Chapter 7

Environmental and Social Considerations

The objectives of this chapter are:

- to explain the role of water in environment,
- to provide an overview of environmental impacts of water resources projects,
- to explain the procedures of assessment of environmental impact of water resources projects,
- to discuss rehabilitation and resettlement aspects, and
- to provide detailed description of environmental and social issues associated with Sardar Sarovar Dam, a major multipurpose project in India.

The word environment means "surrounding conditions influencing development or growth". The surroundings encompass the whole complex of factors - including all the living beings (the flora and the fauna); the various life supporting systems, such as land, air and water; as well as society. The study of interaction amongst the various elements of the environment is the subject of ecology. The ecology is "the branch of science concerned with the relationships between organisms and their environment." Environment can be considered a natural resource. When this resource is over-utilized, problems usually arise. Overexploitation of resources is common in both developing and developed countries, albeit due to different reasons.

The environmental 'hot spots' are the locations that have critical deficiency in assimilative or supportive capacity. Water, both quantitatively and qualitatively, is the limiting resource in most regions and the future planning should be based on this reality. Among natural resources development projects, water related projects have the most profound impact on the environment. The interest and involvement of general public in environmental issues began to grow in the 1960s. This, of course, does not mean that these problems were not recognized or the issues were not addressed in past projects. Nevertheless, the attention and the resources earmarked to address these issues have grown with the public concern. The Environmental Impact Assessment (EIA) became an integral part of each important project in the 1990s. Currently, for many projects, social and environmental problems are proving to be more difficult to handle than technical problems. Now, along with technical and financial feasibility, it is necessary to examine social and environmental feasibility of a water resources project.

A major man-made intervention, like a storage reservoir or extensive ground water pumping, will change the existing balance and force the environment to seek a new stable state. The new state does not get established immediately, it takes time to get developed, and it might be better and acceptable or worse and distressing. Thus, it is the duty of developers to ensure that any development does not aggravate the processes which are undesirable or harmful for the society. The magnitude of intervention is crucial. Any intervention that will adversely affect environment with consequential irreversible harm to life is to be checked. Further, no intervention is not always the right strategy.

As is true for many other natural processes, environment is not a static concept. It is an ever-evolving and dynamic entity. This concept is elaborated in the next section.

7.1 DYNAMISM OF ENVIRONMENT

Environment is in dynamic balance with its elements. Any major change in one element upsets this balance and depending on the quality and intensity of the destabilizing action, the environment regains its balance or attains a new dynamic balance over a period. Consider this: in a dense forest, chopping-off a few branches of trees upsets the balance but this is not noticeable as the balance is restored in a short period. Controlled exploitation of forests also disturbs the balance but the new dynamic balance is attained in a reasonable period of time. However, after uncontrolled plunder of forests, the balance and biodiversity may be lost forever, leading to progressive degradation of the environment.

The environment at a place keeps on evolving due to natural processes, changing climatic conditions as well as man's activities. There is no unique steady state for the environment at a place. For example, the Indo-Gangetic plains in north India are the result of natural processes over millions of years. The place where mighty Himalayas stand today was occupied by ocean in the geologic past. Many climatic and hydrologic variables follow a long-term cycle. Therefore, when nature itself is not in a permanent state, the life of man-made systems cannot be unlimited and it is futile to talk of their permanency. What needs to be ensured is that the longevity of these structures, harmony with the environment, and ability to meet reasonable future requirements.

Depending on the malaise, the remedy may be simple and painless or it may be drastic and painful. The shortage of water in an area may be overcome by a few wells or it may require long distance inter-basin transfer of water. Flood mitigation may necessitate the construction of a large reservoir. The analogy is similar to human illness – the person may need a small tablet or may even require a major surgery. In cases of extensive treatment, expert supervision coupled with the necessary follow-up and monitoring is necessary to avoid adverse side effects. Equally important is the reversibility of the system. For some environmental problems, if a remedial action is not initiated in time, consequences may be irreversible and it may be impossible to restore the system to its initial state.

While assessing the degree of intervention that is likely to be bearable, the natural variability in the environment is an important factor. Environmental systems are stretchable to some extent, the range of stretch is different under different natural settings. It is not possible to quantify this inherent property of nature and provide some index in view of the large number of variables and uncertainties. The idea can only be expressed in somewhat qualitative manner. Nevertheless, the systems should not be stretched so much that they collapse or breakdown.

7.2 WATER IN ENVIRONMENT

Water has a central and key role in the environment. But the contribution and importance of water in the environment is not the same in all geographical areas or all the year round in the same area. Depending on the location, topography, geology, and precipitation characteristics, some areas have higher water availability than others. The role of water in the environmental system also depends on other conditions. Many times, forests, pastures, agricultural cultivation, and urban areas provide different sets of environmental parameters. A change in the land use brings in a new 'environmental state' for water. The developmental potential also varies considerably from area to area. Many ills of the development programmes for water have their roots in the inadequate appreciation of these differences and similar solution for dissimilar environmental situations. Water management in arid regions must be different than in humid areas. Vegetation is a good indicator of availability of water in an area. Plants are an indicator of the quality of water in the ecosystem; all tree species do not survive well in saline or waterlogged areas.

Most environment-centered discussions and writings tend to be influenced by emotions and ignore the hard ground realities. Apparently, people form their opinion about the environment mostly based on what they see around the picnic spots or in movies. However, the natural environment is not beautiful and pleasant everywhere. It can be extremely harsh, dangerous, ruthless and furious. Imagine the conditions in the deserts, droughts, avalanches, cyclones, hurricanes, or a river in spate. Those who have been through these can appreciate what these words mean. Even seemingly innocuous weather with temperatures close to 40° C causes several hundred deaths each year. Besides, the environment of a place, which is pleasant in one season, may become quite hostile in other seasons. After all, the migratory birds from near-polar regions move to warmer places in winter because their habitats are no longer fit for living. Natural water is also not always pristine and healthy as is widely believed. Pure rainwater, after falling on the earth and mixing with the pollutants, may no longer be fit for human consumption. This is the reason when countryside is inundated by floods, paradoxically, water may spread epidemic, and clean drinking water is a serious problem for the sustenance of population.

In adverse situations, only human effort and ingenuity can mellow the harshness of the environment and make the areas comfortable and beautiful. Places, such as Israel and Kuwait, are testimony to this. Because of the increasing pressure of population, people are settling to harsher areas. Providing a life support system to them either by transfer of water or by protection against floods is necessary. Water is the dominant element in the ecology that can bring about a desired change. Obviously, land and air cannot be as easily manipulated as water. Hence, water has an additional role to play, namely improving the environment, and is to be managed and developed in harmony with its surroundings. The principal aim of water management must be to create this harmony where it does not exist by changing the availability pattern in a dry area or protecting an area from water excesses. While dealing with water, the objective should not be just environmental protection but also improvement.

In many regions, because of poverty, lack of resources, and increasing pressure of population, environment has been degraded and forest wealth has been plundered. Water management in such areas has, therefore, an additional important role -- regenerating and restoring the lost plant life which, in turn, can support other life and lead to improvement in the environment.

Every effort to develop water resources results in some modification of the environment. Sometimes, the impact is confined mainly in the river course, aquifer or lake itself. In other instances, effects are much more widespread and may result in considerable alterations in land resources, forests or fisheries. Beyond this, water resources development (WRD) may have major impacts on human settlements and economic activities. The extent of these impacts depends on the ability of various physical, natural and human systems to absorb them.

Sustainable development and environmental protection are two mutually related aspects of an optimal resource utilization strategy. Due to the sheer size and consequent developmental activities, the WRD projects do result in significant impacts on the regional environment -- these impacts can be positive as well as negative. In order to have proper development of the resources without destroying the ecological balance, an environmentally sound planning is needed.

Environmental issues were not viewed with seriousness but the awareness has considerably increased during the past two decades. There is a growing concern about the adverse social and environmental impacts of water development projects in many countries. The reason is the results of studies carried out all over the world which have demonstrated the significance of environmental impacts. Therefore, it has become imperative for any development plan, and especially WRD projects, to be evaluated from the environmental standpoint.

7.3 ENVIRONMENTAL IMPACTS OF WATER RESOURCES PROJECTS

WRD activities date back to thousands of years. However, only during the last 4-5 decades, both the size and number of projects have increased significantly, with concomitant impact on the environment. The water resources related activities that lead to major environmental impacts are: construction of dams and canals, submergence due to reservoirs, irrigation and water logging, excessive withdrawal of ground water over a large area, and inter-basin transfer of water. Although the environment impacts could be beneficial or adverse, the impacts which are adverse need detailed analysis and investigation.

The interaction between the various environmental components is a polymorphous task. Man is the cause of many environmental disturbances and also the hub around which the impact assessment should be addressed. Assuming that the environmental system is in "equilibrium" stage (i), the development of a water resources project will induce an action into the system. This action will produce reaction and dynamic interaction between the environmental components involved. After a quasi-steady state has been reached, a new "equilibrium" stage (i+l) of the environmental system will be evolved. A schematic representation of the man-nature interaction is given in Fig. 7.1. The purpose of EIA is to predict stage (i+l), compare with stage (i) and improve decisions, planning, implementation, and monitoring of the project. A trade off between conditions of the human component and ecological system at stage (i+l) is possible. During the EIA, emphasis should be placed on the analysis of the proposed water project effects; however when applicable, the effects of natural evolution processes must be taken into account.

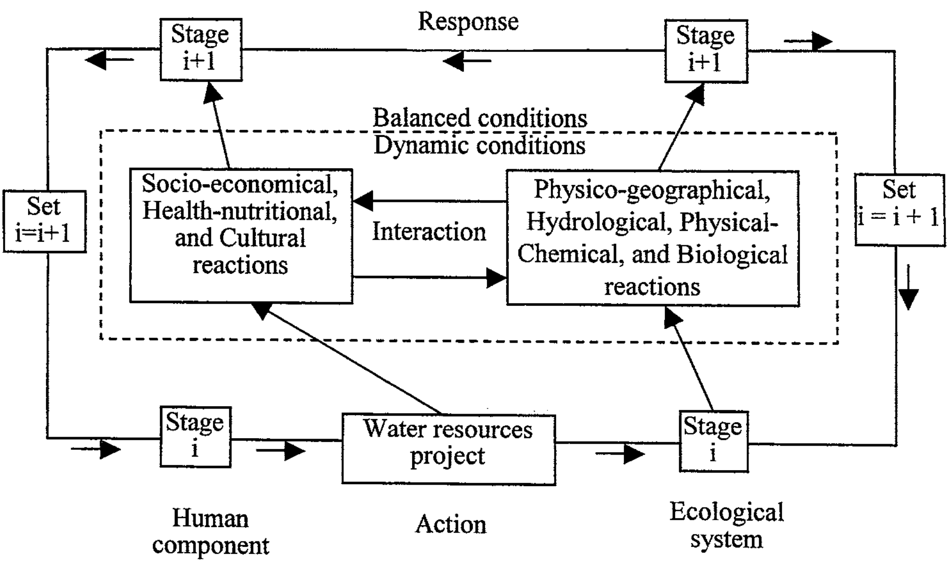

Fig. 7.1 Human-nature interaction resulting from a water resources project.

There are many ways to classify environmental impacts as discussed below.

Primary and Secondary Impacts

Environmental impacts can be generally classified as primary or secondary. Primary impacts are caused directly by the project works, such as loss of forests due to submergence, change of a river regime due to the construction of a dam, etc. These impacts are relatively easy to measure. Secondary impacts are caused by the project outputs such as flow regulation, channelization, and water supply. These are indirect consequences of project outputs. For example, a project may begin supply of water for irrigation and its effect on the fertility of the irrigated soil can be termed as a secondary impact. Secondary impacts could be equal or more pronounced than the primary impacts and, unfortunately, often more difficult to predict and measure. The distinction between primary and secondary impacts is often arbitrary.

In an ecosystem, impacts are usually complex and one impact may lead to another, resulting in chain reaction. For instance, deforestation could contribute to increased reservoir siltation which could lead to a loss in the downstream fishery, causing malnutrition which, in turn, may increase sickness. A major impact may often arise due to a combination of factors. The causal linkages between impacts may not be direct or clear-cut. Various types of water-related activities, such as land clearance, construction, water impoundment, water channelization, and changes in land-use patterns, can cause beneficial or adverse impacts on the environment.

Long- and Short-term Impacts

Environmental impacts can also be classified as short-term and long-term. Short-term impacts occur during investigation, construction and immediate post-construction phases. After these activities are over, the impacts also subside. Long-term impacts stem from permanent large-scale changes, such as creation of a large lake, development of perennial irrigation instead of seasonal irrigation, construction of a large canal, and large-scale deforestation.

Acceptable and Unacceptable Impacts

Environmental impacts can also be broadly categorized as:

1. Totally unacceptable impacts, e.g., submergence of important places. Such a place could be a large city, an important historical monument, a national park, or a forest inhabiting rare species.
2. Conditionally acceptable impacts, such as dislocation of population, submergence of forest land, submergence of mineral deposits, water-logging due to canal irrigation.
3. Neutral impacts that are neither desired nor adverse, such as submergence of unproductive wasteland.

Environmental impacts can be further classified as quantifiable or non-quantifiable. The impacts that can be measured and mathematically expressed as functions of decision variables are quantifiable. For example, the area of submergence of forest land can be measured and, in turn, can be expressed as a function of the storage capacity of the reservoir, a decision variable. An increase in the incidence of malaria because of the construction of the reservoir is an example of a non-quantifiable impact. Howsoever important a non-quantifiable impact may be, it cannot be satisfactorily incorporated in mathematical modeling. Its impacts can be gauged only through the qualitative studies and judgment.

7.3.1 Adverse Impacts

Adverse impacts of WRD projects need to be identified during their planning and investigation phase, followed by implementation and operation phases. Although these phases appear sequentially in time, in practice there could be considerable gap between them. It is necessary to anticipate the adverse impact of all the project phases in advance so that measures to eliminate or mitigate them, where practicable, are initiated in time. Every effort needs to be made to enhance the beneficial impacts to the extent possible. Since adverse impacts need to be examined very carefully, they are listed first.

Planning and Investigation Phase

The major activities which are liable to affect the environment are: construction of access roads; foundation investigations, drilling and blasting; locating quarries for construction materials; layout of construction plants, etc. Sometimes it is necessary to construct access roads or tracks in the mountains during the project investigation phase. In fact, most such tracks are small clearings where land is leveled so that vehicles can pass. Creating access roads or even motorable tracks in otherwise inaccessible areas does not have significant environmental consequences. Sometimes these paths are used for undesirable and illegal plunder of forest wealth. Closing the tracks or barricading the entries after the investigations usually checks the problem.

Forest cutting in the investigation stage is generally not substantial and the adverse impact is essentially temporary. If the period between the investigation and implementation phases is large, the forest is expected to rejuvenate itself. Adverse impact of drilling and blasting in the investigation phase is expected to be minimal as these operations are carried over small areas. Similarly, areas of quarries and construction plants, etc. are generally quite small compared to the catchment area and the influence during the investigation stage is not important. Of course, the news that a project is likely to come up in the area may trigger new economic activities.

Construction Phase

The planning phase of a project is often continuation of the investigation phase. The environment near the dam site faces extensive disturbance during the construction phase but this phase is of very short duration compared to the life of a project. While some dislocation is unavoidable, timely actions could largely mitigate the long-term adverse impacts. Immediately after construction is over, all efforts should be made to restore the environment to original or even a better state. In case of canals, the construction activity is spread over a large geographical area. But there is not much impact on the environment, except chopping of a few trees and minor changes in the topography due to cutting or filling. Similarly, in case of hydropower projects, some trees may have to be felled to lay transmission lines.

To minimize the adverse effect to the environment, the construction equipment should meet applicable norms. The sound levels may be kept within specified limits and blasting operations should not coincide with nesting periods of birds. If new evidences of archaeological importance are encountered during digging, the work at that place should be suspended and concerned experts should be immediately approached for advice.

Operation Phase

During this phase, the impacts are either due to diversion of water from an area to another, which may also involve trans-basin diversion, or applying water to an area where there was inadequate water. In all diversion projects, only the excess water after considering the need of that region is diverted. Hence, this should not lead to any undesirable consequences.

The negative environmental impacts of a WRD project are summarized in Table 7.1.

Table 7.1 Summary of negative environmental impacts of WRD projects.

Phase	Impacts on physical environment	Impacts on socio-economic environment	Impacts on biotic environment
Planning and investigation	Minor increase in pollution.	Small increase in economic activities.	Some forest cutting.
Construction	Higher erosion and pollution at construction site. Temporary change of flow patterns and sediment load of rivers. Blasting operations.	Law and order problems due to influx of 'outsiders'. Loss of cultural and historical monuments. Dislocation of people from construction area. Influx of people with different cultural backgrounds.	Workers' health. Destruction of flora and fauna. Deterioration in downstream water quality. Water borne diseases.
Operation	Possibility of water logging in command. Changes in river flow regime. Less water in downstream areas due to diversion. Less flooding of wetlands with silt. Changed flow regime in coastal zone. Saline water intrusion. Sedimentation of reservoirs.	Displacement of people from submerged area. Loss of income from the area impounded. Possibility of spread of water borne diseases. Population increase. Ill effects of tourism and recreation.	Loss of flora and fauna, wildlife habitat. Loss of natural reserves. Changes in water quality and sediment load (eutrophication). Damage to ecology due to tourism. Spread of aquatic weeds in water bodies. Spread of diseases.

7.3.2 Beneficial Impacts

It is interesting to note that of all the registered large dams in the world, only about 5% are in Africa where most of the countries facing severe water scarcity are located. About 55% of large dams are in North America and Europe and largely because of this, there are not likely to be severe water shortages (Keller, 2000). To take a holistic view of WRD, it is necessary to examine the beneficial impacts of WRD projects.

Irrigation Benefits

Increase in agricultural production is the most important beneficial impact of irrigation projects. In the global context of food production, there is no alternative to self-sufficiency in food production on a sustained basis. Consider the case of India with about one-third area being drought prone and about one-eighth flood prone. This coupled with the need to feed over one billion people, the importance of irrigation is self-evident.

For many countries, irrigation is the key to rural and national development. With assured irrigation, agricultural production increases, there are diversified crops, better per capita food availability, and higher food and nutrition intakes. Higher availability of water also yields increased livestock holding; this can be a source for assistance in farming and increased availability of animal protein. In addition to the improved food and nutrition, the improvements in education, health facilities, the status of women, and general advances in the overall quality of life further advance the health status of the rural people.

Based on a study of an irrigation project, Shah (1993) concluded that gross receipts per man-day in irrigation areas increased by more than 100% in all economic activities. Irrigated farming also increased permanent employment of the order of 30-50 man-days per ha. This is a very significant improvement in view of the large-scale unemployment in many countries. Not only this, the growth of agriculture output also triggers growth in other sectors of the economy. For example, it leads to increased demand for fertilizers, pesticides, farm machinery, water pumps, motors, transportation, cold storages, etc. Of course, there is a need for repair and maintenance of farm equipment and this generates more employment.

Coming to secondary and tertiary benefits, in India the average receipts for households with irrigation are found to be more than double than those without. As it happens, families with higher income spend more on non-food items, say cloths, TV, house building, vehicles, and so on. The sale of cement, consumer durable (washing machine, TV), and automobiles etc. has been found to be higher during the years of good crops when the farmers have higher disposable income.

Hydro-power Benefits

Many large water projects also generate hydropower. The generation of clear energy from a renewable resource where no fossil fuel is burnt is a boon for air quality. The operation and maintenance costs of hydropower plants are very low, of the order of 1% of capital cost, and these can be started and stopped in a few minutes. The water is not consumed in the process and is immediately available for other uses. According to estimates, about 19% of the world's electricity comes from hydro sources.

Flood Control

The storage of excess flood waters behind a dam or confining the river flow in between embankments are two major strategies of flood control. The amelioration of the distress from flooding and consequent increase in food production from the areas protected from ravages of floods is, by no means, a small benefit. The benefits from the Tennessee Valley development in U.S.A. are well known. A series of dams built in Damodar basin in India, has substantially controlled flooding in a basin which was earlier termed as 'the sorrow of Bengal'. The Three Gorges Project will function as the backbone in the flood control system to protect the areas in the middle and lower reaches of the Yangtze River in China. CWRC (1997) reported that the flood control capability in the Jingjiang River section, which is the most critical section, would be improved from the present 10-year to 100-year frequency flood. This will be achieved using the 22.15 billion m^3 of flood control storage capacity of the reservoir, and the threat of flooding in the Wuhan city would be mitigated. The average annual savings from flood damage alone are likely to be equal to a significant part of the project cost. The influence of the High Aswan Dam (HAD) on the economy of Egypt is well known. The stored water saved Egypt from famine in 1972-73 and again in nine successive drought years 1979-87. The lake Nasser (reservoir behind HAD) has protected the Nile valley from major floods in 1964, 1975 and 1988.

Municipal and Industrial Water Supply

A number of metropolitan cities depend on dams and canals for domestic water supplies. Sometimes water is supplied over large distances, e.g., for the city of Mumbai (from dams in Western Ghats) and Delhi (Upper Ganga Canal and Ramganga dam). Many industries, e.g., steel making, thermal power generation, petroleum refining, etc. critically depend on water. The Rihand dam provides water for several mega-thermal power plants in India. Reservoirs have been specifically constructed to meet industrial water needs, e.g., Tenughat dam in India for water needs of the Bokaro Steel plant.

Water resources projects provide a dependable source of drinking water. The very availability of drinking water leads to improvement of health and sanitation. Improved economic status due to these projects also raises the general standard of living. Improved economy generates funds and helps in creating infrastructure for health and sanitary services.

Fisheries, Flora and Fauna

Large reservoirs also provide a good site for development of fisheries. Large reservoirs in many countries have helped fisheries development by stocking them with fingerlings of sweet water fish varieties. The reservoirs are also known to have attracted aquatic birds from long distances in the migration season and may be developed as aquatic bird sanctuaries. Many wild life and bird sanctuaries around the world are by-products of river valley projects.

The reservoirs also have positive impact on climate of the nearby area. In contrast to creation of heat-islands by mega cities, large industries, or thermal power plants, reservoirs create cool-islands. Cool winds coming from the lake give a refreshing and relaxing feeling.

Recreation

Water has a central role in outdoor recreation. Large water bodies are tourist attractions and places for recreation because water-based sports, such as swimming, boating, skiing, etc., are immensely popular. Many reservoir sites are used or are being developed as recreational centeres around the world. Vrindavan Garden at Krishnaraj Sagar in Karnataka (India), is a world famous example. The High Aswan Dam and its surroundings are tourist attractions and the number of tourists per annum has increased from 80,000 in 1960 to 300,000 in 1990s (Abu-Zeid and El-Shibini, 1997). Sailing along the Nile from Cairo to Aswan in winter has become a popular sport.

Besides the above, there are many other benefits like navigation, wild life preservation, micro-climatic improvements due to water bodies, etc. The positive environmental impacts of WRD projects are summarized in Table 7.2.

Asmal (2002) presented a balanced opinion about dams by stating: "... dams are neither the problem nor the solution. They are merely one tool that society may collectively select or reject to improve their lives. ...it is safe to say that dams have delivered many benefits. It is also safe to say that in too many cases, the price paid to secure these benefits has been unacceptable and often unnecessary."

7.4 ENVIRONMENTAL IMPACTS OF RESERVOIRS

The creation of reservoirs results in far-reaching changes in the ecosystem. The major effect is on the land which is inundated and on the aquatic environment. Sedimentation, soil erosion, stratification, adverse effect on fish, and proliferation of aquatic weeds are some of the major disruptions in the ecosystem which may involve economic loss. The effects of the reservoirs on the terrestrial environment are generally felt in case of forests, wild life, ground water, climate and agriculture. Human environment is affected in respect of alterations of human settlement and occupational patterns, etc. and water borne diseases. But it will be unfair to blame dams for all the ills – they are just one of the options or tools that society may choose to solve water related problems.

An increasing constraining factor in dam construction is the conflict between the concern for environmental effects of reservoirs and the growing need to manage water resources for irrigation, electric energy demands, flood control, etc. Compared to big dams, small dams are said to be less destructive to aquatic life, and cause less damage to the general environment and other aesthetic factors. However, they can control streamflow to a limited extent. A series of small dams cost more than one big dam of equivalent capacity.

An understanding of the interrelationship between the reservoirs and natural ecosystems of the region is essential to not only preserve the existing environments but also to further improve its quality. Such goals as the improvement of natural conditions and environments are adequately achieved by the construction of multipurpose reservoirs. The long-term use of reservoirs has clearly proved that in a variety of climatic zones, the reservoirs very well harmonize with the natural environment. The environmental impact of reservoirs and remedial measures are given below.

7.4.1 Physical Impacts

Most of these impacts have been discussed in Section 7.3. A few important impacts that are specifically due to reservoirs are discussed here.

Table 7.2 Summary of positive environmental impacts of WRD projects.

Phase	Impacts on physical environment	Impacts on socio-economic environment	Impacts on biotic environment
Planning & investigation		Some reduction in un-employment. Escalation of real estate prices.	
Construction	Development of infrastructure, means of communication such as roads etc.	Higher employment and incomes. More commercial activities. More visitors to the area.	Compensatory afforestation
Operation	Conservation of water. More pleasant climate. Regulated stream flow. Generation of electric power. Improved quality of water. Reduced down-stream silting. Raising groundwater levels. Navigation facilities. Catchment area improvement. Command area development.	Higher and diversified grain and fibre production. Lesser damages due to floods. Reliable domestic and industrial water supply. Diversification of economic activities. Better health care. More avenues of recreation. Higher earnings from tourism. Poverty alleviation.	More species and quantity of aquatic life. More visits by migratory and seasonal birds. Diversity of flora.

Submergence of Land

Submergence of lands behind a reservoir cannot be avoided. Usually, the dam site is selected to keep the submergence as small as possible, subject to the project objectives, and technical requirements of the dam foundation, abutment, and the reservoir. Usually, submergence is less than 10% of the benefited area. Although no hard and fast rule can be laid down, such submergence should not be more than 20% of the extent of the benefited area, because with larger submergence, problems of resettlement and rehabilitation become intractable. It may be noted that generally the displaced population is about 2-4% of the population benefited by the project. This issue is discussed in detail later in Section 7.10.

While large dams lead to submergence of the land area, they are not a major cause of deforestation. For example, even if all the envisaged dams in the Ganga basin are constructed, the submerged area of the forest will be less than 2%. Poor people in many countries depend on wood for domestic fuel requirements. The availability of cheap electrical energy by hydroelectric projects will help in reduction of deforestation because some fuel requirements can be met by electricity. In fact, a large number of trees are cut every year to meet the needs of packaging industries, timber for building construction, furniture and transport sector, etc. Indiscriminate grazing is also harmful to the forests.

As most dams are constructed in upper reaches of a river, submergence of forests and wasteland cannot be avoided. Clearly, there is a trade-off between submergence of cultivable and forest lands, or submergence of lands at one site against another site. However, the forest cover lost on account of WRD projects is a very small part of the total forest loss in a country. In any case, to reduce this loss, the permission to cut forest is usually given with the stipulation of compensatory afforestation. Various countries have evolved different norms. In India, for example, an area equivalent to five times the area of forest likely to be affected (submerged or cut for any of the project features, such as canal) is to be afforested and maintained for five years at project costs. The project estimates should provide about 1% of the project costs for this purpose. These provisions, if properly followed, should more than compensate for the ensuing de-forestation.

The reservoir may also submerge private agricultural or non-agricultural lands; such lands are required to be acquired under the prevailing land acquisition act. Experience shows that the land acquisition usually takes time and it is not feasible to strictly apply the legal provisions to such acquisition. Many matters are better sorted through dialogue and persuasion rather by confrontation.

At times, reservoirs may submerge structures of public importance, such as temples, mosques, etc. which are owned by the community. As a rehabilitation policy, such structures are usually recreated at a somewhat improved scale of facilities at the new rehabilitation sites. The project may also submerge structures of an architectural importance or of cultural heritage. Such structures may have to be shifted block-by-block to a new safe site. At times, such submergence involves sites occupied by past civilisation (for example, Nagarjunkonda behind Nagarjunsagar reservoir in India). Of course, in some cases it may be impractical to shift the ruins and reconstruct them at safe places except at prohibitive costs. It might then be appropriate to create a museum at project costs with extensive photographic records of the past civilization. The important monuments recovered from such excavations could be exhibited so that the future generations are made familiar with the culture of the past civilisation. While constructing the High Aswan Dam, 17 temples which were considered as important monuments were shifted to higher elevations. These include Abu-Simbel, Philae, Kalabsha, and these are now attractions for tourists (Abu-Zeid and El-Shibini, 1997).

It is important to ensure that the proposed project does not submerge or affect adversely any endangered species of flora or fauna. Therefore, it is desirable that botanical and zoological survey of the submergence area is done by experts from related fields. The remedial steps, if necessary, should be initiated in the planning stage itself.

Reservoir Induced Seismicity

One important objection to large WRD projects is reservoir induced seismicity (RIS). RIS is the incidence of earthquake triggered due to impoundment of water behind a dam. Many people believe that reservoirs trigger earth tremors due to load of water. However, a reservoir, at worst, can only advance an earthquake which would have occurred otherwise too. The magnitude of forces associated with an earthquake is several orders bigger compared to the additional load of water in the reservoir. The change in stresses due to water load is too small to cause fracture in the earth's crust (Srivastava, 1993). Therefore, the presence of a reservoir does not increase the severity of an earthquake. While RIS may be associated with some of the large dams and reservoirs, there is adequate evidence to demonstrate that some of the large dams have not shown RIS (for example, Bhakra, Beas, Pong, Ramganga, and Tarbela projects which are located in the Himalayas). In some areas, earthquakes have occurred after the reservoirs were created but there is no conclusive evidence that these were caused by the reservoirs. Yet, another view is that the water seeped from the dam provides a lubricant effect and triggers small quakes. In fact, this is a positive feature as it helps in release of energy in small shots which are less damaging than a big earthquake. While there is no complete agreement on this issue, a general belief is that earthquakes are caused by the filling of reservoir at sites where natural stresses in the underlying rock mass have developed to a state close to rupture. Perhaps, reservoirs might advance the earthquake which would otherwise have occurred some time later.

Earth or rock fall dams have a better capacity to resist earthquakes than a rigid dam due to their inertia, high damping, and the ability to undergo large strains without cracking. The dam design can take care of earthquakes by choosing an appropriate type of dam and a reasonable safety factor. The designs of project elements, such as the intakes, powerhouse should provide for earthquake resistance. Modern technology has enabled designers to build safe dams in highly seismic regions in central Asia, U.S.A., Japan, etc. Many tall dams have successfully withstood large earthquakes.

Siltation

The river water deposits silt into the reservoir which, in turn, triggers a number of environmental problems. Silting may be reduced by placing outlets in the dam at such points that allow some of the silt to escape to the downstream channel. Siltation of reservoirs due to sedimentation from catchment area is incorrectly attributed as an adverse impact of WRD Projects. Increased siltation should be attributed to indiscriminate activities in the watershed areas, such as shifting cultivation, overgrazing, faulty cultivation practices, etc. Reservoir sedimentation has been discussed at length in Chapter 12.

7.4.2 Biological Impacts

Some of the major impacts in this category are as follows:

Flora and Fauna

Deforestation of the reservoir or canal submerged area and consequent displacement of wild life and population is inevitable. Adverse impacts include removal of feeding areas, some loss of habitat and limitations of movement. Area submerged in a reservoir constitutes an insignificant percentage of its catchment area and canals occupy a small part of the command area. Moreover, mature ecosystems, such as primary forests, are not much affected by the reservoir and its surroundings. However, to enhance flora and fauna, it is essential to develop national parks, game reserves, and forest reserves. Many times the data on forest loss is exaggerated. In India, of the reported 3% loss of the forest area due to river valley projects, much of it has occurred in areas which are often described as forests but do not have the required forest cover (Hasan and Goel, 2000).

Fishery

Some species of fish migrate upstream for breeding. Creation of reservoirs without fish ladders obstructs this movement. Therefore, whenever possible fish ladders should be provided. However, if the dam height is large, say more than 25-30 meters, the fish ladder becomes long and expensive. Free passage of migratory fish to and from their spawning grounds is also disturbed due to the obstruction created by the construction of dam. The change in river regime downstream of the dam may be harmful for the fish growth. LaBounty (1984) noted that the construction of Three Gorges dam on the Yangtze River would result in loss of habitat for many kinds of aquatic life, including the unique Chinese Sturgeon and there is a possibility of reducing nutrient input to the downstream and estuarine fisheries. On the benefit side, creation of reservoir provides conducive environments favoring reproduction of several fish species. If the river flows below the reservoir are higher during dry season than under natural pre-storage conditions, this creates favorable conditions for the development of fisheries in the downstream river reach.

Water-borne Diseases

Large aquatic bodies are prone to give rise to water borne diseases such as malaria, filaria and schisto somiasis. In developing countries, a significant number of children die every year due to water borne diseases. Therefore, it is extremely important that precautionary steps are taken so that these adverse impacts are minimized.

Aquatic Nuisance Plants

Proliferation of aquatic nuisance vegetation is associated with reservoirs. Concern, however, is limited to those aquatic plants which are larger than microscopic algae. Early planning and action can avoid some of the hazards posed by aquatic plants to public health, fisheries intake structures, and navigation. Of particular importance is the vegetation menace of water hyacinth or bull rush. Water hyacinth is a floating weed which has a prolific growth and in a relatively short period, it can cover large areas of water bodies like a carpet. This carpet harbors mosquitoes, depletes dissolved oxygen and affects fish life. If not checked in time, this problem can attain menacing proportions. In one instance, a hydropower plant had to be shutdown temporarily because the weeds had choked the intakes. Existence of water hyacinth could be an indicator of organic pollution of water. Removal of weeds is difficult and mechanical means have to be employed. Weeds have been used for biogas generation with some success.

Water Quality

The quality of water is an important consideration for all WRD projects as it affects all aspects of water use – for humans, animals, crops, and even industries. Construction of a project does not degrade the quality of water -- the reckless and indiscriminate use of chemical fertilizers, pesticides, and disposal without proper treatment does that. Of course, building a dam over a river deprives the downstream land of nutrients normally brought by the river in the form of silt. After the construction of a dam, riverflow is stored in the reservoir and this alters the supply of freshwater to the downstream area. There are instances where, to get the 'maximum' benefit from the reservoir, the flow in the channel downstream of the dam has been reduced to almost nil. In the areas near the river mouth, this can lead to saltwater intrusion into low-land or estuarine areas. In any case, the annual release of water from a reservoir is lower than that in the pre-construction period, because of water losses through evaporation from the reservoir and diversions. The operation policy can ensure that certain minimum flow is always released in the river.

7.4.3 Small Dams Versus Big Dams

Although this is not an environment-related issue, it is discussed here because an oft-repeated suggestion in may discussions related to the environment is that small dams are more suitable than big dams. Basically, there are three places to store water: soil profile, surface storages, and aquifers. The storage in soil profile is very important for agriculture but only small quantities of water can be stored for a short period. A comparative analysis of advantages, limitations, and key issues associated with groundwater, a small reservoir, and a large surface reservoir are given in Table 7.3.

The main argument against big reservoirs is that they submerge large areas compared to many small reservoirs. Any dam, big or small, needs a suitable site. One just cannot build a dam wherever one wants. If a major dam is to be replaced by a number of small dams, there must be a number of suitable sites on the same river. Keller et al. (2000) argued that it is very difficult to construct safe small dams. Of course, one will also have to build dams in lower reaches which will mean more submergence (often of good agricultural land) due to flat slopes and more population displacement due to higher population density.

Table 7.3 Comparative advantages, limitations, and key issues associated with groundwater, small surface reservoir, and a large surface reservoir.

	Groundwater storage	Small surface reservoirs	Large surface reservoirs
Advantages	Negligible evaporation loss Ubiquitous distribution Operational efficiency Available on demand Good water quality	Ease of operation Multiple use Groundwater recharge	Multipurpose Large, reliable yield Carryover storage Low cost per m^3 water stored Groundwater recharge
Limitations	Slow recharge rate Groundwater contamination Cost of extraction Recoverable fraction	High evaporation loss fraction Relatively high unit cost Absence of over-year storage	Complexity of operations Sedimentation High initial investment Large gestation period Requires good sites
Key Issues	Declining water levels Rising water levels Regulation of use Groundwater pollution	Sedimentation Population displacement Submergence Environmental impacts	Social and environmental impacts Rehabilitation and resettlement

Source: Adapted from Keller et al. (2000).

It is useful now to examine some real cases. Consider Britain's largest reservoir Quoich on Quoich River near Fort Augustus in the Scottish Highlands. The lake behind 38 m high earth-rockfill dam has a storage capacity of 3828 million m^3. According to Robbroeck (1996), if all British reservoirs are arranged in an ascending order of size and their volumes and surface areas aggregated, the total volume of the 327 smallest reservoirs would be needed to replace the volume of the largest, and that the total submerged area would be 6705 ha, 3.5 times the area of Quoich. A similar analysis for South Africa shows that 433 small reservoirs would be needed to replace the volume (5246 million m^3) of the Gariep reservoir, with an aggregate area 222 times larger. A comparison was also made by Shah (1993) in India between the proposed Girna dam in the Mahanadi basin in Orissa and a smaller Girna dam plus 8 satellite storages making up the same volume. In case of smaller dams, the cost would be 150% higher, 60% more land would be submerged, considerably less energy would be generated, and evaporation will be 50-60% higher.

Although social and environmental problems are probably not in direct proportion to the area submerged, it can be safely deduced that a large number of small reservoirs will be far less acceptable from that point of view. Economics would also be much worse: loss of advantage of scale, more site establishment, more spillways, and diversion and outlet works. Silt accumulation is also substantially less, as the United States Department of

Agriculture figures show: reservoirs smaller than 10 acre feet (ac-ft) silted up at an average rate of 3.5%/year, smaller than 100 ac-ft at 2.7%/year and smaller than 1000,000 ac-ft at 0.16%/year. This alone is a powerful argument against a large number of small reservoirs. A comparative study of some key characteristics of three sizes of structures is made in Table 7.4.

Table 7.4 Contrast of characteristics of the High Aswan Dam, Dharoi reservoir, and a minor tank in Sri Lanka.

Characteristic	High Aswan Dam	Dharoi reservoir	Typical minor tank in Sri Lanka
Storage capacity	168.9 km^3	1.321 km^3	4.1 ha-m
Surface area	6500 km^2	138 km^2	5.0 ha
Net irrigated area	2,648,000 ha	36827 ha	5.0 ha
Storage fraction of area times depth	0.29	NA	0.4
Annual evaporation loss	14 km^3	0.15 km^3	2.0 ha-m
Annual evaporation depth	2.7 m	2.458	1.0 m
Dam height	111 m	45.87 m	2 m
Crest length	3.830 m	1207 m	170 m
Embankment volume	44,300,000 m^3	NA	2,600 m^3
Command area	3.4 million irrigated hectares	773778 ha.	<10 ha

Adapted from Keller et al. (2000).

While dealing with hydropower projects, comparisons must look at impacts per unit of output. The impacts of a single large hydro project must be compared with the cumulative impacts of several small projects yielding the same power and level of service. The most fundamental determinant of the nature and magnitude of impacts of hydropower projects are the specific site conditions and not the scale of the project (www.hydropower.org).

Clearly, the degree of regulation and reliability that is provided by a large dam is not possible with a small tank. Small dams tend to dry up fast during droughts as the surface area is large. In such periods, major and medium projects are the mainstay of water supply. One has to consider this aspect also when planning projects in drought-prone and arid regions. To conclude, one must go for the optimal size of the project rather than getting bogged down in small vs. big controversy.

7.5 ENVIRONMENTAL PROBLEMS IN COMMAND AREAS

The adverse environmental impacts at the level of commands are essentially a human-induced problem; irrigation per se is not responsible for environmental degradation. The problems arise due to mismanagement of irrigation water and flawed policies that do little to check its injudicious use and wastage. The affected areas are, on an average, about 3-5% of the benefited areas. Moreover, the problems are not present in all commands and the affected command is not completely spoiled.

The canal water charges are kept at a very low level in many countries. Usually, neither the cost of irrigation system management nor the water productivity is a basis for deciding irrigation charges. In many countries, a strong political lobby is behind fixing irrigation charges and payment of dues and concerns, other than economic, may be the dominating factor. Mismanagement of irrigation water and defective policies are largely responsible for several environmental problems in command areas. The main problems are discussed below.

Two problems of considerable importance in surface irrigated areas are water-logging and soil salinity. The problems arise because water and chemicals are applied in excess. Also, the drainage aspects of agricultural areas has not been given due attention. In many irrigation projects, adequate drainage is not planned initially because it will jack-up the project cost. The problem surfaces only after many years of operation. These problems have spread to many fertile and irrigated lands, particularly in arid and semi-arid regions.

In some instances, seepage from canals is responsible for raising ground water table (GWT) to rather undesirable levels or for salinity and alkalinity problems in command areas. It is not possible to completely prevent seepage from canals unless the entire section is lined. However, such linings are quite expensive and their maintenance is a problem. Excess seepage from canals is due to deficiencies in design, construction or maintenance. But seepage from canals is not all that bad because it also helps recharge ground water. In many parts of the world, properly designed canals are in use for more than a century without any adverse effect.

GWT can be controlled through horizontal and vertical drainage. Horizontal drains are deep drains which take away the excess water from fields to natural drainage channels. In vertical drainage, ground water is pumped out by vertical wells (shallow or deep tubewells depending on situation) and either using this water for irrigation (with or without dilution depending on its quality) or draining it through natural surface drainages.

Degradation of soil fertility by water-logging is a common and serious impact of irrigation. Many irrigation commands suffer from water-logging to some degree. In arid regions, more irrigation water than is needed for evapotranspiration must be applied to soil to avoid accumulation of salts in the root zone. As a result, ground water is easily contaminated by fertilisers and pesticides percolating with irrigation water. This problem is more acute if groundwater is extensively used for irrigation and has a high dissolved solid content.

Lowering of Water Table

Over-exploitation of ground water is a serious problem in many parts of the world. Electric or fossil fuel powered pumps and tubewells find extensive use to exploit this vital resource. Since there is no state regulation for the use of ground water in many parts of the world, GWTs are drastically falling in intensively cropped areas as withdrawals exceed recharge. The main reasons for the excessive use of ground water are: (i) inadequate availability or absence of surface water, (ii) no disincentive to extract larger quantities of water, (iii) subsidized or flat rates of electricity to extract ground water, and (iv) low rainfall. The decline in water table results in increase in pumping cost over time. Other problems could be land subsidence, induction of rock chemicals in water, and sea water intrusion in coastal areas.

Building-up of nitrate and pesticide residues in ground water

Irrigation projects influence groundwater in various ways. Irrigation has induced the use of more fertilisers and pesticides. Fertiliser consumption has increased because it has, in conjunction with irrigation, augmented production while more pesticides are being used to control more diseases and pests. Application of more irrigation water without proper drainage leads to increase in soil salinity and alkalinity. As water evaporates, it leaves behind salt particles on the top soil layers. This damages vegetation and disturbs the ecosystem balance.

Important problems related to fertilizer vis-a-vis environmental quality are nitrate pollution of groundwater, eutrophication of lake and river water, increased emission of gaseous nitrogen, and metal toxicities. The fertilizer-related pollution is rapidly increasing in many countries. It is affecting agricultural production and deteriorating the quality of land and water. There are reports of nitrate pollution of groundwater and surface flows through saline seeps originating from feed lots or high fertilizer fields.

The agriculture sector is the major user of pesticides. The injudicious use of chemicals deteriorates land quality and contaminates water, food and environment. The spurt in the pesticide use has resulted in secondary pest outbreak. The pesticide residues in soil may create a variety of hazards. Soil micro-organisms which cause breakdown of cellulose, nitrification, turn over of organic matter, and other biological materials may be adversely affected by pesticides. Pesticides and chemicals inhibit the microbial population in soil, thereby resulting in reduced nitrogen fixation by symbiotic bacteria. There may be a serious decline in population of earthworm due to pesticide residues and this affects crop yields.

Problem of Weeds

The problem of weed infestation is common in canal irrigation projects. An adequate and reliable supply of water, sunlight, and nutrients provides optimal conditions for weed growth. Bull rush, a type of grass, grows in canals, ditches, drains, and in water logged lands. It disturbs the flow of water causing obstruction to canal flow or drainage. Manual recourse of weed removal is expensive. It is better to drain the area where these weeds grow which limits their growth.

Health Hazards

Spread of some diseases which are injurious to human health is another side effect of canal irrigation. The major water-borne diseases observed in rural areas are dysentery, cholera, malaria, and filariasis. Although huge amounts of money are spent on disease eradication and health improvement programs, the incidence of water-borne diseases shows no sign of abatement in rural areas in some developing countries. But, only a small part of it can be attributed to WRD projects.

Since the causes of human-induced environmental degradation vary from command to command, the remedial measures are also different. Basically what is needed is the judicious use of irrigation water for sustained agricultural development. Some of the ways to do this are: better on-farm management, drainage of agricultural land, conjunctive use of surface and groundwater, environmental friendly input-output pricing policy, and formation of water users association.

7.6 ENVIRONMENTAL IMPACT ASSESSMENT

The purpose of an environmental impact assessment (EIA) is to determine, before implementation, the environmental impacts of a proposed action so that unintended or undesired consequences can be reduced or eliminated. EIA is a process to identify, understand, evaluate, and predict the influence of some action of man on the environment. These influences have spatial and temporal dimensions and the comparison is made with the scenario if the action had not taken place. It has been explained in Fig. 7.2. EIA should be a part of policy analysis. It defines and assesses a proposed project's physical, biological and socio-economic effects, bringing together all aspects in a form that permits a rational decision. Negative environmental impacts are exposed, thus allowing their alleviation through the identification of possible alternative site and construction process. In many countries, EIA has been incorporated in legislation.

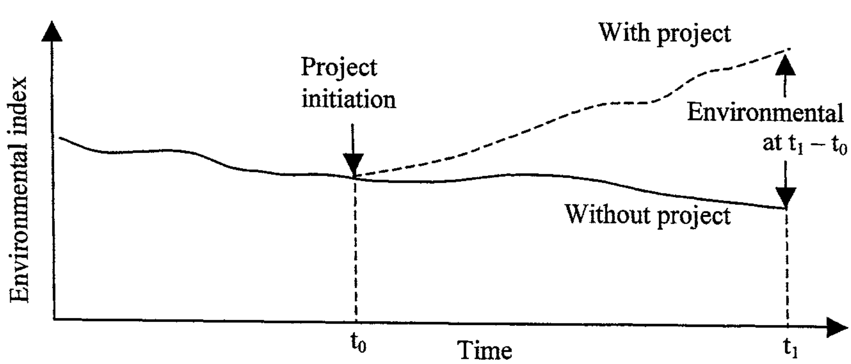

Fig. 7.2 Conceptual representation of environmental impacts.

A large investment in any sector, including water, precludes funds and resources from going to other sectors in any given economy. International funding agencies evaluate such aspects before they fund large-scale water resources projects. The impact analysis component is particularly important in the planning process. Besides environment, a water project can have an impact on many aspects of society, e.g., commerce, disposable income, consumption amount and patterns, construction activities, population distribution, and health. Therefore, every project document should be accompanied by an analysis of these so that all future project consequences (both favorable and unfavorable) can be identified, assessed, quantified (to the extent possible), and integrated in the decision-making process.

The scope of an EIA study can be very large. Rees (1981) has suggested that the following details may be included:

- a description of the nature and characteristics of the proposed development,
- a description of the existing bio-physical and socio-economic environment,
- an assessment of significant types of environmental impacts during site preparation, construction and operation,
- integration of the expected bio-physical impact with indirect socio-economic consequences and community response,
- review of the compatibility of the proposed development with approved land and water management objectives, and environmental standards and quality criteria for the area(s) likely to be impacted, and
- reasons for choosing the particular location and project specification and operation from among possible alternative, adverse impacts which cannot be avoided, and
- a summary suitable for decision makers and other interested parties.

A multi-disciplinary approach is a must to analyse the above details properly.

7.6.1 Environmental Impact Assessment Procedure

A comprehensive EIA procedure involves evaluation in two stages, viz., preliminary assessment and detailed assessment. The idea of preliminary assessment is to have an early judgment of severe or important impacts on the existing environment. The preliminary assessment is based on initially available data such as maps, reports, photographs, plans, siting & operation alternatives of the project, and feedback from projects of similar nature. By systematically relating the characteristics of the proposed development to the site chosen and its surroundings, an information matrix can be developed which will contain the characteristics of the proposed development in columns and characteristics of the site and its environs in rows. From this matrix, the critical components of the environment, which are likely to be severely affected can be identified. This identification will indicate whether there is any need for detailed impact assessment.

If no adverse impacts are confirmed or if after preliminary assessment, the problem sites are eliminated from further consideration, there is no need to carry out detailed impact assessment. If it is confirmed that certain components of the environmental system will be seriously affected, these are subjected to greater scrutiny. The impacts are then examined in more detail by using more detailed data and better models. More expert opinions are sought on the impacts in terms of their duration, reversibility, directness and cumulative and synergistic effects. Finally, a summary of the assessment is prepared which contains the details of the cost/benefits of the proposed project, an explanation of how adverse impacts can be minimized, offset or compensated for, and details of follow-up surveillance/monitoring. The summary is useful for the decision-makers and other interested parties to appreciate the environmental consequences of the proposed project and how adverse outcomes could be minimized.

While assessing the impacts of proposed development, sufficient details should be available to give a clear picture in respect of the following aspects:

- general location, specific siting on a detailed map, and project layout;
- size/magnitude of operation;
- site preparation and construction;
- transportation/communications requirement;
- possible damages due natural hazards and preventive strategy
- dangers due to hazards such as spill of poisonous chemicals, leakage of dangerous gases, fire etc., and safety set-up;
- waste treatment and disposal; and
- monitoring and surveillance systems.

Before analyzing the likely effects on the environmental system by proposed development, it is worthwhile to assess the nature and characteristics of the existing environment. For this purpose, the existing environment will need to be described in terms of its present characteristics, especially the ones which are likely to prevail for the entire duration of the proposed development. Such an evaluation may require initiation of large-scale surveys and/or long term monitoring programmes, and therefore, needs sufficient time for completion. The effects on environmental system may be evaluated by knowing the effects on various elements, e.g., physical and biological resources, socio-economic development, etc.

7.6.2 Techniques of Environmental Impact Assessment

EIA is helpful to identify the possible negative impacts of the project and the design can be appropriately modified to ensure environmental protection. Fig. 7.3 shows a flowchart of preliminary and detailed assessment procedure for WRD projects. In a technique known as the Delphi process, selected experts first individually rank the projects, say, on a 1-100 scale. Next, the statistics of these rankings are presented to the experts who are asked to come up with a new individual ranking. A rapid convergence is obtained and finally the mean of the impacts is determined. This process is repeated for all alternatives and these are ranked in order of increasing impacts. The advantages and disadvantages of this method have been described by Westman (1985). Some of the methodologies which are used in EIA studies are described in what follows.

Preliminary assessment procedure

Step 1 Identify Problems and Specify Alternatives
- State problems and requirements
- Nature and extent of each alternative

⇓

Step 2 Assemble Available Data
- Collect data relevant to each site and project construction/operation alternatives

⇓

Step 3 Assess Staff Competence
- In-house sufficiency or external assistance required ?

⇓

Step 4 Initial Impact Identification
- Review of site and construction/operation alternatives in relation to the available data on the existing environment
- Identification of impacts via an "interaction" matrix

⇓

Step 5 Preliminary Assessment
- Application of screening tests – are there any potential adverse impacts generated by the proposed project?

⇓

No. Further assessment not required. Stop

Yes ⇓

Detailed assessment procedure

Step 6 Preparation: Execution of Detailed Baseline and Project Construction/Operation Studies
- Define terms of reference for further environmental assessment tasks; appoint appropriate specialists
- Execution of detailed studies – data collection and analysis.

⇓

Step 7 Identification/confirmation of Potential Adverse Impacts
- On existing environment
- Initial consideration of appropriate constraints during construction and operational phases of the project.

⇓

Step 8 Impact Assessment
- Assessment of impacts of the project activities in terms of duration, reversibility, directness, and cumulative and synergistic effects.

⇓

Step 9 Summarise and Present Findings
- Summary sheet
- Provisions for follow-up surveillance and monitoring.

Fig. 7.3 Flowchart of preliminary and detailed assessment of a WRD project.

Ad-hoc Method

This technique of EIA is quantitative by nature and gives information in comparative statements for different development alternatives of a WRD project. The method is simple and can be easily understood by decision makers as well as laymen. It is not based on expert opinion and can be completed quite fast. In this method, the area and nature of the expected impacts are identified. A team of technical experts representing related disciplines arrives on a consensus in qualitative terms. The ad-hoc method is not much preferred as the results are subjective and lack consistency. Its use is discouraged these days.

Example 7.1: Four alternate sites are available for a project. Determine environmental impacts of these using the ad-hoc method.

Solution: The quantitative and qualitative assessment of the consequences of the alternate project sites is given in Table 7.5.

Table 7.5 An example of Ad-hoc method.

S N	Item	Alternative sites			
		A	B	C	D
1	Submerged area (Ha)	10000	3000	5000	8000
2	Irrigation potential (Ha)	50000	10000	20000	5000
3	Power generation (MW)	11000	10000	7000	3000
4	Soil erosion	severe	mild	mild	insignificant
5	Displacement (number of people)	25000	15000	10000	5000
6	Weed growth	Yes	No	Yes	No
7	Fish culture	No	Yes	Yes	Yes
8	Water quality impacts	Yes	Yes	No	No

Environmental Indices

An index is a quantified representation of a specific element, in this case an environmental consequence. The quantification can be made by assigning a numerical value or a simple 'yes' or 'no'. Depending on the project, a certain number of indices must be incorporated into the impact study. The indices can be subdivided as:

a. Resources indices: These types of indices show the change of the potential of the system or its subsystem.
b. Ecological indices: These types of indices show the change of abiotic and biotic environmental component.
c. Socio-economic indices & cultural indices: These types of indices show the changes toward the improvement of living conditions.

Example 7.2: This example of application of the environmental indices method is based on Sahu (1992). The task is to evaluate the impact of some components of the Narmada Sagar project in India.

Solution: The Table 7.6 gives evaluation of environmental impacts in the catchment, reservoir, and at the dam site by following the environmental indices method.

Table 7.6 EIA of some components of Narmada Sagar Project.

SN	Item	Impact	
A. Catchment Area		-ve	+ve
1.	Change in the erosion and deposition pattern	-1	
2.	Some loss of forest cover and grasses due to fuel needs and grazing cattle	-2	
	Total	-3	+0
B. Reservoir Area			
1.	Scenic spots, archaeological sites, temples ruins	-1	
2.	Mines of semi-precious materials, rocks, boulders, sand would be submerged	-2	
3.	Flora will be affected	-1	
4.	Wild life will be affected	-2	
5.	Sedimentation in reservoir would occur, causing subsidence of late bottom	-2	
6.	Lake eutrofication	-1	
7.	Water quality degradation	-1	
8.	Weeds development in lakes	-1	
9.	Rehabilitation & resettlement of displaced persons	-8	
10.	Hazards due to water infestation to human and cattle health	-1	
11.	Railway and highway dislocation and recounting	-3	
12.	Fishery development in lakes		+7
13.	Recreation and tourist resorts		+4
14.	Fore-shore bed will be available for cultivation		+2
15.	Micro-climatic improvement due to low temperature		+3
	Total	-23	+16
C. Dam site and Related Area			
1.	Communication facility over bridge on spillway		+4
2.	Ornamental garden on top of dam, toe of the dam on downstream side		+2
3.	Flood control benefits to area situated on river banks of towns and villages		+3
4.	Seepage from dam may produce beneficial effects		+1
5.	Fish mortality down stream of the spillway	-1	
6.	Seismic activity may trigger due to impoundment of water in the lake	-1	
7.	Township and community development in the area		+7
8.	Rise of water table in wells thereby reducing pumping lifts		+4
	Total	-2	+21

The environment indices are described in detail in Section 7.6.3. The use of such indices can be seen in the ad-hoc method explained earlier. Proper identification, selection and classification of environmental indices are essential for a successful impact assessment study. Most EIA studies contain a list of indices ranging between 50 to 200 with the majority having 50 to 100 indices. The number of indices used in a particular study depends on the quantity and quality of data available. While developing or identifying indices for a new WRD project, the baseline data and the data of an existing project in the vicinity is very useful. The ad-hoc method and indices methods have many common features.

Matrix Assessment Method

ICOLD (1982) developed a matrix method to analyse environmental impact of dams. This method is based on the action-response relations that are expressed using a matrix. The matrix of environmental variables and project activities identifies a cause-effect relationship between specific activities of the project and environmental impacts. During analysis, a matrix is constructed in terms of actions causing impacts (rows) and effects (columns). Expected impacts are incorporated and quantified in this matrix. Note that sometimes, the construction effects may prove to be more damaging than the operational effects. Such a procedure helps in identification of activities which need more attention and scrutiny. Note that there are different methods to compute the total in the table. Table 7.7 gives an example of the matrix method. Whenever a detailed appraisal of certain aspects included in the initial matrix is needed, an expanded matrix is developed (Pendse, 1987).

Table 7.7 Illustrative example of Matrix Method of EIA.

Priority values	Proposed action → Impact on ↓	Dam construction	Reservoir filling	Relocation of population	Toxic discharge	Total
10	Health	3 5	4 6		5 7	12 18
9	Forestry	4 4	6 7			10 11
5	Archaeological sites	2 5	4 7			6 12
3	Tourism		7 6			7 6
4	Fishery	2 6			4 7	6 13
7	Social life	2 4		9 8		11 32
6	Navigation		5 5			5 5
8	Downstream water quality		6 7		7 8	13 15
Total		13 24	32 38	9 8	16 22	

Legend: First number in a cell – magnitude of likely impact, Second number – importance of likely impact.

Example 7.3: The Tallahala development is a water impoundment project on the Tallahala river, southern Mississippi, constructed to provide water supply, flood control, and water quality control. An earthfill dam will create an artificial lake of 80.76 million m^3 of storage for flood control, 80.76 million m^3 of storage for water supply, 16 million m^3 of storage for water quality regulation, 7.2 million m^3 and for sedimentation. The lake will have 64 km shoreline with a maximum length and width of 9.6 and 3.2 km, respectively, at normal water levels. Total lands required for satisfactory implementation of the project is 62.82 sq. km.

The area to be affected by the project is a low-population, low-income area. The major urban zones are the cities of Laurel (24,000 inhabitants), Bay Springs and Heidelburg, which are showing declining population. Recreation activities are limited in the area. The water quality of the Tallahala River is acceptable north of Laurel, but dramatically polluted downstream of Laurel, where one major industrial installation produces an average loading of about 2,600 lb/day of BOD. Two to three times a year, the land experiences extensive flooding on both urban and agricultural areas with negative impact on the economy. Due to environmental conditions, mosquitoes are a problem, and malaria is still a concern. About 70 % of the land in the Tallahala drainage basin is devoted to agriculture and 30 % is woodland. About 80 % of the agricultural land is utilized for cotton and 20 % for pasture. Woodland areas consist of more than 40 wood plant species. Principal wildlife present in the project area comprises deer, wild turkey, squirrel, rabbit, and quail. Habitat is available within the basin for either rare or endangered species. Historical or archeological sites have not been documented.

Solution: Based on the interaction matrix system developed by the ICOLD, the impact assessment is presented in Table 7.8. Positive impacts are denoted by (+), while negative by (-). Explanation of the ICOLD matrix system symbols is provided in Table 7.9. From Table 7.8, it is evident that most of the actions will have beneficial effects on the economy of the area. Health and ecology will be subjected to gains and losses so that a detailed quantitative analysis should be conducted. Deforestation and possible industrialization have the most detrimental impacts.

Checklist Method

This is a quantitative method which facilitates rapid assessment of the impacts on the environment. Checklist methodologies range from simple listing of environmental elements to sophisticated techniques where a weighing factor is assigned to each element according to its importance, and then scaling techniques evaluate the impact from each alternate solution. A large number of checklists have been formulated. Canter (1981) developed a checklist of factors related to environmental quality. The checklists can be of different types: Simple checklist, descriptive checklist, scaling checklist, or weighing checklist.

An example of the simple checklist method is given in Table 7.10.

Table 7.8 ICOLD interaction matrix for Tallahala River dam (For symbols, see Table 7.9)

Effects	Actions											
	101	103	104	105	106	108	201	202	207	302	303	305
101				+								
102	+			+	+							
103		+	+		+	+		+				
104	+									+		
105		+	+		+			+				
106	+											
107			±	±								
108	+	+	+	+	+		±		-	+	-	
109					+	+		+		+		
112		+										
113			+							+		
115			+									
116		+		-		+					-	
202	-		+						-			
203	-		+						-			
205	-								-			
206									-			
302	-			-	-							
501									-	+		
502	+									+		
504	+		+							+		
505				-								
507				-			+					-
508				-					-			
601				-					-	+		
602				-					-	+		
603				-					-	+		
604			-	-		+						-
605				-		+						-
606				-								-
607				-			+					-
608				-		+						
609				-								

Table 7.9 ICOLD matrix system: explanation of symbols.

Actions	
A 101: Irrigation	A 201: Presence of the Dam
A 103: Potable Water	A 202: Reservoir
A 104: River Control	A 207: Deforestation
A 105: Industrial Use	A 302: Reservoir Shores
A 106: Navigation	A 303: Fluctuation Zone
A 108: Fishing	A 305: Down River of Reservoir

Effects	
E 101: Industrialization	E 302: Physics and Chemistry
E 102: Employment	E 501: Forest
E 103: Tourism	E 502: Pasture
E 104: Agriculture and Livestock	E 504: Cultivation Land
E 105: Communication	E 505: Superior Plants
E 106: Commerce or Trade	E 507: Phytoplankton
E 107: Relocation and Land Value	E 508: Rare and Threatened Species
E 108: Social Acceptance	E 601: Mammiferous
E 109: Recreation	E 602: Birds
E 112: Domestic Water Supply	E 603: Insects
E 113: Purchase of Land	E 604: Economic Fish Species
E 115: Protection Against Natural Hazards	E 605: Other Species
E 116: Health	E 606: Macroinvertebrate
E 202: Erosion	E 607: Microorganism
E 203: Material in Suspension	E 608: Zooplankton
E 205: Sedimentation	E 609: Rare and Threatened Species
E 206: Stability	

Table 7.10 Checklist method of EIA.

Item	Likely impacts					
		Beneficial			Harmful	
	Short-term/ Long-term	Reversible/ Irreversible	Local/ Widespread	Short-term/ Long-term	Significant / Normal	Local / Wide
1. Atmospheric						
a. Air pollution						
b. Climate						
c. Temperature						
2. Land use						
a. Forests						
b. Grazing						
c. Residential						
d. Industrial						
e. Agriculture						
3. Water						
a. Lakes						
b. Rivers						

A simple example of a weighting checklist is the water quality index (WQI) developed by National Sanitation Foundation of U.S.A. WQI is the aggregated result of nine environmental factors and is computed by

$$WQI = \prod_{i=1}^{9} I_i^{W_i} \tag{7.1}$$

where I_i is the subindex value of environmental factors and w_i is the assigned weighting importance. The nine factors and their weights are given in Table 7.11.The subindex value depends on the measured value of the factor through functional relationship. WQI ranges between 1 and 100, and classifies the system accordingly as: 0-25, very bad; 26-50, bad; 51-70, medium; 71-90, good; 91-100, excellent. Canter (1981) provides a thorough discussion of checklist methods.

Example 7.4: River Iskar is 368 km long, it springs from Rila mountain in southwestern Bulgaria and it flows north where it joins the Danube River. The river is a recipient of industrial and domestic wastes (purified and unpurified) from many factories and urban areas. As a result of this pollution, detrimental environmental effects have been documented. In order to assess the impact of river water quality on the-environment, a number of data were collected from three river sites. These data were dissolved oxygen, biological-oxygen demand, oxydizability, dissolved and undissolved substances, NH_4, Fe, Mn, and phenols (Ivanov, 1984). Assessment of environmental detriment was done according to losses in fish economy, recreation, irrigation, inert material yield and flora in flooded areas. Compute the water quality index using the method developed by the National Sanitation Foundation of U.S.A.

Solution: For application of the NSF water quality index method, five additional water quality factors should be provided. These factors are fecial coliforms, pH, phosphates, turbidity and temperature. Since no information was available, it is assumed that these factors are of minor importance and therefore moderate values can be assigned for the study. In Table 7.11, the water quality index is estimated for the three river sites. At site one, the water quality is bad and polluted, while at sites two and three the water quality is good and acceptable. From the same table, it is evident that bad water quality causes an alarming rate of environmental deterioration.

Network Method

The environmental components interact with human elements and hence are very complicated and complex. These represent the impact causes and consequences through an integrated network system. The network is generally shown as a tree, sometimes known as 'impact tree'. To arrive at the tree structure, one has to answer a series of questions related to each of the project activity, such as primary impact area, secondary impact area, etc. The main limitation of the network approach is that this provides inadequate information on the technological treatment of the problem. An example of this method is given in Table 7.12. It is nothing but a way to present factual information. But the network can become very complex for a real-life problem.

Overlay Method

In this procedure, environmental impacts are assessed by using cartographic techniques. The project area is depicted by physical, social, and ecological characteristics of the

Table 7.11 Water quality index and environmental impact of Iskar River, Bulgaria.

Water quality factors	Weight w_i	Site I			Site II			Site III		
		Measured quantity	$I_i^{(+)}$	$I_i^{w_i}$	Measured quantity	$I_i^{(+)}$	$I_i^{w_i}$	Measured quantity	$I_i^{(+)}$	$I_i^{w_i}$
DO (%)	0.17	1	2	1.125	104	98	2.180	101	99	2.184
BOD (mg/l)	0.10	48	2	1.072	8	35	1.427	4	60	1.506
Suspended solids (mg/l)	0.08	580	20	1.271	420	45	1.356	500	35	1.329
Nitrates (mg/l)	0.10	2.40	88	1.565	0.70	98	1.582	0.05	99	1.583
Fecal Coliforms (N/100ml)	0.15	2*	90	1.964	2*	90	1.964	2*	90	1.964
pH	0.12	7*	90	1.716	7*	90	1.716	7*	90	1.716
Phosphate (mg/l)	0.10	0.3*	80	1.550	0.3*	80	1.550	0.3*	80	1.550
Turbidity (Jtu)	0.08	5*	90	1.433	5*	90	1.433	5*	90	1.433
Temperature variation °C	0.10	2*	83	1.556	2*	83	1.556	2*	83	1.556
Remarks		Bad		27.942	Good		77.131	Good		80.6
Loss in % per year										
Fish economy		12.9			0			0		
Recreation		32.2			0			0		
Irrigation		6.5			0			0		
Inert material yield		41.9			0			0		
Flora in flooded areas		6.5			0			0		

Note: * denotes assumed values; + the subindex value was estimated from Ott (1978).

Table 7.12 Network method of EIA.

Specific activity	Create a reservoir			
Basic affected resources	Land			Water
Change in land use	Decrease in forest area	Increase in built-up area	Decrease in stream length	Increase in lake area
Physical effects	Faster flow velocities. Higher erosion.	Reduced infiltration.	Change in flow regime.	Change in evaporation. Change in ground water regime. Sedimentation.
Biological effects	Higher crop production. Loss of bio-diversity.	Less bio-mass production. Loss of bio-diversity.		More fish production. More aquatic plants.
Social impacts	Decrease in tranquility.	Higher population density. More conflicts.		More recreational opportunities
Importance of terminal effects	High	Medium	Low	High

environment. Maps are superimposed on each other to assess the environmental characteristics within the project boundary. The method draws its strength from graphical display of types of impacts, the extent of these and the geographical area affected. This method is useful for selecting a site among various alternatives. The base map of the project is prepared on a transparency and the existing environmental features and their boundaries are marked. The severity of impacts can be depicted using colour codes. Various transparencies for different impacts give an overall picture of the degree, severity and extent of the impacts. Fig. 7.4 illustrates the method with a simple example.

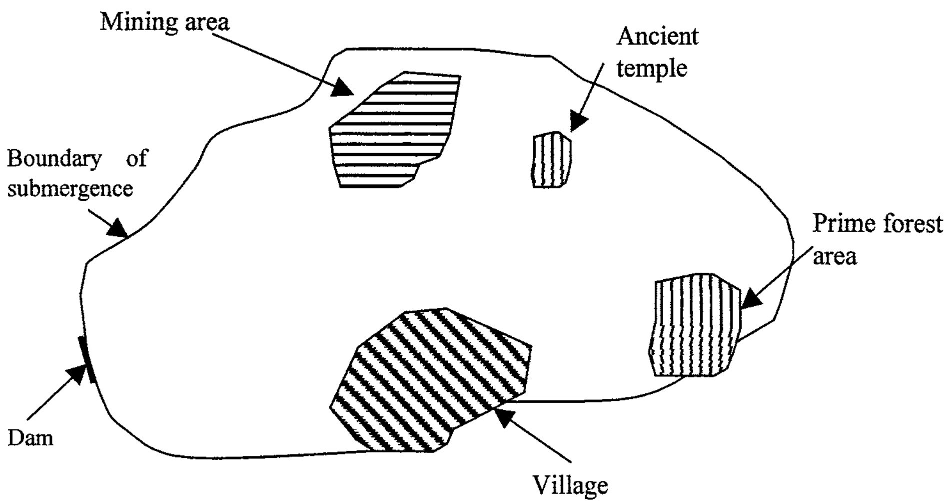

Fig. 7.4 Illustration of overlay method of EIA.

The availability of powerful GIS packages has considerably improved the ease and effectiveness of this method. CBIP (1995) contains a number of environmental impact assessment case studies.

7.6.3 Indices for Environmental Impact Assessment

An index is a means devised to reduce a large quantity of data down to its simplest form, retaining essential features to answer the questions that are being asked. In short, an index is designed to simplify. In the process of simplification, of course, some information is lost. But if the index is designed properly, the lost information will not seriously distort the interpretation. Indices are also defined as the quantified limits for indicators. Quantification in this context means, but is not restricted to, a certain amount or concentration which can be the uppermost or the lowest value permitted. Hence, a 'yes' or 'no' answer would also fall under this quantification. Indices are intended to be protective measures for man or for man's direct sources for food and water. The indices have been developed for the short-term protection of nature. In terms of near future, limits have to be set as to the degree to which the existing nature should be protected. But as nature is a composite whole, standards have to be found for selected indicators, thus defining and transforming the selected indicators into indices.

Indices of environmental impacts are a means to quantify and evaluate the quality of environment with regard to some particular element. Environmental monitoring data consist of routine measurements of physical, chemical, and biological variables that are intended to give insight into environmental conditions. These data often provide an important yardstick to judge the effectiveness of regulatory programs in improving environmental quality. From a purely conceptual point of view, environmental monitoring data serve as a feedback loop to evaluate the effectiveness of regulatory activities. Once the requisite data are collected, there is a further need to translate these into a form that is easily understood. After the indices are developed, they should serve as 'indicators' to examine trends, to highlight specific environmental conditions, and to help governmental decision-makers in evaluating the effectiveness of regulatory programs. Of course, indices are not the only source of information that forms the basis of decisions. Decision-making is based on many other considerations besides indices and monitoring data.

Six basic uses of environmental indices are:

a) Resource allocation - Indices may be applied to environmental decisions to assist managers in allocating funds and determining priorities.
b) Ranking of allocations - Indices may be applied to assist in comparing environmental conditions at different locations or geographical areas.
c) Enforcement of standards - Indices may be applied to specific locations to determine the extent to which legislative standards and existing criteria are being met.
d) Trend analysis - to determine the changes in environmental quality.
e) Public information - to inform the public about environmental conditions.
f) Scientific research - Indices are a means to reduce a large quantity of data to a form that gives insights to the environmental phenomenon and help in scientific research.

In each of these applications, an index helps in conveying information about the nature and state of the environmental process. Because the questions being asked are different in each application, the index may differ in terms of the variables included, the basic structure, and the manner in which it is applied. Since different users have different data-reporting needs, identification of the users should be a critical part of the development and application of environmental indices. Some of the indices are discussed as below (see Unesco, 1984).

Resource Indices

The potential use of a system or a component within a system may be referred to as a resource and the index showing the status of resource's potential as it is developed is known as resource index. This index regulates the human health requirements by setting limits to usable potential of the resource or its components. These resources may include potable and industrial water supply, food production resources, energy creation resources, mineral resources and resources for recreation.

Indices for resources for water supply may cover hydrological and quality properties. The indices would depend on the source of water such as surface and underground, the amount available from each source with its variations, and the amount and quality of water returned after use. The indices for food supply sources may depend on the type of seeds, fertilizers, pesticides, soil, climate, quantity and quality of irrigation water, and water management practices. Water is also used to generate energy, the quantum depending on the volume and head of water. The relevant index will depend on these factors as well as their natural variation.

Ecological indices

A basic understanding of the ecological system is needed to identify indicators which are significant for protecting the ecological system. Based on the experience gained in protecting the sub-systems, such as rivers, lakes, and wetlands, limits have been set for import of organic and inorganic pollutants as well as for plant nutrients. These indices are being evolved. Unesco (1984) has suggested the following ways to develop the indices:

Changes of abiotic components

The hydrological components to be used could be percentage of surface runoff, percentage of ground water supply, evaporation over the course of the year, etc. The climate component to be used could be change of velocity and direction, and change of mean temperature over the years. The physical components to be used could be the change of flow, change of temperature, stratification, etc. The chemical components to be used could be the quality of water:

Changes of biotic components

The pattern of natural and cultivated land or water bodies, diversity and variety of species, food web chain, metabolism of the system, vulnerability to eco-system, toxic effects of components in the system, probity and tropic status are some of the biotic components. As all man-made changes and human actions induce stress on an ecosystem, the total amount of energy import could be used as a general index.

Other Indices

All man-made and man-induced changes have to be measured and quantified with respect to social, economical, cultural or a combination of one or more of these goals. However, the time frame is of great importance in such goal setting. The benefits should pass on to the future generations rather than limiting to the present generations.

7.6.4 Current EIA Procedures

The assessment of environmental impact became a necessary requirement in many countries from the 1970's onwards. However, the practices of EIA have not undergone major improvement during the past 30 years or so. The only change has been that more parameters and data are now being analysed with wider availability of computers. According to Biswas (1998), there are at least three fundamental problems with the current EIA techniques:

1. The linkages between environmental assessment and the socio-economic aspects of water development at the policy level are not clear. Even when attempts to link have been made, the linkages were, at best, descriptive.
2. Although some progress has been made in the application of EIA at the project level, commensurate progress at policy and program level has been missing. The usable EIA techniques for water resources are still in their early stages and much progress is needed before water policy and programs can be analysed and made environmentally sound before implementation.
3. EIA studies have followed more or less the same philosophy irrespective of the location of the application area. The studies have concentrated on what is not environmentally sound WRD than what it is. In this way, the attention has been focussed only on one part of the problem. A holistic approach to the issue should be to identify the factors which contribute to sustainable development of water resources.

Biswas (1998) cites the example of High Aswan Dam of Egypt to highlight the political and ideological factors behind the negative publicity of this dam in respect of environmental impacts. This dam was completed in 1968 and this was the period when the environmental movement was initiated. After the United States withdrew from this project, it was completed with the technical and financial support from the Soviet Union. This project was technically and economically sound and, therefore, it was possible to criticize it only on environmental grounds in the era of cold war. Although no scientific evidences were available, a series of articles in the popular media at that time caught the imagination of public in the west. Many myths surrounding the High Aswan Dam have been repeated so many times that these have come to be accepted as facts though, according to him, this is a remarkably successful dam without which, Egypt would have been in dire economic straits. Since not building the dam would have been a catastrophic decision for Egypt, the issue should have been what steps should have been taken to maximize the positive environmental impacts and reduce the negative ones.

7.7 INTEGRATION OF ENVIRONMENTAL ASPECTS IN WATER RESOURCES PLANNING

For a long time, environmental issues were given a minor importance in WRD and operation. This perspective has completely changed in recent times, mostly based on the results of the studies carried out all over the world which have demonstrated, beyond doubt, that environmental impacts of major WRD projects are significant. Without rallying to extreme views advanced by some environmentalists that any change in natural environment is detrimental, a balanced approach is that such impacts have to be adequately assessed for each project so as to enable their incorporation as integral part in the planning process. The ultimate goal of WRD is to ensure that water of acceptable quality is available in sufficient quantity at the right location, at the right time, at the right price, on a reliable basis. Another developmental goal could be the protection against excess water, i.e., flood management and control. Because of the uncertainties inherently associated with all phases of water resources management, all this can be achieved only within some limits of assurance, reliability, and cost.

It is necessary that multipurpose WRD projects should take into account, right at the planning stage, appropriate steps for protection, preservation, and development of the environment. Environmentally sound water management implies that:

a) development be controlled so as to ensure that the resource itself is maintained and that adverse effects on other resources are considered and where possible, ameliorated;
b) options for future development are not foreclosed; and
c) efficiency in water use and in the use of capital are key criteria in strategy selection.

The beneficial and harmful aspects of WRD projects have been discussed earlier. Learning from the results of case studies of existing projects, the planners are now better aware of the lacuna in the previous planning approaches. Such studies have brought out the consequences of unbalanced development which were earlier difficult to foresee. Many of the environmental studies that have been carried out assess environmental impacts through indicators. However, most models that have been developed for EIA concentrate on limited aspects, such as water pollution, and not on overall river basin development.

There is a significant difference in the socio-economic conditions, availability and usage of resources, and technology in the developing and developed countries. The priorities that developing countries set for their own environment will not necessarily be those that people in richer countries might want to adopt. Thus, although some cultures in poor countries may value their natural heritage strongly, most developing country governments are likely to give lower priority to amenity damage as long as basic human needs remain unmet (Herchy, 1998). Consequently, the approach and the methodology of environmental studies differ from country to country. An automatic transposition of methodologies from one place to the other is likely to produce unrealistic results. Generally, studies try to assess the environmental impacts through selected commensurate units, termed environmental impact units (EIU). Differences in the EIU scores describe the condition of environmental factors with and without the project.

There are many constraints that limit the potential application of available knowledge by water professionals and decision-makers for reducing environmental disruptions to a minimum. The methodologies are still being developed and the baseline data are usually not available. The framework currently used to consider various environmental impacts is overwhelmingly biased towards assessing only the negative impacts. Realistically, any reasonable water development project will have discernible positive impacts, among others, on environment in varying degrees. Thus, while considering impacts, one should not ignore positive benefits, which are the real motivation for development projects. Technology developments aim to achieve balanced environmental development. On one hand, more water, food and other commodities have to be supplied to each person in an ever-expanding population. On the other hand, the area of cultivable land is reducing and water is becoming scarcer each day. This necessitates a need for striking a balance between the environment and development.

Water resource planning calls for consideration of possible impacts on the environment, both beneficial and adverse. Water resource planners assess, quantify and present them to the decision-maker who chooses an appropriate plan from the various competing alternatives. Any policy in isolation does not help in preventing the deterioration of environmental quality. A blend of technical, economic, social, and political aspects should form a part of developmental strategy to achieve the twin objectives of increasing production and improving environment.

7.7.1 Optimization Methods

It is required that the adverse environmental impacts from the development are minimized while the optimum level of development is achieved. This can be accomplished through the use of optimization techniques, such as multi-objective or goal programming. Suppose there are two objectives: minimization of the total cost (TC) and minimization of population displaced (P). If C is a vector of reservoir capacities, the problem can be stated as:

$$\text{Min } z = f[TC(C), P(C)] \qquad (7.2)$$

subject to usual constraints. The techniques to solve an optimization problem have been described in Chapter 5.

The optimized matrix approach can be useful in cases where the number of objectives is large. This approach is based on search techniques and can provide a set of feasible non-inferior alternatives in matrix form. The set of solutions, while satisfying the upper bounds fixed on cost, and impact, provides optimal plans for both impact and cost. The problem formulation is as follows:

Minimize (cost, environmental impacts, population displacement) (7.3)

subject to

$$C(Y_k) \le C \quad k=1,2...n \quad \text{(cost constraint)} \qquad (7.4)$$
$$P(Y_k) \le P \quad k=1,2...n \quad \text{(population displacement constraint)} \qquad (7.5)$$
$$A(Y_k) \le A \quad k=1,2...n \quad \text{(area submergence constraint)} \qquad (7.6)$$
$$F(Y_k) \le F \quad k=1,2...n \quad \text{(forest submergence constraint)} \qquad (7.7)$$

where Y_k is the yield of k^{th} reservoir; and P, C, A, and F are the upper limits fixed on population, cost, area of submergence, and forest submergence, respectively.

The matrix approach works out the total cost and the total magnitude of each type of impact for each combination. If any of the upper bounds is violated, the combination is rejected, thus leaving only the feasible alternatives for consideration in the next step. The feasible alternatives are compared with each other to locate the inferior alternatives. The model provides a set or feasible non-interior plans. These alternatives include the minimum-cost and minimum-impact plans and help in detailed trade-off studies between cost and impact and between various impacts.

7.8 ENVIRONMENTAL CONSIDERATIONS IN RESERVOIR PLANNING AND OPERATION

Water resources projects influence and transform the environment to a degree and over a range that varies from project to project. In addition to the classical criteria of technical, economic, and financial feasibility, dam projects have to satisfy a fourth and particularly stringent criterion, namely social and political acceptance. An important factor for such an acceptance is compatibility with the environment. The solution is to be found by striking a balance between divergent, and sometimes contradictory, goals.

Dams are essential because of the benefits which their reservoirs offer all over the world, by storing water in times of surplus and dispensing it in times of scarcity. Dams prevent or mitigate devastating floods and catastrophic droughts. Thus, dams are an integral part of engineered infrastructure. Still more dams will be needed in the future for the adequate management of the world's limited, unevenly distributed and in many places, acutely scarce water resources. Simultaneously, there is a need to protect and improve natural environment as the supporter of all life. Then, there is the social side to the comprehensive concept of the environment: the people, their land and settlements, their economy, and traditions. The impact of dams and reservoirs on this environment is inevitable and undeniable; land is flooded, people are resettled, the continuity of aquatic life along a river is interrupted, and its runoff modified and often reduced by diversions.

Thus, dam engineers find themselves confronted with the basic problems inherent in the transformation of the natural world into a human environment. In their never ending quest to provide a growing number of people with a better life, the need to develop natural resources, including water, means that the natural environment cannot be kept completely unchanged. But great care must be taken to protect the environment from all avoidable harm or interference. We must cooperate with nature's inherent fragility, its dynamism without overtaxing its powers of regeneration, and its ability to adapt to a new equilibrium that is beneficial. Importantly, all this is to be attained while ensuring that the people directly affected by a project are better off than before.

The contribution of dam engineers to the development of water resources is based on proven technology which is testified by over 39,000 large dams. This technology continues to benefit from ongoing refinement and a steady growth of knowledge and experience, in particular with regard to its social and environmental consequences.

7.8.1 Guidelines of ICOLD

The International Commission on Large Dams (ICOLD), a premier international organization, has attached great importance to the environmental and social aspects of dams and reservoirs. It has emphasized that these aspects should be addressed with the same concern which has made the question of dam safety a predominant concept. With the aim at balancing the need for the development of water resources with the conservation of the environment in a way which will not compromise future generations and to enhance the awareness of the environmental issues of dam engineering, ICOLD (1998) has brought out a *Position Paper on Dams and Environment* (available at its website). This paper emphasizes the following aspects of environmental policy:

a) Concern for the environment, including both natural conditions and social aspects, must be manifest from the first planning steps, throughout all phases of design and implementation, and during the entire operating life of a project. Dam promoters must be aware of the fact that although dams are the most important means of making surface water available at the place and time of demand, there are also other, non-structural means of increasing water utilization which can be applied in addition to dams or as an alternative, such as the tapping and recharging of groundwater or desalination of seawater.

b) In the past it has been the hallmark of our very best engineers to see the natural environment as one of their responsibilities too, which is why many dams and reservoirs harmonize so well with their environment. Today, however, the enormous increase in human knowledge, including that in the field of environmental science, means that a whole team of specialists is needed to access and utilize that knowledge for a WRD project.

c) The larger the project, the greater the effects on the natural and social environment to be expected, and the wider the scope of the multidisciplinary, holistic studies which they require. Large-scale development demands integrated planning for an entire river basin before the implementation of the first individual project(s). Where a river basin is a part of more than one country, such planning presupposes international cooperation.

d) Projects must be judged everywhere and without exception by the state-of-the-art of the technologies involved and by current standards of environmental care. The scope for reducing any detrimental impacts on the environment through alternative solutions, project modifications in response to particular needs, or mitigating measures should be thoroughly investigated, evaluated and implemented.

e) The decision on what is usually a very considerable investment for a dam project must be based on an unequivocally realistic economic analysis, especially in the case of a large project in a developing country which would tie down a major share of its financial resources for many years. Any tendency to overstate the benefits and understate the costs must be strictly avoided. This also requires taking the impacts on the natural and social environment into account. In spite of proposals put forward by international financing institutions and a growing literature on the subject, some such impacts are difficult to quantify or express in monetary terms. In such cases, they must be incorporated in the decision making process at a higher level of judgment.

An important item on the benefit side is the useful life of the reservoir. The available live storage volume must be estimated according to reliable data on the transportation of solids according to realistic assumptions on reservoir sedimentation.

f) Involuntary resettlement must be handled with special care, managerial skill and political concern based on comprehensive social research, and sound planning for implementation. The associated costs must be included in the comparative economic analyses of alternative projects, but should be managed independently to make sure that the affected population will be properly compensated. For the population involved, resettlement must result in a clear improvement of their living standard, because the people directly affected by a project should always be the first to benefit instead of suffering for the benefit of others. Special care must be given to vulnerable ethnic groups.

g) Even if there is no resettlement problem, the impact of WRD projects on local people can be considerable during both construction and operation. All such projects have to be planned, implemented and operated with the clear consent of the public concerned. Hence, the organization of the overall decision-making process, incorporating the technical design as a sub-process, should involve all relevant interest groups from the initial stages of project conceptualization, even if existing legislation does not (yet) demand it.

h) A complete post-construction audit of an entire project or at least a performance analysis of major impacts should be carried out in order to determine the extent to which the environmental objectives of the project or of certain mitigating measures are being achieved.

i) As soon as a project becomes operational, its impact on the environment should be assessed at regular intervals, based on data and sources resulting from adequate pre-construction monitoring. Depending on the individual situation, certain critical parameters should be monitored as a basis for a subsequent performance analysis of the project.

j) There is also a need for more ecological research on dams and reservoirs which have already seen many years of service. Mistakes and shortcomings could be avoided, many of the recurring controversies relating to the ecological impacts of new dam projects could be prevented and the problems involved could be clarified and solved more easily, if our latent store of long-term experience with the operation of so many dams and reservoirs were to be collected, processed, evaluated and published in the framework of research projects based on carefully directed investigations.

7.8.2 Guidelines for Planning

The following is a list of do's and don'ts for those who are involved in planning and development of water resources projects. These steps can go a long way in overcoming and controlling the resistance and hatred towards the projects.

1. Before taking up a project, the promoters should look at other means of meeting the objectives, such as demand management, minimization of wastage, more effective use of exiting developed resources, combating of pollution, recycling and improved irrigation practices. This is also necessary to pre-empt the accusations by the opponents.
2. The final plan of any project should contain a realistic and credible balance sheet setting out the direct and indirect costs and the direct and indirect benefits. Environmental and social costs and benefits must be established by experts in their field and be given their due weight.

3. The balance sheet must clearly reflect the cost and benefits of the various uses that the water will be put to. An engineering department alone cannot prepare such a compilation. A multi-disciplinary team of engineers, geologists, economists, agronomists, biologists, botanists, sociologists, etc. is needed.
4. It is evident that a WRD project cannot be evaluated in isolation. The alternative uses of the resources required for the project should always be considered.
5. In the past, the developers have been on the defensive. Armed with the true facts and a well-conducted public relations and participation campaign, it will be easier to put across their viewpoint. Based on the experiences of some recent projects, the expectations and aspirations of the public at large are well known now.
6. The views of the people and agencies in one country, though expressed with good intentions, may be out of place for another country. Many countries possess limited resources, which are often urgently needed for social upliftment: better education, health, housing, clean water and proper sanitation. These countries need to prioritize the application of these resources and decide what percentage should be earmarked for development works and what should be set aside for the protection of the environment.
7. Water resources specialists are increasingly being called upon to answer questions on dam safety, the stability of slopes of reservoirs, earthquake resistant design, erosion below the dam, reservoir sedimentation, etc. These arguments are viewed with suspicion and people feel that they give conservative estimate of likely costs, damage to the environment, land submerged and people affected, water quality as affected by storage and the like, while exaggerating the benefits due to dam, flood control, hydropower, etc. Serious and patient efforts are needed to improve the image and establish the credibility.
8. If people do not believe in a project then either the people are right or the promoters have not been successful in putting across their arguments. A free and frank discussion helps in bringing forward the truth and a better solution to the problem.
9. The technologists can predict the extent to which a reservoir can protect a valley from likely floods, but they cannot put in place a legislation to prevent people from settling in a flood plain. The success of many projects depends on forming appropriate rules and implementing them.

7.9 SUSTAINABLE DEVELOPMENT

The earth is essentially a single system with various biological, chemical and physical interactions occurring within its environs. Based on the analyses of the environmental systems, their trends, and experience, two things are clear: (i) the environmental problems arising today are largely caused by various human activities, and (ii) environmental problems transcend all boundaries and thus affect all nations and communities. In view of these, it is considered necessary all over the world that all the developmental activities should be planned such that current demands are appropriately met without unduly limiting the various options of future generations. In fact, this is a refined form of the concepts such as 'eco-development' which were prevalent in the early 1970s.

The term *sustainable development* (SD) became fashionable in the 1980s. It rapidly captured the imagination of development practitioners and analysts. This term was popularized mainly by the Brundtland Commission report, *Our Common Future*, WCED (1987). Although it may appear to be so, the concept itself is not new. As noted by Biswas (1994), the general philosophy behind the sustainability concept was expounded centuries, if not millennia, earlier. Similar thoughts on living in harmony with nature can be found in ancient Indian religious texts, such as *Rig-Veda.*

Today the foremost issue in the minds of political leaders, planners, engineers and social scientists is the issue of SD. Basically, SD aims at maintaining equilibrium between human needs and economic development, while preserving the environmental conservation through efficient use of natural resources. It emphasizes the need to review environmental protection and economic growth with parallel compatibility. Now, it is considered to be the most reasonable way of combining the current growth with planning of future projects.

Sustainability issues are not new issues, nor is sustainability a new concept. The current interest in sustainable water resources management has come from a realization that some of the past or current activities have or could cause irreversible damage to the ecosystem. This damage may adversely affect not only our own lives but also the lives of our successors. To address these questions, it is helpful to differentiate growth from development. According to Loucks et al. (2000), growth involves making the pie bigger, building new capacity in new places, improving the standard of living, changing land use, etc. Development involves capacity expansion in situ, redistribution of existing resources, more efficient use of scarce resources, water quality management, and the like.

Water resources management is the vector sum of a progression of legislation, policies, regulations, engineering practice, and institutional traditions. In many instances, natural calamities like floods, droughts, etc., are the motivation for changes in the way water resources are managed. These changes could be directed towards attainment of the objective of sustainable development.

7.9.1 Defining Sustainable Development

There are many ways in which the term 'sustainable development' has been defined. It was defined by WCED (1987) as the "development that meets the needs of the present without compromising the ability of the future generations to meet their own needs". However, this definition has been criticized as vague, simplistic, and internally inconsistent. Biswas (1994) claimed that one could easily identify more than one hundred definitions of sustainable development without much difficulty. Even an organization like the United Nations does not have a uniform and acceptable definition for use by its various component organs and the definitions used by UNEP, FAO or ILO differ in significant ways. With specific reference to water resources, ASCE (1998) has defined the concept as: "Sustainable water resource systems are those designed and managed to fully contribute to the objectives of society, now and in the future, while maintaining their ecological, environmental, and hydrological integrity." In the opinion of Loucks et al. (2000), sustainable management implies managing for the long term. Water resource systems that are able to satisfy, to the extent possible, the changing demands placed on them over time without system degradation, can be called "sustainable".

It is important to note that sustainable development is not a top-down but a bottom-up approach. It requires that development efforts are decentralized and local people are involved at all levels of planning, design, and implementation. These days, the notion of sustainability is applied at all levels and in ecological, sociological, and economic terms. The popularity of this term emanates from the fact that the current development trends appear to be unsustainable in a variety of ways. Given concerns with economic decline, population growth, and heavy resource depletion during the past two decades, many analysts have made pessimistic predictions about the future possibilities for the continued growth of the global economy and the ability of developing countries to attain the economic levels reached by developed industrial societies.

Some societies seem to have exceeded the carrying capacity of the land and resources to provide food and basic needs. For example, the results of recent investigations indicate that the rise of sea level has averaged 1 to 2 mm per annum during the last century. Acceleration in this rate arising from global warming could trigger ocean thermal expansion or the recession of glaciers at a rate of 8 to 29 cm by 2030. This could drastically increase the frequency of flooding on islands and low-lying coastal areas and a reduction in the reserves of fresh water due to increase in saltwater encroachment. Here, it is pertinent to note that there is a lot of uncertainty in interpretation of recent climate data. Kite (2000) has shown that if the climate data from all climate stations in California are averaged, there is an upward trend in temperature. However, if the stations are divided into urban and rural stations, two different trends are seen: the curve of urban stations shows an upward trend while the curve for rural stations shows a downward trend. Clearly, more research is needed before making a prophetic warning.

While discussing about sustainability, the ideas of renewability, resilience, and recoverability are also important. Extensive literature is available on these concepts. See Clark and Gardiner (1994) for definition and discussion. Renewability signifies the rate at which a resource can be replaced, so that sustainability is achieved by restricting the level of use to something at or below the rate of replacement. Resilience signifies ability to withstand stress without long-term or irreversible damage. Recoverability is a concept which accepts that detrimental impact may take place but concentrates on the rate or frequency of impact in relation to the inherent rate of recovery.

Xu et al. (2002) have defined an index, named sustainability index (SI), as the ratio of aggregated possible water deficit to the corresponding supply in the same region:

$$SI = \begin{cases} (S-D)/S, & S > D \\ 0, & S \leq D \end{cases} \tag{7.8}$$

where D is the water demand, and S is the available supply. SI values greater than 0.2 correspond to low or no stress of water supply (demand $\leq$ 80% of the potential water supply), whereas those smaller than 0.2 reflect vulnerable conditions (demand > 80% of the potential water supply). SI = 0 indicates an unsustainable water supply, i.e., water demand equals or exceeds all available local water resources. Note that this index is based on arbitrary thresholds and considers only a small part of the much wider scope encompassed in the definitions given above.

Many people view SD from ethical and moral angles. According to Hussain (1992): "...the question of SD involves the question of morality. ... I feel that economic growth without concern for morality becomes unsustainable. But at the same time morality without economic growth becomes an empty word". This idea can be further developed by arguing that SD and enforcement of human rights are interdependent and mutually supporting principles. Thus, any development that violates human rights cannot be sustainable. The preservation of natural wealth, its flora, fauna, and pristine environment ensures that the options and rights of future generations are safeguarded.

The origins of the SD concept lie in a criticism of the other paradigms of development. On account of the support this term has got from many individuals and institutions, it has tremendous driver and force. Thus, SD is argued to be the best and any other kind of development is considered bad. Given the widespread acceptance of the term, it is almost obligatory for all sincere developers to ensure that their practices are sustainable.

The definition of sustainability completely directs attention on those aspects which cannot be sustained. By trying to define sustainable water development in terms of only those factors that could contribute to unsustainability, the entire attention is focused on one part of the equation. The other part that has been completely ignored could possibly be as important as the negative aspects, if not more. Sustainable water development, as it is analysed at present, focuses only on what it is not, and then attempts to ameliorate the potential negative effects. To take a holistic approach, consideration should first be given to what is sustainable water development, and then move on to what is unsustainable.

Fisher (1997) pointed that the use of this term evokes more questions than answers about what a new paradigm of development might be. In spite of detailed discussions, it has not yet been possible to identify a development process which can be planned and implemented, and which would be inherently sustainable, however this may be defined. Biswas (1994) concluded that there is more success in identifying certain aspects of development which are unsustainable - then taking appropriate remedial steps to reduce or even eliminate those undesirable effects - than in devising a holistic process that is intrinsically sustainable right from the very beginning. In his opinion, it is easier to agree upon what is unsustainable than what is sustainable.

Coming to hydrological processes, by nature these have fluctuations which could be so great that statistically significant data would be very expensive to obtain in order to categorically conclude whether such variations are natural or not. If additional factors, such as potential climatic changes, are superimposed on already complex issues, the degree of uncertainty in terms of detecting or predicting the transition process greatly increases (Abu-Zeid & Biswas, 1992). One is then confronted with the difficult issue of even identifying the direction of any change, let alone the degree of change. The critical question then is:

what early warnings could indicate the beginning of a transition process from sustainable to unsustainable? The present knowledge is inadequate even to identify the parameters that could indicate the passage from one stage to the other. Thus, currently we really cannot accurately detect, much less predict, the transition of any such sustainable system to an unsustainable one.

7.9.2 Issues in Sustainable Development

The following issues about the concept of SD have been compiled from recent technical literature.

1. What exactly is to be sustained and how long does it have to be sustained? At what level does sustainability operate: at the level of the individual, specific cultural groups, a region, a country or the world? And over what spatial scales should sustainability considerations apply?
2. What are the appropriate temporal scales when considering the sustainability of specific project? One of the challenges of measuring sustainability is to identify the appropriate temporal scales in which those measurements should be made.
3. How would a WRD project or a watershed development strategy that is planned under SD principles compare to one planned under the current (unsustainable) practices?
4. How can sustainability be measured? Is it an ecological concept, a social concept, or something else?
5. Is sustainability an ability to adapt to changing circumstances or is it the maintenance of interrelationships through the suppression of change? Is the ideology based upon conservative foundations or is it progressive?
6. We do not know what future generations will want from us. They may not appreciate and interpret our actions the way we did for our forefathers. How can we identify what our descendants would like us to do?
7. We do not even know with certainty what all the short-term, let alone the long-term, impacts of our current management decisions will be. How to put sustainability in operation?
8. Is it appropriate to try to satisfy the present needs even if they overstress the system designed to meet them? If not, what are, if any, other sustainable ways to meet these needs? Is it really feasible to increase the benefits derived from water resources and at the same time increase or maintain the sustainability of those systems?
9. Biswas (1994) has raised a very pertinent question about the concept. According to him, no attempt has been made to define or even discuss what is meant by long term. Does sustainability cover 50 years, or 100, 500, 1000 or even more? Some people vaguely speak of 'several' generations. Even if one considers the lowest figure of 50 years, there is a fundamental dichotomy as to its use in the real world. For example, considering irrigated agriculture, generally the economic planning horizon of farmers extends to one cropping season or at most two. The overriding philosophy of nearly all farmers has been to maximize economic returns from their agricultural activities within this time frame. Thus, the mind-set is inherently based on maximizing profits over a continual series of short-term periods. Although short-term benefits could have long-term costs, generally short-term considerations have won over the long-term

implications.

10. How to allocate, over time and space, renewable as well as non-renewable resources, e.g., the waters that exist in many deep ground-water aquifers that are not being replenished by nature? Loucks et al. (2000) note that to preserve nonrenewable resources now for the use of our descendent in the future, the interests of sustainability would imply that those resources should never be consumed as long as there is a future. If permanent preservation seems unreasonable, then how much of a nonrenewable resource might be consumed, and when?
11. How to determine the correct strategy or the optimal future? How to account for the inevitable and profound effects of future technological developments that may mitigate many of the adverse effects of current unsustainable practices? With the exception of the loss of species, what other resources are vulnerable to irreversible decisions?
12. The available resources and demands balance is completely different in developing countries compared to developed ones. For instance, due to increase in population, the nutrition demands are rising in developing countries. Due to financial reasons, small farmers in developing countries (most of whom are poor), are forced to consider only the short-term economic implications for their survival. Up to what level agricultural activities can be intensified without sacrificing sustainability? Clearly, the sustainable development strategies in these two situations will be different. But in what ways?

This list is not exhaustive by any means. There are many unanswered questions related to the sustainable development and management of any renewable or nonrenewable natural system. These issues are unresolved, variously defined, or openly contested to hinder sustainable development of a practical guide for developers. A better understanding of these questions will clarify the ramifications of sustainable development and only then the true implementation of sustainable development principles and goals may begin. A number of studies related to different sectors have been carried out to analyze and identify the relevant factors. For example, Bassam (1999) identified five major elements for sustainability in agricultural production system: policy and management, energy and input, genetic resources, climate, and soil and water.

On account of the impending crisis, crucial and important planning and management decisions in various regions of the world have to be taken now. No decision maker can wait until all the questions are answered. But at the same time, they need to work towards increasingly sustainable levels of development and management. This includes learning how to get more from limited resources and how to minimize wastage. New ideas and technology will have to be developed to achieve increased economically efficient recycling. Management approaches that are more nonstructural and compatible with the environmental and ecological life-support systems must be identified. Better ways of planning, developing, upgrading, maintaining, and paying for the infrastructure that permits effective and efficient resource management and provides needed services must also be defined. No single discipline, profession, or stakeholder group has the wisdom to know what will be sustainable and what is right for all of us, living now and in the future. Such decisions can only be made through a process involving all the relevant disciplines and all the interested and affected stakeholders.

Change over time is certain; the direction is uncertain. Sustainability requires that public and private institutions also change over time in ways that are responsive to the demands of societies. The aspirations of societies change with time. Earlier, people wanted to control and manage natural water systems to meet the social requirements. Now many societies are moving towards 'conservation'. A number of national, state, and local restoration projects are underway in Australia, Europe, and North America that are an evidence of changing expectations and values. To achieve higher levels of sustainability of renewable water resource systems, their renewing capacity, i.e., ability to produce the desired amounts and qualities of water and to support the environment and ecosystems must be preserved and enhanced. This is a necessary pre-requisite to enable such systems to satisfy to the maximum extent possible, the needs of future generations.

Professionals must work within the social infrastructure of a community or region and in collaboration with an informed and involved public. This can certainly lead to more socially compatible, creative, appropriate, and hence sustainable, uses of technology and resources for addressing a community's or region's water resource problems or needs. From the perspective of water resources management in developing countries, two things are important: a) the development process must not be impeded, and b) the environment must be protected simultaneously. It is not an easy task because of the complex technical, economic, social and political factors involved. But then there is no other choice. Equally, in terms of environmental management, it is essential to move beyond the current negative-reactive approach to a proactive-creative one. For the sake of a better quality of life for the millions of people in developing countries, a more optimistic approach is necessary.

The United Nations Conference on Environment and Development (UNCED) was held in 1992, in Rio de Janeiro, Brazil. It was convened to address urgent problems of environmental protection and socio-economic development. The conference adopted Agenda 21, a plan to achieve sustainable development in the 21st century. To ensure effective follow-up, the Commission on Sustainable Development (CSD) was created in December 1992. The CSD is a functional commission of the UN Economic and Social Council. Details about this commission are available on Internet at http://www.un.org/esa/sustdev/csdgen.htm.

7.10 SOCIAL IMPACTS

The aim of social impact analysis is to study the influence of water resources projects on social and cultural life of the region. The people who are affected by a project were classified in three categories by Scudder (1998a): those who must be relocated because of project work and inundation due to reservoirs (the relocatees); the communities, or the host population who receive the relocates; and the other project affected people. The last category includes the people who live in the vicinity of the project, those who live near the reservoir periphery but do not require relocation, and those who live downstream of the projects and whose lives are affected by, say changes in river regimes, etc. Usually the number of people in the third category is far more than the relocatees and the hosts. It is, however, not easy to determine who are the people in the last two categories and to find their exact numbers except in simple cases where, say, relocatees are settled near a town.

Since the relocatees are the people who are most affected by a project and their problems are 'visible', they get the most attention while the other two categories do not get a fair share. Importantly, most discussions on social impacts of water resources projects are biased towards those who are adversely affected; the beneficiaries are usually not highlighted. A possible cause is that while the adversaries are usually vocal and organize protests, strikes, etc., the beneficiaries choose to remain invisible.

It is true that resettlement leads to a number of stresses, at least in the initial years. The availability of land, other resources, and employment opportunities to the displaced people are gradually reducing. The stresses that project affected people have to undergo are physiological, psychological, and socio-cultural. The main cause of these stresses is that the people have to leave behind their ancestral place and settle in a new climate (to which they may not be habitual) and adjust to a strange society whose values, cultures, and traditions they may not like. They may feel intimidated by jeering host population and may have to adopt a profession of which they have no liking and experience. According to Cernea (1990), forced population displacement caused by dam construction is the single most counter developmental social consequence of water resources development.

The degree of stress faced by the relocates also depends on the ability of national economy to provide gainful employment to the resettlers. In the absence of employment, resettlers may be worse off because their earlier sources of daily necessities, etc. are lost. Besides, the population densities as well as government authority and control tend to increase after resettlement. Strangely, political leaders may be caught in a 'no win' situation (Scudder, 1998b). If they support migration, they lose their constituency since people generally resist change and do not wish to move. If they oppose removal, their clout is adversely affected when displacement occurs.

Another important social problem that needs careful attention is the economic and cultural difference between the displaced people and the host society. Naturally, the attempts to shift the people to completely different climatic conditions, e.g., hilly people to plains, have also been resisted and rejected. Ideally, both should have similar ethnic and linguistic composition to avoid conflicts. Sometimes, social problems crop up because of lack of knowledge or concern by the planners and implementing agency. For example, in the Mahaweli project in Sri Lanka, ethnically opposite groups were made to settle in common area leading to communal disturbances (Scudder, 1998b). It was reported that due to ethnic problems in Ghana's Kpong dam, fighting broke out between resettlers and host population, killing many people.

Accurate data on the number of people that are affected by WRD projects are not readily available except for the projects whose impacts are confined to a well-defined area or to a small population whose number is already known. Among the three groups above, one may get data about relocatess only. Very little is known about the projects that were completed more than a decade ago. The number of affected people varies from thousands for a smaller project to more than a million for a project like the Three Gorges Dam on Yangtze River in China. According to the World Bank (1994) estimates, the displacement toll of 300 large dams that, on the average, enter into construction every year is estimated to be above 4 million people. Unfortunately, governments worldwide have been accused of deliberate underestimation of the number of relocatees as well as the range and extent of impacts. Yet, another cause of difficulty in understanding the social impacts is the non-availability of data on pre-project status against which the impacts due to the project can be compared. What is required is a carefully chosen sample of at least 1% families who are tracked and periodically interviewed beginning with the initiation of detailed planning. The focus should not be limited to just the major projects; medium and minor projects should also be covered.

It is generally assumed that the impacts of a river valley project on the people living in the downstream areas is positive, i.e., they get benefitted by flood control aspects but lose nothing. However, there are cases where the construction of levees and other flood control mechanisms coupled with urbanisation led to reduction in wetlands. This reduction was responsible to lesser outputs from them and reduced bio-diversity depriving benefits to many local people who depended upon productive use of these wetlands.

The moment a dam project is approved and the area for submergence is earmarked, the government as well as private parties stop making investments for improvement and, in many cases, for routine maintenance. During the time between project approval and initiation of settlement, the life of relocatees is already adversely affected and their living standards drop. Most large WRD projects have seen significant cost overruns and in this eventuality, it is common to see that the funds allocated to overcome social problems are diverted to meet construction and establishment expenses.

7.10.1 Rehabilitation and Resettlement

Worldwide, a large number of people migrate to new areas of habitat every year. Displacement of people for nation-building or development is often considered unavoidable. There are various types of resettlement: spontaneous resettlement, facilitated spontaneous resettlement, sponsored voluntary resettlement, and involuntary resettlement. Here our attention is confined to involuntary resettlement consequent to a WRD project. Rehabilitation and Resettlement (R&R) of the population displaced or affected by a WRD project is a hotly debated topic of recent times.

A major reason of opposition to WRD projects in recent years is the displacement of population due to these projects. It is now a concern because of the realization that displacement, by its very nature, results in the breakdown of family and community networks, and causes social and economic distress. Nevertheless, the governments have carried out national development plans and the displaced people have been compensated in some way. It is important to note that the number of people that are subject to involuntary resettlement due to reasons, such as natural calamities (floods and droughts), political suppression, law and order problems, war, terrorist acts, and search for jobs, etc. is much larger than the water resources projects. Among the development induced activities, the proportion of WRD projects is coming down because fewer and fewer of these projects are being constructed while the number of peoples affected by infrastructural development works is increasing.

With the increasing depletion of natural resources and the competition for land, the issues associated with the displacement of people through infrastructure development have become more complex, requiring more attention, more resources, in short a new paradigm. When the majority of the project-affected people are poor and unskilled, besides relocation, rehabilitation of these people becomes equally important. Can a project be termed as a developmental activity if it leads to dislocation of vast populations? To avoid social tensions, involuntary resettlement should be planned such that the resettlers and the host population, both are benefited. This could be in terms of higher income, improved living standards and health of the affected people.

The problem of resettlement attains gigantic proportions in densely populated or resource starved nations. In recent times, a number of dams have been constructed or are being constructed in developing countries. Table 7.13 gives the number of people that were or will be subject to displacement due to large water resources projects. The Gezhouba project in China displaced more than 20000 people and The Three Gorges Dam in the same region is likely to result in displacement of over a million people. The Saguling dam in Indonesia necessitated resettlement of about 65000 people. The Srisailam dam in South India has displaced about 100000 people and the Sardar Sarovar project on Narmada will affect even more number of people. According to Herschy and Fairbridge (1998), the water resources projects constructed in China in the past 30 years have displaced more than 10 million people, the corresponding number for the last four decades in India is 20 million. It is also reported that in many cases, the actual displacement is much more than estimated. The feasibility report of the Kiambere dam in Kenya estimated that some 1000 people would be displaced but during construction, this number turned out to be 6000. The same authors also report that against the estimate that 200 people will be affected by the Ruzizi II hydro-power project, the actual number turned out to be 16000.

A detailed and up-to-date baseline socio-economic database is essential to prepare R&R plans. One of the major criticisms in many projects has been that some planners come out with different figures at different times and the numbers given by different agencies do not match. The confusion can go up to the extent that the number of affected villages/towns may not be consistent. A well-organized database will be necessary to clearly identify the project-affected-persons. There are numerous cases where rogue elements try to force or bribe for inclusion of their names in such lists to enable them to claim the declared benefits. A database will also help in arriving at the realistic outlay for R&R and thereby a realistic estimate of the project cost. There is a need for a class-benefit analysis of the project to understand who stands to gain and who are the losers. Although detailed plans exists for physical structure of a project, a detailed blueprint for R&R does not exist even for all major projects.

At present not many countries have well defined policies for resettlement. Even where such policies exist, the political and administrative will to implement them in a human-centric approach is generally missing. Due to immense variations in policies and socio-economic factors, the R&R programs vary considerably from one country to the other. In many countries, such programs are still being evolved and modified in light of experiences. While doing that, the basic principles of fairness, transparency and equity

Table 7.13 The number of resettlers from some major projects.

Project	Country	Number of resettlers
Three Gorges	China	1,250,000
Danjiangkou	China	383,000
Sanmenxia	China	319,000
Xinjiang	China	306,000
Dongpinghu	India	278,000
Upper Krishna II	India	220,000
Xiaolangdi	China	180,000
MCIP III Irrigation	India	168,000
Andhra Pradesh Irrigation II	India	150,000
Gujarat Med. Irrigation II	India	140,000
Sardar Sarovar	India	127,000
Tehri	India	105,000
Aswan High Dam	Egypt	100,000
Subarnarekha Group	India	100,000
Srisalam	India	100,000
Kossou	Ivory Coast	85,000
Akosombo	Ghana	84,000
Longtan	China	73,000
Shuikou I and II	China	67,000
Mahaweli I-IV	Sri Lanka	60,000
Saguling	Indonesia	65,000
Kariba	Zambia and Zimbabwe	67,000
Cirata	Indonesia	56,000
Sobradinho	Brazil	55,000
Paulo Af. IV	Brazil	52,000
Yacyreta	Argentina and Paraguay	50,000
Itaparica	Brazil	50,000
Kainji	Nigeria	44,000
Yantan	China	40,000

Source: Scudder (1998) and others.

should be adhered to in all cases. In India which is a large country, each state has its own R&R policy. The packages for rehabilitation at the new site generally consist of infrastructure facilities, compensation for the land submerged and plots for building houses at the new site at nominal costs. Free facilities for transport of perennial effects and loans, etc. are provided to the population displaced. A successful implementation also requires that R&R plans are properly phased in time so that there is no eleventh-hour shifting. A rush through these activities generates tension and heart burning.

While considering and evaluating various project alternatives, appropriate weight should be given to minimize displacement of population because higher the magnitude of displacement, more will be human misery, expenditure, and delay. It is important to perceive and propagate unavoidable resettlement as a development opportunity. It is noted that many R & R programs are rejected by the project-affected people on the ground that these are inadequate, and unacceptable. While a certain element of greed and desire of getting the maximum out of it cannot be ruled out, many of the packages prepared by the government agencies were clearly inadequate and were improved after agitation. To avoid complications and agitation, it would be better (although difficult) if the resettlement programs are prepared by involving the affected population. Such a close working relationship will also help overcome the problems due to arrogance of officials. The extra time and efforts spent should be considered as an investment since it will eliminate many future problems.

The requirement of funds for resettlement also increases day by day. Scudder (1998b) reports that the resettlement component of 20 projects financed by the World Bank between 1986 and 1993 was 9% of the total cost. In countries where population densities are higher, this amount will be considerably more. For example, the Three Gorges Project of China will require one third of project funds for resettlement if the Chinese policy guidelines were followed. The finances required for Sardar Sarovar Project in India are also quite high.

Often resettlement is considered inadequate because the government agencies may lack awareness of the complexity and range of issues, the goals may be improperly perceived, and in some cases, they may pretend to ignore the reality because this will weaken the justification for the project. Of course, one can imagine that finding land and employment for over one million people who will be affected by the Three Gorges Project is a real Herculean task.

R&R of tribals or hill-area people whose life styles and culture are radically different from the people of plains needs careful attention. The tribals are used to living in hills and forests form an integral part of their life. They practice their own way of agriculture. Their relocation even in command areas of nearby canals can inflict a cultural shock to them and could be a cause of avoidable social conflict. It would be desirable to relocate them within the forests on the fringes of the reservoir. Side-by-side, measures for their health and economic uplift should also be initiated so that they are brought in the national mainstream while retaining their own identity.

The displaced people usually find that while they loose everything, they gain very little from the projects that displaced them. As pointed by Gill (1997), the result is that those who are made to sacrifice for the 'national good' are not those who ultimately benefit from the development projects that displace them. It does not seem to be merely coincidental that a major proportion of the displaced are the poor and the powerless. However, the justification is that some people will have to sacrifice in the 'national interest'. But the equally important questions are: who sacrifices and who benefits? What happens to the displaced? Do they benefit or gain from the process that displaces them?

And what is their role in the whole process? These questions should be addressed in the right earnest.

All said and done, resettlement can also be viewed as an opportunity in the long run because it can remove cultural constraints to the developmental and entrepreneurial initiative, and political and other restrictions. It can also bring the tribal people into the national mainstream, although they are likely to be different opinions on this matter. Every human being has a right to development, but in order for it to be just and sustainable, it must be development for all – not development for some at the cost of others. The process of development must not violate the principles of democracy and human rights of the people involved. Instead it must ensure, as far as possible, people's participation in planning and implementation, and it must bring a share of the benefits to them. Recognizing this, Article 1 Clause 1 of the United Nations General Assembly Declaration on the Right to Development states: "The human person is the central subject of development and should be the active participant and the beneficiary of the right to development." The same article in Clause 3 goes on to add, "States have the right and the duty to formulate appropriate natural development policies that aim at the constant improvement of the well being of the entire population of all individuals."

Importantly, R&R is not an administrative problem; it is a human problem. Since R&R deals with people, pragmatic policy decisions with involvement of the affected people at appropriate levels and stages is necessary. Many people, particularly the old, who may have been born and brought up on that land, consider it as their ancestral property and have an emotional and nostalgic attachment. Such cases should be dealt with care, respect, and patience that they deserve. The use of force should always be avoided and people should be motivated to move by giving them higher standard of living and sustainable means to lead a dignified life. It is also necessary to ensure that the displaced people are made partners in prosperity due to the project and do not turn into adversaries.

7.11 CASE STUDY - SARDAR SAROVAR PROJECT, INDIA

The Sardar Sarovar Project in Narmada basin, India, is one the most ambitious and equally controversial projects of recent times. The salient features of the project, its benefits, environmental impacts and opposition are described in the following. The material is based on Chitale (1997), Fisher (1997), SSNNL (2000), Internet, newspaper reports, etc.

Narmada, the largest westward flowing river in India, traverses over 1310 km. It rises in the state of Madhya Pradesh in central India and passes through the states of Maharashtra and Gujarat on its way to the Gulf of Khambhat. The Narmada drainage basin covers 98,796 square km. About 85% of the Narmada's average annual flow of 50 km^3 occurs during four months of monsoon rains, from June through September (Chitale, 1997). Floods are intense and sudden, reaching their peaks in a short time. Harvesting this flow would require a large system of reservoirs. Hence, the Narmada River is the subject of one of the largest basin development schemes in the world that would include, when completed, 30 major, 135 medium, and about 3,000 minor dam projects in the Narmada basin.

Tapping the resources of the Narmada has been the dream of political leaders and development planners for decades. Large parts of Gujarat and Rajasthan face recurrent droughts and there have been instances when water had to be transported by trains to save the people from famine. The idea of constructing dams on the Narmada River was first suggested in 1946. For quite some time, this idea could not materialize because the states did not agree on the distribution of the river water. The then Prime Minister of India, Mr. Jawaharlal Nehru, laid the foundation stone for the Sardar Sarovar dam, a multipurpose project which is the terminal dam of the basin-wide scheme in 1961. This project was delayed and in 1965, a committee was appointed by the Government of India to prepare a detailed plan for the development of the Narmada basin. The committee recommended the construction of a dam and a canal in Gujarat and twelve major projects in Madhya Pradesh. The two principal dams proposed were the Indira Sagar Dam and the Sardar Sarovar. The recommendations of the committee were endorsed by the Government of Gujarat but rejected by the Governments of Madhya Pradesh and Maharashtra. Subsequently in 1969, the issue was referred to the Narmada Water Disputes Tribunal which was established under India's Interstate Water Disputes Act of 1956. The Tribunal considered the issues for a decade and made its final award in 1979.

This award, which provides for diversion of 11718.25 million m^3 (9.5 million acre-feet, MAF) of water from the reservoir into a canal and irrigation system, has formed the basis for construction of the current Sardar Sarovar Project. Finances for this ambitious project were secured in 1985 when the World Bank entered into credit and loan agreements with the Governments of Gujarat, Madhya Pradesh, and Maharashtra. It provided U.S. $ 450 million for the construction of the dam and the canal. The construction of the dam began in earnest in 1987. Another major project under construction upstream of Sardar Sarovar is the Indira Sagar project.

7.11.1 The Project

Sardar Sarovar is an ambitious and technologically complex irrigation scheme which is to draw upon the flow of the Narmada River to alleviate the water needs of large areas of the state of Gujarat. The project, which is one of the largest water resource projects ever undertaken in India, includes a dam, a riverbed powerhouse, a main canal, a canal powerhouse, and an irrigation network. Its projected impact extends over a large area, and it will potentially affect 25-40 million people. The components of the project are designed to irrigate a vast area of Gujarat and Rajasthan (although not a basin state, was also later allocated a share of its waters), and to provide drinking water to areas of central and northern Gujarat. The water is to be delivered by creating a storage reservoir on the Narmada River with a full reservoir level of 138.684m (455 feet), along with an extensive canal and irrigation system.

The dam is being constructed in a hilly region, and the reservoir created behind the dam will resemble a narrow lake extending from the dam over 200 km upstream, submerging approximately 35,000 hectares of land in three states: Gujarat, Maharashtra, and Madhya Pradesh. Out of this, 11,300 ha is agricultural, 10,700 ha forest land, and the rest consists of river bed and waste land. While the full impact of the project remains in dispute, it is generally acknowledged that 248 villages will be submerged, mostly partially, affecting about 100,000 people. Many of these people, especially in Gujarat and Maharashtra, are considered to be 'tribals' and have no formal title to their land. A large number of farmers, about 140,000 according to an estimate, will lose land to the canal and irrigation systems. In addition, thousands of people living downstream will find their lives affected by the project. Weigh this up against the benefits: irrigation of 1.8 million ha, 1450 MW of hydroelectric power, drinking water to 135 towns and 8215 villages (some of these suffer frequent droughts), flood protection for 210 villages with an aggregate population of 750,000 and other less important benefits. The area that will be submerged is about 1.65% of the area that will get benefits. The ratio of population displaced to the population benefited is 1:37. Generation of wealth in an area also contributes to general economic development of the area.

The Narmada main canal will be the largest of its kind in the world, extending 450 km to the Rajasthan border and crossing 19 major rivers and 244 railway lines or roads. With 31 branch canals, the aggregate length of the distribution system will be 75,000 km which will require approximately 80,000 hectares of land. The main canal will be 250 meters wide at the head and 100 meters wide at the border: the capacity of this canal system is such that it will be able to empty the proposed reservoir storage in less than two months. The canal will also transport Narmada water to Saurashtra and Kutch region of Gujarat which are drought prone areas. Many wild life sanctuaries and parks will get water from the project. Fig. 7.5 shows the Sardar Sarovar Project Area, including the river basin, the submergence area, and the canal system.

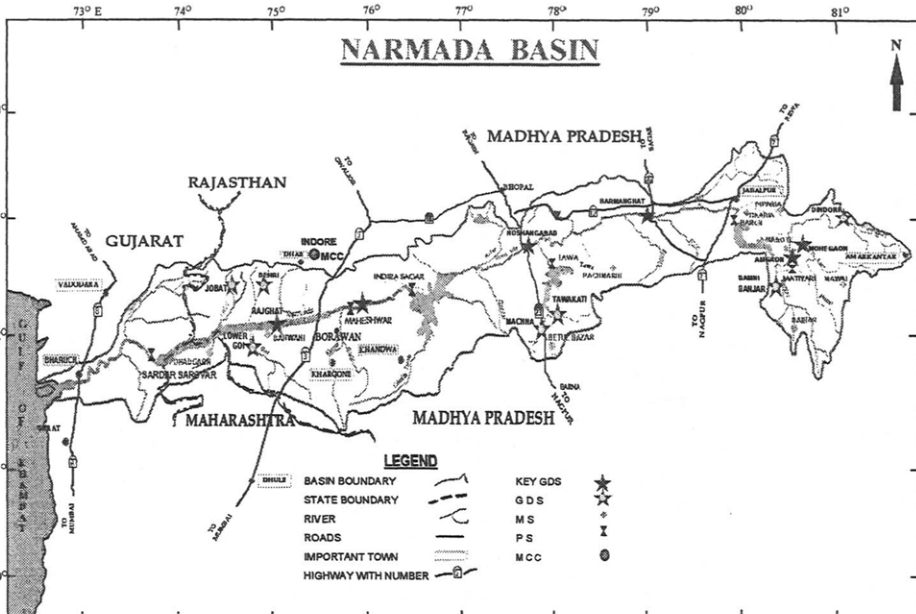

Fig. 7.5 Narmada Basin, India [Source: Narmada Control Authority].

Only one-sixth of the project cost is for construction of the dam. An additional equal amount is required for hydro-power installation at the dam and canal bed powerhouse. The other one-third of the cost is for the main canal and the rest is for development of the irrigation network in the command area. For different levels of irrigation efficiency, the internal rate of return was between 16.77 and 21.88 on economic prices of the inputs and outputs and the corresponding benefit-cost ratios between 1.59 and 3.29 (Chitale, 1997). The acceptable levels are 9 and 1, respectively.

7.11.2 The Controversy

The complexity of the project allows for considerable dispute about how to best calculate and compare the projected costs and anticipated benefits. The project's proponents emphasize the enormous benefits it is expected to bring to millions of people at the cost of displacing comparatively few. They ask that these projected benefits – the provision of drinking water to as many as 40 million people and the irrigation of 1.8 million hectares of land – be weighed against the relatively small number of people who will be displaced from land. From their perspective this balance tilts heavily in favour of the project.

The opponents of the project question both the projected benefits and the cost of the project. They argue that the irrigation benefits have been vastly overestimated and that adequate drinking water may never reach the most needy drought-prone areas of Gujarat, such as Kutch. According to them, the economic costs are based on unrealistic figures and have been grossly underestimated. Also, the human and environmental costs have been vastly underestimated or ignored by mis-reporting the number and the extent to which people will be affected by the project, and disregarding the costs of cultural disruption that will occur when tribal people are moved from their traditional lands. In their opinion, the number of people to be affected must include those living in the submergence area, those displaced by construction of infrastructure, those affected by the canal, and those living downstream whose lives and livelihoods will be affected. The reservoir submergence has ignored the adverse effect on the forest cover and Narmada water will never reach far flung drought prone Kutch area, an oft-repeated dream of the dam builders.

In the Sardar Sarovar Project, the major concern about compensation has focussed on the category of people identified as "oustee". An oustee is an individual "whether landed or landless, who since at least one year prior to the date of publication of the notification under the relevant Indian Land Acquisition Act, has been ordinarily residing, or cultivating land, or carrying on any trade, occupation, or calling or working for gain in Gujarat, Madhya Pradesh, and Maharashtra, who would be displaced from his usual habitat due to the carrying out of the Project." Two factors affect the compensation to which the Sardar Sarovar Project oustee is entitled. One is the assessment of an oustee's right to compensation, which is complicated by disparity between the way the government administers, registers, and taxes land and the way people conceive of and use resources. Secondly, the R&R policies of the three states of Gujarat, Madhya Pradesh, and Maharashtra vary in the compensation they give to oustees. The policy of Gujarat is considered to be the most 'lucrative'. Consequently, the oustees want the states of Madhya Pradesh and Maharashtra to match their policies with those of Gujarat.

The three states have different norms for treatment of "major" sons (sons over the age of eighteen), encroachers (those residing on and cultivating land to which they do not have legal title), and the landless. The Gujarat policy makes no distinction between landed and landless oustees and offers full benefits to major sons. According to the award of the Narmada Water Disputes Tribunal, all people displaced by the Sardar Sarovar reservoir have the right to settle in Gujarat, if they so desire. Naturally, so long as Gujarat's resettlement and rehabilitation benefits are significantly better than those offered by the other two states, most displaced people are apt to take this option. Hence, Madhya Pradesh resettlement plans anticipate that only 10 percent of the displaced people from that state will remain in the state. An unequal compensation is seen to violate the spirit of the Tribunal Award which provides that all oustees may remain in their home states. To do so under current policies would entail a financial sacrifice for some, while relocation to Gujarat would mean for many "a long cultural journey." Therefore, while the right of choice still exists in principle, the disparity in benefits means a choice between migration to another state or a lower standard of living.

The concern of compensation dominates the discussions of R&R; there are disagreements about what constitutes full, fair, and appropriate compensation, and further disagreements about whether all the oustees will or can be fully, fairly, and appropriately compensated under prevailing circumstances. The proponents argue that displacement should be treated as a development opportunity and that project-affected people should not only regain their standard of living but also be treated as the first beneficiaries of the project. Clearly, high costs attached to R&R reduce the cost-benefit ratio, making it more difficult to raise political and financial support. Even in cases where project benefits make it possible to offer attractive R&R packages, high compensation is opposed by the decision-makers fearing that this will set a precedent of high awards which could not be met by all future projects. Note that the oustees mostly belong to marginal and disempowered communities and R&R requires that all people affected by the project must 'improve or at least regain the standard of living they were enjoying prior to their displacement'.

7.11.3 The Protests by NGO's

Meanwhile, a number of Indian Non-Governmental Organizations (NGOs) began opposing the project, mainly on the grounds of environmental, human (tribal) rights, the skewed economics of the project, etc. The *Narmada Bachao Andolan* (NBA) is the main opponent. They were later joined by several foreign NGOs. Some NGOs, such as *Action Research in Community Health Association* (ARCH), who were originally opposed to the project because of insufficient compensation for the affected population, later accepted the improved measures and supported the continuation of construction.

Originally, the campaign against the Sardar Sarovar Project revolved around resettlement issues. Earlier disagreement between the states, mainly about water allocation and the height of the proposed dams, had been resolved amicably by the middle of 1974. After certain clarifications, this was made an award by a Tribunal under the Inter-State Water Disputes Act at the end of 1979. This Tribunal also set out a resettlement and rehabilitation scheme which, at that time, was considered very liberal though the World

Bank insisted on even higher standards. Landless farm laborers and so called "encroachers" were to receive 2 ha compensation, often more than the area possessed by the communities among whom they were to be resettled. It had been planned to resettle some of the displaced people on degraded forest land. In the meantime a new "Forest Conservation Act" had been passed in 1980, forbidding any forest land to be diverted to other purposes, unless specifically sanctioned by the Central Government. This led to a shortage of land needed for resettlement.

Gradually, NGOs started to employ radical protest techniques, such as marches, hunger strikes, traffic disruptions, and intimidation of those wanting to be resettled. They even instituted a "mass drowning rather than relocate" campaign at the first village threatened by the rising waters. Much was made of the fact that many of the so called "oustees" were still tribal. A lot of incitation of these relatively primitive people took place. The proponents, however, claim that the tribal families have shown a desire to avail of this development opportunity. The NGOs also started convassing for foreign support through newspaper articles, talks, petitions to heads of the governments, the UN, and the donor agencies. All this led to Japan withdrawing its financial support to the project. The World Bank appointed an Independent Review Mission, the first of its kind in the history of the Bank. The report of this mission was interpreted variously by various people; it was criticized by many, e.g., Alagh and Buch (1997), and apparently further complicated the matter. After the World Bank withdrew from the project, the Government of India decided to proceed without external help.

The opponents managed to mobilize a substantial number of people in India and elsewhere against the project, but a large scale popular support for it was shown by about a million people turning up for a pro-project demonstration. Public issue of bonds was floated by the Government of Gujarat to mobilize funds for the project. All the issues were over-subscribed, showing public support to the project.

7.11.4 Project Status

More than 98% of the excavation and 86% of concreting for the main dam were over by 2000 (SSNNL 2000). The canal-bed and dam powerhouses are in advanced stage. The matter regarding the final height of the dam was considered by the Supreme Court of India. On October 18, 2000, the Supreme Court of India delivered its judgment on the Sardar Sarovar Project. In a 2 to 1 majority judgment, it allowed immediate construction on the dam up to a height of 90m. Further, the judgment authorized construction up to the originally planned height of 138m in 5-meter increments subject to receiving approval from the Relief and Rehabilitation Subgroup of the Narmada Control Authority. In 2002 summer, the dam height was allowed to be raised to 95 m. When the lowest block of the dam attains an elevation of 110m, 450,000 ha area will start receiving irrigation water and power generation will also commence. As per the schedule, the project in all respects is expected to be completed by 2010.

Many websites contain information about this project, for example, Sardar Sarovar Narmada Nigam Ltd. (www.sardarsarovardam.org), Narmada Control Authority (www.nca.nic.in), and an NGO's site www.narmada.org/sardarsarovar.html.

7.12 CLOSURE

Sometimes it is fashionable to denounce all technologies and raise a slogan for going "back to nature." But one should not forget the risks faced by our ancestors. Even today, a fishermen who faces the periodic onslaught of cyclones needs to be provided with advance warnings and damage proof shelters for protection during cyclones. The traditional mud houses in the villages cannot provide the required safety. Similarly, during an extended drought, the people and cattles have to be provided water at least for survival. While facing the furies of nature, the role of high technology can hardly be ignored. The technology is a result of human ingenuity, efforts and skills. It is, therefore, not appropriate to denounce them mindlessly.

Most people do not prefer the "natural" and raw living environment, but developed and managed conditions; not the natural water from the ground which may be polluted but treated water, free from impurities. It is wrong to believe that nature has provided all waters as healthy. Natural lakes can get heavily polluted by excessive decay of the vegetative matter flowing into it. It is for the human endeavours to arrest such excessive decay and/or to transform these waters into consumable ones by utilizing proper technology.

In the present situation it is necessary to filter "environmental noise" from a few serious efforts for true environmental awakening. It is true that efforts of the so called environmentalists, as distinct from environmental scientists, have succeeded in retarding the pace of harnessing of additional waters for irrigation, drinking or hydropower or for putting up of new flood control works. It is not in the interest of the developing societies to allow this unsettled situation to continue for a long time. A determined effort is necessary to resolve the issues and move ahead quickly with refined and improved policies in light of new environmental data and proper analysis. Discussion on an issue, beyond a limit, is counter productive. It will be very unfortunate if WRD gets bogged down in 'paralysis by analysis !'

7.13 REFERENCES

Abu-Zeid, M.A. and A.K. Biswas (1992). Some major implications of climatic fluctuations on water management, in Abu-Zeid, M.A. and A.K. Biswas (ed), Climatic Fluctuations and Water Management, Oxford, Butter-Heinemann.

Abu-Zeid, M.A. and F.Z. El-Shibini (1997). Egypt's High Aswan Dam, Water Resources Development, 13(2), 209-217.

Alagh, Y.K. and D.T. Buch (1997). The Sardar Sarovar Project and Sustainable Development, in Fisher, W.F. (Ed.). Toward Sustainable Development: Struggling Over India's Narmada River, Rawat Publications, Jaipur, India.

ASCE Task Committee for Sustainability Criteria. (1998). Sustainability criteria for water resource systems, Division of Water Resources Planning and Management, ASCE, Reston, USA.

Asmal, K. (2002). Parting the waters. Journal of Water Resources Planning and

Management, ASCE, 128(2), 87-90.

Bassam, Nasir El. (1999). Developments in agriculture – Global key issues, Natural resources and development, Vol. 51, 39-57, Institute for Scientific Cooperation, Tubingen, Germany.

Biswas, A.K. (1994). Sustainable Water resources Development: Some Personal Thoughts, Water Resources Development, 10(2), 109-116.

Biswas, A.K. (1997). Water Development and the Environment, Water Resources Development, 13(2), 141-167.

Biswas, A.K. (Ed.) (1998). Water Resources Environmental Planning, Management, and Development, Tata McGraw Hill Publishing Company Ltd., New Delhi.

Canter, L.W (1981). Methods of Environmental Impact Assessment: Theory and Applications (Emphasis of Weighting-Scaling Checklists and Networks). Environmental Impact Assessment, NATO ASI Series, Toulouse, France.

CBIP (1995). Environment Impact Assessment Studies (case studies). Publication No. 248, Central Board of Irrigation and Power, New Delhi.

Cernea, M.M. (1990). Poverty Risks from Population Displacement in Water Resources Development. Development Discussion Paper 355, Harvard Institute for International Development, Cambridge, USA.

Chitale, M.V. (1997). The Narmada Project, Water Resources Development, 13(2), 169-179.

Clark, M.J., and Gardiner, J. (1994). Strategies for handling uncertainty in integrated river basin planning, in Integrated River Basin Development, edited by C. Kirby and W.R. White. John Wiley & Sons, Chichester.

CWRC (1997). Three Gorges Project, Changjiang Water Resources Commission, Wuhan, China.

Fisher, W.F. (Ed.) (1997). Toward Sustainable Development: Struggling Over India's Narmada River, Rawat Publications, Jaipur, India.

Gill, M.S. (1997). Resettlement and Rehabilitation in Maharashtra for the Sardar Sarovar Narmada Project, in Fisher, W.F. (Ed.). Toward Sustainable Development: Struggling Over India's Narmada River, Rawat Publications, Jaipur, India.

Hasan, Z., and Goel, R.S. (2000). Water Resources Development in Himalayan Region and Environmental Impacts. In Environmental Impacts Assessment of Water Resources Projects. Edited by R.S. Goel. Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi.

Hussain, A. (1992). Working towards sustainable development. Conference report. Southern Asian Institute, New York.

Herschy, R.W. (1998). 'Environment Priorities for Development: Water', in Herschy, R.W. and R.W. Fairbridge (Ed.). Encyclopedia of Hydrology and Water Resources, Kluwer Academic Publishers, Dordrecht.

ICOLD (1982). Dams and Environment. Bulletin 35. The International Commission on Large Dams, Paris.

ICOLD (1998). Position Paper on Dams and Environment. The International Commission on Large Dams. Available at Web-site http://genepi.louis-jean.com/cigb/chartean.htm.

Ivanov, K. (1984). A Method for Estimation of the Chemical Indices and its Application to Project 'Iskar' in Bulgaria. In Hydro-environmental Indices: A Review and Evaluation of their use in the Assessment of Environmental Impacts of Water Resources Projects. Working Group on IHP-II, Project A3.2, Unesco, Paris.

Keller, A., Sakthivadivel, R., and Seckler, D. (2000). Water scarcity and the role of storage in development. Research Report 39. International Water Management Institute. Colombo, Sri Lanka.

Kite, G.W. (2000). Climate change and water resources planning: a somewhat skeptical view. Proceedings of International Conference on Integrated Water Resources Management for Sustainable Development (ICIWRM 2000), New Delhi.

LaBounty, J.F. (1984). 'Assessment of the environmental aspects of construction of the Three Gorges project on the Yangtze river', Water International, Vol. 9, 10-17.

Loucks, D.P., E.Z. Stakhiv, and L.R. Martin (2000). Editorial: Sustainable water resources management, Journal of Water Resources Planning and Management, ASCE, 43-47, March.

Ott, W. R. (1978). Environmental Indices – Theory and Practice. Ann Arbor Science Publishers, Michigan.

Pendse, Y.D. (1987). 'Environmental aspects of water resources development in India', Commemorative Volume, CBIP Diamond Jubilee, New Delhi.

Rees, C.P. (1981). 'Guidelines for environmental impact assessment of dam and reservoir projects'. Journal of Water Science and Technology, Vol. 13, 57-71.

Robbroeck, Theo van. (1996). Reservoirs: Bane or Boon ?, Geoffrey Binnie Lecture, British Dam Society, London.

Sahu, H. (1992). 'Evaluation impacts on environment of Narmada Sagar Project, India', in Water Resources & Reservoir Engineering, Edited by N.M. Parr, J.A. Charles, and S. Walker, The British Dam Society, London.

Scudder, T. (1998a). Social Impacts, in Biswas, A.K. (Ed.). Water Resources Environmental Planning, Management, and Development, Tata McGraw Hill Publishing Company Ltd., New Delhi.

Scudder, T. (1998b). Resettlement, in Biswas, A.K. (Ed.). Water Resources Environmental Planning, Management, and Development, Tata McGraw Hill Publishing Company Ltd., New Delhi.

Shah, R.B. (1993). Role of Major Dams in the Indian Economy, Water Resources Development, 9(3), 319-336.

Srivastava, L.S. (1993). Hydrodynamic behaviour of water reservoirs. National Seminar of Hydrological Hazards – Prevention and Mitigation, Indian Association of Hydrologists, Roorkee, India.

SSNNL (2000). Meeting the Challenges of development - Sardar Sarovar Project on River Narmada, Sardar Sarovar Narmada Nigam Ltd., Govt. of Gujarat, Gandhinagar.

Unesco (1984). Hydro-environmental indices: A review and evaluation of their use in the assessment of the environmental impacts of water resources. Technical Document in Hydrology, Working Group Report on IHP-II.

WCED (1987), Our Common Future (The Brundtland Report), World Commission on Environment and Development, Oxford University Press.

Westman, W.E. (1985). Ecology, Impact Assessment, and Environmental Planning. John Wiley and Sons, New York.

World Bank (1994). Resettlement and Development. The Bankwide Review of Projects Involving Resettlement 1986-1993. The World Bank. Washington D.C.

World Commission on Dams (2000). Dams and Development: A new Framework. Earthscan, London.

Xu, Z. X., Takeuchi, K., Ishidaira, H., and Zhang, X.W. (2002). Sustainability analysis for Yellow river water resources using the system dynamics approach. Water Resources Management, 16, 239-261.

APPENDIX 7A

7.A THE REPORT OF WORLD COMMISSION ON DAMS

The World Commission on Dams (WCD) launched its Final Report *Dams And Development: A New Framework for Decision-Making,* in 2000 (WCD, 2000). The Commission tried to gather views of all parties in the increasingly confrontational debate about the role that 45,000 large dams worldwide have played in development. Estimates suggest that some 40-80 million people have been displaced by dams worldwide while the livelihoods of many more living downstream were affected but not recognised. This report will have impact on the future role of the $42 billion dam industry. Expectedly, the report was appreciated by a section of people while it was rejected by another group.

Key Findings of the Review of Large Dams

The WCD report provides a mammoth review of technical, financial, and economic performance of dams as well as their environmental and social performance. Together with its assessment of potential alternatives to dams and the study of decision making processes, it offers an insight into one of the most controversial development debates of our time.

WCD conducted detailed reviews of eight large dams in Turkey, Norway, the United States, Zambia and Zimbabwe, Thailand, Pakistan, Brazil, and South Africa. It also prepared country reviews for India and China, as well as a briefing paper on Russia and the newly formed Commonwealth of Independent States. A survey of 125 large dams was also undertaken, along with 17 thematic reviews on social, environmental, and economic issues; on alternatives to dams; and on governance and institutional processes.

The commission concluded that dams have made an important and significant contribution to human development, but in too many cases, the social and environmental costs have been unacceptable and unnecessary. A new framework for decision-making that moves beyond simple cost-benefit trade-offs to introduce an inclusive 'rights and risks approach' which recognises all legitimate stakeholders in negotiating development choices was suggested.

The commission found that

- Dams deliver significant development services in more than 140 countries.
- On a global scale, hydropower dams account for 19% of electricity generated and for an estimated 12 to 16 % of global food production.
- About 12% of large dams supply domestic and industrial water, and large dams provide flood control services in more than 70 countries.

- Large dams display a high degree of variability in delivering predicted water and electricity services - and related social benefits - with a considerable portion falling short of physical and economic targets, while others continue to generate benefits after 30 - 40 years.
- Large dams have demonstrated a marked tendency towards schedule delays and cost overruns.
- Large dams have led to the loss of forests and wildlife habitat and the loss of aquatic biodiversity of upstream and downstream fisheries. The efforts to counter the ecosystem impact of large dams have met with limited success.
- The negative social impacts reflect a pervasive and systematic failure to assess and account for the range of potential negative impacts on displaced and resettled people as well as downstream communities.

Alternatives to Dams for Water & Energy Resources Development

The commission examined the alternatives for meeting energy, water and food needs and found that while there is far greater scope for utilising these, no universal formula applies as local and national conditions are central to determining viable options. Obstacles, such as market, institutional, intellectual and financial barriers, limit the adoption rate of alternatives. Improved system management, particularly in the irrigation sector but also through reduction in water losses, more efficient system management and an upgrading of distribution technology, can alleviate demand for new supply sources. Demand-side management has significant potential and provides a major opportunity to reduce water stress and power requirements.

Key Recommendations

The commission argued that it is not necessary to trade off one person's gain against another's loss. Rather, by negotiating outcomes through multi-criteria analysis -- technical, environmental, economic, social and financial -- the development effectiveness of water and energy projects will be improved, unfavorable projects will be eliminated at an early stage, and the options chosen will be what key stakeholders agree best meets the needs in question.

- A set of five core values should be adopted for future decision-making: Equity; Sustainability; Efficiency; Participatory decision-making; and Accountability.
- Seven strategy priorities for water and energy resources development: Gaining Public Acceptance; Comprehensive Options Assessment; Addressing Existing Dams; Sustaining Rivers and Livelihoods; Recognizing Entitlements and Sharing Benefits; Ensuring Compliance; and Sharing Rivers for Peace, Development and Security.
- National Governments should review existing procedures and regulations concerning large dam projects and time-bound licenses for all dams.
- Bilateral aid agencies, export credit agencies and multilateral development banks should establish procedures which ensure that approved financing for dam projects emerge from an agreed process of ranking alternatives.