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Aquifer System and Salinity Hazards in Parts of Yamuna River Sub-Basin, India

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ABSTRACT. The regional aquifer system, the hydrogeological condition and salinity hazards in the middle part of Yamuna river sub-basin were investigated. Locally there occurs two to three tier aquifer system, but on a regional scale a single aquifer system down to depth of 100 m can be visualized. The sediments forming the aquifers are medium to coarse grained sands and gravels with thin layers of clay beds. In general the groundwater flow is towards east and southeast with some variation. Groundwater troughs have been developed at many places due to excessive groundwater withdrawal. There is wide spatial variation in the salinity of groundwater as evident from wide range of electrical conductivity (E.C.) values (500-6700 μS/cm). Large scale practice of dumping solid industrial wastes in the open field, utilization of canal and river water containing effluents of industries for irrigational purpose may be responsible for some increase in the salinity of groundwater in the study area, where natural processes are mainly responsible for the high salinity of the groundwater.

Introduction

India is gifted by nature with a large number of major rivers. There is an extreme disparity in the distribution of water resource spatially and temporally in these river basins due to unequal precipitation. The Indo-gangetic plain is the largest alluvial plain of the world, which has been formed by deposition of terrigenous clastic sediments through the streams of Indus, Ganga and Brahmaputra river system (Singh, 1992). The Ganga plain makes the central part of this alluvial plain. The Yamuna river sub-basin makes the western part of the

Ganga basin which, forms an important groundwater province of India. A series of hydrgeological surveys have been conducted in Indo-gangetic plain by Sinha (1980), Pathak (1982, 85, 88), Bhatnagar *et al.* (1997), Khanna (1992) and Singh *et al.* (1994). Chen and Gocke (1999), and Keith (1999) have worked on hydraulic properties of alluvial aquifers. Recent hydrochemical investigations in Indo-gangetic plain have been carried out by Ansari *et al.* (2000) and Mohan (2000). The present study concerns the aquifer system in the middle part of the Yamuna river sub-basin.

Geologically, the area is occupied by Quaternary alluvium and Precambrian Alwar quartzites of Delhi Super group. The Alwar quartzites occur as peneplained ridges and developed in small portion in the western part of the area. The quartzites are compact, dirty white, pale grey and purple in colour and highly jointed. Unconformably overlying the folded and faulted quartzites, are the deposits of Quaternary alluvium comprising sands of various grades, clay and silt interbedded with kankar forming the potential groundwater reservoir. The precipitation takes place due to south-west monsoon during the months of July to September and accounts for nearly 80 to 90 % of the annual rainfall. The remaining 10 to 20 % of rainfall occurs from January to March during winter period. The mean annual rainfall in the area is 584 mm. The area witnesses excess evaporation during summer.

Materials and Methods

In order to study the hydrogeological conditions including groundwater movement and changes in water level in response to rainfall, evaporation, groundwater use and other local factors, systematic well investigations in 55 observation wells were carried out. Pre- and post-monsoon water levels during 1997 were measured to monitor changes in water level in response to rainfall. Lithological logs of tube wells drilled by Geological Survey of India were utilized for the preparation of hydrogeological cross sections and fence diagrams to synthesize the aquifer systems. The locations of the inventoried tube wells and section lines are shown in Fig. 1. Sixty five groundwater samples from shallow hand pumps, and deep tube wells were collected and analyzed for their electrical conductivity using a water analysis kit to study the salinity hazards in the area.

Groundwater Hydrology

The Quaternary alluvium covering the major part of the area forms the potential groundwater horizons. Groundwater occurs in the alluvium and the underlying weathered and jointed quatrzites of the area, under phreatic condition at shallow depths and under confined condition at greater depths. The thickness

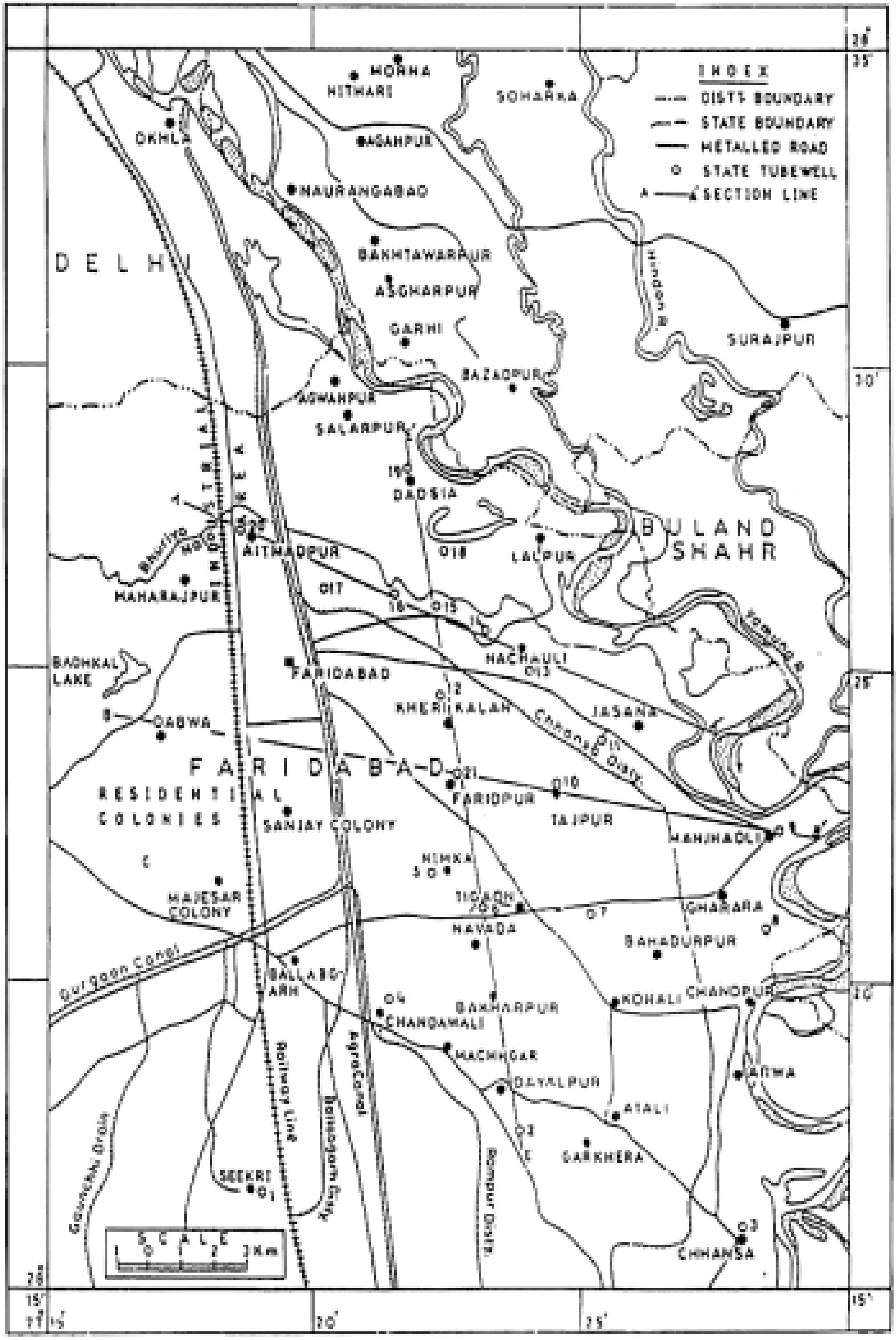

FIG. 1. Location map showing position of tubewells inventoried in the study area.

of alluvium increases from 25 m in the area close to quartzite outcrops in the northwest to over 150 m in the south eastern part of the area.

The depth to water level varied between 3.30 and 21.50 m below ground level during pre-monsoon (June, 1997) and from 2.05 to 20.06 m.b.g.l. during post-monsoon period (Nov., 1997). Seasonal fluctuation in water level varied from 0.27 to 2.44 m in 1997. To understand the groundwater regime and the direction of groundwater flow in the shallow aquifer system, as well as to evaluate the inter-relationship between canal system and groundwater, water table contour maps were prepared.

Pre-monsoon water table contour map (Fig. 2) shows that the elevation of water table varies from 178 to 200 m above mean sea level. Further it is observed that the groundwater flow, in general is towards east and southeast with some variations probably controlled by drainage pattern and canal network. Due to excessive groundwater withdrawal, groundwater troughs are developed in the northern industrial area, in the central residential area and in the south-eastern part around Tigaon and Bahadurpur. Groundwater mounds appear to have developed around Dabwa in the east of Badhkal lake and west of Gurgaon canal around Jasana close to Yamuna river. The formation of these mounds is probably due to large scale seepage from unlined Gurgaon and Agra canals and Chhansa distributary.

In the major part of the area, the hydraulic gradient ranges from 0.65 to 1.85 m/km. Steeper gradients are seen in areas close to the quartzite outcrop and in the industrial area. In the southern rural area as well as near the banks of the Yamuna river, the hydraulic gradient is gentle and is indicative of presence of highly permeable aquifers. Water table contour map of post-monsoon period (Fig. 3) exhibits no significant changes in water table contour values because of the low fluctuation in the water level.

Subsurface Geological Configuration and Aquifer Disposition

To understand the subsurface configuration of the aquifer system and the control of sediments, two hydrogeological cross sections along line BB' and EE' (Fig. 4 & 5) and a fence diagram (Fig. 6) have been prepared.

The cross section BB' encompasses the central part of the study area running in west-east direction. The sediments forming the aquifer are medium to coarse grained sand separated by clay beds. Alternate beds of sand, sand-kankar have been encountered. Thick units of clay beds ranging in thickness from few meter to 15 m are predominant. The cross section along line EE' shows two to three tier aquifer systems.

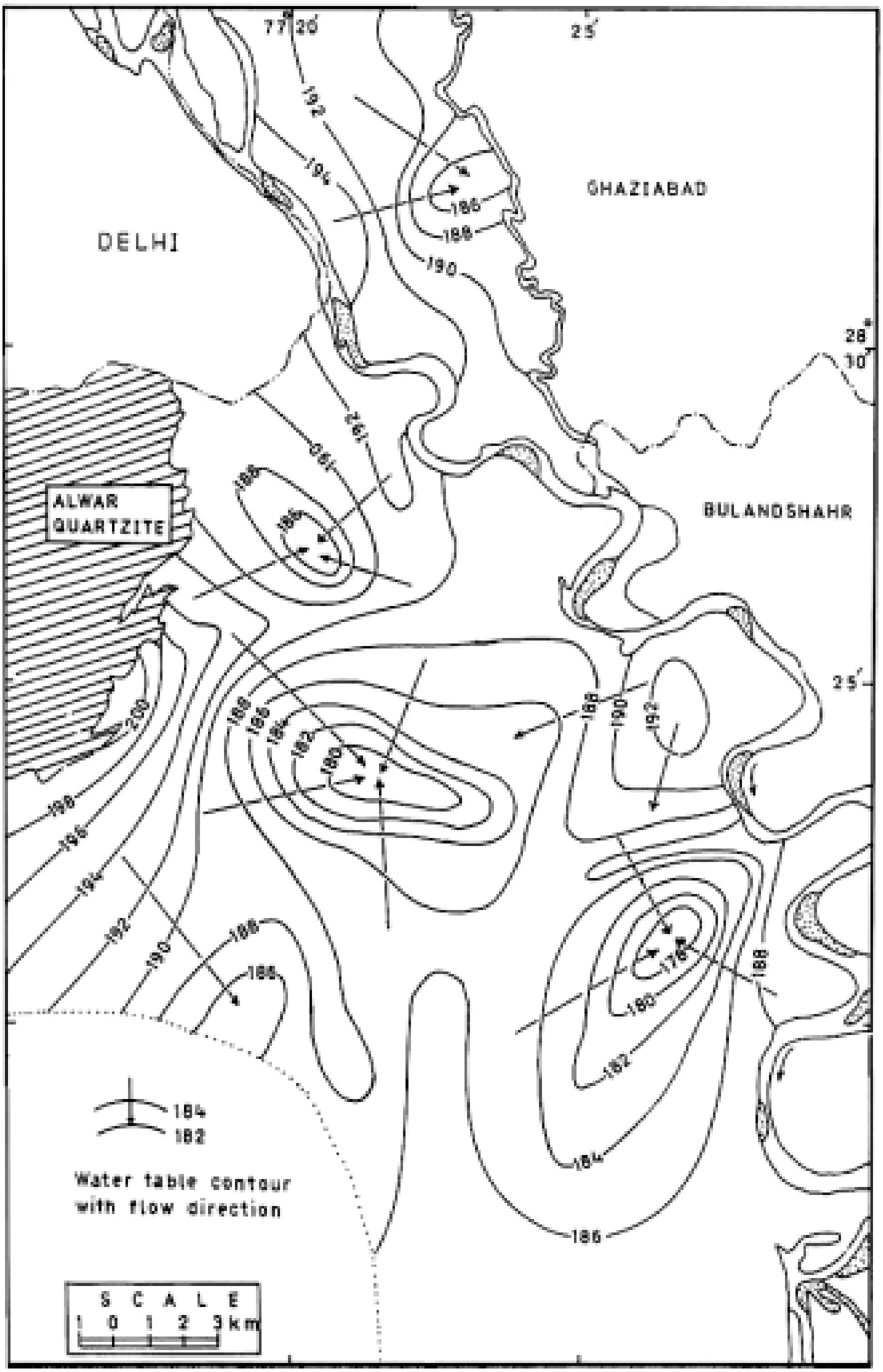

FIG. 2. Pre-monsoon water table contour map, June 1997. Arrows indicate groundwater flow direction.

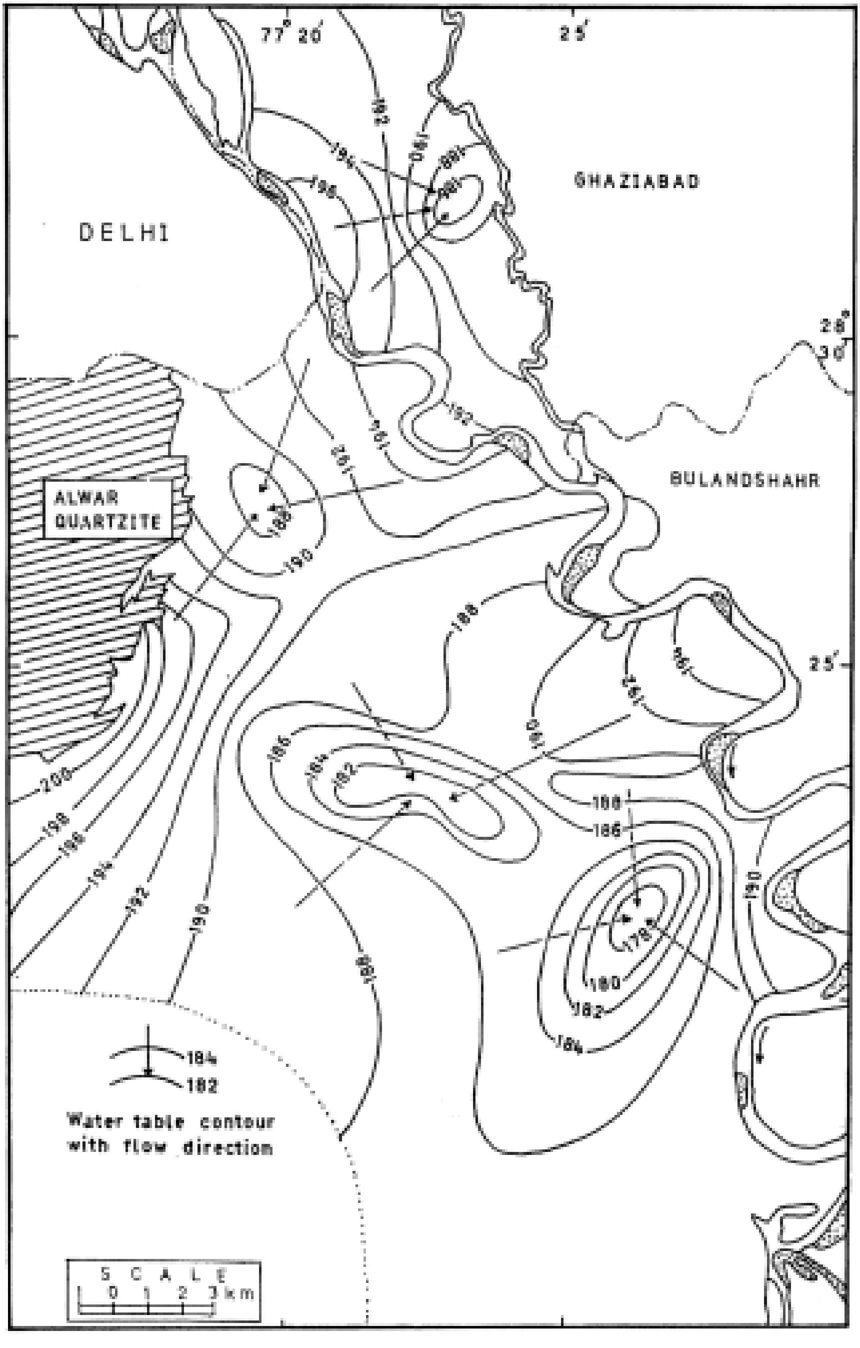

FIG. 3. Post-monsoon water table contour map, Nov., 1997. Arrows indicate groundwater flow direction.

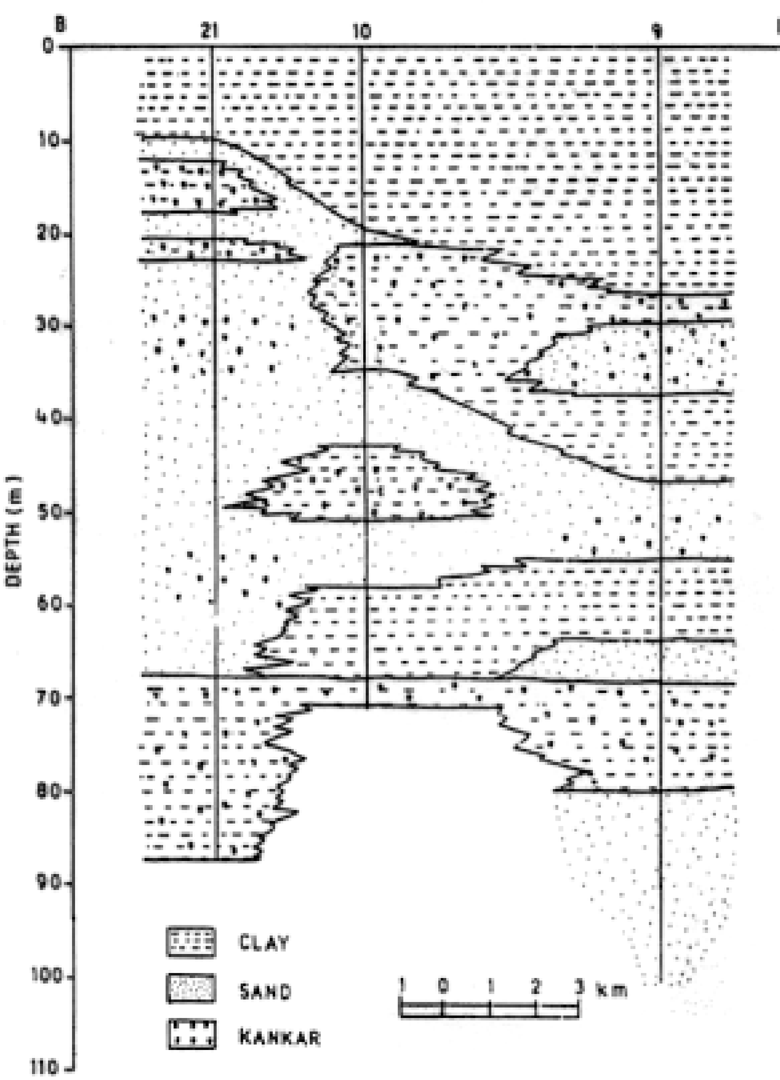

FIG. 4. Hydrogeological cross section along line BB' showing nature of sediments and thickness of aquifer.

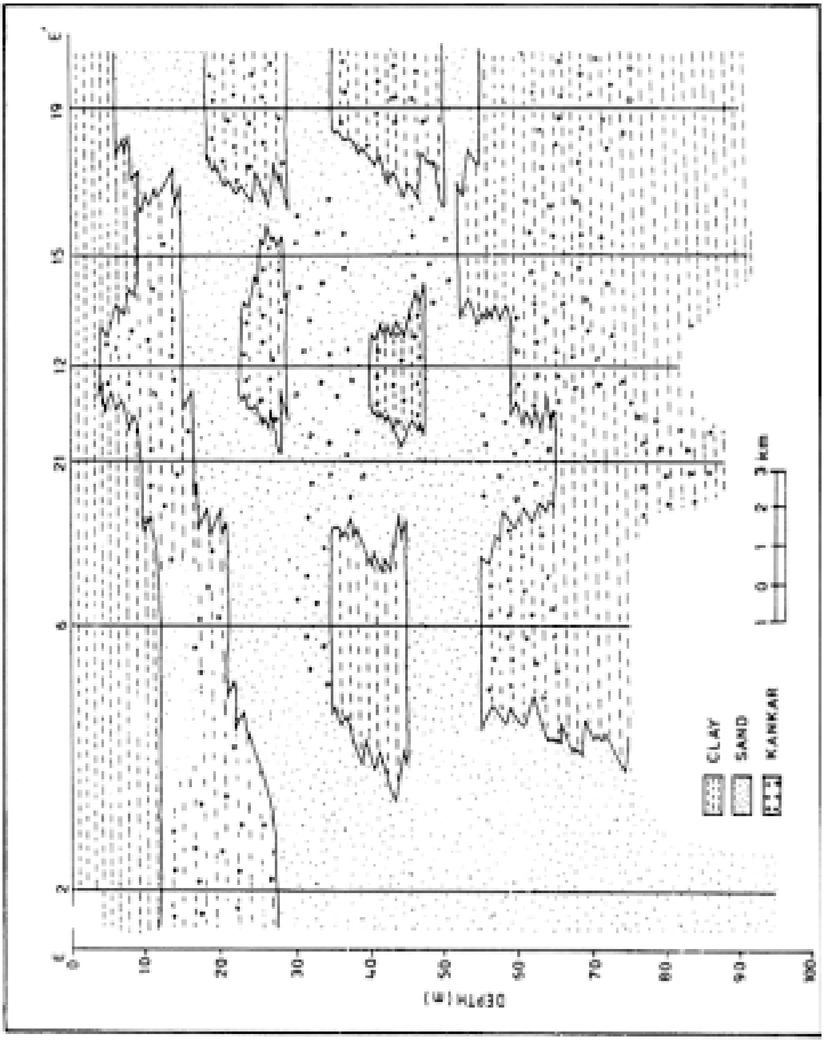

FIG. 5. Hydrogeological cross section along line EE' showing two to three tier aquifer system.

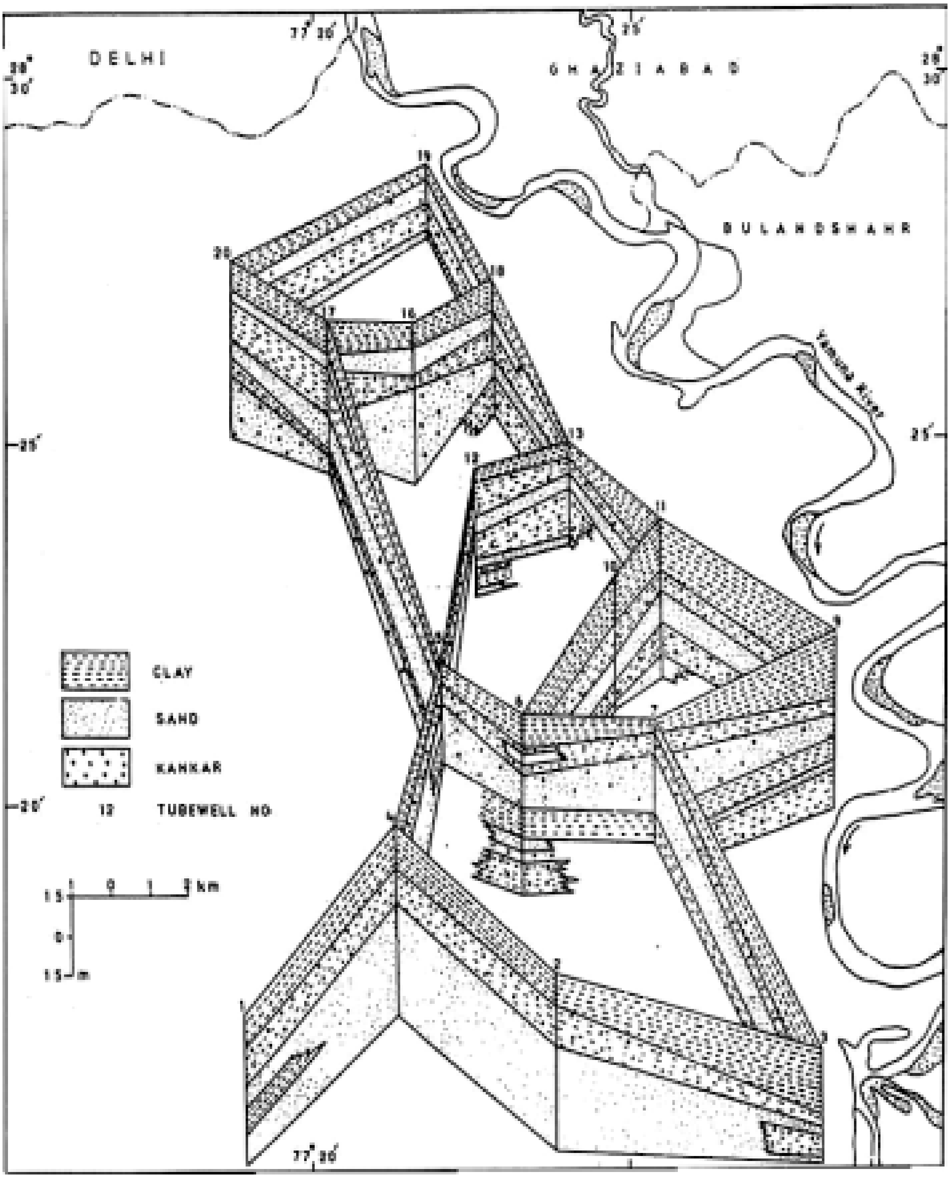

FIG. 6. Fence diagram showing distribution of regional aquifer system and their disposition.

The fence diagram depicts the subsurface distribution of the aquifer system, where top clay beds have variable thickness. On a regional scale a single aquifer system down to depth of 100 m can be visualized. The aquifer is made up of fine to medium grained sand with occasional coarse sand. Sandy sediments are dominant in the western part whereas the eastern part is dominated by clay sediments.

Salinity Hazards

The successively increasing amount of chemicals in river and other water bodies resulting from enhanced discharge of industrial and municipal waste water has become a matter of great concern as it affects the groundwater quality. As the area is located in the most industrialized zone of northern India, the discharge of industrial effluents and solid wastes in the open field and unlined drains is a common practice. These may cause the higher level of total dissolved solids (T.D.S.) in groundwater, thereby resulting in the salinity hazards. Lithologic and climatic factors also contribute to the salinity hazards. The study area has a semi-arid climate characterized by high temperature variation (44 to 5ºC) and low rainfall (502.5 mm) during monsoon season. Dry condition in summer causes capillary rise of water from pores of silt-clay and subsequent evaporation of water leads to precipitation of salts in the surface soil. These soil salts are moved by rainwater into the groundwater leading to enrichment of salt content of groundwater. At present, it is difficult to estimate how much salts are contributed by natural processes and how much are of anthropogenic origin. However, because of high evaporation in the region, salts derived from natural processes of weathering ... etc. must be a major contributor.

The collected groundwater samples were analyzed for electrical conductivity to get an idea on the extent of mineralization, which is indicative of salinity of water. The electrical conductivity with 400 µS/cm at 25ºC is considered suitable for human consumption. The groundwater in the central part of the area is characterized by high degree of mineralization (Fig. 7). The value of E.C. for all the samples ranged between 500 and 6700 µS/cm averaging 1993 µS/cm. Higher values of E.C. (1630-4930 µS/cm) were recorded in residential colonies of Faridabad by Khurshid and Zaheeruddin (1998).

The continuous increase in salinity of groundwater makes the soil hard and impervious particularly in low water level region. These modifications in the soil hamper the optimum plant growth by changing the osmotic pressure and physiology of the plants (Saini and Mujtaba, 1996). The ameliorative measures are therefore, required to minimize the salinity and facilitate optimum use of groundwater and soil.

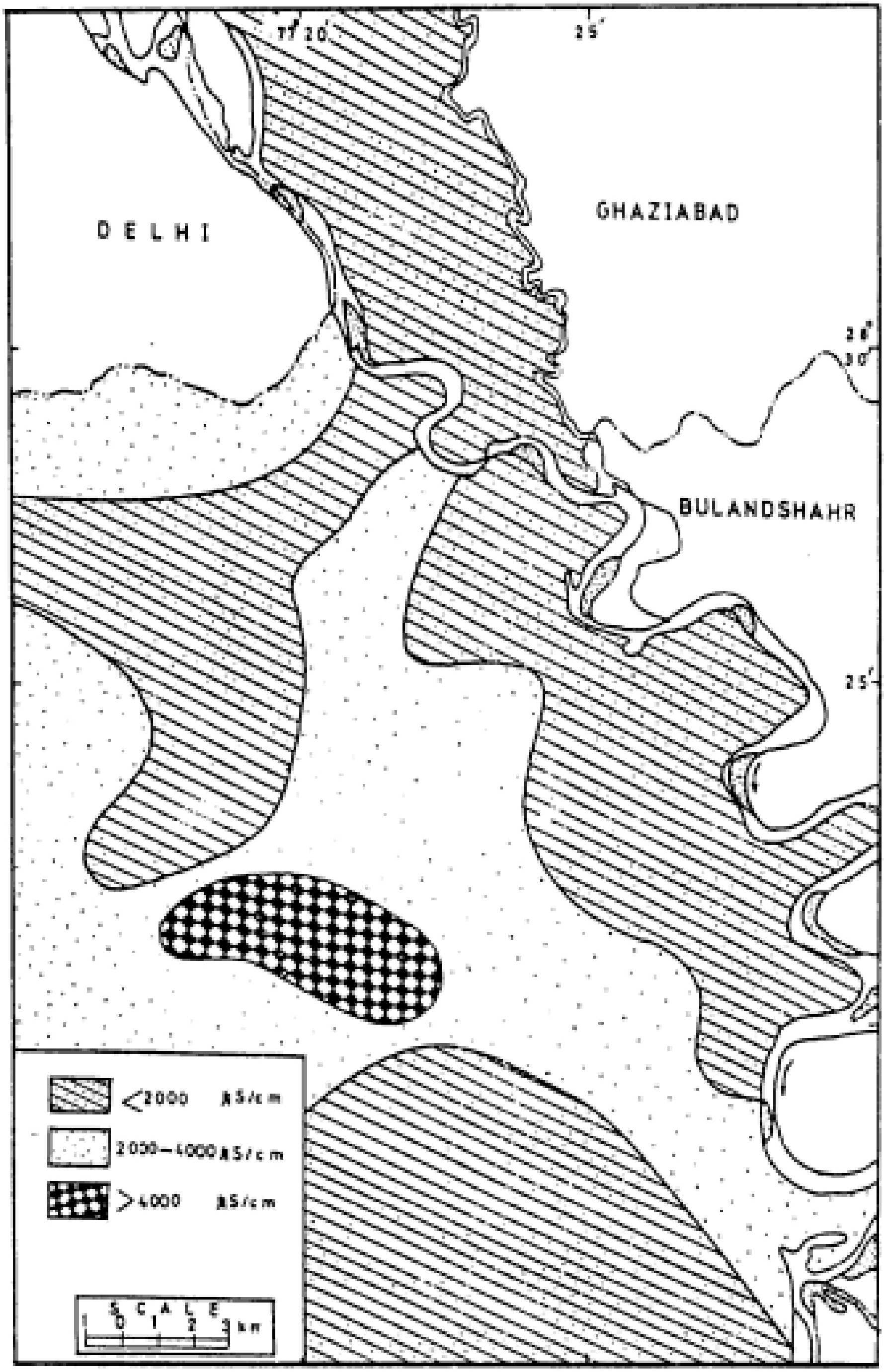

FIG. 7. Electrical conductivity distribution map demarcating different salinity zones in the study area.

Conclusion

Hydrogeological studies suggest presence of a single aquifer system on a regional scale down to depth of 100 m.b.g.l. in the middle part of the Yamuna river sub-basin. The aquifer is made up of fine to medium grained sand with occasional coarse sand. Occurrence of clay beds intermixed with silt and kankar serve as aquitard. Groundwater occurs under water table condition at shallow depth and in semi-confined to confined conditions at greater depth. Depth to water level varies from 3.30 to 21.50 m.b.g.l. during pre-monsoon period (June, 1997). Groundwater flow is towards east and southeast. The salinity of groundwater is not uniformly high in the area, but highly mineralized water found in parts.

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خطر تملح الخزان الجوفي تحت أجزاء من حوض أحد فروع نهر يامونا ، الهند

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المســتــخلص. بدراسة الخـزان الجــوفي الإقليــمي والظروف الهيدروجيولوجية وأسباب التملح في الجزء الأوسط من حوض أحد فروع نهر يامونا على نطاق محلي ، اتضح وجود عدد من ٢ إلى ٣ خزانات تؤول كلها إلى خزان واحد عند عمق ١٠٠ متر . تتصرف المياه الجوفية بشكل عام إلى اتجاه الشرق والجنوب الشرقي مع بعض الاختلاف. تم سحب كميات هائلة من المياه إلى خزانات سطحية أعدت لذلك . وبقياس التوصيلية الكهربية كمؤشر لقياس درجة الملوحة ، اتضح وجود تغيرات ملحوظة في ملوحة المياه الجوفية ، حيث وجد أن التوصيلية الكهربية تتراوح بين ٥٠٠-٦٠٠ ميكرو سيمنز/ سم .

قد يرجع سبب ملوحة المياه الجوفية المسجل في منطقة الدراسة إلى عملية صرف النفايات الصناعية الصلبة على نطاق واسع إلى القنوات التي تستخدم في الري ، مما يؤدي إلى زيادة تركيزها في المياه الجوفية بفعل العوامل الطبيعية .