CHAPTER – IX

CONSERVATION, MANAGEMENT AND PLANNING FOR GROUNDWATER DEVELOPMENT

INTRODUCTION

Water is among the most essential requisites that nature has provided to sustain life on the Earth. Most of us are conscious nearly all the time of the importance of water in our life but actually our knowledge of it is pretty skimpy. Now a day, perhaps water outstress all geo-environmental factors to enter more prominently into considerations of human and economic development and environmental quality. It must be realized that rapidly increasing demand for water, degradation of water due to contamination, water scarcity in urban areas, frequent incidences of water born diseases etc., are becoming order of the day. Hence, the development of water resources for their optimum use involves proper conservation, management and proper planning of the resources. Normally, the principal target is to obtain water in required quantity and quality at the minimum cost. Water is available through the hydrologic cycle over space and time as a limited renewable resource, through a complex physical-economic-socio-ecological pattern. It is required by man, in locations and time, in quantity and of quality which may be different from the existing method of supply.

In this regard, the principal issue in scarce and precious resources planning is to adjust the supply and demand imbalance through structural facilities of storage, conveyance, processing and their operation. Groundwater and surface water are in hydraulic continuity that is surface water enters into the earth become groundwater and emerge again on the surface. For the greater achievement, the conservation and management of water resources should therefore involve the conjunctive use of surface and groundwater resources.

9.1 CONSERVATION AND MANAGEMENT OF WATER RESOURCES

Water covers nearly 70 percent of the earth's surface, but most of it is not usable. On a global basis, about 95% of the water is available in the seas and the oceans. Fresh waters account for only 5 percent. With the present day technology, only 1 percent of the global waters can be economically exploited. Of this nearly 99 percent is groundwater and river flows constitute only 0.1 percent. Only 7 percent of the rainfall is available as run-off as 77 percent falls on oceans and 16 percent goes off as evaporation from the land (Rajan, 1978). Moreover, the distribution of usable water, which is hardly 0.5 percent of the earth's total volume of water, is highly variable in time and space. This variation is well marked in the study area with a monsoonal rainfall regime. Water surplus and deficit conditions occur over the whole area during the same season. Hence, significance of conservation of water resources can hardly be over emphasized. Apart from utilization of a resource, its conservation also confirm that it will be available in sufficient quantity to meet the needs, taking into account the trend of socio-economic development of the study area.

Water is essential for survival. But today about 200 million people in India do not have access to safe drinking water. Most of our water sources are polluted with untreated or partially treated wastes from industry, domestic sewage and fertilizer or pesticide run-off from agricultural fields. According to the Ministry of Rural Development of India, about 1.5 million children under five years die each year due to water related diseases, and the country also loses over 200 million person days of work a year because of these diseases (Parikh & Parikh, 1999). But recent studies show that better water supply and sanitation facilities can considerably reduce illness and death due to water related diseases.

Though India has a long tradition of managing water, but increasing demands due to population and industrial growth and agricultural development pose new challenges. The quantity and quality of available water is decreasing, aggravating the already serious situation. According to the Ministry of Water Resources (MWR), water shortage in India will become even more pervasive by 2025 and stress human and economic development. Appropriate management of water resources is crucial for future economic development and protection of human health and life itself. Water resource management is a stable and concurrent subject under schedule VII of the Indian constitution. The aim of this

Constitution brief is to ensure water security for present and future generation, preserve water quality and assure that water is available equitably to all members in the society. The strategy recognizes that every water use generates wastes water that damages water quality thus reduces quantity of water available for use. Hence, the strategy brief focuses on efficient and sustainable water quantity management while suggesting ways to maintain the integrity of ecosystems.

In another sense, demographic pressure in the country has added a separate dimension to the problems in the fields of domestic, agriculture, livestock and industrial water demands. The shrinking per capita fresh water availability in the country over the last few decades is alarming (Basak, 1998). Over the last two decades, per capita water availability in the country has decreased more than two times. Similar is the case of per capita land availability. Consequently it will have to sustain itself with ever shrinking land-man and water-man ratio. Herein, lies the imperativeness and desperate need of water management. It may be noted here that water can largely be managed through the coupled management of land and bio-mass. These three (land, water and bio-mass) are inseparable and the term, water management includes related management of land and bio-mass also. In this context, the appropriate water management will be —

- Rain water conservation and management in the non-irrigated areas.
- Irrigation and drainage management in the command area of major irrigation projects.
- Potable water and its quality management for domestic needs in the rural and urban sectors.
- Drought management and region specific know-how generation for the same.
- Ecological management for water resources in relation to harmonizing land, water and bio-mass.
- Monsoon flood management in the river plains, and
- Fresh water development and conservation in the coastal belts and islands.

Based on the prevailing hydrogeological conditions and the available data, it is opined that solution to water supply problem of the study area lies in managing groundwater resources of Mechi-Mahananda interfluvial basin enclosing the Terai belt area. A time bound programme must be initiated to ensure sustainable use of invaluable water resources. The ministries and agencies that control water resources, those that use them and those that control quality and treat wastewater have to work together. A multi-layered approach, which involves implementation of checking the water losses through the natural processes, storing water by artificial recharge and conserving it for subsequent use are required to be accomplished for judicious management of water resources, introduction of new and traditional technologies for water quality management and conservation, recycling and reuse, economic incentives for users and the involvement of people who have a stake in the use of the resource and required. The different conservation measures suggested for the study area are as follows :

a) Control of the Water Losses :

This method is applicable mainly in the uses of groundwater as well as surface water in irrigation. In the investigated area, about 86 percent of the total water is being used in irrigation in 1997-98 but 60 percent of it goes to meet the crop water requirements and the rest 40 percent is lost due to application losses on the field, following adoption of faulty irrigation on the practices and seepage from the canal system The application losses result from over irrigation, and also when field irrigation channels, grading and shaping of fields, consolidation and rectangulation of holdings, suitable methods of irrigation, irrigation scheduling, rotational supply of water, appropriate cropping patterns etc. are either inadequate or non-existent. The irrigation water losses in the investigated area are mainly due to over-irrigation, evaporation, and by seepage from canal system Apart from loss of a valuable resource, it may also create a number of problems like water-logging, soil salinity and alkalinity, and adverse effect on community health, in combination with factors like poor drainage system and flooding from streams.

Water losses of the study area from over-irrigation can be checked by volumetric charging for water or educating the farmers about its adverse consequences and providing the assured or rotational supply of water whereas those from canal seepage can be checked by lining the canals. However, lining involves heavy expenditure and has not so far been restored in the investigated area. Loss of irrigation water also occurs due to unscientific method of irrigation, which is, by inundation from one field to the other. Actually, there should be provision of field irrigation channels so that each field would have direct access to irrigation water and drip and sprinkler method of irrigation should be increasingly adopted. Now-a-day, irrigation is mainly by the border strip, check basin and furrow irrigation methods. Most of the water losses could be minimized by adopting the concept of "conservation irrigation", that is, a combination of irrigation and cropping pattern, best suited to the area, keeping in view the physical and socio-economic conditions of the area.

Domestic and livestock water losses of the area of investigation can only be controlled by creation of general awareness about them amongst the habitants of the area. A regular inspection of pipelines and other constructional fault may also help in checking the municipal as well as domestic water losses. But, unfortunately, this badly needed awareness is generally lacking amongst the people. On the other hand, the industrial water uses in the study area is very low, that is only 1.46 percent of the total water used in 1997-98. The problem of the disposal of industrial wastewater is, therefore, almost non-existent at present. However, the problem may have to be tackled in future, in view of the increasing pace of industrial development of the hilly area, by suitable arrangements for the purification and recycling of wastewater.

b) Conservation through Artificial Recharge :

Artificial recharge of the groundwater of the study area may be defined as the augmentation of the natural infiltration or precipitation or surface water into under ground formations by approximate methods. Artificial recharge may be needed for augmenting the quantity of groundwater, for disposal of flood waters and for reduction of salt water intrusion and for the prevention of land subsidence etc. The selection of a suitable recharging method depends upon local topography, geology, soil conditions and quantity of water to be recharged and its ultimate use.

Climate, land value, and quality of water may play an important role in choice of the method, under special conditions.

Studies and pilot projects on artificial recharge have been initiated in most of the water crisis area for checking the decline in groundwater table and also ensure its effective utilization. However, there is no set pattern of planning, design, execution and maintenance of artificial projects. Among the various methods of artificial recharge—water spreading, recharging through wells and pumping and seepage have been most commonly used. The total amount of water infiltrated into the soil depends on the infiltration opportunity type, which depends on the slope and the field structures, which tend to hold the run-off water over long periods on the land surface.

i) Methods of Artificial Recharge by Water Spreading :

The main objective of this method is to release water over the land surface, to increase quantity of water percolating to the water table. The essential prerequisites are maximum duration of contact of recharging water with land surface and maximum area of contact. The various methods of water spreading are as follows :

Flooding Method : The flooding method is recommended in areas where sufficient quantity of water is available but not monetary resources available to go for more effective techniques of artificial recharge. The water spreads evenly in a thin sheet over quite a large area without disturbing the soil.

Basin Method : In this method, water is diverted to the upper most of a series of basins constructed by dikes of levees which generally run on contours. This is the most practical method of artificial recharge. Recharging water laden with sediments may sometimes seal the basins, which can be avoided by using the upper most basins as settling basins or by scrapping or disking of the bottom surfaces. The basin method is particularly suitable where the ground surface is irregular and infested with a number of shallow gullies and ridges.

Furrow or Ditch Method : In the furrow or ditch method, water from a canal is distributed into a series of parallel ditches which are shallow, flat bottom and closely spaced. The orientation of the furrow or ditches may be contour type, lateral type or tree shaped. This method has the advantages of being used in rough terrain and with recharging water has fairly high silt content.

Natural Channel Method : It involves releasing of water in existing stream channels. In most cases a series of small check dams in flat channels are constructed either across the channel or in 'L' shape, as the water may spills from one check dam to the other or in the case of 'L' shape, water flows around from one basin to other. Often these channel works are removed in the flood period.

Irrigation Method : In this method, extra water is supplied to the irrigated fields so as to allow it to infiltrate underground. Though no land preparation is required, leaching effects of percolating water on crops and soils have to be carefully ascertained.

ii) Recharge through Wells :

Recharge through wells is generally practical where enough land area is not available for recharge because of cultivation requirements or is unsuitable for recharge as in urban areas of the area of investigation. The amount of water that can be recharge through wells is larger compared to the other methods. For economy pumping wells may be used as recharge wells at the time of requirement. The best recharge rates in wells have been observed in very permeable formations. Recharge wells are also used as a means of disposal of storm water in study area.

iii) Recharge through Seepage :

The seepage from canals and field channels, ponds, tanks and rivers and deep percolation from irrigated fields and also contribute significantly to groundwater augmentation. For unlined canals it may vary between 1.8 and 2.5 cusecs/ 10^6 m^2 of wetted area in normal soils with some clay contents to 3.0 – 3.5 cusecs/ 10^6 m^2 of wetted area in sandy soil. In most of the canal irrigated areas a substantial component (35 to 40 percent of water delivered) percolates below the root zones and contributes to groundwater recharge. When irrigation with groundwater sources, this contribution may like between 30 and 35 percent. The seepage from tanks may vary from 9 to 20 percent of their live storage capacity. The seepage from percolation tanks may be as high as 50 percent of its gross storage.

c) Conservation by Soil Moisture Storage :

The moisture content of the soil is defined as the amount of water lost when it is oven dried and may be expressed as the volume of water per unit volume of bulk soil. The infiltrating water when stored in the soil pores raises the moisture content. The forces that keep the soil and water.together are based on the attraction between adhesion and cohesion. The amount of water held in the fine capillaries depends upon the surface tension and capillary size but when held in bigger pores, gravitational forces become active. The dissolved salts tend to decrease the free energy of water and hold the water through osmotic forces. Under the gravitational force, the water in large pores starts draining out. The moisture content of the soil after the drainage of gravitational water is called field capacity of the soil. It is expressed as a percent by volume and varies with soil texture. The gravitational drainage, however slow it may be, does not stop at field capacity and continue to deplete the soil moisture. The major losses of water are occurred through evapotranspiration by plants. The extraction of water through roots and evaporation losses, progressively reduce the moisture content of the soil below the field capacity. Soil with large amount of available water are generally more favourable for plant growth. The maximum available water for plant growth is calculated up to root zone depth and varies with the type of crop and its rooting system Soil moisture measurements are important for estimating the quantity of irrigation water as well as for scheduling of irrigation.

9.2 CONJUNCTIVE USE OF SURFACE AND GROUNDWATER RESOURCES

Conjunctive use of water resources of an area or a region means proper utilization of its groundwater and surface water together, in a planned manner. In view of the variable nature of the surface water supplies from year to year as contrasted with groundwater supplies, large development can be achieved by integrating both these resources. Hence, it follows that the conjunctive use involves optimum utilization of available surface water during the years in which the rainfall is above the average, and storing the excess water underground by artificial recharge. During the years of below average rainfall, when the surface water resources are limited, the sub-surface water reservoir becomes the main source of the water supply. So, the combined yield from these two sources are larger and more economic than the yield obtained from either source separately. In future years, when the natural water resources are fully utilized, the meaning of conjunctive use will assume greater significance. It is commonly known that conjunctive use of surface water and sub-surface water on small scale has been an age of traditional practice in India. In many parts of the study area, the farmers and cultivators use water both from surface storage such as bunds and ponds, from springs and streams and also from the wells to irrigate their fields and for many other issues.

The conjunctive water use approach also helps in solving the problems as referred to earlier Chapter–VIII, arising out of use of land and water. For instance, as anti-water-logging measure, pumping from tube wells has been resorted to different blocks. Similarly, a battery of tube wells has been constructed in Kharibari and Phansidewa blocks along the canals to supplement their dry period consumption. Moreover, in areas with salinity and alkalinity characters, the water could be mixed with fresh surface water for use in irrigation purposes etc.

9.3 WATER QUALITY MANAGEMENT

Qualitative water is not a luxury. It is a necessity to all respects. With sensible policies, the renewable resources can be cleaned, saving crores of rupees in health costs and protecting our land and water resources for future generations. A comprehensive multi-pronged water quality management strategy includes strict implementation of pollution control laws, promotion of cleaner technologies, fiscal incentives and economic instruments of appropriate prices, taxes and property rights. An aware, active and citizenry is critical for success. The water quality management strategy has to be bold on several approaches simultaneously to address the problems. Five such approaches are highlighted as follows :

a) Water Conservation for Pollution Control :

The water quality management strategy provides a broad framework for pollution control. All water use produces effluents. Minimizing the amount of water used can have an immediate impact on the quality of water. The strategy identifies demand reduction for water as a major priority. Water is still treated a free goods, to be used liberally, and to be sullied with impunity. Pricing water to reflect its scarcity value, can encourage users to be more prudent in its use. The price of water should also include opportunity costs and environmental impact on its use. Better pipeline management, reused and recycled of domestic wastewater for agricultural and industrial purposes, drip and sprinkler irrigation technologies can curtail water losses as well as to reduce water demands and uses and also reduce fertilizer or pesticide or chemicals run-off from agricultural fields, reducing the amount of pollutants that eventually find their way into the water bodies.

Polluters usually do not feel the effects of the pollution caused by them and adverse effects are born by third parties. The polluter is rarely held accountable for the damage and continues to pollute with impunity. Quantifying and putting a cost to the polluter for these adverse effects of pollution and then incorporating them into the decision making process and deciding the price of water accordingly can resolve such problems.

b) Encouraging Industry to Act :

Industry is gradually beginning to realize that pollution control is a reality they can not avoid. However, their reluctance to act has to be tackled in a manner that is more effective than the existing command and control regime. Large investments in treatment facilities are essential and these must be encouraged through economic incentives. Water efficient and cleaner technologies should be made mandatory, particularly in new industries as nothing in production sector can be absolutely cleaned.

c) Domestic and Agriculture Pollution Control :

As there is a framework in place to deal with industrial pollution mechanisms to address pollution in the agriculture sectors are not in place. This is out of the ambit of the Central or State Pollution Control Boards. So why, new institutional mechanisms need to be explored to monitor and manage domestic and agricultural pollution. Responsibilities should be either vested with the Central or State Pollution Control Boards or existing institutions like the Public Works Department, Municipalities or Gram Panchayats.

As most municipalities are cash-strapped, involvement of the private sector and partnership between private and public institutions, need to be explored to provide domestic water supply, sanitation and wastewater treatment facilities, in urban and semi-urban areas. Cheaper domestic wastewater treatment technologies, like biological treatment need to be examined as alternatives to the more expensive conventional treatments. An important first step is to curtail overuse of fertilizers and pesticides through appropriate pricing. Subsidies that encourage should be removed. Environment friendly practices like vermiculture, use of organic manure and integrated pest management practices that obviate the need for persistent pesticides should be vigorously encouraged.

d) People in Partnership :

It has become increasingly evident that it is virtually impossible for the Government to monitor the activities of individuals, industries and institutions across the country. A vigilant stakeholder with strong and technically equipped institutional support can play a very important role in managing the environment. Vigorous awareness campaigns should be encouraged as experience in the industrialized countries has shown that polluting firms react to popular pressure, and are keen to clean up their act to maintain a green profile. A citizen's right to information and regular publication of environmental audits of firms can be very effective in clearing up industrial pollution.

e) **Institutions** :

To monitor industrial, domestic and agricultural pollution institutional mechanisms that could involve the stack holders need to be evolved. The pollution control board should generate and maintain data that can be made available to concerned citizens, who can apply a crucial role in ensuring that water resources are conserved and environment health is maintained. They should be provided the necessary teeth to implement the law. State-of-the art monitoring technology should be provided to measure pollution, and the technical skills of the manpower upgraded.

9.4 LEGAL DIMENSIONS OF GROUNDWATER RESOURCES

The rapidly increasing use of groundwater of varied purposes may create critical problems dealing as much with the individual interest and rights as with the ultimate conservation and sanitation of the resources itself. As has been discussed in the foregoing chapter, the indulgence in indiscriminate exploitation under the conflicting doctrines of water right may lead to depletion of the reserves and also, in some localities, to land subsidence and encroachment of salt waters. Further, this may create conflicts of interest over its use and management leading to insecurity of investments and impeded or unbalanced economic growth. It is, therefore, necessary for the Government to re-orient basic groundwater policies and to adopt legal measures to ensure a fair distribution of the supply, reduction of water and conservation of this important resource. The legislation should clearly define the groundwater rights, the responsibilities of water authorities, control of groundwater exploration and development, allocation and distribution of water-supplies as well as water conservation and sanitation.

The laws of groundwater rights in particular, and water rights in general must be considered in addition to hydrogeologic environments. A groundwater right is a right, granted by law, to take possession of groundwater and to put it to beneficial use. Two aspects relating to groundwater development and management that require legislation are — (a) control and regulation of groundwater use to prevent over draft and mining of aquifers, and (b) prevention and control of groundwater pollution.

a) Control and Regulation of Groundwater Use :

Right of exploration for groundwater, either on public or private land should rest with government and be carried out by an authority approved by the government. The result of unrestricted groundwater development is that a stage is reached when the yield of every new well is derived by significantly reducing the yield of some other, or by capturing part of stream discharge and reducing water for irrigation or some other facility. In this process, a well owner previously enjoying an uninterrupted supply of water may find his well going dry or the water turning saline, forcing him to abandon the old well and sink a new one. Stream flow depletion may render useless costly diversion works, besides adversely affecting surface water supplies to lands situated along stream banks. In the absence of the groundwater law, there is no machinery to redress harm done or ensure equitable distribution of this precious resource. The lack of legislation in many countries is in part, due to resistance to subjecting one self to discipline in the utilization of the commodity that is elan vital, and in part due to the exploitation not reaching alarmingly high levels for the ill effects to be felt by society as a whole. Groundwater being a State subject, as per Entry 17 of List II of the Seventh Schedule of the Constitution of India, only States are empowered to enact laws to control and regulate groundwater exploitation. The Groundwater (Control and Regulation) Bill of 1970 envisages the setting up of a Groundwater Authority. The doctrines of the groundwater law applied in different States of India as well as the study area covers a wide spectrum of water rights, which are briefly cited as follows :

➢ Any person wishing to have a well drilled on his land or on the land of the third party, whether private or public, should obtain prior authorization from the approved authority.

- Any person drilling or constructing wells or deepening wells in his or another person's land should obtain a water well driller's licence from the government or administrative authority approved by the government.
- Wells should be drilled and built according to certain specifications in respect of diameter, casing, depth, material used and the like.
- The driller or the owner of the well should allow access to the well-site for inspection and provide available facilities for carrying out tests considered desirable by the authority concerned.
- Wells and water works for the supply of groundwater should be maintained in such a way as to comply with the condition set forth by the law. It should be the duty of a person owning springs or underground water for which he finds no use to code them against a reasonable indemnity for water supply service or any other public utility service.
- The water of underground channels, artesian basins, reservoirs or lakes, which have reasonably ascertained boundaries, should be declared to be public waters to belong to the public and to be subject to appropriation for beneficial use. When such declared basins have reached the limits of practical development, further appropriation should be stopped accordingly.
- For the allocation of water supplies, public health should be given priority over other uses, which may be subsequently rated according to their status in the given area.
- The authority should likewise restrict over development of groundwater in any area, the development of the groundwater resources should be in accordance with the availability in a given area.
- Regulations may prescribe the planned utilization of groundwater basins for carry over storage, including necessary control of the pattern of pumping.

- Regulations should be set forth to prescribe the control and provision of recharge of depleted groundwater basins. The number, location, spacing and types of wells to be approved.
- The depletion of the wells may be controlled by the prescribed rate of pumping and declaration of complete appropriation.
- Near surface groundwater aquifers to a depth of 30 m or to a depth as decided by the approved authority on the basis of geological and hydrological conditions, should be prevented from being tapped by tube wells on a large scale.
- In recent years, availability of institutional finance for programmes of construction and energisation of wells has, while giving a fillip to exploitation of groundwater for irrigated agriculture, increased prospects of reaching a stage of critical overdraft in the not-too-distant future in some points of the country, if some sort of control is not exercised to prevent indiscriminate sinking of wells. According to the existing procedure, pending appropriate legislation, groundwater organizations of States are required to carry out water balance studies, on a block-level basis, in areas declared critical by the Central Ground Water Board. If it is found, on the basis of the studies, that adequate groundwater balance is available for further exploitation.

b) Prevention and Control of Groundwater Pollution :

Pollution control is possible if thorough investigation is made, prior to the disposal of effluents, as to its effect on groundwater quality. Further, if by legislation, discharge of effluents is licensed, it is easier to trace sources of pollution. Hence, to overcome this problem, Parliament has passed the Water Act 1974 which is India's first to deal comprehensively with an environmental issue of vital importance. The concern of the government has been summarized in the 'statement of object and reason' of the act.

The problem of pollution of rivers and streams has assumed importance and urgency in recent years as a result of the growth of industries and the increasing tendency of urbanization. It is, therefore, essential to ensure that domestic and industrial effluents are not allowed to be discharged into the water courses without adequate treatment and discharges would render the water unsuitable as source of drinking water as well as for supporting fish and for use in irrigation. Pollution of rivers and streams also causes in increasing the damage to the country's economy.

Under the water Act'74 and its Amendment Act 1988, pollution has been explained in a comprehensive manner to include contamination of water; alteration of physical, chemical or biological properties of water, discharge of sewage, trade effluents or any liquid, gaseous or solid substance into water as may or is likely to cause nuisance or render it harmful or injurious to public health or safety, to domestic, commercial, industrial, agricultural or other legitimate uses, or to the life and health of animals or aquatic organisms. Disposal of pollutants in streams or 'subterranean waters' is restricted.

Moreover, a Central Board of Prevention and Control of Water Pollution was constituted, according to this Act. The Act also provides for constitution of boards in the states. The functions of the Central Board are generally advisory, while the States have regulatory functions of inspection of effluents, plants and works, and the power to enforce the provisions in the Act and impose penalties.

Finally it may be concluded that water is paramount for the survival of human race. The pollution of water has deleterious effect on the health of the people. A strict law and more rigorous enforcing machinery is the need of the hour. The role of the Board is not up to the mark. It is also realized that different punishment has also not achieved much success. The remedy lies in the evolution of participatory model of legal regime. It calls for a fresh look into the act to make it more effective.

9.5 PLANNED DEVELOPMENT OF GROUNDWATER RESOURCES

Groundwater is a critical resource in much of the semi-arid or more arid parts of the country. It may set the limit on the use that man can make of the other resources, and thus ultimately own the density of population and the standard of living that can be sustained in those regions. In the regions of abundant rainfall, however, water is not generally the first of the natural resources falter. Nature generally provides a surplus of water in those regions where water flows to the sea, and this surplus can be put to many uses. Even here local shortages of water may develop, because of the failure to pattern the development and management in accordance with the availability of groundwater. The groundwater reservoirs in humid regions having adequate replacement are by no means devoid of groundwater problems. As the number of producing wells has increased, there has inevitably been a lowering of the water level or artesian pressure in many areas, with resulting decline or cessation of yield from production wells, and increased cost of obtaining water by pumping. Climatic cycles have caused concern in several areas because the sub-normal replenishment in a series of dry years has caused decline in water tables and artesian pressures and suggested the possibility of over development.

The principal source of groundwater recharge in the Alluvial plain of the Terai belt of Darjeeling district (Siliguri sub-division) is the infiltration of precipitation. Other sources of recharge are seepage from surface water bodies like jhoras, ponds and tanks etc. and return flow from applied irrigation. Contribution from influent recharge of negligible as the rivers flowing in the area are generally effluent in nature. Block-wise dynamic groundwater resources for the investigated area as computed till the end of 1998 have been presented on Table–6.1, where total groundwater resources of the four blocks of Siliguri sub-division is 33,896.44 ha m/ year. But the annual groundwater draft of the study area for different purposes is 4,367.80 ha m (Table–6.4) and balance groundwater available has been estimated to be 29,528.64 ha m per year (Table–6.5). The level of groundwater development is 12.89 percent only, against the State's average of 44 percent. As such, four blocks of the Siliguri sub-division hold promise for large scale groundwater development both for agriculture, domestic and industrial purposes.

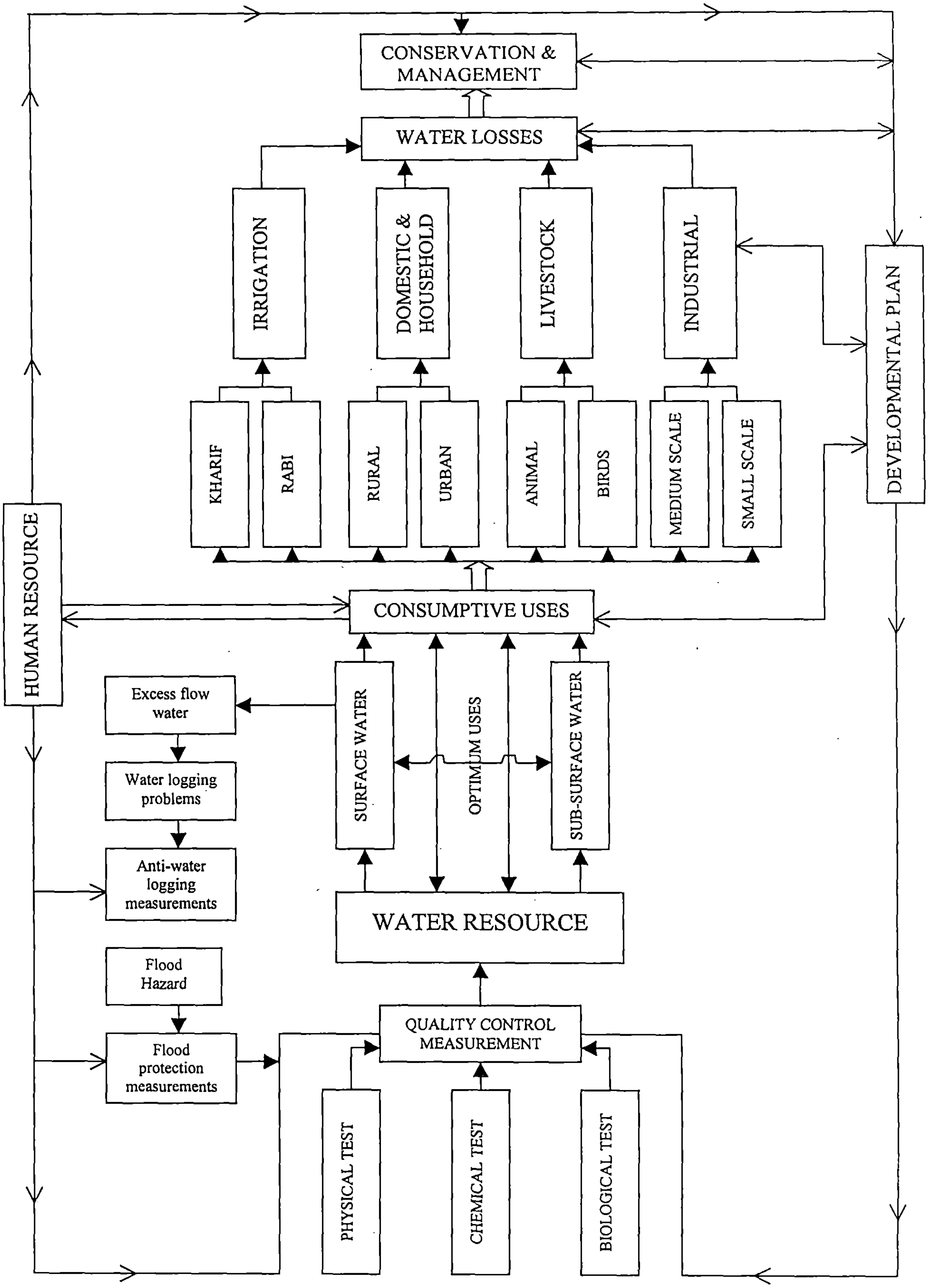
The precious renewable resources development in Darjiling district, even though in the study area is very low as compared to other districts of West Bengal

State. Groundwater is utilized in this area through dug wells, shallow tube wells, deep tube wells and hand tube wells for domestic, agricultural, livestock and industrial needs. But the level of utilization of the resource is significant now a day. There is need to develop groundwater resource for irrigation, domestic, livestock and industrial purposes substantial development could not be done inspite of easy availability of institutional finance due to drilling hazards in boulder formations and prohibitive cost. Besides, the rainwater, which is available in abundance, goes wasted as a rejected recharge. Most of the urban and in very recent some of the rural areas, water supply is through deep tube wells and hand tube wells in Siliguri Municipality area, in and around Bagdogra, Naxalbari, Kharibari and Phansidewa area.

The exploratory drilling in the study area has shown that large quantities of artesian water supply is available for utilization in the Terai region. Powerful artesian aquifers are made with at relatively shallow depths in the northern parts of Terai and at a greater depths in southward direction. In the piedmont zone where the yield of the suitably constructed well is above 60 m^3/hour, quite often yield decreases in the long run due to high concentration of iron in groundwater causing the encrustation of the tube well assembly made up of iron pipes and consequently choking the strainers. Use of fibre glass strainers or PVC well assembly is suggested to over this serious economic problems.

In the alluvial plains small diameter shallow irrigation tube well of 45 to 85 m depth tapping 12 to15 m thick sediments can yield 0.053 million cubic meters (MCM) of water. Irrigation through shallow tube wells has been found to be quite suitable as operation and maintenance is easily maneuvered by the cooperatives. However, while developing groundwater through shallow tube wells, proper care has to be taken in keeping safe spacing of the tube wells in such a way that these do not cause drying up of shallow dug wells which are the principal source of water supply for domestic purposes in villages of each block. Large scale groundwater development programme in the vicinity of river banks should be introduced for lowering of water table to a great extent in the lean period so that the thickness of unsaturated zone within the aquifer is increased. As a result, significant amount of recharge to groundwater can take place during

Figure-9.1 : Water Resources Management for Developmental Plan.



monsoon period and ultimately help to control the floods which cause devastating damage to the people and the property almost every year by the large rivers flowing through the hilly section, open up in the plains. The withdrawal of groundwater in large scale in the lean period will also help in raising crops in post-Kharif season, thereby improving agro-economic condition of the area.

From the field work analysis, it has been observed that during last one decade, hand pumps are replacing dug wells successfully mainly due to its two major advantages — (i) easy maneuverability and dependability in different land forms unit and (ii) geologic terrain. And quantitatively more than 10 percent of the total groundwater draft in the study area is made through heavy duty of deep tube wells. The use of deep tube wells has the following advantages over other sources for serving the both domestic, irrigation as well as industrial sectors— (i) the cost-benefit ratio is favourable for supplying water from shallow tube wells, (ii) it can be developed near the source of supply. This is particularly important for domestic supply considering the settlement pattern of the area. In general, within a village the residential plots are clustered in hamlets which sometimes are widely spaced within a village and (iii) minimum gestation period. Another great advantage for domestic water supply is the quality of groundwater. The groundwater of the area needs no desiltation or disinfection or any other type of chemical treatment.

During the last one decade there is constant increase in the number of DTW and in last 2 to 3 years, the area (especially in urban area) experienced a boom for construction of DTWs. In the year 1988, the study area has a negligible number of DTW (less than 10 no.) which has increased to 52 during the year 1998. The density of the DTW is fairly high in Siliguri Municipal Area and in Phansidewa block. In the major portion of the remaining part of the study area, the density of DTW is very low. Though the share of DTW in providing irrigation is still very low except in 5 to 6 tea gardens in the study area, it is playing a commendable role in providing water in domestic and in some cases of industrial sectors. Population wise nearly 70 percent in urban and area wise more than 20 percent have already been covered under pipe water supply from DTWs. Considering the pumping test data and local hydrogeology, the save distance has been considered as 2.5 km for 24 hours of pumping. Hence, the limiting number

DTW comes out as 6 with an unit (16 km^2 treated as one unit). But the present development is quite below this number for most part of the area.

Hence, the area has an ample scope for development of groundwater resources. A consideration of all aspects related to its exploitation indicated that the deep tube well is the most technically suitable and cost-effective structure to serve domestic, irrigation, as well as industrial sector. The other type of spot sources, that is hand pumps, dug wells and shallow tube wells may be useful in some critical localities, but broadly their role should be to supplement the deep tube well schemes. Two most important factor that control the number of DTW feasible in an area — (i) groundwater availability, and (ii) availability of space of installation. The average discharge of a explored DTW is observed as 7,500 to 12,000 gallon/ hr (GPH) with an average running period of 8 hours in a day. The annual draft of each DTW comes to about 16 ha m. Considering the draft, the net recoverable recharge can be accommodate 335 deep tube wells. Due to topography and land form condition, the northern part is less suitable for sinking of deep tube well, whereas it is much more favourable in the southern part especially in the Phansidewa and Kharibari Blocks of the study area. Finally the greatest step towards the conservation vis-à-vis development would be to prevent large scale wastage of water by allowing the artesian wells to flow all the times. Putting a check valve on these, and regulating its use, wastage of water not only stop but also help to eliminate the marshy condition of the land around the wells.

9.6 PROJECTION OF GROUNDWATER RESOURCES IN 2011 AD

While water is a renewable resource, it is at the same time a finite resource. It is important to appreciate the fact that only 3 percent of the world's water is fresh—roughly one-third of which is inaccessible. The rest is very unevenly distributed. On one hand, water is used with abandon, on the other, available supplies of water have become increasingly contaminated with wastage and pollution from industry, agriculture and households.

Over the years, rising population, growing industrialization, and expanding agriculture have pushed up the demand for water. Efforts have been made to collect water by building dams and reservoirs and creating groundwater structures such as wells, somewhere have been tried to recycle and desalinate water, often at very high costs. However, there is a growing realization that there are limits to 'finding more water'; in the long run, we need to know the amount of water we can reasonably expect to tap and learn to use it more efficiently.

Water resources planning for future projection has to be organically linked with the total socioeconomic planning. Hence, it is impossible to develop urban or rural water supply unless it is integrated with the total urban or rural development. The future plan of the renewable resources has been put forward for the investigated areas which takes into account the constraints in progress, the different type of consumption, the problems and their remedies through conjunctive and integrated use of water resources and the selection of an optimal system that best satisfy the objectives (Fig.-9.1). Water consumption and its requirement is very much proportionate to populations and other associates. So that, the demand for water is increasing rapidly with increasing rate of urbanization, agricultural and industrial development in the projected area. The projected demand of water for the period 1998 to 2011 AD has been estimated as 270,471.24 ha m based on the trend of water uses, probable growth rates in population and livestock population and in the different sectors of the economy in the Country (Table-9.3). The projected water consumption as well as the requirements for different purposes in the study area are considered as follows :

a) Requirements of Groundwater in 2011 AD :

The annual as well as the total requirement of fresh water for the projected period of irrigation and the other requirements is continuously growing (Table-9.3). The projected requirements of different purposes in 2011 AD are described below successively :

i) Irrigation Purpose :

The water requirements for the total cropping pattern in the investigated

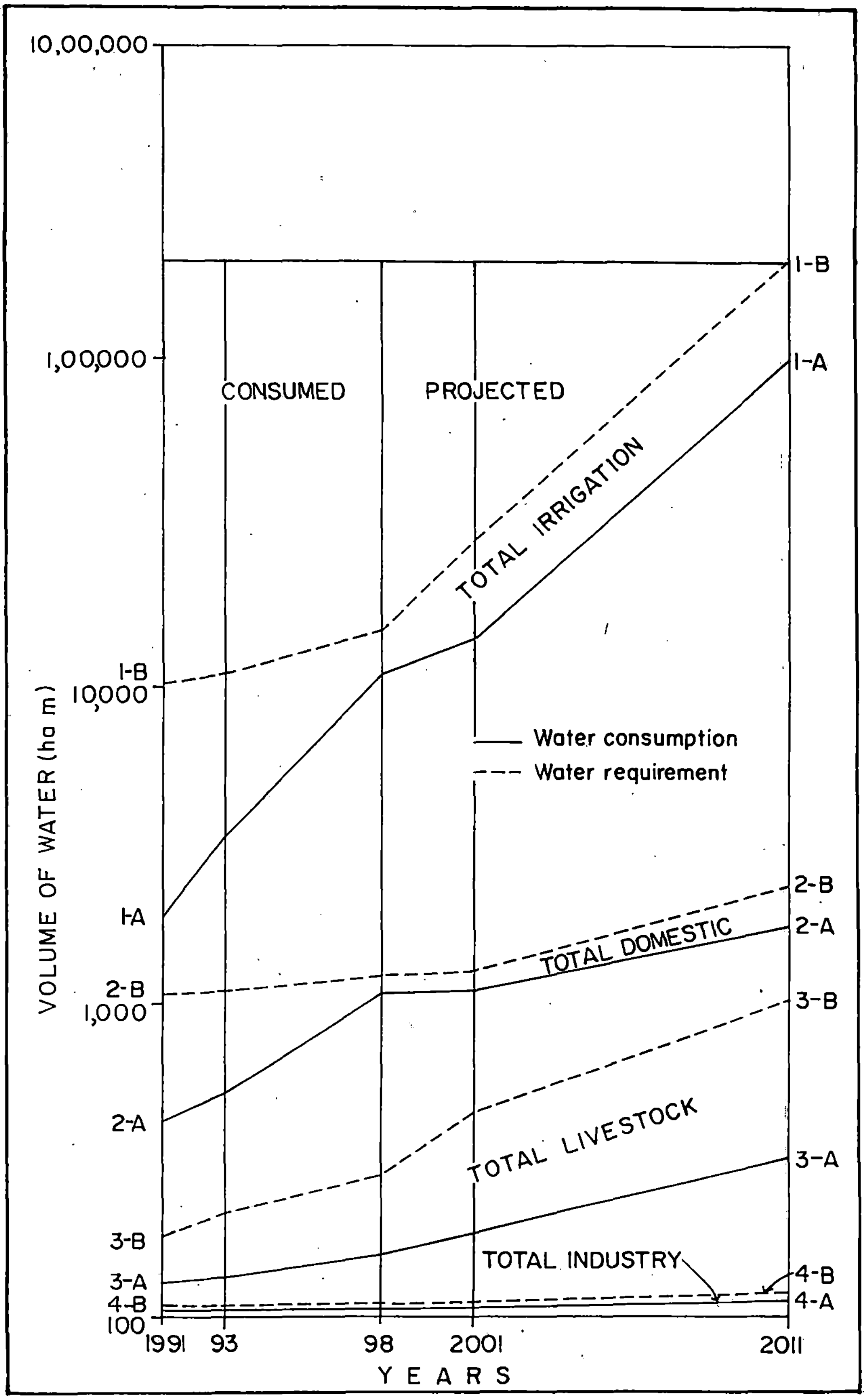


Fig.-9·2: WATER CONSUMPTION AND REQUIREMENT : PRESENT AND PROJECTED OF THE STUDY AREA

area in 2011 AD have been computed at 390,236.55 ha m based on factors like changing cropping pattern and a marked value of the agricultural products. For example, during 1992-93 to 1997-98, there has been an increase in the area under paddy, jute, potato, maize, lentil, pine apple, vegetable; whereas a decline rate has been recorded in the case of wheat and some other vegetables. As shown in the foregoing Chapter-VIII, rainwater meets 100 percent of Kharif and 36.74 percent of Rabi crop water requirements. Hence, irrigation water required in a crop year is taken as zero percent of the Kharif and 63.26 percent of the Rabi crop requirements. Thus, total irrigation water requirement in 2011 AD would amount to 262,117.08 ha m that is 96.91 percent of the total requirements from all types of utilization in the study area, and it varies from 19,100.48 ha m in Matigara block to 92,295.15 ha m in Kharibari block (Table-9.3).

ii) Domestic Purpose :

Even after 50 years of independence, we are not able to provide adequate and safe drinking water to entire population. But in this context West Bengal State, condition is very good in position in the whole country. However it has been estimated at 6,797.65 ha m i.e., 2.51 percent of the total requirements and varies from 652.69 ha m in Kharibari block to 3,514.65 ha m in Siliguri Municipality Area (Table-9.3 and Fig.-9.2). The rural and urban requirements are

Table – 9.1 : Projected Rural and Urban Population Water Consumption and Requirements (ha m) in the study area in 2011 AD.

Type of Population		Population	Litres / day / head		Annual in ha m	
			Consumption	Requirement	Consumption	Requirement
Rural	Served with organized water supply	115670	115	145	485.52	612.18
	Not served with organized water supply	480243	90	115	1577.60	2015.82
Total of Rural		595913	-	-	2063.12	2628.00
urban	Served with organized water supply	405080	205	265	3031.01	3918.14
	Not served with organized water supply	53006	105	130	203.15	251.51
Total of Urban		458086	-	-	3234.16	4169.65
Grand Total		1053999	-	-	5297.28	6797.65

Source : *Same as for Table-8.7. Population for 2011 AD computed by extrapolation from the 1981 and 1991 Population Census Data, Darjiling district, West Bengal, India.*

respectively 38.66 percent and 61.34 percent of the total domestic requirements. They are calculated from the projected growth rate of population, both urban and rural, for the period of 1998 to 2011 AD, derived by extrapolation of the population census data of 1981 and 1991 of Darjiling district (Table-9.1). The rural water requirements have been computed at the rate of 145 litres per day per head (lpdh) for organized supply and 115 lpdh for unorganized supply, whereas the urban water requirements with organized water supply have been estimated at 265 lpdh (Table-9.1).

iii) Livestock Purpose :

The livestock requirements have been computed to 1,298.51 ha m which is 0.48 percent of the grand total requirements, varying from 145.57 ha m in Matigara block to 521.57 ha m in Phansidewa block (Tables-9.2 & 9.3, Fig.-9.2). They are projected through the population growth of livestock, as derived from census of 1990 and 1995. According to the existing trends, population of each and every type of domestic animals is on the increasing tendency. The average rate of water requirements for buffalo (125 lpdh) is the maximum and that for rabbit (01 lpdh) is the minimum (Table-9.2).

iv) Industrial Purpose :

The total industrial requirements of water have been calculated at 258 ha m which is 0.1 percent of the total requirements of the study area. It varies from 17.75 ha m in Kharibari block to 106.90 ha m in Matigara block (Table-9.3). The actual number of medium to large scale as well as small scale industries and the industrial water demand during 1992-93 to 1997-98, has increased from 872 to 1250 and from 151.32 ha m to 172.44 ha m respectively (most of the newly formed industries are the small scale and less water consumptive characteristics), registering a moderate growth rate in both the cases. The projected growth rates for the duration to 1998-2011 have been fixed at 60 percent of the study period growth rate.

Table– 9.2 : Projected Livestock Population, Water Consumptions and Requirements (ha m)in the study area in 2011 AD.
[Upper Figure : Consumption; Lower Figure : Requirements for column 09-13]

Livestock Type	Bolck-wise Livestock Population					Water uses in lpdh		Annual in ha m				
	Matigara	Naxalbari	Kharibari	Phansidewa	Total	Consumption	Requirement	Matigara	Naxalbari	Kharibari	Phansidewa	Total
01	02	03	04	05	06	07	08	09	10	11	12	13
Cross-breed cattle	700	910	1617	2142	5369	75	105	1.92	2.49	4.43	5.86	14.70
								2.68	3.49	6.20	8.21	20.58
Indigenous cattle	35111	39666	119168	124117	318062	60	95	76.89	86.87	260.98	271.82	696.56
								121.75	137.54	413.22	430.38	1102.89
Buffaloes	735	881	2328	4074	8018	100	125	2.68	3.22	8.50	14.87	29.27
								3.35	4.02	10.62	18.59	36.78
Goats	21907	27693	35605	70332	155537	05	15	4.00	5.05	6.50	12.84	28.39
								11.99	15.16	19.49	38.51	85.15
Sheep	-	46	32	132	210	05	15	-	0.008	0.006	0.024	0.04
								-	0.025	0.018	0.072	0.12
Horse & Pony	-	-	08	-	08	30	60	-	-	0.009	-	0.009
								-	-	0.018	-	0.018
Poultry Birds	48657	64470	71558	133695	318380	0.75	03	1.33	1.76	1.96	3.66	8.71
								5.33	7.06	7.84	14.64	34.87
Ducks	2588	4140	9755	8501	24984	0.75	05	0.07	0.11	0.27	0.23	0.68
								0.47	0.76	1.78	1.55	4.56
Rabbit	-	-	177	-	177	0.50	01	-	-	0.003	-	0.003
								-	-	0.006	-	0.006
Pig	-	168	2338	5856	8362	15	45	-	0.09	1.28	3.21	4.58
								-	0.28	3.84	9.62	13.74
Total								86.89	99.60	283.94	312.51	782.94
								145.57	168.34	463.03	521.57	1298.71

Sources : *Same as for Table-8.8. Livestock population for 2011 AD computed by extrapolation from the 1991 & 1995 Livestock Population Census Data.*

v) Total Water Requirements in 2011 AD :

The Total Water Requirements in 2011 AD have been computed to 270,471.24 ha m varying from 3,540.30 ha m in Siliguri Municipal area to 93,428.62 ha m in Kharibari block in the study area.

b) Consumption of Groundwater in 2011 AD :

On a United Nations projections India with a population of one billion will have a per capita water availability of about 1,621 m^3 instead of 1,700 m^3 in 1995 by the turns of the century. Urban population in India grows at twice the rate of over all growth rate of population. A greater portion of urban as well as rural population will not have access to running water but have to be served either by vendors or by part-time service system The annual as well as the total consumption of standard water for the projected duration of irrigation and other uses is continuously growing up (Table-9.3). The projected consumption of water for different purposes in 2011 AD are described below :

i) Irrigation Purpose :

The total crop water consumption in the study area have been estimated at 208,888.44 ha m based on the factors changing the cropping pattern and the agricultural product. In 1997-98, the consumption of irrigation water in a block varied from 17.64 percent in Naxalbari block to 73.97 percent in Phansidewa block of irrigation water requirements of the corresponding blocks. With the implementation of different tube wells schemes, canal projects, adaptation of conservation practices, including conjunctive use of surface and groundwater in the area and the advancement of socio-economic development of the study area during the different five year plans, it has been estimated that in 2011 AD the irrigation potential utilized by a block would be 53.40 percent in Matigara block to 87.96 percent in Phansidewa block of the irrigation water requirements for the corresponding blocks (Table-9.3). Hence, the total irrigational projected water consumption upto 2011 AD would be 208,888.44 ha m which is, 97.08 percent of the total expected consumption from all types of utilization in the investigated area (Table-9.3).

Table–9.3 : Total Projected Water Consumption and Requirements (ha m) in study area in 2011 AD. [Upper Figure : Consumption; Lower Figure : Requirements]

Name of block or SMC / Purposes	Siliguri Municipal Corporation	Matigara Block	Naxalbari Block	Kharibari Block	Phansidewa Block	Total	% of the Total
Irrigation	-	10199.03	54243.21	75635.95	68810.25	208888.44	97.08
	-	19100.48	72489.23	92295.15	78232.22	262117.08	96.91
Domestic	2730.60	605.53	676.48	480.94	803.73	5297.28	2.46
	3514.65	743.69	846.24	652.69	1040.38	6797.65	2.51
Livestock	-	86.89	99.60	283.94	312.51	782.94	0.36
	-	145.57	168.34	463.03	521.57	1298.51	0.48
Industrial	22.20	79.25	42.53	14.37	48.56	206.91	0.10
	25.65	106.90	49.02	17.75	58.68	258.00	0.10
Total	2752.80	10970.70	55061.82	76415.20	69975.05	215175.57	100.0
	3540.30	20096.64	73552.83	93428.62	79852.85	270471.24	100.0

Note : *Irrigation Water Consumption and Requirement in a Crop Year is taken 63.26 % of the Rabi Crop Water requirement, the rest being made up from precipitation.*

Sources : *Computed from the Data presented in Tables-9.1, 9.2 and foregoing chapter's Tables-8.5, 8.9, 8.10 & 8.11.*

(ii) Domestic Purpose :

It is difficult to estimate the proportion of population that had access to clean drinking water at the time of independence. But it could be assumed at the time of independence, piped and treated drinking water was available only in cities and only to 48 percent of those who lived in them At the end of 1991, the figure was 86 percent and by 1994-95, as much as 82 percent of the rural population was covered (CWC, 1996). Certainly, about 81 percent of the countries of total population has accessed safe water (Centre for Science and Environment, 1997). But in the study area, the domestic water utilization in 1997-98 has been 52.90 percent of the requirements. With the increasing population of the area and with the implementation of rural and urban water supply schemes, it has been computed that 77.93 percent of the requirements would be fulfilled by 2011 AD. Hence, the total water consumption for the domestic purposes in 2011 AD would be 5,297.28 ha m which is 2.46 percent of the total expected utilized water varying from 480.94 ha m in Kharibari block to 2,730.60 ha m in Siliguri Municipal Corporation area (Tables-9.1 & 9.3; Fig.-9.2).

(iii) Livestock Purpose :

The livestock population is sharply increasing in each of the block of the study area, and the water consumption by 2011 AD would be 782.94 ha m which is 0.36 percent of the total expected consumed water varying from 86.89 ha m in Matigara block to 312.51 ha m in Phansidewa block. Thus, 60.30 percent of the livestock water requirements of the study area would be fulfilled systematically (Tables-9.2 & 9.3, Fig.-9.2).

(iv) Industrial Purpose :

Till now the area has not grown up as an industrial area. Though the total number of industry is increasing sharply, but no remarkably heavy or large industry have been established here during the last five years except the existing 7 medium to large scale industry from the early date and most of the industries are non-consumptive water based of small scale industry. Depending upon the expected rate of development, it has been estimated that about 80.20 percent of the total industrial water requirement would be fulfilled by 2011 AD from the available water resources. Thus, the amount of water consumed would be 206.91 ha m i.e., 0.10 percent of the total expected consumed water from all types of uses (Table-9.3; Fig.-9.2).

(v) Total Water Consumption :

The total expected water consumption in the investigated area in 2011 AD has been projected at 215,175.57 ha m; which is 79.56 percent of the total requirement in the same year; varying from 2,752.80 ha m in Siliguri Municipal Corporation Area to 76,415.20 ha m in Kharibari block area.

CONCLUSION

The foregoing analysis of this Chapter presents the relative importance, scheme and suggestions for future development of groundwater resources. A conjunctive use of the surface and groundwater resources management and various conservational practices, suited to the area, in the context of problems made within the area have been recommended. Water losses from over irrigation can be checked by volumetric charging for water, educating the farmers and land owners about its adverse consequences and providing them assured or rational supply of water. Losses from domestic, livestock and industrial uses can be checked by creation of general awareness amongst the people of the study area. The emerging issues in the management of water resources are chiefly of identifying and examining alternative institutional and policy arrangements. In the context of groundwater, the real issue is not over exploitation but management of groundwater to address a wide array of environmental, equity and sustainability concerns. At the same time, the role of improved technology in augmenting the carrying capacity of water resources to be looked at. A model for water resources management plan has been designed for the study area. It takes into account, the constraints in developments, the various modes of uses, the several problems and their remedies through conjunctive and integrated use of water resources.

There is enough scope for the development of the groundwater resources in the study area either by bringing new areas under the tube well pumping scheme or by additional development in the existing tube well areas by, firstly, increasing the tube well running hours and secondly, by installing more than 335 DTWs. The projected total water requirements by 2011 AD has been computed to about 270,000 ha m for different purposes, of which 79.63 percent i.e., 215,000 ha m has been computed for expected consumption in 2011 AD. All these model, thought and ideas, awareness, planning etc. have been sum up in the next Chapter systematically.