CHAPTER - III

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INTRODUCTION


OCCURRENCE

It is generally agreed and understood that the characters of soil and weathered jointed / fractured horizons control the occurrence and movement of groundwater. The joints / fractures play an important role in the groundwater storage. The greywackes are the litho units in ANW and are less weathered. Because of their resistance nature, these are fractured and jointed. These secondary openings, greatly help for easy infiltration of surface water and further at depth storage of water to form aquifers. The litho units are devoid of original or primary openings. Thus, the groundwater occur under water table conditions i.e., phreatic conditions or under unconfined aquifer conditions. On the basis of hydrological properties the litho unit of ANW can be classified as consolidated formations. However, a small patch of alluvial near the confluence point of ANW with Tungabhadra river are found (alluvial deposits).

The large part of ANW is covered by reddish coloured grey soil. The soil is coarse grained and highly permeable in nature. Thus, suitable for easy infiltration of surface water or rainwater. This is followed by thick fractured zone. The thickness of fractured zones varies from place to place. Normally
first 10 to 30 mts weathered greywackes occur. This is followed by highly fractured greywackes. The highly fractured layer varies from 40 to 125 mts. This layer is followed by hard and compact greywackes. However, there are deep bore wells with 160 mts depth yielding less quantity of groundwater.

**WELL INVENTORY**

Recording of details about groundwater structures such as total depth of well, depth to water level, diameter, aquifers, and related information is included in well inventory. The study of characters of dug and bore wells is a prerequisite of all type of hydrogeological studies. In ANW the groundwater occurs under water table conditions as said earlier. Due to highly fractured and jointed nature of the greywackes of ANW the surface water infilters into deeper levels and is stored. Thus, the occurrence of groundwater at shallow depth i.e., less than 30 mts is not frequent. Hence, there are only a few dug wells in ANW. These dug wells are totally dry for last 10 – 15 years. This may be because of sinking of more number of bore wells. There are hundreds of bore wells in ANW sunk by many private agencies as well as government. Most of the bore wells are yielding water and used for domestic and agricultural purposes. Submersible electrical and normal electrical pumps are used to draft the groundwater. The hand pumps are also used to draw water from many of bore wells. These are normally public bore wells.

**ANALYSIS OF BORE WELL DATA**

The relation between depth and yield relations are studied by Gourshetty and Puranik (1997), Patil and Puranik (1990) and others. The study of depth, yield and casing of bore wells give an idea of about the availability of groundwater and economic depth of drilling around the particular study area. The details of bore wells like depth, yield, and casing, are obtained by consulting owner by owner of bore wells throughout ANW in respective villages. In this process 306 bore well data are obtained. The locations of bore wells studied are
shown in Fig. 3.1. The study of depth yield relations bore wells normally reveal following relations viz.,

A. Yield increase with depth.
B. Yield decrease with depth.
C. Yield remains the same on increase in depth.
D. Yield increase with the same depth.
E. No trend is seen.

Characters of depth and yield of bore wells

The depth and yield character of bore wells with respect to each village is described below.

Hullatti Tanda (Fig. 3.2)

This village is located in the eastern part of ANW. Seven bore well data is collected around this village. Generally the yield increases with depth i.e. relation A. Three of the bore wells show that yield remains same with increase in depth i.e. relation C.

Hullatti (Fig. 3.3)

This village is located in the northwest of Hullatti Tanda. Nine bore well data is collected around this village. Generally yield increases with same depth i.e., relation ‘D’.

Guddadanveri (Fig. 3.4)

This village is located in the eastern central part of ANW. Twenty bore well data is collected around this village. Generally yield remains the same with increasing in depth i.e. relation ‘C’. Seven of the bore wells show that yield increase with the same depth i.e. relation ‘D’.

Sidaganal (Fig. 3.5)

This village is located in the central part of ANW. Nine bore wells data is collected around this village. Generally the bore wells show that yield decreases with depth i.e. relation ‘B’.
Devaragudda (Fig. 3.6)

This village is located in northern part of Sidaganal village. Nine bore well data is collected around this village. Generally the yield decreases with depth i.e. relation 'B'. Seven of the bore wells show that yield remains same with increase in depth i.e., relation 'C'

Gudagur Tanda (Fig. 3.7)

This village is located in the northeast of Devaragudda village. Eight bore well data is collected around this village. Generally the yield remains the same with an increase in depth i.e. relation ‘C’. Three of the bore wells show that yield decreases with depth i.e. relation ‘B’.

Gudagur (Fig. 3.8)

This village is located in the northeast of Gudagur Tanda. Six bore well data is collected around this village and all the bore well show that yield increases with depth i.e. relation ‘A’.

Maidur (Fig. 3.9)

This village is located in south of Gudagur village. Only two bore well data is collected, around this village. The two existing bore wells show that yield increases with depth i.e. relation ‘A’.

Kajjari (Fig. 3.10)

This village is located in the central part of ANW. Five bore well data is collected around this village. Generally the yield decreases with depth i.e. relation ‘B’.

Haranagiri (Fig. 3.11)

This village is located in the northeastern part of ANW. Seven bore well data is collected around this village. Generally the yield decreases with depth i.e. relation ‘B’. Four of the bore well show that yield remains same with increase in depth i.e. relation ‘C’.

Honnatti (Fig. 3.12)

This village is located west of Haranguer village. Nine bore well data is collected around this village. Generally the yield remains same with increases
with depth i.e. relation 'C'. Three of the bore wells show that yield increases with depth i.e. relation 'A'.

**Hale Honnatti (Fig. 3.13)**

This village is located south of the Honnatti village. Four bore well data is collected around this village. Generally the yield decreases with depth i.e. relation 'B'.

**Kerimallapur (Fig. 3.14)**

This village is located south of the Hale Honnatti village. Seven bore well data is collected around this village. Generally the yield remains the same with an increase in depth i.e., relation ‘C’. Four of the bore wells show that yield increases with depth i.e., relation ‘A’.

**Chikkarlihalli (Fig. 3.15)**

This village is located in the northeastern part of the ANW. Eight bore wells data is collected around this village. Generally the bore wells show that yield decreases with depth i.e. relation ‘B’.

**Hosa Chandapur (Fig. 3.16)**

This village is located in the near confluence point of the ANW i.e. close to Tungabhadra River. Only two bore well data is collected from this village on the river water. The two bore wells show that the yield increases with the same depth i.e. relation ‘D’.

**Chikkuravatti (Fig. 3.17)**

This village is located in the northeastern part of the ANW. Only three bore well data is collected around this village. Generally the three bore wells show that yield decreases with depth i.e. relation ‘A’.

**Haranagiri (Fig. 3.18)**

This village is located south of the Chikkuravatti village. Four bore wells data is collected around this village. Generally all the bore wells show that yield increases with depth i.e. relation ‘D’.

**Kudrihal (Fig. 3.19)**

This village is located south of the Haranagiri village. Eleven bore wells data is collected around this village. Generally the bore wells show that yield
decreases with depth i.e. relation ‘B’. Two of the bore wells show that the yield remains same with increase in depth i.e. relation ‘C’.

Gangapur (Fig. 3.20)
This village is located in the eastern part of the ANW four bore wells data is collected around this village. Generally the bore wells show that yield increases with depth i.e. relation ‘A’.

Kunbevu (Fig. 3.21)
This village is located in the central part of the ANW. Seven bore wells data is collected around this village. Generally the bore wells show that yield decreases with depth i.e. relation ‘B’. Two of the bore well show that the yield remains the same with an increase in depth.

Kakol Tanda (Fig. 3.22)
This village is located in the western part of ANW. Eight bore wells data is collected around this village. Generally the bore wells show that yield increases with depth i.e. relation ‘C’. Four of the bore wells show that the yield increase with the same depth i.e. relation ‘D’

Kakol (Fig. 3.23)
This village is located south of the Kakol Tanda. Nine bore well data is collected around this village. Generally the bore wells show that yield decreases with depth i.e. relation ‘B’. Three of the bore wells show that the yield remains same with increase in depth i.e., relation ‘C’.

Hanumanamatti (Fig. 3.24)
This village is located in the central part of ANW. Eight bore well data is collected around this village. Generally the bore wells show that yield increases with depth i.e. relation ‘C’. Two of the bore wells show that the yield decreases with depth i.e. relation ‘B’.

Hosa Huliballi (Fig. 3.25)
This village is located west of the Kunbevu village. Seven bore wells data is collected around this village. Generally the bore wells show that yield increases with depth i.e. relation ‘C’. Three of the bore wells show that the yield increases with depth i.e. relation ‘A’.
Hulihalli (Fig. 3.26)
This village is located south of Hosa Hulihalli village. Six bore wells data is collected around this village. Generally the bore wells show that yield increases with depth i.e. relation ‘C’. Two of the bore wells show that the yield increases with depth i.e. relation ‘A’.

Chetra (Fig. 3.27)
This village is located northwest of Kakol Tanda. Nine bore wells data is collected around this village. Generally the bore wells show that yield increases with depth i.e. relation ‘C’. Four of the bore wells show that the yield increases with depth i.e. relation ‘A’.

Kadarmandalagi (Fig. 3.28)
This village is located in the western part of ANW. Nine bore wells data is collected around this village. Generally the bore wells show that yield increases with depth i.e. relation ‘C’. Two of the bore wells show that the yield increases with depth i.e., relation ‘A’.

Asundi (Fig. 3.29)
This village is located South of Kadarmandalagi village. Seven bore wells data is collected around this village. Generally the bore wells show that yield increases with depth i.e. relation ‘C’. Two of the bore wells show that the yield increases with depth i.e. relation ‘A’.

Lakmojikop (Fig. 3.30)
This village is located in the Southwest of ANW. Nine bore wells data is collected around this village. Generally the bore wells show that yield increases with depth i.e. relation ‘C’. Two of the bore wells show that the yield increases with depth i.e. relation ‘A’.

Ramagondanahalli (Fig. 3.31)
This village is located south west of Lakmojikop village. Nine bore wells data is collected around this village. Generally the bore wells show that yield increases with depth i.e. relation ‘C’. Two of the bore wells show that the yield increases with depth i.e. relation ‘A’.

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Bannihatti (Fig. 3.32)
This village is located south of Ramagondanahalli village. Nine bore wells data is collected around this village. Generally the bore wells show that yield increases with depth i.e. relation ‘B’. Two of the bore wells show that the yield increases with depth i.e. relation ‘C’.

Belakeri (Fig. 3.33)
This village is located south east of Barihatti village. Nine bore wells data is collected around this village. Generally the bore wells show that yield increases with depth i.e. relation ‘C’. Two of the bore wells show that the yield increases with depth i.e. relation ‘A’.

Ukkunda (Fig. 3.34)
This village is located southeast of Timmenahalli village. Eight bore wells data is collected around this village. Generally the bore wells show that yield increases with depth i.e. relation ‘C’. Two of the bore wells show that the yield increases with depth i.e. relation ‘A’.

Timmenahalli (Fig. 3.35)
This village is located east of Bisilahalli village. Nine bore wells data is collected around this village. Generally the bore wells show that yield decreases with depth i.e. relation ‘B’. Three of the bore wells show that the yield increases with depth i.e. relation ‘C’.

Bisilahalli (Fig. 3.36)
This village is located west of Timmenahalli village. Eight bore wells data is collected around this village. Generally the bore wells show that yield increases with depth i.e. relation ‘C’. Three of the bore wells show that the yield increases with depth i.e. relation ‘A’.

Kolhapur (Fig. 3.37)
This village is located in the southwest of ANW. Eight bore wells data is collected around this village. Generally the bore wells show that yield increases with depth i.e. relation ‘C’. Two of the bore wells show that the yield increases with depth i.e. relation ‘A’.
Anur (Fig. 3.38)

This village is located south of Kolhapur village. Ten bore wells data is collected around this village. Generally the bore well show that yield decreases with depth i.e. relation 'B'. Four of the bore wells show that the yield remains the same with an increase with depth i.e. relation 'C'.

From the above five relations it may be said that when the fractures and joints increases with depth, it results good yield. If the fracture and joints reduce with depth, it results in decrease in the yield with increase in depth. If the yield is nearly the same with increases in depth, it indicates that the aquifer is having uniform joints and fractures. If the yield varies with same depth it indicates that the aquifer is with the uneven joints and fractures. In some cases there is no relation between the yield, depth and lithology. This indicates complicated structures in the lithounits and an uncertain water bearing aquifer. The average values of depth, yield and casing depth of bore wells of each village are given in the table 3.3. The above discussion clarifies that the maximum depth of drilling should be between 70 to 130 mts for obtaining good yield of groundwater and this is economic depth of drilling in ANW.

Classification of Bore Wells

The bore wells are classified with respect to the depth, yield and casing (table 3.1 and 3.2). The study of these tables reveals the following points.

1. Sixteen percent of bore wells yield less than 1 lps, 70% of bore wells yield between 1 to 4 lps, and 15% of bore wells yield between 4 to 8 lps.
2. 62.42% of bore wells have depth of 70 to 110 mts and 9.9 percentage of bore wells have depth less than 70 mts. and 28% of bore wells have depth more than 110 mts.
3. 78.43% of bore wells have casing upto a depth of 10 mts., 18.95% of bore wells have a casing up to a depth of 20 m. 1.93% of bore wells have casing upto a depth of 25 m; and just 0.65% have casing more than 30 mts.
Percentage of bore wells in different depth range represented by histogram (Fig. 3.39). The Fig. 3.39 indicates that 28.43% of the bore wells have a depth range of 90 to 100 mts. 21.57% of bore wells have a depth range of 100 to 120 mts. 4.25% of bore wells have a depth range of 140 to 160 mts, just 32.68% of bore wells have a depth range of 70 to 100 mts.

Fig. 3.40 represents a bar diagram showing percentage of bore well with respect to casing. It indicates that about 78% of bore wells have less than 10 mts, casing. 19% of bore wells have 10 to 20 mts casing, 2% of bore wells have 20 to 30 mts casing and just 1% of bore wells have casing range from 30 mts to 40 mts. (Fig. 3.41) 16.01% of bore wells show yield less than 1 lps. 24.18% of bore wells show 1 to 2 lps, 30.06 % of bore wells show 2 to 3 lps, 15.03 % bore wells show 3 to 4 lps and 14.6 % show more than 4 lps.

**Contour Maps of Depth And Yield of Bore Wells**

The contour map of depth of bore wells and the contour map of yield of bore wells in ANW are shown in Fig. 3.42 and 3.43 respectively. These are prepared to know the locations of high yielding and low yielding area in ANW with respect depth of bore wells. These two figures reveal following points:

1. The yield of bore wells is 2 to 4 lps in the southern part.
2. The yield of bore wells is 1.5 to 5 lps in the central part.
3. The yield of bore wells is 3 to 6 lps in the northern part.
4. The depth of bore wells is 50 to 110 mts in the southern part
5. The depth of bore wells is 80 to 120 mts in the central part
6. The depth of bore wells is 80 to 125 mts in the northern part

On comparing or over lapping contour map of yield of bore wells with the lineament map it is found the areas showing high yield are close to the lineaments and the areas showing low yield are away from the lineaments. In the northern most part of ANW the concentration of contours show high yielding area. This may be due to the confluence point of ANW with Tungabhadra River.
The concentration of contours in north central part again shows high yielding area. At this location there are more number of lineaments. Similarly, the concentration of contours in the east central part also shows high yielding area with cross cutting lineaments. Widely distributed contours in the southern and western part shows low yielding area. In the southern and western part of ANW the drilling depth is shallow. This depth of drilling may be because of low yield. The drilling depth is slightly more in the central northern part with good yield of bore wells. Thus, there is good and positive relation between yield and lineament. There is no direct relation between drilling depth and yield.

RELATION BETWEEN BORE WELL YIELD AND LINEAMENTS

The lineaments help in natural recharge and indicate the possibility of groundwater potential zones. The lineaments are structural signatures on the ground. As said earlier ANW has hard rock formations (greywackes) exhibiting numerous lineaments criss-crossing each other (Fig. 3.44). In order to know the relation between lineaments and yield of bore wells 13 locations are chosen which are close to lineaments or on lineaments and 11 locations are chosen which are away from lineaments. The table on next page gives the list of villages close to the lineaments along with number of bore wells in the village, average yield and average depth of bore wells. The table on next page gives the list of villages away from the lineaments along with number of bore wells in the village, the average yield and average depth of bore wells. The bore wells close to the lineaments or on the lineaments yield more and those away from the lineaments yield comparatively less of water. However there are exceptions. For example near Guddadanveri village there are as many as 20 bore wells. Their average yield is 2.26 lps. There are many lineaments around this village. Near Gudagur village there are as many as 10 bore wells. Their average yield is 6.30 lps. There are only a few lineaments around this village.

The above explanation reveals that the bore wells near the vicinity of lineaments show more yield than those away from the lineaments. The high
yield of bore wells adjacent to lineament may be attributed to the availability of numerous secondary opening for the storage of groundwater. It could be said that the locations closer to the lineaments are the potential areas / zones for future groundwater exploration and exploitation.

Further, three locations are selected in the northern most part of ANW, where alluvial formations are encountered. Here the yield and depth of villages viz., Kudrihal, Chikkuravatti and Hosa Chandapur are noted and given in table next page. All these localities show very high yielding bore wells i.e., 3 to 8 lps. Here depth of drilling is shallower. The yielding bore wells may be attributed to their locations close to confluence point and alluvial formations.

Bore wells locations nearer to lineaments:

<table>
<thead>
<tr>
<th>Sl.No.</th>
<th>Location of the villages nearer to lineaments</th>
<th>Total number of bore wells</th>
<th>Ave yield in (lps)</th>
<th>Ave depth in (mts)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Chikkaralihalli</td>
<td>8</td>
<td>1.47</td>
<td>83.33</td>
</tr>
<tr>
<td>2</td>
<td>Gudagur</td>
<td>6</td>
<td>3.25</td>
<td>130.2</td>
</tr>
<tr>
<td>3</td>
<td>Maidur</td>
<td>3</td>
<td>2.20</td>
<td>98.96</td>
</tr>
<tr>
<td>4</td>
<td>Sidaganal</td>
<td>9</td>
<td>6.39</td>
<td>60.6</td>
</tr>
<tr>
<td>5</td>
<td>Guddadanveri</td>
<td>20</td>
<td>2.26</td>
<td>106.06</td>
</tr>
<tr>
<td>6</td>
<td>Chetra</td>
<td>10</td>
<td>4.98</td>
<td>87.4</td>
</tr>
<tr>
<td>7</td>
<td>Kakol</td>
<td>8</td>
<td>2.39</td>
<td>101.94</td>
</tr>
<tr>
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<td>Kajjari</td>
<td>5</td>
<td>4.84</td>
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<td>11</td>
<td>Siddapur Tanda</td>
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<td>3.25</td>
<td>101.64</td>
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<tr>
<td>12</td>
<td>Gangapur</td>
<td>11</td>
<td>4.98</td>
<td>98.48</td>
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</table>
### Bore wells locations away from lineaments:

<table>
<thead>
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<th></th>
<th>Location</th>
<th>Distance</th>
<th>Depth</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Gudagur Tanda</td>
<td>10</td>
<td>6.30</td>
</tr>
<tr>
<td>2</td>
<td>Devaragudda</td>
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<td>1.47</td>
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<td>Bannihatti</td>
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<tr>
<td>4</td>
<td>Bisalhalli</td>
<td>9</td>
<td>2.12</td>
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<td>5</td>
<td>Belakeri</td>
<td>9</td>
<td>2.41</td>
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<td>6</td>
<td>Hosahulihalli</td>
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</tr>
<tr>
<td>7</td>
<td>Hulihalli</td>
<td>9</td>
<td>1.99</td>
</tr>
<tr>
<td>8</td>
<td>Basalikatti Tanda</td>
<td>5</td>
<td>2.01</td>
</tr>
<tr>
<td>9</td>
<td>Ranebennur</td>
<td>10</td>
<td>2.12</td>
</tr>
<tr>
<td>10</td>
<td>Hale Honnatti</td>
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<td>Honnatti</td>
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<td>Kakol Tanda</td>
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</tr>
<tr>
<td>13</td>
<td>Hullatti</td>
<td>9</td>
<td>1.05</td>
</tr>
</tbody>
</table>

### Bore wells locations nearer to confluence point of Tungabhadra River (ANW):  

<table>
<thead>
<tr>
<th></th>
<th>Location</th>
<th>Distance</th>
<th>Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Kudrihal</td>
<td>13</td>
<td>4.95</td>
</tr>
<tr>
<td>2</td>
<td>Chikkuravatti</td>
<td>4</td>
<td>3.25</td>
</tr>
<tr>
<td>3</td>
<td>Hosa Chandapur</td>
<td>2</td>
<td>8.18</td>
</tr>
</tbody>
</table>

### GROUNDWATER LEVEL FLUCTUATION

Mayer (1960) and Kohout (1961) have suggested following parameter that control the change in groundwater levels:

1. Changes in groundwater storage atmospheric pressure
2. Deformation of aquifers.
3. Disturbance within the wells
4. Chemical and thermal changes near the wells.
Karanth (1987) has proposed following parameters that control the change in groundwater levels.

1. Climate
2. Drainage
3. Topography
5. Density of vegetation
6. Soil permeability proximity of water level to the ground surface.
7. Specific yield of the formation.

In the present study groundwater level data of four stations in ANW are collected from Department of Mines and Geology Office, Dharwad. The four stations are Asundi, Honnatti, Ranebennur and Chetra (Fig. 3.45). Asundi, station is in the southwestern part, Honnatti Station is in the northern part, Ranebennur station is in the southeastern part and Chetra station is in the northwestern part of ANW. The water level data of pre and post monsoon are collected for all four stations. The water level data (pre and post monsoon) for 27 years is available for study (1976 – 2002). This data is presented in table 3.4.

**Water Level Fluctuation with respective stations**

**Asundi Station Data**

The data of water level fluctuation is available for 14 years. From 1976 – 1983 the water level fluctuation is 3 to 4 mts. In 1979 the fluctuation is 1.08 mts and in 1989 and 1990 it is 1.90 mts. From 1993 – 1994 the fluctuation is 0.85 mts and 0.20 mts respectively. The variation diagram of water level fluctuation for Asundi station (Fig. 3.46) indicates that the fluctuation is upto 5 mts.

**Honnatti Station Data**

The data of water level fluctuation is available for 5 years. From 1979 to 1983 the fluctuation is 0.22 to 1.99 mts. In 1978 it is 6.81 and in 1976 it is 3.10. The fluctuation for Honnatti Station (Fig. 3.47) indicates that the fluctuation is low before 1992 and the fluctuation is very high after 1989.
Ranebennur Station Data

The data of water level fluctuation is available for 24 years. From 1976 – 1989 the fluctuation is 2 to 4 mts. In 1987 the fluctuation is 7.33 mts. The fluctuation is too low in 1985 i.e., 28 mts in 1989 it is 0.37 mts. After 1993 till 2002 the fluctuation is from 4 to 13 mts. The variation diagram of water level fluctuation for Ranebennur station (Fig. 3.48) indicates that the fluctuation is low before 1989 and is very high after that till 2002.

Chetra Station Data

The data of water level fluctuation is available for 12 years. From 1976 – 1988 the fluctuation is upto 5 mts. In the years 1976, 1980, 1984, 1988, 1990, 1996 and 1999 the fluctuation is less than one. In the years 1989, 1991, 1992 and 2000 the fluctuation is more than 7 mts. The variation diagram of water level fluctuation for Chetra station (Fig. 3.49) indicates that the fluctuation is low before 1988 and is very high after that till 2002.

Government of Karnataka, Minor Irrigation Department in the year 1989 – 90 – 91, took up the development of ANW. Constructing check dams/barriers and plugging gullies performed this. The above explanations regarding water level fluctuations in four stations clearly reveal that three stations except Asundi station show wide fluctuation. This may be related to the construction of barriers and check dams at various places in ANW. By withholding of surface water from flowing has caused more infiltration into the subsurface and has charged aquifer system.

Contour maps showing water level fluctuations


Water level fluctuation in 1976 (Fig. 3.50)

The fluctuation is high as 4 mts around Asundi village and it is as low as 1.6 mts around Ranebennur town. Towards north the fluctuation is around 0.4 mts near Chetra village while in the extreme north i.e., it is 3 mts (Honnatti village). There are 4 mounds developed around above said four locations.
Water level fluctuation in 1980 (Fig. 3.51)
The fluctuation is as high as 4.2 mts around Asundi village and as low as 0.8 mts near Chetra village. The fluctuation is 2 to 2 – 6 mts in the eastern part of the ANW. There are 2 mounds developed around Chetra and Asundi village.

Water Level Fluctuation In 1983 (Fig. 3.52)
The fluctuation is as high as 3.6 mts around Asundi village and it is less than 2 mts in other part of ANW. There is only one mound developed around Asundi village.

Water level fluctuation in 1989(Fig. 3.53)
The fluctuation is as high as 6.5 mts around Chetra village and it is 2.5 mts near Asundi village. It is less than 1.5 in other part of ANW. There is only one mound developed around Chetra village.

Water level fluctuation in 1993 (Fig. 3.54)
The fluctuation is as high as 4.8 mts around Ranebennur town. It is 2.2 to 2.6 mts in northern part of ANW. In the central part of ANW the fluctuation it is 1 to 4.2 mts. There is only one mound developed around Ranebennur town.

Water level fluctuation in 1995 (Fig. 3.55)
The fluctuation is as high as 12 mts in the northern part i.e. near Honnatti village. It is as low as 2 mts around Chetra village and 5 mts around Asundi village and Ranebennur town. There is only one mound developed around Chetra village.

Water level fluctuation in 1999 (Fig. 3.56)
The fluctuation is as high as 12.8 mts around Ranebennur town and as low as 0.8 mts around Chetra village. The fluctuation is 10 to 3 mts in the rest of ANW. There is only one mound developed around Ranebennur towns.

Water level fluctuation in 2002 (Fig. 3.57)
The fluctuation is as high as 12 mts around Ranebennur town. It is about 3.5 to 4 mts with Chetra and Honnatti village. Around Asundi village it is around 7.5 mts. There is a partial mound developed around Ranebennur town.

The above explanation clearly shows that there is a wide variation in the fluctuation of water level in ANW for last 27 years. This may be attributed to the
erratic rainfall and differential recharge of aquifers. In addition to this the construction barriers to stop free flow of surface water has definitely contributed to the aquifer system in raising the water levels in ANW.

Water Table Contours

The study of subsurface movement of groundwater can be visualized by preparing water table contour maps. The water table contour maps for ANW are prepared considering water level recorded in the previous year by Department of Mines and Geology, Government of Karnataka. The water table contour maps (Fig. 3.58 to 3.65) are prepared for the years 1976, 1980, 1983, 1989, 1993, 1995, 1999, and 2002 based on table 3.5. All the water table maps show similar behavior of subsurface movement of water. There is a groundwater table mound in the northwestern corner of ANW water samples. Here the flow lines are diverging in all direction. This area forms the zone of recharge. There is another partial around in the northern most part of ANW. Here the flow lines are converging towards centre. This indicates that this part of ANW is discharge area. The subsurface flow of water is from northwestern corner towards southeast, from west to southeast, from center towards east and northeast and towards north. This behavior of subsurface movement is similar to the surface flow direction of varies streams of ANW.

The spacing of water table contours is closer in northern part compared to those in the southern part. This indicates the hydraulic gradient is slightly more in the northern part than in the southern part. The hydraulic gradient varies from 0.016 to 0.028 mts/kms. The behaviors of water table contours of ANW indicate that the subsurface structures are evenly spaced and there is little variation in the opening within the greywackes. Earlier it is said that the construction of barrier for various streams in ANW to store water and recharge groundwater has shown more fluctuation in the water level. Even after construction of barrier the flow directions and the hydraulic gradients remains same. This supports the evenly spaced opening within greywackes for storage and movement of groundwater.