Chapter 7: Environmental Impact Assessment

7.1 Introduction

All developmental activities use natural resources as raw material and the wastes generated are disposed into different environmental media. The signs of stress on the scarce natural resources are evident from the deteriorating air quality, soil degradation, polluted rivers and streams and in the general status of environment in various regions. It is now well recognized that, for sustainable development and optimal use of natural resources, environmental considerations are required to be integrated in planning, designing and implementation of development projects. The envisaged benefits from development projects cannot be fully realized unless they are environmentally and socially sound and sustainable. Environmental Impact Assessment (EIA) is one of the proven management tools for incorporating environmental concerns in development process and also in improved decision making. The growing awareness, over the years, on environmental protection and sustainable development has further given emphasis on sound environmental management practices through preparation of Environmental Management Plans (EMPs) for minimizing the impacts from developmental activities.

7.2 Concept of EIA

The world’s concern on environment vividly expressed at the Stockholm Conference (1972) led many nations to have a critical look at the developmental activities and their impact on the environment. Environmental impact Assessment (EIA) or Environmental Impact Statement (EIS) first originated in U.S.A, after the federal Government brought into effect, a public law ‘National Environmental Protection Act’ (NEPA) on January 1st, 1970. NEPA made all the developmental projects to undergo an environmental scrutiny before execution. Hence, this necessitated the preparation of guidelines and procedures regarding the preparation, review, evaluation and distribution of EIS with the basic objective of evaluating the environmental impacts of any developmental activity. Since then, it has been adopted by a large number of countries. In most of the countries, Governments have
specified Departments to undertake EIA. In fact, an EIA can be conducted even by a private agency, but an appropriate authority does the decision-making.

7.2.1 EIA in India

The concept of environmental protection and resource management has traditionally been given due emphasis and woven in all facets of life in India. These age-old practices teach people to live in perfect harmony with nature. Nevertheless, changing life styles, increasing pace of urbanization, industrialization and infrastructure development have caused environmental pollution and degradation (Chopra et al., 1993). The losses manifest as pollution in air, water and land leading to biodiversity losses and potential health hazards. Consequently, rules, laws and policies on environmental protection were introduced. One such effort, i.e., the Environmental Impact Assessment (EIA), particularly aims to optimise a trade-off between developmental activities and socio-ecological losses. It is a management tool to be linked closely to the project life cycle to ensure that appropriate environmental information is provided at the correct time (Wood, 1995). The overall objective of the EIA is to design developmental projects and activities taking into consideration the environmental perspective. In India, the first EIA was ordered, during early 1980s, on the Silent river valley hydroelectric project, which was a controversial project (Valappil et al., 1994 and MoEF, 2003a). This project, proposed by the Kerala State Electricity Board (KSEB) to build a 130 m high dam across the Kuntipuzha River and a reservoir, and was considered a big threat to the biodiversity and forest ecosystem of the Silent valley. However, EIA was introduced in 1994, when Ministry of environment and forestry (MoEF) passed an EIA notification under Environmental Protection Act (EPA), 1986, which made EIA mandatory for 29 highly polluting activities) (MoEF, 1994 and MoEF, 2004). Over the years, the system has undergone several amendments to improve the environmental clearance (EC) process and to make it an integral component of decision-making.

7.3 Objectives of EIA

In order to assess the changes occurring in an environment, like the increase level of green house gas in air or introduction of an effluent discharge in to a river system, the
existing condition in the air or river system must be measured against well defined environmental quality objectives; and then, the impacts must be anticipated. The setting of appropriate effluent discharge standards is based on prior formulation of environmental quality objectives, which for example should reflect the needs of various users of rivers (Bisset, 1996).

Some of the main aims and objectives of EIA are listed in brief as follow:

1) Modify and improve the existing designs ensuring environmental factors are considered in the decision-making process
2) ensuring that possible adverse environmental impacts are identified and avoided or minimised
3) ensure efficient resource use
4) enhance social aspects
5) identify key impacts and measures for mitigating them
6) inform decision-making and condition-setting
7) avoid serious and irreversible damage to the environment
8) protect human health and safety

**7.4 Methodology**

There are several methods which are adopted in EIA, however, of the variety of techniques and methods available, only a few are applicable to developing countries. It is generally assumed that developing countries have limited financial resources, technical expertise, and baseline data. Because of the pressure for rapid economic development, the methods used in developing countries must be effective in a relative short time frame. Some of the methods used in EIA are Adhoc method, Check list method, Matrix method, Leopold method, Overlay technique and Battelle technique. Not all of these techniques are suitable for water quality studies. Some of the methods like Adhoc and check list only the impacts would be indicated but the magnitude of the impact won’t be taken into consideration. Hence for the present study, the Battelle technique has been adopted which fits for water quality studies and impact and magnitude of the impact is also studied. An EIA with reference to water quality studies should aim at covering all aspects of environmental
activities being carried out. In the present study the Battelle method has been selected which takes into account all the environmental aspects.

7.4.1 The Battelle Technique

This method is also referred as ‘BEES’ (Battelle Environmental Evaluation System). The environmental evaluation system was designed by the Battelle Columbus Laboratories in the United States to assess impacts of water-resource developments, water-quality management plans, highways, nuclear power plants, and other projects (Dee et al., 1972, 1973a, b).

In this system, the environment is classified into four broad categories.

- Ecology
- Physical/chemical
- Aesthetics
- Human interest/social

Each category contains a number of components that have been selected specifically for use in all U.S. Bureau of Reclamation water-resource development project. The environment as a whole is assigned certain weighted factors with respect to the importance of the impact and the magnitude of the impact on the environment. A numerical value is assigned to each attribute as an indication of importance. These weighted factors are termed as ‘Parameter Important Unit’ (PIU). This numerical weighting scheme is explicit, permitting calculation of a project impact for each alternative. In Battelle, the weighted to different parameters are based on the ‘Delphi technique’.

The Delphi method was developed in the 1960s as one of the many techniques used in decision analysis, probability estimates, and long-range forecasts. It was developed by the Rand Corporation as part of a U.S. Air Force contract in the early 1950s (Brown and Helmer 1967; Brown 1968; Harman 1975; Leitch et al., 1983; Canter 1985, 1996; Linstone and Turnoff, 1975). Delphi method aims to encourage independent and unbiased assessments from each individual. The method has been widely used for environmental assessment and
for monitoring programs (Kreisel, 1984). In its simplest form, the Delphi technique is a carefully designed series of individual interrogations interspersed with information/opinion feedback (Mohorjy and Omar S. Aburizaiza, 1977).

The magnitude of impact on environment is described in terms of a relationship between the parameter value and a quality index. The environmental quality of each parameter is predicted by giving each parameter an Environmental Quality Score (EQS). For this purpose Battelle developed an index of environmental quality, normalized to a scale ranging from 0 to 1, using a value function method (Goyal and V.A., Deshpande, 2001). Environment quality (EQ) with respect to a particular parameter is determined using value function graphs developed by the experts in the field considering the major/significant impact on the environment. The Value of EQS for the prevailing environment quality is given in the Table 7.1. The EQS for the different impacts are assigned after taking into consideration the field visits, water quality analysis and taking the opinion of the people residing in the rural area of the study by which a final score was given.

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Values on Scale</th>
<th>Environmental Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.1</td>
<td>Unacceptable</td>
</tr>
<tr>
<td>2</td>
<td>0.2</td>
<td>Very Worst</td>
</tr>
<tr>
<td>3</td>
<td>0.3</td>
<td>Worst</td>
</tr>
<tr>
<td>4</td>
<td>0.4</td>
<td>Very Bad</td>
</tr>
<tr>
<td>5</td>
<td>0.5</td>
<td>Bad</td>
</tr>
<tr>
<td>6</td>
<td>0.6</td>
<td>Medium</td>
</tr>
<tr>
<td>7</td>
<td>0.7</td>
<td>Good</td>
</tr>
<tr>
<td>8</td>
<td>0.8</td>
<td>Very Good</td>
</tr>
<tr>
<td>9</td>
<td>0.9</td>
<td>Best</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>Excellent</td>
</tr>
</tbody>
</table>

Table 7.1: Values of Environmental Quality Score (EQS)

By adopting the Battelle technique, the Environmental Quality Index can be calculated using the following formula:

\[ \text{EQI} = \text{EQS} \times \text{PIU} \]
Where, $EQS = \text{Environmental Quality Score}$

$PIU = \text{Parameter Importance Unit}$

The overall impact is studied by aggregating all such environmental Quality Indices of all the parameters considered. In the present study among the environmental impact assessment methods, which were described briefly earlier, the Battelle method was adopted.

### 7.5 Environmental Impact Assessment and Water Quality Studies

All components of the environment like air, water, soil, living being and etc., are precious and have their own significance in terms of their importance. In fact these components are not only important individually but also they form an interlocking unitary system. A slight disturbance or modification in any of these components may have its own repercussions. This sort of disturbances in the environment especially on water resources can sometime cause very serious damages which is difficult to overcome. Pollution of water resources is one of the areas of major concern to environmentalists. Water quality is an index of health and wealth of the society. Industrialization, urbanization and modern agricultural practices have direct impact on water resources and especially in India the environment has become fragile and has become a major concern (Mohapatra and Singh, 1999). Rivers due to their role in carrying off the municipal and industrial waste water and run-off from agricultural land in their vast drainage basins are among the most vulnerable water bodies to pollution which in fact influences the quality of groundwater too. The surface water quality in a region is largely determined both by natural processes (precipitation rate, weathering process, soil erosion) and anthropogenic influences viz. urban, industrial and agricultural activities and increasing exploitation of water resources (Carpenter et al., 1998 and Jarvie et al., 1998). Due to these natural and anthropogenic activities the existing environmental condition gets altered. In order to assess the magnitude of the above mentioned impacts, the Environmental Impact Assessment is adopted and forms a basic pre-requisite to assess the physic-chemical and social impact.
7.5.1 EIA of the water resources of the study area

In the past few years, increase of population and change of the environment due to the sophisticated world demands, has become a major concern especially to the environmentalists. Like in other places of India, in Hunsur also agricultural, domestic and industrial sectors have also had certain impacts on the natural water resources of the area. Some of the impacts, due to these activities, are positive, some negative and in some cases there would be neutral in nature. The aim of performing an EIA on the water resources of western part of Hunsur Taluk is to give an indication on the impact and its magnitude.

7.5.1.1 Ecology

Ecology is the study of organisms or groups of organisms and their interrelations between them and with the environment. It is important to study the impact of the various activities on the ecology of the study area which is studied in this section under two sub-headings viz., Terrestrial Species and population and Aquatic Habitat.
<table>
<thead>
<tr>
<th>Category</th>
<th>Sub-Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ecology</td>
<td>Terrestrial species and population</td>
</tr>
<tr>
<td></td>
<td>Aquatic Species and Population</td>
</tr>
<tr>
<td></td>
<td>Terrestrial Habitat and communities</td>
</tr>
<tr>
<td></td>
<td>Aquatic Habitat and communities</td>
</tr>
<tr>
<td></td>
<td>Ecosystem</td>
</tr>
<tr>
<td>Physicochemical</td>
<td>Water Quality</td>
</tr>
<tr>
<td></td>
<td>B.O.D</td>
</tr>
<tr>
<td></td>
<td>Fecal Coliform</td>
</tr>
<tr>
<td></td>
<td>Inorganic Carbon</td>
</tr>
<tr>
<td></td>
<td>Inorganic nitrogen</td>
</tr>
<tr>
<td></td>
<td>pH</td>
</tr>
<tr>
<td></td>
<td>Total Dissolved Solids</td>
</tr>
<tr>
<td></td>
<td>Turbidity</td>
</tr>
<tr>
<td>Aesthetics</td>
<td>Land</td>
</tr>
<tr>
<td></td>
<td>Air</td>
</tr>
<tr>
<td></td>
<td>Water</td>
</tr>
<tr>
<td></td>
<td>Biota</td>
</tr>
<tr>
<td></td>
<td>Manmade objects</td>
</tr>
<tr>
<td>Social</td>
<td>Educational/Scientific</td>
</tr>
<tr>
<td></td>
<td>Historical</td>
</tr>
<tr>
<td></td>
<td>Cultures</td>
</tr>
<tr>
<td></td>
<td>Life patterns</td>
</tr>
</tbody>
</table>

Table 7.2: Battelle Environmental Classification for Water-Resource

**A) Terrestrial species and populations:** In this category, sub-attributes like Crops and Natural vegetation are discussed.

**i) Crops:** The major crops which are cultivated in the study area are wet paddy, sugarcane, Garden, Mulberry, Turmeric and semi-dry Ragi. Lakshmamirtha River which passes through the study area is an ephemeral river and the crops of this area were dependent on the vagaries of monsoon. To overcome the vagaries of monsoon for cultivation purpose an
anicut was constructed across Lakshmantirtha river. The main channel after running for distance of 17 km, a branch called Nallur channel takes off, and continues parallel to Lakshmantirtha river for a length of 10.20 km and ends by entering into a small irrigation tank namely Chikka hunsur tank. By construction of this man made Nellur channel, many cultivable lands came under this command area. There are few small irrigation tanks in this command which serves as balancing tanks and few pick-ups have also been constructed in this command to reuse the seepage water; some exclusively for irrigational purposes. This has helped the agricultural prospects of the basin. Taking the faltering of monsoon in some years which had lead to drought condition, the overall EQS of this sub-attribute is 0.7.

ii) **Natural Vegetation:** The existence of Lakshmantirtha River with many lakes and reservoirs in the study area represents the climate of it which in turn determines the type of vegetation in that region. Study area lies in a moderate to semi-arid region. The natural vegetation in the study area is mainly confined to forests which are dense mixed scrubs, dense open scrubs and occupy 132.34 sq.km of the study area which equals to almost 21 % of the total study area. As the statistics reveals, one fifth of the study area is covered by dense mixed forest and there has not been much changes from the earlier times. These findings were confirmed after field visits and comparing the toposheets with the satellite imageries.

It can be observed that, human activities on the sub-attributes of Crops and Natural vegetation under ‘Terrestrial species and population ‘does not seem to have any noticeable impact. But through the years slight changes must have occurred. Hence, the Environmental Quality Score (EQS) for these sub-attributes on a scale of 0 to 1 is ‘0.8’ since there are no major conspicuous impacts on these sub-attributes of Ecology.

**B) Aquatic Habitats:** In this section for EIA studies, sub-attributes like Characteristics of river and Species diversity are been taken in to consideration.

i) **Characteristics of surface water resources:** This feature explains about the nature of the river and its flow pattern. As discussed earlier Lakshmantirtha river is an ephemeral in nature. As the name suggests, its flow rate decreases profoundly in summer seasons where there is no rainfall. During this time the river gets reduced to mere trickles at places and also
dries up in patches. And during monsoon and post monsoon its flow rate increases remarkably. Human activities sometimes cause some alteration in the river flow path and in its course of flow which are due to constructions of dams, check dams and many other kind of physical activities which lead to some changes in the nature of the river. By comparing the course flow of the river in the toposheets as well as the new satellite imageries no major alterations were found. Thus it can be concluded that the human activities have not produced any serious changes in the physical characteristics of the river. Hence the EQS of this attribute is 0.7.

**ii) Species diversity:** In the surface water resources of the study area when discussing about Lakshmántirtha River, as stated in the above section, it comes under the ephemeral rivers. In such cases the diversity of species it less when compared to a perennial rivers. This is due to the water flow rate which reduces significantly during the summer seasons and has an impact on the diversity of species living in it. A similar kind of condition is observed in the lakes and ponds of the study area where the water level had reduced in the summer season.

But on the other hand, the trophic status of the water has the most significant impact on the diversity of the algae and the planktons. In oligotrophic conditions, where the nutrient rate of the water is more, the density of these species increase as they feed on the nutrients dissolved in water. As discussed in chapter 6, it was observed that BOD concentration was comparatively higher at few places than the other places in the study. This is an indication of pollution which is due to the addition of sewage waste, agricultural runoff, etc. This will give a boost in dominance of the diversity of the species. So it can be concluded that although the flow rate and quantity of the water resources of the area reduces in pre monsoon and has a negative impact on the species diversity but the nutrient status of the water resources has in fact a positive impact and hence, the EQS for this attribute is 0.6.

The environmental Quality Indices computed for this attribute ‘Ecology of Lakshmántirtha River and lakes of the study area is given in the Table 7.3.
<table>
<thead>
<tr>
<th>Sl.No.</th>
<th>Major Attributes</th>
<th>Minor Attributes</th>
<th>EQS</th>
<th>PIU</th>
<th>EQI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Terrestrial species and Population</td>
<td>Crops</td>
<td>0.7</td>
<td>14</td>
<td>9.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Natural vegetation</td>
<td>0.8</td>
<td>14</td>
<td>11.2</td>
</tr>
<tr>
<td>2</td>
<td>Aquatic Habitat and Communities</td>
<td>River Characteristics</td>
<td>0.7</td>
<td>12</td>
<td>8.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Species diversity</td>
<td>0.6</td>
<td>12</td>
<td>7.2</td>
</tr>
</tbody>
</table>

Table 7.3: Environmental Quality Indices of “Ecology” of the study area

7.5.1.2 Physical-Chemical

Physical and chemical aspects of the water resources of the study area influence the water quality significantly. Hence it is important to study some of the physical and chemical properties of the surface water resources which include the TDS, pH, B.O.D and nitrate. These four main attributes considered for water quality in this EIA would be studied separately for both surface and ground water of the study area.

i) BOD: As explained in the previous chapter BOD is one of the most common measures of pollutant organic material in water. Therefore, a low BOD is an indicator of good quality water, while a high BOD indicates polluted water. Dissolved oxygen (DO) is consumed by bacteria when large amounts of organic matter from sewage or other discharges are present in the water. According to Bureau of Indian Standards (BIS), the maximum permissible limit of BOD for drinking and bathing are 2.0 and 3.0 mg/l respectively. As discussed previously the BOD values of River Lakshmantirtha and lakes vary between 1.0 to 3.1 mg/l. This reveals that the adverse impact of environmental activities on the surface water resources appears to be gaining attention and slight pollution is observed. Hence, EQS for this sub-attribute is 0.5.
In the groundwater samples the BOD value are very low and are within the drinking permissible limit. It is found that no adverse impact was seen on groundwater samples. Hence, EQS for this attribute is 1.0.

ii) pH: pH is an important parameter in the determination of water quality. This is mainly due to the biochemical activities taking place in the water resources which depend on the pH factor. According to WHO water quality standards the idea pH for unpolluted surface water resources is in the range of 6-8. In India it has been proved that the majority of the rivers are found to be alkaline in nature. The pH value for surface water resources of the study area ranges between 6.06 -8.86. Although in some samples the pH level is slightly above the permissible limit, impact of the various environmental activities on this sub-attribute is not adverse. Therefore, EQS of this attribute for surface water is 0.8.

The pH value for groundwater resources of the study area ranges between 6.0- 7.8. While comparing these values with the WHO standards it is understood that they are within the permissible limit. Hence, RQS of the attribute for groundwater resources of the area are 1.0

iii) Total Dissolved Solids (TDS): Total dissolved solids are nothings but the different kinds of salts which are found dissolved in the different water resources. Based on its concentration the suitability of the water for different purposes will be determined. According to the ISI standards (IS-10500, 1991) waters having a TDS between 500-3000 mg/l are within the limit for various uses. The TDS of the surface waters of the study area were found to be all within 500 mg/l. This indicated that the impact of various human activities on TDS is negligible. Hence, EQS of this attribute is 1.0. In groundwater resources too is is found that in all samples the TDS levels are all within the permissible limits indicating that there is no adverse environmental impact on the groundwater resources of the study area. Hence, EQS of this attribute is 1.0.

iv) Nitrate: Nitrate which is the highest oxidised form nitrogen is found to be present in all the samples of the water resources of the study area. The main source of nitrate in Lakshmantirtha River and the lakes is due to the agricultural run-offs and to some extend the
sewage input. According to the WHO (1984) standards, nitrate concentration for drinking purpose should not exceed 45ppm and as per ISI (IS: 105000, 1991) nitrate content for drinking purpose should be within the range of 500-100 mg/l. In Lakshmantirtha River and lakes of the study area it was observed that the nitrate content of all the samples is very low and within the permissible limits. Hence, the EQS of this attribute is 1.0. On the other hand in the ground water samples, NO₃ content is between 14-65 mg/l. Only few samples show concentration of NO₃ within the desirable limit (45 mg/l) and in almost all the samples the value exceeds the desirable limit but all are within the permissible limit for drinking (50-100 mg/l). Hence, the EQS of this attribute is 0.6.

<table>
<thead>
<tr>
<th>Sl.No.</th>
<th>Attributes</th>
<th>EQS</th>
<th>PIU</th>
<th>EQI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>B.O.D</td>
<td>0.5</td>
<td>25</td>
<td>12.5</td>
</tr>
<tr>
<td>2</td>
<td>pH</td>
<td>0.8</td>
<td>18</td>
<td>14.2</td>
</tr>
<tr>
<td>3</td>
<td>T.D.S</td>
<td>1.0</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>4</td>
<td>Nitrates</td>
<td>1.0</td>
<td>25</td>
<td>25</td>
</tr>
</tbody>
</table>

Table 7.4: Environmental Quality Indices of “physical –chemical” properties of surface water resources of the study area

7.5.1.3 Aesthetics

Aesthetics is another parameter by which the impact of human activities on the water resources of the study area can be studied. For this purpose aesthetics has been classified to two attributes of land and water and are further divided into sub-attributes which are classified into Geologic surface material, Relief and topographic character, appearance of water, floating materials etc.

A) Land: Land is one of the important attributes of the EIA studies since all changes caused on the water resources of the study area will have a direct impact on the land. To study these impacts, the land attribute is classified into sub-attributes of Geologic surface material, relief and topographic character of the study area.
i) Geologic surface material: For studying the geologic surface material, rocks and soils of the study area have been taken into consideration which could be referred as Lithological features.

The predominant rocks of the study area are peninsular gneisses. At some places patches of charnockite and quartzite intruded by dolerite dykes are observed. In this section what is most important factor in assessing the impact on environment are the mining activities taking place at a region. Coming to the study area few small scale mines were present earlie. Except one or two the remaining are inactive mine at present. Intensive and prolonged mining activities will produce some adverse impact on the surrounding environment and on its water resources. Some of these can be summarized as wasting of fertile top –soil, alteration of existing relief features, increased siltation of the nearby tanks , increase in TDS of the nearby surface water resources. All these changes take place at regions surrounding the mining activity.

Studying the soil types of the study area is of importance since soil and its texture have a direct impact on the recharge of groundwater and also on the chemical quality of the groundwater of the area. The soil types of the study area have been described in detail in chapter 2. Due to some human activities like mining of river beds and deforestation the soil layer can be wasted. Such kind of activity will have a negative impact on groundwater recharge in course of time also on the benthic life forms of the river basin. Fortunately this scenario is not seen at a large scale at the study area. Altogether, it can be said that over a course of time some negative impacts will be seen but as of now the various human activities carried out in study area have not much produced intense impact related to water resources of the study area. Hence the EQS of this attribute is 0.7.

ii) Relief and topographic character: Relief and topographic features of the basin includes aspects like hills, valleys, river, small streams and tanks. In general topography of the area is said to have a gentle undulating terrain. As discussed in earlier sections not much mining activities have been seen in the study area and have not caused severe impact on the environment. In fact the there has not been a major change of river course since the earlier days which is substantiated by comparing the older toposheets with the latest satellite...
imageries. Also except a few small check dams, construction of major dams and reservoirs has not taken place in the times. However, with course of geological time some of these adverse impacts may be seen on the environment of the study area. It can be concluded that not any adverse environmental impacts have been appeared as of now. Hence, EQS of the study area is 0.8.

B) Water: Clean and pure water is one the basic human necessities of every human being. No life form can survive without water. However, due to several human activities taking place on our surrounding, pollution of water resources takes place at different scales. In order to study the existing nature of water, the physical aspects like appearance of water, odour and floating material in the water have been studied.

I) Appearance of water and ii) Odour and floating material: The general appearance of water in nature is influenced by various factors like wind, climate, rainfall, inflow, outflow, silt etc. The overall appearance with striking effects is closely interwoven aspects.

The colour of the river water and lakes of the study area are resulting from the colloidal substances and material in solution. In river water and lakes the colour may occur due to the humic acids, fluvic acids, metallic ions, and suspended matter, phytoplanktons, and weeds, industrial and municipal effluents. The colour of the Lakshmantirtha River varies widely from its point of origin till its confluence point. However, during its course of flow, it acquires several colour and odours. At a point where Laskmantirtha River passes through Hunsur town, it acquires a darker colour, close to back, with a strong odour. The lakes of the study area too show different hues and odour. Most of them exhibit a light green in colour. Some of them which are brown in colour give a fishy to muddy smell. Altogether, it can be said that, human activities have produced such an impact on nature of water, which is neither adverse nor beneficial and therefore, EQS for this attribute is 0.5.
### Table 7.5: Environmental Quality of Indices of “Aesthetics” of surface water resources of the study area

<table>
<thead>
<tr>
<th>Sl.No.</th>
<th>Major Attributes</th>
<th>Sub Attributes</th>
<th>EQS</th>
<th>PIU</th>
<th>EQI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Land</td>
<td>i)Geologic Surface Material</td>
<td>0.7</td>
<td>6</td>
<td>4.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ii)Relief and topographic character</td>
<td>0.8</td>
<td>16</td>
<td>12.8</td>
</tr>
<tr>
<td>2</td>
<td>Water</td>
<td>i)Appearance of water</td>
<td>0.5</td>
<td>10</td>
<td>5.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ii)Odour and floating material</td>
<td>0.5</td>
<td>6</td>
<td>3.0</td>
</tr>
</tbody>
</table>

#### 7.5.1.4 Social

The last section in the present EIA studies, is studying the social activities of man which has a direct impact on our surroundings like the other aspects which were explained. In the social category, two attributes are being studied which are Scientific/Educational and life patterns are studied which are in turn classified further into sub-attributes like Geological, Ecological, Hydrological, Persons and Employment opportunities.

**A) Scientific:**

**i) Geological:** Geological aspects of the study area include the rock types, soil types and the river drainage characteristics. As discussed earlier the study area lies on crystalline rocks of Archaen age. The abundant rocks of the study area are peninsular gneisses, patches of charnokites and quartzites intruded places by dolerite dykes. Very few mining activities have taken place. Out which most of the mines are inactive at present. Some of the rocks are quarried and used for construction purpose. Socially mining and quarrying activities are...
beneficial from one point of view but at the same time can cause negative environmental impact as discussed in the earlier portion of this chapter.

Few checks dams and reservoirs have been constructed on the flow path of the river. For example in Harangi a check dam has been constructed. However, these constructions have not altered the flow path of the river and the original drainage pattern of the river and have not had so far any negative impact on any drainage characteristics of the river. Thus, it can be concluded that, the impact of the various environmental activities on geological aspects under the scientific attribute from the social aspect is almost negligible. Hence, the EQS for this attribute is 0.8.

ii) **Hydrological**: Hydrological aspects involve the study of water resources of the study area. This involves the surface water aspects and also groundwater resources. The groundwater studies touches upon topics like quality and quantity of groundwater, aquifer type, water table levels and fluctuation, groundwater recharge etc. Several organizations like Mines and Geology Department and Central Ground Water Board have been studying extensively on the groundwater aspects of the study area. Based on the data collected from these organizations and the interpretations, it has been observed that ground water levels reduce during the months of summer and recharge in monsoon and by post-monsoon the water level increases to its maximum height. But continuous exploitation of groundwater accompanied by lack of proper recharging is slowly causing a decline in the groundwater level. As discussed in the previous chapters, it was noticed that in some points of the study area a negative discharge was noticed. Hence, it can be said that, the impacts of the environmental activities has induced a negative impact, which however are not very severe in nature at this point of time. Therefore, the EQS of this attribute is 0.6.

**B) Life patterns**

i) **Persons**: Agriculture is the main occupation of the people in the area. Most of the people are economically backward. However, after many environmental activities being carried out like quarrying activities, urbanization, the economical conditions of people improved gradually as compared to the earlier days. So it can be concluded that the various
environmental activities has brought about the economic significance and it has not revealed any other negative impact on persons living in the study area. Hence, the EQS for this sub-attribute is 0.6.

**ii) Employment Opportunities:** This is another sub-attribute having direct bearing on the lives of the people in the study area. Various environmental activities over the years have in their own way created employment opportunities for the local people. Environmental activities like construction reservoirs, check dams have aided irrigation, thus providing the land holders and labourers with employment opportunities; many small scale industries have come up in the recent years and have provided employment to labour class of people. Thus, it can be said that various environmental activities have improved on the lives of the people as far as this attribute is concerned which needs to be improved more. Therefore, EQS of this attribute is 0.6.

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Major attributes</th>
<th>Sub-attributes</th>
<th>EQS</th>
<th>PIU</th>
<th>EQI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Scientific</td>
<td>i)Geological</td>
<td>0.9</td>
<td>11</td>
<td>9.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ii)Hydrological</td>
<td>0.6</td>
<td>11</td>
<td>6.6</td>
</tr>
<tr>
<td>2</td>
<td>Life-patterns</td>
<td>i)Persons</td>
<td>0.6</td>
<td>13</td>
<td>7.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ii)Employment opportunities</td>
<td>0.6</td>
<td>13</td>
<td>7.8</td>
</tr>
</tbody>
</table>

Table 7.6: Environmental Quality Indices of Social aspects of the study area

7.5.2 Environmental Quality Indices of Western Part of Hunsur

For calculating the Environmental Quality Indices of the study area, four major attributes of Ecology, physical-chemical, Aesthetics and Social aspects were discussed in the previous sections. The overall EQI calculated for each of the mentioned attributes will give the EQI for the study area. Estimated values of Environmental Quality Indices of the study area are given in the following table.
<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Attributes</th>
<th>Values of Environmental Quality Index</th>
<th>Estimated Values</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Supposed Values (In an Ideal environment)</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Ecology</td>
<td>52</td>
<td>36.6</td>
</tr>
<tr>
<td>2</td>
<td>Physical-Chemical (Avg. Of surface &amp; groundwater)</td>
<td>93</td>
<td>76.7</td>
</tr>
<tr>
<td>3</td>
<td>Aesthetics</td>
<td>38</td>
<td>25.6</td>
</tr>
<tr>
<td>4</td>
<td>Human interest/Social</td>
<td>48</td>
<td>32.1</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>231</strong></td>
<td><strong>171</strong></td>
</tr>
</tbody>
</table>

Table 7.7: Estimated values of Environmental Quality Indices (EQI) for the considered attributes in the study area

The EQI are estimated values using the EQS whose values vary between 0-1 for every sub-attribute considered, under each of the major attribute. The determined EQS values are given in table. The PIU value as given by Delphi method is considered. An Environmental classification based on EQI scoring is given in the Table 7.9.

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>EQI value (%)</th>
<th>Corresponding Environmental Ranking</th>
<th>Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0-25</td>
<td>Poor</td>
<td>IV</td>
</tr>
<tr>
<td>2</td>
<td>26-50</td>
<td>Satisfactory</td>
<td>III</td>
</tr>
<tr>
<td>3</td>
<td>51-75</td>
<td>Good</td>
<td>II</td>
</tr>
<tr>
<td>4</td>
<td>76-100</td>
<td>Excellent</td>
<td>I</td>
</tr>
</tbody>
</table>

Table 7.8: BEES Environmental Classification

By using the values of EQS and PIU, EQI was determined. According to Table 7.7 an ideal environment without any alteration would have an EQI score of 231. However, this situation is practically non-existence and unrealistic, as it can occur only in an ideal environment. The EQI estimated for the study area is 171 which is equivalent to 74 %. This means that, the ranking assigned to the environmental condition in the study area is ‘Good’ which corresponds to class.
7.6 Sustainable Irrigation Water Management

The purpose of sustainable water resources management is to sustain both the water supply capability and the environment, now and in the future. Water supply capability encompasses both the availability of water and the infrastructure to sustain water supply and use. The environment takes into account the water source and the land and air systems that support human production activities. As water demands in agricultural, municipal, and industrial uses change over time because of policy and technological changes, among others the relationship between water use and the environment needs to be continually reviewed and adapted. In river basins where irrigation is the major water use, sustainable water management should ensure a long-term, stable, and flexible water supply to meet crop demands, as well as growing municipal and industrial demands, while at the same time mitigating or preventing negative environmental consequences from irrigation. Sustainability reflects a systems concept for irrigation water management that is, applying a set of elements that interact in interdependent fashion. Moreover, sustainability, by its nature, implies a dynamic system whose status is determined by a balance of opposing forces or trends (Svendsen, 1987).

7.6.1 Measuring Sustainability: Indicators

Set of manageable indicators of sustainability based on broad guidelines and principles are necessary to detect problems as they arise and to provide an early warning system for decision makers. The indicators should be monitored and measured on the basis of the performance of natural systems and anthropogenic interactions, and action should be taken once specified thresholds are passed. In particular, the indicators should be helpful in tracing long-term cumulative environmental changes due to irrigation practices, which can potentially create irreversible problems. In the basins where irrigation is the dominant water use, sustainability in irrigation water management can be indicated by a) Water supply system reliability, reversibility, and vulnerability, b) Environmental system integrity, c) Equity in water sharing, and d) Economic acceptability.
These indicators, defined at the basin scale, are supposed to be used by basin authorities or related national administrative agencies, instead of individual farmers. An example of indicators designed for farmers can be found in MAF (1997).

7.6.1.1 Reliability, Reversibility, and Vulnerability of the Water Supply System

Water supply systems are subject to substantial risk because of inherent stochastic variability and a fundamental lack of knowledge. Sustainable water resources management requires a stable water supply system with enough flexibility to deal with various extreme conditions. Risk has been identified as one of the key sustainability issues in water resources management (Simonovic, 1997). The traditional measures of system performance are insufficient to capture risk behaviour, and additional criteria must be used to quantify recurrence, duration, severity, and other consequences of unsatisfactory system performance. These criteria include reliability, reversibility, and vulnerability (Kundzewicz and Kindler, 1995). These risk indicators can be used for various aspects such as water quantity and quality, crop area, yield or production, and flow requirement for environmental and ecological purposes.

7.6.1.2 Environmental System Integrity

A guiding criterion for sustainable irrigation water management is to minimize the interference of the irrigation system with the associated environmental system, including the effects on the water bodies that receive irrigation water through wind-drift, surface runoff, or drainage to groundwater. In addition, to sustain irrigation profit over the long term, irrigation water management must meet legislative requirements with respect to the environment. The adverse environmental effects of irrigation (such as waterlogging and salinization, groundwater pollution, and soil erosion) are often cumulative and may develop to an irreversible state because of long-term poor irrigation management. The measure of these indicators should be connected to both the short-term irrigation practices and performances and the long-term dynamic transmissions through some physical processes.
7.6.1.3 Equity:

Equity is one of the basic concepts of sustainable development. Water is not just an economic resource; it is also a community resource with deep emotional and symbolic value. Experience has shown that plentiful and clean water flows toward the rich and powerful and away from the poor and powerless (Ingram, 1997). Factors affecting temporal equity and spatial equity in water resources development can be either anthropogenic or natural, or both. Temporal equity is associated with resource depletion and long-term cumulative consequences that may lead to damages or even disasters in the future. Spatial equity often concerns the conflict between upstream and downstream areas in a river basin and the conflict between various water users.

7.6.1.4 Economic Acceptability

Economically acceptable irrigation systems provide lifestyle and social options for farmers and also contribute to the wider economy and community. From the perspective of using water more economically, the great challenge in irrigated agriculture is to include the opportunity costs of irrigation water supply, which are often an order of magnitude higher than current charges, (Briscoe, 1999). Another challenge is to include the long-term economic damage to the environment due to irrigation.

7.6.2 Water delivery practices in India

Depending on the type of schemes the water distribution system for irrigation can be different for surface irrigation and groundwater projects. The important models of distribution of water below outlets in surface irrigation commands developed over time in India on the basis of requirements and experience are the warabandi or osrabori system of Punjab, Haryana, Rajasthan and Uttar Pradesh; the shejpali and block systems of Maharashtra and Gujarat and satta system of Bihar; and the localised system for paddy areas in the southern states of Andhra Pradesh, Karnataka, Tamil Nadu, etc.
7.6.2.1 Conventional operation of canals in the study area

The canal system of the study area is like the majority of canal systems in India, operated in a manner which is referred to as conventional operation. A conventional operation consists of a scheduled delivery, an upstream operational concept and a constant downstream depth operational method. Conventional operation evolved as a practical method of satisfying irrigation needs within traditional canal system limitations. By using delivery schedules, it essentially combines demand-based needs with supply-based operation. The purpose of conventionally operated canals is demand-oriented, since the primary goal is to satisfy the needs of the water users. The downstream demand for water is assessed in advance so as to schedule the supply of water entering the canal through the headwork. Although the headwork flow is based on this schedule of anticipated demand, the actual operation of the canal is based on the supply. Check structures are operated to respond to upstream conditions, and the outflow from a pool reacts to the inflow.

7.6.2.2 Drawbacks of the conventional canal operations

One weakness of conventional operation is the inevitable discrepancy between forecast and actual delivery flows. In addition, there will be always inaccuracies in checking the flow and the amount of water stored in the canal pools. Since the canal system is not operated to react to actual demand, any such errors are transferred downstream. The sum of all operational errors will accumulate at the far end of the canal. Tail-end water users will often suffer from too much or too little water. To prevent shortages of water at the downstream end, excess water must be supplied at the headwork. Most of the time, this excess ends up being wasted near the downstream end of the system. The typical wastage in a conventionally operated canal system is about 5 to 10 % of the total flow.

7.7 Suggestive methods for efficient water management in the study area

Like it was discussed in the previous chapters a slight decrease of trend in the rainfall and also decrease trend of groundwater levels of the observation wells were seen which could be related to the vagaries in the amount of rainfall and also the stress put on groundwater resources. Also due to the improved living standards, the water demand has
been growing faster than its population. Per capita consumption is much greater than it was few decades ago. Hence, for efficient utilization of both surface and groundwater and to meet the growing needs for assured irrigation, it is essential to have sound planning and management of water resources.

7.7.1 Quantitative management of water resource of the study area

7.7.1.1 Modernization of irrigation system and operational management by way of canal automation

Automation has become a common term when discussing modern canal systems. Automation is defined as a procedure or control method used to operate a water system by mechanical or electronic equipment that takes the place of human observation, effort and decision; the condition of being automatically controlled or operated. The overall water use efficiency of a manually operated system, exclusive of the use of any return flow, seldom exceeds 40 percent. It is reasonable to expect an increase of the overall efficiency of about 10 percent or more for a system with some automation. The advantages of automation are not limited to savings in operation cost and in water. It also alleviates the risk of waterlogging and salinization. A further advantage is that it increases the reliability and accuracy of water distribution. This contributes to the establishment of a climate of confidence between the operating authority and the farmers, which in turn contributes to the effective organization of water user groups and their participation in operation and maintenance activities. With automation, it may also be possible to accurately know the volume of water delivered to individuals or groups of farmers. This makes possible the introduction of volumetric water charges, combined or not with a system of annual volumetric allocation. This approach is a useful tool for encouraging farmers to optimize the use of limited water allocations and to increase productivity. Automating a canal system is therefore implementing a control system that includes automatic monitoring or the control equipment that upgrades the conventional method of canal system operation. Automation is used to simplify and reduce or replace the decision-making process of the operators and to implement a decision. It is increasingly used to improve the effectiveness and to reduce the cost of water supply system operations. The flexible, high-quality operation of a canal system will yield many benefits, some of which are:
• increased crop production,
• reduced water use,
• better service to the water users,
• increased power generation,
• decreased power consumption,
• labour savings,
• less water wasted,
• easier management of the water system,
• improved protection of the conveyance facilities,
• reduced maintenance requirements,
• more accurate and equitable distribution of water,
• fish and wildlife enhancement,
• decreased flood damage,
• less need for subsurface drainage,
• better response to emergencies,
• social benefits (user's satisfaction, less conflict),
• environmental protection, and
• improved co-ordination with power operations.

7.7.1.2 Conjunctive Use Method

Conjunctive use management can be defined as the management of multiple water resource in a coordinated operation such that the total water yields of the system over a period of time exceeds the sum of water yields of the individual components of the system resulting from uncoordinated operation (Singh et al., 1997). Conjunctive irrigation maybe defined as irrigation based on a coordinated use of both surface and groundwater in the same command. The objectives of such coordination maybe higher agricultural production, improve sustainability acceptable socio-economic equity (Prasad and Prasad, 1977).

The main objective of conjunctive use of surface and groundwater is to achieve optimal utilization of water resource and maximize the agricultural production per unit of
water, simultaneously ensuring that the altering dynamic balance of environment, aiming towards its improvement and does not damage the same (Prakash Bahadur, 1997).

Some of the main objectives of conjunctive use are:

1. Reclamation of water logged lands.
2. Control over draft of groundwater reservoirs.
3. Control of salt–water intrusion in costal aquifers.
4. Increasing the dependability of existing water supply.
5. Alleviating the problems of high water table and salinity resulting from introduction of canal irrigation.
6. Mitigating the effects of shortage in canal water supplies often subjected to steep variation in river flow during different periods in the year.

In the study area the canal water is supplied continuously for two seasons i.e., Kharif and Rabi. Because of the continuous supply of canal water most of the existing wells in area are put completely out of use. The farmers are used to irrigation through surface water rather than groundwater because it does not involve any lifting or pumping effort. In such cases conjunctive use of the available water resources will improve the optimal utilization of both surface and ground water and will lead to a more sustainable condition.

7.7.1.3 Conjunctive Use Possibilities

Conjunctive use of surface and groundwater resources can be achieved by considering the following aspects while planning and designing and implementing the methods.

i) Storage and distribution aspects: The water can be stored in many ways by constructing big reservoirs, tanks, check dams, ponds, wells, harvesting pits. The water stored during the monsoon periods can be used later according to the necessity. But the total water occurred during monsoon cannot be stored, only a part of it can be stored in reservoirs and rest of water flows into the river and then into the ocean. The unused water can be diverted to recharge the groundwater. This would be of great help in the areas where discharge is
exceeding the recharge. The recharge/discharge zones have been explained in chapter 5. Diverting the extra amount of the run-off water in to the discharge zones will augment their water table.

In chapter 5 groundwater prospects zones have been explained in detail. As discussed almost 20% of the study area fall under the poor to poor-nil category in terms of groundwater prospecting zones. In these areas uses of surface water resources are recommended rather than conjunctive use of both surface and groundwater, since it will lead to over drafting of the groundwater and recharge of groundwater by diverting the extra amount of run-off in these zones should be practiced.

**ii) Use aspects:** The various possibilities of conjunctive use in the study area are listed below:

1. Groundwater may be used for irrigation uplands and pockets within or near the command perimeter, which cannot be served by surface irrigation canal system.

2. Groundwater may be used for irrigation in shallow water table areas (where water table is < 6.00 m.b.g.l) and waterlogged areas by constructing shallow dug wells and bore wells.

3. Groundwater may be used for extra crop growing as a supplement to surface water irrigation.

4. Groundwater may be used to meet the demands of a part of the existing command of surface water schemes and released surface water utilized in areas where there us deficit water supply.

5. Command areas may be irrigated by canal water for one-crop seasons and by groundwater for another crop season.

6. Surface canal water may be used to entire command area with reduced number of watering. Groundwater may be used conjunctively for providing intensive irrigation to the possible extent.

7. Surface canal may be used for both seasons for irrigating dry crops. And the groundwater may be used to raise crops for farmer’s choice.
8. Saline groundwater may be mixed with good quality surface water to make the water suitable for irrigation and domestic purpose.

iii) **Control aspects:** To control some of the adverse effects of irrigation the conjunctive use fit certain advantages. Groundwater maybe used to the maximum to control the water logging conditions. In deep water table area surface water may be used to increase the groundwater recharge. Pumping of groundwater may be used to facilitate vertical drainage as means of removing unwanted soils and root zone. Pumping back into the canal or using directly for irrigation may control seepage from the unlined canals. The seepage losses are common in any surface irrigation system (Khanna and Rai, 1991). According to Chawla and Ansari (1989), the seepage loses can be determined by constricting augmentation wells along the canal.

iv) **Time aspects:** Timely supply of water for irrigation from both surface and ground forms an important aspect of water management. During monsoon periods reservoirs once filled to maximum can meet the needs of water requirements for paddy cultivation. But during the adverse monsoon periods when reservoirs cannot meet the demands, groundwater can be used to meet the demand. Time sequence permits a phased and economical development of water resources.

v) **Economic and financial aspects:** Various economic and financial factors have an important bearing on the development of integrated and conjunctive use. Proper economic and financial policies will help promote conjunctive use and also prevent lopsided development.

### 7.7.1.4 Command Area Development Program

This program aims at improving the utilization of groundwater for irrigation at the field level through economical use of water, which helps in controlling the water logging to some extent. The program covers on farm development works comprising filed channels, filed drains, land levelling, desilting of tanks and construction of wells. It also envisages groundwater development in the command areas, adoption of suitable cropping pattern, proper regulation of canal irrigation, and provision of adequate drainage facilities. It is
suggested to construct more number of dug wells; dug cum bore wells in the command area. This program also encourages the conjunctive use of surface and groundwater to check the rise of water table in the command area.

**7.7.1.5 Rainwater Harvesting**

As discussed earlier in chapter 3, a slight decrease in the trend of rainfall in the study area was noticed. Hence, proper utilization of rainfall especially rainfall which flows in the forms of run-off plays an important role in proper management of the available rain which reaches the earth surface. Rainwater runoff refers to rainwater which flows off a surface. If the surface is impervious then runoff occurs immediately. If the surface is pervious, then runoff will not occur until the surface is saturated. Runoff can be harvested (captured) and used immediately to water plants or can be stored for later use. Studies have shown that rainwater harvesting is the cheapest form of water management, particularly in a developing country with abundant rainfall. Rainwater harvesting will also help in augmenting the depleted groundwater resources of the study area. In the study area there are many water harvesting opportunities on developed sites and also it can easily be planned into a new landscape during the design phase. There are many inexpensive methods which could be constructed for rain water harvesting in the study area. An example would be storing water in a barrel for later use or constructing small berms and drainages to direct water to a row of trees.

**7.7.1.6 Proper matching between cropping pattern and the water availability**

In this scarce water scenario, especially in case of agriculture, a proper matching between the cropping pattern and the water availability is very essential. Too much water is as bad as too little. The nature of the crop should be matched to the water availability. For example, the pulse crops or oil seeds crop may be grown after paddy crops, which need less water. The study area is mainly cultivated under paddy. After paddy cropping, the soil contains sufficient water moisture for pulse/oil seed/millet crops. Such a cropping pattern not only helps in proper utilization of scarce water but also helps in producing sufficient food for poor farmers and other beneficiaries. Such planning greatly help in managing the water resources and increasing the overall yield.
7.7.1.7 Environmental education

Environmental education is needed to create awareness among farmers regarding (a) damage on irrigation and health due to inferior quality of groundwater, (b) crop-water requirements, soil characteristics and cropping-patterns, and (c) efficient methods of irrigation to improve agricultural production. Farmers should be better educated to increase agrarian income and improve living conditions, and better agronomy will contribute to the gross national product of the country.

7.7.2 Suggestive Methods for Water Quality Enhancement

7.7.2.1 Tackling the Nitrate problem

In India, several studies have reported groundwater contamination by nitrate due to agricultural activities (Mukherjee and Pandey, 1994; Chandu et al., 1995 and Prasad, 1998). High concentrations of nitrate in the groundwater samples were attributed to animal and human sources or irrigation return flows from agricultural fields dressed with fertilizers.

Nitrates are derived from nitrogenous fertilizers, organic manure, and human and animal wastes. Hantzsche and Finnemore (1992) described the various processes by which soil microorganisms and nitrogen interact to form nitrates. Organic nitrogen (manure, plant waste, etc.) can be easily converted to the ammonium ion through the process of ammonification. The ammonium is subsequently oxidized to nitrate by nitrification (Freeze and Cherry, 1979). The main source of nitrate in the study area is the application of fertilizer in the irrigation water. The common fertilizer applied is $(\text{NH}_4)_2\text{SO}_4$. Through nitrification processes in the presence of oxygen, ammonia is transferred to nitrates, according to the reaction:

$$2\text{O}_2 + \text{NH}_4 = \text{NO}_3 + \text{H}_2\text{O}$$

Greater mineralization is generally associated with higher nitrate concentration. The high nitrate concentration may occur due to leaching of NO$_3$ from fertilizers and biocides during the irrigation of agriculture land. The average value of nitrate was higher for the post-monsoon due to the monsoon effect. For overcoming the nitrate problem excess use of
fertilizers for higher crop yields should be avoided to reduce NO₃ which also would reduce Na, C-, SO₄ and F. Selection of fertilizers for plant growth should be based on soil characteristics and crop requirements. Use of organic manure should be encouraged by farmers which is not only commercially cheaper but also safe for the environment. Some other advantages of application of organic manures are listed as follow:

- Organic fertilizer releases nutrients slower, meaning you don't have to put it down as often.
- Since the manure contains a lot of organic matter, it increases the water holding capacity in sandy soils and drainage in clayey soils. This enhances the soil permeability which in turn facilitates irrigation.
- Organic manures provide food for soil organisms like earthworms which are responsible for improving soil quality.
- Organic manures include (i) Farmyard manure (FYM), (ii) Compost, (iii) Green manure, (iv) Vermi compost.

**7.7.2.2 Softening Techniques**

Concentration of TDS, hardness, Na⁺, Cl⁻, NO₃⁻ and SO₄²⁻ currently exceed safe limits for drinking waters in some of the groundwater samples. Proper treatment of groundwater, such as water softening, ion exchange, and demineralization of water, should be used to reduce their concentrations. As discussed in chapter 6, in most of the groundwater samples the hardness was above the permissible limit. The hardness of water of the water samples were grouped into two categories of temporary and permanent hardness.

**a) Removing temporary hardness:** Temporary hardness is due to the presence of calcium hydrogencarbonate Ca(HCO₃)₂(aq) and magnesium hydrogencarbonate Mg(HCO₃)₂(aq). Boiling the water causes the precipitation of solid calcium carbonate or solid magnesium carbonate. This removes the calcium ions or magnesium ions from the water, and so removes the hardness. Therefore, hardness due to hydrogencarbonates is said to be temporary.
b) **Removing permanent hardness:** Permanent hardness is hardness (mineral content) that cannot be removed by boiling. When this is the case, it is usually caused by the presence of calcium and magnesium sulphates and/or chlorides in the water, which become more soluble as the temperature rises. Some of the methods adopted for removal of permanent hardness are listed as follow:

(i) Lime-Soda process
(ii) Ion-exchange process

(i) **Lime-Soda process:** The aim of lime-soda process in to convert the calcium and magnesium compounds to the virtually insoluble forms, calcium carbonate (CaCO3) and magnesium hydroxide (Mg(OH)2). The insoluble forms a precipitate which can be removed as sludge.

(ii) **Ion-exchange process:** Most conventional water-softening devices depend on a process known as *ion-exchange* in which "hardness" ions trade places with sodium and chloride ions that are loosely bound to an ion-exchange resin or a zeolite (many zeolite minerals occur in nature, but specialized ones are often made artificially). Zeolite is a complex salt called sodium aluminium silicate (zeolite) which is used to remove permanent hardness in water. Zeolite which is made synthetically is packed into a column and the hard water is allowed to flow through it. Double decomposition occurs and calcium aluminium silicate is formed. Eventually the zeolite is completely converted into its calcium salt. It can be made fit for use again by pouring a strong solution of common salt through the column.