Modelling the impact of a subsurface barrier on groundwater flow in the lower Palar River basin, southern India

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Abstract Groundwater modelling is widely used as a management tool to understand the behaviour of aquifer systems under different hydrological stresses, whether induced naturally or by humans. The objective of this study was to assess the effect of a subsurface barrier on groundwater flow in the Palar River basin, Tamil Nadu, southern India. Groundwater is supplied to a nearby nuclear power plant and groundwater also supplies irrigation, industrial and domestic needs. In order to meet the increasing demand for groundwater for the nuclear power station, a subsurface barrier/dam was proposed across Palar River to increase the groundwater heads and to minimise the subsurface discharge of groundwater into the sea. The groundwater model used in this study predicted that groundwater levels would increase by about 0.1–0.3m extending out a distance of about 1.5–2km from the upstream side of the barrier, while on the downstream side, the groundwater head would lower by about 0.1–0.2m. The model also predicted that with the subsurface barrier in place the additional groundwater requirement of approximately 13,600m^3/day (3 million gallons (UK)/day) can be met with minimum decline in regional groundwater head.

Keywords Numerical modelling · India · Coastal aquifer · MODFLOW · Subsurface barrier

Introduction

Groundwater is a major source of freshwater that is widely used for domestic, industrial and agricultural purposes in most parts of the world. Increasing demand for groundwater due to ever-increasing population has highlighted the importance of using scientific techniques to properly manage this precious resource. Demand has created a need for proper and effective management of available groundwater resources. Groundwater modelling is a powerful management tool that can serve multiple purposes such as providing a framework for organising hydrological data, quantifying the properties and behaviour of the systems and allowing quantitative prediction of the responses of those systems to externally applied stresses. Three-dimensional groundwater models are usually very effective groundwater management tools. Many groundwater modelling studies have been carried out around the world for effective groundwater management (Corbet and Bethke 1992; Gnanasundar and Elango 2000; Senthilkumar and Elango 2001 and Strom and Mallory s1995).

Groundwater modelling had already been carried out for the lower Palar River basin, southern India (Fig. 1a), by Senthilkumar and Elango (2004). The purpose of this earlier study was to develop a groundwater flow model to effectively manage the aquifer system, as a remedy for over-dependence on groundwater for domestic, irrigation and industrial purposes. Industrial abstraction includes the water supply for Madras Atomic Power Station (MAPS), which is located 1 km north of the study area, on the coast. The earlier study indicated that the current level of abstraction from the aquifer would be sustainable. However, there are plans to expand MAPS, which would involve an increase in groundwater pumping by approximately 13,600 m^3/day, 3 million gallons (UK) per day (MGD), in this area. Senthilkumar and Elango (2004) showed that this would lead to a decline in the groundwater levels in this area, which would in turn affect farmers' irrigation wells and other pumping stations. They also showed that even if the abstraction increase were limited to pumping 2 MGD (~9,000 m^3/day) this would still affect the region to the east of the MAPS pumping station (Fig. 1a), which may also lead to seawater intrusion. Furthermore, the regional groundwater levels indicate that groundwater flows into the sea for most of the year.

In order to meet the increased demand for groundwater, it was proposed that a subsurface barrier/dam be built across Palar River (Fig. 1b) in this area, with the aim of increasing the groundwater availability and minimising

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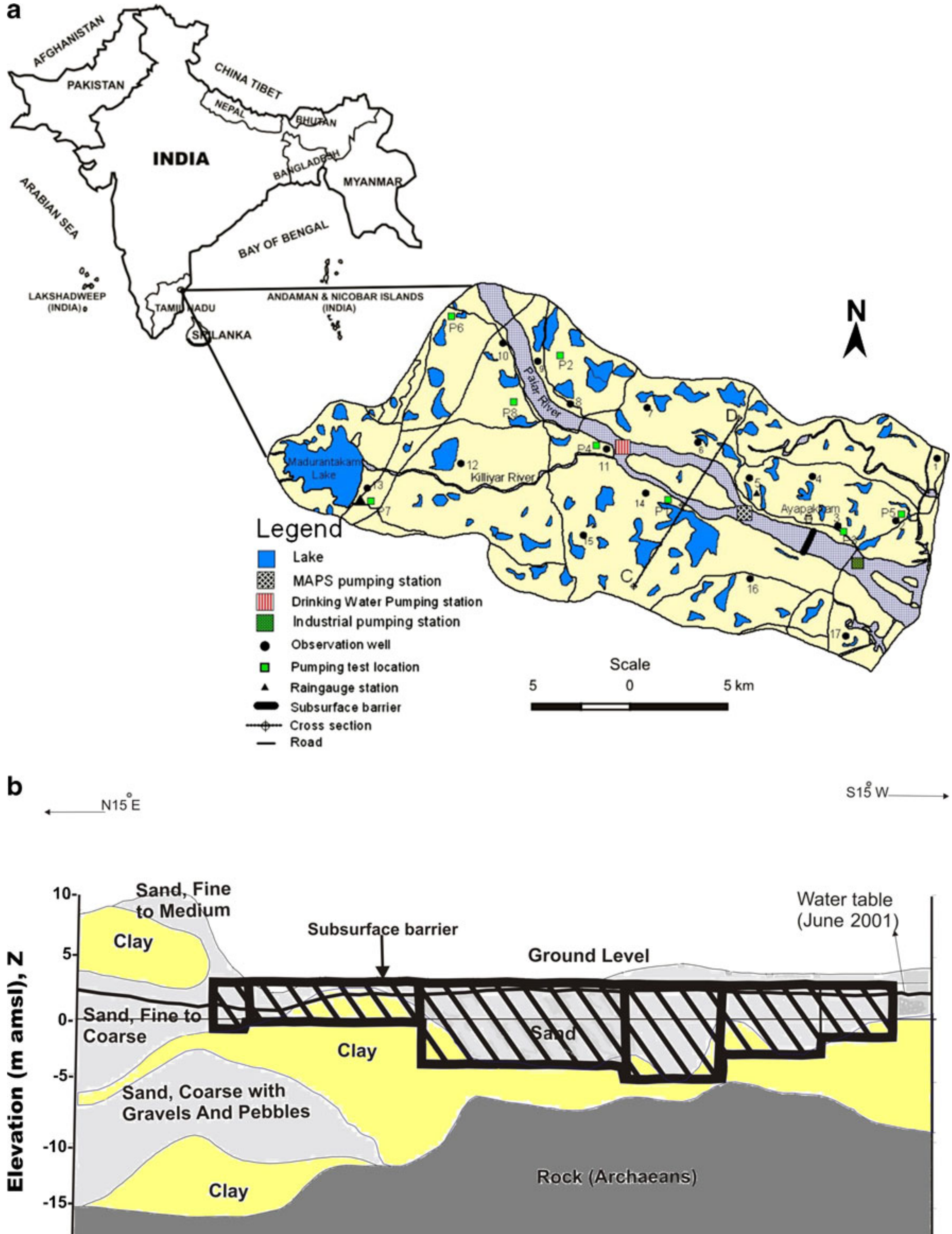

Fig. 1 **a** Part of the lower Palar River basin, southern India. **b** Design of the subsurface barrier across the Palar River

the subsurface discharge of groundwater into the sea. Subsurface barriers are impervious walls constructed below the ground surface across the groundwater flow direction, generally to prevent seawater intrusion and to enable the groundwater resource to be managed effectively. The usefulness and effect of a subsurface barrier for the conservation of freshwater in coastal aquifers was studied by Anwar (1983). Sugio et al. (1987) studied the

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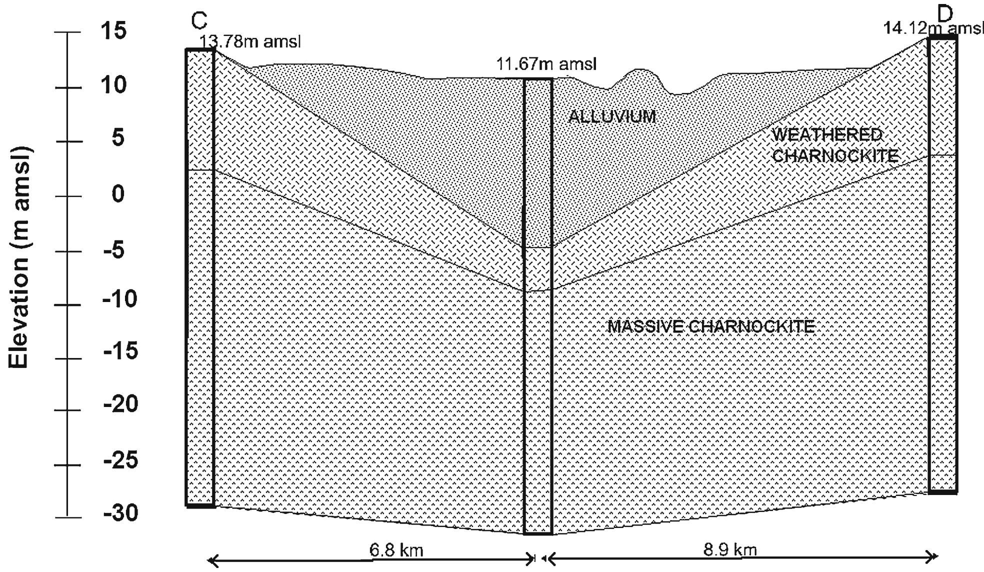

Fig. 2 Geological cross-section along C–D

technical feasibility of subsurface barriers and their viability in addressing the problem of seawater intrusion in coastal aquifers. Very few researchers have attempted to model the impacts of underground dams on groundwater heads (Onder and Yilmaz 2005). The present study was carried out with the objective of assessing the impact of the construction of a subsurface barrier on the groundwater head at the village of Ayapakkam, and on the groundwater system both upstream and downstream of the barrier site in the lower Palar River basin.

Study area

The part of the lower Palar River basin, Tamil Nadu, India, being considered in this study, is located about 75 km south of Chennai (formerly Madras) and covers an area of 392 km^2 (Fig. 1a). The figure shows the three important pumping wells located on this river. The pumping station located in the upstream part of the river supplies water for domestic purposes, including drinking water, to the western part of the study area. The other two pumping stations shown in Fig. 1a supply water to MAPS and to various small industries in the area. The study area is bounded on the east by the Bay of Bengal, and enjoys a sub-tropical monsoon climate with January and February as the dry period, March–May as the summer period, followed by the monsoon period. The maximum temperature is about 42°C during the months of May and June, with the minimum temperature of about 21°C being recorded during the months of December and January. The southwest monsoon (July–September), the northeast monsoon (October–December) and the transition period contribute 40, 51 and 9% respectively to the total average annual rainfall (1,167 mm) measured in the two rainfall stations (Fig. 1a). The area is split more or less into two halves by the Palar River. This is a seasonal river, which generally flows for a few days during heavy rains in the months of November and December. Numerous ponds are present in the depressed parts of the undulating topography of the study area.

Hydrogeology

The study area has a varied topography, with ground elevation ranging from 40 m amsl (above mean sea level) in the west to sea level in the east. Geologically, the area has two distinct formations: crystalline rocks of Archaean age and recent alluvium. The alluvial deposits occur along the present and palaeo Palar River courses. Crystalline rocks comprising charnockites and gneiss form the basement and some exposures are found in the northern and southern parts of the study area. The thicknesses and lithological compositions of the formations were identified from intensive field surveys, consisting of a river section, well sections from 12 boreholes (Fig. 1a; PWD 2000) and

Table 1 Rainfall-recharge percentage

Rainfall in mm per month	Percentage of recharge	
	Alluvial formation	Hard rock formation
10 –<60	5	0
60 –<100	15	8
100 –<200	20	10
200 –<300	25	12
300 –<400	30	14
≥400	25	12

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inspection of 224 open wells. A geological section (along the line C–D in Fig. 1a) is given in Fig. 2. Alluvium occurs as the upper layer and is characterised by sand, gravel and sandy clay. Its thickness ranges from less than 1 m to a maximum of 30 m along the river (the central part of the model area). In the northern and southern boundaries of the model area the alluvial formation is absent. The hydraulic conductivity of the alluvium is

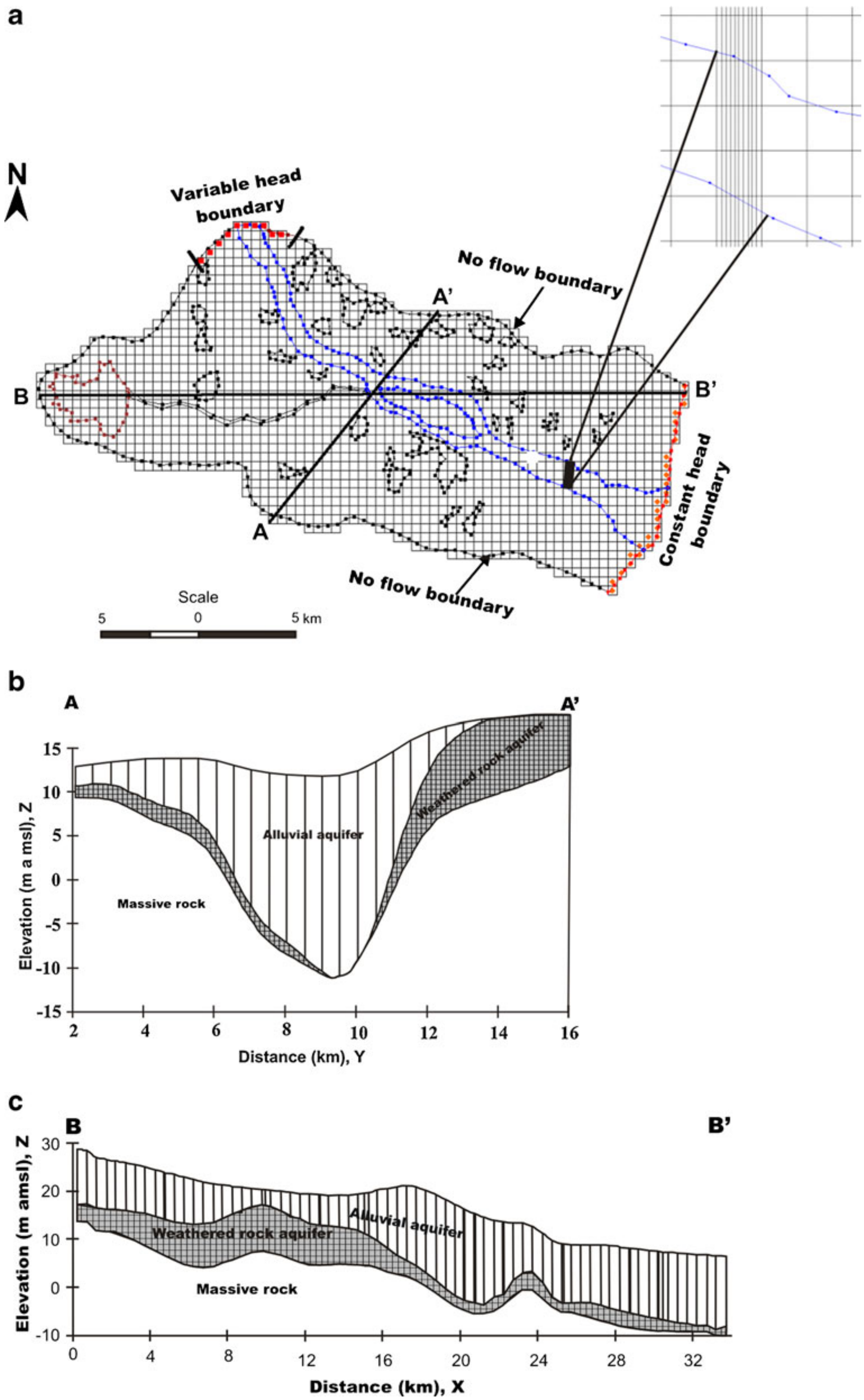

Fig. 3 **a** Model boundary and discretisation of the study area. **b** Cross-section along A–A'. **c** Cross-section along B–B'

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Table 2 Pumping test results (after PWD 2000)

Well	Name of village	Lithology	Hydraulic conductivity, K (m/day)	Specific yield, S_y
P1	Paiganallur	GL-21 m, sand, gravels with pebbles	54	0.32
P2	Pillappur	GL-11.6 m, sand and clay; 11.6–16.7 m, sand	40	0.228
P3	Ayapakkam	GL-4 m, fine to coarse sand; 4 –12 m, silt; 12–19.8 m, clayey silt	69	0.348
P4	Issur	GL-1.5 m, granular zone; 1.5–9 m, weathered charnockite	8	0.012
P5	Voyalur	GL-7 m, coarse sand; 7–11 m, clay sand; 11–23 m, sand, gravel with pebbles	61	0.322
P6	Manapakkam	GL-1 m, topsoil; 1–5 m, kankar; 5–17 m, weathered charnockite	10	0.01
P7	Madurantakam	GL-1.5 m, topsoil; 1.5–5 m, sandy clay; 5–7.5 m, weathered charnockite	12	0.01
P8	Pallipattu	GL-4.5 m, fine to coarse sand; 4.5–10.8 m, sand, gravel	48	0.228

GL ground level

between 20 and 69 m/day and the specific yield value varies in the range 0.037–0.32 (PWD 2000). The lower layer comprises weathered crystalline rocks with thicknesses of 0–7 m. Rock exposures are observed in the northern and southern parts of the model area. The hydraulic conductivity of the weathered crystalline rock layer is 0.5–12 m/day and specific yield values are 0.002–0.01 (PWD 2000). The alluvium and weathered crystalline charnockites function as an unconfined aquifer system. Groundwater occurs under unconfined conditions in both the alluvial and underlying weathered rocks. Depth to groundwater level, measured in local monitoring wells (Fig. 1a), ranges from 5–8 m bgl (below ground level) during the pre-monsoon period and 2–5.5 m bgl during the post-monsoon period.

Rainfall is the principal source of groundwater recharge. The recharge to the aquifer varies considerably due to differences in land-use pattern, soil type, topography and relief. In addition to rainfall, other sources of recharge to the aquifer are irrigation return flow and inflow from the river and from storage ponds. Recharge from rainfall was calculated based on the rainfall infiltration method as per the Groundwater Resources Estimation Committee methodology (GREC 1997). Detailed study of the relationship between rainfall and groundwater levels indicate that wells located in hard-rock regions showed no rise in water level when the monthly rainfall is less than 60 mm. Hence, while estimating the groundwater recharge, it was assumed that no recharge occurs when the monthly rainfall is less than 60 mm. Table 1 shows the recharge values calculated using the rainfall infiltration method. Five zones were demarcated spatially, based on the geology, soil types and land-use pattern.

Model description

One of the objectives of this study was to assess the magnitude of increase in groundwater level in this area after the construction of a subsurface barrier. Groundwater modeling was considered to be the best option available to determine the effect of the subsurface barrier on groundwater levels. Hence, an intensive field survey was carried out in the study area and seventeen wells were chosen for periodical monitoring of groundwater level. Groundwater levels were measured every month from April 2001 to December 2002. The historical groundwater level data and the rainfall data for this region were also collected from the Government Public Works Department. The partial differential equation (Rushton and Redshaw 1979) of the anisotropic and heterogeneous three-dimensional groundwater flow equation was assumed to have constant

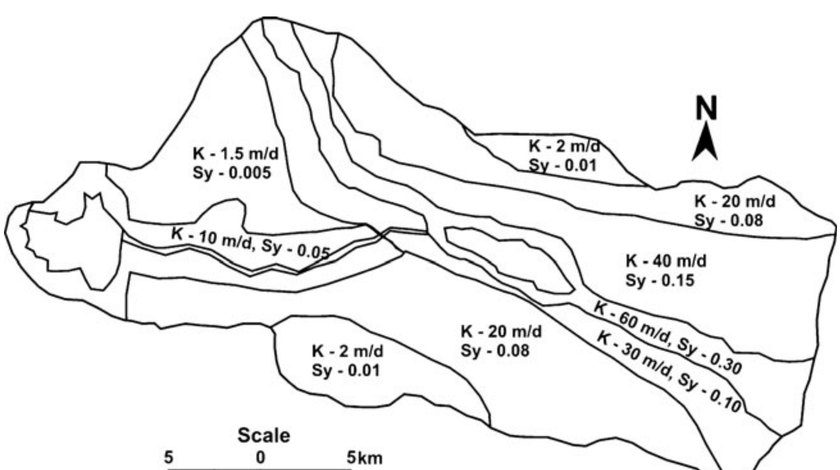

Fig. 4 Spatial distribution of hydraulic conductivity (K) and specific yield (S_y)

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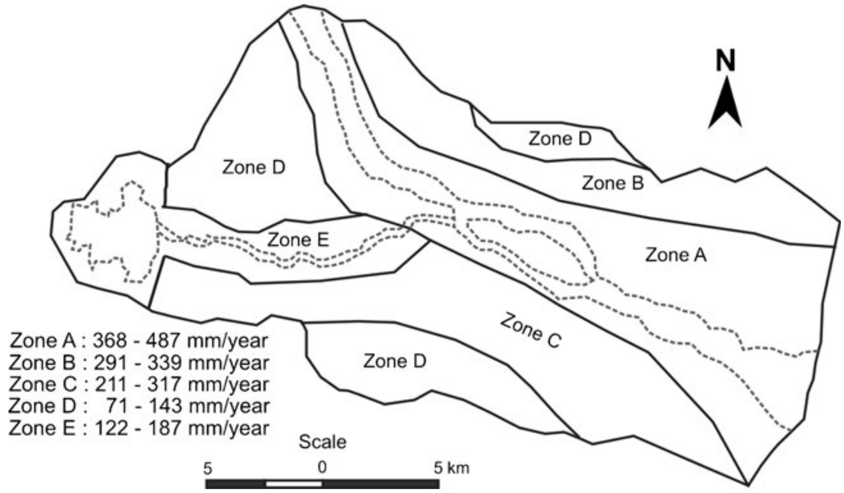

Fig. 5 Rainfall recharge zones of the study area

density, and was used to model the groundwater flow in the study area. The finite-difference computer code MODFLOW (McDonald and Harbaugh 1998), which numerically approximates the equation, was used to simulate the groundwater flow. The pre- and post-processor developed by the United States Department of Defense, Groundwater Modelling System (GMS) version 3.1, was used to process the input data and the model output.

Model formulation

The northern, western and southern boundaries of the study area are the watershed boundary formed by massive charnockite. The flow across these boundaries into the system is negligible and hence they are considered as no-flow boundaries (Fig. 3a). A boundary length of about 4 km in the north-western part of the study area is considered to be a variable-head (time-variant prescribed head) boundary (Fig. 3a), as this region has alluvial deposits of about 10-m thickness. The eastern part of the study area is bounded by the Bay of Bengal, which is taken to be a constant-head boundary. The top and bottom of the aquifer were derived mainly from the lithology obtained from 12 boreholes (PWD 2000) and by intensive field surveys. The unconfined aquifer is divided into two layers: the upper alluvial layer and the lower weathered-rock layer. The thickness of the upper layer varies in the range 0–31 m, with maximum thickness along the sides of the Palar River. The thickness of the lower layer is 0–7 m.

The model grid, covering 392 km^2 of the study area, was discretised into 4,800 cells with 70 rows and 40 columns, and vertically by 2 layers (Fig. 3a). The dimensions of the model cells are 500 m in both the east–west and north–south directions. However, one column of cells was further divided into 50 cells in a north–south direction (Fig. 3a). This was done in order to be able to model the subsurface barrier on the river bed. Vertical cross-sections of this system along A–A' and B–B' are shown in Fig. 3b and c respectively. The calibration of the model was carried out by simulating the groundwater head from January 1991 to December 2002 with daily time steps. The model was calibrated for both steady-state and transient conditions.

Input parameters

Aquifer characteristics

The aquifer properties such as horizontal hydraulic conductivity (K) and specific yield (S_y) used in the model were derived from eight pumping tests, the locations of which are shown in Fig. 1a (PWD 2000). The pumping test results are given in Table 2 and presented in Fig. 4. The area was divided into different zones based on the geology, and the aquifer parameters obtained from pumping tests (Senthilkumar and Elango 2004) were assigned to these zones. The vertical hydraulic conductivity was assumed to be 10% of the horizontal hydraulic conductivity.

Groundwater abstraction

The groundwater in the study area is abstracted for irrigation, industrial and domestic purposes, with agriculture being the main activity. The land use of the study area

Table 3 Initial and calibrated hydraulic parameters

Geology of the area	Hydraulic conductivity, K (m/day)		Specific yield, S_y	
	Initial	Calibrated	Initial	Calibrated
Sand	69	76	0.29	0.34
Sandy clay	37	32	0.18	0.24
Weathered charnockite	12	7	0.02	0.03

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includes about 210 km^2 of irrigation activities, of which 147 km^2 are dependent on groundwater. The groundwater abstraction for irrigation was calculated based on the total area of crops, yields of the abstraction wells and hours of pumping. Industrial pumping includes about 16,000 m^3/day (3.5 MGD; PWD 2000) for the MAPS from its pumping station on the Palar River (Fig. 1a). A pumping station located in the eastern part of the study area supplies about 3,500 m^3/day (0.75 MGD) of water to other industries (PWD 2000). Another pumping station supplies about 2,300 m^3/day (0.5 MGD; PWD 2000) of drinking water for the outskirts of Chennai city. Apart from these major abstractions, total domestic pumping for household needs was calculated to be about 1,400 m^3/day (0.3 MGD) based on population, and was assigned to the model cells covering the locations of settlements.

Groundwater recharge

As mentioned in the previous, recharge is from rainfall, irrigation return flow and inflow from the river and from storage ponds, with rainfall being the principal source of groundwater recharge. The study area was divided into five zones (zone A, zone B, zone C, zone D and zone E) based on the rock and soil types. The distribution of the zones, and the recharge values incorporated into the model for each zone, are shown in Fig. 5. The maximum recharge occurs along the banks of the Palar River, that is, in zone A. A comparison between the monthly rainfall value and consequent variation of groundwater level for a span of 30 years revealed that groundwater is replenished whenever the monthly rainfall exceeds 60 mm. The rate of leakage between the river and aquifer was estimated using the difference between the river head and groundwater head. The contribution to recharge of Killiyar River (Fig. 1a), a passage canal from Madurantakam pond to the Palar River, was also considered. Numerous storage ponds are present in the study area (Fig. 1a). The recharge from the storage ponds was estimated from the difference between the head in each pond and the groundwater head. In almost all the ponds, water is available only during the months of rainfall. No actual pond water level data are

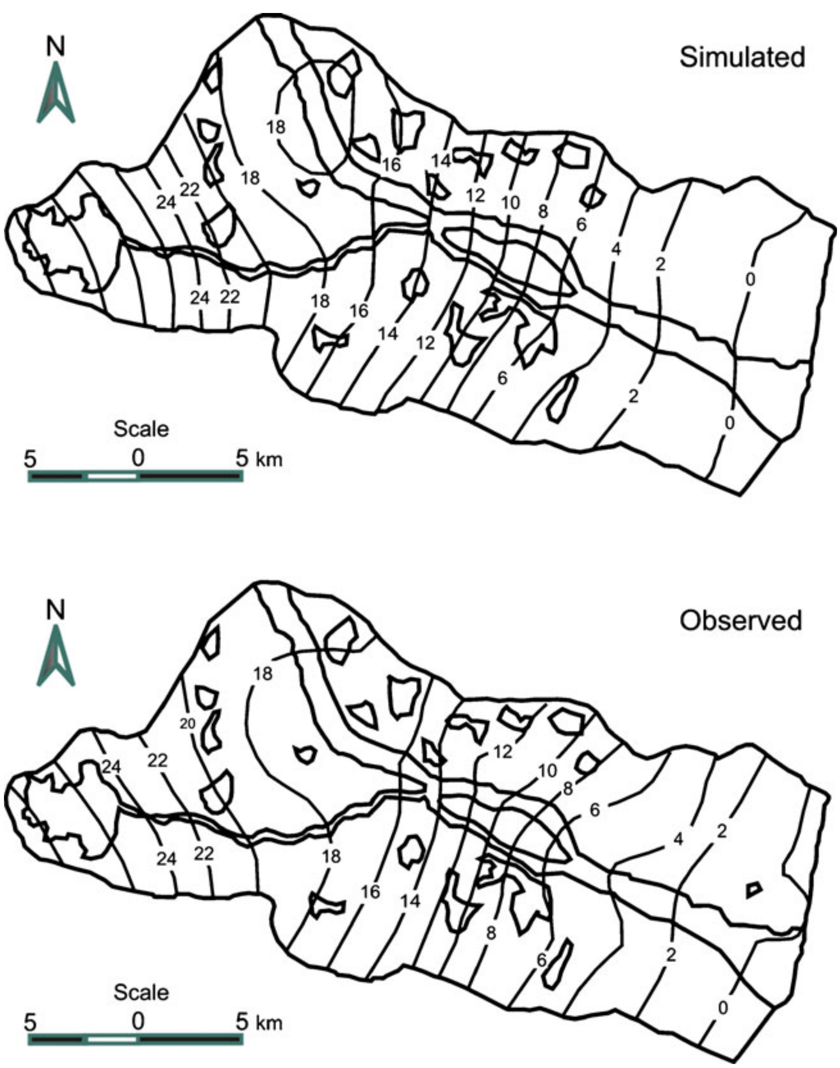

Fig. 6 Regional variation of simulated and observed groundwater head (m amsl) in July 2002

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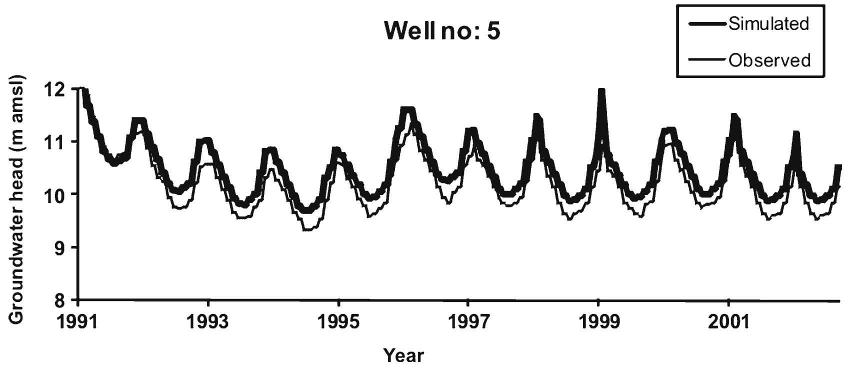

Fig. 7 Simulated and observed head at well No. 5

available, so recharge from the ponds was estimated by assuming pond water levels of 50 cm above ground level during the months when the rainfall exceeds 300 mm. In the case of Madurantakam lake, which is the only perennial lake in the study area, the recharge rates were calculated using the monthly lake water level data.

Model calibration

The calibration strategy was to vary the best-known parameters as little as possible, and vary the poorly known or unknown values the most, to achieve the best overall agreement between simulated results and observed data. Steady-state model calibration was carried out to minimize the difference between the simulated and observed water levels. Water level data from January 1991 in 17 wells distributed over the study area were used for the steady-state calibration. Out of all the input parameters, the values for hydraulic conductivity are the least well known, as only eight pumping tests have been carried out in this area. The lithological variations in the area and lithology of existing large-diameter wells were studied. Based on this, it was decided to vary hydraulic conductivity values by up to 10% of the pumping test results, for both upper and lower model layers, in order to get a good match between the simulated and observed heads. Transient simulation was carried out for a period of 11 years from January 1991 to December 2002, with monthly stress periods and 24-h time steps. The calibration of the transient model was achieved by trial and error until a good match was achieved between simulated and observed heads over space and time. The hydraulic conductivity values incorporated in the transient model were modified slightly from those obtained from the steady-state model calibration. Table 3 gives the initial and calibrated hydraulic conductivity values. Based on the close agreement between measured and simulated heads from January 1991 to December 2002, at 17 observation wells distributed throughout the aquifer, the transient model was considered to be calibrated satisfactorily.

Results and discussion

Simulation of groundwater flow

The groundwater flow model of the lower Palar River basin (Senthilkumar and Elango 2004) reveals that the aquifer system is stable under present pumping conditions. The simulated groundwater heads indicate that the highest heads are found on the western side of the study area, which is a general reflection of the topography. The simulated and observed groundwater heads for the stress period July 2002 are shown in Fig. 6. The simulated head values follow observed head values in most of the well locations. The time-series analysis of the simulated and observed groundwater heads in well No. 5 (Fig. 7) shows a very good match. The regional groundwater flow direction is from the northwest towards the east.

Table 4 Sensitivity analysis of parameters. *RMSE* root mean square error

Parameter	Change (in %)	Change in water level (m)		RMSE
		Alluvial wells	Hard rock wells	
Hydraulic conductivity	+05	–0.1 to −0.2	–0.1 to −0.3	–1.02
	+10	–0.4 to −0.5	–0.5 to −0.6	–1.14
	–05	–0.1 to −0.2	–0.1 to −0.2	–0.88
	–10	+0.2 to +0.4	+0.2 to +0.4	0.155
Specific yield	+05	+0.5 to +0.7	+0.5 to +0.7	0.57
	+10	+1.1 to +1.3	+1.1 to +1.5	1.54
	–05	–0.4 to −0.6	–0.4 to −0.6	–1.33
	–10	–1.0 to −1.3	–1.1 to −1.7	–1.99
Recharge	–05	–0.8 to −1.1	–0.8 to −1.1	–1.15
	–10	–1.2 to −1.6	–1.2 to −1.8	–1.68
	–15	–1.8 to −2.1	–1.8 to −2.3	–2.48

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As groundwater is the major source of water for the industries and agricultural fields located in this region, there has been an increase in abstraction over the years. Hence, it is essential to know the behaviour of the system under increased hydrological stress. In the model, the total groundwater abstraction for the entire study area was increased by an additional 13,600 m^3/day (3 MGD). For these model runs, monthly average rainfall calculated from 60 years of rainfall data was used.

Sensitivity analysis

Sensitivity analysis was used to identify the input parameters that have the most influence on the output for

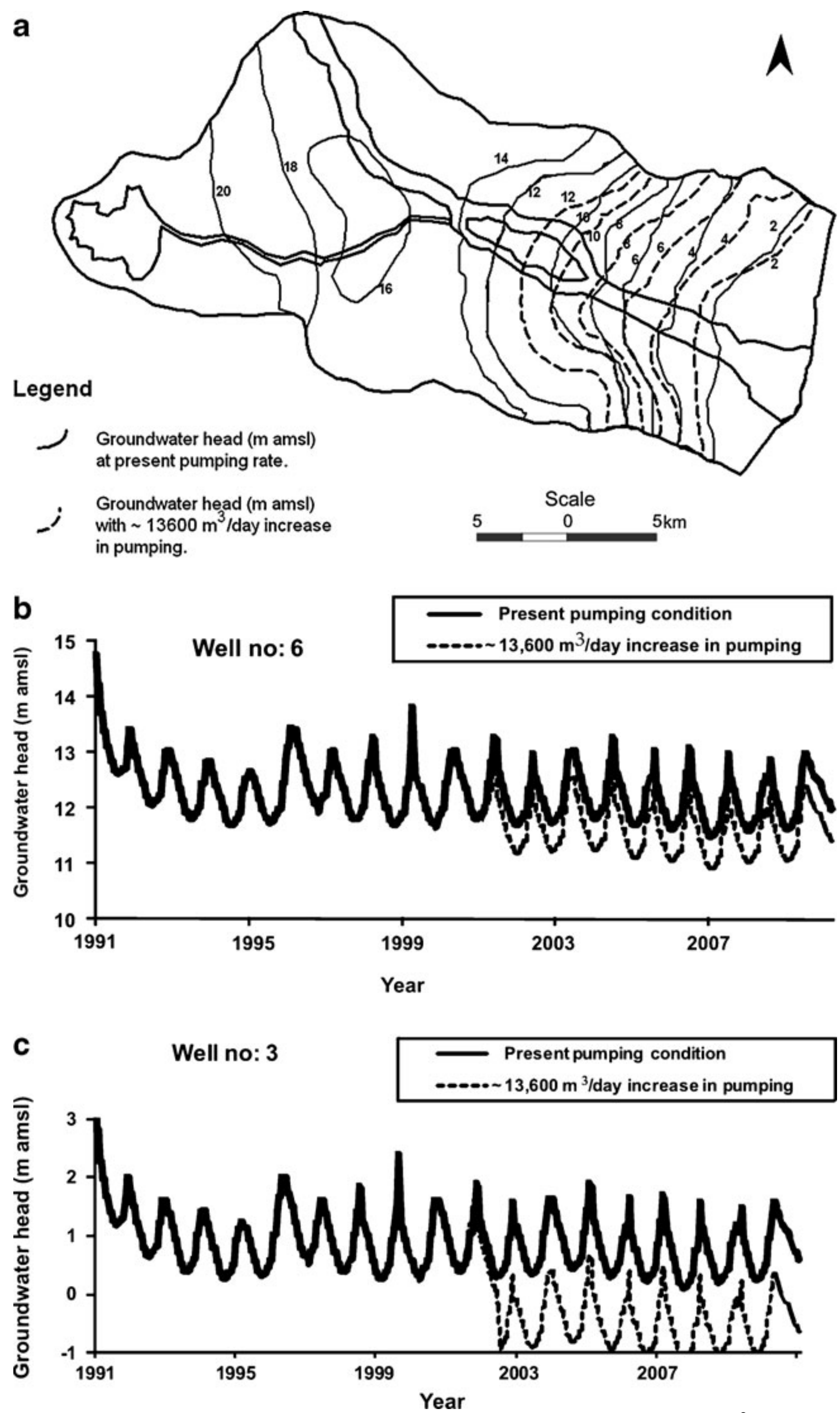

Fig. 8 **a** Predicted groundwater head for September 2010 with increase in pumping by 13,600 m^3/day at MAPS pumping station. **b** Groundwater head with increase in pumping by 13,600 m^3/day at well No. 6 (western side of maps pumping station) without subsurface barrier. **c** Groundwater head with increase in pumping by 13,600 m^3/day at well No. 3 (eastern side of maps pumping station) without subsurface barrier

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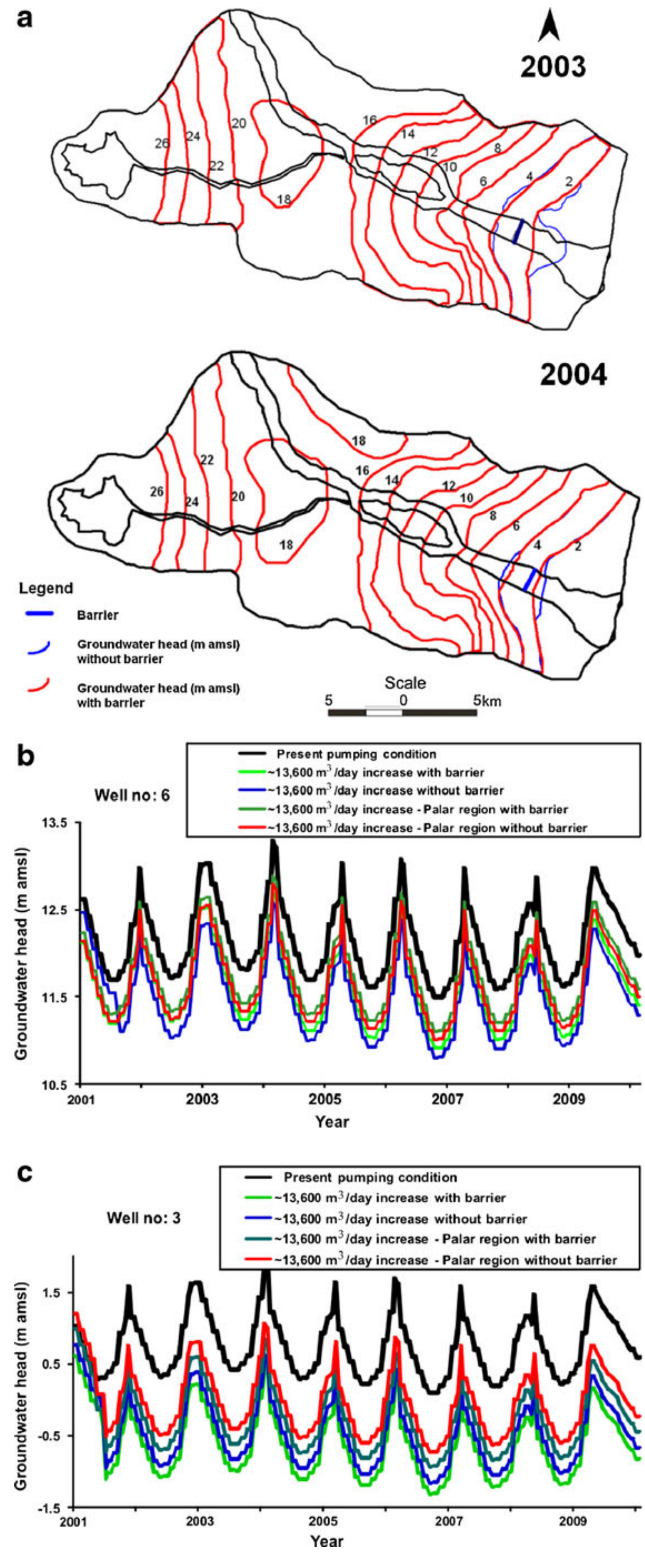

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◀ **Fig. 9** **a** Predicted regional groundwater head with impact of subsurface barrier during September 2003 and 2004. **b** Different scenarios: effect on the groundwater head on the upstream side of the barrier. **c** Different scenarios: effect on the groundwater head on the downstream side of the barrier

both the historical and predictive simulations, in order to have a better understanding of the response of the system to changing hydrological parameters. Sensitivity analysis was carried out on the following input parameters: hydraulic conductivity, specific yield and rainfall recharge (Table 4). It was found that when the recharge values were decreased by 15%, there was a drastic decrease in the groundwater head (Table 4). This clearly indicates that the aquifer system is very sensitive to recharge.

Effect of increase in pumping

It is anticipated that groundwater abstraction will be increased by 13,600 m^3/day for the expansion of MAPS, so the model was run with this abstraction increase at the existing pumping station for MAPS (Fig. 1a). For these model runs, the monthly average rainfall calculated from 60 years of rainfall data was used. The predicted spatial regional groundwater head with an increase in abstraction of 13,600 m^3/day is shown in Fig. 8a. This figure shows the inward-moving trend of the groundwater head contours on the eastern side, indicating a lowering of the groundwater head. In well No. 6 (located on the western side of the pumping station) the groundwater head is lowered by 0.5–0.8 m (Fig. 8b). In well No. 3 (on the eastern side of the pumping station) the groundwater head is lowered by 0.8–1.2 m (Fig. 8c). A comparison between these two wells indicates that the groundwater level decreases more on the eastern side. Even under the current rate of pumping, the groundwater head along the coastal boundary of the study area (well Nos. 1 and 2 in Fig. 1a) falls below sea level during the dry seasons as the zero groundwater level contour does not coincide with the boundary (Fig. 6). With an increase in pumping from the MAPS pumping station, it is considered that the groundwater heads would decline much lower than sea level, which may result in seawater intrusion.

Impact of subsurface barrier

The expansion of MAPS would create an additional demand of 13,600 m^3/day (Senthilkumar and Elango 2004). As the model predicts that this additional abstraction would cause a decline in groundwater levels of 0.8–1.2 m (explained in the previous section), various possibilities for meeting the additional demand were studied. As one of the possibilities, it was proposed that a subsurface barrier be constructed across the Palar River to augment the groundwater resources. Village Ayapakkam lies between the MAPS pumping station and the industrial pumping station (Fig. 1a), and the width of the Palar River is a maximum of 1.3 km at this location. The proposed site was chosen because of the maximum width of the Palar River and the convergence of the groundwater head contours in this location. The proposed dimensions of the subsurface barrier, stretching across the Palar River, are about 1,342 m in length with the depth ranging from 3.66–6.90 m (Fig. 1b). In order to assess the impact of the subsurface barrier on groundwater heads, a three-dimensional numerical model of this area was developed. The subsurface barrier was simulated in the model by assigning hydraulic conductivity values of zero to the cells where the subsurface barrier is located, near the village of Ayapakkam. Although the actual size of the proposed subsurface barrier is about 7 m × 1,342 m, dimensions of 10 m × 1,500 m were used in the model. The model predicted an increase in the groundwater head adjacent to the barrier of 0.1–0.3 m on the upstream side, extending out about 1.5–2 km from the barrier, while on the downstream side the groundwater head would fall by 0.1–0.2 m. The impact of an increase in abstraction of 13,600 m^3/day from the MAPS pumping station on the groundwater regime, with the barrier in place, was predicted (Fig. 9a). The model predicts that the impact of the barrier would be a decrease in the groundwater head by 0.4–0.6 m on the upstream side (Fig. 9b), extending out about 1.5–2 km from the barrier, while on the downstream side the groundwater head would fall by 0.9–1.1 m (Fig. 9c).

Effect of increase in pumping by 13,600 m^3/day in Palar River alluvium

The model predicts that the groundwater head will decrease by 0.4–0.6 m on the upstream side of the barrier with the proposed increase in abstraction at the MAPS pumping station. In order to minimize this effect, the abstraction could be split between several wells in the alluvium, distributed along the Palar River up to a distance of 5 km from the MAPS pumping station, on its

Table 5 Effect of increase in abstraction with and without subsurface barrier

Scenario	Western side (upstream of barrier)	Eastern side (downstream of barrier)
Additional abstraction of 13,600 m^3/day at MAPS pumping station, without barrier	Groundwater head decline by 0.5–0.8 m	Groundwater head decline by 0.8–1.2 m
Additional abstraction of 13,600 m^3/day at MAPS pumping station, with barrier	Groundwater head decline by 0.4–0.6 m.	Groundwater head decline by 0.9–1.1 m
Additional abstraction of 13,600 m^3/day distributed over the Palar River alluvium, without barrier	Groundwater head decline by 0.4–0.7 m	Groundwater head decline by 0.5–0.7 m
Additional abstraction of 13,600 m^3/day distributed over the Palar River alluvium, with barrier	Groundwater head decline by 0.3–0.5 m	Groundwater head decline by 0.6–0.9 m

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western side. The effect of distributing the abstraction over this region was studied using the model. Initially, the model was run by distributing the increase in pumping in the alluvium without considering the subsurface barrier. It was observed that the groundwater head on the upstream side declines by about 0.4–0.7 m, without the barrier (Fig. 9b). Subsequently, simulation with the subsurface barrier in place indicates that the groundwater head will decline by 0.3–0.5 m on the upstream side (Fig. 9c). In the Palar River alluvium, the model indicates a decline in groundwater head by about 0.5–0.7 m on the downstream side without the barrier (Fig. 9b), and a decline in groundwater head by about 0.6–0.9 m with the barrier in place (Fig. 9c). A summary of the effects of the additional abstraction, with and without the barrier in place, is shown in Table 5.

Limitations

Only eight pumping test results were available, which were extrapolated for the entire study area based on the geological characteristics. Subsurface characterisation was based on the interpolation of 12 lithological logs and field inspection of 224 open wells.

Conclusion

Simulation of groundwater heads in part of the lower Palar River basin was carried out using a finite-difference flow model, in order to study the effect on the groundwater flow regime of the construction of a subsurface barrier across the Palar River. The groundwater model achieved a reasonable match between the simulated and observed groundwater heads. It was found that the aquifer system is stable with the present rate of abstraction. An increase in groundwater abstraction from this aquifer of 13,600 m^3/day can be met, with marginal decrease in groundwater heads, with the construction of a subsurface barrier. The model predicts that the additional abstraction with the subsurface barrier in place will lead to a decrease in groundwater head of 0.4–0.6 m on the upstream side of the barrier. Based on this study, it is suggested that the additional abstraction can best be met by distributing the pumping over several wells located in the alluvium (up to 4 km radial distance from the MAPS pumping station) rather than restricting it to the MAPS pumping station, which would lead to the lowering of groundwater head by 0.3–0.5 m. Thus, the study concludes that by constructing a subsurface barrier, it will be possible to increase groundwater abstraction in this area by 13,600 m^3/day with a marginal decline in groundwater heads.

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