

# Findings and impacts

## CATCHMENT AREA TREATMENT

### IMPACTS AND MANAGEMENT

#### Studies and Findings

##### *Studies*

Surveys and studies have been undertaken to aid the development of a management plan for CAT in the SSP catchment which have dealt with the following topics:

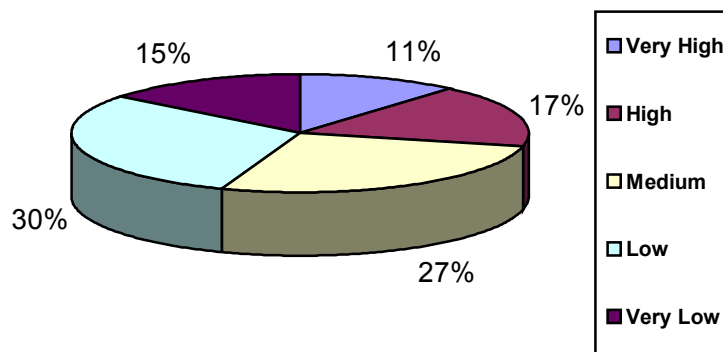
- Mapping of the types and quality of soils:
- Reporting on the present status of the study areas;
- Prioritising the sub-watersheds for treatment;
- Recommending treatment methods.

These studies included the following:

- Report of Inter-Departmental Committee on Soil Conservation and Afforestation: (the Dewan Committee Report), 1985 presented the findings and recommendations of an inter-departmental committee set up by the Ministry of Agriculture to:
  - Report on conditions in the catchment:
  - Suggest soil conservation and afforestation measures and
  - Prepare a phased programme of work and financial outlays.
- Report on Prioritisation of Sub-watersheds in Sub-catchments of Narmada Catchment, 1991 presents the results of a three-year study conducted by AISLUSO in accordance with the recommendations of the Dewan Committee. The catchment of Sardar Sarovar was divided into eight sub-catchments and each of these was further sub-divided yielding a total of more than one thousand sub-watersheds. These were then subject to detailed survey to establish the potential for erosion through consideration of such factors as slope, vegetative cover, soil characteristics, surface condition, physiography etc. This information was used to prioritize the sub-watersheds for CAT.

##### *Findings*

The outcome of the study by AISLUSO to prioritize sub-watersheds is presented in Table below, which includes all sub-watersheds above the SSP and below the ISP (i.e. the catchment of SSP, Omkareshwar Project and Maheshwar Project). About 28% of the total catchment area prioritized falls into the 'very high' and 'high' categories most susceptible to erosion.



### Prioritisation of Sub-watersheds

Category	No. of Sub-watersheds	Area (ha)	% of Total Area
Very high	123	278.309	11.4
High	159	415.282	17.0
Medium	262	656.456	26.8
Low	313	730.575	29.9
Very Low	171	354.541	14.9
Total	1,028	2,445.163	100

## COMPENSATORY AFFORESTATION

### IMPACTS AND MANAGEMENT

#### Studies and Findings

##### *Studies*

There have been a number of studies in three States aimed at assessing the extent and significance of the loss of forestlands attributable to the SSP.

- Sardar Sarovar (Narmada) Project Development Plan, Volume II prepared by the Narmada Planning Group (NPG) in 1983 contained a chapter on the various environmental aspects of the SSP. Details of land use and forest cover derived from aerial photography were included.
- Studies on Ecology and Environment by MS University of Baroda (MSU) in 1983, used satellite photography, statistical sampling techniques, and an extensive programme of field work to determine the density, species composition and productivity of forests in the submergence area of Gujarat.
- Sardar Sarovar Project: Preparation of Environmental Work Plan by the Forests Department of Maharashtra in 1988 was a survey listing all-important flora in the submergence area of Maharashtra.
- Eco-Environmental and Wildlife Management Studies on the Sardar Sarovar Submergence Area in Gujarat reported on work done between November 1989 and May 1992 by MSU. This provided more detailed reports on the status of the forests in the submergence area and environs of Gujarat.

- Impact Assessment of Madhya Pradesh Land to be submerged under Sardar Sarovar Project and Adjoining Ecosystems. The study was conducted by the State Forest Research Institute (SFRI) in Jabalpur. A detailed analysis of the growing stock and species composition of forest to be submerged besides survey of some of the socio-economic parameters was conducted. This report was submitted during 1994.
- Status of Flora and Fauna in and around Sardar Sarovar Project, Maharashtra by the University of Pune was submitted during 1997. It has used satellite imagery and GIS techniques coupled with an extensive programme of fieldwork to report on the density and species composition of forest area in Maharashtra.

### ***Findings***

The MSU studies demonstrated that the forests in the submergence area of Gujarat are of low density and quality. Although they could be classified as dry deciduous teak forest and must once have supported a rich fauna but pressure from human activities and soil erosion has reduced these areas to low productivity, highly degraded forest.

In Maharashtra the forest areas in the submergence zone are contiguous with those of Gujarat on the south side of the Narmada and are in the same poor condition. Reports by the University of Pune and field visit's by NCA officials suggest that overexploitation, encroachment by people for agriculture and consequent erosion has reduced much of the area to a highly degraded state. The forests to be used for resettlement in Maharashtra are also heavily degraded so that of the total designated forest area to be diverted in Maharashtra, less than 50% had significant tree cover.

Reports from Madhya Pradesh suggested that the situation is similar there. Fires, over grazing and shifting cultivation have led to degradation of the forest and caused erosion. Study by the SFRI indicated that the SSP submergence areas in Madhya Pradesh were very highly degraded and in only a small patch of 2,732 ha of very poor quality forest most of which was hacked, pollarded and damaged, was to be submerged by the SSP reservoir. Ground flora such as grasses, herbs and shrubs were altogether absent in some areas, and under-stocked, small and bushy in others. In the absence of vegetation cover and due to scarcity of water holes and the lack of fodder, the area harbours little or no wildlife of value.

## **FLORA , FAUNA AND CARRYING CAPACITY**

### **IMPACT AND MANAGEMENT**

#### **Studies and Findings**

### **Studies**

There have been extensive studies/surveys of the flora and fauna in all the project affected areas of the States of Gujarat, Maharashtra and Madhya Pradesh carried out by the identified institutions/agencies. In general, the aim of these surveys has been to establish the composition and status of the terrestrial ecological resources. This information is being used as a basis to develop mitigation measures and management strategies. Important survey work included the following

<b>TITLE OF THE STUDY / REPORT</b>	<b>YEAR OF COMPLETION</b>	<b>AGENCY</b>
The Environmental Impact Study	1983	Maharaja Sayaji University, Vadodara
Preliminary Report on First Botanical Exploration and Plant Collection from Narmada Valley	1986	Botanical Survey of India
Narmada Basin Water Development Plan: Development of Fisheries	1987	Narmada Planning Agency, GOMP.
Rapid Reconnaissance Survey of Limnological Aspects Part I, II and III	1987	Bhopal, Vikram and Rani Durgavati Universities for GOMP.
Report on the Survey of the Narmada Sagar Area.	1988	Zoological Survey of India
Note on Sardar Sarovar Project - Preparation of Environmental Work Plan for Forest and Wildlife	1988	State Forest Department, GOM,.
People's Involvement in Wildlife Management	1991	VIKSAT
Narmada River Basin Development Project: Fisheries Component.	1991	GOPA, German Consultants to the World Bank,.
Sociological Survey of the Fishing Families of the Narmada River	1991	Central Inland Capture Fisheries Research Institute, Barrackpore.
Aquatic Fauna (Fish) Studies in Indira Sagar Submergence Area.	1991	Friends of Nature Society
Eco-Environmental and Wildlife Management Studies in the Sardar Sarovar Area in Gujarat	1992	Maharaja Sayaji University, Vadodara
Wildlife Management Studies in the Submergence and Catchment Area of Narmada Project: With Special Reference to Shoolpaneshwar Wildlife Sanctuary.	1992	Sardar Sarovar Narmada Nigam Ltd., GOG
Studies on Fish Conservation in Narmada Sagar, Sardar Sarovar and it's Downstream	1993	Central inland Capture Fisheries Research Institute, Barrackpore.
Status of Flora and Fauna in and Around Sardar Sarovar Project, Maharashtra	1994	University of Pune
Impact Assessment of Madhya Pradesh Land to be Submerged Under Sardar Sarovar	1994	State Forest Research Institute

Project and Adjoining Ecosystems.		(SFRI) Jabalpur
Pre-and Post-Impoundment Limnological Studies of Narmada Basin.	1994	Bhopal, Vikram and Rani Durgavati Universities for GOMP.
Ecology and Fisheries of the Narmada Estuarine System with Special Reference to Proposed Impoundment (Sardar Sarovar Dam)	Contd.	Central Inland Capture Fisheries Research Institute, Barrackpore..

The key reports pertaining to upstream terrestrial environment and command area, which have been helpful for developing management plan, are described in following paragraphs.

### Upstream Terrestrial Environment

- ☐ The Environmental Impact Study of 1983 prepared by MSU, Baroda. This study included a botanical survey of the forest submergence areas in Gujarat. Lists of tree species and medicinal plants were compiled and recommendations for further, more detailed, work were made.
- ☐ Preliminary Report on First Botanical Exploration and Plant Collection from Narmada Valley by the Botanical Survey of India in 1986. It reported on field survey work carried out in the different phytogeographical zones of the Narmada Basin. More than 700 specimens were collected for laboratory study and a detailed species list of the flora was prepared. The areas investigated were located within the Narmada Sagar Complex (NSC), outside the submergence area of the SSP but within the same ecological zone.
- ☐ Report on the survey of the Narmada Sagar Area by Zoological Survey of India, 1988. It reported on a two-week field survey undertaken by a group of zoologists with expertise in five different animal groups in the submergence area of the Narmada Sagar Project (NSP) in Madhya Pradesh. A list was compiled of animal species which were either found to be present or had been reliably reported in the area.
- ☐ Note on Sardar Sarovar Project – Preparation of Environmental Work Plan for Forest and Wildlife by the State Forest Department, GOM, 1988. This short note lists the main flora and fauna present in the submergence area of Maharashtra and comments on their frequency of occurrence in the State.
- ☐ Status of Flora and Fauna in and around Sardar Sarovar Project, Maharashtra is a study by the University of Pune. The report, lists species of plants found in the submergence areas and reports on such aspects as the species abundance, density, frequency of occurrence etc. Report on the Faunal Studies, lists the animal species identified in the

same areas with the aid of field visits and interviews with the local population. The School of Environmental Sciences, Pune completed their study in the submergence area by the end of 1993. The final report was, however, submitted during 1997.

- ⇒ Eco-Environmental and Wildlife Management Studies in the Sardar Sarovar Area in Gujarat, 1992, by MSU reports on extremely thorough and comprehensive surveys of flora and fauna in the State of Gujarat. The surveys had the aim of assessing the present status and composition of flora and fauna in the submergence area and environs and noting the presence of any rare or endangered species. More than 70 field trips spending more than 2,000 staff days over a period of two and a half years were used to collect data in accordance with a rigorous statistical sampling regime.
- ⇒ Impact Assessment of Madhya Pradesh Land to be submerged under Sardar Sarovar Project and Adjoining Ecosystems is study, which began in September, 1990 and for which quarterly reports were submitted from-time-to-time. The study was conducted by the State Forest Research Institute (SFRI) in Jabalpur and financed by NVDA, the final report was available at the end of March 1994. Botanical Surveys have been conducted, species lists have been compiled and the condition and utility to the local population of the flora are being assessed.

### Command Area in Gujarat

Biodiversity has played a vital role in enabling agriculture to develop to its current productive state. Genetic variation has allowed plant breeders to select desirable characteristics and manipulate plant characters & productivity.

Though large part of SSP command is semi-arid & have fewer species than moist forestland, it may harbor species potentially valuable genetic resources having developed advance physical & biological defense against the harsh Environment. Detailed inventories have been directed to investigate the flora & fauna of the vast command of the SSP

TITLE OF THE STUDY / REPORT	YEAR OF COMPLETION	AGENCY
1. Study on Flora and Fauna of the Command Area of Sardar Sarovar (Narmada) Project Lying in Saurashtra and Kachchh Area (EIA studies).	Saurashtra University, Rajkot.	January 1996
2. Study of Flora and Fauna of the Command Area of Sardar Sarovar (Narmada) Project: Lying Between the Narmada & Sabarmati Rivers (EIA Studies).	Sardar Patel University, Vallabh Vidyanagar.	November 1995
3. Study on Flora and Fauna of the Command	Gujarat University,	March, 1998

Area of SS(N) Project: Lying Between Sabarmati River and Rajasthan Border, EIA Studies.	Ahmedabad.	
4. Ecological Study of Wild Ass Sanctuary and Surrounding Area Using Remote Sensing Technology for EIA.	GEER Foundation, Gandhinagar.	March 1998
5. Environmental Impact Assessment of Nal Sarovar Bird Sanctuary.	GEER Foundation	March, 1998
6. Environmental Impact Assessment of Black Buck National Park located at Velavadar in the command area of SSP.	Gujarat. Ecological Education & Research Foundation (GEER Foundation) Gandhinagar	December 1993

### **Findings**

Final studies/surveys of the terrestrial flora and fauna were conducted to identifying rare or endangered species for devising appropriate conservation measures. Detailed studies of flora and fauna in the submergence zone of Gujarat, Maharashtra and Madhya Pradesh have concluded that no valuable flora or fauna will be threatened by the SSP.

Creation of a reservoir in the present water deficit terrestrial ecology is going to significantly modify the moisture regime. The river & reservoir bank areas, which remain dry on high lands, will be most benefited both in the upstream and downstream by the changed moisture regime as well as greater water availability round the year. The impoundment of water will provide new scope for revitalization and rebuilding of a better and more productive ecosystem. The project offers a promising opportunity for recreating healthier forests.

An opportunity for environmental improvement provided by the SSP is the creation or enhancement of areas of wildlife sanctuaries in all three States. The function of these sanctuaries will be to provide habitats for fauna following submergence and to encourage development of a diverse wildlife. Some of the new finds have been reported from the areas of Shoolpaneshwar sanctuary & the forests of Narmada Sagar Complex areas like Hodgson's frogmouth bird was never reported from this region, before. This bird is found in dry bamboo brakes of the Dadiapada area in Gujarat (part of Shoolpaneshwar Sanctuary).

### **Gujarat**

*Eco-Environmental and Wildlife Management Studies in the Sardar Sarovar Area in Gujarat, 1992 Maharaja Sayaji University, Vadodara*

The study area was about 20 km. on each side of Sardar Sarovar in Gujarat & extended Shoolpaneshwar sanctuary encompassing about 1599 sq.km. area. The study concentrates upon ecology & environmental aspects of the submergence & catchment area and essentially was an extension of the earlier bench-mark study conducted during 1983 by the same institute which highlighted the positive & negative aspects of the Sardar Sarovar Project for it's upstream, downstream & command area.

The thrust areas of the study were:

- a) The biological inventory mainly concerned with the rate & endangered plant & animal species and attempt at their in-situ & ex-situ conversation & propagation.
- b) The biomass studies to highlight distribution of productive systems as an aid to salvage & monitor the existing wildlife.
- c) Restoration & enhancement of eco-system following tents of the newly evolving field of "Restoration ecology".

The survey work in Gujarat by Maharaja Sayajirao University (MSU) confirmed that much of the submergence area and surrounding catchment has all the characteristics of a highly degraded ecosystem. In particular, the north bank of the proposed reservoir had very little vegetative cover apart from a few isolated patches of forest. On the south bank there were some areas of fairly good forest cover however, located within the area designated was the Shoolpaneshwar Wildlife Sanctuary. These were somewhat degraded, but the presence of small numbers of indicator species of teak forest (*Dillenia pentagyna* and *Careya arborea* for example) showed that the area was once good forest and had the potential to recover. The study group noticed no endemic, rare or endangered species.

The study of animal life also showed a marked difference between the degraded north bank and the comparatively diverse fauna of the Shoolpaneshwar Sanctuary. The north bank was devoid of wildlife. South of the river, however, particularly within the original boundaries of the Shoolpaneshwar Wildlife Sanctuary, there was diverse fauna. Overall, 539 species of animals were identified including 173 species of birds and 28 mammals. The presence of notable species like Heartspotted Woodpecker (*Hemicircus canenze*), the Rusty spotted Cat (*Felis rubiginosa*) and the Barking Deer (*Muntiacus muntjak*) etc. suggested desirability of considering this Sanctuary as priority conservation area.

### Key Recommendations

The studies suggested enhancement plans and management strategies for eco-system of the area spread to 20 km on each side of the Sardar Sarovar in Gujarat and also the existed Shoolpaneshwar sanctuary in the vicinity of Sardar

Sarovar and Karjan reservoir and measures for sanctuary improvement were suggested. The study covered Shoolpaneshwar Wildlife Sanctuary on the left bank, right bank catchment area of Sardar Sarovar and besides right bank extended area beyond the basin boundaries. Recommendations were also made for management of aquatic ecosystem and management strategies for the study areas were suggested by the study group.

The above findings were presented before a group of experts of GOG / NCA who accepted the findings with following recommendations:

1. The group observed that any endangered or threatened endemic plant or animal species were not present in the study area, however, a few plant species like yellow variant of Palas *Butea monosperma* and *Radermaschera*, *xylcorpa* which were rare in distribution ,were noticed.
2. The Group suggested measures for controlling aquatic weeds, which though were not found in the Sardar Sarovar areas but were noticed close to the dam site. The study group expected a positive threat of invasion by these species once the lake is formed. Study group suggested measures to control undesirable species like *Eichhormia and Pistia*.
3. The Group stressed the need for catchment area treatment to control soil erosion by stabilization of the slopes and enhancement of the ecosystem. It recommended the vegetative measures as inexpensive and efficient measures for CAT works besides bamboo, grass, herbs, shrubs, and trees, which can be propagated vegetatively.

The study report also included a section on management strategies and Action Plan for the enhancement of ecosystem of the Sardar Sarovar environment.

### **Madhya Pradesh**

Studies of the Narmada basin catalogued a very rich and diverse flora and fauna but no rare or endangered plant species were identified. These studies were undertaken as part of the preparatory work for the Indira Sagar Project and so concentrated on the submergence area of the dam. Nevertheless, the study areas were in the same ecological zone as the submergence area of the SSP in Madhya Pradesh and, therefore, the same species of flora and fauna was expected to be endemic in the two areas, unless the natural biota has been disturbed by anthropogenic activity.

The study entitled "*Impact assessment of Madhya Pradesh lands to be submerged under Sardar Sarovar Project and adjoining ecosystem : flora, fauna and other listed components*" was conducted by the State Forest Research Institute, Jabalpur ,Madhya Pradesh. The MOU for the study was signed in June

1990 and study was submitted in 1994. The object of the study was to suggest compensatory conservation measures with particular reference to the floral & faunal status. Main focus of attention was to investigate into the impacts of the project on the flora & fauna within the impact area of SSP falling in the state of Madhya Pradesh.

Report of the SFRI indicated that the SSP submergence areas in Madhya Pradesh were very highly degraded. Moreover, in Madhya Pradesh, only a small patch of 2,732 ha of very poor quality forest most of which was hacked, pollarded and damaged, was to be submerged by the SSP reservoir, Ground flora such as grasses, herbs and shrubs were altogether absent in some areas, and under-stocked, small and bushy in others. In the absence of vegetation cover, and with the scarcity of water holes and the lack of fodder, the area harbours little or no wildlife of value.

The study identified that the submergence (impact) areas were mainly falling in the three districts namely Dhar, Jabua and Khargone. It indicated that the forests in the impact area were highly under stocked and their distribution by girth class very erratic the condition of impact area was not conducive to support good wildlife and as such it was not considered desirable to provide corridors for migration of wild animals as escape route during progressive filling of the reservoir. However, a plan for felling the forest being submerged was prepared.

The key recommendations / findings were:

1. To reestablish indigenous forest ecosystem and local diversity besides catchment protection work.
2. Production of fodder through agroforestry or silvi-pastoral system through management of village wastelands and production of bamboo through agro forestry.
3. Using state-of-art technology for devising the management plans for the forests under study area with special reference to protection from fire and stringent control of grazing in the development area.
4. Intensive campaign for forestry-cum-environment awareness, people's participation backed by development legislation.
5. To cater the increased requirement / demand of timber, fuel-wood etc. intensive social forestry programme shall be undertaken.
6. Introduction of quick growing exotics in interest of soil stabilization and meeting the requirement of people in short time.

7. Proposal for creating two sanctuaries namely Mathwad (34659 sq. km.) in Jhabua district and Bokrata (3559 sq. km.) in Khargone district to provide habitat for the wildlife.
8. 60 islands which will be found in the reservoir varying in extent from 1 ha to 75 ha should be left undisturbed for study of the process of natural succession and to provide refuge to bird life in the area.

## **Maharashtra**

The submergence area of Maharashtra is highly degraded forest, which has been subject to over-exploitation and encroachment for agriculture. The submergence areas are contiguous with those on the south bank of the Narmada in Gujarat and the survey has been carried out earlier by the Forest Department and more detailed work undertaken by the University of Pune. Plant life included only commonly occurring species and animal life was not abundant but there is still a wide diversity of invertebrates, reptiles and birds. Larger mammals have almost disappeared from the area although some traces of large cats were found.

The study entitled "*Status of Flora and Fauna in and around Sardar Sarovar Project: Maharashtra*" was conducted by School of Environmental Sciences, University of Pune at the instance of Department of Environment, Government of Maharashtra. the key objectives of the study were :

- ⇒ Survey of the plant and animal wealth
- ⇒ Estimation of value of existing forests.
- ⇒ Identification & Assessment of submergence area & biological elements that would be lost in submergence.

The study was conducted for a period of 18 months (1992-1994). The area covered roughly 70 Km long and 20 Km wide belts along the southern bank of Narmada River in Maharashtra. The survey was carried out in the submergence and catchment areas of Sardar Sarovar Project. The study was based on remote sensing data of 1990 for vegetation & land cover identification. Aerial photographs of the areas on 1: 60000 scale were used. Ground truth checking was done on a few points. The study included Land use pattern of study area, soil characteristics, water resources which included ground water potential & its quality. No reference of carrying capacity of wildlife has been made in the study, but carrying capacity of seeds was discussed. The methodology used was as follows:

- ⇒ The satellite images (1:50,000) and aerial photographs (1:60,000) were used to analyse a number of observable spectral elements such as brightness, colour, texture, space such as relief, shadow, shape, location

and association and temporal nature in order to combine these elements into distinctive pathways whose limits serve to determine land use and cover types.

- ⇒ The frequency, abundance & density of the vegetation in the study area, and faunal studies were carried out at more than 35 localities using quadrants of different sizes, line and belt transect methods.
- ⇒ Soil analysis was carried out for the samples collected from submergence and catchment areas.
- ⇒ Survey was done to identify ground water potential and the area was classified into different types, depending upon ground water potential.

The area under study was hilly, undulating with precipitous slopes. It was rugged with very narrow 'V' shaped valleys that hardly showed any development of floodplain. The foothill zones, however, showed very narrow alluvial patches. The hills and plateau had very thin (less than 10 cm) reddish-brown soil cover. The soil profile was ill developed and poorly defined. The organic content of soil was low in the uppermost horizon because of poor vegetative cover. The clay content of these soils was very low and they had very poor fertility. On the other hand, narrow patches of land on valley floors had thicker (20-60 cm) grayish-black to brownish-black soils that were well defined with well-developed profiles. The upper-most organic horizon was rich in clay and was relatively more fertile.

The ecological studies carried out at more than 35 localities revealed that the density of forest was in the range of 0.1 to maximum of 0.6 at Pimpalkuntha in the catchment area of Sardar Sarovar Project. The minimum cover of canopy on the basis of 0.1 to 1.0 scale indicated poor vegetation cover in the region as a whole with some patches of good vegetation in the areas in inaccessible zone. In the submergence zone, the canopy cover was found to vary between from 0.1 to 0.2. The submergence villages such as Manibeli, Chimankhedi, Dhankhedi, Bhusha, Bilgaon bear poor vegetal cover

In all 511 plant species were listed in the area. The plant inventory thus prepared revealed that none of the species were endemic, rare and endangered. Phytosociology, shifting agriculture, herbaceous flora, biomass and carrying capacity studies were included. The carrying capacity studies revealed that the soil cover in the study area is much degraded, eroded & poor.

Studies on animal resources including insect, reptiles & mammalian fauna, besides phytoplankton & zooplanktons were carried out. In all 90 insect species were identified by the study group. For studying wildlife indirect methods were used, overall 263 species belonging to class Aves & 12 each of Mammals & Reptiles were noticed.

### **Key Recommendations and Findings**

To minimize the loss of biomass and life, including wildlife, anticipated due to submergence because of filling the reservoir, following measures were recommended

1. Management of corridors for shifting of wildlife, several corridors, passing through moderate to good >0.3 vegetation cover was suggested.
2. Seed bank status of soils of low-lying (e.g. valley bottoms) areas were good, therefore, it was suggested that surface soils from such areas be used to develop vegetation (natural) in degraded areas.
3. Tree species with high diversity in the region (e.g. *Buchanania lanzan*) should be conserved on large scale, in the form of multi-region seed banks. Some of these seeds from each variety should be planted in iso-climate regions, with care, if such regions fall in degraded areas.
4. Small storages of run-off water, was suggested with adoption of local methods of soil conservation suiting to the different types of terrain found in the study area.
5. Considering the good vegetative growth along the crevices and slopes, it was suggested to develop microhabitats on difficult terrain by making use of the identified species with a view to form a pioneer stages of secondary succession on distributed habitats. This was expected to help to consolidate the substratum and pave the way for further regeneration on steep slopes and areas with poor soil cover.
6. To aim at improvement of carrying capacity of the region, efforts should be made to encourage conservation of soil on slopes and crests and restore adequate soil cover on undulating grounds, through deposition of soil, restoration of degraded lands, formation and retention of plant cover and eventually improvement of water potential.

## The Aquatic Environment

### IMPACT AND MANAGEMENT

#### Studies and Findings

##### *Studies*

In India, the overall conservation and development of fisheries is the responsibility of the Ministry of Agriculture (MOA) which directs the efforts of the State Ministries of fisheries. Amongst the benefit's of the SSP which these agencies are keen to exploit is the potential for increased fish catches in the

reservoir. A number of studies have been carried out to establish a baseline and help to predict future conditions for aquatic life behind the Sardar Sarovar dam. Many of these studies predated the planning of the SSP but have provided a useful basis for further work and have been reviewed and synthesised by the Central Inland Capture Fisheries Research Institute (CICFRI).

In addition to these early studies, studies undertaken as part of SSP planning include the following.

### **Gujarat**

- 9 Environmental Impact Analysis, in the Sardar Sarovar (Narmada) Project Studies on Ecology and Environment by Department of Botany, MS University of Vadodara (July 1983).

The Environmental Impact Study of 1983 prepared by MSU catalogued the flora along the riverbanks and examined the planktonic flora and fauna. Data on fish catches was also examined and some preliminary conclusions about the potential for increased fish yields were reached, although further in-depth studies of likely conditions in the deeper parts of the reservoir were recommended.

The report covers issues such as forestry, fishery, zoology, soils, land use, aquatic vegetation, health profile etc. Various experts did primary data generation by visiting the sites during February-July, 1982. On flora, fauna and forest, the report brings out that less hardy species had already disappeared and the hardier ones like teak, Khakhro, Timru and Gugal (all local names) are surviving. Natural regeneration of these species is almost absent. The floristic composition of the forest on the right and left banks of the river is different especially near the dam site. The difference in vegetation is due to slope/gradient and the thickness of soil layer. The density of trees on slopes is low, more so on the right bank than on the left bank. During the survey conducted, the undergrowth was not observed.

The conclusions and recommendations brings out that agriculture would markedly benefited by the project. It has advised avoidance of heavy inputs of pesticides and fertilisers in crop fields in the neighbour-hood of the dam to avoid contamination of the river and canal waters. The fisheries in the upstream by get a boost by development of inland fisheries but the fishing in the downstream stretch might face a set back particularly in the later stages of operation of dam. Suitable measures will, therefore, have to be adopted for development of breeding of Hilsa which is important fish of Narmada river. The report has suggested development of wildlife/bird sanctuaries in the vicinity of the project.

- 9 Sardar Sarovar (Narmada) Project Development Plan Vol.II Chapter-11 - Environmental Aspects - May 1983.

This Plan analyses the effect of reservoir creation on upstream and downstream areas of the dam. On flora and fauna, the report covers the composition of forest type (dry deciduous), type of slopes, fauna noticed in the area, inland fisheries etc. On fisheries, the report observed that the main groups of major fishes were Carps, Catla, Labio, Catfish, Hilsa and Prawns. It was envisaged that biology of fishing pattern would change from riverine to lake model on formation of the reservoir, which would help a different physical chemical composition of water. The changes may be positive for some species while these may be negative for others. One of the negative impact of the dam in the downstream would be on migration of Hilsa and giant Indian prawn upstream of the Narmada estuary for breeding. The dam, therefore, will affect the process of breeding and the total fish catch on the downstream of dam including deep sea.

- 9 Sardar Sarovar Project - Work Plan for Environmental Effects (Sector-Fish and Fisheries) - February 1986.

This Work Plan covered the following 3 stages:

- Investigative studies to assess the impact on fish and fisheries and suggesting mitigative measures.
- Development of fisheries in Sardar Sarovar Area.
- Development of fisheries in four ponds between Sardar Sarovar and Mahi Dam.

In the investigation stage, the thrust was to assess present state of fishing in respect of Hilsa, Prawn, correlation of catch to discharge in different seasons and change in discharge over years, and to identify breeding ground for commercially important species of fish. It was also decided to evaluate probable loss of fish downstream and probable benefit by developing fisheries. For development of fisheries in Sardar Sarovar area, proposed activities were, hydro-biological surveys, jungle clearance in the area to be submerged, stocking of fish seed etc. Training of fishermen was also a component of the work plan.

### **Maharashtra**

*Note on SSP - Preparation of Environmental Work Plan for Fisheries Development in Maharashtra, 1987.*

This note covered the reservoir details, survey of river basin, deforestation of reservoir basin, fish seed hatchery, stocking, training, management etc. The proposed work plan included location of suitable land for construction of fish seed hatchery, collection of information regarding fishermen who were desirous to take up fisheries as vocation, location of breeding ground before impoundment etc. The work relating to survey of fish fauna of Narmada river was undertaken by Fisheries Survey Division, GOI. It was observed from the survey carried out

during the period from 1958-59 to 1969-70 that this river system harbors Indian major carps to an extent of 60 percent. The other local species include *Punties sorana*, *Mystus singhala*, *Wallago attu*, *Notopterus* and *Chana*. It further emphasises that since existence of major carps was established it was essential to supplement the stock of major carps by restoring to stocking of these species in the form of fingerlings for steady fish production from the reservoir. It was estimated that considering the fisheries potential, active work force of about 2000 fishermen will be essential for harvesting the fisheries potential. Families from affected villages were to be engaged in this activity. Training and management also formed part of the work plan.

## **Madhya Pradesh**

*Aquatic Fauna (Fish) Studies in Indira Sagar Submergence Area, prepared by the Friends of Nature Society in 1991 on behalf of the NVDA.*

These studies were carried out for the Indira Sagar (Narmada Sagar) Dam. However, due to similarities in the limnological environment, comparisons can be drawn with the SSP. The status of the present fauna was assessed, the changes, which could be expected after impoundment, were predicted and the ecology of more than twenty of the most important fish species was described.

*Narmada Basin Water Development Plan for Development of Fisheries by Narmada Planning Agency, GOMP, 1984.*

This was a desk study for synthesis of the earlier Limnological and fisheries studies and development of proposal for fisheries management within the reservoir. The report gave detail description of physio-chemical characteristics and the biota in the upstream environment together with an analysis of fish catch statistics, potential impacts of impoundment and a plan for future fisheries development.

*Rapid Reconnaissance Survey of limnological Aspects Part I, II and III. 1984 undertaken by the University of Bhopal, Vikram and Rani Durgavati for GOMP.*

The stretch of the river within Madhya Pradesh was divided into three zones, east, central and west, of which the western zone abuts the SSP area. The physico-chemical and biological status of each zone was assessed by means of samples taken on several occasions at a number of sites in each of the three zones. This rapid survey provided background information for the setting up of a more detailed study, described below:

*Report on rapid Pre-impoundment Limnological Survey of Narmada river for Water Quality and Aquatic Aspects under Narmada Planning Agency - By*

*Department of Limnology, Bhopal University - 1984-85. for the areas in Madhya Pradesh.*

The objective of undertaking this study was to decide the work plan on limnological and water quality monitoring studies of western regions of Narmada River. It dealt with the eutrophication analysis of benthic fauna of the sandy basin of the river. It covered rapid survey of the western zone of Narmada River. Detailed sampling of the physico-chemical features, plankton, benthos and periphytonic organisms along with details of aquatic macrophytes were made. Particle analyses of the sediment samples from different locations were studied. Water samples were collected and analysed from different locations along the Narmada. Study included Morphometry, Physical Kinetics in the river belt, Physico-chemical characteristics, Biological characteristics such as Biomass, Plankton, Periphyton, Benthic etc., Productivity study, Energy Budget, Seasonal Impact Study, Fresh Water Resources Utilization and Fisheries potential were also studied. The report concluded that establishment of reservoir eco-system would help in economic upliftment of this area by providing power, irrigation facilities, increasing food output and fisheries development, opening vast potentials of employment in agriculture power generation, industry and fisheries. This would help to develop a thriving reservoir ecosystem with continued fish yield and preservation of the delicate, niches throughout the extent of the fresh water resource.

The report compared the findings from the impounded reservoirs on the main stream of the Narmada to that of reservoirs like Sardar Sarovar and Indira Sagar proposed to be impounded. The results showed that Bargi reservoir was ecologically healthy because it contained low BOD, chlorides, nitrate, phosphate and algal biomass and a higher concentration of dissolved oxygen. All the reservoirs including Bargi reservoirs did not show any thermal stratification. This might be mainly due to wind action, convective overturn and circulation. These lakes were newly constructed and their ecology was to be developed by succession and establishment of different communities. Narmada River was found to be on very sound ecological health and was considered the least polluted west flowing Indian river. Study made the assessment and recommendations based on the data collected and suggested a long term monitoring. Corrective measures for checking degradation of environment of the river were also discussed. Report also dealt on fisheries in the river Narmada.

The report contained details of limnological investigations in free-flowing regions of the Narmada and in some of the impoundments already completed. Analysis of around 20 physico-chemical parameters was carried out monthly, for two years. In conjunction with this, sampling was undertaken to identify and assess the abundance of large plants and of the planktonic and benthic biota. The Report included detailed analyses of the water samples collected and recommended that the water management measures should be planned and a continuous monitoring and modeling of the lake ecosystem. To prevent silting

eutrophication and deterioration in water quality, afforestation in the catchment was suggested in the report. It was pointed out that deterioration in the water quality would otherwise may affect flora and fauna including certain species of fishes. It recommended measures to prevent eutrophication.

### ***Other key studies***

*Sociological Survey of the Fishing Families of the Narmada River, by CICFRI, 1991.*

This report recorded the results of an investigation into the socio-economic status of the fishing communities of the Narmada basin. Over 8,000 families in 453 fishing villages were interviewed with the aid of a structured questionnaire and the results analysed to provide information on the income, secondary occupations, demography, fishing methods, culture, access to social services etc. of the fishing families. The report also recommended strategies for fisheries development

*Narmada River Basin Development Project: Fisheries Component, 1991, GOPA*

The German consultants to the World Bank, GOPA, studied the potential for fisheries development in:

- The catchment area of the Narmada River:
- The Command Area of the SSP:
- The estuary of the Narmada River.

The report focused on the logistic and costing of fisheries development in the Narmada basin but also provided a summary of the environmental conditions in the SSP reservoir and made recommendations for further studies.

*Studies on Fish Conservation in Narmada Sagar, Sardar Sarovar and it's Downstream is a desk review sponsored by the NCA and undertaken by CICFRI during 1994.*

The review was commissioned in October 1992 to summarize the existing baseline information on the fisheries of the Narmada basin, investigate potential adverse impacts on the aquatic environment and to recommend strategies for the conservation of important fish species. CICFRI considered over 140 articles of published research on fisheries in the Narmada, in the Indian sub-continent and in impoundments around the world. They also consulted 30 scientists and administrators familiar with the Fisheries aspects of the SSP. The Terms of Reference (TOR) for Fisheries Conservation Studies were

- Listing of all important fishery species found in the river system, which may be categorised, as rare, endangered or threatened.

- Suggest methodologies, research the endangered Fish Fauna,
- Predict the effect of impoundment on estuarine environment of the river keeping in view of the stipulations of Narmada Water Tribunal Award.

The study is a desk review of studies carried out on aquatic life in Narmada River. The emphasis in the report was on identification of endangered, vulnerable and rare species and their conservation through in-situ and ex-situ measures.

The recommendations of the study in the form of Action Plan were contained in the report. The Action Plan had suggested measures to be implemented during pre-impoundment and post-impoundment stage. The Pre-impoundment suggestions included

- Tree felling plan prior to submergence. This would enable smooth execution of exploitation programme.
- Action Plan for Post Impoundment Stage covers stocking norms, multi species stockings based on eco-oriented approach, observation of closed season for allowing possible natural recruitment.

The study covered the Narmada river system and the consequences and impoundment; it enlisted important fish fauna and categorized them under rare endangered or threatened categories. It deliberated on impact of varied land use pattern, fisheries scenario consequent to human intervention, fisheries scenario of Narmada river in space and time besides detailed work out on threatened fish fauna of Narmada river system with reference to Narmada Sagar, Sardar Sarovar and it's downstream. The report also gave detailed description of the rehabilitation, methodologies for endangered fish fauna including artificial propagation. The report described in detail the possible impact of impoundment on estuary at 10th, 30th, 45th year of development.

Mitigation for formation of hydro-sulphuric sludge was described. Management methodology and action plans were suggested. The report stated that as per IUCN Red data book of 1988 does not contain any fish species from India. It also stated that Zoological Survey of India has also not published any list pertaining to threatened fishes of India. However, the study proposed eight species of fishes for consideration as vulnerable from the Narmada River. In other words, there was no threat to the gene pool of the fishes. As these fishes are wide in their geographic distribution. Study suggested rehabilitation programme for fishes through in-situ and ex-situ conservation.

*Ecology and Fisheries of the Narmada Estuarine System with Special Reference to Proposed Impoundment (Sardar Sarovar Dam), is an ongoing study begun in 1988 by CICFRI.*

This comprises five sub-projects, as follows:

- 9 Monitoring of ecological parameters:
- 9 Assessment of fishery resources
- 9 Biological investigations and stock evaluation studies

- 9 Artificial breeding and rearing of Hilsa;
- 9 Identification of point pollution sources and monitoring of discharges.

The study has been extended to develop models of estuary water quality under different scenarios. In addition, pre-impoundment investigations for developing rational management practices are also being undertaken by CIFCRI.

## COMMAND AREA DEVELOPMENT

### **Findings**

The command area encompasses twelve districts, viz. Bharuch, Vadodara, Panchmahals, Kheda, Ahmedabad, Gandhinagar, Mahesana, Bhavnagar, Surendranagar, Rajkot, Banaskantha and Kutch. Total number of the talukas of these districts wholly or partially covered in the command is 62 and about 3344 villages of these talukas are expected to be served by the project for irrigation.

The Canal system would command a gross area of 3.43 M ha. and cultivable area of 2.124 M ha. It is envisaged to irrigate annually 1.792 M ha. with the availability of 9 MAF of surface water from the project. From management point of view, for laying down a set of prescriptions for crop pattern, water allocation and management, conjunctive use etc., the command has been divided into regions based on the following factors:

- (a) Annual rainfall
- (b) Land irrigability class including drainage characteristics
- (c) Ground water quantity and quality in terms of ground water table and salinity of water in the upper aquifers
- (d) Alignment and the command of major branches.

Considering these factors, the command has been divided into 13 regions. The main regions, their names, GCA and CCA are as follows:

Sl.No.	Name of the region	Region No.	GCA	CCA
1.	Sankheda-Savli	1	2531	1619
2.	Sinor-Vadodara	2	2731	1876
3.	Bharuch-Amod	3	1532	849
4.	Vagra-Jambusar	4	1113	368
5.	Mehmedabad-Daskroi	5	2957	1923
6.	Sanand-Kadi	6	1817	1257
7.	Dholka-Dhandhuka	7	4760	2643
8.	Limdi-Botad	8	2940	1826

9.	Halvad-Malia	9	2684	1680
10.	Viramgam-Dasada	10	3446	2421
11.	Sami-Harij	11	1917	1152
12.	Radhanpur-Vav	12	4628	3197
13.	Rapar-Mundra	13	1229	428
	All regions	14	34285	21239

The Soil Survey Manual (IARI 1970) recognises six irrigability classes.

Class 1 : Lands that have few limitations for sustained use under irrigation.

Class 2 : Lands that have moderate limitations for sustained use under irrigation.

Class 3 : Lands that have severe limitations for sustained use under irrigation.

Class 4 : Lands that are marginal for sustained use under irrigation because of very severe limitations.

Class 5 : Lands that are temporarily classified as not suitable for sustained use under irrigation pending further investigations.

Class 6 : Land not suitable for sustained use under irrigation.

## PUBLIC HEALTH

### IMPACTS AND MANAGEMENT

#### Studies and Findings

##### *Studies*

A large number of studies have been carried out on the health profile of villages in the three beneficiary States. The key studies are summarised below:

1. Narmada Programme - Schistosomiasis - Back-to-Office Report by Good land. 1986 described the schistosomiasis assessment carried out. Consultant to the World Bank, the National Institute of Communicable Diseases (NICD) and the World Health Organisation (WHO). The assessment confirmed the Incidence of schistosomiasis in Gimvi Village, Ratnagiri District, Maharashtra about 700 Km away. This is the only location where the disease had been recorded. The report also concluded that the Ratnagiri pocket was stable and that concerns expressed over the spread of schistosomiasis due to the SSP were unfounded.
2. Proceedings and Recommendations of the Meeting on Schistosomiasis Research and Surveillance held at NICD on 22nd November 1985. In 1985

the NICD carried out a survey of several Narmada submergence villages In Gujarat and Madhya Pradesh. Several thousand urine samples were tested for parasite eggs yielding negative results. The results and conclusions of the survey were presented and discussed at the 1985 workshop.

3. Disease Profile of Command Area by the Commissariat of Health, Medical Services and Medical Education (SCHMS), 1986 contained an analysis of the disease profile in the Command Area and formed the basis of the Gujarat state work plan for environmental health. As part of the study, the potential Impacts of the SSP on public health were considered and discussed with the World Bank and GOI officials. Conclusions from these consultations were used to assist in formulation of the work plan on health.
4. Health Statistics, GOM, 1987. The State department of health produced a report on the health profile of 33 project-affected villages in Dhule District, Maharashtra. This report concluded that:
  - Schistosomiasis was only found In one village and was unlikely to spread because of the SSP;
  - The influx of labourers, formation of irrigation canals and cesspools along the canals could lead to Increased Incidence of malaria;
  - Measures should be taken to prevent the possible spread of cholera and gastroenteritis due to misuse of Irrigation waters for washing etc.
  - Filaria is not present in SSP areas but careful monitoring should be undertaken to ensure it does not enter the area. These results were used to formulate the Initial GOM Action Plan on public health, which was subsequently modified in the years 1991-92. Final revised Action Plan way submitted in 1993.
5. Health Statistics 1982-84, GOMP: This study, published by GOMP in 1985. Presented an analysis of the distribution and prevalence of water-related diseases In the Narmada Basin and provided baseline data for the State Action Plan for public health). The study concluded that malaria; guinea worm infections, goiter, gastroenteritis and worm Infestations were the most common diseases. Schistosomiasis and leishmaniasis were not found to be endemic to the area. The study concluded that careful monitoring for malaria and filaria would be needed & that guineaworm was likely to be eradicated once the reservoir was full.
6. The Sardar Sarovar Narmada Project “Studies on Ecology and Environment” by Maharaja Sayajirao University (MSU), Vadodara in 1983 considered public health in earlier Chapter. To obtain an overall picture of the health profile of the Narmada River, MSU visited 42 sites from Hamfeshwar to the river

mouth. Data was collected from public health centres and public health unit's to establish the rates of occurrence and distribution of disease over the previous five years. This data was used to produce an assessment of the likely health impacts upstream and downstream of the dam site.

7. Existing disease distribution data indicates that malaria occurs sporadically throughout the region from the Narmada source to it's estuary in the Gulf of Cambay. Levels of malaria are generally low although the anopheline mosquito vector has the potential to proliferate in the reservoir, drawdown area and canals. Numerous studies have been conducted on the incidence of malaria in India by, amongst others, the Malaria Research Centre (MRC) and Kaira This work is summarised in a consultant's report to the World Bank.
8. Health Aspect and Water Quality by the NVDA, 1988, reports on the status of the more common diseases In the Narmada Sagar area but suggests that it's conclusions apply also to the SSP. The report also outlines the likely health impacts of submergence.
9. Environmental Impact Assessment study of Water Related Diseases in Sardar Sarovar Project command area, Gujarat, Volume-I & Volume-II, This study was commissioned by SCHMS, Gandhinagar, Gujarat in 1992 to ascertain the likely impacts of project on public health living in the command area & in downstream areas of the dam. Volume-I of the study contained preliminary report on Water Related Diseases in the command area. Volume-II of the study presents profile of Water Related Diseases in the SSP command, likely consequences of the project when it becomes operational based on the morbidity data of Water Related Diseases available with SCHMS, Gujarat. The main objectives of the study were as follows:
  - a) To collect base line data.
  - b) To collect time series data on Water Related Diseases, from health institutions located in CA & Downstream of dam.
  - c) To provide indicators of the problems areas for specific diseases needing special focus & in-depth studies.
  - d) To indicate positive impacts on preventive health.
  - e) To indicate cost effective mitigatory measures to control diseases.
10. Baseline survey to assess the health & morbidity pattern in the rising of SSP. (Phase-I) 1995-96 by Department of preventive & social medicine of T.N. Medical College & B. Nair Charitable Hospital, Mumbai and Directorate of Health Services Maharashtra. This study was aimed at epidemiological surveillance in the vicinity of SSP to study it's impact on health & morbidity plants of the population directing or indicating affected. The main objectives of this study were:
  - a) To study the socioeconomic & demographic profile.

- b) To determine the status of health, morbidity & mortality pattern.
- c) To study the changes & degree of impact in the status of health, morbidity & mortality pattern.
- d) To develop suitable indicators for monitoring.
- e) To establish effective disease surveillance mechanism.
- f) To strengthening existing facilities.

### ***Findings***

The MSU study of 1983 and other studies concluded that the most of the important diseases in the Narmada Basin were malaria, scabies, dysentery and diarrhea of these diseases, only the threat of increased incidence of malaria is the prime concern of the SSP project authorities. Occurrence of the other diseases is, in general, results from poor hygiene, poor sanitation and the lack of drinking water. The study concluded that the incidence of these hygiene-related diseases would be reduced by better water availability.

Several other studies have also identified malaria and Japanese Encephalitis as the greatest potential health threats in the SSP affected areas, but have indicated that timely mitigative measures would greatly reduce any risk. The SCHMS report, for example, pointed out that much of the Command Area was already under irrigation and that the addition of new areas would not have a marked impact on malaria incidence. Moreover, the vector would not be able to breed in the irrigation branch canals under flow. The report did recommend, however, that the incidence of malaria should be subject to surveillance and recommended that practical measures to be implemented where necessary, to protect agricultural communities.

A consensus was reached that schistosomiasis will not constitute a serious health issue. This view was put forward in the NICD report and confirmed by the subsequent World Bank/WHO missions.

According to the MSU report of 1983, filaria is confined to the coastal areas of Saurashtra and South Gujarat. Filaria has also been reported in Surat, near to the reservoir site, but the study concluded that the disease was unlikely to spread to the reservoir area.

The baseline study conducted by the Department of Health & Medical Services, Maharashtra, recommended for :

- ❖ Posting 2 Medical officers one at Kevadia & other at floating dispensary with required health assistants.
- ❖ Existing norms of 1 PHC for 2000 population shall be modified to 1:1000. This called for 16 PHC's instead of 8 PHC suggested on the final work plan on health of GOM in 1993.
- ❖ New upgraded health unit with OT & Lab. facilities at Dhadgaon & Mulgi.

- ❖ A new rural hospital at Mulgi or Kathi.
  - ❖ Establishment of anganwadis to cater to the nutritional needs of children & other programmes for nutritional necessities.
  - ❖ Additional posts of lab. Technical at each PHC.
  - ❖ One dispensary for each 3-4 villages in remote areas.
  - ❖ Educating youth, periodic spraying of deltamethrine, for which organizational setup has been proposed.
- ❖ The NVDA report concludes that, given the rise of the water table and consequent reduced potential for cyclopic proliferation, the likelihood that guinea worm infestation will increase is extremely remote.

## SEISMICITY AND RIM-STABILITY

### IMPACT AND MANAGEMENT

#### Studies and Findings

##### *Studies*

The Geological Survey of India (GSI), Central Water and Power Research Station (CWPRS) have carried out studies of reservoir-induced seismicity (RIS) and rim stability. The principal studies are described below :

University of Roorkee. 1980. Geological and Seismological Investigations of the Environs of Narmada Valley around Navagam Dam Site in Gujarat :

Roorkee University carried out a micro seismic survey of the SSP dam site for a period of 6 months in 1980. This survey indicated that no active lineament could be identified in the region, the river bed fault did not show any seismic activity and the magnitude of an earthquake would normally not exceed 5 and. in any case, be under the design specification of 6.5 (Richter Magnitude).

G.S.I. 1981-82 and 1982-83. A Geotechnical Report on the Reservoir Competency Investigations In Parts of Sardar Sarovar Area. Bharuch & Vadodara Districts. Volume I & II.

The first volume of this report describes the background geology and tectonics of the SSP site and analyses the problems of reservoir seepage and landslides in order to assess reservoir competence. Brief conclusions are presented and recommendations made for additional work. A second volume was published in 1983 in which further information was presented on the composition and location of faults and the risk of landslides.

Shenol et al. 1982 presented a paper at the New Delhi conference on the significance of seismotectonic aspects on reservoir development.

The paper discussed the Narmada valley reservoir projects as a case study and demonstrated how a conservative horizontal seismic coefficient had been adopted for the dam design to ensure protection of the structure from potential RIS.

Balsundaram, M.S. 1982. Sardar Sarovar Project.

A Geotechnical Report Compiled and Edited for the Government of Gujarat.

This report gives a full account of the geotechnical aspects of the SSP and was conducted during feasibility Investigations early in 1982

MSU. 1983. The Sardar Sarovar Narmada Project Studies on Ecology and Environment.

The MSU report contains a full description of the geology, tectonics and pattern of fault structures within the Narmada Basin. MSU based their report on the Initial work of the Geological Survey of India and Government of Gujarat but carried out additional verification surveys using ground checks, aerial photographs and topographical maps.

NVDA published a Position Paper on Seismic Studies in January, 1986 summarising the results of detailed studies on the seismic aspects of the Narmada Sagar dam.

Krishna, J. 1989. Dams and Seismicity.

In this document, Dr Krishna presented a layman's guide to the issue of dams and seismicity. He described in some detail the relationships between reservoir depth, base rock materials, fissure zones and the conditions needed to induce an earthquake. He also discussed the likelihood of reservoirs to Induce seismic activity and cited case studies from. amongst other, India, the former USSR and Africa.

G.S.I. 1990. Study of the Rim Stability of the SSP.

This is an ongoing study of the assessment of rim stability in the states of Madhya Pradesh and Maharashtra. The study has established that the reservoir rim is stable but has recommended that further seismic refraction studies be completed by CWPRS to confirm these findings.

GOI. 1993. Sardar Sarovar Project Seismicity and Sardar Sarovar Dam.

This report, produced by the Central Water Commission for the NCA provides a concise summary of work done to date on the seismological aspects of the SSP 1401. The report begins with a description of the tectonic setting of the dam and goes on to discuss the evolution of earthquake dam design parameters including the seismic coefficient and Design Basis Earthquake (DBE). The general conclusions of the study, as reflected in earlier reports, are that the design parameters for the dam comply both with national and International standards and that safety requirements have been scrutinised and approved at the highest level.

## Findings

### Seismic Sources

The data on earthquake occurrence in peninsular India show that the MCE can have a maximum magnitude of 6.5. The fault and tectonic lineaments of relevance for SSD are as follows:

Rajpardi and associated faults forming the Eastern boundary of Cambay basin West Coast seismotectonic province.	shortest distance to the lineament from dam site is 55 km towards West.
Barkhadi-Barwani fault.	Shortest distance from site is 110 Km East.
Piplod fault.	Shortest distance 12 Km South of dam site.
Tilakwada-Bardoli fault.	Shortest distance 17 Km North of dam.

While it is plausible to apply the earthquake with Richter magnitude 6.5 only to cases (i) & (ii) above which are the only seismogenic lineaments that are capable/active, a 'worst case scenario' of a Richter magnitude 6.5 earthquake has been postulated at an epicentral distance of 12 Km with a depth of focus of 18 Km for case (iii) in order to have conservative estimates of ground motion characteristics for design purposes.

It has been concluded that reservoir impoundments may in some cases trigger earthquakes where tectonic deformations already exist in the geological structures. The threat of reservoir-induced seismic activity by the SSP is extremely low. The dam has been designed to accommodate the Maximum Credible Earthquake (MCE) Richter Mag. 6.50 and as it is established that the levels of Reservoir Induced Seismicity have never exceeded 6.3, the safety requirements are adequately met with.

The rim of the reservoir has been found to be stable; further seismic refraction studies are in progress to strengthen this finding.

## THE CULTURAL HERITAGE

### IMPACT AND MANAGEMENT

#### Studies and Findings

##### *Studies*

The three State governments carried out a complete survey of cultural and religious sites within the submergence zone under the direction of the project proponents. The principal aim of these studies was to list all archaeological sites, identify and name any sites under state-protection and further identify sites of religious or cultural significance which, although not protected under national law, are of sufficient value to merit relocation. These studies are summarised below :

##### **Gujarat**

- 9 Archaeological Survey of Nineteen Villages submerged by Sardar Sarovar Reservoir, 1989: - The Department of Archaeology was instructed to carry out a survey of archaeological sites in 19 villages of the proposed SSP submergence zone in Gujarat. By June, 1989, 12 villages had been surveyed. The initial report, submitted by the Director of Archaeology, contained a full list of villages surveyed and photographs of the Shoolpaneshwar and Hamfeshwar temples. Two further studies of sites in the remaining seven villages were carried out in March 1992 and a supplementary report issued.

##### **Maharashtra**

- 9 ***State Department of Archaeology*** : A survey was carried out by the Department of Archaeology of cultural sites in 24 villages of Akkrani Taluk and nine villages from Akkalkuva Taluk, Dhule District. A brief summary note was submitted by the Director of Archaeology in February 1992 which stated that no state-protected monuments were located in the area but recommended the preservation of monuments at the village of Manibeli, Dhule District.

##### **Madhya Pradesh**

- 9 ***State Department of Archaeology and Museum*** : The Archaeology Department of Madhya Pradesh compiled a detailed report of archaeological sites in 120 villages likely to be affected by SSP. A second study of 73 villages was completed in July, 1991. Each study contained photographs together with detailed descriptions of the current use and historical significance of the sites.

In addition to baseline studies on archaeological aspects, work has been carried out on the anthropological heritage of the Narmada Basin including examination of evidence of ancient dwellings and cultural artifacts. The principal studies in this area are described below.

- 9 Anthropological Survey of India. Narmada Salvage Plan : The Narmada Salvage Plan contains detailed background data on palaeo-anthropological, human ecological and other aspects of the Narmada valley. By May 1992, surface scanning of 17 sample villages coming under submergence had been carried out, 424 specimens including ancient tools etc had been collected.
- 9 Anthropological Survey of India. Peoples' of India : This project entailed a complete survey of 33 tribes of India including those of the Narmada Basin. The study covered all aspects of tribal culture in India and was published in 61 volumes in 1992.
- 9 Parishad, A.K. Survey of Material Culture in the Narmada Valley : Work was completed and a report published by the National Museum of Humanity, Bhopal, on cultural objects from tribal artisans in Madhya Pradesh in 1990. Copies of the interim report were circulated to the Ministry of Environment and Forests and the Narmada Control Authority in April 1991.

### ***Findings***

No centrally or State-protected cultural sites are located in the submergence area of the SSP. Baseline studies, however, identified several sites which were considered of cultural value and should be relocated where practicable.

### **Gujarat**

The Department of Archaeology concluded that the temples of Shoolpaneshwar and Hamfeshwar were important monuments and should be shifted to high ground. Six other temples within the submergence zone were not considered of sufficient value to merit relocation.

### **Maharashtra**

No State-protected sites were found in the villages surveyed; however, the Department of Archaeology and Museums recommended the relocation and proper preservation of the Shoolpaneshwar temple in the village of Manibeli, which lies on the border of Gujarat and Maharashtra states.

### **Madhya Pradesh**

Following the initial survey of the State Department of Archaeology and Museums, in 193 villages yielded 36 monuments, 88 images and 33 archaeological mounds as per Action Plan 1993. No state-protected anthropological sites were found within the submergence zone.