CHAPTER 3

HYDROGEOLOGY OF THE STUDY AREA

3.1.Hydrogeology of the Indogangatic plain of Uttar Pradesh

Indo–Gangetic plain is the largest alluvial plain of the World, which has been formed by deposition of terigenous clastic sediments through streams of Indus, Ganga and Bramhaputra River Systems. The alluvial plains shows highly differentiated alluvial geomorphic features; many of them formed above to changing climatic conditions.

The Gangetic plain occupies the central position in the indo-Gangetic plain and extends from Delhi ridge in the West to Rajmahal hills in the East; Siwalik hills in the North and Bundelkhand–Vindhayan high land in the South. It is a foreland basis formed in response to the Himalaya tectonics (Figure 3.1).

Figure 3.1: Sketch map of Gangetic plain showing position of major basement structures below the alluvium. I. Delhi ridge, II. Faizabad Ridge, III. Monghyr-Saharsa Ridge. 1. Moradabad fault, 2. Bareilly fault, 3. Lucknow fault, 4. Patna fault, 5. Malda fault. Based on data of Sastri et. al. (1971), and Rao (1973).

3.2. Subsurface Basement Structure of the Indogangatic plain of Uttar Pradesh

The Quarternary alluvium of Gangetic plain including Siwalik sediments rests on a basement which is sometimes made up of late Proterozoic sediments or metamorphic Pre-cambrian rocks. The basement rocks show some major structures which have controlled the thickness of alluvium. The interpretation of basement structure is based on the aeromagnetic studies. There are three major basement highs referred to as ridges below the Gangetic plain near the western margin of Gangetic plain the rocks of Delhi – Aravalli tectonic trend continue towards North to North-East below the alluvium. The thickness of alluvium over this Delhi ridge is much reduced, and also termed as Delhi-Haridwar Ridge or Delhi –Muzaffarnagar ridge. In middle part of Gangetic plain, a basement ridge structure exists as Bundelkhand massif. This basement high is known as Faizabad ridge. This ridge also reduced thickness of alluvium. In the Eastern part of the Gangetic plain, a continuation of Satpura Bundelkhand massif. This basement trend extends below the alluvium in the form of ridge, Monghyr–Saharsa ridge (Figure 3.2).

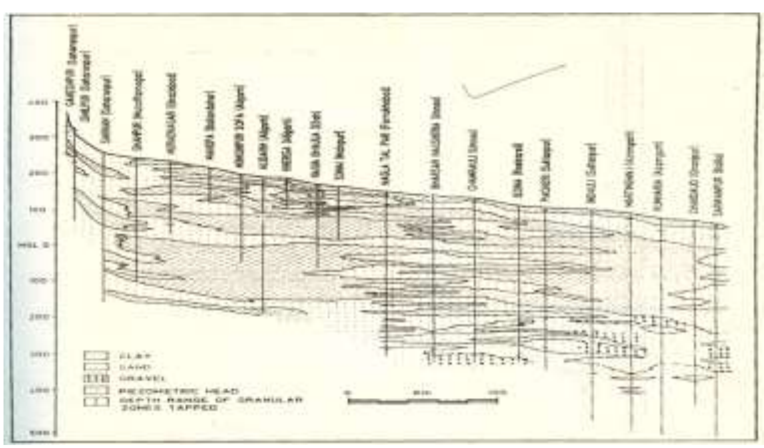

Figure 3.2: Lithological correlation chart of the Ganga basin from Saharanpur to Ballia districts, U.P., showing major aquifers and interbedded clay horizons.

Besides these three major basements ridges, there are a number of faults identified in the basement. These faults are: Moradabad fault, Bareilly fault, Lucknow fault, Patna fault and Malda Fault .Though basement highs have controlled the thickness of alluvium, there seem to be no surface and sub-surface expression of these faults in the alluvium .It appears that these faults are inactive faults in the basement.

3.3. Geomorphology of the Indogangatic plain of Uttar Pradesh

In classical literature, essentially two types of deposits and geomorphic regional features in Gangetic plain are identified namely older alluvium or Bhangar and the newer alluvium and / or khaddar. The older alluvium makes the regional high surface, while the newer alluvium refers to the river valley deposits and present flood plain deposits.

3.3.1. Based on geomorphic character and drainage patterns, Gangetic plain can be classified Western, Median and Eastern plains.(Singh,1989).

3.3.1.1. Western Gangetic plain

It stands from Yamuna River near Delhi-Aravalli ridge (elevation 225m) upto Allahabad (following 100m contour line).

3.3.1.2. Median Gangetic Plain

It is located between Allahabad and Manghyr-Saharsa, between 100-50 m. contour lines.

3.3.1.3. Eastern Gangetic Plain

Located between Manghyre-Saharsa in West and Rajmahal mills in the East, between 50-30 m. contour lines.

3.3.2. Based on geomorphology and Hydro geological features, the Gangetic plain is classified into four distinct areas from North to South (Pathak, 1982).

3.3.2.1. Bhabar Belt

It is located along the Himalayas foot hill, has southerly slopes of 10-20 m. /km. The rivers are gravel bearing, shallow braided streams. Ground water level is deep and water bearing strata are more potential.

3.3.2.2. Tarai Belt

It is located South of Bhabar belt with very high gentle slopes 20-30 cm. /km. It is flat, more waterlogged areas with ponds, swamps and many small sandy streams. The ground water level is very shallow varying from 0 to 6 mbgl.

3.3.2.3. Central Alluvial Plain

It makes the wide zone showing prominent higher surface with gentle South-easterly slope. The rivers flowing South-Eastern and Eastern directions, showing wide river valleys or Khadar.

3.3.2.4. Marginal Alluvial Plain

It is located south of axial river showing extensive higher plateau surfaces, narrow entrenched river valleys. It occupies the area south of Yamuna River in U.P. and South of Ganga River in eastern U.P. The rivers are mostly North and North-Easterly flowing gravel-coarse sand carrying streams.Bhabar and Tarai belts correspond to the northern domain, central alluvial plain to central domain and marginal alluvial plain to the southern domain of the Gangetic plain foreland basin.

3.4. Geomorphic Features

There are number of regionally significant geomorphic surfaces identified in Gangetic plain, along with a number of specific geomorphic features, based on reports of remote sensing data.

3.4.1. Upland Terrace Surface

It is most important regional planer surface, making gentle sloping higher areas. In the central alluvial plain it shows in 1/km. slopes in eastern and South-Eastern direction. It is probably the oldest geomorphic surface. It is made up of essentially silt sediments, with mud and sand horizons, and shows extensive development of calcrete bands. Often abandoned channel belts of highly sinuous streams are present. The surface is gentle undulating and shows a number of distinctive geomorphic features, namely ponds, lakes, abandoned channels, zones of alkaline soils, zones of extensive gulley. All the active rivers of Gangetic plain are entrenched in this surface. This surface makes the highest terraces for the active streams and is designated as T-2 surface. In the marginal alluvial plain, south of Yamuna River in Western part and South of Ganga River in eastern part, extensive high, plateau surface is developed showing prominent calcrete formation.

3.4.2. Large Relict Alluvial Fan Surface

The northern part of Gangetic plain shows a prominent southward sloping surface, which was formed by coalescence of large alluvial fans (F), which were about 100 km. wide. It starts from Siwalik Hills and extends deep into the Central Alluvial plain. In the areas of Ghaghra and Gandak Rivers a number of evidences for the presence of large alluvial fan surfaces are seen, namely abandoned diverging channels, linear lakes etc. but it is difficult to identify the boundary of these large relict fans. This fan surface shows evidence of gradual shrinkage towards Himalayas, due to decreased sediment supply and at present is confined to a narrow zone close to the Himalaya (Figure 3.3).

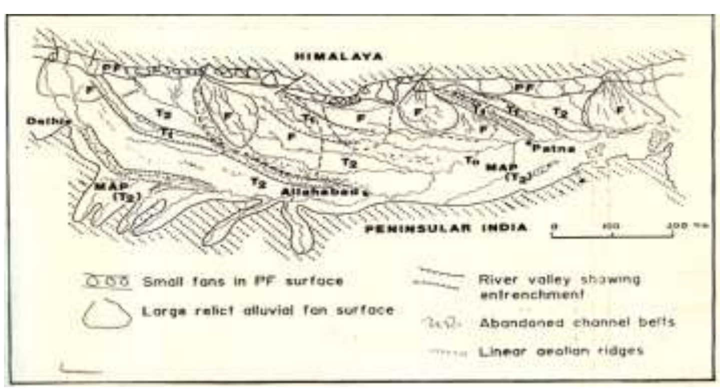

Figure 3.3: Schematic geomorphic map of Gangetic plain showing major geomorphic features. T2-Upland terrace surface, MAP (T2)-Upland terrace surface of Marginal alluvial plain, F-Large relict alluvial fan surface, PF-Piedmont fan surface, T_1-River valley terrace surface, T_0-Active flood plain.

3.4.3. Piedmont Fan Surface

The northern part of Gangetic plain near the Himalayan orogen shows a prominent narrow zone made up of coalescing, discrete alluvial fans (PF). These zones are about 10-20 km. wide and often correspond to the Bhabar zone. It is much younger than the large relict fan surface and is sometimes superimposed on the later. There is evidence of gradual decrease in the size of fans of this piedmont fan surface in the last few thousand years. On this surface, gravely sediments are present below few tens of meter thick sandy-muddy sediments.

3.4.4. River Valley terrace Surface

All the major rivers of Gangetic plain shows rather broad valleys in which a narrow present-day active flood plain is located. These broad river valleys are entrenched within the upland terrace surface (T2). It is newer alluvium which also included the present day active flood plain (T0). This surface is designated as T-1 surface, forming gentle sloping terrace surface, a few meter above the active flood plain.

3.4.5. Active Flood Plain

All the major rivers of Gangetic plain are subjected to annual flooding and make prominent flood plain predominantly make upto sandy sediments. In large rivers, it can be several km. wide, while in the smaller rivers; it is few hundred meters wide. This surface is designated as to surface, made up of active channel, braid bars, point bars, sandy flats and muddy flood plains.

3.5-Characteristic of the drainage

The Gangetic plain shows a wide variety of streams with respect to origin, direction of flow, dimensions, channel characteristics and hydraulic parameters. Based on their source, these rivers are classed into three broad categories: Himalayan Source Rivers, ground water fed rivers and Peninsular Source Rivers.

The Ganga is the trunk or axial river to which all the rivers join in a distinct pattern. The major rivers originating in Himalaya and within alluvium run parallel to each other for considerable distance, before joining the larger streams. Similarly, streams from Peninsular India also run parallel to each other before meeting the Yamuna or Ganga Rivers. Further, Central Alluvial plain shows a number of abandoned channel belts showing highly sinuous, free-meandering streams. The channel patterns of Gangetic plain are anatomizing, braided and meandering.

All the major rivers, originating in the Himalaya, e.g. Yamuna, Ganga, Ramganga, Ghaghra, Gandak show distinct braiding characters in the northern part of the Gangetic plain, slightly sinuous nature in the Central Alluvial plain. The central alluvial plain shows NW-SE oriented sub-parallel drainage system made up of Himalayan Rivers as well as ground water fed Rivers. The active channels are rather stable and show moderate to deep entrenchment and do not show evidences of river avulsion time scale of 10^2-10^3 years. The groundwater fed channels are meandering streams with narrow flood plains. The upland terrace surface shows many abandoned meanders, cut off meanders, etc often arranged in distinct channel belts.

3.6. Nature of Alluvial Fill

The sub- surface information on the nature of alluvium is essential based on the bore hole data of CGWB. It is about 2000 m in the northern part and gradually decreases to 10 m in the southern part. The Central Ganga Plain is very wide and shows much variability in sub-surface lithology in terms of sand: clay ratio and grain size characteristics. Information is usually available for top about 400m .The succession is made up of mainly clay and clay with kankar intercalated with few meter thick mostly fine sand horizons.

Few gravel horizons are recorded in deeper parts, which are mainly reworked carbonate-cemented sand and calcrete. The proportion of sand is high in the north-western part, but drops drastically in South-Eastern part of U.P. Topmost about 15 m of the alluvium is essentially made up of clay with thin lenses of very fine sand, often containing dispersed kankar.

The alluvial plain between Ganga and Yamuna River shows marked thinning of the alluvium. The thickness mostly varies from about 500m in the northern part to about 250 m in the southern part, resting on basement rocks. The sediments immediately above the basement are reddish coloured, arkosic sand and gravel derived from the peninsular source, locally known as Moorang. The arkosic sediments are followed by a succession of clay with kankar along with thin horizon of fine to medium grained sand. These are micaceous grey sand, derived from the Himalaya. The topmost 100 m lithology is essentially clay with kankar and thin lenses of very fine sand.

A significant aspect of the alluvial stratigraphy in Gangetic Plain is the presence of fining upward, about 5-10 m thick, clay dominant thickness at top, throughout the Gangetic Plain. The sub–surface lithology shows a number of fining upward or coarsening upward successions which must have been formed due to changing Climatic and tectonic conditions during late Quaternary.

The area between Ganga and Yamuna rivers is very important in understanding the southward shift of the foreland basin margin, just above the basement; southern derived arkosic sediments were deposited by Peninsular Rivers. Later Himalayan rivers pushed the peninsular rivers further south and depositing Himalayan derived micaceous lithic sand and mud over the arkosic sediment. (Singh, Bajpai 1989). Presence of clay-dominant sequence at the top of the alluvium throughout the Gangetic Plain suggests that at least, during Holocene, there has been strong alleviation of the Gangetic Plain by fluvial processes.

3.7.Physiography

The soil exhibits a wide variance; sandy on the elevated locations, clayey in the topographical lows and loamy on the flat surfaces. According to Singh (1992), the Gangetic alluvial plain has a gentle consistent regional slope and a narrow range of grain sizes but the channel shows a variety of forms namely braided, slightly sinuous, highly sinuous, anastomosing, ox-bow lakes, etc.

3.8. Aquifers in Indogangatic plains of Uttar Pradesh

Through the geophysical studies done by CGWB in 1992 using electric logs, four groups of aquifers namely 1, 2, 3 and 4 are recognized in order of increasing depth (Figure 3.4). Group 1 aquifers extend from the water table to a depth of 50 m to 110 m. Group 2 aquifers underlies group 1 at a depth of 70 m to 260 m, followed by Group 3 aquifers at a depth of 90 m to 375 m. The Group 4 aquifers have an upper boundary at a depth of 280 m to 400 m, while the lower limit remains largely unexplored. The aquifer material is generally fine to medium grained sand, which is micaceous in nature.

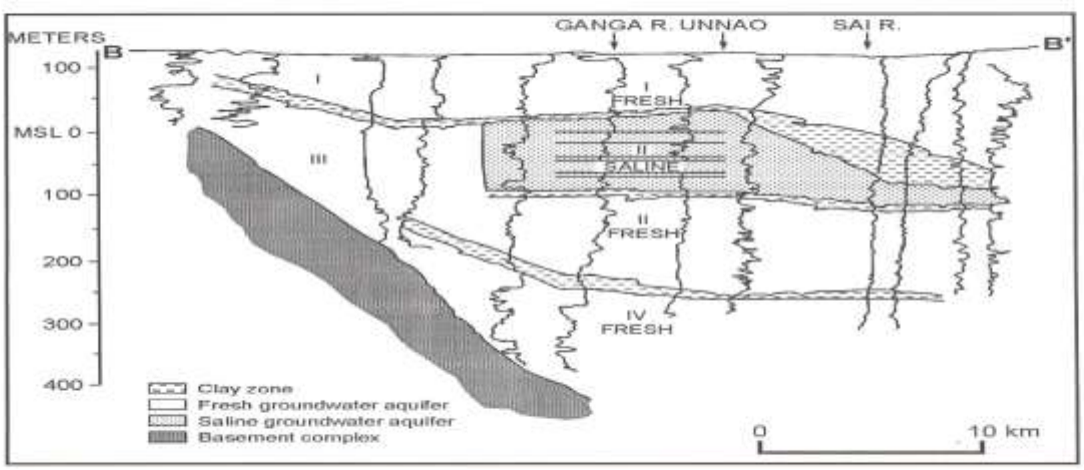

Figure 3.4 Group of 4 aquifers as reported by CGWB (1992)

Generally, flow of ground water in the unconfined zone follows the surface topography. It moves S to SE in foothills of Himalayas, then to the E-SE and then to the E in eastern most districts i.e. in Ghazipur and Ballia. Near the Gomti, Sai, Pilli and other rivers, flow direction is mostly towards river banks indicating that all the streams and rivers are being fed by ground water. Except for the Ghaghra River, which originates from the

Himalayas, all other rivers of this Basin originate from ground water springs, tanks and ponds. Ground water seeps into the Tarai zone of Pilibhit district and forms the Gomti River. The Sai River originates through a group of springs in Sitapur district at Namisarnya and other streams of Hardoi district contribute to its base flow downstream.

3.9.Regional analysis based on fence diagram in each of the Agro-Climatic zones from Central Ground Water Board and that of State Ground Water department

In the Bhabar zone sub-surface lithology is dominated by coarse sands and morum mixed with cobbles, pebbles, gravels with thin intercalation of clay lenses. The Tarai zone is also dominated by coarse sands and medium sands with thin inter-bedded clay layers. At some places sandy layers are very thin or absent up to the depth range of 60 to 100 m and farmers face problems for construction of tube wells due to unavailability of potential aquifers.

In North West plains the sub-surface lithology is dominant with medium to coarse sands inter layered with clay layers. The aquifers are wide extensive and highly potential for construction of both shallow and deep tube wells.

The lithology of Central plain is variable from place to place, but in general the proportion of sand-clay ratio is more or less the same up to the depth range of 50 m. In some areas the upper most sub-surface lithology is dominance with clays more suited for cavity tube wells up to 40 m depth and in other areas, sand layers are dominant inter layered with clays feasible for both cavity and screened tube wells.

The sub-surface lithology of North-East plain is widely variable from place to place; in general the upper most layer is dominant with medium to coarse sands and suitable for shallow tube wells. The under lying strata is dominance with clays, commonly intercalated with medium to fine sands. At many places the underlying clay layers are thick and extensive so that shallow and deep tube wells are not feasible.

Sub-surface lithology of Eastern plain is widely variable from place to place because of being fluvial deposit. In some areas clay lithology is dominant and in other areas sand layers are dominant with thin intercalation of clay layers. From place to place, there are also small kankars of in-situ origin. In most parts of the eastern plain, shallow tube wells are feasible with fresh ground water.

3.10. Aquifers in Gomti basin

The ground water aquifers in the area occur under unconfined, semi-confined and confined conditions. In the unconfined state the ground water occurs in the zone of saturation in the pore spaces of granular beds. The top granular zone which consists of sand, silt and Kankar, forms a phreatic aquifer and acts as a major source of water to open wells, hand pumps and shallow tube wells. The aquifer drawdown ranges up to 70 mbgl in locations where it is under severe stress due to the impact of human activities. In the semi-confined and confined condition, the ground water occurs below a confining layer. The middle and lower aquifers have alternate bands of clay and sand of pinching and variable thickness, starting from 70 mbgl to 200 mbgl. As an example, the semi-confined and confined aquifers in Sai–Gomti interfluve area are classified and given in Table 3.1

Table 3.1 Semi-confined and confined aquifers in Gomti basin

Aquifer	Lithology	Depth range (mbgl)	Quality of Ground water
I	Sand, silt and clay in various proportions	50-160	Fresh
II	Predominantly clayey silt with occasional thin beds of sand and clay	160-250	Brackish to saline
III	Fairly extensive sand beds and clay	Below 250	Fresh

(CGWB, 1995)

The hydraulic gradient of the aquifer is very high in the upper reaches of the Basin in Pilibhit district, with flows in south and south–east direction, whereas in central Ghaghra Gomti plain, hydraulic gradient is gentle and flows are in an almost west to east in direction. Hydraulic gradient varies with the influence of topography, and the presence or absence of water bodies. Hydraulic gradients in both river sub-basins do not show much variation. The gradient observed in the area is about 0.52 m/km in Sai basin and while hydraulic gradient varies between 0.44 m/km and 1.08 m/km in Gomti Sub-basin (CGWB, 1999). In the Jaunpur Branch Sub-basin, in the district of Jaunpur, hydraulic gradient varies from 0.155 m/km near Murladeeh to 0.624 m/km near Nanora in Suitha Kalan block in the north of the Gomti Sub-basin. In the Gomti sub-basin it varies from 0.155 m/km near Gujartal in Shahganj block to 3.12 m/km south of Kairadih in Khutahan block. It is recorded to be 2.81 m/km in Mahrajgunj block, north of the Sai

River to 1.66 m/km in eastern part of Sujanganj block, south of the Sai River. Similar conditions persist with different values of hydraulic gradient in almost all districts.

3.11. Fence Diagrams

The detail report based on fence diagrams from CGWB and SBWB, U.P is illustrated below.

3.11.1. Barabanki

In Barabanki, aquifers upto depth ranges 50 m are unconfined, and occur in alternation with clay layers. In wide extensive area upto depth range 50 m sand:clay ratio is 40:60, but the proportion of sandy strata is higher in Northern zones, and lower in Southern areas. In the North –East areas, the upper clay layer is thick, varying from 5 m to 40m, so the depth of potential aquifer is deeper. In South-Eastern areas, especially at Dariyabad, potential aquifers are at a depth of 50-70 m. Partially confined aquifers are interbedded in the clay layer (Figure 3.5).

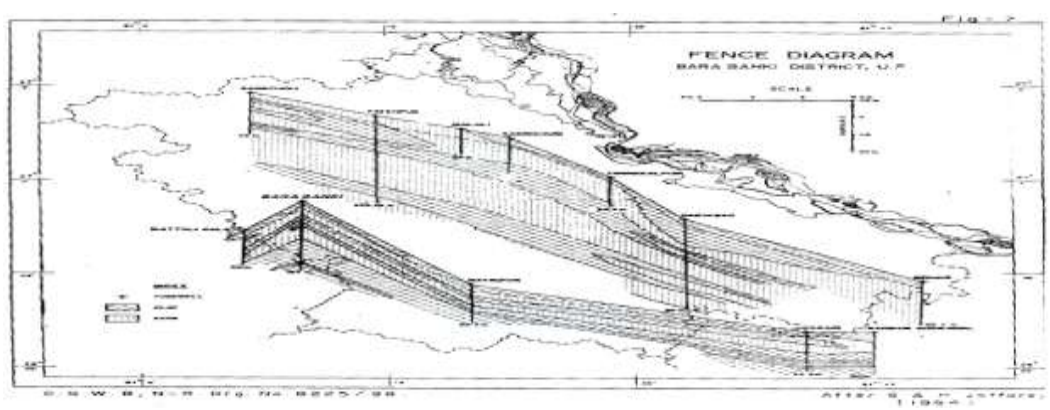

Figure 3.5: Fence Diagram for Barabanki

3.11.2. Jaunpur

The sub –surface geology of Jaunpur is more clay dominated. The thickness of the upper clay layer varies from 5 m to 30 m at Atardiha, Gairwa in north extremity. In north-zone, aquifers are of limited thickness, inter-layered with thick clay zones. They are partially confined and have saline ground water. In the southern part of the district, in Sikrara block, sand:clay ratio upto 50m depth is 45:55. The aquifer occurs at medium depth, is extensive laterally, with high potential for shallow tube wells. Deeper aquifers are partially confined, with thick clay layers. Groundwater quality is moderate to saline (Figure 3.6).

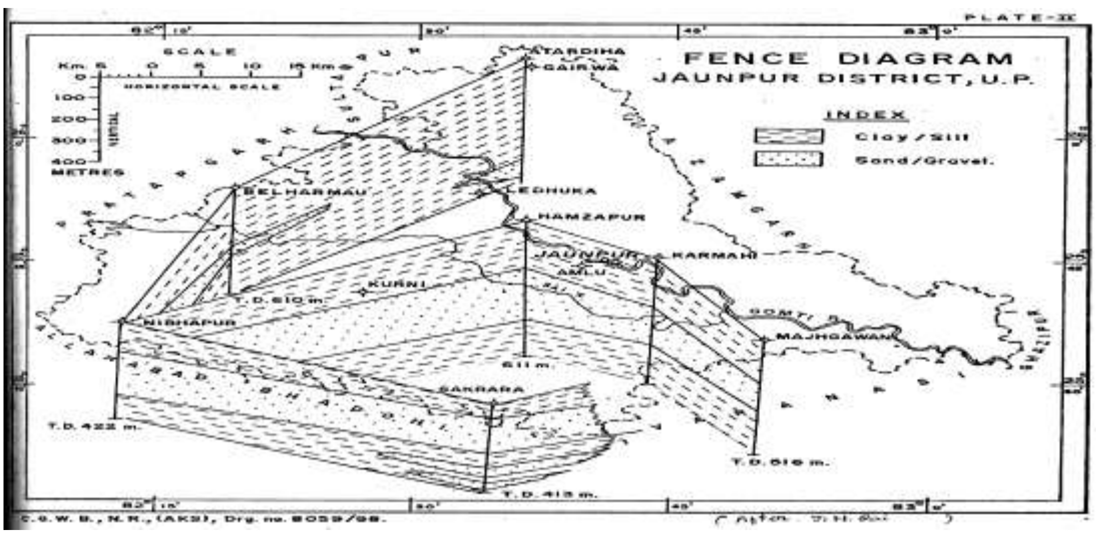

Figure 3.6: Fence Diagram for Jaunpur

3.11.3.Pratapgarh

The sub-surface geology of north-west areas, especially at Kandhari, shows the overlying clay layer being thick, with thin intercalation of sandy layers beyond the depth of 60 m. The thin aquifers are partially confined and the quality of groundwater is moderately saline. In North and Eastern areas, sand and clay strata occur in alternations and aquifers are of limited thickness, with moderate potential for shallow tube wells. Deep aquifers are partially confined, and have moderately saline ground water (Figure 3.7).

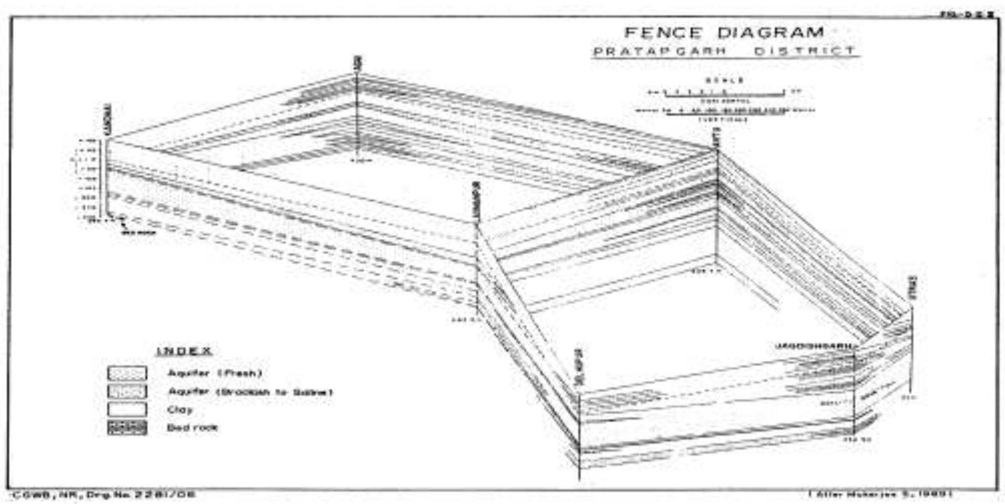

Figure 3.7: Fence Diagram for Pratapgarh

3.11.4-Raebareli

Sub-surface geology of Raebareli is more or less similar to Barabanki , having in general upto 50 m sand:clay ratio is 40: 60 . in North areas the sand layers upto 60-70percent in thickness. In South- Eastern areas the proportion of clay is comparatively high, causing deeper tube wells. The quality of groundwater is good for irrigation use (Figure 3.8).

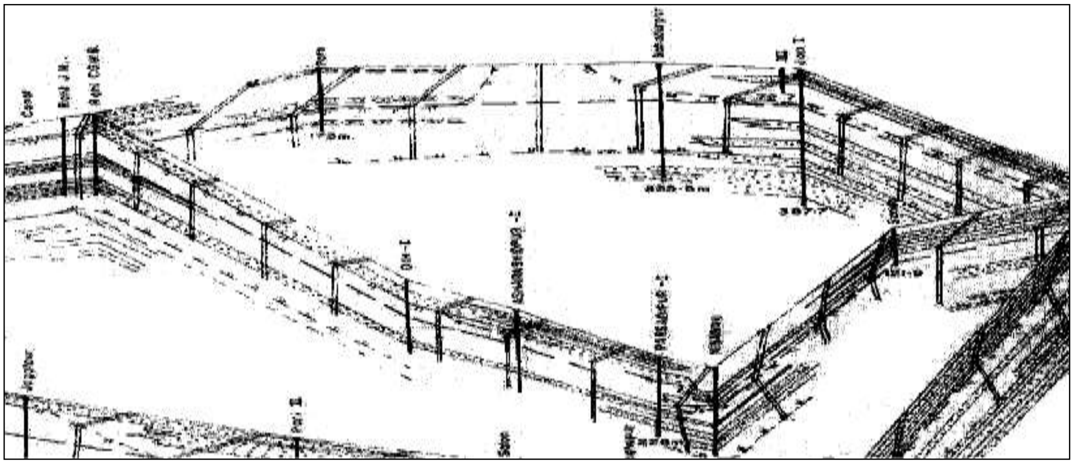

Figure 3.8: Fence Diagram for Raebareli

3.11.5.Sultanpur

The sub–surface geology is more or less similar to Jaunpur, dominated by clay lithology. In Southern and Western areas, a wide extensive thick clay layer occurs, varying in thickness from 5 m to 50 m , with thin intercalation of sandy zones (Bhadar). In general, the shallow aquifers are unconfined having good ground water. Deep aquifers beyond the depth of 70 m are partially confined. The thin semi-confined aquifers have moderately saline ground water (Figure 3.9).

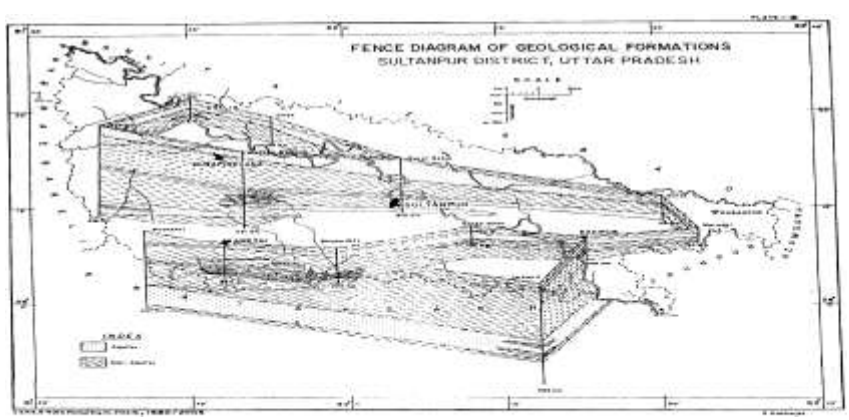

Figure 3.9: Fence Diagram for Sultanpur

3.12. Aquifer Parameters from Pumping Tests

The locations of the three pumping tests conducted by CGWB were at Amethi area in Sultanpur district, Indian Telephone Industries in Raebareli and Jagdishgarh in Pratapgarh district. The variation in lithology in these pumping tests for the top 50 m of depth are given in Table 3.2 to3.4.

Table 3.2: Koiripur, Bhadur and Amethi Areas - Dist Sultanpur

S. N	Depth Range in meters	Thickness	Lithology
1	0.00 - 16.27	16.27	Clay earthy mixed with varying amount of Kankar
2	16.27 - 19.27	6.88	Gravel and kankar (2 to 3mm) mixed with earthy sticky clay
3	19.277 - 26.15	6.88	Clay earthy mixed with varying amount of Kankar
4	26.15 - 44.30	18.15	Kankar (3 to 6 mm) mixed with earthy sticky clay (50%)
5	44.30 - 332.59	288.29	Clay earthy to yellowish brown, sticky mixed with sub-ordinate amount of kankar and medium to fine sand

Table 3.3: Indian Telephone Industries - II Dist – Raebareli

S. No	Depth Range in meters	Thickness	Lithology
1	00.00 - 20.65	20.65	Surface Soil - Silty clay
2	20.65 - 32.81	12.16	Kankar mixed with sand indurated greyish
3	32.81 - 44.81	12.00	Sand medium to fine grained greyish mixed with ferromagnesian minerals
4	44.81 - 54.04	9.15	Sand medium greyish mixed with kankar
5	54.04 - 76.96	22.92	Clay sticky and yellowish mixed with kankar

Table 3.4: Jagdishgarh Exploratory Dist – Pratapgarh

S. N	Depth Range in meters	Thickness	Lithology
1	0.00 - 3.00	3.00	Surface soil and clay yellowish
2	3.00 - 19.00	16.00	Clay sandy greyish fine grained
3	19.00 - 34.00	15.00	Sand fine grained
4	34.00 - 36.00	2.00	Clay plastic mixed with fine sand
5	36.00 - 41.00	5.00	Sand fine grained
6	41.00 - 45.00	4.00	Clay yellow sticky
7	45.00-52.00	7.00	Sand indurated greyish mixed with equal amount of clay
8	52.00 - 58.00	6.00	Sand indurated grayish
9	58.00 - 64.00	6.00	Clay silty
10	64.00 - 70.00	6.00	Clay yellowish

From the analysis of the Shallow aquifer in the aquifer test carried by Central Ground Water Board at Sultanpur area, it appears that silty–clay is the dominant lithology in this area, with the percentage of sand varying from 21%-50%. The aquifer is unconfined and the aquifer material varies from fine to medium sand with intervening clay beds and occasionally admixed with kanker.

At Raebareli, the shallow aquifer is under unconfined conditions and the aquifer material is pre-dominantly silty-sand, with occasional occurrence of kanker. About 27% of sand was found up to the depth of 76 m. The transmissivity and hydraulic conductivity calculated for this area for the 126 m thick shallow aquifer is 1656.2 m2/day and 13 m/day respectively.

In Pratapgarh, the sand percentage was higher than Raebareli and was found to be about 35% of the total sediment column up to the depth of 70 m. The other aquifer characteristics and parameters were found to be consistent with the above two districts.

The data from the ten pumping tests carried out by Ground Water Investigation Organization, U.P. in the Sultanpur and Raebareli districts further support the above findings. From the analysis of four pumping tests in Amethi, Teri, Ghoraha and Kadipur villages of Sultanpur districts, it appears that the lithology in this area varies from clay/silt to fine sand (Table 3.5, 3.6 & 3.7). The lithology of the shallow aquifer up to the depth of 60 m shows that dominant grain size is clay/sand with few sandy (fine sand) horizons. The lithological variations in the grain size for these villages are as follows:

Table 3.5: Village: Ghoraha, Block: Bhader - Dist Sultanpur

S.No	Depth Range (mbgl)	Thickness (m)	Lithology
1	0.00 - 4.00	4.00	Not recorded
2	4.00 - 6.50	2.50	Hard Clay
3	6.50 - 9.00	2.50	Clay
4	9.00 - 12.50	3.50	Clay & Kankar
5	12.50 - 13.50	1.00	Clay
6	13.50 - 17.00	3.50	Clay & Kankar
7	17.00 - 19.50	2.50	Clay
8	19.50 - 20.50	1.00	Clay & Kankar
9	20.50 - 22.50	2.00	Clay
10	22.50 - 26.50	4.00	Clay & Kankar
11	26.50 - 27.50	1.00	Clay
12	27.50 - 30.00	2.50	Clay & Kankar
13	30.00 - 31.50	1.50	Clay
14	31.50 - 37.50	6.00	Clay
15	37.50 - 40.00	2.50	Clay
16	40.00 - 47.00	7.00	Clay & Kankar
17	47.00 - 50.00	3.00	Clay
18	50.00 - 52.50	3.50	Sandy clay / medium sand clay
19	52.00 - 57.50	5.00	Medium sand
20	57.00 - 60.00	2.50	Clay

Table 3.6: Village: Amethi, Block: Amethi - Dist Sultanpur

S.No	Depth Range (mbgl)	Thickness (m)	Lithology
1	0.00 - 3.00	3.00	Not recorded
2	3.00 - 6.00	3.00	Surface clay
3	6.00 - 10.00	4.00	Sandy clay
4	10.00 - 12.00	2.00	Clay
5	12.00 - 16.50	4.50	Clay & kankar
6	16.50 - 19.00	2.50	Clay
7	19.00 - 23.00	4.00	Fine sand
8	23.00 - 28.00	5.00	Clay
9	28.00 - 36.00	8.00	Fine sand
10	36.00 - 38.50	2.50	Clay
11	38.50 - 43.50	5.00	Clay kankar
12	43.50 - 45.00	1.50	Clay
13	45.00 - 50.50	5.50	Clay & kankar
14	50.50 - 54.50	4.00	Clay

Table 3.7: Village: Teri - Dist Sultanpur

S.No	Depth Range (mbgl)	Thickness (m)	Lithology
1	0.00 - 3.04	3.04	Clay Sandy Brown
2	3.04 - 12.19	9.15	Clay Sandy
3	12.019 - 24.38	12.19	Sand, fine with clay blackish
4	24.38 - 39.57	15.19	Clay with sand yellow
5	39.57 - 42.67	3.1	Sand, fine, brown
6	60.96 - 88.29	27.33	Kankar with clay yellow

At Ghoraha village, the geophysical survey (electrical logs) conducted by GWIO, U.P. suggests that in the whole well section, the occurrence of sandy aquifer was very poor and if we consider the well section up to the depth interval to 60 m bgl then the main aquifer was only recorded between the depth interval of 52 m to 57.5 m bgl. On the whole, the section is dominated by clay with occasional patches of kanker.

In Amethi village the conditions are quite different. Here the main sandy aquifer occurs between the depth ranges of 19 m to 23 m and 28 m to 36 m bgl. However, here also whole section is dominated by clay and/with kanker.

In Teri village, the main aquifer in the shallow zone (up to 60 m bgl) ranges between 39 m to 60 m bgl. The section is dominated by silt/sandy clay. The average coefficient of transmissivity of the pumping test was found to be 1234 m2/day.

The infiltration test at Kadipur village, district Sultanpur suggests that the hydraulic conductivity in this area should be 3.43 cm/hr (0.8 m/d) and specific yield is about 9.0 %.

The lithological variations in the grain size for the six villages of Raebareli district are as follows (Table 3.8 to 3.12). (Source: Groundwater Investigation Organization, U.P.):

Table 3.8: Village: Jais Town; Block: Jais; Dist: Raebareli

S. No	Depth Range (mbgl)	Thickness (m)	Lithology
1	0.00 - 2.50	2.50	Sand Clay
2	2.50 - 7.50	5.00	Hard Clay
3	7.50 - 10.00	2.50	Clay
4	10.00 - 15.00	5.00	Silt to fine sand
5	15.00 - 20.00	5.00	Clay
6	20.00 - 30.00	10.00	Fine clay
7	30.00 - 37.50	7.50	Silty or fine sand with kankar
8	37.50 - 40.00	2.50	Clay
9	40.00 - 42.00	2.00	Silty or fine sand with clay
10	42.00 - 45.00	3.00	Silty to fine sand
11	45.00 - 50.50	5.50	Silty or fine sand with clay
12	50.50 - 53.00	2.50	Clay
13	53.00 - 60.50	7.50	Clay with Kankar

Table 3.9: Village: Dlawarpur; Block Deeh - Dist Raebareli

S. No	Depth Range (mbgl)	Thickness (m)	Lithology
1	2.00 - 8.00	6.00	Fine Sand
2	8.00 - 9.00	1.00	Clay
3	9.00 - 12.50	3.50	Sand Clay
4	12.50 - 15.00	2.50	Clay
5	15.00 - 17.50	2.50	Sand Clay
6	17.50 - 18.50	1.00	Clay
7	18.50 - 22.50	4.00	Fine Sand
8	22.50 - 26.50	4.00	Sand Clay
9	26.50 - 31.50	5.00	Fine Sand
10	31.50 - 34.50	3.00	Clay
11	34.50 - 39-50	5.50	Sand Clay
12	39.50 - 42.50	3.00	Clay
13	42.50 - 49.50	6.50	Fine Sand
14	49.00 - 51.00	2.00	Sand Clay
15	51.00 - 53.00	2.00	Fine Sand
16	53.00 - 58.00	5.00	Clay

Table 3.10: Village: Sarai Baheria Khera; Block Sareni - Dist Raebareli

S. No	Depth Range (mbgl)	Thickness (m)	Lithology
1	3.00 - 5.00	2.00	Hard Clay
2	5.00 - 13.00	8.00	Clay
3	13.00 - 15.00	2.00	Fine Clay
4	15.00 - 20.00	5.00	Silty Sand
5	20.00 - 23.00	3.00	Fine Clay
6	23.00 - 25.00	2.00	Silty fine Sand
7	25.00 - 29.00	4.00	Fine to Silty Sand
8	29.00 - 31.00	2.00	Clay
9	31.00 - 36.00	5.00	Clay with kanker
10	36.00 - 40.50	4.50	Clay
11	40.50 - 44.50	4.00	Kankar or fine sand with clay
12	44.50 - 54.50	10.00	Fine sand
13	54.50 - 66.50	12.00	Clay

Table 3.11: Village: Mohiddinpur; Block: Salon; Dist- Raebareli

S.No	Depth Range (mbgl)	Thickness (m)	Lithology
1	3.00 - 9.50	6.50	Fine to medium sand
2	9.50 - 13.00	3.50	Clay
3	13.00 - 17.00	4.00	Fine sand and kankar
4	17.00 - 18.00	1.00	Clay
5	18.00 - 24.50	6.50	Fine sand and kankar
6	24.50 - 26.50	2.00	Clay
7	26.50 - 32.00	5.50	Clay and kankar
8	32.00 - 34.50	2.50	Clay
9	34.50 - 44.50	10.00	Kankar and clay
10	44.50 - 47.00	2.50	Clay
11	47.00 - 50.50	3.50	Clay and kankar

Table 3.12: Village: Kaurapur Gaura; Block: Dih; Dist- Raebareli

S. No	Depth Range (mbgl)	Thickness (m)	Lithology
1	0.0 - 4.0	4.00	Surface clay
2	4.0 - 12.5	8.50	Sand Clay / fine sand with clay
3	12.5 - 15.5	3.00	Fine sand
4	15.50 - 23.0	7.50	Clay
5	23.0 - 28.0	5.00	Fine sand
6	28.0 - 30.5	2.50	Sand Clay
7	30.5 - 35.5	5.00	Fine sand with clay
8	36.5 - 37.5	2.00	Clay
9	37.5 - 39.0	1.50	Silt or sand clay
10	39.0 - 43.0	4.00	Clay
11	43.0 - 47.5	4.50	Fine to Med Sand
12	47.5 - 49.0	1.50	Sandy Clay
13	49.0 - 50.0	1.00	Pure Clay
14	50.0 - 53.00	3.00	Fine to Med Sand
15	53.0 - 56.0	3.00	Sand Clay

The pumping test analysis for the Jais Town suggests that the aquifer material is sand, kanker, clay and their admixtures. In the shallow aquifer (up to 60 m); clay was found to be the dominant grain size fraction. However, the major zone of granular composition occurs at the depth range of 20-37.5 m. This zone could be considered as a good groundwater bearing horizon and construction of shallow tube wells were recommended in the 20-30 m depth zone. At Dlawarpur village, the lithology was found to be sand, kanker, clay and their admixtures. The occurrence of sand starts right from the surface and continues up to the depth of 53 m bgl with interference of clay layers in between. The aquifers are occurring in the depth range from 18.5 m to 22.5 m, 26.5 m to 31.5 m and 42.5 m to 48.5 m. The pumping test at Sarai Baheria Khera suggests that the aquifer material in this village is dominantly silt, clay and fine sand with occasional occurrence of kanker. The Strata Chart prepared on the basis of log interpretation by the Groundwater Investigation Organization suggests that the major shallow aquifers occur at the depth range of 13- 29 m and 44.5-54.5 m bgl.

The electrical log interpretation of Mohiddinpur village suggests that the dominant grain size in this area is fine sand and clay with occasional occurrence of kanker in the clay layers. Clay is dominant in the top 50 m lithology. In Kaurapur Gaura village, the lithology mainly shows the dominance of fine sand, clay and their mixtures. Since the sand formations are mostly fine grained and are comparatively thinner, so it seems to comprise a poor aquifer. It is being also suggested by the Groundwater Investigation Organization that there is lack of potential water bearing zones suitable for large scale exploitation, up to their depth of investigation. However, the fine to medium sand zones are present at the depth range of 43-47.5 m bgl and 50-53 m bgl. Tahal[1] located two measurements of aquifer parameters in the shallow aquifer system in Sultanpur District. At Sultanpur Tehesil, Kurebhar Block, the transmissivity is

68.5 m2/day, Hydraulic Conductivity is 5.48 m/day and at Dhanpatganj transmissivity is 1,012 m2/day, Hydraulic Conductivity 14.6 m/day.

3.13-Hydraulic Conductivity:

With reference to the various available reports and strata charts from State Tube well drilling logs, the aquifer material was found to be more or less fine sand and thus a value of 15 m/day has been found to be appropriate to the conditions, the estimated recharge and prevailing water levels. The value was varied to 10, 20 and 30m/d for modelling purposes and is in conformance with the Central Ground Water Board (CGWB) norms.

3.14-Specific Yield:

The average value of 0.15 has been adopted as per recommendation of CGWB for various grains sized alluvial material in the Ground water estimation committee 1997 norms.

In the sensitivity testing of the developed Model, the testing was carried out for 0.10 and 0.20 to cover the range of grain size most commonly observed in the State Tube well logs.

3.15-Thickness of Aquifer:

From the CGWB report of 1996, the upper aquifer in Jaunpur, Sultanpur and Pratapgarh districts of the study area was stated to average 50 metres thickness. Review of State Tubewell logs and hydrogeological reports for each district showed that it is very difficult to define the unconfined (or phreatic) aquifer. This is because the alluvium consists of multiple inter-fingering layers of sand, silt and clay that are semi-continuous in the study area. However there does appear to be a consistent layer of clay about 20 m to 30 m thick.

In this groundwater modeling, we have focused on the interaction between the shallow phreatic aquifer and surface water (rivers, drains, soil moisture and recharge). Therefore, the model output of concern is the depth to groundwater level and the water balance between surface water and shallow groundwater. Deeper aquifers are of little consequence in this analysis as they do not significantly interchange with the unconfined aquifer in the study area.