CHAPTER 6
GROUND WATER AND ITS QUALITY

6.1 INTRODUCTION

Ground water exists wherever water percolates below land surface and reaches the saturated zone in depth. As such ground water is a replenishable and dynamic natural resource widely distributed on the earth. In fact the largest source of fresh water lies underground and it accounts for 97 per cent of the fresh water if glaciers are excluded.

The arid and semi-arid regions depend more upon ground water for major part of the water requirements, as in such climates generally surface water resources are very meager and surface storage of water results in heavy losses through evaporation. In semi-arid region like Chitravathi basin for having a reliable agricultural sector though limited in spatial extent, for getting adequate drinking water and even for the development of the industrial sector the available ground water resources need to be investigated and developed on scientific lines.

6.2 THE ADVANTAGE OF GROUND WATER

In semi-arid and arid regions water loss through evaporation will be heavy which is to be considered and this heavy evaporation loss emphasizes the need for underground storage than the surface storage to minimize the evaporation losses in semi-arid and arid climates. So, the emphasis should be on construction of percolation dams in large number at micro-basin level in conjunction with the storage tanks and dams on medium and large basins. This clearly helps in restoring and maintaining the ecological balance. The advantages of ground water against surface water springs are (i) it is stored in the excellent storage tanks created by nature itself (ii) the storage does not cost anything (iii) it does not create the problems of siltation, evaporation losses and alkalinity (iv) it does not create the problem of water logging (v)ground
water is usually found in its purest natural form unless contaminated by the man’s activities, (vi) the problem of pollution and contamination is less when compared to surface water, though in the long run it is also prone to pollution if proper preventive measures are not undertaken.

6.3 AQUIFER CHARACTERISTICS IN CHITRAVATHI BASIN

Various factors like morphological features, drainage, rock types and structural characteristics of the rocks and land use pattern influence the occurrence and distribution of ground water. A detailed account of these factors are given here with the help of topographical maps, geological maps, reports of the State and Central Ground water Departments. The quality aspect of the ground water is also discussed in detail based on the water analysis data collected from the Rural Water Supply (RWS) Department.

Permeable water bearing geological formations are known as aquifers. Water enters a ground water reservoir from natural precipitation of artificial means through seepage from reservoirs, tanks and irrigation waters. The ground water flows out by gravity through wells. The quality of water stored and the rate of flow depend on the nature of geological formations.

As already discussed in detail (Chapter 3) the geological formations of the Chitravathi basin can be broadly divided into three distinct and well marked groups’ viz., the old group of Archaean crystalline rocks, the younger group of pre-cambrian sedimentary rocks and the recent forms of alluvium and colluviums. Archaeans consists of peninsular granites, granitic gneisses and dharwar schists and phillites. The Precambrian sedimentary rocks include Cuddapah and Kurnool formations which comprise shales, limestones and quartzites with conglomerates.
6.4 GROUND WATER CONDITIONS IN VARIOUS FORMATIONS

6.4.1 Ground water conditions in granites and granitic gneisses

These geological formations occupy nearly 70 per cent of the area of the basin. Ground water in these formations mainly occurs in weathered, fractured and jointed layers and occurs under water table and semi confined conditions. These crystalline rocks are hard and compact lacking in primary porosity and permeability. They attain water bearing and water yielding properties with the development of secondary porosity and permeability by weathering and fracturing. The occurrence and movement of ground water in these is dominantly controlled by (i) the degree and depth of weathering, jointing and fracturing (ii) the degree of development of interconnections of these secondary openings, and (iii) the topography. These water bearing characteristics in crystalline rocks found to vary from place to place. From the point of view of ground water development, the vertical and inclined joints are more important, than the sheet of near horizontal joints. The depth of weathering generally varies from less than a meter close to rock out crops to about 20 m. in valleys. The depth at which the joints or fractures present in these rocks is found to vary from 25.0 to 60.0 m.

The dyke rocks in this region are also highly weathered and fractured as granitic rocks. At places the fresh dykes are acting as barriers of ground water flow resulting in good ground water supply on upper side and poor ground water supply on the lower side.

Ground water in granitic rocks is developed by means of dug wells, dug-cum-bore wells and by bore wells both for irrigation and drinking purposes. The studies by the state and central ground water Departments have revealed that the depth of open wells in these formations vary from 6.0 m. to 21.0 m. and the depth to water levels vary
from 5.0 to 18.0 m. The aquifer performance tests conducted on dug wells with varied thickness of weathered zone have indicated that the transmissibility value varies from as low as low as 9.87 to 60.8 m\(^3\)/day/m and the specific capacity ranges from 0.039 to 0.462 m\(^3\)/m/m and the rate of inflow factor varies from 0.00039 to 0.002187 m\(^3\)/m\(^2\).

Dug wells generally yield between 4500 and 22500 lph with irrigation capacity of 0.4 to 2.0 hectares. During the summer which precedes the monsoon, most of the dug wells in weathered portion get dried up. Granitic areas with predominance of fractures and joints and with pegmatites and quartz veins are found to be more favorable for dug-cum-bore wells. The in-well bores vary in depth from 15 to 25 m. The yields of in-well bores vary from 2.250 to 18,000 lph and sustain for continuous pumping. The irrigated area varies from 0.8 to 4.0 hectares. The depth of bore wells vary from 25 m. to 70 m. with yields ranging from 4500 to 50,000 lph. The high yields are mostly in bore well areas located along major linear fracture zones and have irrigation potential up to 20 hectares.

6.4.2 Ground water in Dharwar formations

Dharwar formations in the study region occur in narrow linear bands and occupy about 5 per cent of the total basin area. Ground water in these formations occurs under water table and semi-confined conditions in weathered, fractured and jointed portions. The movement of water is controlled by schistose planes. Dharwar formations are generally poor aquifers in the study region as they occupy high lands with thin soil cover and with moderate to poor recharge conditions.

6.4.3 Ground Water in Sedimentary Rocks and quartzites

The ground water potentiality of these formations is very low as they are hard and compact. These are very resistant to both chemical and physical weathering. It is generally believed that quartzites do not store any significant amount of water in their
joints as they are usually compact and tightly jointed. However at the contact with the younger rocks ground water occurs in water table conditions.

**Limestones**

The limestones in the study region belong to the Narji stage of the Jammalamadugu series. These are fine grained, massive and bedded. They occur as dolomite limestones, silicious limestones and as shales. They are intruded by basic sills at places. The weathered material contains limekankar. Ground water occurs under water table conditions in the joints, fractures, bedding planes and in cavernous zones. The studies by Ground Water Department showed that the dug wells vary in depth from 7 to 18 m and water levels between 6 to 13 m. Generally the yield ranges from 6750 lph to 25000 lph and irrigated area varies from 0.6 to 2.2 hectares. In-well bores and irrigated bore wells are also highly successful in these formations. The yield from irrigation bore wells ranges very widely from 10,000 to 54,000 lph. The high yields are associated with cavernous and creek joints. It is reported that near Yellanuru there is a sudden fall of the drill pipe at several places indicating cavernous conditions in the limestone formations.

**Shales**

The shales of this region belong to Tadipatri stage of Chitravathi series (Cuddapah) and Auk stage of the Jammalamadugu series (Kurnools). These formations comprise calcareous shales, shales and slates. At places they are intruded by basic sills and have undergone compaction and metamorphism. The primary porosity and permeability of the rocks depend upon degree of metamorphism and percentage of calcareous material. They trend generally in north-west-south-east direction with dips of 20° to 40° towards north-east. The shales of Tadipatri stage are highly calcareous nature. At places these have developed cavernous conditions and
form good aquifers. The occurrence and movement of groundwater in these formations are controlled by the calcareous nature, degree of compactness, intensity of weathering, nature and number of bedding and joint planes. The studies by ground water department showed that the depth of the wells in these formations, vary from 6 m to 17 m. and at some places it is as high as 21 m. The depth to water levels varies from 5 m. to 14 m. The dug wells generally yield between 4500 to 25,000 lph with irrigation potential of 0.4 to 2.0 hectares. In-well bores of depth ranging from 16 m to 28 m usually have good yields. The irrigation bore wells with depth range of 30 m to 60 m. have yields ranging from 13,500 to 27,000 lph with 5 to 8 hectares of irrigation capacity.

**6.4.4 Ground water in the recent formations**

These formations include the alluvial and colluvial (valley fill) deposits along the main stream courses like Chitravathi and Maddileru. Though the valley fills occur along all the major streams, their areal and vertical extent is limited. The areal extent varies from a few meters along the small streams to more than a kilometer in the lower course of the Chitravathi River. The thickness of the alluvium varies from 4 m to 20 m. and at some places in the lower Chitravathi it is as high as 30 m. Ground water is developed through shallow ring-wells and filter points with yields ranging from 13500 lph to 36000 lph. The yields from the shallow tube-wells with depth range of 8 to 10 m. range from 27000 to 45000 lph and sustain for continuous pumping. The irrigation capacity ranges from 10 to 12 hectares of irrigated dry crops.

**6.5 GROUND WATER POTENTIAL AND UTILISATION**

Ground water potential estimated by the State Ground water department and utilisation data (mandal wise) prepared by the same Department are collected. For calculating the sub basin wise utilisation the part of the sub basin falling in a
particular mandal is assumed to have the same proportion of utilisation. The aggregate is prepared by summing the total estimated utilisation for different parts of the basin falling under different mandals. Sub basin wise estimated ground water potential and utilisation are shown in table 6.1.

Table 6.1 Estimated ground water potential and utilisation

<table>
<thead>
<tr>
<th>Sub basin No</th>
<th>Estimated ground water potential (Mcum)</th>
<th>Estimated utilisation (Mcum)</th>
<th>% of utilisation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>57.44</td>
<td>15.82</td>
<td>27.6</td>
</tr>
<tr>
<td>2</td>
<td>31.55</td>
<td>8.58</td>
<td>27.2</td>
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<td>3</td>
<td>22.58</td>
<td>5.62</td>
<td>24.9</td>
</tr>
<tr>
<td>4</td>
<td>33.56</td>
<td>9.73</td>
<td>29.0</td>
</tr>
<tr>
<td>5</td>
<td>65.18</td>
<td>13.98</td>
<td>21.5</td>
</tr>
<tr>
<td>6</td>
<td>41.74</td>
<td>12.10</td>
<td>29.0</td>
</tr>
<tr>
<td>7</td>
<td>33.02</td>
<td>7.26</td>
<td>22.0</td>
</tr>
<tr>
<td>8</td>
<td>20.03</td>
<td>5.80</td>
<td>29.0</td>
</tr>
<tr>
<td>9</td>
<td>38.89</td>
<td>8.55</td>
<td>22.0</td>
</tr>
<tr>
<td>10</td>
<td>57.22</td>
<td>16.42</td>
<td>28.7</td>
</tr>
<tr>
<td>Total basin</td>
<td><strong>401.21</strong></td>
<td><strong>103.86</strong></td>
<td><strong>25.9</strong></td>
</tr>
</tbody>
</table>

The estimated ground water potential of the Chitravathi basin is 401.21 Mcum of which 103.86 Mcum is utilised leaving an unutilised quantity of 297.35 Mcum. The utilised quantity accounts for only 25.9 per cent of the potential ground water resources. At sub basin level the utilisation of ground water potential varies from 5.62 Mcum in the Nagasamudram Vanka to 16.42 Mcum in the Lower Chitravathi basin. The level of utilisation is less than 30 per cent in all the basins and it varies from 21.5 per cent in the upper Maddilieru sub basin to a maximum of 29 per cent in the Paleteru and Lower Maddileru sub basins. This is mainly because of the cropping
pattern which is dominated by rainfed groundnut crop with 85 per cent of the gross
cropped area.

6.6 FLUCTUATIONS OF WATER TABLE IN CHITRAVATHI BASIN

Ground water exploitation is highly localized and is mostly confined to the buried
pediments. Because of this localized exploitation, though only about 25 per cent of
the ground water potential is tapped, the ground water table fluctuates very widely in
these zones. It is in these zones, irrigated cropping is concentrated and also the Rabi
crop, which is dominated by irrigated paddy and irrigated groundnut crops. Water
table rises and falls very quickly depending on the monsoon rainfall and the
magnitude of water table fluctuation, depends on the success of the monsoon.

Monthly rainfall values (mm) and water table depth (m) below ground level (bgl)
for selected places like Tanakallu, Penukonda, Siddarampuram, kothcheruvu,
Jonnalakothapalli, and Dharmavaram are collected from Ground water Department
and comparative graphs are drawn for the said places as shown in Graphs 6.1(a),
6.1(b), 6.1(c), 6.1(d), 6.1(e) and 6.1(f).

Fig. 6.1 (a) Monthly Fluctuations in Water Table and Rainfall at Tanakallu
Fig. 6.1(b) Monthly fluctuations in water table and rainfall at Penukonda

Fig. 6.1 (C) Monthly fluctuations in water table and rainfall at Siddarampuram
Fig. 6.1 (d) Monthly fluctuations in water table and rainfall at Kothacheruvu

Fig. 6.1 (e) Monthly fluctuations in water table and rainfall at Jonnalakothapalli
Fig. 6.1 (f) Monthly fluctuations in water table and rainfall at Dharmavaram

The water table fluctuations are studied through (1) comparative graphs of the monthly water table levels and monthly rainfall values shown in graphs 6.1(a) to 6.1(f) and (2) by the analysis of water table levels and the maximum fluctuation of water table during the decade 1996-2005 in 30 observation wells of the state ground water department spread over the entire basin shown in Table 6.2.

Table 6.2  **Ground water table fluctuation during the decade 1996-2005**

<table>
<thead>
<tr>
<th>Basin No./o.b well Location</th>
<th>Depth to water Table (bgl)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Well Depth(m)</td>
</tr>
<tr>
<td>1.Upper Chitravathi</td>
<td></td>
</tr>
<tr>
<td>1. Sattaria Palli</td>
<td>7.85</td>
</tr>
<tr>
<td>2. Vanavolu</td>
<td>13.50</td>
</tr>
<tr>
<td>3. Buddili</td>
<td>10.68</td>
</tr>
<tr>
<td>4. Puttapparthy</td>
<td>8.50</td>
</tr>
<tr>
<td>5. Kothacheruvu</td>
<td>10.50</td>
</tr>
<tr>
<td>6.Vengalamma Cheruvu</td>
<td>10.5</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>2. Vangaperu</td>
<td></td>
</tr>
<tr>
<td>1. Pedaballi</td>
<td>15.63</td>
</tr>
<tr>
<td>2. Settipalli</td>
<td>11.28</td>
</tr>
<tr>
<td>3. Buchalahgari palli</td>
<td>12.62</td>
</tr>
<tr>
<td>4. Kadapagani palli</td>
<td>11.0</td>
</tr>
<tr>
<td>3. Nagasamudram Vanka</td>
<td></td>
</tr>
<tr>
<td>1. C.K.Palli</td>
<td>10.78</td>
</tr>
<tr>
<td>2. Tummala</td>
<td>8.40</td>
</tr>
<tr>
<td>3. Dharmavaram</td>
<td>12.25</td>
</tr>
<tr>
<td>4. Paletteru</td>
<td></td>
</tr>
<tr>
<td>1. Muktapuram</td>
<td>10.4</td>
</tr>
<tr>
<td>2. Regatipalle</td>
<td>8.62</td>
</tr>
<tr>
<td>3. Badannapalle</td>
<td>8.50</td>
</tr>
<tr>
<td>5. Upper Maddileru</td>
<td></td>
</tr>
<tr>
<td>1. O.D.Cheruvu</td>
<td>11.05</td>
</tr>
<tr>
<td>2. Kondakamaria</td>
<td>11.92</td>
</tr>
<tr>
<td>4. Nallacheruvu</td>
<td>13.50</td>
</tr>
<tr>
<td>5. Tanakallu</td>
<td>13.50</td>
</tr>
<tr>
<td>6. Lower Maddileru</td>
<td></td>
</tr>
<tr>
<td>1. Patnam</td>
<td>12.82</td>
</tr>
<tr>
<td>7. Jilledubanderu</td>
<td></td>
</tr>
<tr>
<td>1. Krishnapuram</td>
<td>12.50</td>
</tr>
<tr>
<td>2. marala</td>
<td>11.50</td>
</tr>
<tr>
<td>3. Adivi Brahmana palli</td>
<td>8.90</td>
</tr>
<tr>
<td>4. Siddarampuram</td>
<td>16.30</td>
</tr>
<tr>
<td>8. Middle Chitravathi (Right)</td>
<td></td>
</tr>
<tr>
<td>1. Jonnalakotha Palli</td>
<td>10.38</td>
</tr>
<tr>
<td>9. Middle Chitravathi (Left)</td>
<td></td>
</tr>
<tr>
<td>1. Tadimirri</td>
<td>11.40</td>
</tr>
<tr>
<td>2. Bathalapalli</td>
<td>9.50</td>
</tr>
<tr>
<td>10. Lower Chitravathi</td>
<td></td>
</tr>
<tr>
<td>1. Vennapusa Palli</td>
<td>10.5</td>
</tr>
</tbody>
</table>
It is observed that (1) The water table levels are highest in the months of September, October and November (2) Ground water exploitation is intensive during the rabi season and the water table starts falling from the month of December and it reaches the lowest level in the months of April and May. (3) Usually rainfall occurring during the months of May, June and July is not causing significant contribution to the ground water storage and the water table is not changing (4) The rise in water table is occurring nearly a month after good rainfall particularly in the months of September and October. (5) Though usually water table reaches its peak in the monsoon period, during lean rainfall years it exhibits a continuous falling trend till the wells dry up.

The water table data for the decade shows that the minimum depth to water table from ground level varied from 1.2 m. at Vengalammacheruvu in the upper Chitravathi sub basin to as much as 7.22 m. at Patnam in lower Maddileru sub basin, depending on the local relief. But the water table is reaching closest to the ground level at places nearer to the tanks or streams like Sattaria palli, Pedaballi, Kothacheruvu, Settipalli, and Kondakamarla. The maximum depth to the water table is above 10 m. over the entire basin and at some places wells with a depth of over 16 m have dried up during the decade 1996-2005. The ground water fluctuations (difference between maximum and minimum levels) ranged from 4.0 m. at Tadimarri to over 11.55 mm. at Vanavolu. The highest fluctuations are noticed in the Maddileru, Upper Chitravathi and Vangaperu sub basins. Generally the fluctuations are the least near the stream courses while they are the highest away from the stream courses. Profiles of dry well in Marala village, well with water at a deep depth in puttaparthi, and well with water at shallow depth at Siddarampuram village are shown in figures 6.1, 6.2 and 6.3.
Fig 6.1 Dry well at Marala

Fig 6.2 Well with water at deep depth at Puttaparthi
6.7 GROUND WATER ANALYSIS

The primary purpose of water analysis is to determine the suitability of water for a specific use. The main types of use are (1) domestic or household purpose (2) agricultural purpose and 3) industrial purpose. The essential criterion with respect to irrigation suitability of water relates to the concentration of sodium and total dissolved solids. For industrial use hardness and total dissolved solids are the main criteria. For domestic and household purpose hardness, chlorides, total dissolved solids and fluorides are the main parameters to be examined. In the present study, the data (collected from RWS) is available for only few important parameters and because of this the scope is confined to selected important parameters like Total Dissolved Solids (TDS), Specific Electrical Conductance (Salinity), Hardness, PH,
chloride and fluoride content of the water. Standards of the various chemical parameters considered are based on the guidelines followed in the respective departments. The various parameters of ground water at 40 locations in the basin are shown in Table 6.3. The locations are shown in figure 6.4.

Fig 6.4 Locations at which various chemical parameters are considered
Table 6.3 *Ground water quality parameters*  

<table>
<thead>
<tr>
<th>S. No</th>
<th>Location</th>
<th>TDS (ppm)</th>
<th>Hardness (ppm)</th>
<th>Chloride (ppm)</th>
<th>EC (mmhos/cm)</th>
<th>pH</th>
</tr>
</thead>
<tbody>
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<td>1</td>
<td>Kothacheruvu</td>
<td>1472</td>
<td>500</td>
<td>400</td>
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<td>Puttaparthi</td>
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<td>300</td>
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<td>8.00</td>
</tr>
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<td>4</td>
<td>Pedaballi</td>
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<td>280</td>
<td>270</td>
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<td>7.95</td>
</tr>
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</tr>
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<tr>
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<td>200</td>
<td>1.4</td>
<td>7.95</td>
</tr>
<tr>
<td>8</td>
<td>Budili</td>
<td>704</td>
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<td>160</td>
<td>1.1</td>
<td>7.80</td>
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<td>7.90</td>
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<td>Ramapuram</td>
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<td>1.0</td>
<td>7.80</td>
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<td>Settipalli</td>
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<td>360</td>
<td>350</td>
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<td>19</td>
<td>Penukonda</td>
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<td>C.K. Palli</td>
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<td>7.75</td>
</tr>
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<td>240</td>
<td>250</td>
<td>1.6</td>
<td>7.95</td>
</tr>
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<td>7.85</td>
</tr>
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<td>1280</td>
<td>200</td>
<td>300</td>
<td>2.0</td>
<td>8.00</td>
</tr>
<tr>
<td>24</td>
<td>O.D. Cheruvu</td>
<td>768</td>
<td>200</td>
<td>200</td>
<td>1.2</td>
<td>7.65</td>
</tr>
<tr>
<td>25</td>
<td>Kondakamarla</td>
<td>704</td>
<td>200</td>
<td>180</td>
<td>1.1</td>
<td>7.70</td>
</tr>
<tr>
<td>26</td>
<td>Tanakallu</td>
<td>896</td>
<td>200</td>
<td>200</td>
<td>1.4</td>
<td>7.80</td>
</tr>
<tr>
<td>27</td>
<td>NallaCheruvu</td>
<td>768</td>
<td>200</td>
<td>190</td>
<td>1.2</td>
<td>7.65</td>
</tr>
<tr>
<td>28</td>
<td>Kadiri</td>
<td>640</td>
<td>200</td>
<td>180</td>
<td>1.0</td>
<td>7.80</td>
</tr>
<tr>
<td>29</td>
<td>Kadiri Brahmanapalli</td>
<td>704</td>
<td>240</td>
<td>200</td>
<td>1.1</td>
<td>7.70</td>
</tr>
<tr>
<td>30</td>
<td>Patnam</td>
<td>576</td>
<td>200</td>
<td>150</td>
<td>0.9</td>
<td>7.60</td>
</tr>
<tr>
<td>31</td>
<td>Krishnapuram</td>
<td>1280</td>
<td>400</td>
<td>350</td>
<td>2.0</td>
<td>7.95</td>
</tr>
<tr>
<td>32</td>
<td>Marala</td>
<td>1280</td>
<td>500</td>
<td>340</td>
<td>2.0</td>
<td>8.00</td>
</tr>
<tr>
<td>33</td>
<td>Siddarampuram</td>
<td>1024</td>
<td>540</td>
<td>250</td>
<td>1.6</td>
<td>7.95</td>
</tr>
<tr>
<td>34</td>
<td>Gunipalli</td>
<td>960</td>
<td>240</td>
<td>250</td>
<td>1.5</td>
<td>7.90</td>
</tr>
<tr>
<td>35</td>
<td>Bukkapatnam</td>
<td>1344</td>
<td>500</td>
<td>400</td>
<td>2.1</td>
<td>7.90</td>
</tr>
<tr>
<td>36</td>
<td>Jonnalakothapalli</td>
<td>768</td>
<td>200</td>
<td>220</td>
<td>1.2</td>
<td>7.90</td>
</tr>
<tr>
<td>37</td>
<td>Battalapalli</td>
<td>1088</td>
<td>320</td>
<td>250</td>
<td>1.7</td>
<td>7.70</td>
</tr>
<tr>
<td>38</td>
<td>Malayavantham</td>
<td>960</td>
<td>280</td>
<td>200</td>
<td>1.5</td>
<td>7.90</td>
</tr>
<tr>
<td>39</td>
<td>Peddakotla</td>
<td>1920</td>
<td>400</td>
<td>600</td>
<td>3.0</td>
<td>8.00</td>
</tr>
<tr>
<td>40</td>
<td>Vennapusapelli</td>
<td>1344</td>
<td>400</td>
<td>350</td>
<td>2.1</td>
<td>8.00</td>
</tr>
</tbody>
</table>
6.7.1 Total dissolved solids (TDS)

The total concentration of dissolved minerals in water is general indication of overall suitability of water for many types of uses. The TDS include all solid materials in solution whether ionized or not. It does not include suspended sediments, colloids or dissolved gasses. The TDS is the numerical sum of all dissolved solids determined by chemical tests. The quality of water for drinking, irrigation and industrial purposes decrease with the increase in TDS. If water contains less than 500 ppm of dissolved solids, it is generally satisfactory for domestic use and for many industrial purposes. Water with more than 1000 ppm of dissolved solids, usually contains minerals which give it a disagreeable taste or make the water unsuitable for other respects. The number and percentages of samples corresponding to various ranges of TDS are shown in Table 6.4.

Table 6.4 Total dissolved solids in ground water

<table>
<thead>
<tr>
<th>S. No</th>
<th>TDS. (ppm)</th>
<th>No. of Samples</th>
<th>Percentage to total</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>&lt;500</td>
<td>Nil</td>
<td>00</td>
<td>Generally suitable for domestic and most Industrial purposes.</td>
</tr>
<tr>
<td>2</td>
<td>500-1000</td>
<td>19</td>
<td>47.5</td>
<td>Moderately Suitable</td>
</tr>
<tr>
<td>3</td>
<td>&gt;1000</td>
<td>21</td>
<td>52.5</td>
<td>Unsuitable</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>40</td>
<td>100.00</td>
<td></td>
</tr>
</tbody>
</table>

In study area content of the total dissolved solids (TDS) is above the acceptable limit. TDS less than 500 ppm is generally satisfactory for the domestic and most industrial uses. In Chitravathi basins 47.5 per cent of the samples are moderately suitable whereas 52.5 per cent are unsuitable.

Ground water is moderately suitable in the Upper Maddileru sub basin, and parts of Nagasamudram Vanka, Paleteru and Middle Chitravathi sub basins. In the rest of
the study area comprising the Upper Chitravathi, Vangaperu, Jilledubanderu, Lower Chitravathi and parts of Middle Chitravathi the ground water contains TDS beyond suitable limits. Variation of TDS in the basin is shown in figure 6.5.

Fig 6.5 Variation of Total dissolved solids in the basin
6.7.2 Hardness

Calcium and magnesium cause almost all the hardness of water. The total hardness of water consists of two parts (1) carbonate hardness and (2) non-carbonate hardness. Carbonate hardness includes that portion of the calcium and magnesium that would combine with the bicarbonate and the small amount of carbonate present. This is called the temporary hardness and this could be removed by boiling the water. The non-carbonate hardness, which is also called permanent hardness, is the difference between the total and the carbonate hardness. This is caused by the amounts of calcium and magnesium that would normally combine with the sulfate, chloride and nitrate ions and slight hardness effect of other minor constituents. This part of the hardness cannot be removed by boiling. Water with a hardness of less than 50 ppm is considered soft. Hardness in between 50 ppm and 150 ppm is not problematic for most purposes but the amount of soap needed increases with hardness. Hardness of more than 150 ppm is problematic with increasing hardness and it is to be softened. It is also not suitable for industries using large quantities of soap. The number and percentage of samples corresponding to various ranges of hardness are shown in Table 6.5.

Table 6.5 Total hardness in ground water

<table>
<thead>
<tr>
<th>S. No</th>
<th>Hardness (ppm)</th>
<th>No. of Samples</th>
<th>Percentage to total</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>200-300</td>
<td>25</td>
<td>62.5</td>
<td>Hardness beyond 150 is problematic with increasing hardness.</td>
</tr>
<tr>
<td>2</td>
<td>300-400</td>
<td>4</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>400-500</td>
<td>6</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>500-600</td>
<td>5</td>
<td>12.5</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>40</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Hardness beyond 150 ppm is problematic to both domestic and industrial uses. In the study region the hardness ranges from a minimum of 200 ppm to a maximum of 540 ppm it is beyond permissible limits. The hardness is comparatively low in the Maddileru basin, Nagasamudram and Paleteru sub basins. It is comparatively high in Jilledubanderu, parts of upper, middle and lowers Chitravathi sub basins. Variation of hardness in the basin is shown in figure 6.6.

Fig 6.6 Variation of hardness in the basin
6.7.3 Chloride

Water that contains less than 150 ppm of chloride is satisfactory for most purposes. For domestic purposes more than 250 ppm is not acceptable. More than 350 ppm is objectionable for most irrigation and industrial uses. Water containing more than 500 ppm of chloride usually will have disagreeable taste. But for animals water with as much as 300 to 400 ppm of chloride is satisfactory. The number and percentage of samples corresponding to various ranges of chlorides are shown in table 6.6.

Table 6.6 Chloride content in ground water

<table>
<thead>
<tr>
<th>S. No</th>
<th>Chloride (ppm)</th>
<th>No. of Samples</th>
<th>Percentage to total</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>&lt;150</td>
<td>2</td>
<td>5</td>
<td>Good for all purpose</td>
</tr>
<tr>
<td>2</td>
<td>150-250</td>
<td>16</td>
<td>40.0</td>
<td>Acceptable for domestic purpose</td>
</tr>
<tr>
<td>3</td>
<td>250-350</td>
<td>15</td>
<td>37.5</td>
<td>Acceptable for irrigation and industrial purpose.</td>
</tr>
<tr>
<td>4</td>
<td>&gt;350</td>
<td>7</td>
<td>17.5</td>
<td>Objectionable to most irrigation and industrial purpose.</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>40</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>

The chloride content in 40 per cent of the ground water samples, mostly extending over upper parts of Paleteru, Nagasamudram Vanka and Maddileru sub basins, is acceptable for domestic purposes. Water in the rest of the basin is containing more than 250 ppm of chlorides, which is above the prescribed limits for domestic use but within the limits prescribed for irrigation and industrial purposes. At some places like Peddakotla in Middle Chitravathi (Left), Bukkapatnam in Middle Chitravathi Right, Krishnapuram in Jilledubanderu sub basin, Vengalammacheruvu and Vanavolu in the
upper Chitravathi and Vennapusapalli in lower Chitravathi the chloride content is above 350 ppm and is problematic for all uses but is good for animals. Variation of chloride in the basin is shown in figure 6.7.

Fig 6.7 Variation of chlorides in the basin
6.7.4 Fluoride

Too much fluoride in the water causes mottled enamel. Fluoride concentrations below the objectionable limits are actually beneficial to the teeth. The desirable limit is 1.0 ppm with respect to dental effects. For adults, concentrations less than 4 ppm are not likely to cause endemic cumulative fluorosis and skeletal effects. As per the Public Health Service standards in warm climates, 1.4 ppm is maximum permissible limit. Fluoride content of ground water at various locations is represented in table 6.7.

Table 6.7 Fluoride content in the ground water at various locations

<table>
<thead>
<tr>
<th>S. No</th>
<th>Sample Location</th>
<th>Fluoride (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Chagaleru</td>
<td>1.6</td>
</tr>
<tr>
<td>2</td>
<td>Boyalapalli</td>
<td>2.1</td>
</tr>
<tr>
<td>3</td>
<td>Mallapalli</td>
<td>1.9</td>
</tr>
<tr>
<td>4</td>
<td>Mandalapalli</td>
<td>1.65</td>
</tr>
<tr>
<td>5</td>
<td>Kotlapalli</td>
<td>2.0</td>
</tr>
<tr>
<td>6</td>
<td>Beedupalli</td>
<td>2.0</td>
</tr>
<tr>
<td>7</td>
<td>Pothulakunta</td>
<td>2.1</td>
</tr>
<tr>
<td>8</td>
<td>Viraparam</td>
<td>2.1</td>
</tr>
<tr>
<td>9</td>
<td>Mylasamudram</td>
<td>1.7</td>
</tr>
<tr>
<td>10</td>
<td>Magacheruvu</td>
<td>2.4</td>
</tr>
<tr>
<td>11</td>
<td>Penukonda</td>
<td>2.5</td>
</tr>
<tr>
<td>12</td>
<td>C.K.Palli</td>
<td>1.2</td>
</tr>
<tr>
<td>13</td>
<td>Kothacheruvu</td>
<td>0.8</td>
</tr>
<tr>
<td>14</td>
<td>Subbaraopeta</td>
<td>1.7</td>
</tr>
<tr>
<td>15</td>
<td>Buddareddipalli</td>
<td>1.7</td>
</tr>
<tr>
<td>16</td>
<td>Bathalapalli</td>
<td>1.7</td>
</tr>
<tr>
<td>17</td>
<td>D. Cherlopalli</td>
<td>1.6</td>
</tr>
<tr>
<td>18</td>
<td>Apparaao Cheruvu</td>
<td>2.2</td>
</tr>
<tr>
<td>S. No</td>
<td>Sample Location</td>
<td>Fluoride (ppm)</td>
</tr>
<tr>
<td>-------</td>
<td>-----------------------</td>
<td>----------------</td>
</tr>
<tr>
<td>19</td>
<td>Garisalapalli</td>
<td>2.4</td>
</tr>
<tr>
<td>20</td>
<td>Nidigallu</td>
<td>1.9</td>
</tr>
<tr>
<td>21</td>
<td>Dampetla</td>
<td>3.2</td>
</tr>
<tr>
<td>22</td>
<td>O Chintalapalli</td>
<td>1.7</td>
</tr>
<tr>
<td>23</td>
<td>Madugupalli</td>
<td>1.8</td>
</tr>
<tr>
<td>24</td>
<td>Yellutla</td>
<td>1.8</td>
</tr>
<tr>
<td>25</td>
<td>Chinnamallepalli</td>
<td>2.0</td>
</tr>
<tr>
<td>26</td>
<td>Yellanur</td>
<td>2.0</td>
</tr>
<tr>
<td>27</td>
<td>Chilamkur</td>
<td>1.8</td>
</tr>
<tr>
<td>28</td>
<td>Vemulapalli</td>
<td>1.6</td>
</tr>
<tr>
<td>29</td>
<td>Malakavemula</td>
<td>1.6</td>
</tr>
<tr>
<td>30</td>
<td>Jonnalakothapalli</td>
<td>3.3</td>
</tr>
<tr>
<td>31</td>
<td>Uppalapadu</td>
<td>1.8</td>
</tr>
<tr>
<td>32</td>
<td>Brahmadevaramarri</td>
<td>2.8</td>
</tr>
<tr>
<td>33</td>
<td>Mukthapuram</td>
<td>3.0</td>
</tr>
<tr>
<td>34</td>
<td>Nallamada</td>
<td>1.6</td>
</tr>
<tr>
<td>35</td>
<td>Reddipalli</td>
<td>2.1</td>
</tr>
<tr>
<td>36</td>
<td>O.D. Cheruvu</td>
<td>1.7</td>
</tr>
<tr>
<td>37</td>
<td>Mukandlaval kothapalli</td>
<td>1.6</td>
</tr>
<tr>
<td>38</td>
<td>Lakkasamudram</td>
<td>2.4</td>
</tr>
<tr>
<td>39</td>
<td>Alampur</td>
<td>1.9</td>
</tr>
<tr>
<td>40</td>
<td>Yeradoddi</td>
<td>1.7</td>
</tr>
<tr>
<td>41</td>
<td>Muthyalcheruvu</td>
<td>1.8</td>
</tr>
<tr>
<td>42</td>
<td>Kadiri Brahama Palli</td>
<td>2.4</td>
</tr>
<tr>
<td>43</td>
<td>Kadiri</td>
<td>2.0</td>
</tr>
<tr>
<td>44</td>
<td>Nallacheruvu</td>
<td>1.9</td>
</tr>
<tr>
<td>45</td>
<td>Tanakallu</td>
<td>2.0</td>
</tr>
<tr>
<td>46</td>
<td>Chalamakuntapalli</td>
<td>1.8</td>
</tr>
<tr>
<td>47</td>
<td>Pulagampalli</td>
<td>1.6</td>
</tr>
<tr>
<td>48</td>
<td>Sanevari Palli</td>
<td>1.8</td>
</tr>
<tr>
<td>49</td>
<td>Gantmari</td>
<td>1.2</td>
</tr>
</tbody>
</table>
The number and percentage of samples corresponding to various ranges of fluoride are shown in table 6.8.

Table 6.8  **Fluoride content of ground water in study area**

<table>
<thead>
<tr>
<th>S. No</th>
<th>Fluoride (ppm)</th>
<th>No. of Samples</th>
<th>Percentage to total</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.4</td>
<td>3</td>
<td>6.2</td>
<td>Good for drinking</td>
</tr>
<tr>
<td>2</td>
<td>1.4 – 2.0</td>
<td>26</td>
<td>53.1</td>
<td>Causes dental defect known as mottled enamel</td>
</tr>
<tr>
<td>3</td>
<td>2.0 – 2.5</td>
<td>16</td>
<td>32.7</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>2.5 – 3.0</td>
<td>1</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>&gt;3.0</td>
<td>3</td>
<td>6.0</td>
<td>May cause endemic cumulative fluorides and skeletal effects</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>49</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>

The fluoride content in the ground water of Chitravathi basin is generally above the limits prescribed by the Public Health Service. Only 6.2 per cent of the samples are non problematic (1.4 ppm) and good for drinking. The fluoride content is 1.4 ppm to 2.0 ppm. in 53 per cent of the samples, and from 2.0 ppm. to 2.5 ppm. in 32.7 per cent of the samples. In 6.1 percent of the samples it is above 3 ppm. and in general it is likely to cause the dental defect called mottled enamel in children. Variation of fluoride in the basin is shown in figure 6.8. and a look at the figure reveals that the ground water is good in Paleteru basin and a small pocket in the middle Chitravathi basin. The water is highly unsuitable in the middle Chitravathi basin and may cause skeletal effects along with dental defects. In the rest of the basin the fluoride content is high enough to cause dental defects in children.
Fig 6.8 Variation of fluoride in the basin
6.7.5 Specific electrical conductance (Salinity)

A salinity problem related to water quality occurs, if the total quantity of salts in the irrigation water is high enough for the salts to accumulate in the crop root zone to the extent that yields are affected. If excessive quantities of soluble salts accumulate in the root zone, the crop has difficulty in extracting enough water from the salty soil solution. Reduced water uptake by the plant usually results in slow or reduced growth.

Salinity is expressed in terms of specific electrical conductance. The soil quality ratings proposed by the Central Soil Salinity Research Institute, Karnal are as follows for semi-tolerant and tolerant crops. But in general water with EC of more than 3.0 mmhos/cm are considered saline. The number and percentage of samples corresponding to various specific electrical conductance are shown in table 6.9.

<table>
<thead>
<tr>
<th>S. No</th>
<th>Specific electrical conductance (mmhos/cm)</th>
<th>No. of Samples</th>
<th>Percentage</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.0``</td>
<td>2</td>
<td>5</td>
<td>Non Saline (Salinity effects mostly negligible)</td>
</tr>
<tr>
<td>2</td>
<td>1.0 -2.0</td>
<td>25</td>
<td>62.5</td>
<td>Slightly Saline (Yields of very sensitive crops affected)</td>
</tr>
<tr>
<td>3</td>
<td>2.0 – 3.0</td>
<td>11</td>
<td>27.5</td>
<td>Moderately saline (Yields of many crops are restricted)</td>
</tr>
<tr>
<td>4</td>
<td>3.0</td>
<td>2</td>
<td>5</td>
<td>Saline only tolerant crops will give good yields.</td>
</tr>
</tbody>
</table>

In the study area in general the ground water is slightly to moderately saline. About 5 per cent of the samples are non–saline and 5 percent are saline. Majority of
the samples 62.5 per cent are slightly saline and 27.5 per cent are moderately saline.

Variation of specific electric conductance in the basin is shown in figure 6.9.

Fig 6.9 Variation of specific electric conductance in the basin
Non-saline ground water occurs in a small area in the eastern part of the Maddileru. Saline water occurs in isolated pockets in upper Chitravathi, Middle Chitravathi and Lower Chitravathi sub basins and in the remaining part ground water is moderately and slightly saline.

6.7.6 Acidity and alkalinity in the ground water (P$^H$)

The P$^H$ in the ground water of the region ranges from a minimum of 7.65 to a maximum of 8.25 indicating that the ground water is weakly alkaline to alkaline. Variation of P$^H$ in the basin is shown in figure 6.10.

![Fig 6.10 Variation of P$^H$ in the basin](image-url)
6.8 SUMMARY

The geological formations of the Chitravathi basin can be divided into three groups (1) archaean crystalline rocks (2) Precambrian sedimentary rocks and (3) the recent formations. Ground water in archaeans is confined to the weathered and fractured layers and occurs in water table conditions. In Precambrian sedimentary rocks shales and limestones are important from hydrological point of view and the ground water potential is determined by the degree of weathering, jointing, bedding and cavernous conditions. Ground water potential in the alluvial and colluvial zones is dependent on the thickness. In the Chitravathi basin, the area extent is limited but these are good aquifers in the lower basin. It is estimated that the basin has a ground water potential of 401.21 Mcum of which only 103.86 Mcum is exploited which forms just 25.9 per cent of the available potential.

The concentration of ground water exploitation is along the alluvial and colluvial zones. Since the streams are ephemeral, the water table fluctuates very widely. The highest level is reached during months of September and October and the lowest water table in months of April and May. In drought years the water table falls beyond 10 m depth and wells with depth of more than 16 m. have dried up during the decade 1996-2005. But in the wet year the water table rises to less than 1.2 m. from the ground level at some places.

The suitability of water for domestic, irrigation and industrial, purposes can be studied through (1) Total Dissolved Solids (TDS) (2) Hardness (3) Chloride content (4) Fluoride content (5) Specific Electrical Conductance (6) Acidity and Alkalinity .

The TDS content in the water is above acceptable limits, with 47.5 per cent of the samples being moderately suitable for domestic and industrial purposes and 52.5 per
cent of the samples being problematic. The hardness ranges from 200 ppm to 540 ppm while the optimum limit is 150 ppm. The chloride content is above the optimum limits, but 40 per cent of the samples are acceptable for domestic purpose while 37.5 per cent are acceptable for industrial and irrigation purposes and 17.5 percent of the samples are beyond prescribed limits for all purposes.

The region has moderate to high fluoride with 85 per cent of the samples having fluoride that can cause mottled enamel in children and 6.1 per cent having fluoride levels that can cause even skeletal effects in adults. The highly problematic area is Dharmavaram and its surroundings in middle Chitravathi.

The salinity problem is moderate with only 27.5 per cent of the samples having salinity levels that affect the yields of most crops. The pH indicates that the water is weakly alkaline to alkaline.

In conclusion it could be said that the ground water is not meeting the prescribed qualities for drinking purposes in most of the areas, while in some areas it is not suitable for industrial purpose. But in most of the areas it is suitable for irrigation purpose.