CHAPTER-VII
SUMMARY AND CONCLUSION

Demand for fresh water, caused by surging population growth, environmental abuse and poor water management, is becoming a dangerous source of friction in many parts of India. Out of the total exploitation of water resources in the country, groundwater share is almost 54%. However, it has not been given its due share of attention so far in the water resource planning programme. For evolving policies for the better use of ground water resource, basin wise estimates of utilizable groundwater resources, taking into account groundwater recharge and discharge, are the need of the present time. In pursuance of the above, an attempt has been made to study the aquifer systems and groundwater resource potential of "Aligarh city and adjoining areas" in central parts of the Ganga-Yamuna interfluves sub-basin for its optimal utilization. The area of investigation spreads over 36700 ha and lies between the latitude 27°50' to 27°58'N and longitude 78°00' to 78°15'E and falls under the Survey of India toposheet number 54I/1 on 1:50,000 scale. Physiographically, the area from east to west is divisible into three distinct units; Eastern upland, Central depression and Western upland. It is drained by the river Kali and Sengar. Which flow due south. As regards the soil types, they are loam to sandy loam, loam to clayey loam and sand to sandy loam. Irrigation facilities both through tubewells and canals are available, for an area of 18600.074 ha in (which is 77% of the net sown area) of which 78% is irrigated through groundwater and rest 22% by the canals. Application of the remote sensing techniques have helped in delineating various landform features.

The study area lies in the sub-tropical climatic zones of India and experiences very hot summer (46°C) and very cold winters (4°C). The summer season starts by mid March and lasts by late June when the monsoon
sets in. July and August are the months of heavy rainfall. The average annual rainfall is 683.33 mm, the standard deviation of rainfall is 247.41 mm and the coefficient of variation is 36.206%. As per the drought analysis, the frequency of occurrence of the mild drought is 31.31%, the normal drought is 21.21% and the severe drought is 4.04%.

Geologically, Bundelkhand Granite forms the basement complex, which is unconformably overlain by the lower Bhandar limestone and sandstone and further followed by the Upper Bhandar shale and sandstone of Upper Proterozoic age and is finally overlain by the Quaternary alluvium. The Quaternary alluvium consists of alternate beds of sand and clay where clay is observed occasionally intermixed with calcareous concretions.

The exploratory drilling operations by the Central Groundwater Board in Aligarh district encountered the bed rock at varying depths. The well drilled at railway club compound close to Aligarh railway station in June 1976, encountered Upper Bhandar red shale at a depth of 340 m b.g.l. Besides, in an exploratory well drilled by CGWB, the Upper Bhandar Sandstone which overlies the red shale was encountered at Saleempur, 20 km of south-west of Aligarh city, at a depth of 286.36 m b.g.l. Moreover, the same red shale was touched at Hathras 35 km. south of Aligarh city, at a depth of 356 m b.g.l. Further, in an exploratory drilling at Kasganj by Oil and Natural Gas Corporation (ONGC) on the right bank of the Ganga, encountered the Lower Bhandar limestone and Bundelkhand Granite at a depth of 620.0 m b.g.l. and 2061.0 m. b.g.l. respectively, which very well establishes the stratigraphic sequence from the Basement to the Quaternary alluvium.
Further, the study shows that rapid migration and the hydrodynamics of the river Ganga over the years has generated three types of aquifers i.e. channel deposits with much groundwater potential; flood plain deposits, moderately potential and back swamp deposits with poor groundwater potential. A perusal of the fence diagram and various hydrogeological cross-sections depict that by and large there occurs a single aquifer system in the area down to a depth of 166.0 m b.g.l. which is often observed interleaved at places with moderately thick to thin clay beds which imparts it a two tier aquifer system. These aquifers are laterally and vertically extensive and consist of fine to medium sand and are very much potential.

A perusal of grain size analyses data of the aquifer materials collected from the drilling sites depict that the effective grain size ($d_{10}$) of the aquifer materials ranges between 0.065 to 0.124 mm which indicates that the sand size ranges between medium to fine while the effective grain size of the kali bed sediments ranges between 0.07 mm to 0.096 mm which indicates that kali sediments are finer. The uniformity coefficient values of the aquifer materials range between 1.54 to 2.15, which shows that with the exceptions, the porosity is generally high. The uniformity coefficient values of the kali bed sediment range between 1.48 to 2.0 which indicates that the kali bed sediments is highly porous. The hydraulic conductivity of the aquifer materials ranges between 21.6 m/day to 79.4 m/day, while the hydraulic conductivity of the kali bed sediments river ranges between 25.06 m/day to 41.47 m/day.

Further, a network of 167 observation wells were established and the relevant hydrogeological data were collected. Water levels measured in the observation wells, are presented as pre and post monsoon depth to water level maps, water level fluctuation map, pre and post monsoon water table
contour maps, piezometric surface map and hydrographs.

A perusal of the premonsoon depth to water level map shows that the deepest water level 17.8 m b.g.l. was recorded at the western portion of the study area while the shallowest water level 2.30 m b.g.l. was recorded along the Upper Ganga Canal. The post monsoon depth to water level map shows that the water level varies from 1.6 to 16.7 m b.g.l. The water level fluctuation in the area ranges between 0.1 m to 1.9 m in the year 1999. An observation of the water table contour maps show that the elevation of water table ranges from 173.0 m a.m.s.l. in the north-west to 168.0 m a.m.s.l. in the south-east respectively. Which shows a regional groundwater flow from north-west to south-east direction.

A glance at the water table contour maps show that there occurs five groundwater mounds in which two major mounds are developed close to the Upper Ganga Canal, due to the excessive seepage from the canal into the top aquifers below it. Moreover, three troughs are observed in the city centres due to the excessive withdrawal of groundwater much higher to the average annual recharge. The hydraulic gradient varies from 0.47 m/km to 4.67 m/km. A perusal of the piezometric surface level map shows a similar pattern to that of the water table contour map. The similarity of two maps are indicative of same source of recharge to shallow as well as deeper aquifers and hence their interconnected nature.

Hydrographs of permanent observation well networks indicate that the water level variation is cyclic, showing the deepest water level during June and the shallowest in November. There is a sharp decline in the water level from mid November onward till January. After January recession in water level is slow, which indicates natural groundwater discharge through steady subsurface out flow, with respect to regional groundwater flow.
The transmissivity values in the study area calculated from the State Tubewells borehole data range between 250.97 m$^2$day$^{-1}$ to 2515.03 m$^2$day$^{-1}$, the permeability values range between 12.10 m day$^{-1}$ to 114.06 mday$^{-1}$, the specific capacity index values ranges between 9.92 m day$^{-1}$ to 93.49 m day$^{-1}$ and the specific capacity values range between 205.71 m$^2$ day$^{-1}$ to 2061.5 m$^2$ day$^{-1}$. The pumping test data conducted in the area shows the transmissivity values as 810.989 m$^2$ day$^{-1}$ and hydraulic conductivity as 28.92 m day$^{-1}$.

The groundwater resource evaluation studies show that the net annual recharge is estimated as 9337.70 ham while the net annual draft is 7160.37 ham leaving a balance of 2177.33 ham for future development of the groundwater resource through various shallow and deep tubewells. As per the NABARD's norms the area falls under the grey or semi-critical category.

The chemical analyses results show that the groundwater in the area of investigation is an alkaline hard and moderately mineralised in nature. The values of major ions and trace elements are found well with in permissible limits with few exceptions. However, the heavy metals concentration in the top aquifer is observed above the permissible limits. But there concentrations in the deeper aquifer waters are found well within the limits. Further, the study shows that the majority of groundwater samples in the area belongs to bicarbonate type and few samples falls in no dominant type and sulphate type in the anion facies while on the cation facies the water samples belong to sodium or potassium type and few samples belong to no dominant type and magnesium type. Finally, the trilinear diagrams show that groundwater in the study area belongs to an Alkali Bicarbonate Type. However, the groundwater in the area is suitable for drinking, irrigation and industrial uses. The top aquifer water at places were not found suitable for human
health hence, the clean and safe groundwater from deeper aquifers be tapped for human consumptions.

The study shows that the area of investigation is beset with the dual situations of water logging along the Canals and a rapidly declining trend of water level in the city.

To minimize a balance and make an optimum use of water resources in the study area some recommendations are suggested which are as follows

1. The canal should be lined in order to check the further seepage into the top aquifers below the canal beds to control the water logging along the canals.

2. Roof-top rain water harvesting should be brought in practice to recharge the top aquifers.

3. 98% dry dugwells in the villages be recharged through monsoon storm water during the rainy season.

4. A recharge canal should be constructed along the physiographic divide and passed through the various part of the city, where in a 10 m deep dugwells be constructed at every 100 m length of the canal to recharge the groundwater bodies.

5. The earlier ponds constructed by Sabet Khan, the erstwhile governor of Aligarh during Mughal period, be reclean and deepen and a series of new ponds be constructed in order to recharge the depleting aquifer vis-a-vis the huge annual draft.

6. In general the quality of groundwater from top aquifer where found hazardous for human health hence, the safe drinking water from the deeper aquifer be supplied for drinking purposes.