1
Water Resources

1.1 Introduction

Water is a vital natural resource which forms the basis of all life. Further, water is a key resource in all economic activities ranging from agriculture to industry. With ever increasing pressure of human population, there is severe stress on water resources.

In many places where lack of food threatens human survival, it is the lack of water that limits food production. Water also plays key role in the development of earth's surface, moderating climate and diluting pollutants. Infact, without water, life as we know it, cannot exist as for all the physiological activities of plants, animals and microorganisms, it is essential. It is an essential raw material in the process of photosynthesis of green plants which becomes food used by various living systems in all trophic levels. Atmospheric humidity which constitutes water is highly essential for all terrestrial life to protect from dehydration. Atmospheric water is the key factor in combination with temperature in influencing the global ecology, and as a function of hydrological cycle covering 70% of land surface, it influences weather and global climate and flora and fauna. In view of the above it is significantly linked with social, economic, political and ecological intricacies.

1.2 Worldwide Supply, Renewal, and Distribution

Only a tiny fraction of the planet's abundant water is available to us as fresh water. About 97% is found in the oceans and is too salty for drinking, irrigation, or industry.

The remaining 3% is fresh water. About 2.997% of it is locked up in ice caps or glaciers or is buried so deep that it costs too much to extract. Only about 0.0035 of Earth's total volume of water is easily available to us as soil moisture, exploitable ground water, water vapor, and lakes and streams. The pattern of distribution of Earth's Water Resources are presented in Table 1.1.

Table 1.1 Earth's Water Resources

	Volume (thousands of km^{3+})	% Total water	Average residence time
Total	1,403377	100	2800
Ocean	1370000	97.6	3000 years to 30,000 years
Ice and snow	29,000	2.07	1 to 16,000
Groundwater down to 1 km	4000	0.28	From days to thousands of years
Lakes and reservoirs	125	0.009	1 to 100years
Saline lakes	104	0.007	10 to 1000 years
Soil moisture	65	0.005	2 weeks to a year
Biological moisture in plants and animals	65	0.005	1 week
Atmosphere	13	0.001	8 to 10 days
Swamps and marshes	1.7	0.0001	10 to 30 days
Rivers and streams	1.7	0.0001	10 to 30 days

1.3 Indian Water Resources

In India, out of total rainfall in an area of 3290 lakh hectares, a rainfall of 4000 billion cubic meters annually occurs. Out of the total, 41% is lost-evaporation, 40% is lost-run off, 10% is retained– soil moisture, 9% seeps in for recharging ground water. Of the 40% stream flow water, 8% is used for irrigation, 2% for domestic use, 4% for industry, 12% for electric generation. Out of total available water resource 1869 bcm, the usable, water resources are only 1122 bcm, which consists surface water 690 bcm, ground water 432 bcm which the present per capita available water resources is 1122 cm and by 2050 it is likely to reduce to 748 cm.

When the countries per capita water availability is less than 1700 cm it is considered as water stress country.

Main Rivers in India

The Rivers in India can be classified as (a) Himalayan water system (Indus, Ganga, Brahmaputra, Chinab, Jhelum, Ravi and Beas) (b) Deccan Plateau water system (Narmada, Tapti, Mahanadi, Godavari, Krishna, Periyar) (c) Coastal water systems and (d) others including inland water systems.

1.4 Water Resources of Andhra Pradesh

Considering that a normal annual rainfall is about 900 mm, the present estimates of the water balance components are as follows :

Total quality of water received through rainfall	= 24.4 m ha m
Surface run-off (40%)	= 9.8 m ha m
Percolation to groundwater bodies (9%)	= 2.2 m ha m
Evapotranspiration (41%)	= 10.0 m ha m
Retained as soil moisture (10%)	= 2.4 m ha m

The major water bodies of ecological significance are presented in Table 1.2 while the extent of water available in various surface water bodies are presented in Table 1.3.

Table 1.2 Major Water Bodies of Ecological Significance in Andhra Pradesh

Rivers, canals and distributions	13,891 Km2
Actual forest cover	44,229 Km2
Tanks and ponds	
Total irrigation	79,953
Total irrigation tanks (for which records are available)	73,604[b]
Abandoned tanks	29,187
Irrigation tanks with > 40 ha command area	13,000
Tanks with Waters Users Association	8,813

Table 1.3 Surface Water Resources of Andhra Pradesh

River basin	Available bcm (tmc)	Utilized, bcm (tmc)
Godavari	41.90 (1480)	20.39 (720)
Krishna	22.96 (811)	22.96 (811)
Pennar	2.77 (98)	2.77 (98)
Others	10.12 (357)	3.51 (124)
Total	77.75 (2746)	49.63 (1753)

1.5 Hydrological Cycle

The available fresh water is continuously collected, purified, and distributed through the hydrologic cycle Fig. 1.1.

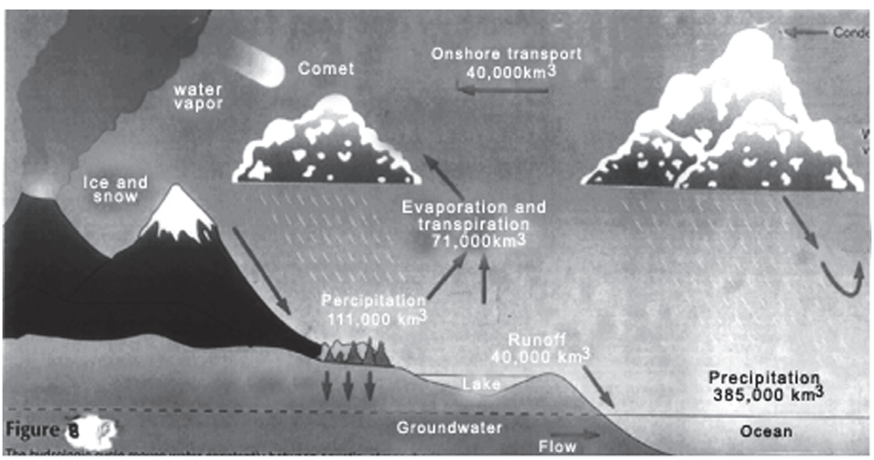

Fig. 1.1 Hydrological cycle

In the hydrological cycle, the factors which control the process of evaporation and evapotranspriration are temperature, humidity, and win. It is a continuous process going on day and night from the ocean surface, ground surface, inland waters (like lakes and streams), and plant and animal surfaces. Rising in the atmosphere this water forms clouds that float around in gaseous or droplet form. The atmosphere above the earth to varying heights of 10 to 17 km (depending upon latitude and season) is called the troposphere up to which the clouds float and in which all weather changes take place. Water returns to the earth in the form of precipitation, most of which takes place over the ocean and a little in the land surface. Rainfall in the land surface may have following fates; it may percolate through the soil and become a part of ground water regime; accumulate in a pond, lake, or reservoir as inland surface water; flow down to the ocean in the form of stream; taken up by plants and animals; or evaporate.

This natural cycling and purification process provides plenty of fresh water so long as it is not interfered by human activities by overloading with slowly degradable and nondegradable wastes or extracted it from underground supplies faster than it is replenished. However, in the process of economic development the above two human activities accompanied with various development programmes are interfering with the natural hydrological cycle and deteriorating the water quality.

1.6 Surface Water

Much of fresh water we use first arrives as the result of precipitation. Precipitation that doesn't seep into the ground or does not return to the atmosphere by evaporation or transpiration is called surface water. It forms streams, lakes, wetlands and artificial reservoirs.

Watersheds, also called drainage basins, are areas of land that drain water into bodies of surface water. Water flowing off the land into these bodies is called surface runoff.

1.7 Groundwater

Groundwater is the source of about 90% country's drinking water. In rural areas, almost all of the water supply comes from groundwater and more than one-third of our 100 largest cities depend on it for at least part of their supply. Historically, groundwater has been considered to be safe to drink. However, of late groundwater is becoming contaminated with industrial effluents discharged on land and septic systems, as well as illegal and uncontrolled hazardous waste sites. Once contaminated, groundwater is difficult, if not impossible, to restore.

Some precipitation infiltrates into the ground and fills the pores in soil and rock Fig. 1.2. The subsurface area where all available soil and rock pore spaces are filled by water is called the zone of saturation, and the water in these pores is called ground water. The water table is the upper surface of the zone of saturation; it is the poorly demarcated and fluctuating the dividing line between saturated soil and rock (in which every available pore is full) and unsaturated (but still wet) rock and soil in which the pores can absorb more water. The water table falls in dry weather and rises in wet weather.

Aquifers

Underground water, or *subsurface water,* occurs in two zones (Fig. 1.2), distinguished by whether or not water fills all of the cracks and pores between particles of soil and rock. The *unsaturated* zone that lies just beneath the land surface is characterized by crevices that contain both air and water. Water in the unsaturated zone, called *yadose water,* is essentially unavailable for use. That is, it cannot be pumped, though plants certainly use soil water that lies near the surface. In the *saturated* zone, all spaces between soil particles are filled with water. Water in the saturated zone is called *groundwater,* and the upper boundary of the saturated zone is called the *water table*. There is a transition region between these two zones called the *capillary fringe,* where water rises into small cracks as a result of the attraction between water and rock surfaces.

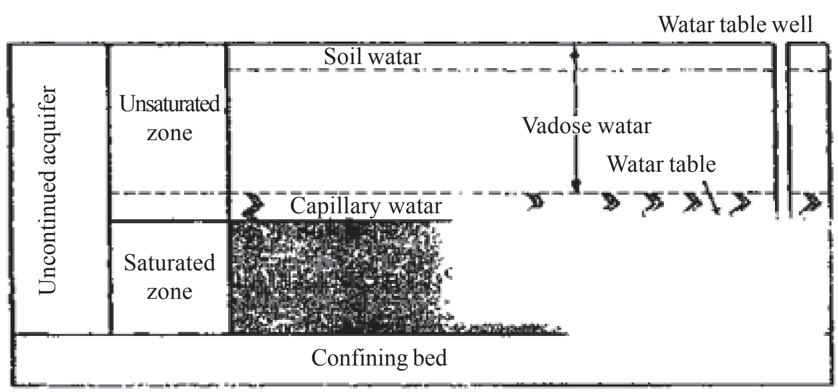

Fig. 1.2 Zonation of ground water source

Fig. 1.3 Illustrates an *unconfined aquifer* situated above a *confining bed.* An aquifer is a saturated geologic layer that is permeable enough to allow water to flow fairly easily through it, while a confining bed, or, as it is sometimes called, an *aquitards* or an *aquiclude,* is a relatively impermeable layer that greatly restricts the movement of groundwater. The two terms are not precisely defined, and are often used in a relative sense. A well drilled into the saturated zone of an unconfined aquifer will have water at atmospheric pressure at the level of the water table. It is not unusual to have a local impermeable layer in the midst of an unsaturated zone, above the main body of groundwater. Downward percolating water is trapped above this layer, creating a *perched water table*.

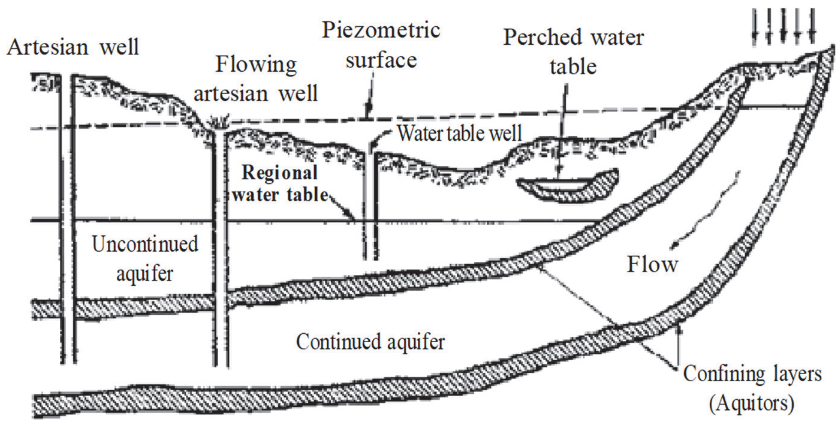

Fig. 1.3 A confined aquifer and artesian wells

Groundwater also occurs in *confined aquifers,* which are aquifers sandwiched between two aquitards. Water in a confined aquifer can be under pressure so that a well drilled into it may have water naturally rising above the upper surface of the aquifer, in which case it is called an *artesian well. A* line drawn at the level to which water would rise in an artesian well defines a surface called the •*piezometric surface* or the *potentiometer surface.* In some cases, enough pressure may exist to force water to rise above ground level and flow without pumping, in which case it is called *flowing artesian well.* Figure shows these distinctions.

The amount of water that can be stored in a saturated aquifer depends on the *porosity* of the soil or rock which makes up the aquifer. Porosity (η) is defined to be the ratio of the volume of voids (openings) to the total volume of material :

$$\text{Porosity} \qquad (\eta) = \frac{\text{Volume of voids}}{\text{Total volume}}$$

The gradient is important because groundwater flows - in the direction of the gradient and at a rate proportional to the gradient. To determine the gradient, it is useful to introduce the notion of hydraulic head as shown in Figure. The *elevation head* at a well, for example, is the vertical distance from some reference datum plane (usually taken to be sea loyal) and the bottom of the well. The *pressure head* is the distance from the bottom of the well to the water level in the well. The sum of the two is the *total head* and has dimensions of length such as "meters of water" or "feet of water" and the hydraulic gradient (Fig. 1.4) is given

$$\text{Hydraulic gradient} = \frac{\text{Change in head}}{\text{Horizontal heads}} = \frac{\Delta h}{L}$$

or, in a microscopic sense.

$$\text{Hydraulic gradient} = \frac{dh}{dL}$$

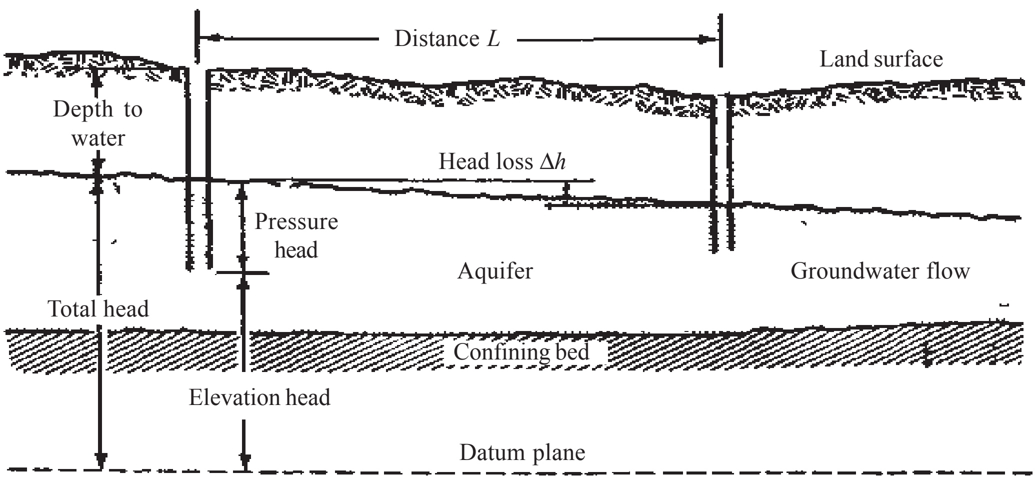

Fig. 1.4 Head in an unconfined aquifer the gradient is *Dh*/*L*

Ground water normally moves from points of high elevation and pressure to points of lower elevation and pressure. This movement is quite slow, typically only a metre or so (about 3 feet) per year and rarely more than 0.3 metre (1foot) per day. Most aquifers are like huge, slow–moving underground lakes.

If the withdrawal rate of aquifer exceeds its natural recharge rate, the water table around the withdrawal well is lowered, creating a waterless volume known as *cone of depression.* Any pollutant discharged onto the land above will be pulled directly into this cone and will pollute water withdrawn by the well.

1.8 World Water Resource Distribution

1.8.1 Surface Water

The large variations in the precipitation pattern result in uneven and even irregular distribution of fresh water resources worldwide. Some regions like Middle East experience perennial shortage of water. Apart from the factors described above, other factors that influence the water availability are, stability of run-off and the size of population.

Nations can be divided into water-rich and water-poor countries. Table 1.4 gives details of select countries under these categories.

Table 1.4 Some water-rich and Water-Poor Countries

Country	Total Water (cu.km/y)	Per Capita (000 cu.m/ y)
water-rich countries		
Canada	3,122	122
Panama	144	66
Nicaragua	175	533
Brazil	5,190	38
Ecuador	314	33
Malaysia	456	29
Sweden	138	22
Finland	104	21
CIS (formerly USSR)	4,714	17
Indonesia	2,530	15
US	2,478	10
water-poor courtiers		
China	2,680	2.5
India	1,850	2.4
Peru	40	2.0
Poland	59	1.5
South Africa	50	1.5
Egypt	56	1.2
Kenya	15	0.7
Libya	1.0	0.02
Malta	0.025	0.07

1.8.2 Rivers

A river is a stream of running fresh water, larger than a brook or creek, which constitutes the runoff after a rainfall or snowmelt. Land surfaces are nowhere perfectly flat and the rivers tend to flow downward by the shortest and steepest courses in depressions formed by the intersection of land slopes. Runoffs of sufficient volume and velocity join to form a stream that deepens its bed by cutting the underlying earth and rock. Groundwater seepage, springs and precipitation that fall directly into the stream, contribute to the flow. The land area that delivers the water, sediment and dissolved substances is called river's drainage basin or watershed. The geographical region of a drainage basin is defined by the river and the tributaries that drain into it. Sea level is the ultimate base of a river. As it approaches the base level, downward cutting is replaced by lateral cutting and the river widens its bed and its valley and develops a curving course. The discharge of a river depends on the cross-section area of its channel and its velocity. The velocity in turn is governed by the volume of water, slope of the bed and shape of the channel. Rivers modify the land topography both by deposition and erosion. The Brahmaputra River is a typical example of both these processes. The quantity and size of the rock fragments a river can carry depend upon its velocity. When the velocity is checked by the changes in gradient, by the water bodies of lakes and oceans or by spreading of water when the river overflows its banks, part of the load carried by the stream is deposited in the streambed as alluvium beyond the channel. Landforms produced by such depositions are called *delta and flood plains*.

The river runoff is one of the main sources of fresh water which meets various water demands. Though it is continuous and renewable by the hydrological cycle, river runoff represents the dynamic component of the total water resource, in contrast to the less mobile volumes of water contained in lakes and groundwater reservoirs. Table 1.5 contains details of the drainage areas of the rivers in different regions of the world. Table 1.6 gives the drainage area of some major Indian rivers.

River valleys have been important centers of civilization as they afford travel routes and their fertile alluvial soil form good agricultural land. These factors have also influenced the growth of cities on the riverbanks.

Table 1.5 Location and Drainage Areas of the World's Largest Rivers

River	Location	Drainage area 10^6 km^2
Amazon	South America	6.15
Zaire	Africa	3.82
Orinoco	South America	0.99
Jansei (Yangtze)	Asia (China)	1.94
Brahmaputra	Asia	0.58
Mississippi	North America	3.27
Yenisei	Asia (Russia)	2.58
Lena	Asia (Russia)	2.49
Mekong	Asia (Victnam)	0.79
Ganges	Asia	0.975
St. Lawrence	North America	1.03
Parana	South America	2.6
Irrawaddy	Asia (Burma)	0.43
MacKenzie	North America	1.81
Columbia	North America	0.67
Indus	Asia (India)	0.975
Hunagho (Red)	Asia (Vietnam)	0.12
Huanghe (Yellow)	Asia (China)	0.77

After Berner and Berner, 1996.

Table 1.6 Stream Flow and Drainage Areas of Major Indian River System

River Basin	Annual Stream flow (cu.km.)	Drainage Area (sq.km.) x 10^3
Indus	321	42
Ganga	550	975
Brahmaputra	590	580
Godavary	115	312
Mahanadi	131	141
Krishna	57	259
Cauvery	18	88
Narmada	40	99

Source : K.L. Rao, India's Water Wealth, Orient Longman (1975), and National Seminar on "New Perspectives in Water Management" CWC & INSA Engineering, New Delhi (1989).

1.8.3 Floods

Floods occur most commonly when water from heavy rainfall, melting ice or snow or a combination of these, exceeds the carrying capacity of the receiving river system. During the floods, the river carries fertile sediment and deposits it on the level land along its lower course. Such areas are called flood plains which are very fertile. Some rivers with extensive flood plains are : the Nile, Ganga, Brahmaputra, Yellow River, Mekong, Godavari etc. Often, the flood plains become areas for human settlement. People are lured to them by the productive soils, reliable water supply, inexpensive means of transport and fishing potential. To reduce the flooding of the flood plains, flood banks are built along the rivers. Another way of controlling flooding is through impounding river water by building dams upstream.

In India floods bring much havoc causing loss of life and property each year. Due to floods, the plains have become silted with mud and sand, thus affecting the cultivable land areas. Extinction of civilization in some coastal areas is mainly due to such natural calamities as flood. The National Commission on floods has calculated that the land area prone to floods has doubled from 20 million hectares in 1971 to 40 million hectares in 1980. Flood damages cost the country Rs. 21. crore in 1951 which increased to Rs. 1,130 crores in 1977. It was Rs. 128 crore per year during the decade 1960-70, increasing to Rs. 739 crore per year during 1970-78. The worst suffering States are Assam, Bihar, Orissa, U.P. and West Bengal. These aspects are to be given serious thought to save further destruction of mankind. Through modern technology and scientific knowledge, there is need of a proper understanding of the ecosystem so that changes could be forecast well in time. Thus, management of rainfall and resultant runoff is very important. Such management can be best based on a natural unit called watershed. A water shed is an area bounded by the divide line of water flow. Thus it may be drainage basin or stream. The Himalayas are one of the most critical watersheds in the world. Our water regimes in the mountain ranges are threatened resulting in the depletion of water resources. The damage to reservoirs and irrigation systems and misuse of Himalayan slopes are mounting as are the costs for control measures during the 'flood season' every year. The vast hydroelectric power potential can be harnessed from Himalayan watersheds only when proper control measures are taken. These include soil and land use survey, soil conservation in catchments of River Valley Projects and flood prone rivers, afforestation/social forestry programmes, drought prone area development programmes and desert development and control of shifting cultivation.

1.8.4 Drought

Drought is a devastating phenomenon. In comparison to fast onset disasters, drought destroys an area slowly, taking hold and tightening its grip with time Fig. 1.5. In severe cases, drought can last for many years, and can have devastating effects on agriculture and water supplies.

Fig. 1.5 Picture of an area in drought

In general, drought is defined as an extended period–a season, a year, several years–of deficient rainfall relative to the statistical multi-year average for the region. Lack of rainfall leads to inadequate water required by plants, animals and human beings. A drought leads to other disasters, namely food insecurity, famine, malnutrition, epidemics and displacement of populations from one area to another.

Rural communities can sometimes cope with one or two successive rain failures and crop or cattle losses : the situation becomes a crucial emergency when they have exhausted all their purchasing resources, food stocks and usual coping mechanisms.

1.8.4.1 Consequences of drought

(a) *Desertification*

The processes by which an area becomes even more barren, less capable of retaining vegetation, and progresses towards becoming a desert. This is often a cause of longterm disasters. This may result either due to a natural phenomenon linked to climatic change or due to abusive land use. In fact even for climatic change, these are the improper land use practices which are largely responsible. Removal of vegetal cover brings about marked changes in the local climate of the area. Thus, deforestation, overgrazing etc. bring about changes in rainfall, temperature, wind velocity etc. and also lead to soil erosion. Such changes then lead to desertification of the area. Desertification often starts as patchy destruction of productive land. Increased dust particles in atmosphere lead to desertification and drought in margins of the zones that are not humid. Even the humid zones are in danger of getting progressively drier if droughts continue to occur over a series of years. Indications are clear that the temporary phenomena of meteorological drought in India is tending to become permanent one. This trend is not restricted to the fringes of existing deserts only. The threat of desertification is thus real, because as the forest diminishes, there is steady rise in the atmospheric temperature.

There is no denying that during the past two decades, there has been increased damage to forests and other ecosystems by man. At the time of independence in the country, out of 75 million hectares, about 22% was under forest cover. Today this has been reduced to 19%. India has been losing 10 million trees every 24 years. Thus, deforestation is one of the main factors leading to desertification, primarily through its effect on climate of the area.

As a result of gross mismanagement of natural resources including land, certain irreversible changes have triggered the breakdown of nutrient cycles and microclimatic equilibrium in the soil indicating the onset of desertic conditions.

The impact of drought on the socio-cultural milieu is significant. The most obvious adverse impact is felt on the health of cattle and human population of the affected area. Water scarcity results in a higher incidence of water diseases. And while drought is a temporary phenomenon, desertification is not.

The chief causes of desertification are (i) climatic factors and (ii) human factors (human cultures). Recent changes in land use and population density had much ecological effects. Human factors are population growth, increased density, reduced nomadism and loss of grazing lands, and (iii) interactions between climate and culture.

(b) *Famine*

It is a catastrophic food shortage affecting large numbers of people due to climatic, environmental and socio economic reasons. The cause of the famine may produce great migration to less affected areas. Fig. 1.6 shows a field crop subjected to serious catastrophe.

Fig. 1.6 Crop field in catastrophe leading to famine

1.8.4.2 Groundwater Resource

The total quantity of groundwater on Earth is estimated at more than 50 million cu.km. Of this, 4 million cu.km. are considered as a reasonable quantity of fresh water that could be exploited, which excludes water that will not drain from small pore spaces, saline water and water lying deep in confined aquifers.

The total groundwater reserves of India upto a depth of 300 metres are estimated to be at 3,700 million hectare metres (mham) and the usable groundwater at around 42 mham, per year. Out of this, 27.37 percent is exploited. The state of Uttar Pradesh has a usable potential of 9.27 mham/y followed by Madhya Pradesh (5.95 mham/y), Andhra Pradesh (2.21 mham/y) and Gujarat (2.03 mham/y).

Depletion of groundwater sources due to the withdrawal of water at a rate far exceeding the natural recharge rate is currently a matter of global concern. The widespread use of ground water for irrigation in several parts of India also is leading to a marked fall in the ground water table. There are reports of declining ground water sources in the states of Punjab, Haryana, Uttar Pradesh, Maharashtra, and Andhra Pradesh in the wake of intensive irrigation through tube wells.

The groundwater potential of Andhra Pradesh was revised in 2002, by dividing the State into 1,195 assessment units using the 2000-01 database developed by the State-Level Groundwater Estimation Committee constituted in 1999. As per the estimates, the net annual available groundwater is 30.41 bcm (1, 074 tmc), out of which about 12.97 (458 tmc) are currently being utilized Table 1.7

1.9 Use and Over Use of World Water Resources

Global Water Resources Use

The present global population of 6.185 billion is expected to rise to 8.303 billion by the year 2025. Current water demand of about 6,650 km^3 to produce plant food is expected to rise to 9,000 km^3 by 2025. At present, the demand for water is growing by 2.4% per year. Total water use in the world has increased from

1000 $km^3\,y^{-1}$ in 1940 to
4130 $km^3\,y^{-1}$ in 1990 to
5000 $km^3\,y^{-1}$ in 2000 to
6650 $km^3\,y^{-1}$ in 2002 to
9000 $km^3\,y^{-1}$ in 2020 projected

At least one fifth of the world's people lack access to safe drinking water. 80 countries account for 40% of the world's population

Forecasts are that by 2025 as much as 2/3 of the world's population will be affected by moderate to severe water scarcity unless appropriate mitigation

Table 1.7 Groundwater Potential Assessments for the Three Region of Andhra Pradesh

Region	Area considered for recharge (km^2)		Net annual groundwater availability (mcm)		Total ground water availability (mcm)	Current gross annual groundwater draft for all uses (mcm)		Current draft for irrigation (mcm)		Demand for domestic and industrial needs in 2025 (mcm)		Allocation for domestic and industrial needs (mcm)		Net annual groundwater availability for future irrigation use (mcm)		Stage[a] of groundwater development (%)	
	C[b]	NC	C	NC		C	NC	C	NC	C	NC	C	NC	C	NC	C	NC
Coastal Andhra region	20,793	47,896	7,404	5,233	12,637	949	2,621	766	2,383	370	606	368	606	6,274	2,332	13	50
Rayalaseema Region	4,351	53,822	817	4,106	4,923	139	2,962	127	2,848	31	400	31	297	659	960	17	72
Telangana Region	9,833	91,080	3,008	9,834	12,842	659	5,641	615	5,222	109	754	109	671	2,288	3,943	22	57
Total for AP	34978	192760	11,232 (397)[c]	19,173 (677)	30,405	1,744 (62)	11,223 (396)	1,506 (53)	10,392 (367)	513 (18)	2,105 (74)	510 (18)	1,643 (58)	9,220 (326)	7,237 (256)	16	56
Total of command and non command	227,738		30,405 (1,074)			12,967 (458)		11,897 (420)		2,618 (92)		2,153 (76)		16,457 (581)		43	

[a]Stage of groundwater development (SGD) = groundwater utilization (draft) divided by groundwater potential (availability).
[b]C = canal command area; NC= non – command area.
[c]Values in parentheses are tmc.
Source: Groundwater Department, 2002.

measures are taken. The number of countries having water shortage at present is 28 (population 315 million), and by 2025, this number will increase to 50 (including India,) involving a population of 3 billion. The demand for usable water, like any other resource, is increasing fast with the continuous increase in per capita demand linked with more of sewage disposal and transport, prolific use of water using gadgets and increased recreational activities. According to an estimate, the daily per capita demand for water of an American was 600 gallons in 1900 which increased to 2700 gallons. Similar is the case with developing world. Possible means of meeting out the impending water deficit problem include: (i) reclamation of sewage and waste water (ii) development of ground water sources and surface storages (iii) long range forecasting of rain; (iv) rain making; (v) transfer of surplus water; and (vi) desalination of sea water. The year 2003 has been declared the *International Year of Freshwater,* underlining the urgent need to raise the awareness of the importance of protecting the Earth's freshwater resources.

There is tremendous increase in the Global Water usage in different sectors like agricultural, industrial and domestic. However there is considerable variety how these resources are used in different parts of the world. Fig. (4.7).

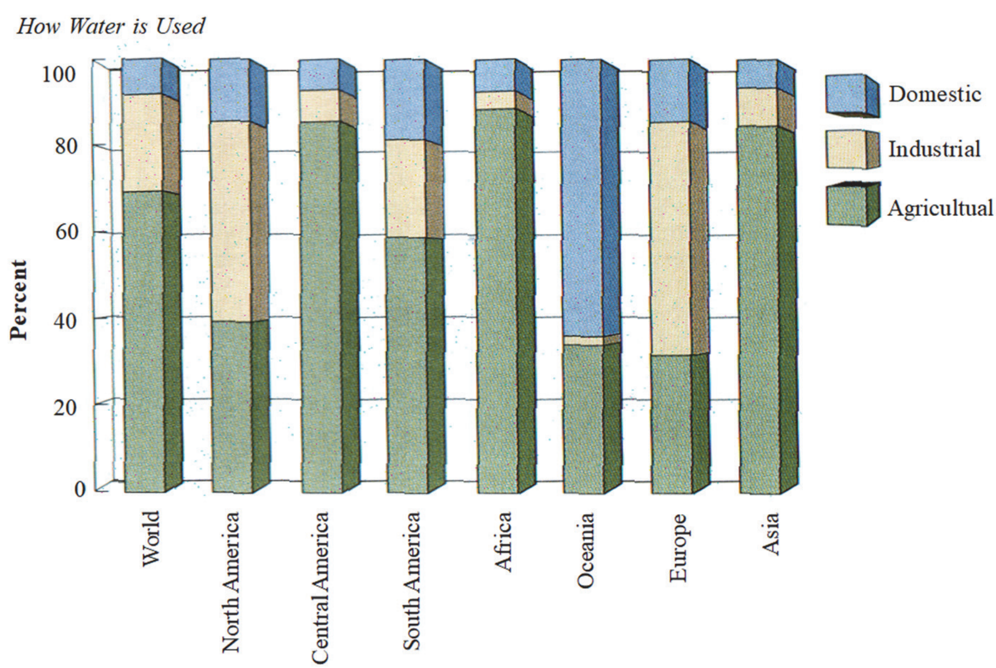

Fig. 1.9 World water usage in different parts of the world

1.10 Water Resources-Indian Scenario

Need for water conservation

Average annual rainfall 1170 mm

Area 3290 lakh hectares

Out of Total Precipitation

41%(10,02,040 lakh) lost as evaporation and transpiration

40% (9,77,600 lakh) lost as run off,

10% (2,44,400 lakh) is retained as soil moisture

9% (2,19,960 lakh) seeps in for recharging ground water.

India will be requiring about 1,2010,000 lakh cubic metres (cum) of water in the year 2050 AD (Table 1.8) to cater to the needs of about 150 crores population for food, drinking water, domestic, industrial, navigational, environmental and ecological requirements due to which there is a great need to conserve water.

Table 1.8 India's Water Budget

Category	**1985**		**2000**		**2025**	
	Surface water	**Ground water**	**Surface water**	**Ground water**	**Surface water**	**Ground water**
Domestic/live stock	16.70		28.70		40.00	
Industries	10.00		30.00		120.00	
Thermal power	2.70		3.30		4.00	
Miscellaneous	40.60		58.00		116.00	
Subtotal	40	30	80	40	1990	90
Irrigation	320	150	420	210	510	260
Subtotal	360	180	500	250	700	350
Total	540		750		1,050	

Experts opine that there would be no underground water by 2025 in Rajasthan if the present rate of indiscriminate utilization continues. Annually, 1/3rd of the area in the country is drought hit while some areas struggle/suffer with natural calamities like flood.

Even 30% of the available water is not efficiently used whereas most of the waters are wasted into the sea.

1.11 Water Resources Andhra Pradesh Scenario

Andhra Pradesh is endowed with 40 major and minor rivers, important among them being Godavari, Krishna, Vamsadhara and Pennar. Krishna and Godavari rivers are inter-state rivers and contribute almost 90% of the State's surface water resources Table 1.10. The rivers are seasonal with the bulk of the flow taking place during the monsoon, from June to October. The State's share of dependable flows at 75% dependability from the river system is estimated at 77.75 bcm (2746 tmc), and 49.63 bcm (1753 tmc) has currently been utilized. The state is divided into 40 river basins. Basin-wise water availability and usage/commitment in each of the basins has been estimated by the Irrigation Department and continuously updated. As per the latest information, 28 basins have surplus water for further development. Godavari river basin has about 21.52 bcm (760 tmc) surplus water, while other river basins have about 6.51 bcm (230 tmc). The water resources of Krishna and Pennar have been completely utilized. Further developments in the basin will mainly depend on the flood waters. Significant imbalance in water utilization among the river basins is prevalent due to local needs.

Groundwater

The groundwater potential of Andhra Pradesh has been revised in 2002, by dividing the State into 1195 assessment using the database of 2000-01 by the State Level Groundwater Estimation Committee constituted in 1999. As per the estimates, the net annual available groundwater is 30.41 bcm (1074 tmc), out of which about 12.97 bcm (458 tmc) is being currently used. The area considered for evaluating groundwater potential is about 22.8 million ha, and groundwater is being used in about 2.6 million ha for irrigation and in areas occupied by villages (26,586) and urban aras (117) for drinking water. Thus the total area from which groundwater exploitation is taking place may be of the order of about 5 million ha. Therefore, consideration of groundwater potential in areas of present use of areas of likely future use could only provide a better picture of supplies and demands. Even considering the groundwater utilization in the entire net sown area of about 39% of the State, which may not increase much in future, consideration of a net groundwater potential of about 50% of the 30.41 bcm could provide a realistic picture of the utilizable groundwater potential. The exploitation of groundwater has tremendously increased with the well potential increasing from 0.8 million in 1975 to 2.2 million in 2001. The area irrigated with groundwater has increased from 1 million ha to 2.6 million ha in the same period Fig. 1.9. The present stage of groundwater development is about 43% (on consideration of net utilizable potential as above, it would be 86%), but is not uniform throughout the State. In certain pockets/areas intensive development has led to a critical situation, and the problem is manifested in the form of declining groundwater levels, shortage in supply, saline water encroachment and increase in the incidence of fluoride, iron, salinity, etc. Contrary to this condition, the groundwater levels are rising in canal command areas leading to water logging and soil salinity. Out of the 1.43 million ha area irrigated by the four major irrigation projects about 0.132 million ha is estimated to be suffering from waterlogging during 1999 (Table 1.9). Areas with water table depths of less than 2m have been considered as waterlogged.

Table 1.9 Extent of Waterlogged Area in Irrigation Commands

S.No.	Project	Command area, million ha	Waterlogged area*, million ha
1.	Sriramsagar	0.178	0.035
2.	Nagarjunasagar Left Canal	0.420	0.030
3.	Nagarjunasagar Right Canal	0.475	0.039
4.	Tungabhadra	0.350	0.028
	Total	**1.43**	**0.132**

Source: Groundwater Department 2001

The total (Surface and Ground water) water resources are estimated to be 108.2 bcm or 3820 tmc of which 62.3 bcm (R, 200 tmc) are being currently utilized for drinking, agriculture, industrial and power generation. The per capita annual water resources are 1400 m^3 which considered as water scarce area (< 1200 m^3 as per UN indicator is called water scarce area while between 1000-2000 m^3 is considered as water stressed). The current withdrawal of water for various purposes is 58%. The various surface water resources of A.P and its present and projected requirements for various sectors are given in Table 1.10 and Table 1.11 depicts future data.

Table 1.10 Surface Water Resources of Andhra Pradesh

S. No.	River sytem	Drainage area (km^2)	Assessed annual yield (m ha m)*
1.	Godavari	73,201	4.23
2.	Krishna	74,382	2.30
3.	Pennar	48,111	0.28
4.	Nagavalli	4,833	0.14
5.	Vamsadhara	1,934	0.04
6.	Other rivers drainging into the sea	74,239	0.79
	Total	276,700	7.78[b]

[a] m ha m = Million hectare metres; tmc=thousand million cubic feet; 1 m ha m = 352.96 tmc [b]7.78 m ha m = 2,746 tmc. As per the Central Ground Water Board, the annual replenishable groundwater in the State = 3.04 m ha m or 1,074 tmc. Total availability of surface and groundwater sources = 2,746+1,074=3,820 tmc or 10.82 m ha m.

Table 1.11 Present and Projected Water Requirement for various Sectors in Andhra Pradesh

S. No	Description	Present Utilization		Needed by 2025		Increase %
		Tmc	mcm	Tmc	mcm	
1.	Drinking water	21	601	122	3468	581
2.	Irrigation	2268	64,252	3,814	108,050	168
3.	Industries	10	288	51	1445	510
4.	Power generation (consumptive use)	1	28	2	56	200
5.	Total	2300	65,169	3,989	113,019	173

1.12 Methods for Managing Water Resources

Management of water implies making the best use of available water resources for human benefit while not only preventing and controlling its depletion and degradation but also developing them keeping in view the present and future needs. Water, like forest, is a multipurpose resource and it is important to see that its various uses should not conflict with each other and it can be enjoyed in its totality by man and others. Thus, its right allocation, and quantitative and qualitative conservation are the primary tasks before water managers.

Floods, droughts, improper use, pollution, and disease transmission are the important problems related to water. Because usable inland water resources constitute a very minute fraction of the world's total water on which the man largely depends, it is important to make efficient use of available water and at the same time prevent misuse of it. This has to be considered not only in giant irrigation projects or industrial and municipal processes but also in everyday life. Taps running unpurposefully, leaking water supply pipes, using filtered water for gardens and building construction are a few instances of inefficient and misuse of water in daily life.

Water being the best and convenient dilution medium is the worst affected resource by pollution. To a common man pollution of water means only the drainage of industrial effluents or domestic sewage in natural waters. However besides chemical alterations, changes in physical condition of water also will have grave effects on the biota of system as during thermal pollution caused by the discharge of heated effluents in a body of water. Pathogens, chiefly entering natural waters through municipal wastes rich in excreta and other organic filth, also render the water unsuitable for human use.

In fact, it is not only the man who has to use the water resources but these are equally important to land animals and more to those fish and other aquatic animals who live in it. Thus, pollution of a body of water does prove detrimental not only to the human society but also to regional ecology and the ecology of the very aquatic ecosystem. It is therefore, essential that the water should not be treated as a simple carrier for waste disposal, and if inevitable, the wastes, only after proper treatment, should be released in to it under strict ecological consideration.

The qualitative degradation of water is also in a way quantitative depletion of usable resources. Therefore, recycling of waste water after due treatment would relieve the water scarcity to a great extent, especially in regions marred by water shortage.

Large scale redistribution of water resources to increase the supply in particular area by building dams and reservoirs to bring surface water from another area, or tapping ground water is a modern approach to improve the efficiency of water use.

1.13 Solutions : Supplying More Water-Dams

Constructing large dams and reservoirs have benefits and drawbacks. Water from rain and melting snow can be captured and stored in large reservoirs created by damming streams. This water can then be released as desired to produce hydroelectric power at the dam site, to irrigate land below the dam, to control flooding of land below the reservoir, and to provide water carried to towns and cities by aqueducts. Reservoirs are also used for recreation activities such as swimming, fishing, and boating. Between 25% and 50% of the total runoff in every continent is now captured and controlled by dams and reservoirs, and many more large projects are planned.

Storage of water by building large dams is regarded by irrigation engineers as a crucial component of India's water management system. Benefits like hydro-electricity, irrigation, flood control, industrial and municipal water supply are not possible "unless the water is stored in reservoirs created by dams". Water storage is necessary because rainfall is very unevently distributed varying from 10,000 mm in Cherpunji in Assam to about 100 mm in western parts of Rajasthan. There are also considerable seasonal variations. Over 75 per cent of the rainfall is received during the monsoon period of June to October and even during this period there are many erratic spells of heavy rain and dry weather. On one hand as many as 99 districts are classified as drought prone; on the other, 85 per cent to 90 per cent of the monsoon water flows as waste to the sea.

Since independence, about 700 storage dams have been constructed. The total storage capacity so far, including those of small tanks, is assessed to be about 16 million hectare-metre. Out of a total of 178 mham surface water available in the country, only 27 mham are now being used and the utilizable potential is about 67 mham. About 90 percent of the water is being used for irrigation alone.

By the year 2005, the government hopes to provide irrigation to 113 million hectares, the ultimate irrigation potential out of a gross cropped area of 200 million hectares. Major and medium irrigation projects would irrigate about 584 million hectares and minor irrigation projects 51.6 million hectares. Between 1980 and 2005 some Rs.60,000 crore (at 1980 prices) will be required for the development of this irrigation potential.

As even by the year 2000 nearly 40 per cent of cropped area was unirrigated, the government is preparing a national perspective plan for water resources development, which will allow for large scale inter-basin transfer of water from water surplus river basins. Transfers of water will again depend primarily on the creation of storage reservoirs: the ultimate storage capacity in that case has been assessed at 37.5 mham.

The irrigation potential will thus increase from 113 million hectares to 148 million hectares with about 25 million hectares coming under surface schemes and about 10 million hectares benefiting from increased use of ground water. This ambitious plan will require an investment of about Rs.50,000 crore.

In India a number of big, medium and minor dams have been envisaged under different river valley projects. These dams have been undertaken for irrigation, power generation and water supply. These dams hailed as the Temples of Modern India by the country's first Prime Minister, Jawaharlal Nehru, have increased agricultural production, power generation and reduced dependence on imports.

Construction of dams are inevitable for a large country like India faced with the task of feeding it growing population and for meeting its energy requirements. The information on number of large dams constructed in different countries and their capacities and location of various large dams in the world are presented in Tables 1.12 and 1.13 respectively.

Table 1.12 Worldwide Statistics of Large Dams with at least 15 Meters High

Country	No. Of Dams
China	22,000
US	6,575
India	4,291
Japan	2,675
Spain	1,196
South Korea	765
Canada	783
Turkey	625
Brazil	594
France	569
Other countries	7,347

Table 1.13 Major Dams in World

Dam	Location	Cu. Mts.	Year completed
Syncrude Tailings	Canada	540,000	UC
Chateton	Argentina	296,200	UC
Pati	Argentina	238,180	UC
New Cornelia Tailings	United States	209,500	1973
Tarbela	Pakistan	121,720	1976
Kambaratinsk	Kyrgyzstan	112,200	UC
Fort Peck	Montana	96,049	1940
Lower Nsuma	Nigeria	93,000	1990
Cipasing	Indonesia	90,000	UC
Ataturk	Turkey	84,500	1990
Yacyreta-Apipe	Paraguay / Argentina	81,000	1998
Guri (Raul Leoni)	Venezuela	78,000	1986
Rogun	Tajikistan	75,500	1985
Oahe	South Dakota	70,339	1963
Mangla	Pakistan	65,651	1967
Gardiner	Canada	65,440	1968
Afsluitdijk	Netherlands	63,400	1932
Oroville	California	59,639	1968
San Luis	California	59,405	1967
Nurak	Tajikistan	58,000	1980
Garrison	North Dakota	50,843	1956
Cochiti	New Mexico	48,052	1975
Tabka (Thawra)	Syria	46,000	1976
Bennett W.A.C.	Canada	43,733	1967
Tucuruii	Brazil	43,000	1984
Boruca	Costa Rica	43,000	UC
High Aswan (Sadd-el-Aali)	Egypt	43,000	1970
San Roque	Philippines	43,000	UC
Kiev	Ukraine	42,841	1964
Dantiwada Left Embankment	India	41,040	1965
Saratov	Russia	40,400	1967
Mission Tailings 2	Arizona	40,088	1973
Fort Randall	South Dakota	38,227	1953
Kanev	Ukraine	37,860	1976
Mosul	Iraq	36,000	1982
Kakhovka	Ukraine	35,640	1955
Itumbiari	Brazil	35600	1980
Lauwerszee	Netherlands	35,575	1969
Beas	India	35,418	1974
Oostrschelde	Netherlands	35,000	1986

Table 1.14 contains details of some of the largest artificial reservoirs in terms of capacity.

Table 1.14 Largest Artificial Reservoirs in Terms of Capacity

Reservoir	River	Country	Capacity (x10^6 cu.m)
Owen falls	Victoria Nile	Uganda	2,04,800
Kariba	Zamberi	Zimbabwe Zambia	1,80,200
Bratsk	Angara	CIS	1,69,000
High Aswan	Nile	Egypt	1,62,000
Akosombo	Volta	Ghana	1,47,850
Daniel johnson	Manicouagaon	Canada	1,41,850
Guri	Caroni	Venezuela	1,35,000
Kransnoyarski	Yenisei	CIS	73,300
WAC Bennett	Peace	Canada	70,309
Zeya	Zeya	CIS	68,400
Cabna Bassa	Zamberi	Mozambique	63,000
La Grande 2	La Grande	Canada	61,710
Chapeton	Parana	Argentina	60,600
La Grande 3	La Grande	Canada	60,020
Ust illrn	Angara	CIS	59,300
Kuibyshev	Volga	CIS	58,000
Serra da Messa	-	Brazil	54,400
Caniapiscau Barrage KA3	Caniapiscau	Canada	53,740
Upper Wainganga	wainganga	India	50,700

Table 1.15 gives details of artificial reservoirs in India with storage capacities exceeding 1,000 million cu.m.

Table 1.15 Storage Capacities of Major Reservoirs in India

River Basin	Reservoir	Storage Capacity (Million cu.m)
Indus	Bhakra Nanagal	7,443
	Pong	6,976
Ganga	Panchet Hill	1,313
	Mainthon	1,358
	Gandhi sagar	6,911
	Ranapratap Sagar	1,568
	Rihand	8,971
	Ramganaga	2,190
	Tehri	2,613

Table 1.15 *Contd...*

River Basin	Reservoir	Storage Capacity (Million cu.m)
Mahi	Kadana	1,217
	Bajaj Sagar	2,016
Narmada	Tawa	2,080
Tapi	Ukai	7,088
Brahmani & Baitharani	Rengali	3,396
Mahanadi	Hirakud	5,799
Godavary	Pochampad	2,303
	Jayakwadi	2,171
	Pench	1,579
	Balimela	2,829
Krishna	Nagarjuna Sagar	5,462
	Srisailam	5,943
	Bhandra	1,784
	Thungabhadra	3,699
	Ghataprabha	1,400
	Bhima	1,709
	Koyna	2,674
Pennar	Somasila	1,877
Cauvery	Krishnarajasagar	1,269
	Mettur	2,646
Sharavati		4,245
Kalanadi		3,962
Idukki		1,542
Idamalayar		1,018

The total water storage capacity of all the projects including najor, medium and minor basins is 1,46,826.5 million cu.m.

Source : K.L. Rao, India's Water Wealth, Orient Longman, New Delhi, (1975)

1.14 Environmental Impacts of Large Dams

The environmental impacts of large dams and hydel power projects could be classified into three categories, viz., (i) impacts within and around the area covered by the dam and reservoir, (ii) downstream effects caused by alteration in hydraulic regime, and (iii) regional effects in terms of overall aspects including resource use and socio-economic aspects.

The impacts caused by construction of dams and reservoirs include changes in the microclimate, loss of vegetal cover, soil erosion, variation in water table and enhanced seismic activities due to pressure of water. The nature and magnitude of the impacts vary with the project locations and the conditions therein. For instance, in hilly tracts, blasting operations, for road construction can cause considerable damage to the environment through loosening of hillsides and resultant landslides, sedimentation of reservoirs, drying up of spring and flash floods. The creation of new settlements for the workmen and rehabilitation of project oustees in the watershed areas are also becoming major problem.

1.15 Major Impacts of Large Dams

1.15.1 Siltation

Though dams ensure a year round water supply they also waste large quantities of water due to evaporation and through seepage into porous bed rocks. In many places, dams almost eliminate sediment from rivers downstream, causing potentially serious problems in the plains where farmers need sediments to fertilize their fields. Before the commissioning of the High Aswan Dam in 1964, the Nile River used to carry 100 million tons of fertile sediment downstream each year. The sediment and the bacteria it contained renewed the fertility of the fields down the Nile Valley and its delta, which is the country's main agricultural region, and also effectively sustained the Mediterranean fisheries. Now, this flow has almost ceased. The coastline of the delta has retreated by more than two kilometers in places, while the eastern Mediterranean fisheries have been wiped out.

Chemical weathering is typically twenty to fifty times faster in the tropics than in the temperate zones. This process leaves behind a crust on rocks that is subjected to fast mechanical erosion by strong winds and heavy tropical rains. This becomes more serious in the young mountain ranges such as the Himalayas which are more vulnerable to erosion. As a result of the clearing of vast forest land upstream, huge quantities of soil are washed into the river dams. All these factors contribute to siltation rates much higher than the values assumed by the designers while designing the dams in the tropics (Table 1.16). Consequently, their storage capacity is subjected to rapid reduction. Hundreds of these dams in India are likely to get significantly silted in the early part of the twenty-first century due to rapid silting.

Table 1.16 Siltation Rates of Some Dams in India

Dam	Siltation Rate (million cu.m / y)	
	Assumed	Observed
Bhakara	28.36	41.27
Maithon	0.84	7.37
Nizamsagar	0.67	10.76
Panchet	2.44	11.75
Tungabhadra	12.08	50.62

Rapid siltation of the Akosombo reservoir on the Volta Lake in Ghana made it ineffective in improving the country's economy.

1.15.2 River Load

Materials that are washed into a river from land, together with the sediment that is eroded from the channel constitute the river load. The river transports its load in suspension, in solution and along the river bed by the thrust of the current (Table 1.17). Soil erosion contributes suspended silt, clay, sand, gravel and bits of detritus along with dissolved substances including plant nutrients (nitrogen, phosphorus, trace metals etc.). The types of substances that are dissolved in a river vary with the climate, the rock and soil composition and the human activities in the basin. The problem of soil erosion is compounded by the poor agricultural practices adopted in conserving the soil. The large scale destruction of the forests in the upstream catchment areas of the of the rivers leads to reduced soil-holding capacity of the ground. For example, the yellow River in China now transports an order of magnitude with more sediment than it did prior to the cultivation of the plateaus in northern China.

After Berner and Berner, 1987, and Berner and Berner, 1996. in some cases figures are post-dam information. Pre-dam suspended loads were higher.

The sediment loads of the Colorado and Nile Rivers which are estimated at 140 x 10^6 and 110 x 10^6 tonnes respectively are now trapped behind the dams. This is true of some other major rivers on which dams are being constructed for irrigation and power generation. This activity is the cause for some adverse effects on the river estuaries.

The prediction of the amount of river water in rainfall reliant river basins such as the Indian Peninsular River Basins is very difficult. During the period when the runoff from the rivers is near zero, the discharge is slowly released

Table 1.17 Dissolved Suspended Loads of World's Largest Rivers

River	Water Tg/yr X 10^5	Dissolved solids Tg/yr	Suspended solids Tg/yr	Dissolved concent. ppm	Suspended concent. ppm	Dissolved / suspended
Ganges	4.50	75	520	170	1160	0.14
St. Lawrence	4.47	45	4	100	9.0	11.3
Parana	4.29	16	79	37	180	0.20
Irrawaddy	4.28	92	265	212	619	0.35
Mac Kenziie	3.06	64	42	210	140	1.5
Columbia	2.51	35	10	140	40	3.5
Indus	2.38	79	59	330	250	1.3
Hunaghe (Red)	1.23	?	130	?	1060	?
Huanghe (Yellow)	0.59	22	1100	370	18600	0.02
Amazon	63.0	275	1200	43.7	190	0.23
Zaire	12.5	41	43	33	34	0.95
Orinoco	11.0	32	150	29	140	0.21
Jansei (Yangtze)	9.00	247	478	274	531	1.94
Brahmaputra	6.03	61	540	100	896	0.11
Mississippi	5.80	125	210	260	362	0.60
Yenisei	5.60	68	13	120	23	5.2
Lena	5.25	49	18	93	34	2.7
Mekong	4.70	57	160	120	340	0.36

from the wetlands. This is called the base flow and is taken as the dependable water supply. Estimates of dependable water supply are often subjects of dispute in river basins spanning more than one beneficiary states (e.g. Krishna River).

1.15.3 Reservoir Induced Seismicity

A phenomenon called **reservoir induced seismicity** could lead to earthquakes of high intensity in the region around the dam. The Koyna Dam on the west coast of India with a height of 130 metres and a storage capacity of near 3,000 million cu.m. has been experiencing frequent tremors. The tremor that occurred in 1967 caused considerable loss of life and property.

1.15.4 Water Logging and Salinity

The rising water table in areas where dams are built leads to water logging in the command area , affecting the production of many crops. As a consequence of the reduced moisture-storing capacity of the soil due to water logging, even a moderate rainfall causes floods. Waterlogging has also been responsible for debilitating diseases like schistomiasis that infect more than 200 million people worldwide. The snail worms hatch in humans after the larvae enter the blood vessels through the skin, causing blood loss and tissue damage.

The water table in the Bhakra canal command area has been rising at the rate of about one metre per year. The managing director of Haryana State Minor Irrigation and Tubewell Corporation, in a press conference in late 1983, expressed serious concern over the raising ground water table in the state. He said that 65 percent of the area in the state covered by canal commands had saline groundwater aquifers underneath and in 4 lakhs hectares, the water table had entered critical zone of up to 3 metres depth. This created water logging accompanied by salinization.

The *rising water table* will adversity affect the reproduction of many crops. The story of canal irrigated areas of Pakistan where cotton has vanished from many fields, is likely to be repeated, says Bhumbla. The high water table, apart from affecting agricultural productivity, has many other adverse effects. Because of the loss of moisture storing capacity of the soil, even slight rains cause floods. The maintenance of road and buildings becomes difficult and diseases increase because of waterlogging. In Hissar in Haryana, the load bearing strength of the soil has become less than 50 per cent in 15 years.

In the sub-humid and humid areas of the country (rainfall more than 1,000 mm), the benefits of canal irrigation are questionable even in the short run. In fact, in many areas, introduction of canals has resulted in reduction in productivity of crops. In Bihar, Madhya Pradesh and Orissa, which together have 2.5 million ha of canal irrigated area and where rice is the main irrigated crop, the yield per ha is not only less than one tonne, but there has been perceptible increase for the last 20 years in Uttar Pradesh, which has the maximum canal irrigated area a part, there is a general complaint that from pre-sowing irrigation, hardly one irrigation is possible and the wheat crop frequently suffers from moisture stress.

1.15.5 Displacement of Population

A human problem arising from the construction of large dams in thickly populated countries such as India, Pakistan, Brazil is the displacement of a large number of human settlement affected by the submersion of the land behind the reservoir which is invariably fertile forest land. Table 1.18 gives the details of population displaced as a consequence of some dam constructions in the world and India. Roy (1999), based on a survey of 54 projects, estimated the people displaced by large dams in last 50 years in India to be 33 million." Another estimate gives it as 56 million.

Table 1.18 Table examples of the number of Resettled People due to Dams

Project	Country	Completed	Resettled people
Sanmenxia	China	1960	870,000
Maduru Oya	Sri Lanka	1993	200,000
Aswan	Egypt	1970	120,000
Akasombo	Ghana	1965	80,000
Itaparica	Brazil	1988	50,000
Yacyreta	Argentina	Under construction	50,000
Ataturk	Turkey	1991	40,000
Yantan	China	Under construction	40,000

Sources : Gleick 1992, Cernea 1990, World Bank, 1002.

1.15.6 High Capital Cost

The initial capital investments for river dams are very high. The construction work takes a very long time resulting in cost and time overturns. The cost overruns were 500 percent on the average.

1.15.7 Dam Failures

There have been episodes of dam failures causing loss of property and life. Some major dam failure in history are listed in Table 1.19.

1.16 Environmental Impacts of Large Dams-Indian Scenario

A number of guidelines to project various environmental components during site selection for large dams are given by Ministry of Environment, Government of India. These include short and long-term impact on population in the unidentified and watershed areas; impact on landuse, potential seismic impact of reservoir loading, water balance and hydrological regime, siltation, socio-economic impacts such as rehabilitation of project oustees and public health problems.

Table 1.19 Some Major Dam Failure in History

Dam	Country	Year
Bradfield	UK	1864
Johnstown	US	1889
Walnut grove	US	1890
Bouzey	France	1895
Tigra	India	1917
Gleneo	Italy	1923
Kualalumpur	Malaysia	1961
Babiyar	CIS	1961
Buffalo Creek	US	1972
Teton	US	1976
Kelly Baines	US	1977
Macchu II	India	1979

1.16.1 Impacts of Irrigation (Water Logging and Salinity) in Massive Irrigation Projects

Rainwater is conserved through walls and reservoirs, bunding of streams and canal systems. Since independence there has been an increase in net irrigated area of the country. Since the start of the Five Year Plans the area increased to 38.0 million ha. Of this 60% is by wells and tube wells. Canal irrigation increased by 63 million ha from 1950-51 onwards.

Through there has been phenomenal growth in irrigation potential it has not given returns in terms of yield or money commensurate with the investments. Moreover, large areas became submerged under reservoirs and have been destroyed by construction of roads and colonies. Added to these are the problems of salinity and water logging. Net result is the loss of land productivity. Canal irrigation in arid or low rainfall areas of Punjab, Haryana, Rajasthan, Gujarat and Karnataka increased crop production but only when water logging is controlled by effective drainage. In Punjab the seepage from unlined canals raised the water table 7-10 metres above the previous levels. In medium rainfall area of A.P., Maharashtra, Tamil Nadu and U.P. except for rice and post-rainy season crops, the effect on crop production is marginal. Canal irrigation is harmful to soils which degrade due to water logging and salinity. In India, more than 20% or irrigated land is damaged due to water logging and salinity. It is estimated that fertility between 30 to 80% of the world's irrigated land has been affected due to salinization. In high rainfall areas of Assam, Bihar, M.P., Orissa, W.Bengal and Kerala, canal water is difficult to manage during rainy season. Water logging and increased salinity are mostly the outcome of poor drainage in areas with massive irrigation projects.

Based on above, following conclusions could be drawn: (i) benefits from canal irrigation can be sustained in low rainfall areas for the first 15-20 years and thereafter occur waterlogging and salinity, (ii) canal distributaries and field channel are to be lined, (iii) water needs proper management at the farm level for regular and timely supplies, (iv) proper land leveling and shaping to increase water use efficiency, (v) a critical review of the extent and nature of irrigation in high rainfall areas.

For cost benefit analysis it has been suggested in the guidelines that the costs for environmental protection and mitigative measures should also be included in the overall estimates. These should include measures like compensatory afforestation, restoration of land in construction areas, control of aquatic weeds, control of water and soil borne diseases and rehabilitation of project oustees.

As per the Ministry of Environment, Government of India guidelines the following mitigative and environmental safeguards are to be guaranteed before clearance of a project. (i) submergence of valuable agricultural and forest areas; (ii) siltation of reservoirs due to degraded catchment conditions; (iii) satisfactory rehabilitation of oustees; (iv) loss of flora and fauna (v) reservoir induced seismicity; and (vi) water borne and soil borne diseases.

But according to some experts, the social, environmental and even economic cost of these dams, however, far outweighs their benefits. According to them most important social consequence of big dams has been the displacement of millions of tribals from their homeland and their eventual influx into urban areas, almost as refugees. Scientists, environmentalists, journalists, social activists, lawyers and bureaucrats have now taken up the issue against big dams.

Mounting opposition from scientists and environmentalists has forced the Government to review a number of proposed dams in the light of their impact on local tribals, flora and fauna. A glaring example that had effect on

Government policy was the scrapping of the Silent valley project in Kerala. Another example is Koel and Karo project in Bihar. This was also abandoned due to opposition from local people as it would have displaced several thousands of Santhal tribals in the area.

Some details of the major projects which have generated much controversy, (i) Sardar Sarovar Project, Gujarat, (ii) Narmada Sagar Project, M.P., (iii) Bodhghat Project, M.P. (iv) The Koel Karo project in Bihar (v) Tehri dam in U.P. are discussed below.

(i) Sardar Sarovar (SS) Project

Near Navagam in Bharuch district of Gujarat is one of the costliest projects affecting villages in three states-Madhya Pradesh, Maharashtra and Gujarat. About 245 villages will be submerged, of which about 193 are in M.P. alone. Over 75,000 (nearly 50,000 in M.P alone) people will be evicted. Additional displacement is likely to be caused during social and environmental rehabilitation work undertaken to repair the dislocation and damages caused by the project. Thus compensatory afforestation and setting of wildlife sanctuary will displace or affect other villagers in the area. It has been officially admitted that nearly 43,000 ha of land will be needed for rehabilitation of the oustees in the Sardar Sarovar Project.

(ii) Bodhghat Project

On Indravati river in M.P is in heavily forested Bastar district. The project will destroy teak and sal forests, and spell doom for the last surviving wild buffaloes. The criticism of the project forced the Govt., and the world bank to reconsider its construction.

(iii) Narmada Valley Project

The Narmada Valley Development Project consists of 30 major, 135 medium and 3,000 minor dams aimed at irrigating 4.8 million hectares and power generation of 2,700 MW, benefiting the states of Gujarat, Madhya Pradesh and Rajasthan. The Sardar Sarovar Project and Narmada Sagar project form part of the development project. The former consists of a reservoir of gravity type with of 75,000 km., for irrigating nearly 2 million hectares and generating 1450 MW of Power. The project is also aimed at providing drinking water for 40 million people in drought-prone areas. The estimated cost of the project is US $ 3 billion and is partly financed by the World Bank to the extent of US $ 470 million. As a consequence of the project construction, 39,134 hectares of land covering 13,744 hectares of forest and 11,318 hectares of cultivated land will be sub-merged, and 150,000 people will be displaced. Large number of birds belonging to 25 different species will lose their habitat. The rehabilitation of such a huge number of people is posing a difficult problem for want of sufficient land of good quality, the fishery, supporting thousands.

(iv) The Koel Karo Struggle

The potentially violent confrontation seems to be on the cards in Bihar over the Rs. 6,000 crore Koel Karo project, whose 710 MW capacity equals the entire state's current power generation capability. For years, tribals organised into the Koel Karo Jana Sangathan, made of people who will be displaced, have stalled construction, charging that the state government is deliberately underplaying the extent of inundation. According to their estimates, one lakh people, 15,000 families in about 100 villages, will be affected. According to government estimates, around 50,000 acres of land will have to be acquired, out of which half will be agricultural, affecting 7,573 families in 50 villages. Both estimated are just guess estimates since even the government department has not been able to survey the area so far.

(v) Tehri Dam

The 260.5 metre high with 3.5 cu.km. storage capacity Tehri Dam in Uttar Pradesh in India is being built at a cost of US $ 2 billion on a narrow Himalayan gorge at the end of a wide trough-shaped valley. It is praised as the most ambitious development project of the country. As the Himalayas are geologically young formations, the silt content of the river is very high. If effective steps are not taken for the soil conservation, the life of the dam is expected to be as low as 25 years compared to the expected average life span of one to two centuries for a dam. But the most serious objection is the fact that the dam is coming up in a seismically sensitive zone. The designers of the dam assure that the latest engineering expertise has gone into the design to prevent any change to the dam even in the event of a serious earthquake. But an earthquake that rocked the Uttarakashi region close to the dam site on October20, 1991, causing considerable damage, has raised doubts about the advisability of the dam construction. In the event of the Tehri Dam burst, it will create damage of unimaginable magnitude. Rishikesh will be under water in 63 minutes. Hardwar in 83 minutes, Bijnor in 4 hours and 45 minutes, Meerut in 7 hours and 25 minutes. Harpur in 9 hours and 50 minutes and Bulandshar in 12 hours.

This project, is soviet-financed project which was challenged in the Supreme Court. This dam will display over 85,000 people, and will totally immerse the Tehri town and completely or partly submerge nearly 100 villages. The site is prone to intense seismic activity. The 3200 million tonnes of water that the dam would impound could cause a major earth tremor. In the event of a disaster the entire religious townships of Deoprayag, Haridwar and Rishikesh would be devastated. Thousands of hectares of rice and agriculture land will be drowned. The project costs about Rs. 3,000 crores. The major draw back is the site, situated barely 100 km from the Chinese border.

1.16.2 Problems Associated Rehabilitation of Displaced People/ Tribals due to Major Dams

Though massive dams were built over three decades in India, the rehabilitation of displaced people is not adequate. Rehabilitation becomes much more important and difficult when most of the displaced are tribals. Tribal life and culture are so uniquely interwoven and integrated with the forests that once uprooted, they are totally disoriented. The quantum displacement in some of the major projects in India are given in Table 1.20.

Rehabilitation has always been considered an obstacle in implementing a project and an extra financial burden; the authorities always try and get away with minimum. No guidelines exist to include even the barest arrangements for rehabilitation in project plans; and facilities provided differ from project to project as per the study reported by centre for social studies Surat on Sardar Sarovar and Srisailam Project.

Provision of measures like ”land for land” and basic amenities like drinking water, schools, dispensaries and so on were made obligatory in the case of Sardar Sarovar. That had been made possible because of a dispute between the three states-Maharashtra, Madhya Pradesh and Gujarat-which was handed over to tribunal. The tribunal outlined the rehabilitation arrangement to be carried out by the Gujarat government. As Gujarat was to bear the costs of rehabilitation of the affected villagers of Maharashtra and Madhya Pradesh these two states saw to it that fairly elaborate measures were given in the tribunal’s award.

Table 1.20 Quantum of Displacement in some of the major Projects in the Country

S.No	Project	River	State	No.of villages affected fully	No.of villages affected partly	No.of families affected	Population affected
1.	Sardar Sarovar	Narmada	M.P.	-	193	14,994	45,000
			Maharashtra	-	36	1,665	11,000
			Gujarat	3	16	4,700	10,593
			Total 3+245	248		421,249	66,593
2.	Narmadasagar	Narmada	M.P.	254		N.A.	80,576
3.	Subarnarekha	Subarnarekha	Bihar &	182 &		9,722	50,116
			Orissa	24 (fully)	40	9,044	N.A.
4.	Ghataprabha	(partly) Ghataprabha (tributary of Krishna)	Karnataka	22		N.A.	15,660
5.	Malaprabha	Malaprabha (tributary of Krishna)	Karnataka	43		N.A.	41,000
6.	Upper Krishna	Krishna	Karnataka	169		16,017	N.A.
7.	Nagarjunasagar	Krishna	Andhra Pradesh	57		5,100	25,500
8.	Srisailam	Krishna	Andhra Pradesh	78		22,000	73,460
9.	Tehri Dam	Bhagirathi	Uttar Pradesh	95+1town		N.A.	46,000
10.	Tungabhadra	Tungabhadra	Karnataka	90		12,000	55,000
11.	Hirakud	Mahanadi	Orissa/M.P.	249		22,144	N.A.

The award was silent about the rehabilitation of the 'oustees' from affected villages in Gujarat. It was only after a tough stand by voluntary agencies that the Gujarat government agreed to similar provisions for its own reported to be shirking its promises. In any event, The Narmada Award has become a precedent for subsequent hydro projects.

1.16.3 Meagre Compensation

Compensation for land and houses is usually grossly inadequate, and none has ever been paid for loss of employment or disruption of livelihood other than from land. Landless labourers, marginal farmers, share croppers, tenant cultivators and those who live on collecting and selling forest produce have suffered most. Village artisans whose base is the village also get uprooted. Small farmers who supplement their income by rearing cattle are hit because new settlements never have enough grazing land. Villages are forced to sell off their cattle at throwaway prices before shifting.

People engaged in non-agriculture activity, like fishing are also not entitled to compensation. For example, there are 750 families along a 150km river stretch downstream of Broach town who make a living out of catching hilsa fish. The construction of Sardar Soravar will interfere with hilsa migration and 750 families will be rendered unemployed. No one in authority even pauses to ponder over the fate of the people involved in so-called marginal occupations.

The law requires that written notice be issued individually to the villagers for acquisition of their land and houses. The villagers, mostly tribals, are illiterate and ignorant of the legalities and get confused. As the experience of the Koel-karo in Bihar shows, panic spreads from much earlier when the project is being planned. Rumours abound about the rate of compensation and resettlement sites.

In the case of Srisilam, the notice specified terms of compensation with a clause that appeals about the rate that had to be submitted in writing by stipulated date. The rate of compensation was very low and depended upon the type of land, house and so on thus leaving a lot of elbow room to the land acquisition officers. Though the law provided for compensation at the market rate according to the latest land deals in the area, the authorities arbitrarily fixed the compensation.

It has been the experience everywhere that rich framers bribe the officers and manage to get higher compensation and better alternative lands, whereas the poor keep running from pillar to post. Vidut Joshi of the CSS in Surat points out that the terms of acquisition and other procedures were never orally explained to the people in the Sardar Sarovar project and in the process illiterate people were cheated by the officers and their intermediates, except in cases where activists of voluntary organizations came to their help.

Even when compensation is paid to villagers through their bank accounts, it has been found that part of it goes in sustaining them during the shift to a new site and too much of the rest is frittered away in non-productive expenditure. Another problem is that government takes only that land which is to be submerged or is required for other purposes, leaving many partly affected people in the lurch. When part of a village is shifted elsewhere, the families left behind face a life of isolation, in some cases, when the major portion of a family's land is taken over, it can neither survive on the remaining area nor get any compensation for the remaining land or for its house if it decides to shift along with fellow villagers.

Such cases were never considered until the Narmada tribunal specified that if 75% of a family's land was affected, the entire land should be taken over and it should be also be paid compensation for the house and transport for families who are isolated in partly affected villages. Almost all the farmers left in the vicinity of Shivsagara (Koyana) reservoir live on scattered basis, below the poverty line as they have no means of subsistence except for a few quintals of paddy grown by primitive methods.

1.16.4 Resettlement Problems

"*Land for land*" is better a policy than cash settlement and the Narmada Tribunal has in fact specified that a minimum of 5acres should be given to each affected family. Even in implementing this policy, the land is not given in the command area in most cases, forest land is either cleared on waste fallow land given without any provision for developing the land or for the supply of necessary inputs; a village is broken up and families dispersed; villagers are usually left to buy private land, take loans from the government, which puts poor villagers at a disadvantage-land prices in neighbouring villages shoot up steeply if the environment takes up resettlement, the villagers are resettled in distant places, sometimes in a totally alien environment and culture, thus creating insurmountable adjustment problems.

Oustees from Pong dam in Himachal Pradesh were setlled in Anupgarh in Rajasthan, bordering on Pakistan. Though the land falls in the command area of the Rajasthan canal the villagers, who were used to hill cultivation, found it difficult to adjust to the rigours of the desert.

Tribals affected by Inchampalli and Bhopalpatnam in Maharashtra do not even speak Marathi and if they are resettled away from the forests and in an alien Marathi-speaking area, they will find it difficult to survive and shifting them to any other area would amount to 'ethnocide', in other words of Baba Amte, the social activist who has been leading a mass movement against the two dams.

When the construction schedule of a dam is planned, residential quarters for officers and other staff are always given priority. In the Sardar Sarovor project, Kevadia colony; a well developed residential area with markets, schools, parks and other facilities was kept ready before the staff moved in. On the other hand, when villagers were served legal notices for acquisition of lands, no preparation was made for their shift to alternative sites. Even if some sites were located, no effort was made to develop the sites. Arrangements for drinking water, dispensaries, schools, village roads or drainage at the rehabilitation sites are only completed years later.

1.16.5 Rehabilitation Policy

A comprehensive rehabilitation policy can be spelt out only when development is understood as a process which benefits the people. If the completion of the project at the minimum cost becomes the overriding objective, rehabilitation simply amounts to evacuation. People who could previously barely manage to survive in their traditional environment are uprooted as a result. If the people are the major focus, any projects should seek to improve the conditions of those living in abject poverty.

According to the CSS, the objectives of rehabilitation should be :

- The people displaced should get an appropriate share in the fruits of development.
- They should be rehabilitated by creating new settlements within their own environment.

- Removal of poverty should be also be an objective of the rehabilitation policy, and therefore, some land to all.
- Oustees (even the landless) should be given assurance of employment.
- While dealing with tribals one should also keep in mind Jawaharlal Nehru's – 'tribal panchsheel'
- Tribals should be developed along the lines of their own genius and one should avoid imposing anything on them.
- We should try to train a team of their own people to do the work of administration and development.
- Tribal rights in land and forests should be preserved.
- We should try to encourage their own traditional arts and culture in every way.
- We should not over administer these areas or overwhelm them with a multiplicity of schemes but should rather work through, and not in rivalry with, their own social and cultural institutions.

Keeping these in view, the following general guidelines can be specified for any rehabilitation programme:

- Land for land should be provided with an economically viable minimum of 5 acres even to the landless.
- Resettlement should be in the neighbourhood of their environment.
- If resettlement is not possible in the command area, top priority should be given to the development of irrigation facilities and supply of basic inputs for agriculture; drinking water, wells, grazing grounds for cattle, schools for the children, primary health care units and other amenities should be arranged.
- In partly affected village, villagers should be given the option of shifting out with others with the same compensation as available to evacuees.
- Training facilities should be set up to up grade the skills of affected people and reservation in jobs should be made for the willing adults among the evacuees.

1.17 Ecologically Sound, Economically Viable Engineering Alternatives to Large Dams

In the light of recent experience, questions are now being raised about the viability of large dams which have often proved to be ecological disasters. Can there be ecologically sound and economically viable engineering alternatives to large dams? If dams are inevitable for a large country faced with the task of feeding its growing millions and for meeting its energy requirements, can the destruction they cause be minimized and adequately managed?

Groundwater development, minor irrigation schemes and micro hydel projects are often cited as alternatives to big dams, units wells, ponds, small dams, largest dams. Through small schemes cannot be considered as alternative to big dams for water management and power generation in all cases but there is definitely a strong case for ground water development and minor schemes for irrigation, while power generation needs can be partly met through small hydel projects.

The small schemes will probably receive their due only when the overall development of far flung rural areas becomes the focus of the country’s planning. China is a good example where thousands of small dams and mini hydel projects have been constructed which have provided water and power right at the point where they are needed and thus helped in overall development, ensuring basic amentities to the entire population. A much greter decentralized organizational effort is required to plan and implement schemes on the lines of China. On the other hand, large dams are constructed by centralized organizations and big contractors with huge funds borrowed from the World Bank and with imported machinery.

If irrigation alone is considered, small schemes are far better than large ones. But small hydel projects cannot meet the hydro requirements of the central power grid. The country will have to search for other sources of renewable energy because even so-called “clean” hydel is not so spotless if the destruction caused by big dams is analysed.

Like surface water, ground water resources in the country are being depleted because of the lower water retention in catchment areas which have been deprived of forest cover. The *development of catchment areas*, therefore, *should become an integral part of an irrigation programme*. This will also *check the flow of silt into big reservoirs*. There have been calls for the creation of a catchment area development authority. Wherever water resources have been harnessed through small reservoirs by constructing *bunds or small dams, the lives and environment of the people in the area have been transformed without anyone having to pay the cost of development.*

1.18 River Water Disputes

Where water is scarce, competition for the limited supplied makes nations to consider access to water as a matter of national security. From the early times, extending back to 5,000 years, there have been episodes of competition and disputes over shared fresh water resources in several regions, especially in parts of southern and central Asia, central Europe and Middle East. These conflicts are a continuing phenomena and are bound to become more intense as growing population demand more water for agricultural, industrial and domestic purposes.

Water sources have also been used as instruments of war. When Sennacherib of Assyria destroyed Babylon in 689 BC he purposefully destroyed the water-supply canals to the city. During World War II, water dams have been bombed. The central dams on the Yalu River serving North Korea and China were attacked during the Korean War. Irrigation water-supply systems in North Vietnam were bombed by the US in the late 1960's. Dam's, desalination plants and water conveyance systems were targeted during the 1991 Gulf War. In 1993, the Peruca Dam, the largest in the former Yugoslavia, was intentionally destroyed during the civil war.

In recent times, the most pressing water conflicts in the Middle East have centered on the control of the Jordan River Basin. Though the Jordan is a small river, its basin is shared by Israel, Syria, Jordan and Lebanon. All these nations have few alternate sources of water. During 1967 Arab-Israeli War, Israel occupied much of the headwaters of the Jordan River, ensuring for itself a more reliable water supply and denying Jordan a significant fraction of its available water.

Ninety seven percent of Egypt's water comes from the Nile River while more than ninety five percent of the Nile's runoff originates in eight other nations of the Basin: the Sudan, Ethiopia, Kenya, Rwanda, Burundi, Uganda, Tanzania and Zaire. Egypt is thus extremely vulnerable to any reduction in the flow of the Nile through the intervention of any these nations. According to former President Anwar Sadat of Egypt, “the only matter that takes Egypt to war is water”.

The construction of the Farakka Barrage across the Ganga by India to divert water into the Hoogley River to protect the Calcutta port from problems of silting, has been the subject of dispute between India and Bangladesh. Some more instances of international river water disputes are listed in Table 1.21.

The sharing of river waters at local and regional levels is an equally sensitive issue in many countries. In India, violent conflicts have arisen over water allocations among beneficiary states. In 1992, over fifty people were reported killed in riots in Karnataka following a court decision to allocate additional waters from Cauvery to Tamilnadu. Table 1.22 lists some disputes of this nature.

Table 1.21 Some International River Water Disputes

River	Parties to disputes
Ganga	India, Bangladesh and Nepal
Brahmaputra	India, Bangladesh
Euphrates	Turkey, Jordan, Syria, Iraq and Iran
Parana	Brazil, Paraguay, and Argentina
Danube	Hungary and Czechoslovakia (now Czech and Slovak Republics)
Colorado	US and Mexico
Zambezi	Zambia and Zimbabwe
Han	South Korea and North Korea

Table 1.22 Local and Regional Water Disputes

River	Disputes
Colorado	Seven States in US including Colorado, Arizona, California and Utah
Yamuna	Delhi, Haryana, Rajasthan, Himachal Pradesh and U.P.
Narmada	Maharashtra, Gujarat, Rajasthan and Madhya Pradesh.
Krishna	Andhra Pradesh, Maharashtra, Tamilnadu and Karnataka
Godavari	Andhra Pradesh, Maharashtra, Orissa and Madhya Pradesh
Cauvery	Karnataka, Tamilnadu and Kerala

1.19 Krishna Water Disputes

The Krishna river rises in the Western ghats from a water spring at an elevation of 1360 meters and after flowing over a distance 1400 km joins the Bay of Bengal. Out of its drainage area of about 2.6 lakh sq. km of which 27% lies in Maharashtra, 47% in Karnataka and 29% in A.P. state. The shape of the river basin is very wide, fan shaped in the western ghats where very high intense rainfall of about 3000 mm is received during South West monsoon which gradually gets reduced to 500 mm middle part and subsequently raises to 1000 mm on the East Coast. The river has many important tributaries like Koyna, Ghataprabha, Malaprabha, Bhima, Tungabhadra, Musi and Munneru river. The total annual average flow in Krishna river is 67,675 million cubic meters (2396 TMC).

The gross sown area is more than 16 million hectares, forming 80% of the cultivable area. The percentage of irrigation is about 21%. The soil consists of black, red, laterite, aluminium, mixed soil, etc., Ground water can be tapped from open wells and bore wells in most of the areas of basin. Tanks and wells irrigate about 40% of the irrigated lands. Drought conditions prevail due to failure of monsoons and hence irrigation systems were developed since 1850s. After independence a number of irrigation projects were executed by the basin states of Maharashtra, Karnataka and Andhra Pradesh. With the growth of population there is an escalating demand for food production and hence more land is brought under irrigation in all the states without a corresponding increase in the availability of fertile river water for irrigation. Since the upper states have been diverting the natural river flows to meet their own rising demands for food production, the riparian rights of the farmers in the lower states are getting adversely affected resulting in conflicts over the sharing of the dwindling river flows.

When the states were quarreling over the sharing of this river water the Union Government appointed a tribunal on 10-4-1969 to resolve the Krishna river water dispute and this tribunal is known as Bachawat Tribunal and its reports of 1973 and 1976 are known as the Bachawat Tribunal Reports.

Bachawat Tribunal Award

Bachawat Tribunal distributed the 75% dependable annual yield of Krishna water amounting to 2060 TMC at 560 TMC to Maharashtra, 700 TMC TO

Karnataka and 800 TMC to Andhra Pradesh and added the regenerated flow of 25 TMC to Maharashtra, 34 TMC to Karnataka and 11 TMC to Andhra Pradesh state under Scheme ‘A̶. But if the above absolute quantities are treated in terms of ratio of 560:700:800 for distribution of the average annual flow of 2396 TMC (which includes the surplus waters) it becomes Scheme & # 8216; B &# 8217; as considered but not recommended by the Bachawat Tribunal.

Infact when Telugu Ganga scheme was to be launched Dr.K.L.Rao warned that there was no water in Krishna to be used for irrigation in Rayalaseema to supply drinking water for Madras. But the then Irrigation Minister claimed that there was surplus water in Krishna rive due to under utilisation by Karnataka and Maharashtra.

But the scenario drastically changed now due to excessive storage in several reservoirs in Maharashtra and Karnataka state including the over-sized Alamatti dam. Moreover due to extensive deforestation in Western ghats perpetrated by the Maharashtra and Karnataka Governments for supplying the wood for number of industries and paper mills there has been a gradual reduction in forest cover resulting in reduced inflows into the major rivers and their tributaries. Hence the dependable flow in the Krishna River itself has come down and consequently the allotted quota of 800 TMC by Bachawat Tribunal has not been realized during the past 10 years and it is not likely to be realized in the coming future.

1.20 Water Pollution

According to some reports, 90% of the surface water in India is contaminated, causing serious water pollution in the rivers nationwide especially large ones, resulting from the inflow of domestic or industrial and agriculture effluent.

Among the most polluting industries are sugar, distilleries, pulp and paper, synthetic fibre, dyestuff and textile dyeing, and tanneries. There are large number of industrial estates across the country e.g., Kanpur (tanneries), Jetpur, Jodhpur, Thirpur (all textile dyeing), Salem (sago processing), Jeedimetla, Patancheru (pharmaceutical), Vapi, Ankaleshwar (chemical), Allapuzha (coir processing), Ludhiana and Jalandhar (electroplating & textile dyeing) etc. where

Table 1.23 Comparative Statement of the Water Quality Status of Rivers in Andhra Pradesh

River and location	Desired DBU class	Water quality status		River and location	Desired DBU	Water quality status	
		1998[a]	2000[b]			1998[a]	2000[b]
Godavari River				Jaggaiahpet	C	C	C
Mancherial	C	D	B	Amarvathi	C	-	C
Polavarm	C	B	D	Vijayawada	C	C	C
Rajahmundry/s	C	C	D	Hamsala deevi	C	-	C
Rajahmundry d/s	C	D	D	*Tungabhadra River*			
Manjira River				Mantralaya	C	-	C
Raipally	C	D	C	Bahavapura	A	B	D
Shivampet	C	-[c]	C	*Musi River*			
Maneru River			C	Musi u/s[d]	E	D	C
Somanpally	C	D	C	Musi u/s[d]	E	E	E
Krishna River				*Pennar River*			
Thangadi	C	-	C	Unganor	C	D	D
Gadwal	C	-	C	Pushpagiri	E	E	D
Srisailam	C	D	D	Siddavatam	C	D	D
Wadapally	C	D	C	Somasila	C	D	C
Vedadri	C	-	C	*Nagavali*			
Keesara	C	C	C	Nagavali	C	B	C

[a] as per CPCB Annual report; [b] As per APPCB water quality assessment
[c] Status not available; [d] Upstream/downstream of Hyderabad

the cumulative discharges from the small scale industries have damaged the ground water resource to the point of no return.

Status of recipient bodies

Rivers such as Krishna, Godavari, Musi, Nakkavagu, Pennar, etc., have been found to be polluted at different stretches, mainly due to industrial, domestic and agricultural waste discharges. The Musi is the most polluted river. The polluted stretches are mainly at locations where waste water from industries and habitations is being discharged into the rivers. The water bodies (lakes, tanks) are being polluted mainly by industrial and domestic waste water discharges. At several places, the ground water too has been found to be polluted, mainly due to industries and aquaculture farms. The groundwater pollution profile of the state is given in Table 1.23.

Questions

1. List the major ways humans are altering the water cycle, and describe some of the environmental and social impacts of these alterations.
2. Explain how dams and reservoirs can cause more flood damage than they prevent. Should all proposed large dam and reservoir projects be scrapped? Explain.
3. List 10 major ways to conserve water on a personal level. Which, if any, of these practices do you know use or intend to use?
4. What are water's unique physical properties?
5. How much fresh water is available to us, and how much of it are we using?
6. What are the world's water resource problems?
7. How can we get more water, and how can we use it more efficiently?
8. Describe the hydrologic cycle.
9. Do you believe that large dam projects like the Tehri Dam of India Gorges Dam project in China on the whole, beneficial or not? What other alternatives would you recommend? Why?

10. Do you believe that the large scale hydro electric power should be promoted as a renewable alternative to power plants that burn fossil fuels? What criteria do you use for this decision?
11. How might you be able to help save fresh water in your daily life? Would the savings be worth the costs?
12. What do think about the increased development in arid regions? If development continues and water resources decline, what do you think the political effects will be?