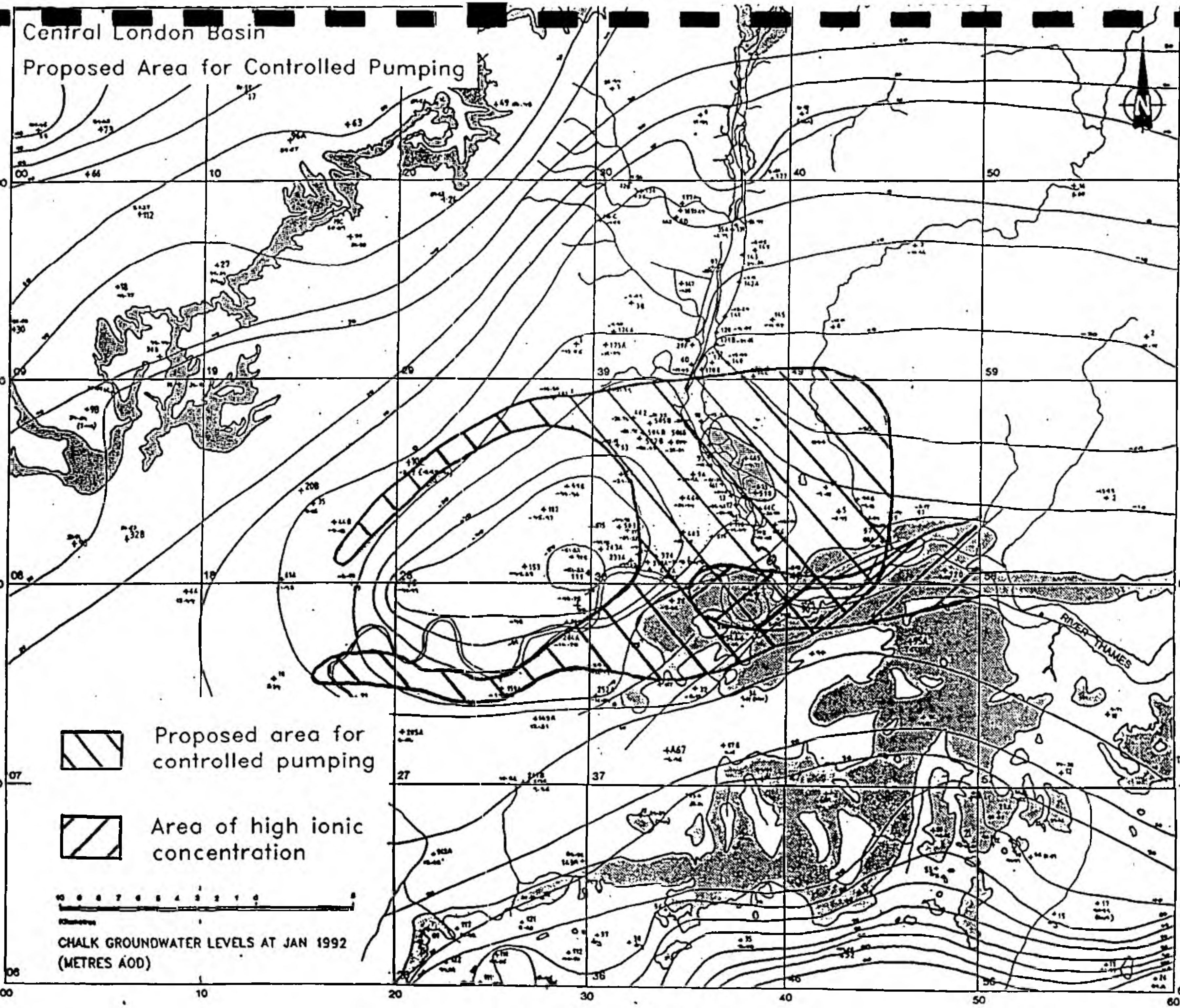

Central London Basin
Proposed Area for Controlled Pumping
Proposed area for controlled pumping
Area of high ionic concentration
RIVER THAMES
CHALK GROUNDWATER LEVELS AT JAN 1992
(METRES AOD)

Fig. 17