Chapter 12

Conclusions

1. The CMC and HMC areas form a part of the lower deltaic plains of the Bhagirathi-Ganga river system and lie on both sides of the Hugli distributary. Apart from this active channel, there is a system of abandoned and almost filled up distributaries on the Calcutta side viz Adi Ganga and Bidhyadhar. The land gently slopes towards south and east on the eastern side of the Hugli river while on the western side the general slope is towards west.

2. The climate of the area shows appreciable variation in characteristic features with a mild winter, a brief spring, a hot summer with occasional nor'westers and heavy monsoon. The months from mid-June to mid-October are characterised by heavy rainfall. The average annual rainfall is about 1650 mm.

3. The formations belonging to the Quaternary System are the principal repository of groundwater. The lithologs indicate that the sediments consist of a top clay bed of average thickness of 40 m followed by sands of varying texture which is again followed by a clay bed at a depth ranging from 296 m to 414 m below land surface. Lithofacies analysis indicates that the sediments within the depth range of 80 - 120 m are the potential water bearing formations and tubewells tapping this zone are expected to have better yield compared to the zones above or below it. Particular mention should be made of the gravelly sand which occurs in two linear trends viz E - W (Ahiritala to Bidhan Nagar) and N - S (Bidhan Nagar to Taliganjā) on the Calcutta side within the depth range of 80 - 120 m. However, in the depth range of 120 - 160 m tubewell development will be economic at Bidhan Nagar, Dhapa, Santoshpur and Khidirpur where gravelly sand occurs. The sand constituting the aquifer material is highly micaceous and often tends to be silty. The median diameter of the sediments of the upper horizon (< 90 m)
ranges between 1.5 phi and 2.6 phi with a mean of 2.1 phi (fine sand) while those of the lower horizon (90 - 156 m) varies between 1.13 phi and 2.07 phi with a mean of 1.60 phi (medium sand) The average sorting values of the upper and lower horizons are 0.61 phi and 0.65 phi respectively indicating that the entire aquifer material up to a depth of 156 m is on an average moderately well sorted. The sediments are more or less normally distributed with average skewness of +0.07 and +0.04 for the upper and lower horizons respectively. The sediments of the upper horizon are very leptokurtic (av $K_o = 1.52$) and those of the lower horizon are leptokurtic (av $K_o = 1.28$).

4. Demographic study indicates that during the next 25 years Jadavpur will be the centre of growth of population within the CMC area. Garden Reach, by then will reach the saturation point, while the rest of the CMC area will have a marginal growth of population. The population of the entire CMC area will register 16.9% growth by 2021. Bidhannagar, being a newly developed city will be the centre of growth and it is expected that the population will reach 500,000 by the turn of the century and 838,000 by 2021. The HMC area will have a growth of 13.16% by 2021.

5. Currently water supply is being met from two sources - groundwater and surface water (Hugli river). The total water supplied in the CMC area is 1165 mld out of which c. 277 mld is met from groundwater resource. In HMC area the total water supply is 128 mld out of which c. 18 mld is extracted from the groundwater reservoir. In Bidhannagar groundwater is the only source of water for the residents and about 15 mld of groundwater is being extracted from the aquifers.

6. In the coming decades both population and developmental activities are expected to increase and the demand of water would also concomitantly increase to the tune of 100 mld, 172 mld and 264 mld by 2001, 2011 and 2021 respectively as per the New Master Plan. Therefore, an integrated effort should be taken up.
to manage the water supply of Calcutta, Bidhannagar and Howrah cities by formulating a sustainable water management plan. The efforts should continue for the next few decades with greater emphasis on operation and maintenance, on waste reduction, on appropriate and affordable standard of supply and wise use.

7. **Groundwater** in the deeper aquifers occurs under a confined condition and the principal productive aquifers generally range from 80 - 160 m below land surface. During the post-monsoon (1993) period the piezometric surface in the central and southcentral parts of Calcutta lies at a depth range of 13 - 14.3 m bgl. From this area the piezometric surface progressively shallows up in all directions. The shallowest water level is countered in the southern tip of the study area where the piezometric surface rests at a depth of 7.1 m bgl. On the Howrah side, the piezometric surface shallows up away from the river. The deepest water level (2.6 m bgl) is recorded in three observation wells located close to the Hugli river and the shallowest one (7.7 m bgl) has been recorded in the northwestern part of the HMC area. During the following pre-monsoon period a similar pattern of distribution of the piezometric surface is observed except for a general fall of the water level ranging from 1.20 m to 2.05 m. Over the last 37 years (1956 - 1993) the maximum recession of the piezometric surface has occurred in Gobra-Tiljala area located in the southcentral part of Calcutta. In this area the average depth to piezometric surface during the post-monsoon period of 1956 was 4.32 m bgl and the same is around 12.61 m bgl during the post-monsoon period of 1993 i.e., a drop of the piezometric surface to the tune of 8.29 m.

8. **Prior to large scale withdrawal of groundwater** i.e., during 1950s, the regional groundwater flow was from north to south. But at present the groundwater shows a centripetal flow pattern with the formation of a major groundwater trough in the southcentral part of Calcutta. The dimension of the groundwater...
trough has increased to the north and east compared to that of 1985. The
dimension will further increase with rising demand of water.

9. The aquifers in the northern part of Calcutta have the highest potentiality
\( (av\ T = 6460\ m^2/day) \) while those in the southern parts have the lowest
potentiality \( (av\ T = 1622\ m^2/day) \). The ability of the aquifers to transmit water in
the western part of Calcutta is intermediate with an average transmissivity of
2673m²/day. The hydraulic conductivity of the aquifer material varies vertically
and horizontally. Well sorted sands of medium to coarse textures are
characterised by higher hydraulic conductivity than less sorted fine sands. The
average hydraulic conductivities of the upper horizon \(< 90\ m\) and lower
horizon \((90 - 156\ m)\) are 10.43 m/day and 15.72 m/day respectively.

10. Fluid potential distribution of the aquifers has brought out a zone of stagnation
upto a depth of 300 m. The distribution pattern also indicates that there is no
flow from the Hugli river to the aquifers and vice versa.

11. Over-exploitation of groundwater is to the tune of 73.5 mld for Calcutta and
Bidhannagar. The impacts of over-exploitation are (i) land subsidence, (ii)
depreciation of groundwater quality, and (iii) increase cost of pumping.

12. The calculated average rates of land subsidence in Calcutta and Howrah are
11 mm/year and 4.2 mm/year respectively. The surface expression of the
estimated land subsidence is, however, cryptic because of a time lag between the
settlement of clay and its surface expression. The calculated land subsidence,
however, needs ground verification by recalibrating the reduced levels of the
existing bench marks. Again compaction recorders or extensometers can be
installed in the areas of heavy pumping to measure the actual compaction of the
sediments. Piezometers should also be installed near the extensometers to
record the variation in depth to piezometric surface. This in turn, would help us
to understand the field relationship between head decline and land subsidence.
A satellite-data based system for periodic checking of land subsidence should also be established.

13. The major ion chemistry of groundwater is highly variable considering the relatively small extent of the study area. This possibly indicates the presence of complicated geochemical processes which have led to a wide range in chemical character of groundwater. Heavy metals such as chromium, cadmium, copper, and nickel have been detected in groundwater at many places. Concentration of iron and manganese is high in most places. The percent compliance of the samples analysed with BIS 10500 (1991) is only 9 and 14 respectively. Arsenic has been detected in a small area at Behala and in two places at Howrah. Three major types of groundwater have been identified based on hydrochemical facies analysis viz "fresh", "blended" and "contaminated". "Fresh" groundwater is generally observed in the southern and western parts of Calcutta. "Contaminated" water occurs in the northern, eastern, and southeastern parts of Calcutta and almost in entire Howrah. "Blended" water occurs in small patches within the "fresh" and "contaminated" zones. In Howrah, it occurs on the eastern and western fringes. The "contaminated" water is high in chloride suggesting connate water as a possible potential contaminant. However, PC-analysis using groundwater and connate water indicates that at present there is no direct mixing of fresh water and connate water. This mixing had possibly taken place during the late Quaternary period when the present study area was under the influence of brackish to marine environment. Another PC-analysis using only the groundwater samples resulted in a clear categorisation of the samples into "fresh", "blended" and "contaminated" varieties. At present, mixing of "fresh" and "contaminated" waters in the proportion of 48% is possibly taking place due to heavy groundwater withdrawal. The reasons for which the Calcutta-Howrah aquifer may become permanently polluted are (i) closed groundwater flow system, (ii) leakage of polluted water from the top clay body, (iii) increase flow of
arsenious water from north and south of Calcutta (iv) saline water intrusion from south of the study area and (v) lack of oxidising condition

14. Groundwater in parts of Calcutta and Howrah is bacteriologically contaminated. This contamination has resulted from the leaking sewage system, municipal solid waste dumps, soakage pits, pit latrines, municipal trenching and defective tubewell constructions.

15. In order to protect the CHA from being permanently polluted and to avoid future hazards of land subsidence artificial recharge techniques may be adopted. The suitable methods are (i) Recharge well method at Subhash Sarovar at Beleghata and Rabindra Sarovar at Dhakuria - these two sites are located in the northern and southern extremities of the major groundwater trough in the southcentral part of Calcutta and (ii) Spreading method using SAT system at Kalyani-Ranaghat-Shantipur area, Nadia District and Tarakeswar-Nalikul-Mogra-Pandua area, Howrah district - these two areas are the major groundwater recharge areas of CHA located in the north and northwest of Calcutta.

16. A nature-synchronous groundwater management plan has been formulated on the basis of past and present groundwater flow pattern, present utilisation of groundwater, future demand, status of the piezometric surface, chemical and bacteriological qualities of groundwater. Based on these criteria the entire study area has been divided into 3 zones:

Zone 1 - Central and Southcentral Calcutta

Zone 2 - Northeast Calcutta, parts of Central Calcutta, West Calcutta, Southwest Calcutta, Southeast Calcutta, West Howrah and Southeast Howrah

Zone 3 - South Calcutta, parts of North Calcutta, Northeast Howrah and Northcentral Howrah
The groundwater management plan that may be adopted for these zones are:

**Zone 1** - No tubewells to be developed, withdrawal to be regulated by reducing tubewell operation time

**Zone 2** - *Status quo* to be maintained in respect of tubewell development

**Zone 3** - Further development of a limited number of tubewells possible for municipal use

From Zone 3 about 60.2 mld of groundwater can be further extracted from 86 nos heavy-duty tubewells. For further augmentation of water supply in Zone 1 and Zone 2, the surface water of the Hugli river should be judiciously used and artificial recharging of the already strained parts of the aquifer should be simultaneously carried out.