Comprehensive EIA Report

Environmental Impact Assessment of Proposed Mahadayi Hydroelectric Project

Volume I

Sponsor
Karnataka Power Corporation Limited, Bangalore

National Environmental Engineering Research Institute
Nehru Marg, Nagpur - 440 020

September 1997

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FOREWORD

With a view to mitigating the chronic power shortage in the State, the Karnataka Power Corporation Limited (KPCL), Bangalore proposes to tap the large hydropower potential of the west flowing Mahadayi (Mandovi) river. The Mahadayi Hydro Electric Project (MHEP) envisages construction of three dams across the main river, four diversion dams on its tributaries, and three underground power houses with a total generating capacity of 345 MW. The Government of Karnataka has also proposed to divert 255 Mcum of water from the Mahadayi basin to the adjacent Malaprabha basin for irrigation purpose. To ensure that the proposed developmental activities are sustainable and environmentally sound, and that the environmental consequences are recognised early and mitigation measures integrated in the project, the KPCL retained the National Environmental Engineering Research Institute in July 1995 to conduct EIA for the Project.

This comprehensive EIA report is presented in two volumes. Volume I forms the main report, and presents the baseline status of the environmental components in the project area, viz. air, water, land, biological and socioeconomic aspects. Significant potential impacts during preconstruction, construction and operational phases of the MHEP have been identified, predicted and evaluated. An Environmental Management Plan for mitigating adverse impacts and maximising beneficial impacts has also been delineated. Volume II contains the annexures to the main report including data generated during November 1995 to October 1996 on the ecology of the Mandovi in Goa.

The co-operation and assistance rendered by the officials of KPCL and the Irrigation Department, Government of Goa in the completion of this study are gratefully acknowledged. Thanks are also due to the officials of a number of organisations who readily furnished information for the study.

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Nagpur
September 1997

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ACRONYMS USED

AAQS	:	Ambient Air Quality Status
ALWG	:	Average Linkage Within Group Method
AQMS	:	Ambient Air Quality Monitoring Station
ASP	:	Activated Sludge Process
BFDA	:	Brackishwater Fish Farmers Development Agency
bgl	:	below ground level
BHC	:	Benzene Hexa Chloride
BIS	:	Bureau Of Indian Standards
CCB	:	Cultivable Command Area
CDO	:	Central Design Organisation
CEC	:	Cation Exchange Capacity
CFU	:	Colony Forming Unit
CGWB	:	Central Ground Water Board
cm	:	centimeter
COD	:	Chemical Oxygen Demand
CPCB	:	Central Pollution Control Board
CVP	:	Climate Vegetation Productivity
CWC	:	Central Water Commission
dBA	:	decibel
DDT	:	Dichloro Diphenyl Trichloroethane
DO	:	Dissolved Oxygen
DPR	:	Detailed Project Report
EA	:	Environmental Assessment
ECe	:	Electrical conductivity
EIA	:	Environmental Impact Assessment
EL	:	Elevation Level
EMP	:	Environmental Management Plan
FRL	:	Full Reservoir Level
FSI	:	Forest Survey of India
GOI	:	Government Of India
ha	:	hectares
HQ	:	Headquarter
hr	:	hour
IRD	:	Integrated Rural Development
ISO	:	International Organisation of Standards
IST	:	Indian Standard Time
IVI	:	Importance Value Index
KPCL	:	Karnataka Power Corporation Limited
KPCB	:	Karnataka Pollution Control Board

ACRONYMS USED (CONTD...)

lps	:	litre per second
MCE	:	Maximum Credible Earthquake
Mcum	:	Million cubic meter
MEF	:	Ministry of Environment and Forests
mg	:	milligrams
MHEP	:	Mahadayi Hydro Electric Project
min	:	minutes
mld	:	million litres per day
mm	:	milli meter
MSL	:	Mean Sea Level
mS	:	milli Siemens
MW	:	Mega Watt
m	:	meter
NGO's	:	Non Governmental Organisations
NTU	:	Nephelometric Turbidity Unit
NWDA	:	National Water Development Agency
PAP	:	Project Affected People
PAV	:	Project Affected Village
PET	:	Potential Evapotranspiration
PHC	:	Public Health Centre
ppm	:	parts per million
ppt	:	parts per thousand
PWD	:	Public Works Department
QOL	:	Quality Of Life
R & R	:	Rehabilitation and Resettlement
sec	:	seconds
SHW	:	State Highway
SPCB	:	State Pollution Control Board
SPM	:	Suspended Particulate Matter
SPSS	:	Statistical Package For Social Sciences
sq.km	:	square kilometer
TMC	:	Thousand Million Cubic feet
TOR	:	Terms Of Reference
TSS	:	Total Suspended Solids
T/ha	:	Tonnes per hectare
UGPH	:	Under Ground Power House
UPGMA	:	Unweighted Pair Group Method Arithmetic Averages
USEPA	:	United States Environmental Protection Agency
WASP	:	Water quality Analysis and Simulation Programme
yr	:	year
µg	:	microgram
µS	:	micro Siemens

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1. Introduction

1. Introduction

1.1 Preamble

The state of Karnataka has been a pioneer in power generation from the early 20th century till the 1960s. The state set up the first hydel power station of 42 MW capacity as early as in 1902. Due to rapid industrialization, increased energy consumption in agricultural sector and closure of some of the hydro electric projects, the state has been experiencing severe power shortage continuously since 1972. Of the total power generated in the state, 2524.75 MW is hydro power while thermal power constitutes 967.92 MW. The power scenario in the state of Karnataka is presented in **Table 1.1.**

The estimated hydel power potential in the state is about 7750 MW of which only 2524.75 MW has been harnessed so far. The ongoing hydel power projects viz. Kodasalli, Kadra, Sharavathi Tail Race, Brindavan and Badra (additional unit) would contribute 528 MW to the state grid. Despite continuous efforts by the state to maximise import of power from the neighbouring states/central projects, there has been a persistent shortage of power supply (**Table 1.2**). The demand for energy at the end of VIIIth Plan has been of the order of 24,275 million units as against the total availability of 13,275 million units. Thus, there is a gap of 11,000 million units per annum between the demand and supply.

As part of the efforts to mitigate the power shortage in the state, the Government of Karnataka has proposals to tap the large hydro power potential of the west flowing Mahadayi river. The installed capacity of Mahadayi Hydro Electric Project (MHEP) would be 345 MW. The annual energy generation from this project would be 828 MU. The project envisages construction of three dams on the main river, four diversion dams on its tributaries, diversion tunnels/channels, water conveyance systems, an underground power house and two dam site power houses. The Government, under GO No. PWD.132.PPC 88 dt. 5.11.88 has directed the Karnataka Power Corporation Ltd., (KPCL) and the Irrigation Department to provide in the project for diversion of 113 Mcum of water from Kotni reservoir to Malaprabha river to augment the irrigation potential of the Malaprabha irrigation project. In addition, 142 Mcum of water from the Haltar, Kalsa and Potli nalas is proposed to be diverted to the Malaprabha sub-basin for irrigation. The schematic of the proposed MHEP is depicted in **Fig. 1.1**.

As per the Ministry of Environment and Forests, Government of India guidelines for major developmental projects, environmental impact assessment (EIA)

Table 1.1

Power Scenario in the State of Karnataka (March 1995)

Sl. No.	Item	Installed Capacity (MW)
1.	KPCL stations including thermal stations	3126.15
2.	Karnataka Electricity Board stations	348.52
3.	Privately owned stations	18.00
4.	Central share	729.00
	Total	4221.67

Source : KPCL

Table 1.2

Power Requirement / Supply in Karnataka

Sl. No.	Item	Power (MW)
1.	Power Requirement	3980
2.	Availability including central share	3224
3.	Deficit	756
4.	Percent Deficit	19

Source : KPCL

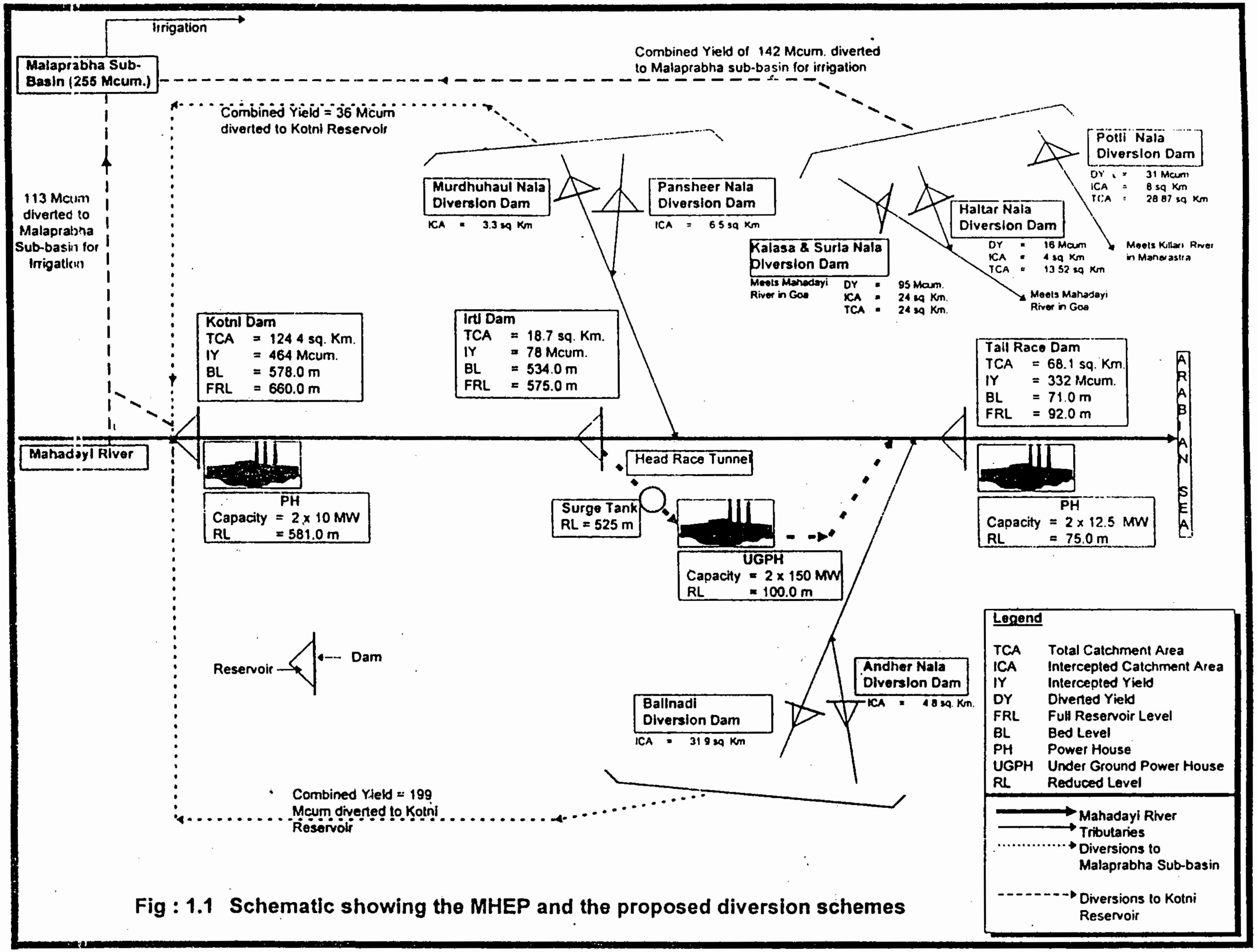


Fig : 1.1 Schematic showing the MHEP and the proposed diversion schemes is mandatory and should form an integral component of the feasibility study. In keeping with this requirement, the KPCL, the project proponent, has retained the National Environmental Engineering Research Institute (NEERI) to prepare the Comprehensive EIA report for the proposed Mahadayi project vide their Work Order letter No.CIJI E/MHD/ENV dt.April 6, 1995.

1.2 Objective of the study

The objective of the study is to ensure, through the following steps, that the developmental options under consideration in the MHEP are environmentally sound and sustainable and that any environmental consequences are recognised early and integrated in the project design.

* Assessment of the existing environmental status covering major environmental components (water, land, biological, socio-economic, health and cultural) of the project area in Mahadayi river basin in Karnataka and Goa

* Identification of potential impacts on various environmental components during pre-construction, construction, and operational phases of the project

* Prediction of significant impacts through identification, calibration and validation of appropriate mathematical /simulation models

* Quantitative evaluation of impacts of the project through appropriate evaluation techniques

* Preparation of an Environmental Management Plan (EMP), outlining control strategies to be adopted for minimising adverse impacts, and to delineate post-construction environmental quality monitoring programme to be pursued by the project proponent

The detailed Terms of Reference (TOR) for environmental assessment of the project are at **Annexure 1.1**.

1.3 Scope of Work

In keeping with the TOR, the broad scope of work under each environmental component is as under:

1.3.1 Air and Noise Environment

* Assessment of ambient air quality, collection and compilation of meteorological data

* Estimation of changes in microclimate due to enhanced evaporation losses and atmospheric humidity arising from the proposed impoundments

* Prediction of impacts arising out of increase in noise levels, dust concentration, and fugitive emissions during construction activity

1.3.2 Water Environment

* Study of surface and ground water resources with respect to quality and quantity in relation to the geomorphological/ geological setting and climatic features of the study area

* Estimation of possible siltation in the river /reservoir(s)

* Prediction of the impact of the project on existing/proposed drinking water supply/irrigation schemes dependent on Mahadayi river

* Identification and study of water holes

* Prediction of changes in salinity of river water and water quality in the reservoir(s)

* Overall impact of the project on the naturally established river regime upstream and downstream of the dam site(s)

* Prediction of impacts of the projects on natural process of sand replenishment along the beach ecosystem of Goa, sand bar formation at the mouth of rivers, general navigation and navigability of Cumbarjua canal

* Impact on environment and wild life due to partial diversion of yield from the catchments of Kalsa, Haltar and Potli in Karnataka to Malaprabha river

1.3.3 Land Environment

* Study of land use pattern, physiography, soil quality, land capability and irrigability classification of soils including identification of tidal marshes/wet lands and saltpans likely to be affected in the project area

* Prediction of impact on agricultural production in flood plain /Khazan paddy lands in Goa

* Prediction of loss of mineral resources due to impoundage and construction activity

* Identification of the effects of seismicity in the region due to the recent earthquake at Killari (Maharashtra) and recommendations for safety measures in the design, construction and maintenance of structures

1.3.4 Biological Environment

* Collection of available information on flora and fauna, including rare and endangered species in the project area

* Assessment of species diversity, density, abundance and vegetation cover in the project area

* Suggestions for compensatory afforestation

* Assessment of the ecology and biology of creeks, backwaters and streams influenced by tidal action; and mangrove ecosystem of Mandovi river

* Estimation of anticipated impacts on fisheries and other useful aquatic flora and fauna and the mangrove ecosystem due to the proposed project

* Prediction of the natural process of dilution of salinity during monsoon, and the consequent influence on mangroves, fish breeding and other marine life processes

1.3.5 Socio-economic, Health and Cultural Components

* Collection of baseline data on demography, infrastructure, economy, health status of community, and existing facilities for social welfare and health care

* Estimation of disruption in social life due to relocation of human settlements and assessment of rehabilitation requirement

* Assessment of existing quality of life in the project affected villages and anticipated changes in the same due to the proposed project

* Collection of baseline data on prominent endemic diseases, and morbidity and mortality rates in the project area

* Prediction of impact due to change in population, density, and distribution of emigrant construction workers

* Assessment of aesthetic impairment due to the proposed project activities

* Collection of information relating to monuments/sites of cultural, historical, religious, archaeological or recreational importance including wild life sanctuaries and national parks likely to be affected by the proposed project

1.4 The Study Area

The study area encompasses the area within the states of Karnataka and Goa along the course of the river Mahadayi, from its origin in Khanapur taluka of Belgaum district, and the catchment area of the river which is proposed to be tapped for the proposed developmental activity. Also areas of concern are, sites for dams/ diversions/ power houses/ rehabilitation townships, areas surrounding the dam/ diversion sites and submergence areas.

The land environment covers a catchment area comprising 500 m/ 5,000 m on either side and all along the stretch of the Mahadayi/ Mandovi river and estuarine region. The river ecosystem in Goa has been studied in detail.

1.5 Methodology

In keeping with the scope of work, the methodology followed in the study comprised the following:

* Inventory of sources for data acquisition

* Discussions with the officials of agencies/ departments identified for the project implementation

* Field visits to the project area for collection of baseline data during the three seasons

* Collection of monthly water samples at various locations in river Mahadayi/ Mandovi in Goa region to study ecological aspects

* Socio-economic survey of the population in the project area

* Desk work on identification of impacts due to the various project activities, prediction and evaluation of these impacts including computer modelling studies, and preparation of environmental management and monitoring plan for eliminating/ mitigating adverse impacts, if any.

1.6 Organisation of the report

This comprehensive EIA report is presented in two volumes; volume I forms the main report and volume II contains the Annexures to the main report including data generated during November 1995 to October 1996 on the ecology of the Mandovi in Goa. The executive summary is presented separately.

Volume I of the report addresses issues pertaining to the impacts of the proposed Mahadayi Hydro Electric Project on the environment and ecology of the river Mahadayi, the area on either side of the river in the states of Karnataka and Goa as also the project sites where the proposed construction activities are to be undertaken, and the submergence areas. The report, presented in eight chapters, commences with an introduction to the project (Chapter 1) including its background, objectives and scope.

Chapter 2 presents a resume of the institutional, legislative and regulatory considerations for environmental assessment of developmental projects at international, national and state levels, and the procedures involved in the clearance of projects by the competent authorities.

Chapter 3 describes the project setting and brings out details of the proposed components of the project including, the alternatives considered, the construction schedule and the estimated cost of the project.

Chapter 4 presents the baseline environmental status of the study area with respect to air, water, land, biological and sociocultural components of the environment.

Chapter 5 deals with the identification of environmental impacts due to the proposed project activities through impact net works with focus on significant impacts.

Chapter 6 presents the prediction of impacts due to the proposed construction activities and due to the altered flow regime in river Mahadayi (Mandovi) following the construction of dams across the river in Karnataka through appropriate modelling studies.

Chapter 7 presents detailed environmental management and monitoring plan for the pre-construction, construction and post-construction phases to be implemented by the project proponents and various government agencies.

Chapter 8 on environmental impact statement summarises the major environmental impacts due to the proposed MHEP, impacts prediction for major environmental components and the environmental management plan.

2. Institutional, Legislative and Regulatory Considerations for Environmental Assessment

2. Institutional, Legislative and Regulatory Considerations for Environmental Assessment

2.1 General

The purpose of Environmental Assessment (EA) is to ensure that the development options under consideration are environmentally sound and sustainable, and that any environmental consequences are recognised early in the project cycle and taken into account in project design. EAs identify ways of improving projects environmentally, and minimizing, mitigating, or compensating for adverse impacts.

EAs enable project designers, implementing agencies, and borrower and funding agencies to (a) address environmental issues in a timely and practical fashion, (b) reduce the need for project conditionality because appropriate steps can be taken in advance or incorporated into project design, and (c) help avoid costs and delays in implementation due to unanticipated environmental problems. EAs also provide a formal mechanism for inter-agency coordination and for addressing the concerns of affected groups and local non-governmental organizations (NGOs). In addition, they can play a major role in building environmental capability in the country.

2.2 World Bank Guidelines

The World Bank has brought out policy guidelines, notes, operational directives and procedures for environmental assessment of investment programmes and projects which provide a framework for action by both the borrowers and the Bank. Of direct relevance in this context are the following:

1. World Bank 1991, Operational Directive (O.D.) 4.01 Environmental Assessment and Annexes A to F thereto

2. World Bank Technical Paper No. 110 (1989), 'Dams and Environment' - Considerations in World Bank Projects

3. World Bank Technical Paper No. 139 (1991), Environmental Assessment Sourcebook', Vol I., Policies, Procedures, and Cross-Sectoral Issues, Environment Department

4. World Bank Technical Paper No. 140 (1991), Environmental Assessment Sourcebook', Vol II., Sectoral Guidelines, Environment Department

5. World Bank Technical Paper No. 154 (1991), 'Environmental Assessment Sourcebook', Vol III., Guidelines for Environmental Assessment of Energy and Industry Projects, Environment Department

As per World Bank O.D.4.01-Annex E (October, 1991), developmental projects are classified depending on the type, location, sensitivity, and the scale of the proposed project as well as the nature and magnitude of its potential impacts, into one of the three categories as under :

Category A	:	A full EA is required
Category B	:	Although a full EA is not required, environmental analysis is required
Category C	:	No EA or environmental analysis is required

In keeping with the above, the MHEP would fall under the category 'A' requiring full EA.

2.3 Provisions under Indian Constitution

The Directive Principles of State Policy of the Indian Constitution provide for the protection of environment and objects of national importance. **Article 48A** enjoins the State to make endeavour for protection and improvement of the environment and to safeguard the forest and wild life of the country. Another land mark provision in respect of environment relates to the Fundamental Duties of every citizen of India. **Article 51A(g)** of the Constitution stipulates that it shall be the duty of every citizen of India to protect and improve the natural environment including forests, lakes, rivers and wild life and to have compassion for living creatures. Further, **Article 49** states that it shall be the obligation of the State to protect every monument or place or object of artistic and historic interest, declared by or under law by Parliament to be of national importance from spoilation, disfigurement, destruction, removal, disposal or export as the case may be.

2.4 The National Water Policy (1987)

Recognising that water is a prime natural resource, a basic human need and precious national asset, the policy provides for the following guidelines in planning and operation of water resources projects as relevant in the context of the proposed project.

* "Water is a scarce and precious national resource to be planned, developed and conserved as such, and on an integrated and environmentally sound basis, keeping in view the needs of the States concerned".

* "Water should be made available to water short areas by transfer from other areas including transfers from one river basin to another, based on a national perspective, after taking into account the requirements of the areas/basins".

* "Water resource development projects should, as far as possible, be planned and developed as multipurpose projects. Provision for drinking water should be a primary consideration. The projects should provide for irrigation, flood mitigation, hydro-electric power generation, navigation, pisciculture and recreation wherever possible."

* "The study of the impact of a project during construction and later, on human lives, settlements, occupations, economic and other aspects should be an essential component of project planning."

* "In the planning, implementation and operation of projects, the preservation of the quality of environment and the ecological balance should be a primary consideration. The adverse impact, if any, on the environment should be minimised and should be off-set by adequate compensatory measures."

* "There should be an integrated and multi-disciplinary approach to the planning, formulation, clearance and implementation of projects, including catchment treatment and management, environmental and ecological aspects, the rehabilitation of affected people and command area development."

* "Special efforts should be made to investigate and formulate projects either in or for the benefit of areas inhabited by tribal or other specially disadvantaged groups such as Scheduled Castes and Scheduled Tribes. In other areas also, project planning should pay special attention to the needs of Scheduled Castes and Scheduled Tribes and other weaker sections of society."

* "The planning of projects in hilly areas should take into account the need to provide assured drinking water, possibilities of hydro-power development and the proper approach to irrigation in such areas, in the context of physical features and constraints such as steep slopes, rapid run-off and the incidence of soil erosion. The economic evaluation of projects in such areas should also take these factors into account".

* "In the planning and operation of systems, water allocation priorities should be broadly as follows:

  - Drinking water
  - Irrigation
  - Hydro-power
  - Navigation
  - Industrial and other uses

However, these priorities might be modified if necessary in particular regions with reference to area specific considerations".

* "There should be a close integration of water-use and land-use policies."

2.5 Environmental Appraisal and Clearance by MEF, Government of India

Environmental clearance of polluting or degrading development activities is done by the Central and/or the State Governments. Till January 1994, obtaining environmental clearance from the Central Ministry was only an administrative requirement intended for mega projects undertaken by the Government or Public Sector Undertakings. However, the new Notification (here in after referred to as the EIA Notification) issued by the Ministry in January 1994 (as amended in May 1994) makes Environment Impact Assessment statutory for 29 different identified activities listed under schedule-I (**Annexure 2.1**). This EIA Notification also includes details of procedures for obtaining environmental clearance and for public involvement besides setting time schedules for decision taking.

2.5.1 Projects which require Environmental Clearance

All the projects listed under Schedule-I of the EIA Notification are required to obtain environmental clearance from the Central Government, even if any of these projects fall under the delicenced category of the New Industrial Policy. Besides this, site specific projects such as mining, pit-head thermal power stations, hydropower, major irrigation projects, ports and harbours will also have to obtain separate site clearance from the central Government (or the State Government as the case may be) as specified in the EIA Notification.

Further, the Government of India (Ministry of Environment and Forests) notifies certain areas as ecologically sensitive/fragile areas from time to time and all developmental projects which are to be located in these notified areas need to obtain environmental clearance from the Central Government irrespective of whether they are listed under Schedule-I of the EIA Notification or not. Some of the identified ecologically sensitive/fragile areas notified under the Environment (Protection) Act, 1986 so far include :

- Doon valley, Murud-Janjira, Dahanu Taluka, Aravalli ranges in Gurgaon district of Haryana and Alwar district of Rajasthan.

- Identified coastal areas as per the Coastal Regulation Zone Notification.

- Forest, Wildlife Sanctuaries, National Parks, Wetlands, Mangroves, Biosphere Reserves, Hill and Mountain areas, etc.

The 29 projects listed in Schedule-I of the EIA Notification can be broadly categorised under the following sectors for the sake of convenience:

- Industries
- Mining
- Thermal Power Plants
- River Valley
- Ports, Harbours and Airports
- Communication
- Atomic Energy
- Transport (rail, road, highway)
- Tourism (including hotels, beach resorts)

2.5.2 River Valley Projects

All river valley projects including hydel power, major irrigation and their combination including flood control, with an investment of Rs. 50 crores or above only need to obtain environmental clearance from the Central Government. All other projects need to approach the concerned State Government departments/agencies only for the necessary clearances and permits.

2.5.3 Needed Documentation

The documents required as per the EIA Notification are listed below :

- Feasibility/Project Report;

- Site clearance (only for site-specific projects mentioned in the EIA Notification);

- No Objection Certificate from the SPCBs and other local authorities;

- Environment Appraisal Questionnaire (available at the Ministry of Environment and Forests and/or Application Form as prescribed in Schedule II of the EIA Notification);

- Environmental Impact Assessment Report/Environmental Management Plan;

- Risk Analysis/Emergency Preparedness Plan, (only in the case of projects involving hazardous substances);

- Rehabilitation plans where large scale displacement of people is anticipated.

2.5.4 Proposals Involving Diversion of Forest Land

The Forest (Conservation) Act, 1980 as amended from time to time, checks the indiscriminate diversion of forest land for non-forest purposes. The State Governments/Union Territories are required to submit formal proposals to the Central Government (Ministry of Environment and Forests) for diversion of forest land for non-forest purposes in the prescribed proforma alongwith details such as flora, fauna, map of the area, compensatory afforestation proposed etc.

As per the amended Forest (Conservation) Rules currently in force, the Regional Chief Conservators of Forests have the powers to decide proposals involving forest land upto 5 ha. Proposals involving forest land between 5-20 ha. shall be processed by the Regional Chief Conservator in consultation with a State Advisory Group consisting of representatives of the concerned State Government. Proposals involving more than 20 ha. of forest land are required to be placed before the Advisory Committee constituted by the Ministry of Environment and Forests.

There are prescribed procedures for submission of proposals involving dereservation of reserved forests or use of forest land for non-forest purposes. The investor is required to furnish a brief note giving essential details of the project relating to the following.

(a) Cost and outlay
(b) Justification for locating the project in the forest area, indicating alternative sites that were examined and reasons for their rejection.
(c) Financial and social benefits
(d) Total population benefited
(e) Employment generated etc.

A comprehensive land-use plan of the area required should be attached if land is required for more than one purpose. The building plan should also be attached if the area is required for construction purposes.

2.5.5 Environmental Appraisal Procedure

The documents submitted by an investor are first scrutinised by a complement of multi-disciplinary staff at the Ministry of Environment and Forests who may also undertake site visits wherever required, interact directly with the investors, affected people and environmental groups and hold consultations with experts on specific issues as and when necessary.

After this preliminary scrutiny, the proposals are placed before specially constituted Committees of Experts whose composition is specified in Schedule-III of the EIA Notification. Such committees, known as Environmental Appraisal Committees, have been constituted for each sector such as River Valley, Industries, and Mining. These committees meet regularly to appraise the proposals received at the Ministry. In case of certain very special/controversial projects which have aroused considerable public interest, the committee may also decide to arrange for public hearings on those projects to ensure public participation in developmental decisions. Announcements for such public hearings shall be made through newspapers atleast 30 days before.

On the basis of the exercise described in the foregoing paragraphs and depicted in **Fig. 2.1**, the Appraisal Committees make their recommendations for approval or rejection of particular projects. The recommendations of the Committees are then processed in the Ministry of Environment and Forests for approval or rejection.

2.5.6 Issue of Environmental Clearance/Rejection Letter

Single Window Clearance

When a project requires both environmental clearance as well as approval under the Forest (Conservation) Act, 1980, proposals for both are required to be submitted simultaneously for clearance/rejection, although separate letters may issue. If the project does not involve diversion of forest land, the case is processed only for environmental clearance.

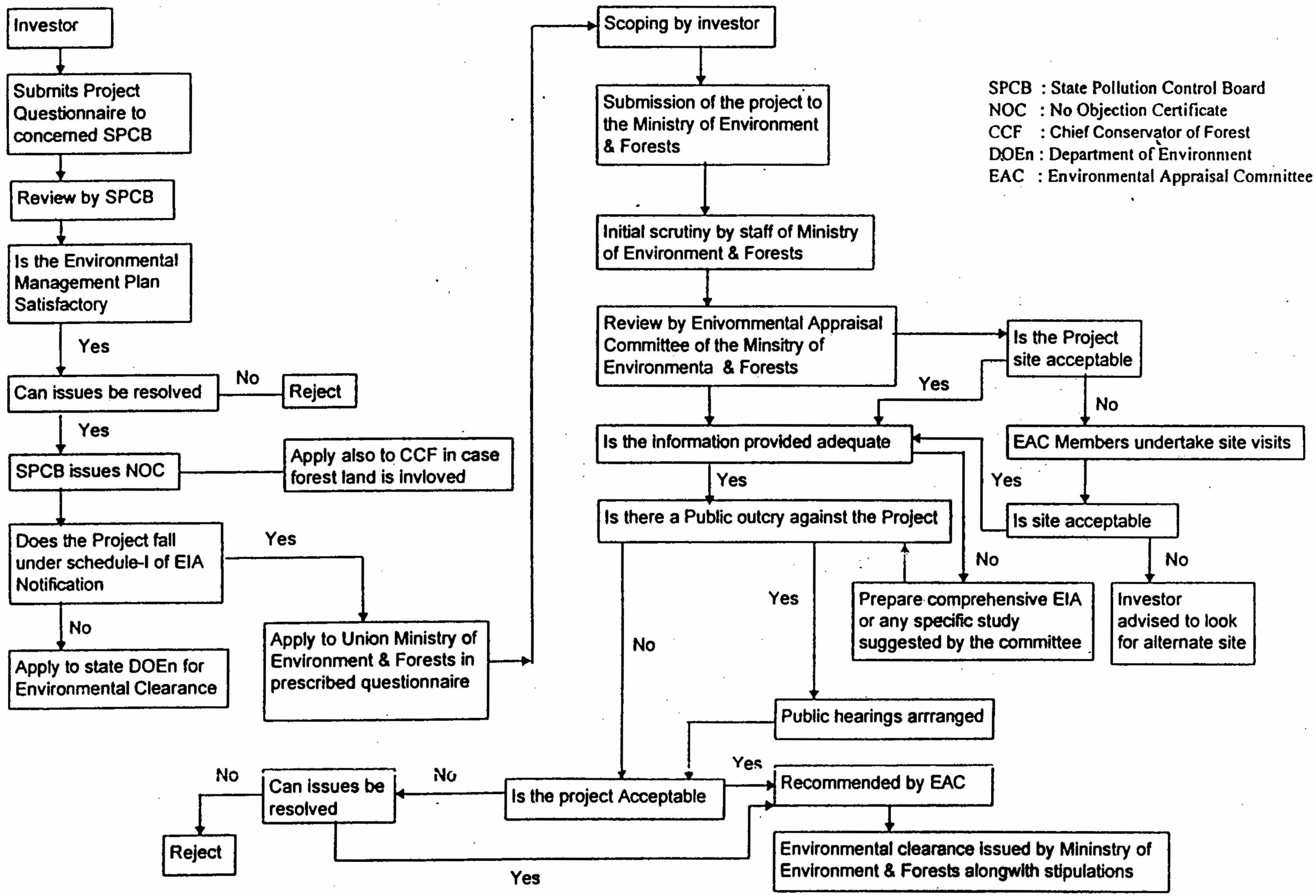


Fig. 2.1 : Flow Chart showing various steps involved in obtaining Environmental Clearance

Time-Frame

Once all the requisite documents and data from the project authorities are received and public hearings (where required) have been held, assessment and evaluation of the project from the environment angle is completed within 90 days and the decision of the Ministry shall be conveyed within 30 days thereafter.

Post Project Monitoring

Whenever a project is given environmental clearance, a set of recommendations and conditions are stipulated by the Appraisal Committee on a case to case basis, which have to be complied with by the investor once the project is commissioned. The investors are required to submit a half-yearly compliance report to the Ministry after the project is commissioned, to enable the Ministry to monitor the implementation of the recommendations and conditions stipulated by the Appraisal committee, subject to which the environmental clearance has been given. The six Regional Offices located at Shillong, Bhubaneswar, Chandigarh, Bangalore, Lucknow and Bhopal help the Ministry in post-project monitoring of the cleared projects. Cases of non-compliance of the recommendations and conditions by the cleared projects/units are brought to the notice of the concerned SPCB, which may then initiate action against the project authorities.

2.6 Central Water Commission (CWC) Guidelines

Guidelines for Sustainable Water Resources Development and Management have been brought out by the Central Water Commission (**Annexure 2.2**). Some of the common safeguards stipulated in the guidelines are

i. Necessary arrangements for supply of fuelwood by the project authorities to the labour force during the construction period

ii. Restoration of construction areas

iii. Compensatory afforestation

iv. Drawing up a master plan for rehabilitation of the oustees

v. To identify the critically eroded areas in the catchment for soil conservation work

vi. Mechanism for free movement of fish upstream and downstream of the structure across the river

vii. Setting up of monitoring units for implementing the suggested safeguards

viii. Alternatives in case of adverse effect on flora and fauna, wildlife, etc and

ix. Command area development (including drainage and anti-waterlogging measures).

2.7 Rehabilitation and Resettlement - Karnataka Govt. Provisions

The Karnataka Resettlement of Project Displaced Persons Act, 1987 (Karnataka Act 24 of 1994) provides for the resettlement of certain persons displaced from lands which are acquired for projects of public utility and for matters connected therewith.

As per definition of this Act "Displaced Person" means any tenure holder, tenant, Government lease or owner of other property, who on account of acquisition of his land including plot in the gramathana or other property in the affected zone for the purpose of the project, has been displaced from such land or other property. The definition of family in relation to a displaced person means the family of the displaced person consisting of such person and his or her spouse, minor sons, unmarried daughters, minor brothers or sisters, father and mother and other members residing with him and dependent on him for their livelihood.

The provisions of this Act apply to villages or areas which are likely to be in the **affected zone** or **benefited zone** of an **irrigation** or a **power project.**

The Act also deals with the Directorate of Resettlement, Resettlement Officer and their powers and duties; the application of the Act to the project and its consequences to ensure improvement therefrom; and resettlement of displaced persons.

3. Project Setting

3. Project Setting

3.1 General

The Mahadayi Hydro Electric Project (MHEP) envisages construction of three dams across the Mahadayi river, four diversion dams on its tributaries, diversion tunnels/channels, water conveyance system, an underground power house and two dam site power houses. The project also envisages diversion, through an intake structure on the periphery of Kotni reservoir and a diversion tunnel, of 113 Mcum (4 TMC) of water from Kotni reservoir to Malaprabha river for augmenting the available flows under the Malaprabha irrigation project. In addition, 142 Mcum (5 TMC) of water is proposed to be diverted from Kalsa, Haltar and Potli nalas to the Malaprabha sub-basin to augment the irrigation facilities in the state. All the construction activities of the project are to be undertaken within the territory of Karnataka state.

3.2 Proposed Works under MHEP

The major components of the proposed project depicted in Fig. 1.1 are detailed below.

i) Dams and Diversions

a) 86 m high dam across the river Mahadayi downstream of the confluence of Kotni nala with the river

b) 62 m high dam across the Bailnadi and a 4.8 km long diversion tunnel from Bailnadi to Kotni reservoir

c) 44 m high pick-up dam across the main river downstream of the confluence of Irti nala with the river

d) 25 m high tail race dam across Mahadayi river near the state border

e) Diversion weirs across Pansheer nala, Muruduhaul nala and Andher nala

All the above works are to be implemented by KPCL.

f) Diversion of water from Kalsa, Haltar and Potli nalas to Malaprabha sub-basin for irrigation through construction of a dam and diversion tunnels. These works are to be undertaken by the Karnataka Irrigation Department.

ii) **Power Houses**

a) Surface power house with an installed capacity of 20 MW (2 x 10 MW) at Kotni dam site

b) Under Ground Power House (UGPH) with 2 units each of 150 MW in the hill range near Krishnapura village

c) Surface power house with an installed capacity of 25 MW (2 x 12.5 MW) at tail race dam site

iii) **Water Conveyance Systems**

a) Intake structure on the foreshore of Irti reservoir and a water conveyance system from Irti reservoir to the UGPH including a 6.4 km long tunnel, a surge tank and a pressure shaft

b) Water conveyance system connecting various diversion schemes at Pansheer nala, Bailnadi, Muruduhaul nala and Andher nala

3.3 Alternatives Evaluated

For the construction of the proposed dams/ diversion structures alternative sites were identified by the project proponents using toposheets of 1:50000 scale at (i) Kongla (ii) Kotni nala confluence with Mahadayi river and (iii) Irti nala confluence with Mahadayi river. Studies, as described below, were undertaken in order to assess the yields at these dam sites, storage capacities at different levels and the corresponding heights of dams for the required storage.

3.3.1 Kongla Dam Site

The catchment area draining at this site is 88 sq. km. The Pansheer nala and Muruduhaul nala could be diverted to this site. The average annual yield (75 % dependability) including the diversion is 306 Mcum. The 90% dependable yield at this dam site is 237 Mcum as against 500 Mcum of storage required. Thus, the storage at this site would not be adequate. If this dam site is selected, there has to be another point of storage, and the total submergence area will be more than that of a single storage dam. Hence, this dam site was not considered.

3.3.2 Kotni and Irti Dam Sites

Diversion of the two nalas viz., Bailnadi and Andher nala is feasible to these dam sites with a total average yield of 664 Mcum at Kotni dam site and 742 Mcum at Irti dam site. The corresponding 90% and 75% dependable yields are 489 and 550 Mcum respectively. Thus, the yield at these dam sites can provide the required storage of 500 Mcum. Further, the storage between Kotni dam site and Irti dam site will be only 2 Mcum with a level difference of about 50 m. Thus, a storage dam at Irti has to be 40-50 m higher than that at Kotni dam site. Hence, the dam site at Kotni has been selected. Irti dam has been chosen as a balancing reservoir with a storage of 3 Mcum and 26 ha of submergence confining mainly to the river course. The yield at Kotni dam site is 664 Mcum average and 489 Mcum at 90% dependable yield. To create a storage of about 500 Mcum, a dam of 90 m height with a submergence of 25 sq. km would be involved. In order to reduce the submergence, it was decided to reduce the storage to about 370 Mcum keeping also in view that the non-monsoon generation supports the peaking requirement. With this decision the power station would run less than 6 hours per day during non-monsoon period.

3.3.3 Pansheer nala, Muruduhaul nala and Andher nala Dam Sites

The diversion dams for Pansheer nala, Muruduhaul nala and Andher nala are planned as non-submersion dams by keeping the invert of the diversion works to the river bed itself. Whenever there is high rainfall, the water may rise a little above the normal flow level in the stream for a short while and subside when the flood recedes.

3.3.4 Bailnadi Dam Site

This dam site has been chosen only for a pickup weir to divert water to the Kotni reservoir. The associated storage is 8 Mcum with a water spread area of about 80 ha. The FRL has been fixed on the basis of the minimum level required for diversion.

3.4 The Mahadayi River Basin

The Mahadayi river basin receives rainfall during the south-west monsoon from June to September. The river carries large flows during this period, and the flow during the remaining 8 months is nominal. It is, therefore, necessary to create adequate storage by impounding the waters during the monsoon period for power generation during the non-monsoon period. The important tributaries of this river are Singar nala, Kotni nala, Doli nala, Irti nala and Bailnadi in Karnataka, and river Khandepar, which meets Mahadayi/Mandovi downstream of Ganjem in Goa. The

Dudhsagar falls is located on Khandepar river. Since Dudhsagar falls is in a different valley and beyond the catchment of Mahadayi in Karnataka, the falls will not be affected due to construction of MHEP. The Mahadayi river has fresh water upto village Usgaon Pali, downstream of which there is saline water intrusion from the Arabian Sea. Due to sea water intrusion, the river stretch upto Amone is saline all through the year. The Central Water Commission (CWC) has installed permanent gauging stations on river Mahadayi and Khandepar at Ganjem and Collem respectively. The other major river in the state of Goa is Zuari which is connected to the Mahadayi by a navigational canal known as Cumbarjua canal.

3.4.1 Catchment Area

Of the total catchment area of Mahadayi basin, 189.6 sq. km lies at high altitudes with heavy rainfall (3800 mm to 4400 mm per annum). It is this combination of a fairly large catchment area receiving heavy rainfall and an elevation head of nearly 600 m that makes Mahadayi river an attractive source of power generation in Karnataka. The total catchment area, the yield from which is proposed to be harnessed for power generation, is 189.6 sq. km upto the UGPH and 257.7 sq. km at the tail race dam site. Rainfall gauging stations are located at Krishnapur, Gavali, Kotni dam site, Jamgaon, Nerse, Chapoli and Amgaon in Karnataka.

Kotni is the main storage dam intercepting runoff from a catchment area of 124.4 sq. km. The other two dams proposed across Mahadayi river are the Irti dam and the tail race dam. Details of the locations of these dams alongwith the catchment areas intercepted are presented in **Table 3.1**. Some of the tributaries of Mahadayi which originate at high altitudes join the main river d/s of Kotni dam. Water from Muruduhaul nala, Pansheer nala, Andher nala and Bailnadi can be diverted to Kotni reservoir. The locations of the diversion dams across these four streams along with the catchment areas intercepted are presented in **Table 3.2**.

From the storage at Kotni dam, 113 Mcum (4 TMC) is to be diverted to Malaprabha sub-basin for irrigation. In addition, 142 Mcum (5 TMC) is proposed to be diverted from the following diversion schemes.

(1) Kalsa and Surla nala : These are tributaries to Mahadayi river and drain a total catchment area of 24 sq. km (Karnataka 21.50 sq. km and Goa 2.50 sq.km).

(2) Haltar nala : This is also a tributary to the river Mahadayi with a catchment area of 13.52 sq. km in Karnataka. It is proposed to construct a dam across Haltar nala near Chorla village to utilise the flows from a catchment area of 4 sq. km

Table 3.1

Details of Catchment Areas of Dams on River Mahadayi

Description	Location		Catchment Area (sq. km)	
	Latitude	Longitude	Individual	Cumulative
Kotni dam	15° 37' 20" N	74° 21' 10" E	124.4	124.4
Irti pick-up dam	15° 37' 40" N	74° 20' 25" E	18.7	143.1
Tail race dam	15° 33' 45" N	74° 16' 02" E	68.1	211.2

Table 3.2

Details of Catchment Areas of Tributaries of River Mahadayi

Description	Location		Catchment Area (sq. km)
	Latitude	Longitude	
Muruduhaul nala dam	15° 33' 45" N	74° 19' 05" E	3.3
Pansheer nala dam	15° 32' 52" N	74° 19' 15" E	6.5
Bailnadi dam	15° 38' 15" N	74° 18' 16" E	31.9
Andher nala dam	15° 38' 02" N	74° 15' 18" E	4.8

(3) Potli nala: A tributary to the Tillari river which flows in Maharashtra and joins the Arabian Sea in Goa. The total catchment area drained in Karnataka state is 28.87 sq.km. It is proposed to construct three small dams viz., Potli-A, B & C draining a catchment of 8 sq.km.

The details of catchment areas of various dams/diversions in the states of Karnataka and Goa are depicted in **Fig. 3.1** and presented in **Table 3.3.**

3.4.2 Yield from Mahadayi River Basin

The total yield from the Mahadayi river basin in Karnataka is 1082 Mcum., of which 113 Mcum (4 TMC), which is 10% of the yield within Karnataka, is proposed to be diverted to Malaprabha basin. An additional 142 Mcum (5TMC) is proposed to be diverted from the total yield of 374 Mcum from Kalsa and Surla nalas, Haltar nala and Potli nala. The details of catchment area and related yield are presented in **Table 3.4** . The total storage capacity at Kotni, Irti, Bail nadi and Pansheer nala dams is 444 Mcum. The storage capacity of diversion dams has not been assessed so far. Information on the yield (maximum, minimum and average) in Mahadayi basin before and after the construction of reservoirs is presented in **Table 3.5** and is depicted graphically in **Fig. 3.2.** The flow data (gross annual yield for the entire basin) based on the rainfall-runoff corelationship as worked out by National Water Development Agency (NWDA) and the gauged data at Ganjem on Mahadayi river and Collem on Khandepar river (total catchment area covered 997 sq. km) is presented in **Table 3.6.** The average total flow in Mahadayi river computed by NWDA is comparable with the actual flow measurements by CWC. Data on the flows in the river Mahadayi before and after the construction of the project is presented in **Fig. 3.3.** The yield available in Goa after construction of reservoirs in Karnataka is 92.61% of average flow during monsoon (June-October), 251.29% during non-monsoon (November-May) and 94.59% during June-May. With only 2% of yield being utilised in the form of diversion and evaporation, the balance 98% will be put back in the river in a regulated manner during the operation of the project.

3.4.2.1 Yield at Kotni Dam Site (Independent and Total)

The monthly yield at Kotni dam site has been worked out on the basis of rainfall runoff coefficients evolved for Kongla site having a hydro-meteorological similarity with Kotni site. The runoff works out to 88% of the catchment rainfall which could be expected from a catchment area receiving a high intensity of rainfall of the order of 4000 mm per annum. The average annual yield for the Kotni dam site including diversion from 4 diversion schemes works out to 664.0 Mcum. The

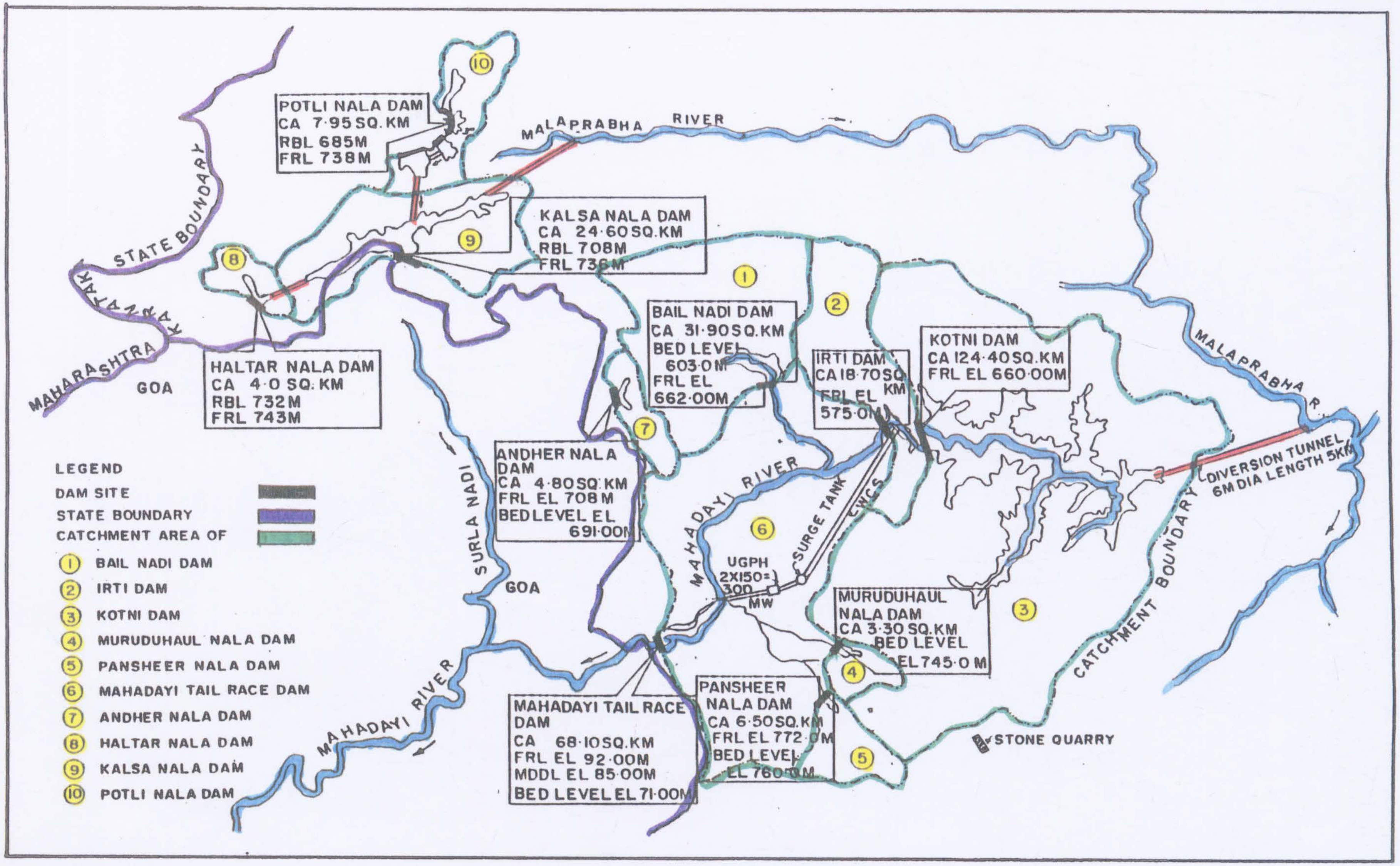


Fig. 3.1 : Details of Catchment Area of Dams

Table 3.3

Catchment Area of West Flowing Nalas (Potli, Kalsa & Surla) and Mahadayi River

Description	Catchment Area (sq.km)			
	Karnataka	Maharashtra	Goa	Total
Kalsa nala	16.00	-	-	16.00
Surla nala	5.50	-	2.50	8.00
Haltar nala	13.52	-	-	13.52
Potli nala	28.87	1.84	-	30.71
Mahadayi river	375.11	76.96	1579.93	2032.00

Table 3.4

Statewise Catchment Area and Yield of Mahadayi Basin

Description of the Region	Catchment Area (sq.km.)	Yield in Mahadayi Basin (Mcum)	
		50% Dependable	75% Dependable
Total area	2032	5703	3164
Karnataka	375	1052	584
Catchment of Mahadayi project	258	723	701
Goa	1580	4434	2460
Area covering salinity intrusion	450	1263	701
Area covering fresh water flow in Goa region	1130	3171	1759

Table 3.5

Yield* in Mcum from Mahadayi Basin at Goa Excluding the Salt Water Zone Before and After the Construction of Reservoirs

Month	Maximum		Minimum		Average		Total		% of total flow available after construction of reservoir
	Before	After	Before	After	Before	After	Before	After	
June	806.26	732.07	331.22	315.80	586.12	487.65	12308.42	10240.69	83.20
July	2938.39	2702.4	1207.14	994.05	2136.09	1876.62	44857.89	39408.99	87.85
August	2979.22	2819.32	1223.92	1090.14	2165.77	1991.82	45481.26	41828.18	91.97
September	702.97	796.54	288.79	324.49	511.03	580.66	10731.67	12193.90	113.63
October	353.89	586.44	145.38	152.02	257.26	303.60	5402.50	6375.70	118.01
November	116.90	105.61	48.02	51.65	84.98	81.63	1784.54	1714.16	96.06
December	54.44	103.65	22.37	39.24	39.58	77.20	831.15	1621.29	195.07
January	25.62	87.31	10.53	30.17	18.63	58.56	391.13	1229.69	314.39
February	12.01	71.46	4.93	22.14	8.73	51.96	183.34	1091.23	595.19
March	8.01	68.59	3.29	19.67	5.82	49.67	122.23	1043.16	853.45
April	4.80	66.31	1.97	17.68	3.49	47.45	73.34	996.43	1358.69
May	4.80	66.31	1.97	17.68	3.49	47.45	73.34	996.43	1358.69
Monsoon June-October	7780.73	7407.15	3196.46	2925.69	6485.26	5240.36	118781.75	110047.47	92.65
Non-Monsoon November-May	226.58	542.23	93.08	218.78	164.72	413.92	3459.07	8692.39	251.29
Total June-May	8007.31	7947.62	3289.55	3144.47	5820.99	5654.28	122240.82	118739.86	97.14

* Adapted from Technical Study No. 93, Preliminary Water Balance Study of Mahadayi (Mandovi) Basin, National Water Development Agency, July, 1989

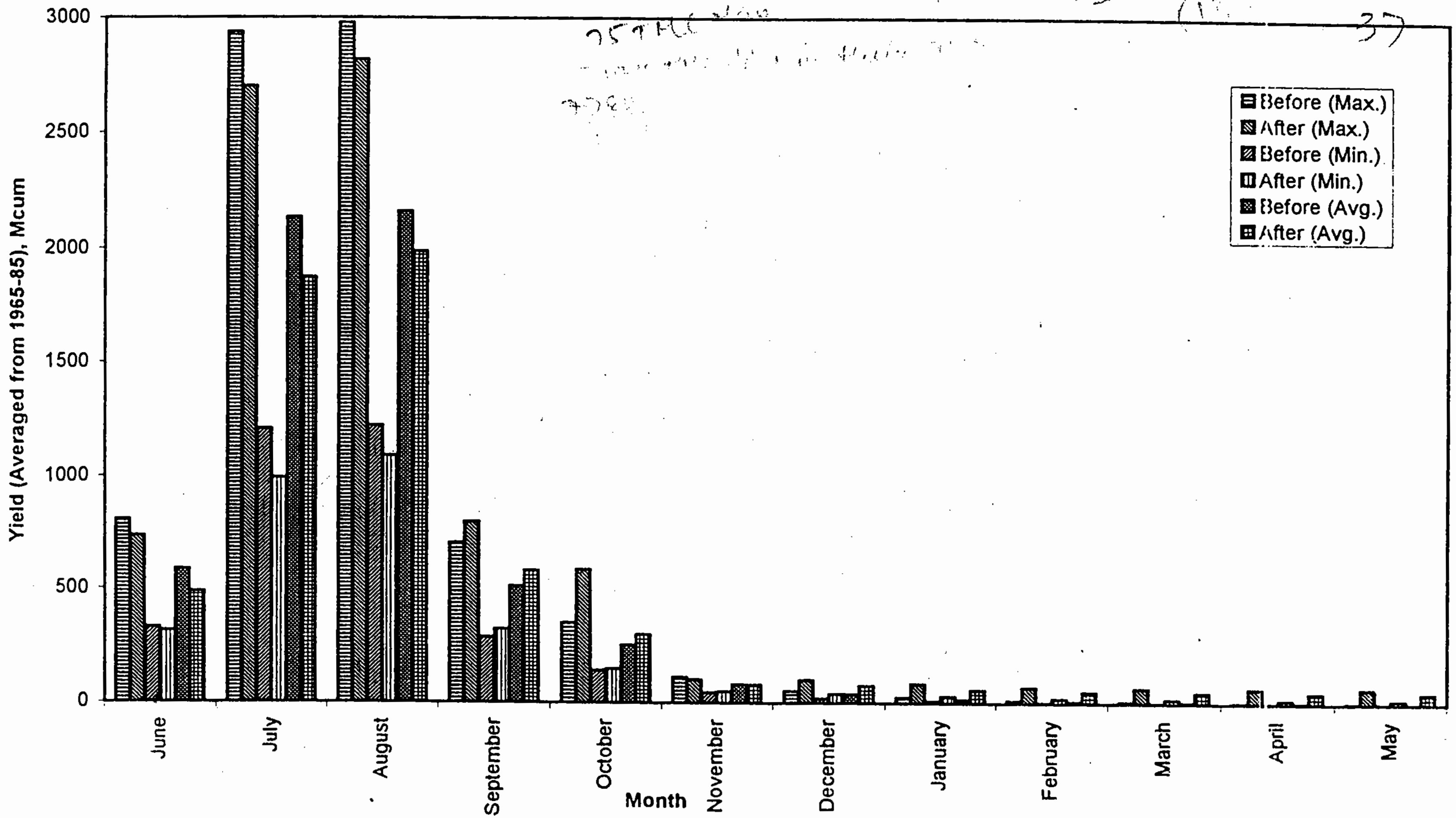


Fig 3.2: Variation in Maximum, Minimum and Average Yield in Mahdayi River Before and After the Project

Table 3.6

Gross Annual Yield Based on NWDA Report and Gauge Data from Ganjem & Collem Gauging Stations on Mahadayi (Mandovi) River

Year	Total Flow Computed by NWDA (Mcum)	Total Inflow as Measured by CWC at Ganjem and Collem Sites (Mcum)
1980-81	7192.66	6845.38
1981-82	7669.59	7280.98
1982-83	7757.24	7409.07
1983-84	7749.60	7031.84
1984-85	5528.98	5757.03
1985-86	5516.95	5421.60
Total	41415.02	39745.90
Average	6902.50	6624.32
Minimum	5516.95	5421.60
Maximum	7757.24	7409.07

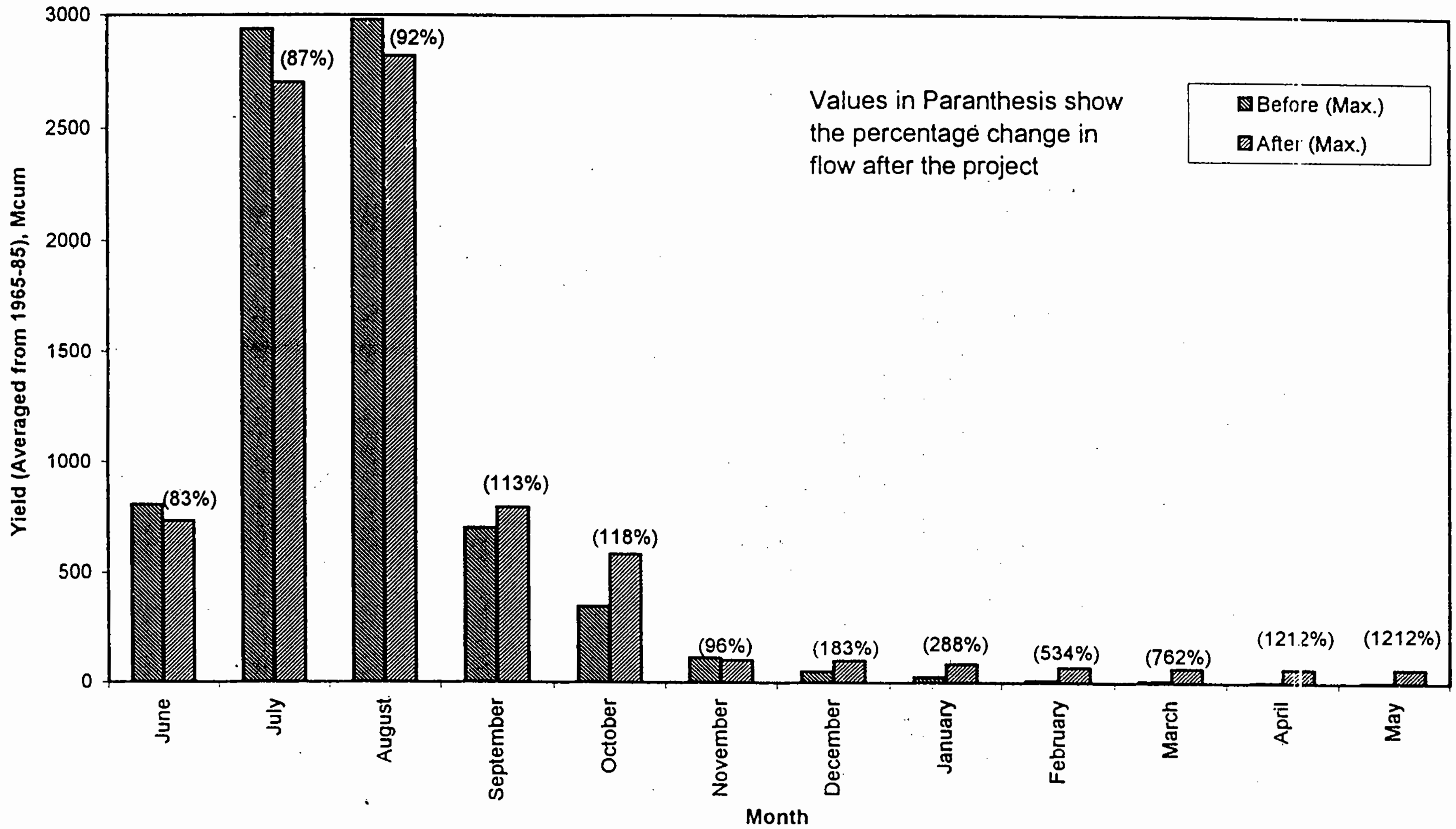


Fig. 3.3 : Variatiion in Maximum Yield in Mahadayi River Before and After the Project

maximum, minimum and the average monthly yields, (independent and total) at Kotni dam site are given in **Table 3.7**.

3.4.2.2 Yield at Irti Dam site

The average annual rainfall in the catchment for a period of 29 years is 4444 mm which is higher than that for the Kotni dam site by 668 mm (18%). The maximum, minimum and the average monthly yields are given in **Table 3.8**.

3.4.2.3 Yield at Tail race Dam site

The average annual catchment rainfall is 5097 mm. The maximum, minimum and the average monthly yields are given in Table 3.8.

3.4.2.4 Yield from Pansheer & Muruduhaul Nalas

Pansheer and Muruduhaul nalas are two tributaries of Mahadayi river joining the river d/s of Irti dam site. With a view to harnessing part of the yield in these streams for power generation, it has been proposed to construct weirs across these streams in the upper reaches, and divert the yield to the Kotni reservoir. The average annual independent yield from the two nalas is 33 Mcum.

3.4:2.5 Yield from Andher nala and Bailnadi

Andher nala and Bailnadi are two tributaries of Mahadayi river joining d/s of Kotni dam site. It is proposed to intercept the yield in the upper reaches of these streams and divert the same into the Kotni reservoir for power generation. This requires construction of two dams and two diversion tunnels, one from Andher nala to Bailnadi, and the other from Bailnadi to Kotni reservoir. The yields at these dam sites have been worked out on the basis of rainfall-runoff correlations for a period of 29 years (1960 to 1989). The average annual yield from these two streams works out to 199 Mcum.

3.4.3 Diversion to Malaprabha sub-basin for Irrigation

The Malaprabha dam has been constructed across river Malaprabha at Naviluteertha, Saundatti taluka, Belgaum district in 1972 to irrigate an area of 218191 ha in Belgaum, and parts of Dharwad and Bijapur districts. The total water utilisation for irrigation is 1368 Mcum. It has been observed since 1972 that the reservoir does not receive the contemplated yield on account of substantial reduction in rainfall in the catchment. Due to this reduction in the yield, it has not been possible to provide

Table 3.7

Details of Yield at Kotni Dam Site

Month	Yield at Kotni Dam (Mcum)					
	Independent Catchment			By Augmenting with Four Diversion Schemes		
	Maximum	Minimum	Average	Maximum	Minimum	Average
June	123	4	48	169	14	75
July	304	49	167	439	131	243
August	233	58	157	330	71	205
September	121	9	41	169	23	62
October	145	1	25	175	7	39
November-May	72	1	25	102	9	40
Total average annual yield	998	122	464	1384	255	664

Note : Yield worked out from 29 years rainfall data

Table 3.8

Details of Yield at Irti and Tail Race Dam Sites

Month	Yield at (Mcum)					
	Irti Dam Site			Tail Race Dam Site		
	Maximum	Minimum	Average	Maximum	Minimum	Average
June	21	-	9	89	9	41
July	63	17	30	193	60	117
August	38	6	24	138	57	92
September	17	2	7	56	12	36
October	10	-	4	47	-	21
November-May	11	-	4	49	-	25
Annual	160	25	78	572	138	332

irrigation facilities for the Kharif, Rabi and two seasonal crops to the area originally envisaged under the project. There is a shortfall of 342 Mcum of water in the upstream of Malaprabha sub-basin due to which approximately 38742 ha of drought prone areas in Bijapur/ Dharwad districts will be deprived of the benefits of irrigation with the consequent loss in production of foodgrains to the extent of about 59150 metric tonnes worth Rs. 53 crores per year. To meet this shortage, there is no other alternative except taking up the diversion schemes viz., Kalsa, Haltar and Potli nalas (142 Mcum).

3.4.3.1 Yield from Kalsa, Haltar and Potli Diversions

In view of the above deficit in the yield of Malaprabha river, it is proposed to augment the flows by diverting 255 Mcum of water, 113 Mcum from Kotni reservoir on the Mahadayi and 142 Mcum from the Kalsa, Haltar and Potli nalas to Malaprabha as per details below.

(1) Kalsa and Surla nala: The average yield works out to 189 Mcum per year. It is proposed to divert 95 Mcum of water by constructing a dam at the confluence of Kalsa and Surla nalas.

(2) Haltar nala: The nala gauging has been done at the proposed dam site from 1991 to 1995 and the average yield works out to 64 Mcum per year. It is proposed to construct a dam across Haltar nala near Chorla village to divert 16 Mcum of water to Kalsa reservoir.

(3) Potli nala: The average yield is 156 Mcum per year. It is proposed to construct 3 small dams viz., Potli-A, B & C to divert 31 Mcum of water to Kalsa reservoir.

The yields in the various nalas and the river Mahadayi are presented in **Table 3.9**. The details of water spread area and capacity at FRL of the four reservoirs are given in **Table 3.10**.

3.5 Submergence due to various Reservoirs

The Kotni reservoir will submerge an area of 2109 ha at FRL of EL 660 m. However, this is a storage reservoir reaching FRL in 12 out of 26 years and EL 658 m in 17 out of 26 years. The period of inundation is a maximum of 3 months. It is, therefore, proposed to limit forest clearance to EL 658 m. The area under submergence at this elevation is 1970 ha. The area of submergence under Irti, Bailnadi, tail race and the other three diversion schemes is 175 ha only. Thus, the total

Table 3.9

Yield from the Potli, Kalsa & Haltar Nala Diversions

Description	Average yield as per river guaging at dam site		Yield considered for diversion		Percentage diversion
	Mcum	TMC	Mcum	TMC	
Kalsa and Surla nalas	189.11	6.68	94.56	3.34	50
Haltar nala	64.26	2.27	19.77	0.56	25
Potli nala	156.00	5.51	31.14	1.10	26
Mahadayi river	3163.36	111.74	113.24	4.00	3.5

Notes :

1) 75 % Dependable rainfall based on Kankumbi rain gauge station is 4993.64 mm.
2) Yield worked out based on Ingli's Ghat formula
3) Proposal for diversion from Potli is under investigation.

Table 3.10

Details of Water Spread area and Capacity of Various Reservoirs

Description	FRL (m)	Water Spread Area (sq.km)	Capacity (Mcum)
Kotni	660.00	21.10	420.50
Irti	575.00	0.25	3.10
Bailnadi	662.00	0.81	11.32
Tail race	92.00	0.39	9.20

area of submergence due to all the reservoirs is 2145 ha. Of this, an area of 1608 ha is under forest which includes an area of 191 ha under river course. Private land accounts for 373 ha. In addition, forest land to the extent of 330 ha is required for the following purposes :

		Area (ha)
i)	Access and deviation roads length 75 km, width 20 m	150
ii)	Dams, power houses and other structures	45
iii)	Township	60
iv)	Other uses including quarry, field office, material stack yard, construction plant area, transmission lines etc.	75
	Total	330

Thus, the total area of forest land affected will be 1938 ha which constitutes 78% of the total area of submergence. Most of this forest land is reserve forest. The area under submergence is shown in **Fig. 3.4** and the details of land under submergence are presented in **Table 3.11**. The submergence area of Haltar dam lies in Belgaum district of Karnataka, whereas that of Kalsa nala partially lies in Goa. The area comprises forest, revenue and government land as presented in **Table 3.12**.

3.6 Resettlement

Three villages viz., Kongla, Kabnali and Kirvale in Khanapur taluka with a total population of 427 persons will be submerged under Kotni reservoir. The number of households affected will be 78. Most of these people depend on the adjoining forest and farm land for their livelihood. They will be rehabilitated on suitable non-forest area and land for cultivation will be given to those who lose land. The remaining persons will be paid rehabilitation grant as approved by the State Government in G.O. No. PWD 282 PPC 85 dated 28.12.85. In addition to the rehabilitation grant, compensation will be paid to the people for the land and buildings lost.

3.7 Project Implementation Schedule

The project at Kotni dam site envisages construction of an 86 m high earthen dam involving 42 lakh m^3 of earthfill, which is the major component of civil engineering works. Since the site is situated in high rainfall area, the number of

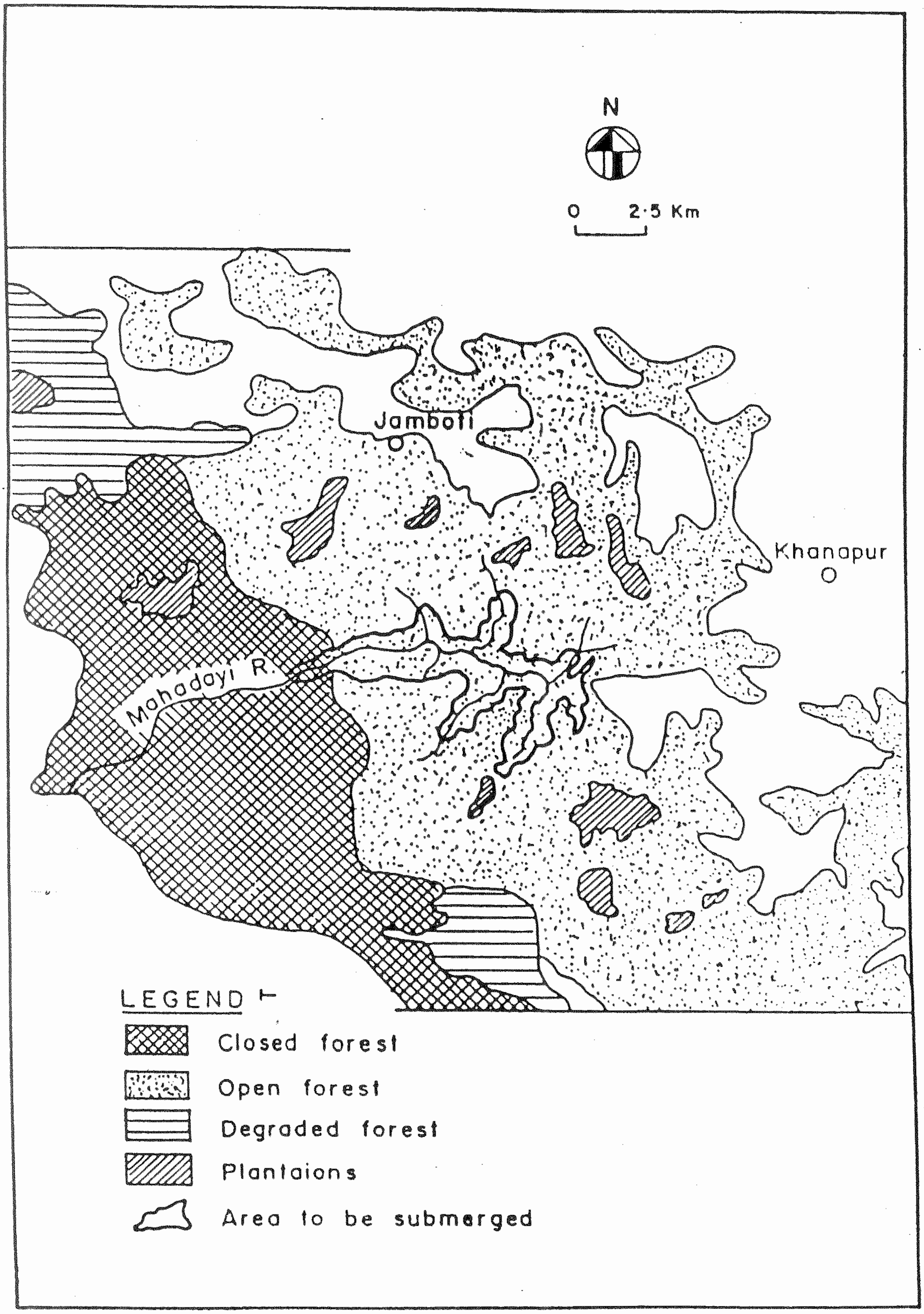


Fig. 3.4 : Area under Submergence in the Kotni Reservoir

Table 3.11

Area under submergence due to Various Reservoirs

Description	Area of Submergence (ha)			
	Forest land	Waste land	Private land	Total
Kotni (upto EL 658 m)	1437	164	369	1970
Irti	25	-	-	25
Bailnadi	81	-	-	81
Tail race	35	-	4	39
Other diversions	30	-	-	30
Total	1608	164	373	2145

Source : MHEP, Detailed Project Report, KPCL, June 1990

Table 3.12

Area under Submergence due to Diversion Dams

Description	Area of Submergence (ha)				Total
	Karnataka		Goa		
	Forest land	Revenue and Govt. land	Forest land	Revenue and Govt. land	
Kalsa	147.45	39.42	53.15	21.12	261.14
Haltar	35.15	5.26	Nil	Nil	40.41

Source : Irrigation Department, Belgaum

working days in a year will be only about 200. Preliminary structures such as river diversion may take one year. A minimum of 5 years thereafter will be required to complete the dam. Work on other components of the project will also have to start almost concurrently so as to complete the same in a period of 6 years. The construction schedule is shown in **Fig. 3.5**.

It would be possible to start power generation on run-of-the river basis even before the completion of Kotni dam. For this, it is necessary to concentrate on the UGPH, tail race dam and power house and erection of equipment in power houses.

3.7.1 Flood Passage During Construction at Various Dam Sites

The following provisions have been made in the project for passage of flood waters during construction period.

1. Kotni Dam Site : A river diversion tunnel taking off from the river bed u/s of the dam site

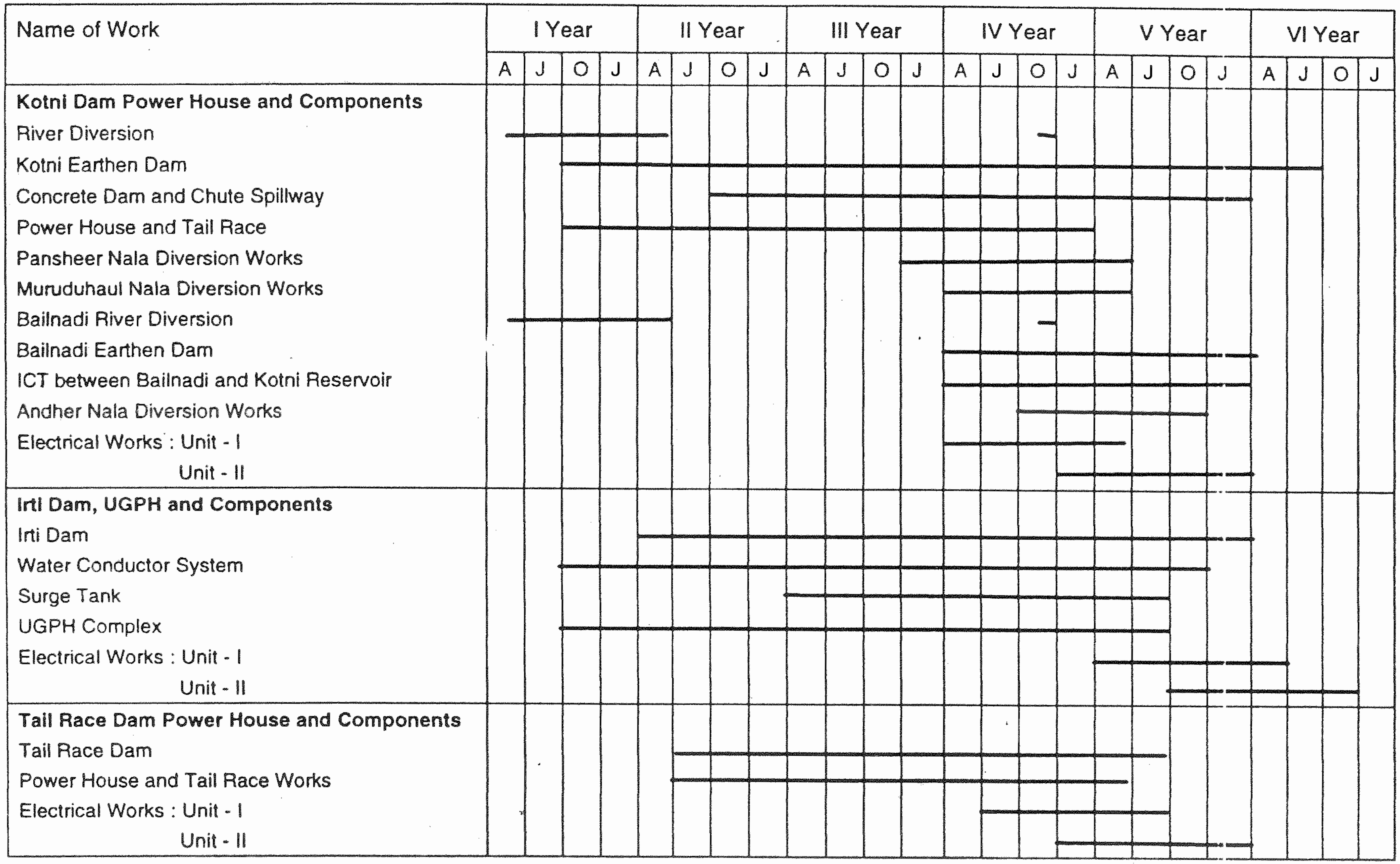
2. Irti Dam Site : As the dam incorporates a central concrete spillway, the flood will be passed over the unfinished spillway until the dam is raised to its crest level and after construction will be passed over the spillway.

3. Bailnadi Dam Site : In the first year a small canal will be dug at the level of the dam upto which it is raised, and pitched for the passage of flood. Subsequently, this passage will be incorporated into the dam and blocked. During the second year, the excavated spillway area will act as flood passage route. The dam will be ready in all respects for the third year flood.

4. Pansheer nala, Muruduhaul nala and Andher nala : In the first year all the preliminaries will be completed and in the second year the dams will be raised to their full height. Thereafter, the diversion system will take care of the full flood that comes.

3.7.2 Project Cost and Power Tariff

The direct and indirect cost of the MHEP at the time of inception of project in 1989-90 was Rs. 30,333 lakhs and Rs. 25 lakhs respectively. The audit and account charges were 292 lakhs at the rate of 1 %. Thus, the total estimated project cost was Rs. 30,650 lakhs. The abstract of cost estimates is presented in **Table 3.13**. The estimated cost of power generation was 58 paise/unit while the selling rate was 73 paise/unit by KPCL. The total project cost as per 1996-97 schedule of rates of



A : April; J: July ; O: October; J: January

Fig 3.5 : Bar Chart Showing Construction Activities for MHEP

Table 3.13

Abstract of Cost Estimate of MHEP (1990)

Sl. No.	Item	Unit-I Civil Engg. Works	Unit-III Hydraulic & Electrical Works	Total (Rs. in lakhs)
I - Works:				
1.	**Direct Charges**			
	A - Preliminaries	100	-	100
	B - Lands	879	-	879
	C - Works			
	i) Kotni dam, power house & components	6802		
	ii) Irti dam, UGPH & components	3944		
	iii) Tail race dam, pH & components	826		
		11572		11572
	D - Regulators	826	-	826
	G - Bridges	68	-	68
	K - Buildings:			
	a. Temporary	1500		
	b. Permanent	735		
		2235		2235
	M - Plantations	50	-	50
	O - Miscellaneous	370	-	370
	R - Communications	445	-	445
	S - Soil Conservation	20	-	20
	P - Maintenance 1% of I works less A, B & Q	156	-	156
	Q - Special tools & plants	398	-	398
	I - Losses on stock at 1/4% of I-Works loss A, b & Q	39	-	39
	Production - Hydraulic and Electrical Engineering Works:			
	i) Kotni power house		1284	
	ii) UGPH		8131	
	iii) Tail race power house		1683	
		-	11098	11098
	Total of I - Works	17158	11098	28256

Table 3.13 (Contd...)

Sl. No.	Item	Unit-I Civil Engg. Works	Unit-III Hydraulic & Electrical Works	Total (Rs. in lakhs)
II	Establishment charges at 8% I works excluding B - Lands	1381	888	2269
III	Tools & plants charges at 1% of I - Works	181	111	292
IV	Suspense	Nil	Nil	Nil
	Recoveries & Receipts:			
	a. Resale value of transport vehicles @ 20% balance T&P @ 75% of cost	246	-	246
	b. Resale value of temporary buildings at 15% of cost	225	-	225
	c. Miscellaneous receipts from lease of land, rents, etc.	13	-	13
	Total of Receipts:	484	-	484
	Net Amount :	18236	12097	30333
2.	**Indirect Charges:**			
	Capitalisation of abatement of land revenue @ 5% of cost of land acquired	25	-	25
	Audit & Account charges @ 1% of I - Works	181	111	292
		18442	12208	30650

Cost of the project at HT bus - Rs. 30,650 lakhs only.

Source : DPR, MHEP

KPCL including interest during construction works out to about Rs. 1,01,671 lakhs and fixed charges at 22.21 % works out to Rs. 22,591 lakhs.

The energy generation from MHEP will be 828 MU per annum. The energy generation can be enhanced by 10 % when more water is available for overloading during monsoon. The power tariff works out to Rs. 2.75 per unit of energy produced and the tariff collection by the state is estimated at 234 crores per annum.

4. Baseline Status of the Environment

4. Baseline Status of the Environment

4.1 Introduction

The Mahadayi, one of the west flowing rivers in Karnataka, takes its birth at an elevation of 914.40 m above MSL in Jamboti ghat 10 Km north-east of Sonasagar in Khanapur taluka in Belgaum district. The river traverses a distance of 28.8 km in Karnataka and 81.2 km in Goa. The river basin lies between latitudes 15° 15' 24" N and 15° 42' 00" N and longitudes 73° 45' 46" E and 74° 23' 54" E. The Mahadayi river is joined by three tributaries in Karnataka viz., Bail nadi, Kotni nadi and Bhendura, and by five tributaries, viz., Khandepar or Dudhsagar, Dicholi, Mapuca, Ragada and Surla or Nanode nadi in the state of Goa, where it is known as Mandovi river. Cumbarjua canal, 17 km in length, connects Mandovi river near village Tonka with Zuari river near village Agasaim at a distance of 14 km and 11 km respectively from their mouths.

The catchment area of the Mahadayi river is 2032 sq. km of which 375.11 sq.km is in Karnataka, 1579.93 sq. km is in Goa, and 76.96 sq.km is in Maharashtra. The state/ district-wise break up of the basin area is given in **Table 4.1** and the basin boundary is depicted in **Fig. 4.1**.

4.2 Physical Environment

4.2.1 Topography

The Mahadayi (Mandovi) basin is bounded on the north by Chapora basin, on the north-east by Kalinadi basin, on the south by Zuari basin and on the west by the Arabian Sea. The Mahadayi basin can be broadly divided into three distinct sub-regions as given below :

i) Regions with undulating up-lands and hills
ii) The coastal plains
iii) The intermediate or transitory regions

The general topographical details of the Mahadayi basin in Karnataka are depicted in Fig. 4.1. The northern portion of the basin is at the highest elevation, which decreases towards south-west. The Mahadayi river in Karnataka is shadowed on either side by mountainous terrain which becomes flatter in the state of Goa as the river flows towards the Arabian Sea.

Table 4.1

State/District-wise breakup of the Mahadayi basin area

Sl. No.	State/District	Area lying within the basin (km^2)	Percentage of the total area of the basin (%)
1.	**Goa :**		
	Goa district	1579.93	77.75
2.	**Karnataka :**		
	Belgaum	305.77	15.05
	Uttara Kannada	69.34	3.41
3.	**Maharashtra :**		
	Ratnagiri	76.96	3.79
	Total :	**2032.00**	**100.00**

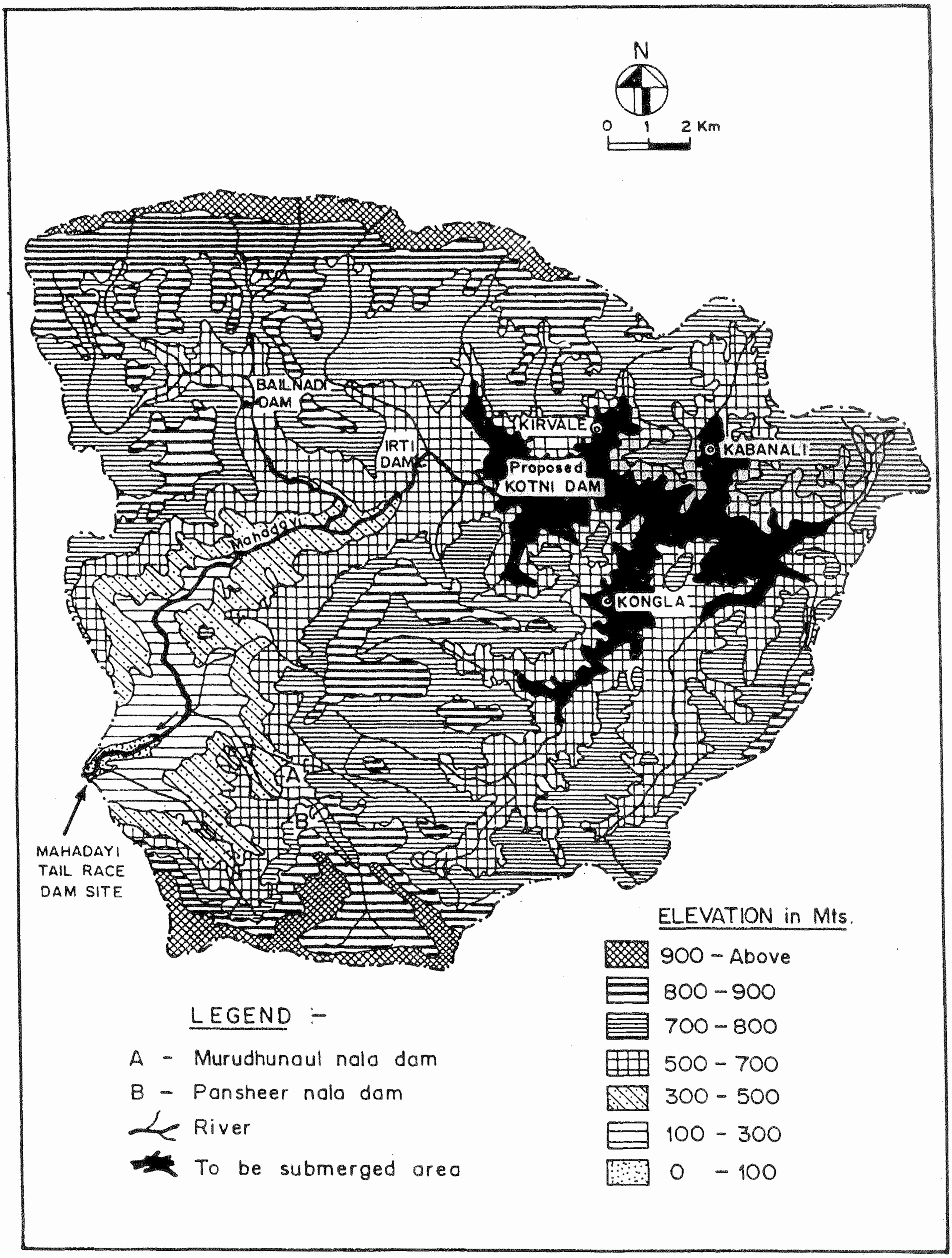


Fig. 4.1 : Topographical Details of Mahadayi Basin in Karnataka

4.2.2 Geology of the Study Area

Karnataka

The geology of the terrain in the project area consists of highly phyllitic meta greywacke and calcareous quartzites belonging to the Dharwar Super group, granitic gneisses and laterites with intrusive dykes and quartz veins. The basalts of the Deccan Trap are the chief formations to the north of the project site. The Dharwar and other major formations in the region are shown in **Fig. 4.2.** The geology and tectonics of the area including the off shore part is shown in **Fig. 4.3.** The geology and tectonics superimposed with the seismic zones in accordance with the seismic zoning map of India (IS : 1983-1984) are shown in **Fig. 4.4.** A detailed description of the geology and tectonics of the region is presented in **Annexure 4.1**. The classification of Dharwar sediments is presented in **Table 4.2.**

The main rock type occurring in the project area is the dark colored meta greywackes highly phyllitic in nature. The strike of this formation varies from N 30° - 60° W, S 30° - 60° E with near horizontal to 15° dip towards NE. The phyllitic meta greywackes are found to be highly foliated with foliations spaced at less than 5 cm and further cut across by four other sets of cross joints.

At the Kotni Dam site in the river section fresh schistose quartzite is exposed for a length of 55 m along the dam axis. On the flanks schistose quartzite has been inferred to occur at depths ranging from 4 m to 21 m. The rock is usually weathered down to depths varying from 1 m to 3m.

At the Irti dam site fresh schistose quartzite is either exposed or available below a very shallow cover of overburden. Similar rock on the left bank would be encountered at depths varying from 10.23 m to 18.5 m. On the right bank there is a 25 m wide dolerite dyke.

The head race tunnel will also encounter two dolerite dykes and a quartz roof, and will have a rock cover varying from 12 m to 225 m. Massive migmatite is the rock type at the tail race dam site.

Quartz chlorite schist is the rock type met with at the Bailnadi dam site and would be the medium through which the interconnecting tunnel between the reservoirs of Bailnadi and Irtinala is to be constructed.

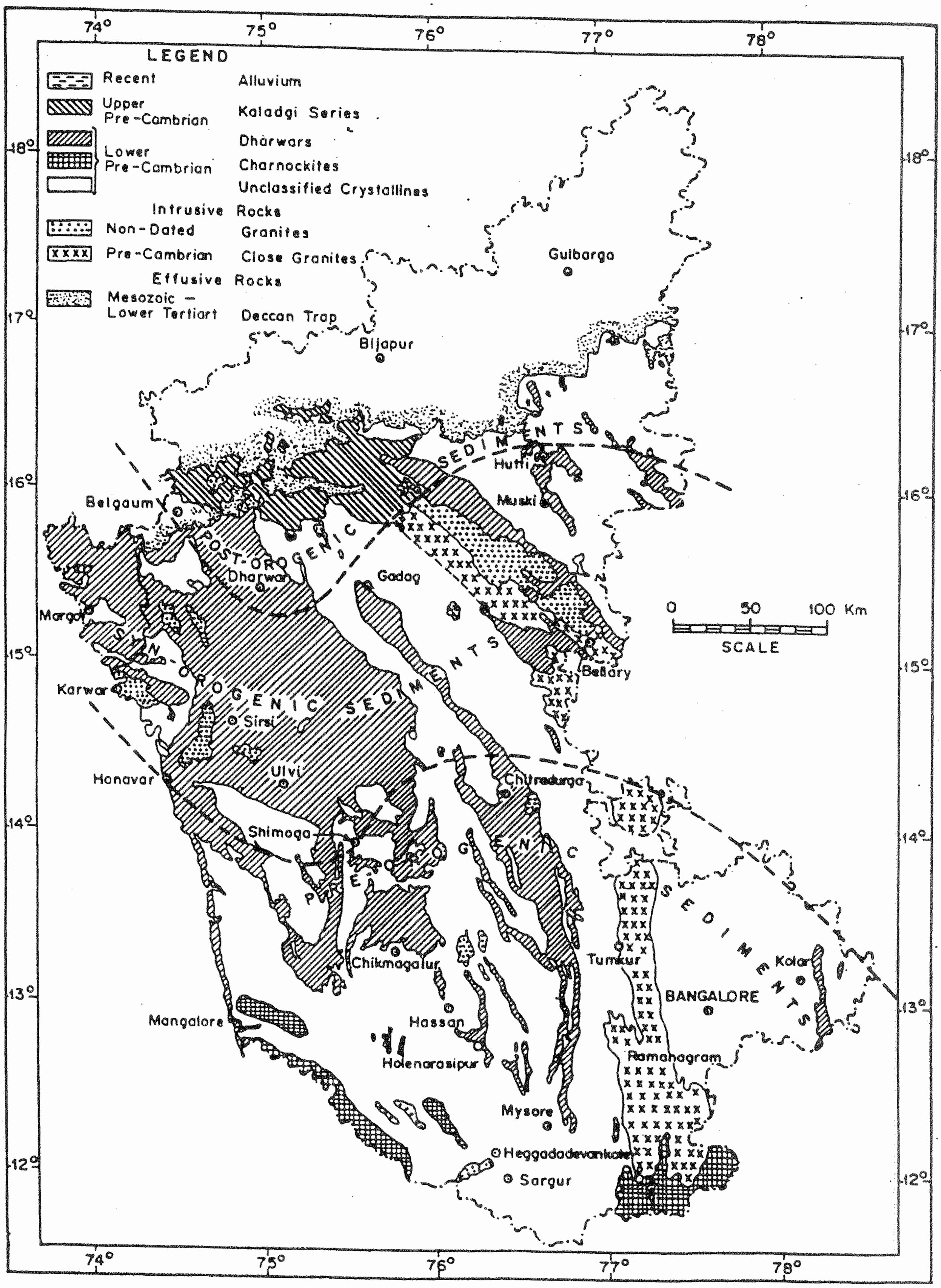


Fig. 4.2 : Dharwars and other Major Formations in the Region

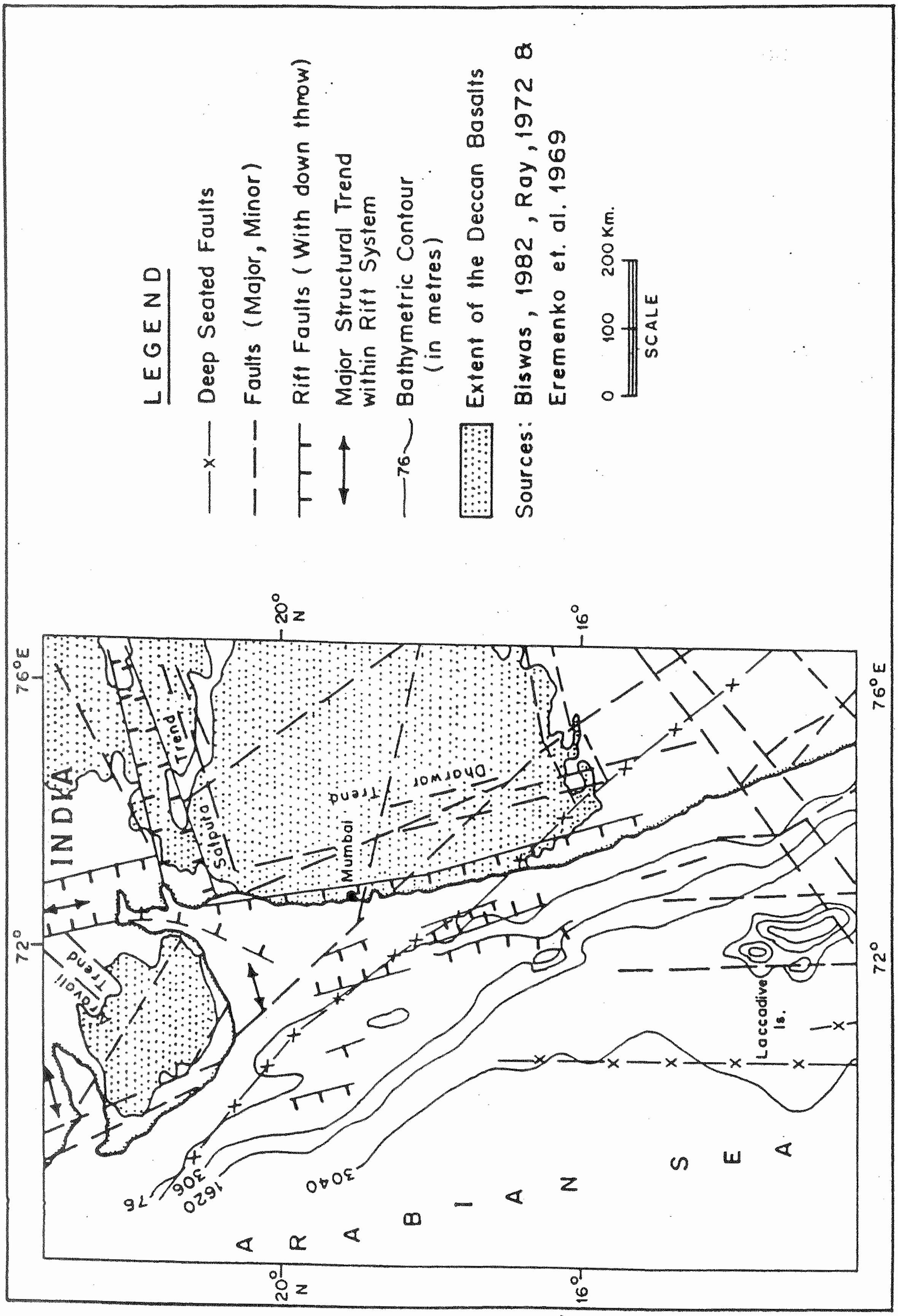


Fig. 4.3 : Geology and Tectonics of the Study Area

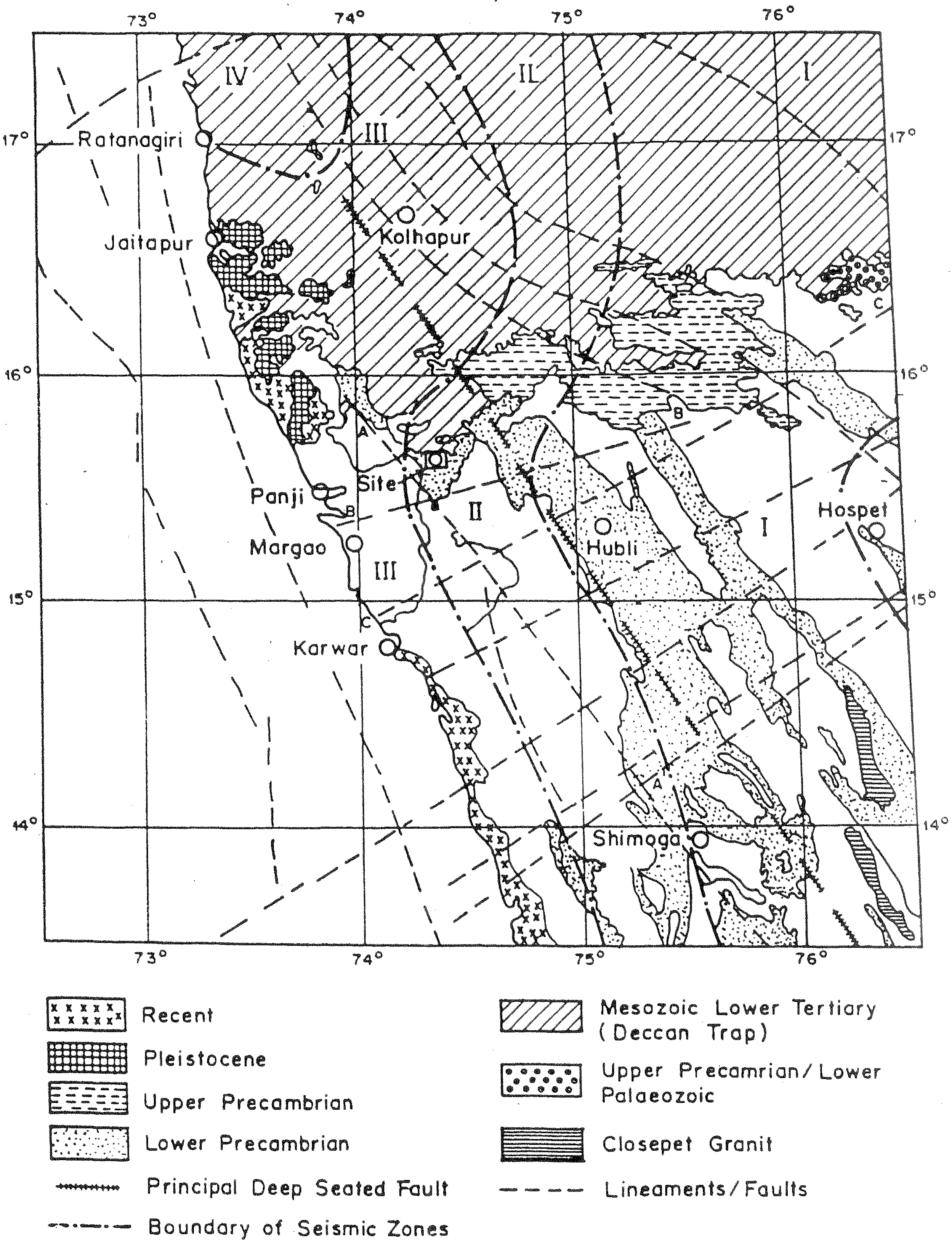


Fig. 4.4 : Seismic Zoning Map of Study Area

Table 4.2

Classification of Dharwar Sediments

Sl. No.	Group	Area	Lithology	Grade of metamorphism	Tectonic activity	Volcanic activity	Plutonic Activity
1.	Post-orogenic sediments	Dharwar and part of North Kanara	Pink shales and sandstones	Molasse facies sandstones and red shales of Dharwar and Hubli	Practically Nil	Nil	Post-orogenic granites Karwar-Siddapur granites
2.	Syn-orogenic sediments	North Kanara, Goa and part of Dharwar	Younger granites Iron, manganese for mations Limestone, Ultrabasics-metavolcanics-metagreywacks quartz-actinolite schists Quartz-sericite schists Quartz-chlorite-biotitealbite-ankerite schists Othoquartzites Conglomerates (?) Arkose	Predominantly greenschist facies and subordinate amphibolite facies	Moderately folded	Moderate. Pillow lavas-variolitic, acid flows etc	Pyroxenite, Gabbro-norite
3.	Pre-orogenic	Shimoga South Kanara Shitradurga Coorg Kolar Hatti-Muski Sandur Holenarasipur Sagur	Younger granites Ferruginous quartzites-manganese and limestone Ultrabasics, metavolcanics Chlorite-actionolite schists Metagreywacke, phyllites Othoquartzites amphibolite Kyanite-staurolite-mica schists Kyanite-sillimanite gneisses	Contrasted grades 1. Kyanite-sillimanite granulite facies 2. Green schist facies	Intensely folded	Intense. Pillow lavasvariolitic, amygdaloidal, tuff etc.	Diapiric granites : Honnali, Shimoga and basement rheomorphism, Pyroxenites, Peridotites

Goa

Goa is underlain by rocks of the Precambrian age comprising banded biotite gneisses, metavolcanics, phyllites, biotite and chlorite schists, greywackes, conglomerate (tilloids) pink phyllites with associated banded ferruginous quartzite and chert braccia. These rocks are intruded by ultrabasic and basic sills and dykes followed by granites and pegmatites. Dolerite dykes and quartz veins form the youngest intrusives in the area. Much later in geologic time, upper and exposed parts of almost all rock formations of Goa underwent laterisation in the warm and humid climate. Almost all the rocks except granite are covered by a mantle of laterite.

Precambrians group comprises a number of granitic and metamorphic rocks, both sedimentary and volcanic in origin, which occupy more than 95% of the area of Goa. Meta-Basalt and associated volcanic rocks predominate in south Goa and occur over about 650 sq.km. The schistose rocks occur mainly in west Goa with small patches in central and eastern Goa also. Pink phyllitic with the banded manganiferous and ferruginous quartzites constitutes the manganese and iron-ore bearing horizon. The pink phyllitic has a wide distribution and occurs over about 1000 sq.km from the river Talpona in the north-west to Salginium in the south-east over a length of about 95 km. Amphibolites occur as narrow, small bodies intruding the country rock, e.g. Tamdi, Maloli and other places in north and central Goa. Granites and granite gneiss occurs over about 500 sq.km in central Goa, east of Sanguem, Chouni in south Goa and along eastern border of Goa along the western ghats. Basaltic lava flows belonging to the Deccan Traps occur along NE part of Goa along the border from NE of Vainguinim to NE of Cheraundem. A mantle of laterite varying in thickness from 3 to about 30 m occurs extensively covering almost all the formations in Goa. Lateritisation is more in coastal areas than in the hilly regions. Beach sands occur as linear, narrow, strips along the coast. The thickness varies from 1 to about 10 m. It is fine yellowish brown to brown, fine to medium grained and composed of quartz, felspar, mica, amphiboles, etc. Alluvium occurs as small lentricular patches along major rivers and comprises laterite gravels, quartz and felspar grains.

Boreholes have mostly been drilled in Goa for water supply and hence they are located generally in villages and towns and in topographical lows. The borehole data indicates a general soil, laterite or weathered zone upto 15 m bgl. However, at places this zone of alteration is as deep as 20 to 25 m bgl. e.g. Mocasana, Panaji, Quepem, Kanura, Cabo Rajniwar, etc. The boreholes in general have encountered soil and alluvium, laterite or weathered zone upto 15 to 30 m.

4.3 Air Environment

The existing ambient air quality status (AAQS) of the proposed dam construction sites was determined through in-situ monitoring whereas, the predictions for different emission scenario were made through air pollution modeling for the existing micro-meteorological and topographical features of the project site and the surrounding area.

In hydro electric power generation, there are no air polluting units/operations. However, air pollution will occur intermittently, mainly during the construction phase. With this in view, air monitoring in the catchment area around the dam sites area was undertaken during winter season. From air environment point, winter is the most critical season as it is conducive for build up of pollutants within the tropospheric zone due to inversion phenomena.Five sampling locations were selected depending upon the importance of the site and/or direction and distance of dam sites within catchment area. Wind direction and speed were recorded during the study period. Wind roses were plotted to demarcate the zone and direction of probable maximum concentrations. The location and bearing of all the five ambient air quality monitoring (AAQM) stations depicted in **Fig. 4.5** are given in **Table 4.3**.

4.3.1 Ambient Air Quality Status

Air pollutants associated with the proposed project construction phase emissions, viz. suspended particulate matter (SPM), sulphur dioxide (SO_2), and oxides of nitrogen (NO_x) were monitored. Samples were collected round the clock for gaseous pollutants (SO_2 and NO_x) at a flowrate of 0.2 lpm. The SPM was monitored using high-volume sampler on 24 hourly basis depending on the availability of electricity and otherwise with the battery operated samplers. The standard methods used for quantification of pollutants are summarized in **Table 4.4**.

The mean SPM concentrations at all the five AAQM stations ranged from 20 to 97 $\mu g/m^3$. All the stations have shown SPM concentration below the CPCB standard of 100 $\mu g/m^3$ for 24 hours for sensitive areas **(Annexure 4.2, Table 1)**. The highest concentration of SPM was recorded at Jamboti sampling station which is at a distance of about 100 m from Belgaum-Kanakumbhi road. This high value may be attributed to local phenomena, viz. traffic (auto exhaust emission) or local dust entrainment due to village activities and combustion of agricultural waste. The low dust concentration at other stations is due to virgin environment and high density of vegetation with associated high humidity in the study area. The levels of gaseous air pollutants, SO_2 and NO_x were mostly below detectable limits. **(Annexure 4.2, Table 2 and 3)**.

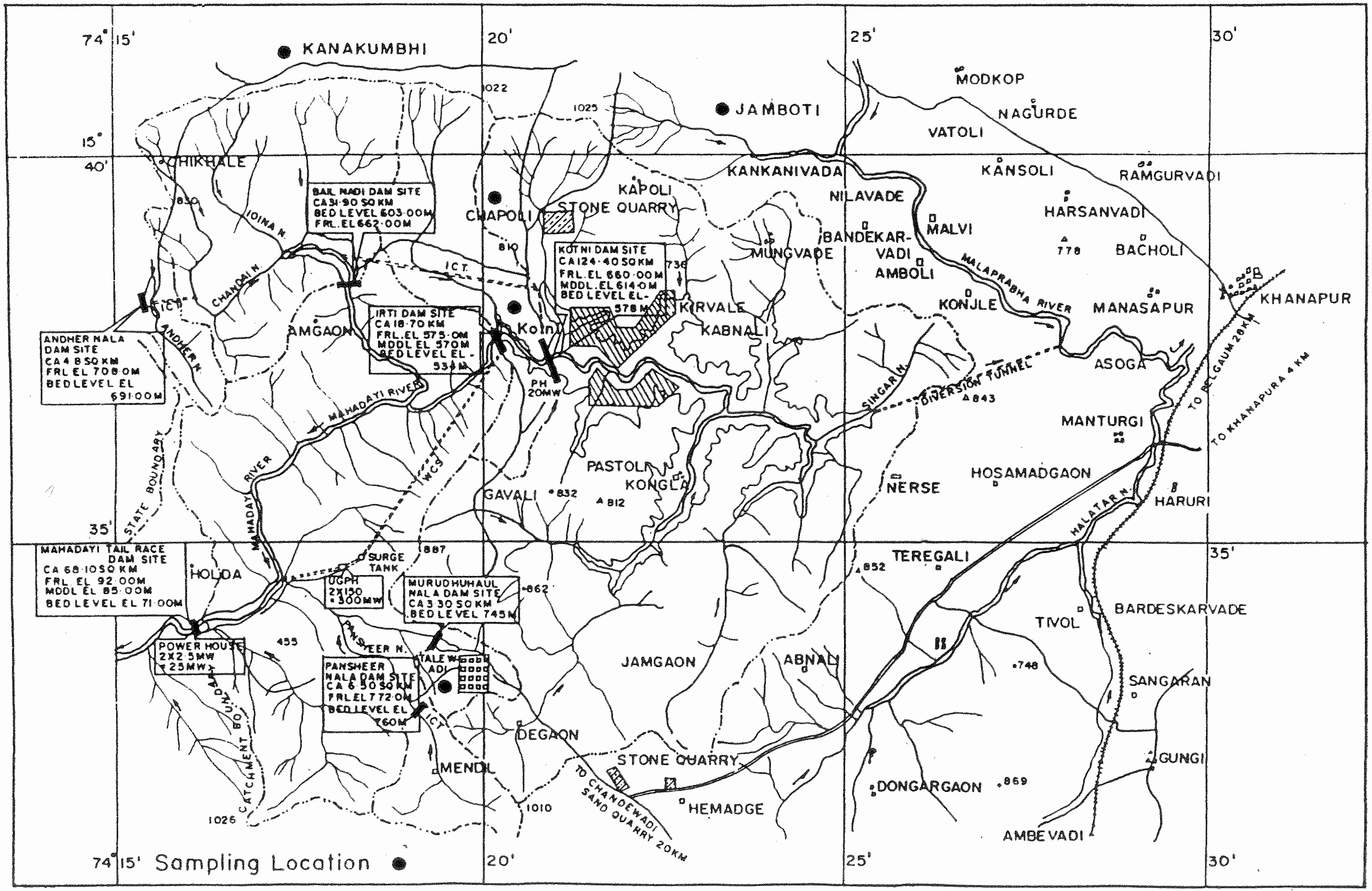


Fig. 4.5 : Location of Ambient Air Quality Monitoring Stations

Table 4.3

Ambient Air Quality Monitoring Stations

Sl. No.	Location	Sampling Height (m)	Altitude MSL (m)	Distance from Dam Site (km.)	Remarks
1.	Jamboti	2	900	Kotni dam : 4	Forest guest house 0.5 km from main road going towards Panji
2.	Chapoli	4	810	Kotni dam : 3	Village with ≤ 25 houses
3.	Kotni	4	578	Kotni dam : 0.5	Inspection cottage of Irrigation Department
4.	Kanakumbhi	4	1000	Kalsa-Surla Nala : 1	PWD/Irrigation guest houses on the main road going towards Panji
5.	Talewadi	4	750	Pansheer Nala dam : 2	Village with ≤ 10 houses, with approach road leading to Pansheer dam

Table 4.4

Techniques used for Ambient Air Quality Monitoring

Pollutant Parameter	Method of Sampling and Analysis	Minimum Detectable Limit ($\mu g/m^3$)	Sensitivity Range
Sulphur Dioxide (SO_2)	West & Gaeka Method	6	0.005-5 ppm
Nitrogen Dioxide (NO_2)	Jacob & Hocheissir	3	0.01-0.4 ppp
Suspended Particulate Matter (SPM)	High volume samplers / Battery operated samplers**	1	1-100 μ

** Sampling locations where electricity supply was not available

4.3.2 Meteorology

Hydrometeorological data for the year 1991-92 of Khanapur taluka **(Annexure 4.2, Table 4)** showed that the daily mean temperature varied between 21-29°C. The lowest and highest mean temperatures recorded were 21.1°C and 29.3°C respectively. Wind velocity was found to be maximum during the rainy season, especially in the day time. The climate of this district is humid throughout the year, recording relative humidity as high as 91 %. The rainfall during the monsoon season mainly contributes to the total annual rainfall. The evaporation rate ranged between 88.6 mm and 161.4 mm, which gradually increased in summer reaching a maximum in the month of May.

Meteorological profiles based on the previous records of the India Meteorological Department observations at Panaji and Belgaum are presented for the region. The construction/submergence area receives an average annual rainfall of 3800-4400 mm and the maximum rainfall is received during June to September. There are 10 rain gauging stations in and around Mahadayi basin influencing the rainfall in the catchment area. Data on total rainfall at 8 rain gauge stations is given in **Annexure 4.2, Table 5**. The annual rainfall varies from a maximum of 7119 mm at Chapoli to a minimum of 790 mm at Nerse.

The average monthly maximum and minimum relative humidity values as recorded at Mormugao observatory are 80% and 60% respectively. The wind direction in the morning is easterly to north easterly during October to April and North East direction in May. In the afternoon , these wind tend towards West or north west due to the effect of sea breeze . During the monsoon period, the winds are generally westerly throughout the day and are fairly strong. The average monthly maximum and minimum wind speed is 23.1 km/hr and 9.5 km/hr respectively.

The south-west monsoon contributes major rainfall and the total annual precipitation varies from 3800-4400 mm which is mainly received during June to October. Pre-monsoon showers during April and May are common. The monthwise distribution of rainfall and potential evapotranspiration at various meteorological stations in Goa are presented in **Annexure 4.2 Table 6**.

The meteorological data of Panaji, situated at sea level in the same region and latitude indicates that the average relative humidity is as high as 93%. The seasonal variation observed in wind pattern is characteristic of coastal region. **Fig. 4.6** shows in graphic form as wind roses the seasonal wind speed and wind direction. These were computed using 1980-1991 meteorological data for 8.30 hrs and 17.30 hrs (IST). In the morning, the sea breeze is from E-NE sector, while at 17.30 hrs it is from E-NE

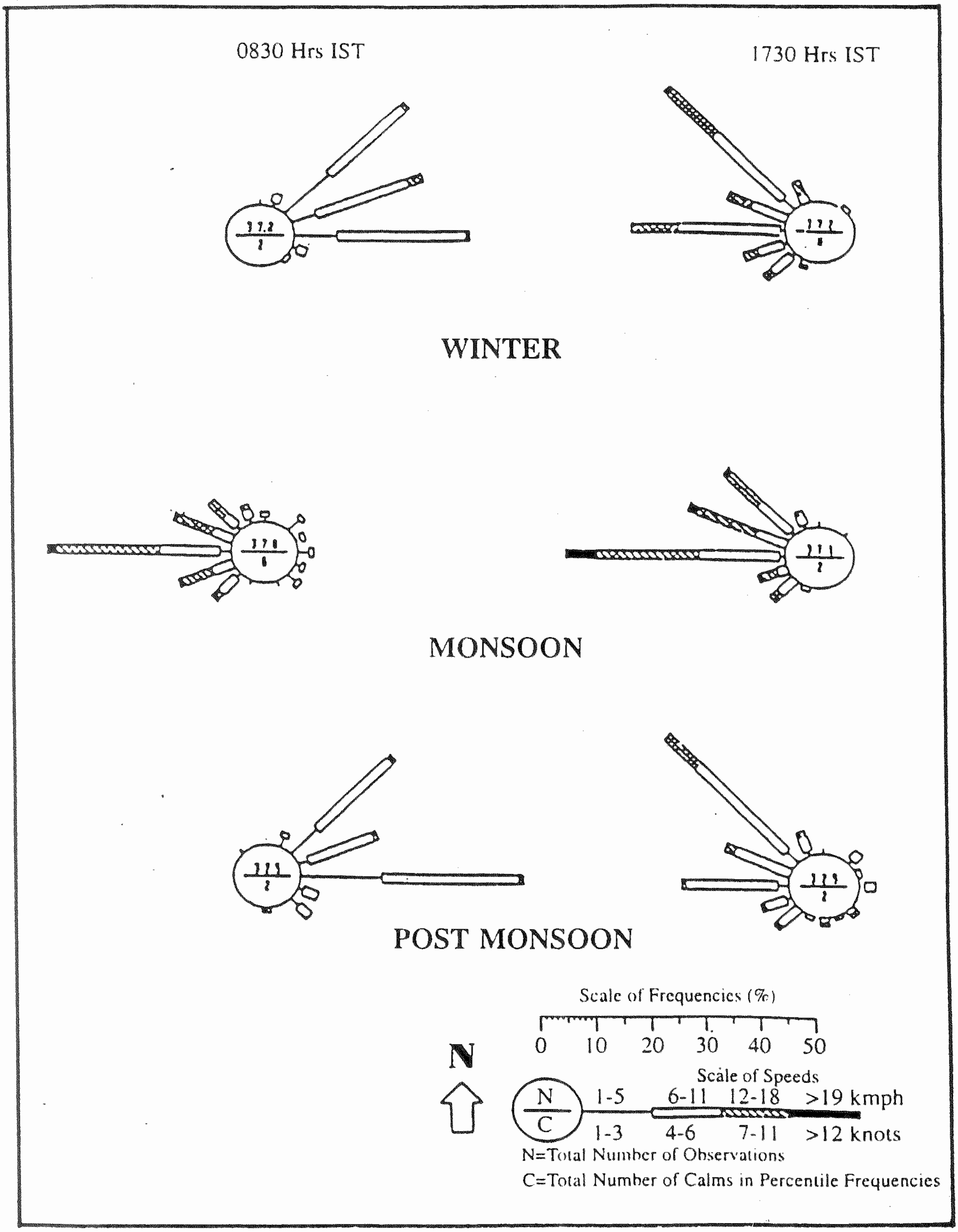


Fig. 4.6 : Seasonal Wind Rose at Panaji (Average : 1980-91)

sector during both winter and post-monsoon seasons. During monsoon season, the winds flow from NW-SW sector at 8.30 hrs as well as at 17.30 hrs.

The bulk of the total annual rainfall occurs during the monsoon season i.e. from June to October. The distribution of rainfall is largely influenced by the topography of the area.

The monthly mean minimum and maximum temperatures(dry bulb and wet bulb observations),rainfall and relative humidity (average of 10 years 1982-1991 meteorological data) recorded at Panaji are given in **Table 4.5**. The relative humidity data reveals that humid atmosphere persists throughout the year. Generally, during rainy season i.e. in June, July and August months, almost every day the relative humidity was observed to be above 80%, whereas during summer season it was found to be as low as 55%. The variation in relative humidity indicates that the project site is not prone to sudden changes in weather condition and untimely occurrence of rainfall.

The minimum temperature ranges from 20-26°C whereas maximum temperature ranges from 28.5-34°C. Being in coastal region, the temperature variations are not significant.

The monthly mean solar radiation (average of 7 years 1985-1991 meteorological data) is depicted in **Fig 4.7.**

4.4 Noise Environment

A noise survey was conducted at different locations in the project area including the proposed sites for construction of dams and diversions. Noise measurements were taken in villages, along highways, sub-highways and at commercial and residential places to determine the background noise levels and to assess the impact of noise due to the activities at the proposed dam sites and power houses on human settlements in and around the project site.

4.4.1 Identification and Characterisation of the Sources of Noise

The proposed hydroelectric power station will be situated 30 km south-west of Belgaum city. The construction activity will be concentrated mainly at Kotni, Irti, Pansheer, Muruduhaul, Haltar and Kalsa nalas. Presently, these sites, being in deep forest, are calm.

Table 4.5

Monthly Variation (Average) in Temperature, Rainfall and Relative Humidity at Panaji (1982 - 1991)

Sl. No.	Months	Temperature (^{o}C)		Rainfall (mm)	Relative Humidity (%)
		Maximum	Minimum		
1.	January	32.43	20.24	0.03	70.8
2.	February	32.07	20.76	0.31	70.8
3.	March	32.13	23.10	0.09	70.8
4.	April	33.00	25.26	3.58	70.6
5.	May	33.67	26.63	51.65	70.5
6.	June	30.64	24.90	806.58	80.5
7.	July	29.19	24.35	790.76	90.0
8.	August	28.80	24.02	667.43	80.8
9.	September	30.05	24.13	225.19	80.6
10.	October	29.92	23.75	116.63	80.2
11.	November	33.16	22.22	19.70	70.2
12.	December	33.00	21.31	2.08	70.0

Source : India Meteorological Department, Pune

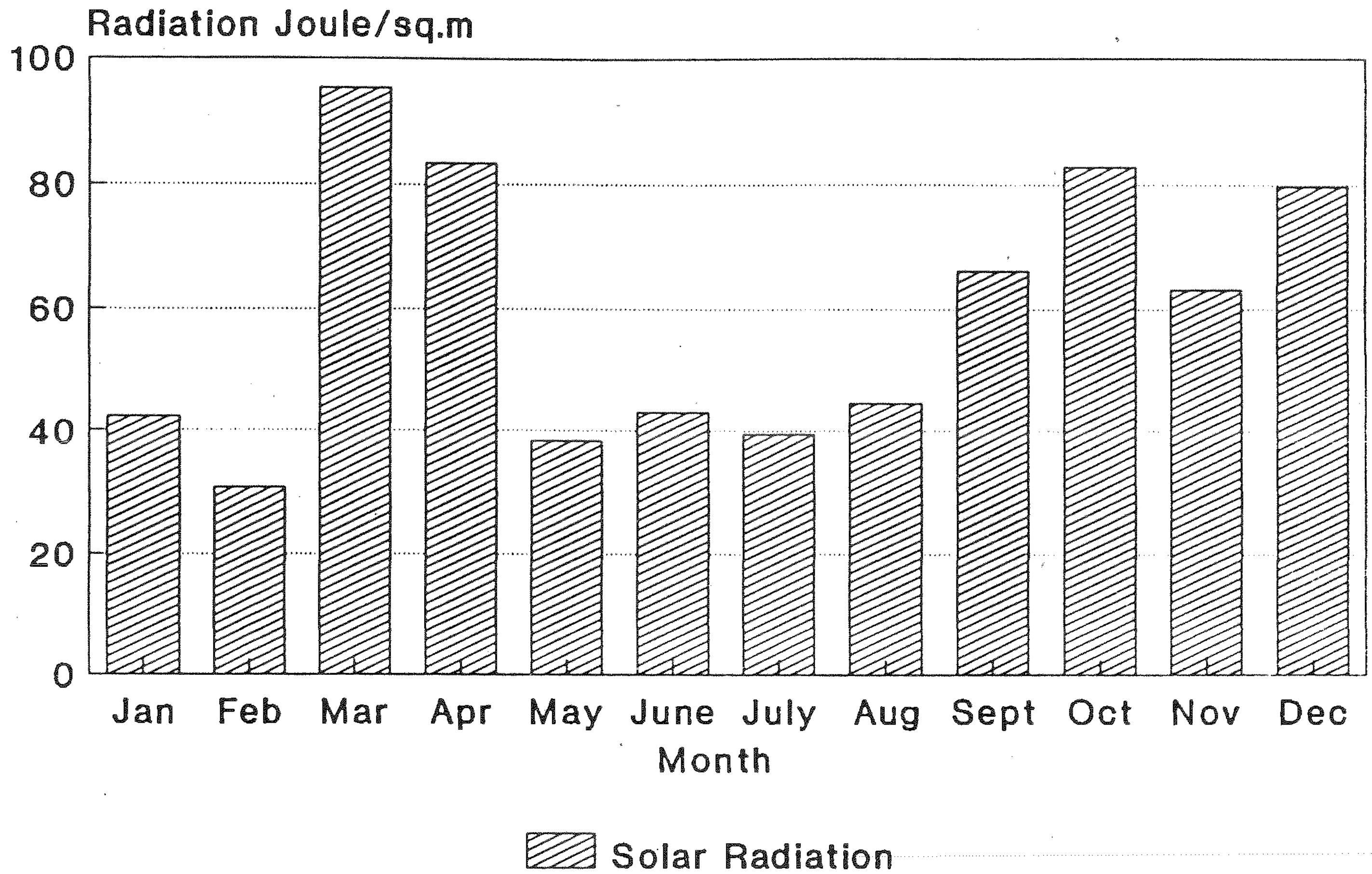


Fig. 4.7 : Monthly Mean Solar Radiation
(7 years average)

The dams will be of composite nature consisting of earth embankments and concrete structure. The main sources of noise during the construction phase will be traxcavators, air-compressors, drilling machines, dumpers, shovels, concrete-mixers and blasting-operations. In addition, stationary sources, mobile sources such as trucks, tippers, and placers are likely to contribute noise levels.

4.4.2 Ambient Noise Levels in the Neighbourhood Human Settlements

Background noise levels in villages in the study area were monitored and the results are presented in **Annexure 4.3, Table 1**. In the villages surveyed, the noise levels were in the range of 38-46 dBA. The noise levels at sensitive receptors viz. schools and dispensaries were in the range of 38-44 dBA (**Annexure 4.3 Table 2**). The day and night noise levels (Leq) monitored at a few residential locations and the proposed dam sites are given in **Annexure 4.3 Table 3**.

4.4.3 Traffic in the Study Area

The traffic activity in the study area is primarily due to the vehicular traffic on NH4(A) (Belgaum-Khanapur) and the Belgaum - Panaji state highway passing through the study area. The other roads are forest roads. The noise levels measured at a few traffic junctions in the study area are presented in **Annexure 4.3 Table 4**.

In general, the observations indicate that the noise levels measured at residential and sensitive areas are well within the standards prescribed by Central Pollution Control Board (CPCB) (**Annexure 4.3 Table 5**).

4.5 Water Environment

4.5.1 Surface Water Hydrology

The Mahadayi river flows through Karnataka and Goa before joining the Arabian Sea. There are a few nalas and rivers joining the river en-route. There are 9 rivers in Goa which drain into the Arabian Sea. These are Terekhol, Chopra, Baga, Mandovi, Zuari, Sal, Saleri, Talpona and Galgibag. The total catchment area of these rivers is 3653 sq.km and the total runoff in these rivers is 8427 Mcum. During monsoon, when the area receives very heavy rainfall, these rivers are flooded inundating large parts of the flood plains. The major and medium projects for storing this flood excess water are as yet not operational. Hence, 60 to 70% of surface runoff flows into the sea without being utilised. Khandepar is a major river joining the Mahadayi in Goa downstream of Ganjem where the CWC permanent gauging station is located. The CWC has gauging stations on both the rivers viz., Mahadayi at Ganjem and Khandepar at Collem. The flow data for the two rivers for the period 1979-92 is presented in **Tables 4.6 and 4.7** respectively. The average monthly flows, as recorded at the CWC gauging stations, and the yield as calculated on the basis of rainfall-runoff correlations are presented in **Table 4.8**. The variation in flow is also depicted graphically in **Figs. 4.8** and **4.9**. The flow data generated by Irrigation Department, Belgaum for Kalsa, Surla and Haltar nalas for the period 1992-1996 is presented in **Annexure 4.4, Table 1, 2 and 3** respectively. The average yield of the three nalas is 409 Mcum of which 139 Mcum is proposed to be diverted to the Malaprabha basin.

The rivers Mandovi and Zuari are linked by the Cumbarjua canal. The salinity level in the canal is influenced more by the Zuari than by the Mandovi. The annual average runoff from the Mandovi and Zuari basins as estimated by the CPCB is 16000 and 11000 Mcum respectively. The saline reaches are navigable and support fisheries. The salinity, temperature and current measurements carried out at different cross sections at different periods of time to determine the mixing characteristics of the estuaries revealed that they are well mixed during low freshwater flows. During monsoon, a salt wedge is formed near the mouths of the rivers. The Bulk Richardson Number, which is a measure of the stability characteristics of the whole flow, determined at different locations was in the range of 0.06 to 48 for Mandovi indicating uniform mixing. High longitudinal dispersion coefficient (10^7 to 10^8 sq.cm/sec indicates quick dispersal of material in the Mandovi estuary.

The physiography of Goa is not conducive to large scale water resources projects. Medium / minor projects constructed at suitable sites can utilise about 50% of available water resources. At present, irrigated area in Goa is only 10% of the net sown area as against the national average of 25%. The area irrigated through storage tanks, diversion bandharas, springs and wells in 1980-81 was 19883 ha. In the interior areas, especially in Ponda and Bicholim tehsils, small kuchha diversion dams are constructed annually to irrigate rice fields and arecanut gardens.Raw water storage tanks are extensively used for irrigation of rabi crops. The tanks which become dry are available for cultivation during kharif. Well irrigation is mostly found in the low lying areas of Pernem and Bardez talukas. In valleys there are a number of natural springs, which are used for cultivation of arecanut and bananas. Nearly 3/4th of the arecanut cultivation is irrigated in this manner. The government encourages lift irrigation from the river and an area of 687.96 ha is irrigated by this method.

Table 4.6

Flow in Mahadayi River at Ganjem in Goa - m^3/sec

Month	Year 1979			Year 1980			Year 1981			Year 1982			Year 1983		
	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum
January	4.5	5.6	2.7	5.6	7.8	4.0	4.05	5.3	2.5	4.5	5.6	2.7	3.33	4.5	2.6
February	1.9	2.8	1.6	3.1	4.5	2.4	1.73	2.6	0.9	1.9	2.8	1.6	2.03	3.2	1.4
March	1.1	1.8	0.7	2.2	4.8	0.8	1.12	2.0	0.6	1.1	1.8	0.7	1.23	1.7	0.9
April	0.79	1.0	0.6	0.9	1.3	0.7	0.85	1.6	0.5	0.79	1.0	0.6	0.85	1.4	0.5
May	1.06	4.3	0.4	0.8	2.5	0.5	0.96	1.8	0.5	1.06	4.3	0.4	0.65	1.2	0.4
June	100.19	690.0	1.1	220.78	1010.0	0.4	131.3	700.80	1.3	100.19	690.0	1.1	171.3	1621.5	0.5
July	630.0	4746.3	42.8	629.16	2837.0	1265.0	538.8	1475.6	118.60	630.0	4746.3	42.8	44.30	1254.4	181.0
August	702.07	2572.1	199.4	591.32	1265.0	263.0	151.02	1570.0	100.5	702.07	2572.1	199.4	512.30	1910.2	169.10
September	83.29	180.6	45.0	120.33	287.3	63.3	151.03	733.0	54.40	83.29	180.6	45.0	211.03	573.3	94.69
October	32.45	59.40	19.0	43.33	118.0	21.9	53.03	148.6	26.0	32.45	59.40	19.0	62.40	117.0	30.0
November	16.60	36.9	8.0	14.83	20.3	10.0	19.49	34.0	11.9	16.60	36.9	8.0	24.0	46.7	12.4
December	6.80	10.1	4.2	8.41	12.3	5.0	8.38	12.0	5.3	6.80	10.1	4.2	8.4	11.3	6.1

Source : Central Water Commisson

Table 4.6 (Contd...)

Month	Year 1984			Year 1985			Year 1986			Year 1987			Year 1988		
	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum
January	4.5	6.3	2.7	4.05	5.3	2.5	4.5	5.6	2.7	3.33	4.5	2.6	5.6	7.8	4.0
February	2.3	3.1	1.7	1.73	2.6	0.9	1.9	2.8	1.6	2.03	3.2	1.4	3.1	4.5	2.4
March	1.1	1.7	0.8	1.12	2.0	0.6	1.1	1.8	0.7	1.23	1.7	0.9	2.2	4.8	0.8
April	0.8	1.1	0.6	0.85	1.6	0.5	0.79	1.0	0.6	0.85	1.4	0.5	0.9	1.3	0.7
May	0.6	0.7	0.4	0.96	1.8	0.5	1.06	4.3	0.4	0.65	1.2	0.4	0.8	2.5	0.5
June	147.8	914.0	0.4	131.3	700.80	1.3	100.19	690.0	1.1	171.3	1621.5	0.5	220.78	1010.0	0.4
July	636.2	3013.2	132.2	538.8	1475.6	118.60	630.0	4746.3	42.8	44.30	1254.4	181.0	629.16	2837.0	1265.0
August	293.5	503.3	138.0	151.02	1570.0	100.5	702.07	2572.1	199.4	512.30	1910.2	169.10	591.32	1265.0	263.0
September	127.7	276.3	69.8	151.03	733.0	54.40	83.29	180.6	45.0	211.03	573.3	94.69	120.33	287.3	63.3
October	79.7	153.4	37.1	53.03	148.6	26.0	32.45	59.40	19.0	62.40	117.0	30.0	43.33	118.0	21.9
November	22.1	35.9	10.0	19.49	34.0	11.9	16.60	36.9	8.0	24.0	46.7	12.4	14.83	20.3	10.0
December	10.1	14.2	6.4	8.38	12.0	5.3	6.80	10.1	4.2	8.4	11.3	6.1	8.41	12.3	5.0

Source : Central Water Commisson

Table 4.6 (Contd...)

Month	Year 1989			Year 1990			Year 1991			Year 1992		
	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum
January	4.05	5.3	2.5	4.5	5.6	2.7	3.33	4.5	2.6	5.6	7.8	4.0
February	1.73	2.6	0.9	1.9	2.8	1.6	2.03	3.2	1.4	3.1	4.5	2.4
March	1.12	2.0	0.6	1.1	1.8	0.7	1.23	1.7	0.9	2.2	4.8	0.8
April	0.85	1.6	0.5	0.79	1.0	0.6	0.85	1.4	0.5	0.9	1.3	0.7
May	0.96	1.8	0.5	1.06	4.3	0.4	0.65	1.2	0.4	0.8	2.5	0.5
June	131.3	700.80	1.3	100.19	690.0	1.1	171.3	1621.5	0.5	220.78	1010.0	0.4
July	538.8	1475.6	118.60	630.0	4746.3	42.8	44.30	1254.4	181.0	629.16	2837.0	1265.0
August	151.02	1570.0	100.5	702.07	2572.1	199.4	512.30	1910.2	169.10	591.32	1265.0	263.0
September	151.03	733.0	54.40	83.29	180.6	45.0	211.03	573.3	94.69	120.33	287.3	63.3
October	53.03	148.6	26.0	32.45	59.40	19.0	62.40	117.0	30.0	43.33	118.0	21.9
November	19.49	34.0	11.9	16.60	36.9	8.0	24.0	46.7	12.4	14.83	20.3	10.0
December	8.38	12.0	5.3	6.80	10.1	4.2	8.4	11.3	6.1	8.41	12.3	5.0

Source : Central Water Commisson

Table 4.7

Flow in Khandepar River at Collem in Goa - m^3/sec

Month	Year 1980			Year 1981			Year 1982			Year 1983			Year 1984		
	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum
January	0.82	1.0	0.60	0.65	0.8	0.5	0.68	0.8	0.6	0.9	1.2	0.6	0.80	1.0	0.5
February	0.6	0.8	0.3	0.42	0.6	0.2	0.44	0.60	0.30	0.60	0.70	0.40	0.2	0.5	-
March	0.29	0.30	0.20	0.29	0.4	0.2	0.36	0.6	0.2	0.50	0.60	0.40	-	-	-
April	0.32	0.50	0.30	0.26	0.3	0.2	0.34	0.50	0.30	0.37	0.50	0.30	-	-	-
May	0.29	0.4	0.2	0.2	0.5	0.2	0.26	0.4	0.20	0.42	0.7	0.3	-	-	-
June	32.10	344.0	0.2	21.3	237	0.4	19.0	74	0.5	18.1	148.6	0	17.20	160.0	-
July	94.0	409.1	24.5	51.2	93.0	15.0	66.9	232.8	4.5	69.2	212.6	12.4	113.5	338	19.6
August	91.7	331.2	34.4	67.59	228.0	14.20	96.77	211.4	36.0	91.6	416.3	30.70	65.8	179.9	29.7
September	19.5	46.4	8.5	18.43	57.7	9.0	17.74	32.5	8.0	35.8	92.8	13.6	18.1	59.6	6.0
October	5.73	13.0	3.1	6.7	20.7	3.7	6.0	13.5	3.7	11.6	46.4	4.0	7.6	17.5	4.0
November	1.67	14.1	0.9	2.12	4.9	1.3	3.4	9.9	1.7	2.5	5.0	1.30	2.3	4.0	1.4
December	0.90	1.3	0.6	0.98	1.30	0.80	1.3	1.7	0.9	1.1	1.4	0.90	1.1	1.4	0.8

Source : Central Water Commisson

Table 4.7 (Contd...)

Month	Year 1985			Year 1986			Year 1987			Year 1988		
	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum
January	0.7	0.8	0.5	0.5	0.6	0.4	0.5	0.7	0.4	0.635	0.95	0.47
February	0.5	0.5	0.4	0.4	0.4	0.2	0.3	0.4	0.3	0.41	0.50	0.31
March	0.3	0.4	-	0.2	0.6	-	0.4	0.6	0.3	0.39	0.77	0.32
April	-	-	-	-	-	-	0.4	0.6	0.3	0.56	0.737	0.39
May	-	-	-	-	-	-	0.4	0.5	0.3	0.51	0.61	0.43
June	32.7	205	-	22.4	270.0	-	5.9	24.6	0.47	3.0	13.0	0.50
July	58.6	173.7	19.0	47.30	150.0	9.0	47.3	158.7	10.5	69.5	273.9	4.0
August	77.5	297.7	19.9	89.6	552.2	7.6	46.7	106.5	11.17	56.6	165.0	19.0
September	11.2	23.2	4.9	9.4	23.2	5.4	14.27	30.18	6.82	40.1	178.0	13.8
October	14.0	119.4	3.2	3.4	6.0	1.0	7.92	19.50	3.77	9.0	33.0	2.58
November	2.20	3.2	1.1	1.5	2.7	0.5	2.22	5.54	1.35	2.05	3.5	1.32
December	1.1	1.1	0.6	0.9	1.1	0.8	1.12	1.54	0.82	1.13	1.35	0.92

Source : Central Water Commisson

Table 4.7 (Contd...)

Month	Year 1989			Year 1990			Year 1991			Year 1992		
	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum
January	0.71	1.016	0.43	0.59	0.88	0.39	0.78	0.88	0.45	0.89	1.10	0.610
February	0.48	0.68	0.33	0.34	0.52	0.22	0.54	0.74	0.35	0.63	0.73	0.58
March	0.38	0.52	0.34	0.27	0.35	0.21	0.32	0.36	0.28	0.41	0.61	0.20
April	0.50	0.69	0.33	0.30	0.48	0.20	0.39	0.52	0.28	0.014	0.075	-
May	0.53	0.65	0.44	0.75	3.101	0.210	0.50	0.80	0.37	-	-	-
June	24.0	73.9	0.43	30.4	158.2	1.13	15.9	44.8	0.70	-	-	-
July	60.64	229.4	18.0	82.4	325.8	27.67	77.3	253.4	16.6	-	-	-
August	50.8	104.5	21.37	77.91	207.1	38.0	64.56	127.8	25.5	-	-	-
September	14.39	39.8	7.89	33.19	253.7	7.37	12.5	29.8	6.0	-	-	-
October	6.84	23.0	3.46	6.16	13.61	3.79	5.0	19.5	2.5	-	-	-
November	1.51	2.57	0.94	2.32	4.09	1.46	1.60	3.0	0.40	-	-	-
December	0.95	1.07	0.77	1.37	1.92	0.620	0.92	1.05	0.77	-	-	-

Source : Central Water Commisson

Table 4.8

Measured Flows at Ganjem and Collem by CWC (1979-92)

Month	Average Flow (m^3/sec.) (1979-92)			Average Yield (m^3/sec.)** in Mahadayi Basin (1969-85)	
	In Mahadayi at Ganjem	In Khandepar at Collem	Total	Before Project	After Project
June	126.10	20.17	146.27	226.13	188.14
July	483.60	69.82	553.42	824.11	724.0
August	447.12	73.09	520.79	835.56	768.45
September	126.47	20.39	146.86	197.16	224.02
October	57.30	7.50	64.79	99.25	117.13
November	20.76	2.12	22.88	32.79	31.49
December	8.60	1.07	9.75	15.27	29.78
January	3.86	0.69	4.54	7.19	22.59
February	1.95	0.44	2.38	3.37	20.05
March	1.19	0.32	1.51	2.25	19.16
April	0.81	0.26	1.06	1.35	18.42
May	0.83	0.30	1.13	1.35	18.42

1278.59

Source :

* Central Water Commission gauging stations at Ganjem and Collem on river Mahadayi and river Khandepar resectively (Averaged over the Period of 1979-92).

** Karnataka Power Corporation Limited (Average yield calculated on the basis of Runoff-Rainfall correlations in the Mahadayi River Basin over the period from 1969-85

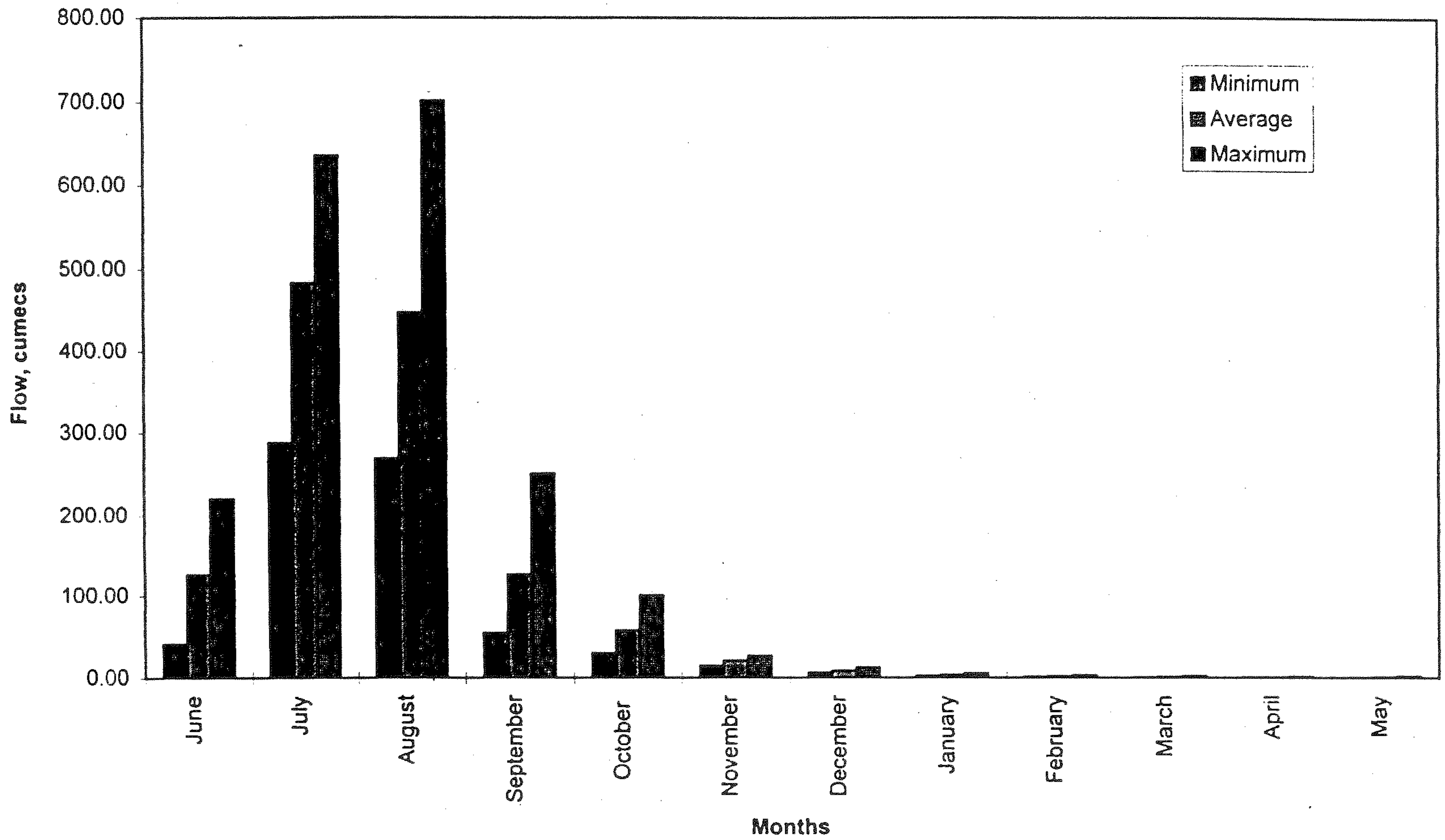


Fig 4.8 : Flow Observations for River Mahadayi (1979-92) at Ganjem, Goa

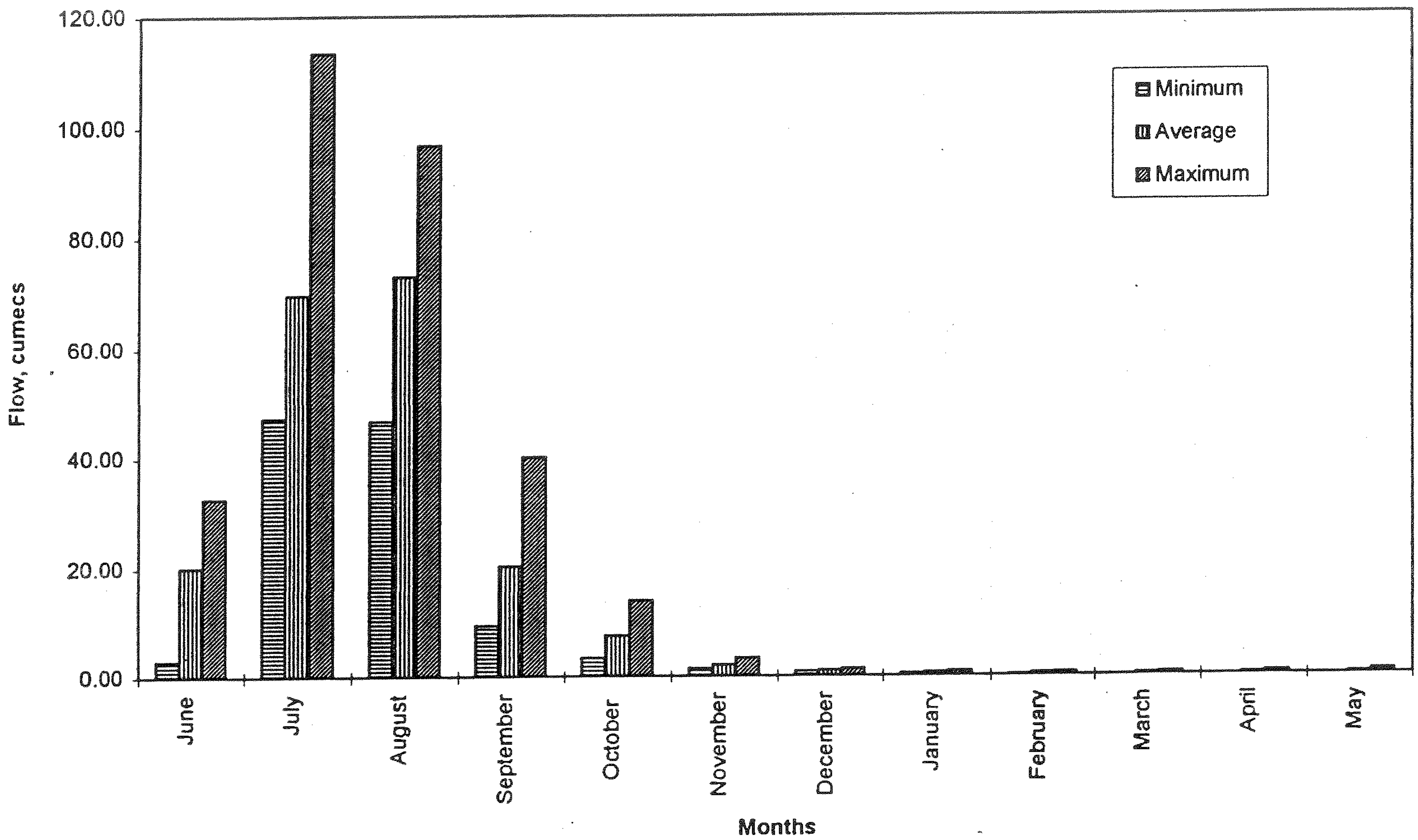


Fig 4.9 : Flow Observations for River Khandepar (1979-92) at Collem, Goa

4.5.2 Ground Water Hydrology

The Mahadayi catchment receives an average annual rainfall of about 3800-4400 mm with water table contours at a depth of about 600 m above MSL. Ground water is restricted to 100 m depth in weathered residual, fractures and fractured zones. The aquifer yield varies from 0.001 to 0.005 m^3/sec. The transmissivity of the aquifer in the region ranges from 143 to 232 m^2/day. The water table fluctuation in the region during pre-monsoon is less than 2 m with the average annual variation between 2 and 4 m.

Water holes are small depressions which retain water a part of the year or yearlong. Water may be derived from seeps or the water hole may be merely a pool in the otherwise dry bed of stream. Existence of water holes in the project area has not been documented by the Forest Department, Panaji, Goa.

Many types of rock formations are present in Goa . Groundwater occurs in water table condition in alluvium, lateritic mantle and in weathered zones wherever there is no laterite cover and in semiconfined to confined conditions in depth in fractured zones, covered weathered zones, iron ore (powdery), etc.

Hydrogeological survey has been carried out by CGWB (1971) in an area of 1800 sq.km in the northern part of Goa district in Pernem, Bardez, Bicholim and Satari talukas and in parts of Ponda and Sanguem talukas. The survey has shown that the wells inventoried penetrated laterite and the underlying lithomarge which form the main aquifer except those around and south west of Sanvordem where the wells are met with either quartz-chlorite schist or granite gneisses, and in the northwestern part where the wells pierced through the jointed schistose rocks. Groundwater occurs under water table condition in these formations and the configuration of the water table is controlled by the topography. In the plateau area and high grounds, the depth of wells ranges from 9.4 to 26.6 m bgl and the depth to water varies between 8.2 and 21.9 m bgl. The wells located in the topographic lows range in depth from 3.1 to 11.95 m bgl and the depth to water table varies from 1.5 to 8.4 m bgl.

Seasonal fluctuation of water levels in wells tapping the beach and alluvium varies between 0.2 and 2.3 m. The seasonal fluctuations in wells tapping the laterite varies from 0 to 2.5 m. In general, laterites are the least affected of all the formations by the normal fluctuations. In some valley portions, there is practically no change in the level between January and April. In the area underlain by granite gneisses, the seasonal fluctuations are more pronounced and vary from just a meter to 4 m (February and April).

Goa receives an average annual rainfall of about 3500 mm. The runoff is very high due to the rugged topography. Similarly, infiltrated water in the shallow aquifers flows out rapidly under the steep hydraulic gradient from eastern high hilly area (recharge zone) to the western plains and valleys (discharge zone). The adverse topographical configuration has inhibited large scale cultivation, network of canals and irrigation.

Deeper aquifers in Goa district were explored by the CGWB during construction of piezometers and deposit wells. Eight piezometers were constructed at Darbandora, Ponda, Bicholim, Panchwad, Valkinim, Wadem, Cuncolim and Fathorda. The depth of these boreholes ranged from 12.2 to 74.5 m bgl. Strata logs show laterite cover upto 10 to 35 m bgl and lithomarge from 15 to 55 m bgl followed by parent rocks like phyllites, greywackes, metabasalt, gneiss, schists, etc. The piezometer yield ranged from 0.3 to 10 lps. It is noticed that joints and fracture zones form better aquifers than the weathered zones.

The state government departments like PWD, PHE and Irrigation have drilled about 300 borewells for water supply to villages. The depth of these borewells ranges from 25 to 85 m bgl and their yields from 0.5 to 18 lps.

The data on 10 hydrograph network stations established by CGWB shows that water levels in Goa during 1981 to 1985 ranged from 5.93 to 15.28 m bgl (pre-monsoon) and from 3.41 to 10.61 m bgl (post-monsoon). The average annual fluctuation during the period ranged from 0.81 to 6.90 m.

The iron and manganese ore mines are situated on a ridge of about 40 to 60 m above the adjacent valley plains where the villages and their dugwells for domestic and irrigation use are situated. Older mines have reached a depth of 30 to 50 m bgl i.e. same elevation as that of the village Dewalvade, Navrangaon, etc. The depth of wells in the area ranged from 6 to 15 m bgl and the depth to water ranged from 4.5 to 12.5 m bgl. The Panchayat well in Devalwada had a depth to water of 10.15 m on 30.5.83 and 7.6 m on 13.9.83. Thus, the annual water level fluctuation was 2.5 m. During rainy season, the mine area receives an average rainfall of 3000 mm. This rain water is pumped out after the rainy season to restart the mining operations.

As a result of mining operations along the ridges, the wells in valley portions receive less groundwater. Lateral recharge ranges from 0.5 to 1 Mcum per working mine. Thus, there is some effect of mining on declining water levels and yields of wells and springs as the flow of groundwater from discharge zones to recharge zones is reduced.

4.5.3 Sediment Influx

Sediment influx is brought into the river systems of Mandovi & Zuari mainly due to the mining activity all along the estuaries (**Fig.4.10**). Most of the material is carried down the river between June and August in Mandovi in the process of overland flow. Literature indicates higher concentration of suspended solids from the tributaries that pass through mining zone than the erosion of hinterland. Improper maintenance of mine dumps and waste is a major leading to heavy influx of sediment load into the river. The erosion caused in the mine dumps is indicated by deep gullies formed in the dump slopes. The sediments in all the three seasons are sand dominated in the upper and middle estuarine region while silt and clay is dominant in the lower reaches of the estuary.

4.5.4 Sources of Pollution in Mandovi River

There are six major industries in the Mandovi basin, one manufacturing pesticides, one sugar, one handmade paper and three iron ore beneficiation. The pesticide industry has provided for biological treatment before discharging the effluents into Cumbarjua canal. The sugar factory has provided wastewater treatment system comprising anaerobic lagoons followed by activated sludge process. The beneficiation plants are located in the respective mining area and are provided with tailing ponds. Municipal Wastewater collection and treatment system is provided only in Panaji with treatment by ASP of capacity 4.5 mld which is overloaded.

Mining contributes significantly to the economy of Goa state. There are 26 iron ore mines in Mandovi basin discharging wastewater in Mandovi river. Based on the quantity of ore mined, the estimated wastewater discharged in the Mandovi river is presented in **Table 4.9**. There are a number of ore loading points on the Mandovi river. Water pollution may result from mining operation due to scouring of stacked rejects and overburden (Fig. 4.10).

Pollution by oil slick due to pumping of oil bilges from ships, leakages from pipelines has been reported in the navigable stretch of Mandovi and Zuari rivers. The major sources of pollution in Mandovi river are runoff through mining rejects, wastewater discharges from municipal towns and fertilizer industry.

4.5.5 Water Needs of Goa State

The sources of ground water recharge in the study area in Goa are infiltration of rain water (479 Mcum); seepage from rivers, tanks, canals etc. (10.25 Mcum) and

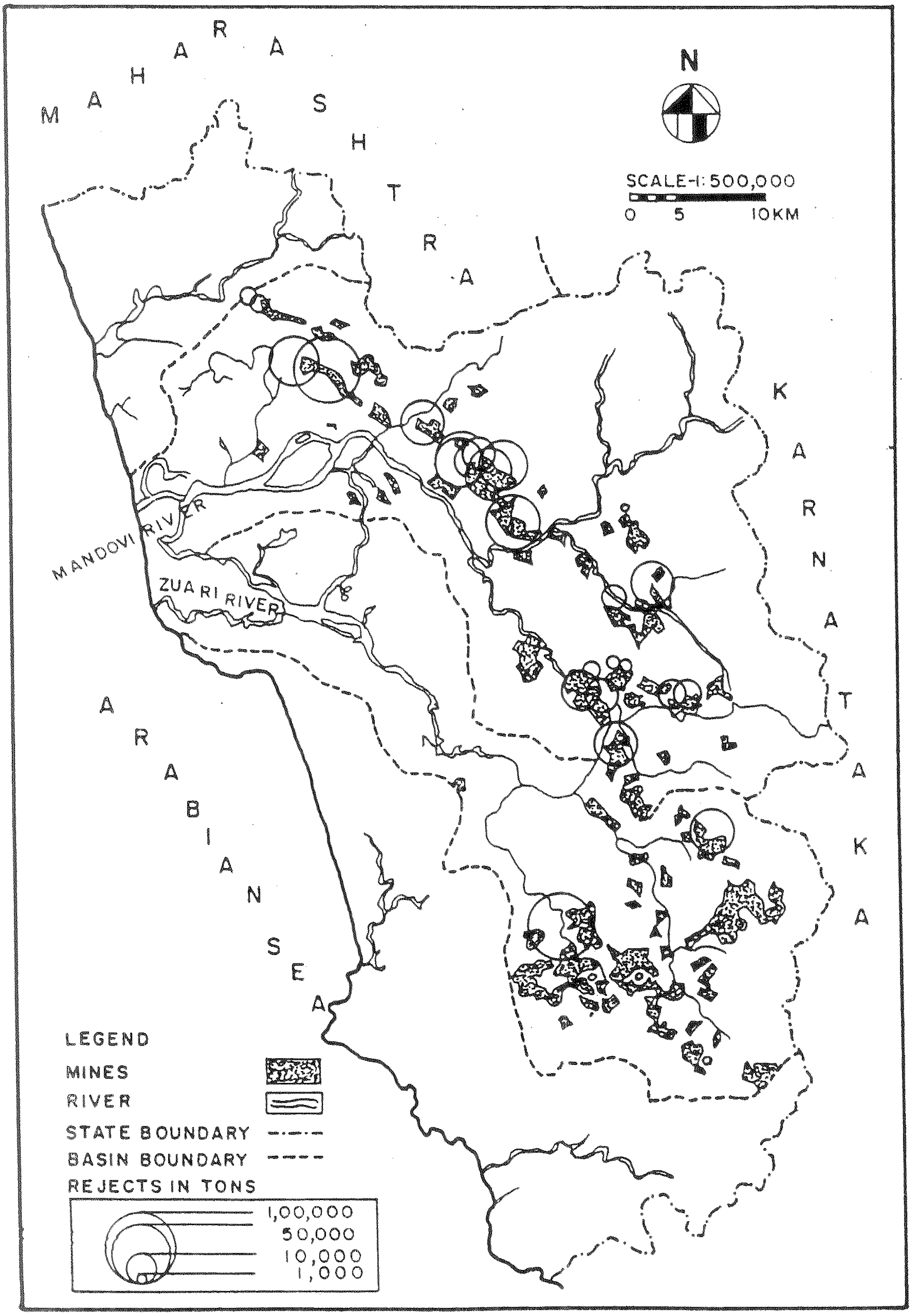


Fig. 4.10 Mineral Deposits and Rejects at Major Mines in Goa

Table 4.9

Classification of Mines by Production Capacity and Wastewater Generated - Mandovi Basin

Wastewater Discharged m^3/d	No. of Mines	No. of Mines in Different Production (tonnes per day) Catagories					
		0 to 1	1 to 5	5 to 10	10 to 50	50-100	>100
0 to 200	5	1	1	-	1	-	2
200 to 500	6	-	1	-	4	1	-
500 to 1000	4	-	1	1	1	1	-
1000 to 2000	4	-	-	-	1	2	1
2000 to 5000	5	-	-	-	1	2	2
> 5000	2	-	-	-	-	-	2
Total	**26**	**1**	**3**	**1**	**8**	**6**	**7**

Source : ADSORBS, Union Territory Of Goa, Daman and Diu (District Goa) irrigation return flow (35.4 Mcum) (**Table 4.10**). About 20% of groundwater potential (105 Mcum) is reserved for domestic and industrial uses and hence not being considered for development and draft. There are very few areas in Goa where well irrigation is common, and only 1450 pump sets with an average capacity of 5 H.P have been installed. Assuming 20 m^3/hr of pumping, the total draft works out to 35 Mcum/annum. The net ground water potential available for development is estimated at 420 Mcum. Only about 8 % of the ground water resource is utilised for irrigation. The balance ground water resource available can cater to the needs of additional 15,000 dugwells or 7,000 borewells.

The anticipated annual water requirements of Goa for domestic water supply, medium and minor irrigation projects from the Mahadayi basin are as follows :

Water Supply	130 Mcum
Medium Irrigation	387 Mcum
Minor Irrigation	67 Mcum
Lift Irrigation	26 Mcum
Total	610 Mcum

The Opa Water Works requirement (109.5 Mcum) is met from Khandepar river, a tributary to Mandovi.

Goa has an area of 3.71 lakh ha, of which the net sown area is 1.28 lakh ha. The area under irrigation is only 10%. The perspective plan for surface water resources envisages construction of 60 minor (**Table 4.11**) and 11 medium irrigation projects (**Table 4.12**) of which six are in Mandovi basin. There are lift irrigation schemes on the Mandovi river and its tributaries catering to about 3800 ha of agricultural land.

A medium irrigation project on Surla (Nanoda) river, a tributary of Mandovi river to irrigate 5902 ha of land was proposed by Government of Goa . The project, though cleared by the erstwhile Government of Goa, Daman and Diu and the Planning Commission, was not approved by the Advisory Committee constituted under the Forest (Conservation) Act 1980 due to the submergence of 503 ha of forest land. A revised proposal with 350 ha of submergence of forest land was also not approved by the Ministry of Environment and Forests, Govt. of India.

Table 4.10

Total Recharge and Ground Water Potential in Goa

Sr. No.	Source	Recharge (Mcum)
1.	Monsoon rainfall	479
2.	Non-monsoon rainfall	Negligible
3.	Seepage from rivers, canals, tanks etc.	10.25
4.	Return seepage	35.4
5.	**Gross annual recharge**	**525**

Source : CGWB, Ground Water Resources and Development Potential of Goa State, July 1988

Table 4.11

Details of Proposed Minor Irrigation Projects in Goa

Sr. No.	Taluka	No. of Minor Irrigation Tanks	Reservoir Area (ha)	Canal Length (km)	Canal Command Area (ha)
1.	Tiswadi	1	40	3	100
2.	Bardez	3	237	13.05	490
3.	Salcete	2	20	-	560
4.	Mormugao	2	110	8	950
5.	Pernem	8	217	23.75	1840
6.	Bicholim	6	247	29.50	1710
7.	Satari	6	172.50	19.50	530
8.	Ponda	5	210	31	1074
9.	Sanguem	16	617.90	68	2324.75
10.	Quepem	5	107	16.5	880
11.	Canacona	6	293.40	52	1780
	Total	**60**	**2271.80**	**264.30**	**12238.75**

Source : CGWB, Ground Water Resources and Development Potential of Goa State, July 1988

Table 4.12

Details of Proposed Medium Irrigation Projects in Goa

Sr. No.	Name of Project	Project Location village/taluka	Catchment Area (ha)	Submer-gence Area (ha)	Capacity of Tank (m^3)	Length of Canal (km)	Command Area (ha)
Mandovi Basin							
1.	Anjunem	Anjunem/Sattari	1718	253	4483	38.00	2100
2.	Mandovi	Nanoda/Sattari	11906	615	11119	56.10	9080
3.	Ragoda	Sancorda (Thandi Surla)/Sanguem	2687	207	3500	22.00	1700
4.	Mayda	Mayda/Sanguem	1500	103	1955	30.00	1350
5.	Khandepar	Caranzol, Sanguem	3673	400	12350	40.00	11195
6.	Dudhsagar	Kuveshi/Supa (Karnataka)	2220	40.1	5289.1	8.40	2832.8
Zuari Basin							
7.	Siridon	Curca (Santan) Tiswadi	718	269	4500	20.00	2000
8.	Uguem	Barmaon/Sanguem	2250	450	5375	22.50	2335
9.	Kushavati	Salkarna, Quepem	2700	425	7000	40.00	5000
10.	Kushavati	Barcen Quepem	2000	280	5000	28.00	2000
11.	Talpona	Quakem/Canacona	1300	112	1982	33.00	1200
12.	Kankon	Chaudi-Canacona	820	106	1820	24.00	1200

Source : CGWB, Ground Water Resources and Development Potential of Goa State, July 1988

4.5.6 Water Quality

Water quality assessment in the study area was undertaken at 32 locations comprising river Mahadayi, its tributaries and ground water sources. Of the samples, 18 were collected from river Mahadayi (Mandovi), 7 from its tributaries in Karnataka and 7 (2 in Karnataka and 5 in Goa) from open wells, handpumps and tube wells. The details of sampling locations depicted in **Figs. 4.11 through 4.13** are presented in **Table 4.13**. Monthly data on salinity and flora and fauna was collected from 14 out of 18 sampling locations along the river Mahadayi, while seasonal data on physico-chemical parameters and heavy metals was collected from 13 locations. Sediment samples from the river bed were collected and analysed for pesticides and bottom fauna. Sampling was carried out during monsoon of 1995, summer of 1996, and post-monsoon of 1996.

The analytical results of physical and chemical parameters, heavy metals and bacteriological quality for surface and ground waters are at **Annexure 4.4 Table 4 through 16** and summarised in **Table 4.14**. The trend in variation of conductivity, turbidity and dissolved oxygen are depicted in **Fig. 4.14 through Fig. 4.16.**. The data revealed that the values of physico-chemical parameters were comparatively higher during summer season when the minimum flow occurs than during monsoon and post-monsoon period. The analysis of data further showed that there are three distinct stretches in the Mahadayi based on salinity as given below:

i. Fresh water zone (limnetic) upto Ganjem site (R5) in which the conductivity ranges between 33 and 120 μS/cm during all seasons

ii. Intermittent oligohaline zone from Usgaon Pali (R6) to Amone village (R7) where the conductivity highly fluctuates and ranges between 60 and 39200 μS/cm, the high value indicating sea water intrusion upto the point R6 during lean flow in the river

iii. Polyhaline (estuarine) zone from R7 to the mouth of the river where the conductivity ranges from 2400 to 55200 μS/cm.

The river water turbidity remained low (1 NTU to 4 NTU) throughout the stretch of the river (Fig. 4.13). The ground water samples had a turbidity of 1 - 3 NTU, and the samples from the tributaries had a turbidity of 1 - 6 NTU. The TSS concentration in all the samples were almost negligible during the study period. The studies carried out by the Department of Marine Science, Goa University during

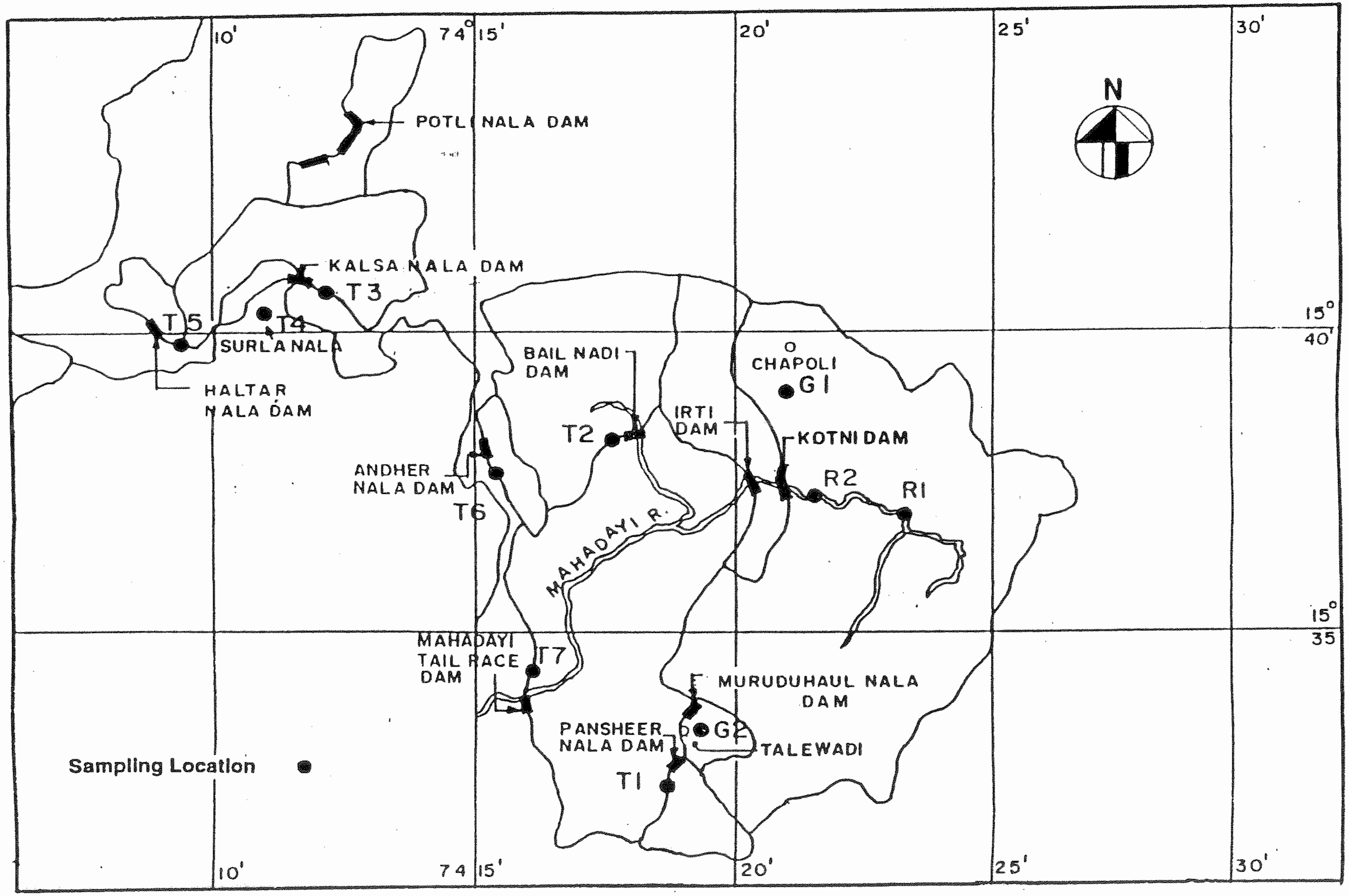


Fig. 4.11 Water Quality Sampling Locations in the Study Area in Karnataka

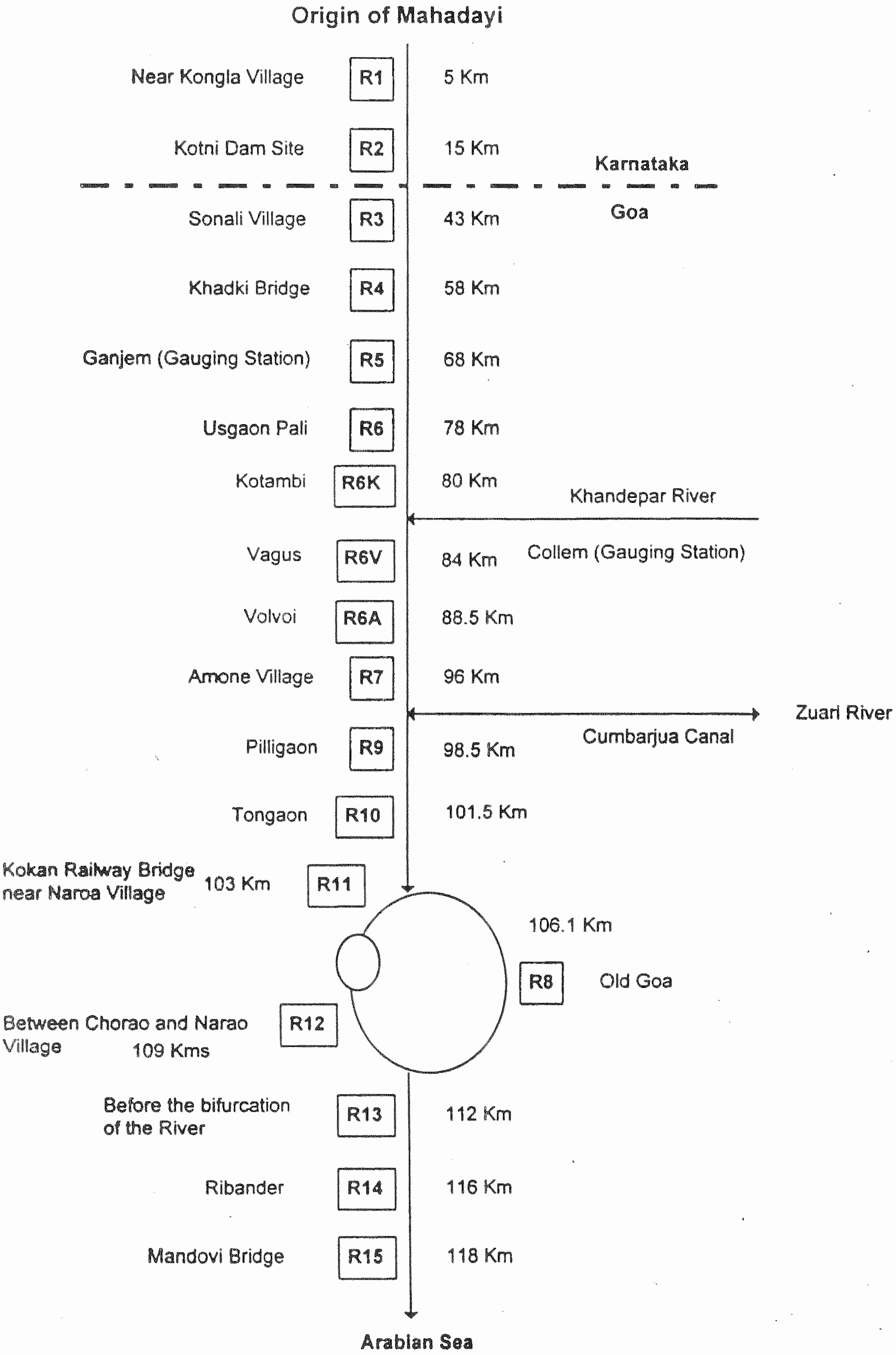


Fig. 4.12 Schematic Diagram of Sampling Locations along River Mahadayi (Mandovi)

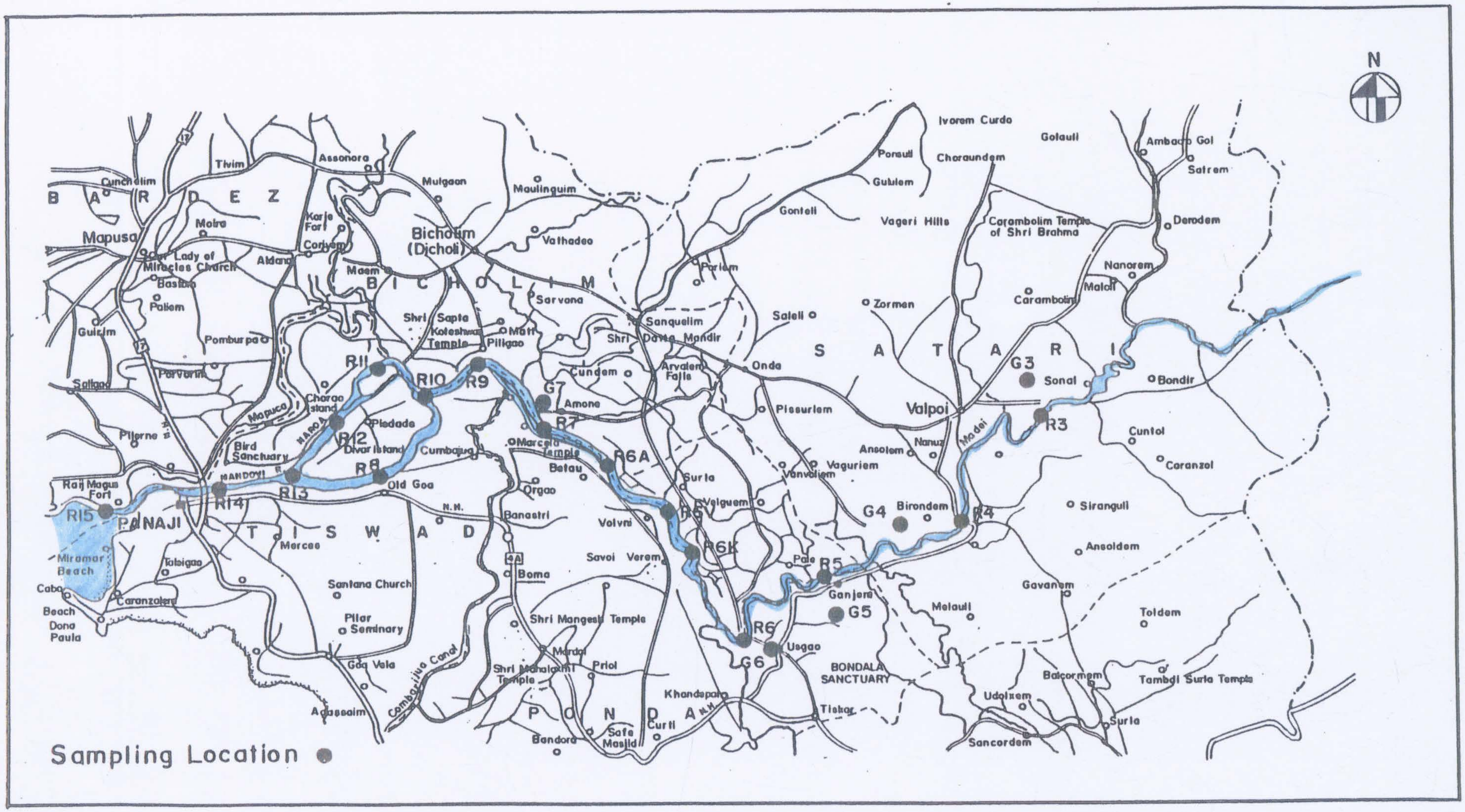


Fig. 4.13 Water Quality Sampling Locations in the Study Area in Goa

Table 4.13

Details of Sampling Locations for Water Environment

Sl. No.	Source	Sampling Location	Location Code
Karnataka State			
1.	Mahadayi River	Near Kongla Village	R1
2.	Mahadayi River	Kotni Dam Site	R2
3.	Hand Pump	Village Chapoli near Vidya Mandir	G1
4.	Nala	Pansheer Nala	T1
5.	Open Well	Village Talewadi (Near Pansheer Nala)	G2
6.	River (Bail Nadi)	Bail Nadi	T2
7.	Nala	Kalsa Nala	T3
8.	Nala	Surla Nala	T4
9.	Nala	Haltar Nala	T5
10.	Nala	Andher Nala	T6
11.	Nala	Mahadayi Nala near Tail Race dam	T7
Goa State			
12.	Mandovi River	Just starting point in Goa region near Sonali Village	R3
13.	Well sample	Near Sonali bus stop in front of Naik's house	G3
14.	Mandovi River	At Kahadki bridge in between Bhironda and Khadki villages	R4
15.	Open Well	Near Bhironda Village bus stand	G4
16.	Mandovi River	At Ganjem near Bondla Water Supply intake point U/S of CWC River Gauging Station	R5
17.	Bore well	At Ganjem near Bondla Water Supply intake point U/S of CWC River Gauging Station	G5
18.	Mandovi River	Bridge at Usgaon Pali	R6

Contd...

Table 4.13 (Contd...)

Sl. No.	Source	Sampling Location	Location Code
19.	Mandovi River	At Kotambi Village	R6K
20.	Mandovi River	At Vagus Village	R6V
21.	Mandovi River	At Volvoi Village	R6A
22.	Open Well	In Usgaon Pali Village	G6
23.	Open Well	In Amone Village	G7
24.	Mandovi River	At Ferri crossing near Amone Village	R7
25.	Mandovi River	At Old Goa area	R8
26.	Mandovi River	Near Tongaon Village	R9
27.	Mandovi River	U/S of Pilligaon Village	R10
28.	Mandovi River	U/S of Konkan Railway Bridge near Narao village	R11
29.	Mandovi River	Between Chora and Deewar Islands	R12
30.	Mandovi River	In Ribandar area near two concrete pillars on right bank	R13
31.	Mandovi River	Before Chorao Island bifurcation	R14
32.	Mandovi River	End of Mandovi river at outfall in Arabian Sea near Jetty in Goa	R15

R - Surface Water
G - Ground Water
T - Tributary

Table 4.14
Summary Data on Water Quality in the Study Area

Parameter	Mahadayi/Mandovi River			Tributaries	Ground Water
	Fresh Water Zone	Oligohaline/ Mesohaline Zone	Polyhaline Zone		
	Range in Values				
I. Physical Characteristics					
Temperature	23 - 35	23 - 32	25 - 31	23 - 33	24 - 35
pH	6.8 - 8.0	6.6 - 7.8	7.0 - 8.1	6.0 - 8.3	5.6 - 8.5
Conductivity (μs/cm)	33 - 120	60 - 39200	2400 - 55200	26 - 170	32 - 1500
TSS (mg/L)	0 - 0.005	0 - 0.002	0.001 - 0.076	0 - 0.007	0 - 0.002
Turbidity NTU	1 - 4	1 - 3	2 - 4	1 - 6	1 - 3
II. Chemical Characteristics					
T-Hardness	9 - 60	17 - 4120	240 - 5800	8 - 58	10 - 200
Ca-Hardness	5 - 36	10 - 700	50 - 1180	4 - 40	4 - 90
Mg-Hardness	4 - 30	7 - 3420	190 - 4695	0 - 30	4 - 156
T-Alkalinity	10 - 52	14 - 60	30 - 100	4 - 48	8 - 126
DO	6.0 - 7.8	4.1 - 7.4	3.6 - 6.9	5.3 - 7.6	5.8 - 6.8
COD	3.9 - 17.3	-	-	0 - 6.2	0 - 9.6
Chloride	10 - 20	11 - 12650	774 - 19500	8 - 36	8 - 556
Salinity (ppt)	0.02 - 0.04	0.02 - 22.85	1.4 - 35.22	0.02 - 0.07	0.02 - 0.21
Phosphate	0 - 0.6	0 - 0.52	0 - 0.04	0 - 0.07	0.02 - 0.09
Nitrate	0.1 - 0.4	0.2 - 0.8	0.3 - 1.0	0.1 - 0.7	0.1 - 6.0
Potassium	0.2 - 1.4	0.4 - 255	15 - 378	0.1 - 1.9	0.3 - 13.2
Sodium	0.4 - 7.2	2.2 - 7260	375 - 1400	2.0 - 6.2	2.3 - 243
Sulphate	1 - 10	2 - 2883	16 - 3880	1 - 6	2.0 - 108
Total Kjeldahl Nitrogen	0.2 - 0.5	0.4 - 0.5	0.3 - 0.5	-	-
Langelier Index	(-0.71)-(-3.26)	(-0.01)-(-2.36)	(-1.74)-(+1.18)	(-0.67)-(-3.85)	(-0.28)-(+0.56)
III. Heavy Metals					
Iron	0.04 - 0.3	0.01 - 0.35	0.06 - 0.33	0.03 - 0.58	0 - 1.23
Manganese	0.01 - 0.1	0.03 - 1.88	0.02 - 0.16	0 - 0.2	0 - 0.35
Lead	0 - 0.01	0 - 0.04	0 - 0.02	0 - 0.02	0 - 0.02
Cadmium	ND	ND	ND	ND	ND
Zinc	0 - 0.37	0 - 0.11	0.01 - 0.09	0 - 0.21	0 - 0.29
Copper	ND	ND	ND	ND	ND
Nickel	0 - 0.02	0 - 0.03	0 - 0.04	0 - 0.03	0 - 0.03

Contd.....

Table 4.14 (Contd...)

Parameter	Mahadayi/Mandovi River			Tributaries	Ground Water
	Fresh Water Zone	Oligohaline/ Mesohaline Zone	Polyhaline Zone		
	Range in Values				
IV. Bacteriological Quality					
Total Coliforms (CFU/100 ml)	540-14000	360-16600	1050-2680000	700-276000	10-20600
Faecal Coliforms (CFU/100 ml)	8-2060	80-12000	37-13800	34-33000	0-4120

All values except pH, turbidity, salinity and Langelier Index are in mg/L

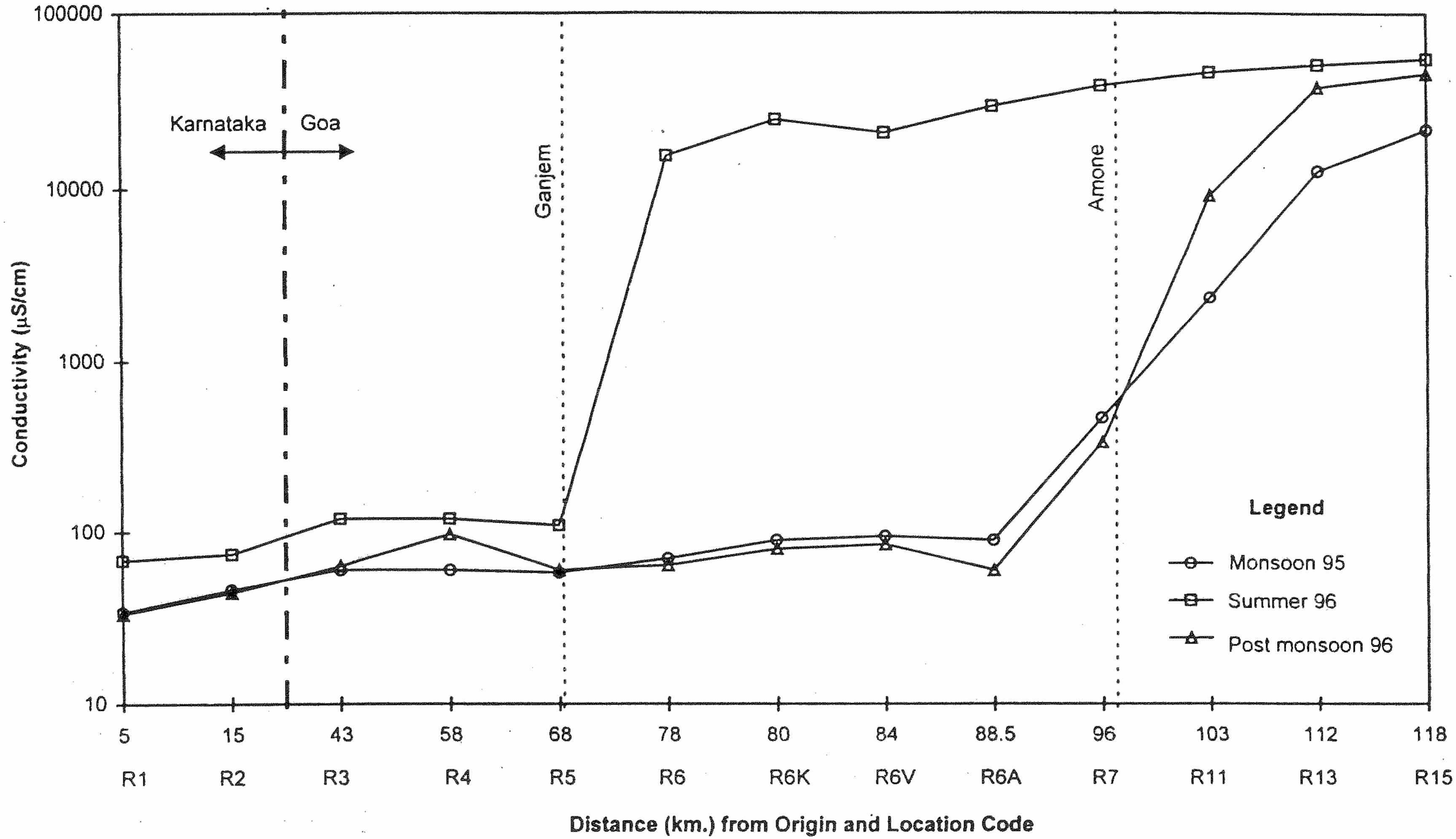


Fig. 4.14 : Seasonal Variation in Conductivity in River Mahadayi

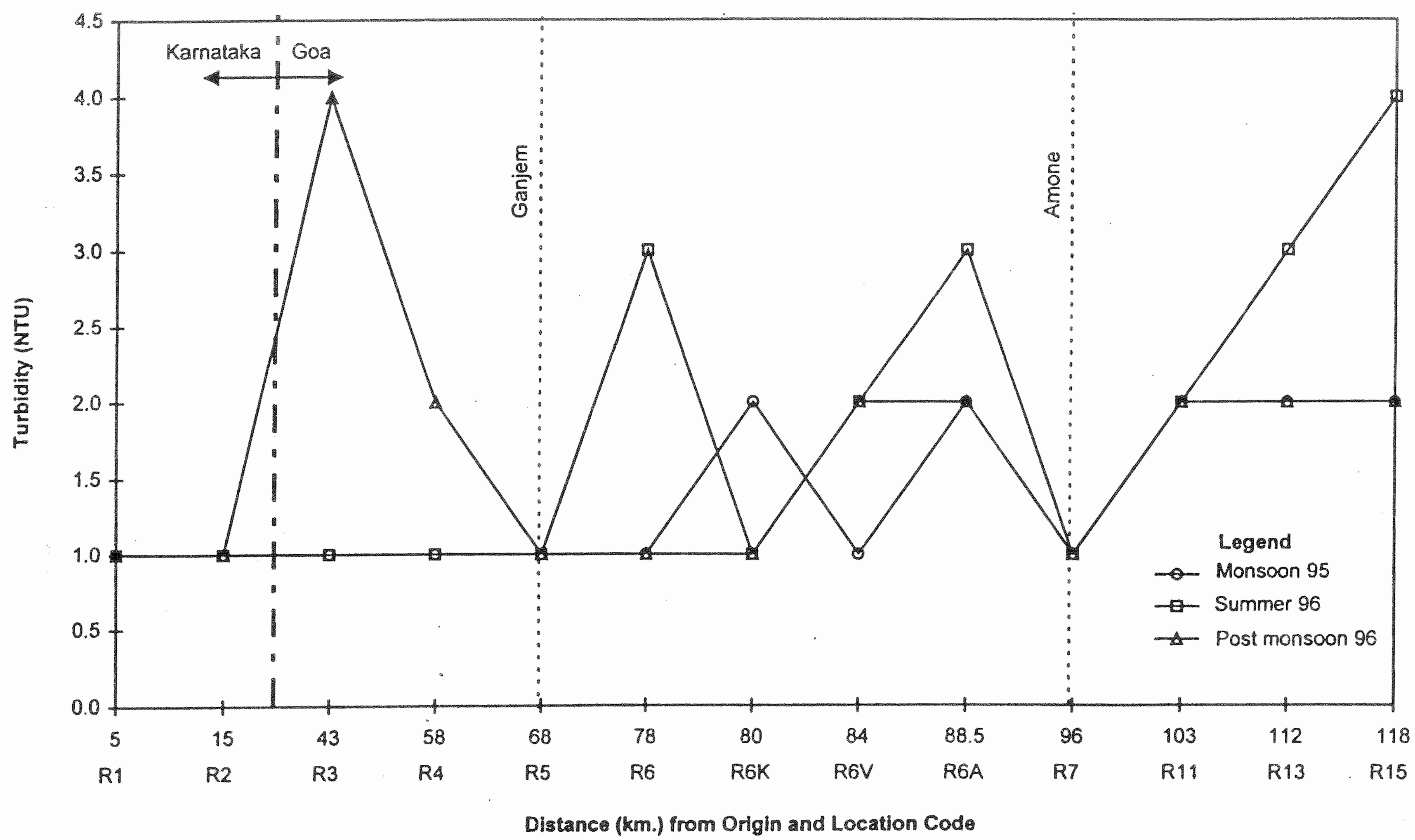


Fig. 4.15 : Seasonal Variation in Turbidity in River Mahadayi

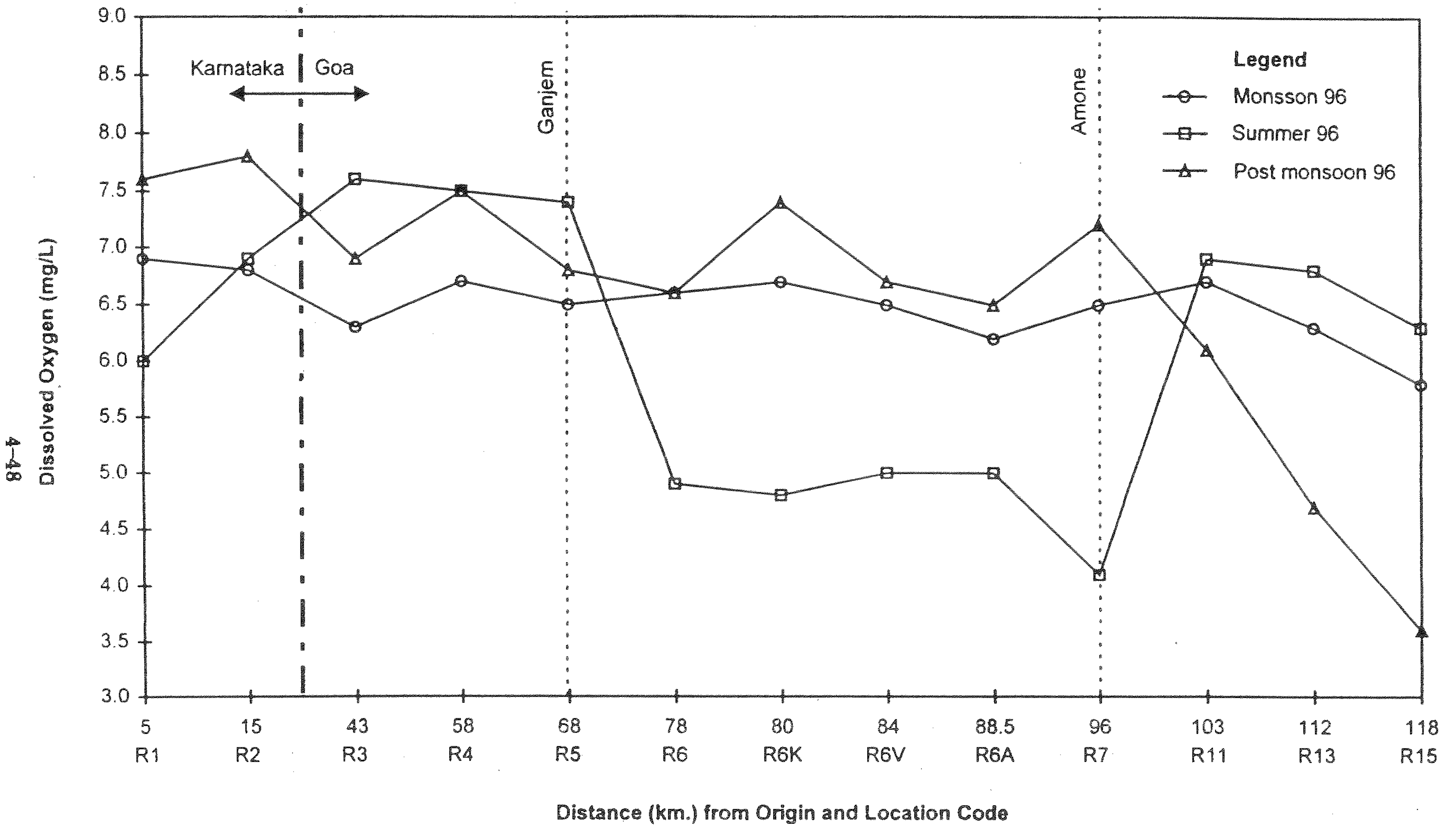


Fig. 4.16 : Seasonal Variation in Dissolved Oxygen in River Mahadayi

1990-93 also indicate very low concentration of TSS in the river water except during August-September when it increases upto 50-100 mg/L near old Goa and Ribandar areas.

The DO in water samples from the river Mahadayi/ Mandovi varied from 3.6 mg/L to 7.8 mg/L (Fig. 4.16). The DO levels in the river were satisfactory except in summer season near Amone village. The DO of ground water samples varied from 6.4 mg/L to 6.9 mg/L, and from 5.3 mg/L to 7.6 mg/L in water samples from the tributaries. The COD values of the water samples along the river Mahadayi/Mandovi in fresh water stretch was low and varied from 3.9 mg/L to 18 mg/L . The higher values of COD were observed during lean flow period.

The salinity of water samples from the river Mahadayi/ Mandovi varied from 0.02 ppt to 35.22 ppt in different seasons. Higher salinity of river water was observed in oligohaline zone and polyhaline zone because of sea water intrusion. The monthly variation in salinity of the river water at various locations is depicted in **Fig. 4.17**. The salinity of water samples collected from tributaries and ground waters was negligible.

Nitrite was not detected in any of the water samples. The total nitrogen concentration was low (<0.5 mg/L) in all the water samples. Phosphates were also very low (<0.05 mg/L) in all samples except during summer at two locations where it was recorded upto 0.6 mg/L which might be a local phenomenon.

In summary, it is observed that the values of physico-chemical parameters were comparatively higher during summer season than those observed during the monsoon and post-monsoon periods. From the sampling location at Ganjem (R6) onwards, the increase in the levels of conductivity, salinity, chlorides, sulphates, sodium and potassium is significant. This is due to the effect of sea water intrusion during lean flow in the river. During post-monsoon, the tidal effect on water quality is felt upto Amone village (R7) as shown by the results of water analysis.

Heavy Metals & Pesticides

The heavy metals tested in the water samples were iron, manganese, lead, cadmium, zinc, copper and nickel (Table 4.14). The high value of manganese (1.88 mg/L) in the Mandovi river at the ferry crossing near Amone village is attributed mainly to the manganese leaching from the adjoining manganese mine dumps. The concentrations of other heavy metals in Mahadayi river water samples were within permissible limits. Water samples of tributaries and ground water samples were found to have heavy metal concentration within permissible limits of BIS 10500 (1991) for drinking water.

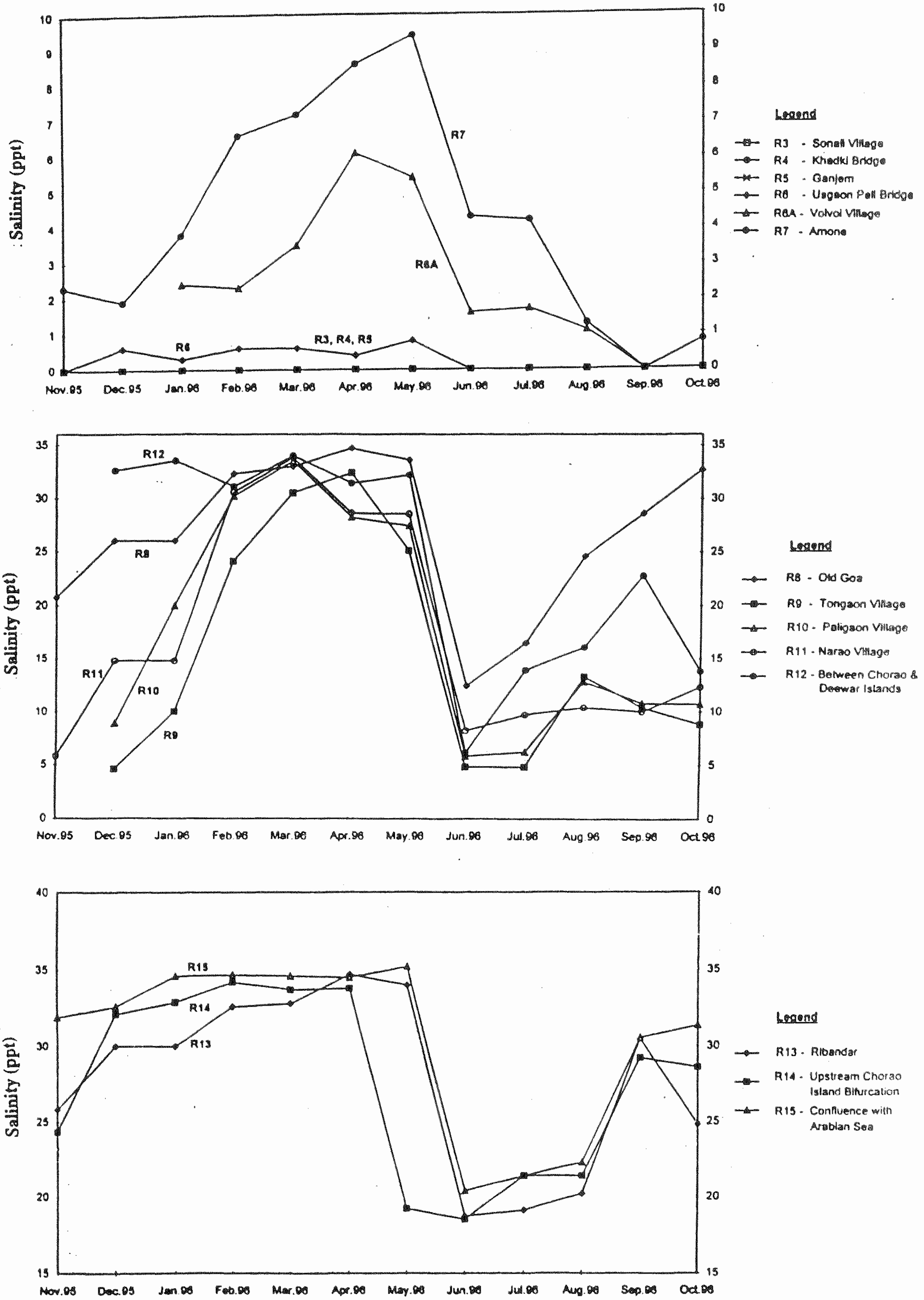


Fig. 4.17 : Monthly Variation in Salinity at Various Sampling Locations along the River Mahadayi in Goa

Samples of sediment from the river bed at Volvoi and Usgaon Pali also showed high concentrations of iron and manganese **(Annexure 4.4, Table 17)** which can be attributed mainly to the leaching from the adjoining manganese mines and spillage during loading and unloading of ore from the containers.

Very low concentrations of BHC and traces of DDT were detected in water samples collected from river Mahadayi during October 1995, while the bottom sediments showed the presence of BHC & DDT upto 38 $\mu g/L$ **(Annexure 4.4, Table 18)**. The pesticides concentration in the river water was below the permissible limit prescribed by WHO and BIS for drinking water.

Bacteriological Quality

The seasonal variation in bacteriological quality of water in river Mahadayi is depicted in **Figs. 4.18 and 4.19**. All or most of the surface water samples showed the presence of coliform and faecal coliform organisms during all the seasons and they showed an increasing trend towards the estuarine region, particularly beyond Amone village. One ground water sample from borewell fitted with a hand pump in Chapoli village (G1) was found to be free from coliforms. During post-monsoon season all the five ground water samples showed the presence of indicator organisms of faecal contamination.

4.6 Land Environment

4.6.1 Karnataka Region

4.6.1.1 Physiography

The geographical area of the Mahadayi basin is 203200 ha of which 37500 ha is in Karnataka and the remaining in Goa. The land use particulars of the basin are given in **Annexure 4.5, Table 1**.

For collection of baseline data on land environment, 18 villages in Khanapur taluka of Belgaum district of Karnataka were identified and surveyed. The villages surveyed are listed in **Annexure 4.5, Table 2** and depicted in **Figure 4.20**

The land use pattern in the villages surveyed and distribution of land under various categories are given in **Annexure 4.5, Table 3** . About 2230 ha (8.9%) of total land is under agriculture of which only 148 ha (0.6%) is irrigated. About 18418 ha (73.3%) area is under forest cover. The main forest products are teak, bamboo, salwood, firewood and mahera. The rest of the area is classified as culturable

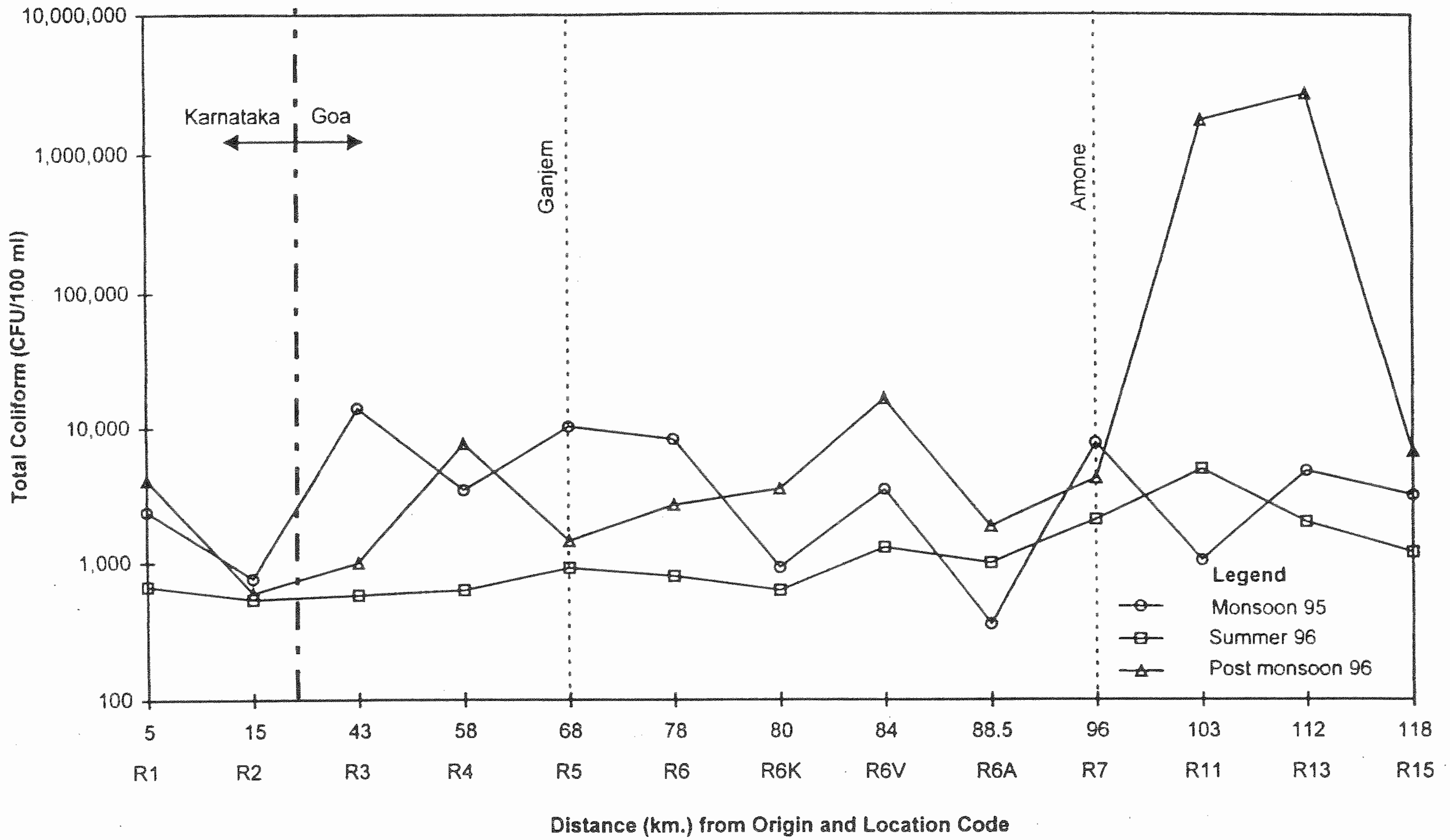


Fig. 4.18 : Seasonal Variation in Total Coliform in River Mahadayi

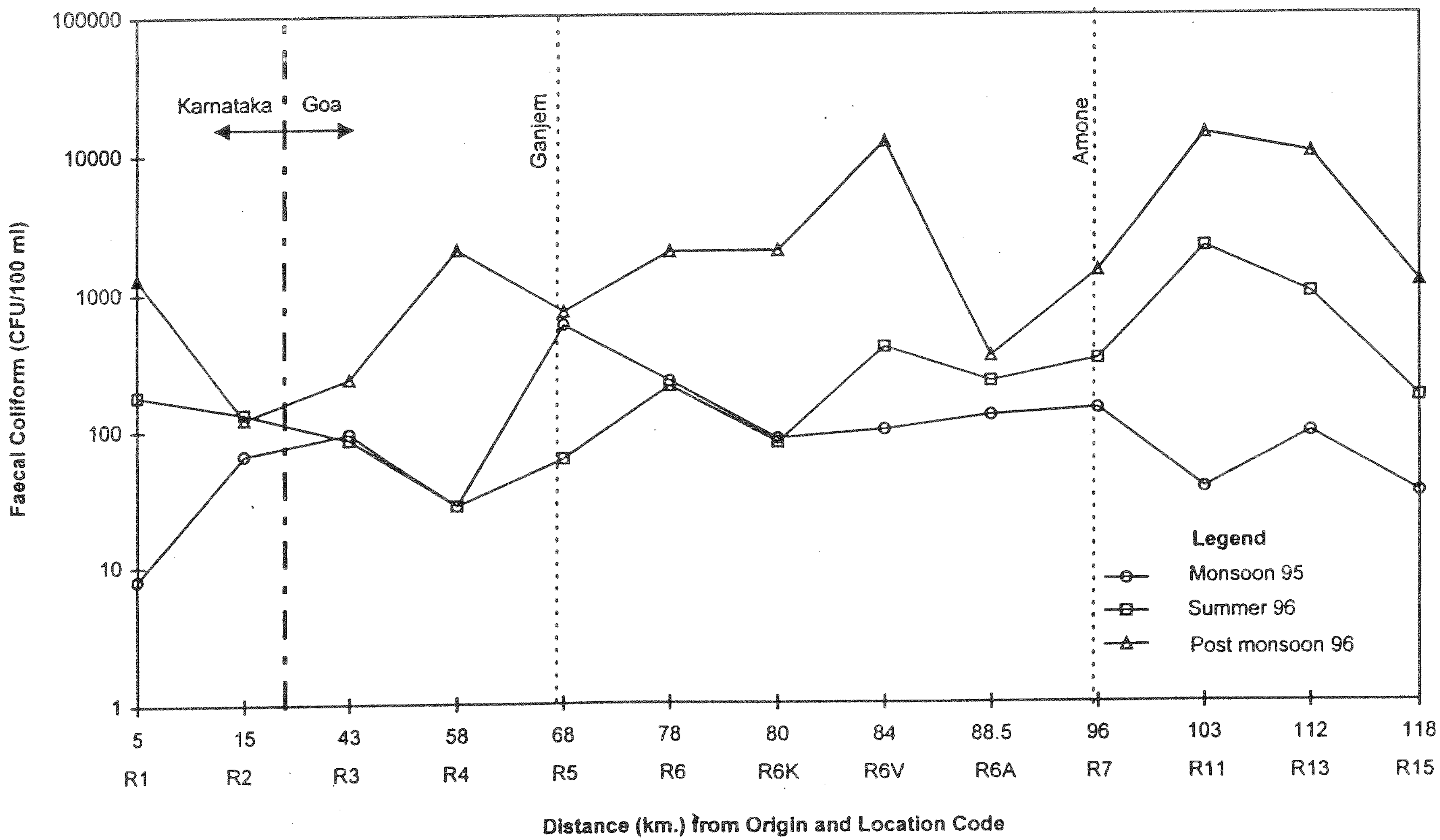


Fig. 4.19 : Seasonal Variation in Faecal Coliform in River Mahadayi

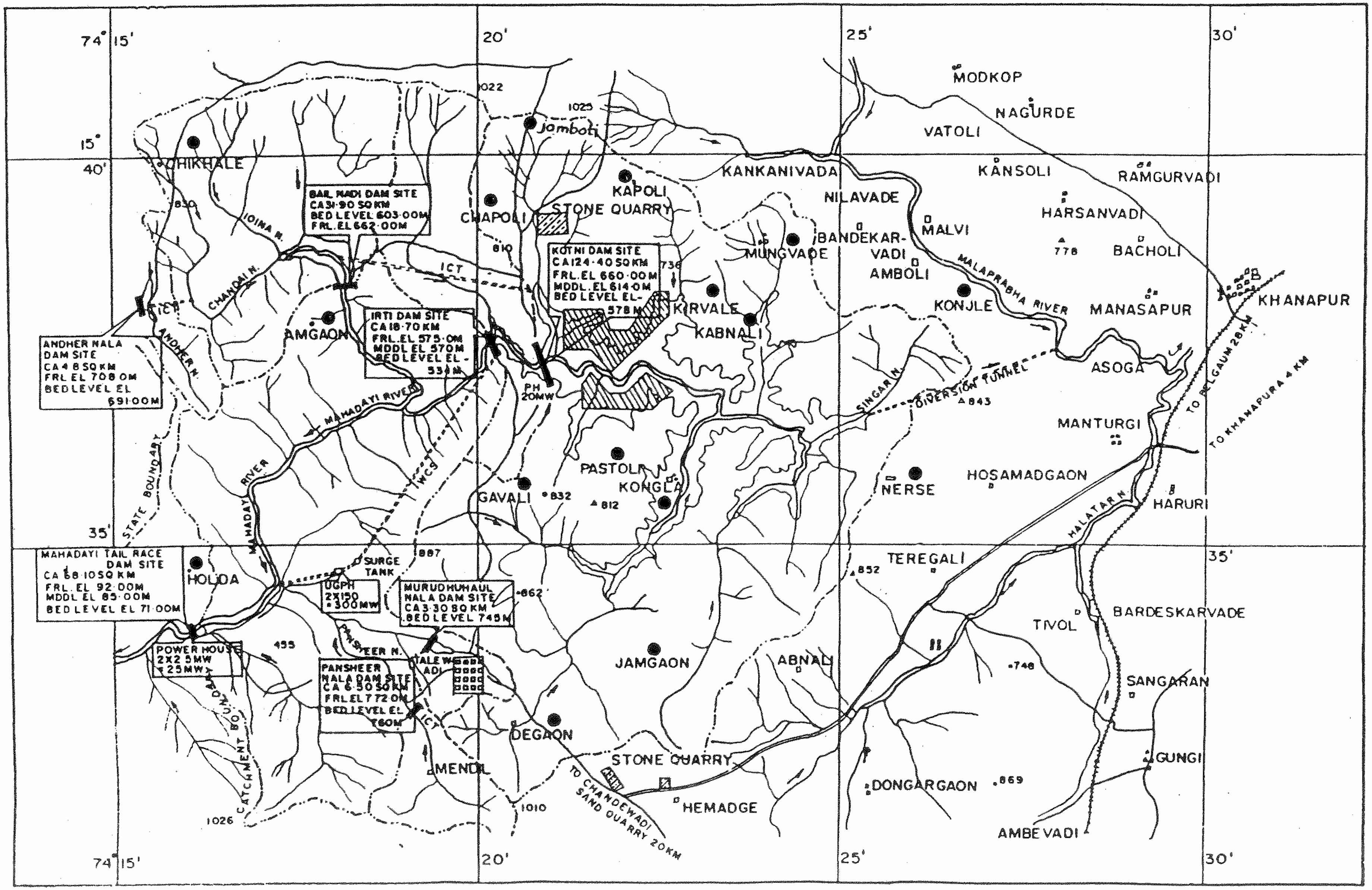


Fig. 4.20 Villages Surveyed for Land Environment in Khanapur Taluka, Belgaum District (Karnataka)

(1400 ha) and unculturable (3071 ha) wasteland. During the period 1980-1991, the forest cover has decreased by 10.4% while the area under agriculture has increased by 4.8% (**Figure 4.21**). The wasteland area has also increased by 5.7%.

4.6.1.2 Soil Quality

Soils in the region are mostly lateritic and are developed from basalts. These soils occur on gently undulating to hilly topography. The major soils in the region are listed in **Annexure 4.5, Table 4** and depicted in **Plate 1**.

The soils of the region are classified into five categories based on the depth of the soil as shown in **Plate 2** and presented in **Annexure 4.5, Table 5.**

The predominant soil texture in the region is clay to clay loam followed by loamy clay and loam (**Plate 3** and **Annexure 4.5, Table 6**).

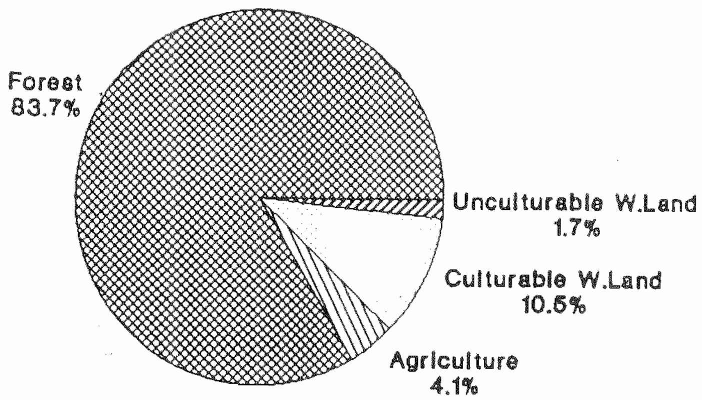
The soils in the area are moderately eroded. The different erosion class in the region and the area under each class is depicted in **Plate 4**, and the details are presented in **Annexure 4.4, Table 7**.

The soil texture in the villages surveyed is sandy clay to sandy clay loam, while it is clay loam at Kalsa and Haltar dam sites. The clay content of the soil ranges from 19.8 to 47% and the silt content varies from 4.9 to 36.8% (**Annexure 4.5, Table 8**). The soils have moderate water holding capacity ranging from 16.8 to 29.4%. The hydraulic conductivity of soil ranges from 12 to 120 mm/hr indicating good drainage characteristics.

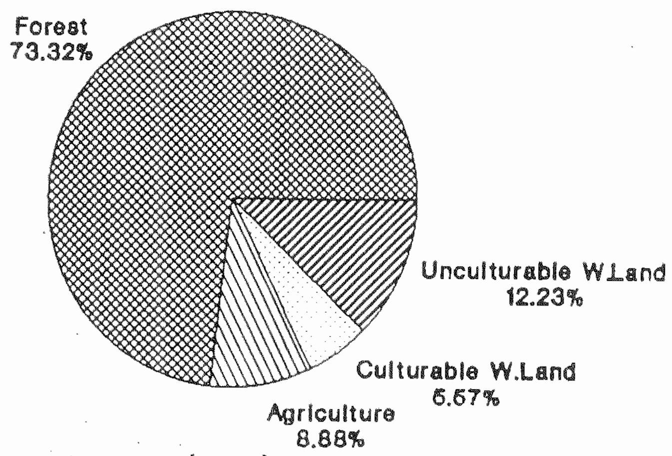
The soils are acidic in reaction with a pH of 5.4 to 6.5. The soluble salt content in the soils is low, and the electrical conductivity of saturation extract of the soil ranges from 0.12 to 0.30 mS/cm. Amongst the cations, calcium is predominant followed by magnesium, while chlorides are the major anions in the soil(**Annexure 4.5, Table 9**). The soils are medium to good with respect to organic matter content which varies from 0.36 to 1.34%.The total nitrogen, phosphorus and potassium are in the range of 0.028 to 0.094%, 0.021 to 0.80 and 0.64 to 1.18% respectively. The soil has low to moderate adsorption capacity and the CEC ranges from 5.8 to 20.8 meq/100g(**Annexure 4.4, Table 10**).

4.6.1.3 Land Capability and Irrigability Classification of Soils

The land capability classes of 15 dominant soils have been grouped into 4 land capability classes suitable for agriculture, forestry or pasture(**Plate 5** and



(1981)



(1991)

Fig. 4.21 : Land Use Pattern in the Study Area in Karnataka

Annexure 4.5, Table 11). The soils in the region are classified into 6 land irrigability classes (**Annexure 4.5, Table 12**) as depicted in **Plate 6**.

4.6.2 Goa Region

4.6.2.1 Physiography

Goa comes under coastal plains, hot humid-perhumid agroecological region with alluvium derived soils. The study area comprises 500m/ 5000m wide strips each on both sides throughout the stretch of the river in the 5 talukas viz. Bardez, Bicholim, Satari, Tiswadi and Ponda.

The western parts of the study area constitute the coastal plains comprising beaches, mudflats, swamps, salt pans and fluvio-littoral plains. Certain land masses of this portion appear to have emerged out of the sea, as can be observed at Panaji. Panaji forms a part of the lagoon where the river Mandovi (Mahadayi) joins the sea. Marshy lands, locally known as Khazan lands, are found in the creeks and river sides. The central and eastern parts of the study area from north to south connecting Bicholi, Ponda and Satari talukas, are occupied by undulating uplands with gentle to moderate slopes, interrupted by concave depressions comprising valleys which are mainly under paddy cultivation.

- In order to collect the detailed baseline data and evaluate the impact of proposed project, 17 villages were identified as listed in **Annexure 4.5, Table 13** and depicted in **Figure 4.22.**

The present land use map of the study area is shown in **Plate 7**. Agriculture is the predominant landuse in different villages and covers 47.6% of the total area. Irrigated agriculture is not well developed and over 5440 ha of land is under rainfed cultivation, while only 10% area of the total agricultural land is irrigated with canal water. Irrigated agriculture is fairly developed in Ponda taluka followed by Bicholim. The forest cover in the area is 7.9% . Candepor, Kodar and Gangem in Ponda taluka are the major villages which account for the forest area.

A large area in different villages comes under the category of unculturable wasteland and accounts for 33% of total area. The culturable wasteland comprises 11.8% of the area and is found largely in village Kodar in Ponda taluka followed by village Pileran in Bardez taluka(**Annexure 4.5, Table 14**).

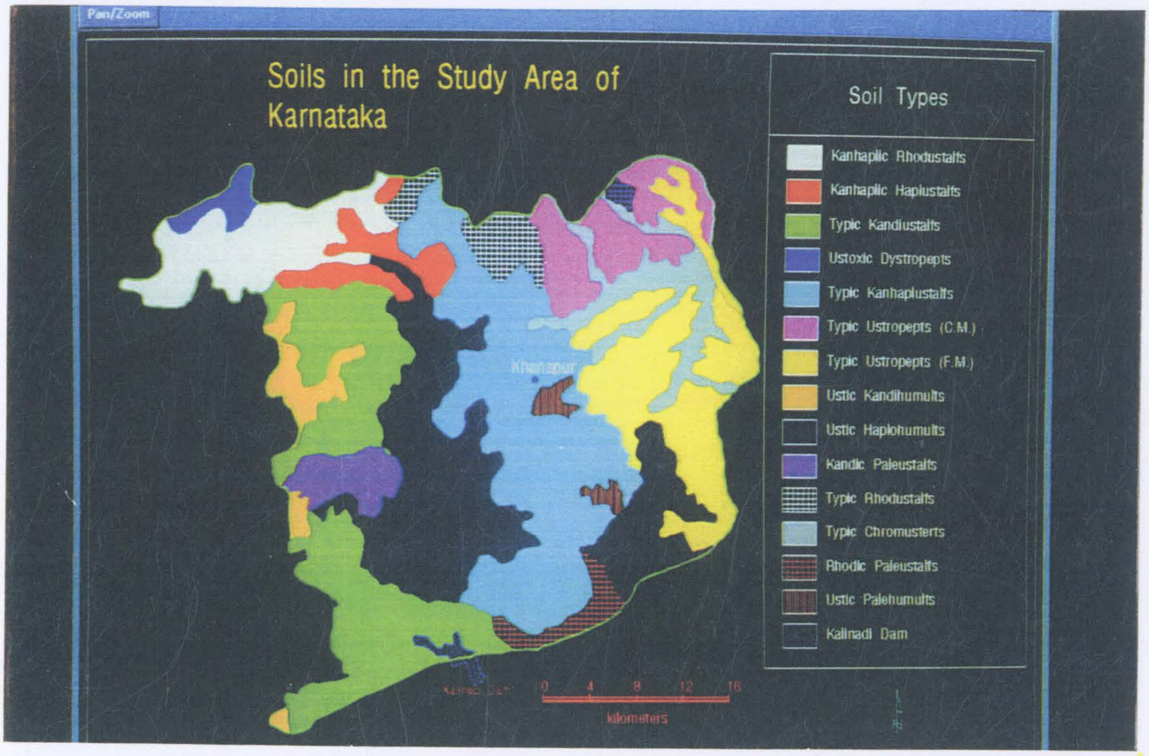

Pan/Zoom
Soils in the Study Area of Karnataka
Soil Types
Kanhaplic Rhodustalfs
Kanhaplic Haplustalfs
Typic Kandiustalfs
Ustoxic Dystropepts
Typic Kanhaplustalfs
Typic Ustropepts (C.M.)
Typic Ustropepts (F.M.)
Ustic Kandihumults
Ustic Haplohumults
Kandic Paleustalfs
Typic Rhodustalfs
Typic Chromusterts
Rhodic Paleustalfs
Ustic Palehumults
Kalinadi Dam
Khanapur
0 4 8 12 16
kilometers

Plate 1

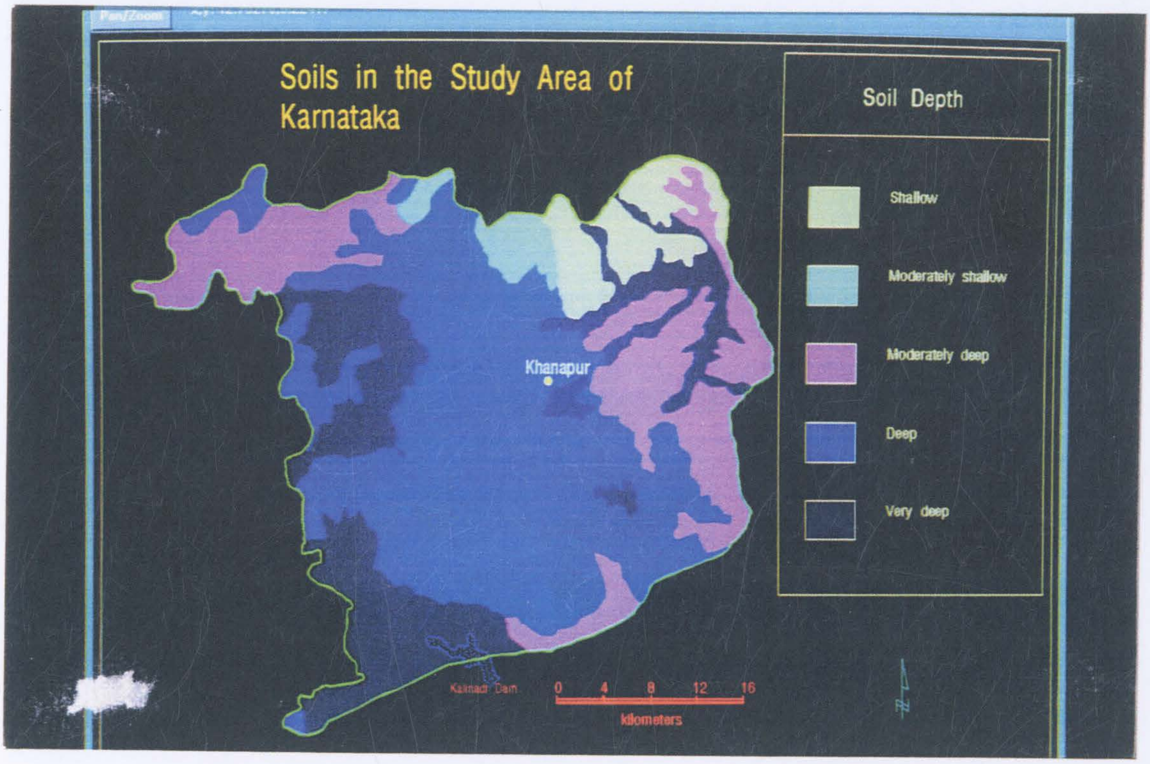

Soils in the Study Area of Karnataka
Soil Depth
Shallow
Moderately shallow
Moderately deep
Deep
Very deep
Khanapur
0 4 8 12 16
kilometers

Plate 2

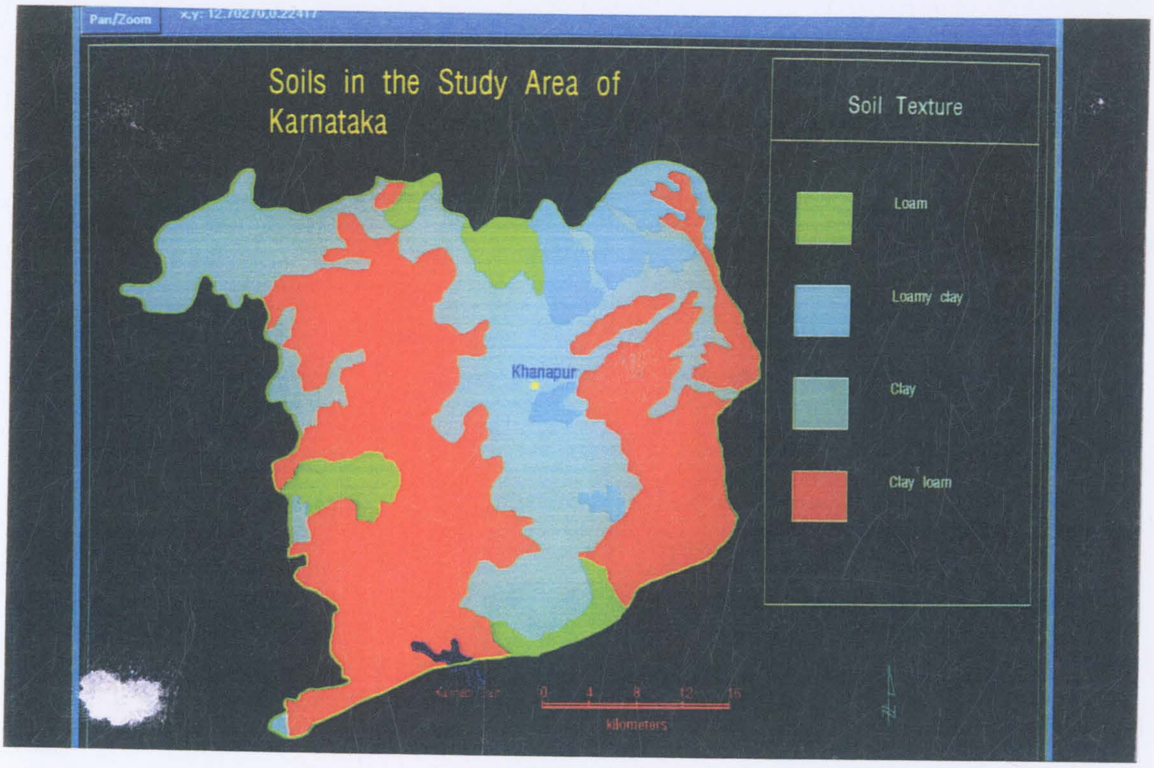

Pan/Zoom
Soils in the Study Area of
Karnataka
Soil Texture
Loam
Loamy clay
Clay
Clay loam
Khanapur
0 4 8 12 16
kilometers

Plate 3

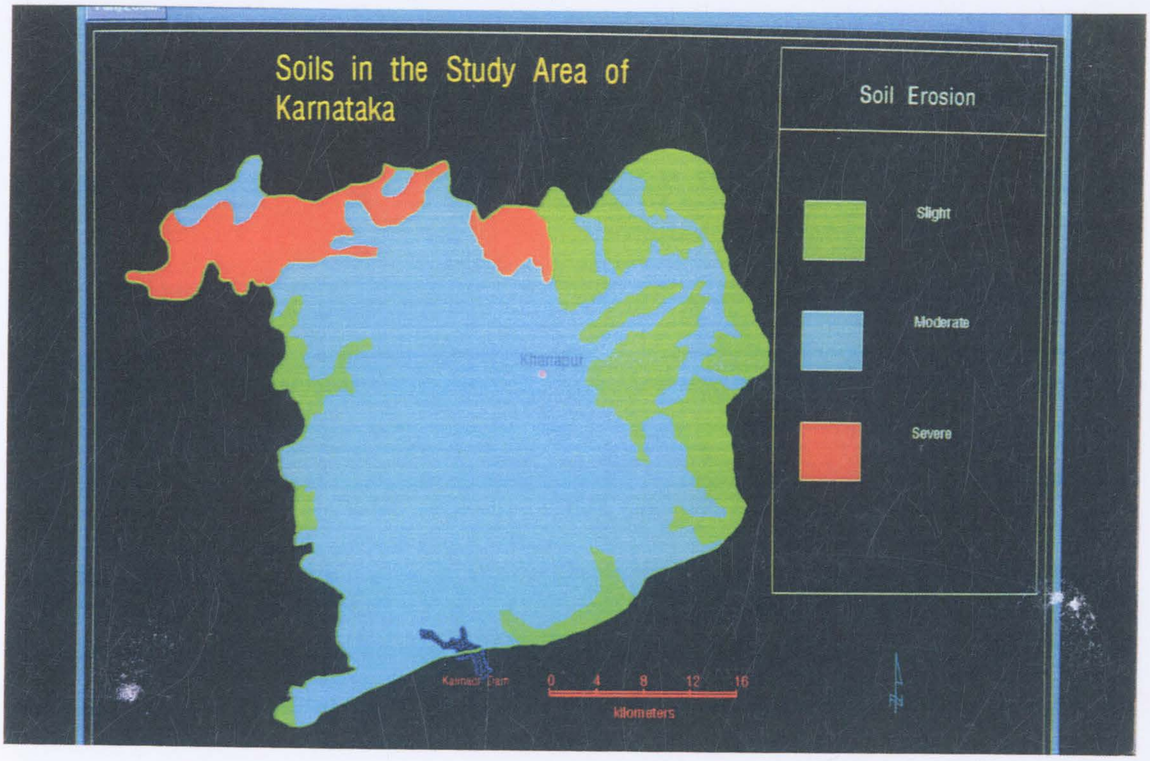

Soils in the Study Area of Karnataka
Soil Erosion
Slight
Moderate
Severe
Khanapur
0 4 8 12 16
kilometers

Plate 4

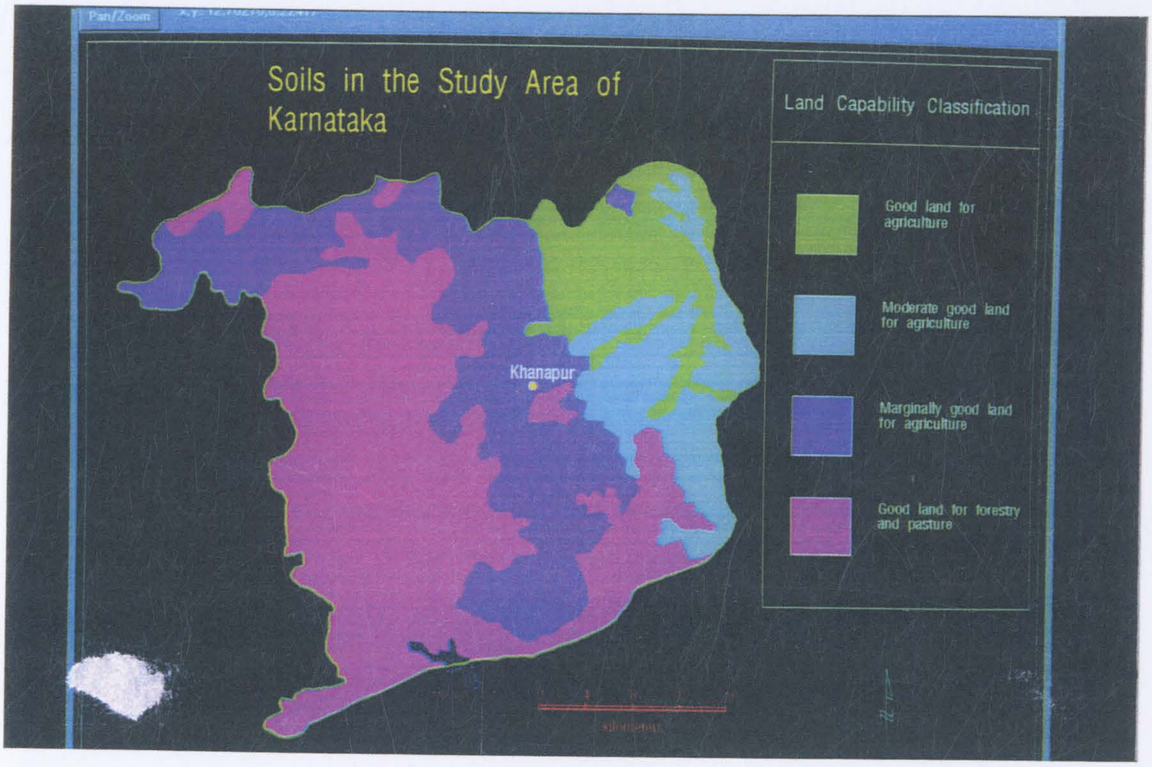

Pan/Zoom
Soils in the Study Area of Karnataka
Land Capability Classification
Good land for agriculture
Moderate good land for agriculture
Marginally good land for agriculture
Good land for forestry and pasture
Khanapur

Plate 5

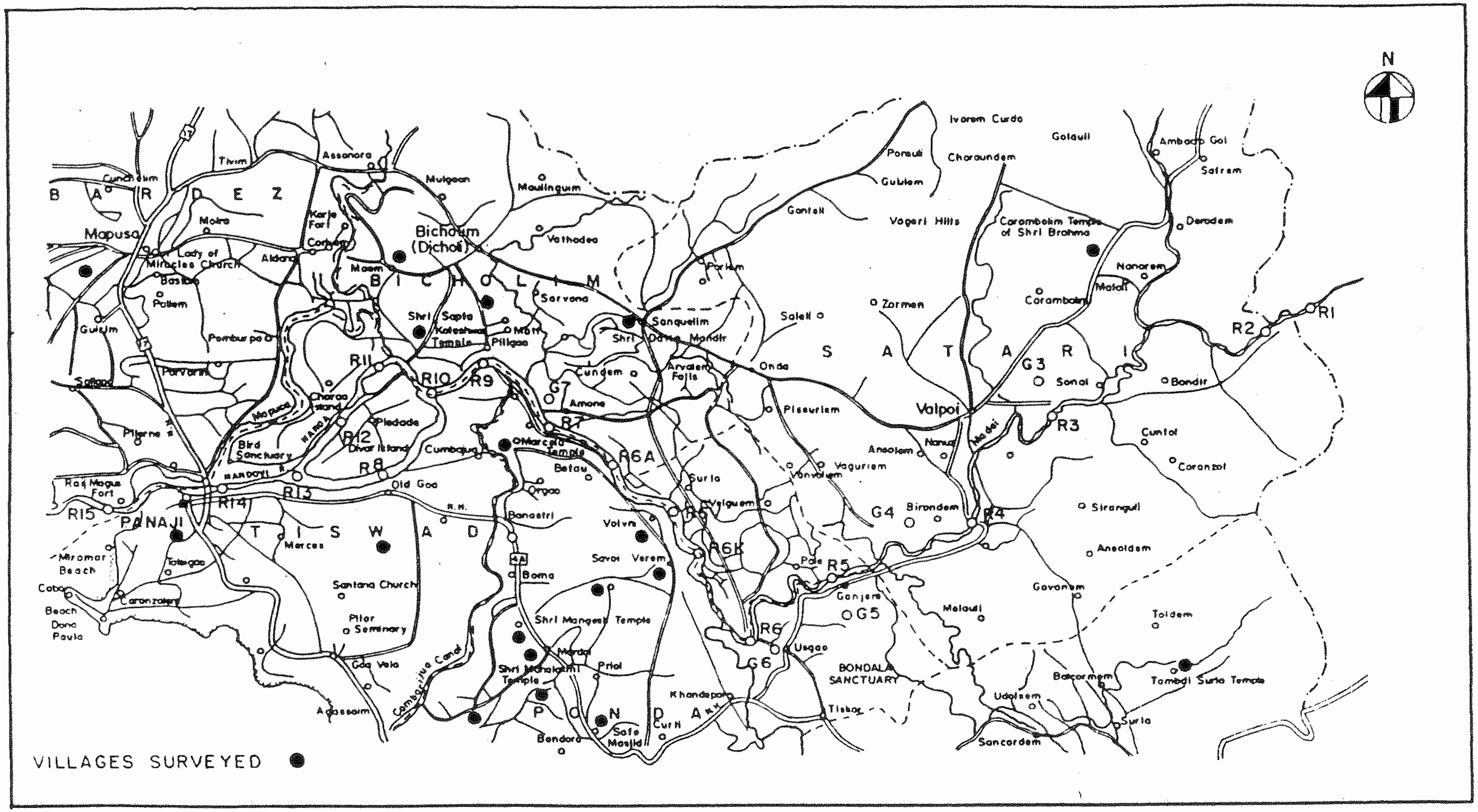


Fig. 4.22 Villages Surveyed for Land Environment in Goa

During the period 1980 - 1991, the forest cover has reduced by 2.4% while agricultural land has increased by 8.3% (**Figure 4.23**). Culturable and unculturable wasteland also increased by 3.9% and 6.8% respectively.

The cultivated land in the area is divided into two main categories (i) paddy lands and (ii) land under other crops including horticultural crops. Paddy land in the area is of three types, viz. Khazan land, Kher land and Morod land.Khazan land is spread over Bardez, Ponda, Bicholi and Pernam talukas and confined to the low lying areas near rivers. These lands are fertile on which salt tolerant local varieties of paddy are widely grown. Kher land is distributed in Ponda, Bicholim and Bardez talukas. Being fairly fertile almost all the area is covered under high yielding varieties of paddy. Morod land, also known as terrace land is confined to hilly areas in the region. These lands are less fertile and prone to erosion.

4.6.2.2 Cropping Pattern

The cropping pattern in the study area is shown in **Plate 8**, and the area covered under each crop is given in **Annexure 4.5, Table 15**. Rice is the main cereal crop and is grown over a large area. To a small extent, millets are also grown. Cash crops like cashewnut, coconut, betelnut, sugarcane and fruit crops such as pineapple, banana and mango are the major crops in the region.

4.6.2.3 Soil Quality

A description of the different soil series, their physiography and approximate area within the 10,000 m wide study area are given in **Annexure 4.5, Table 16** and the dominant soils are shown in **Plate 9**. The climate, topography, geology, and vegetation have played important role in the development of soils in Goa. The soils in the region are divided into 5 major types:

i) Lateritic soils, classified under Netrolim and Zaimolo series, occur on undulating uplands of Satari, Bicholim and Ponda talukas. The soils are strongly acidic in nature, well drained and mostly rich in organic matter. Calcium and phosphorus contents in the soil are very low due to heavy leaching and acidic nature of the soil.

ii) The reddish-brown to yellowish-red coarse-textured alluvial soils occur in patches in the valley bottoms in the study area.

iii) The Calangute, Colva and Betim series constitute the coastal alluvium and beach sands of Tiswadi Taluka.

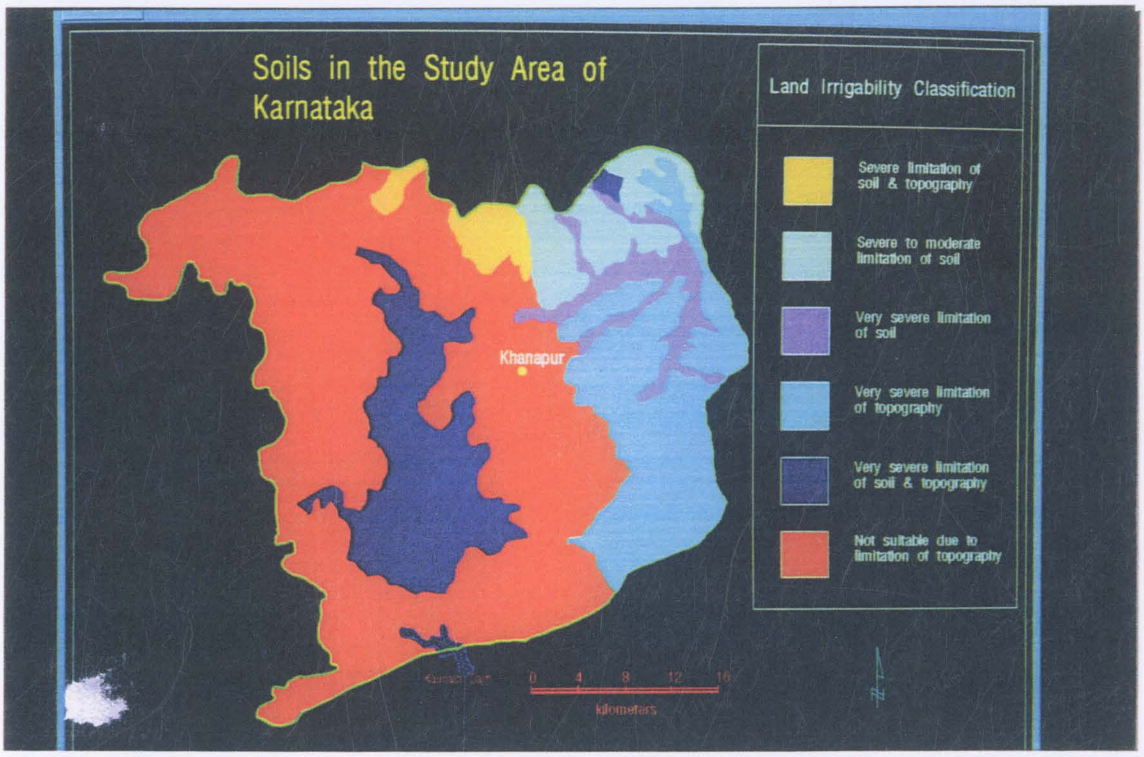

Soils in the Study Area of Karnataka
Land Irrigability Classification
Severe limitation of soil & topography
Severe to moderate limitation of soil
Very severe limitation of soil
Very severe limitation of topography
Very severe limitation of soil & topography
Not suitable due to limitation of topography
Khanapur
0 4 8 12 16
kilometers

Plate 6

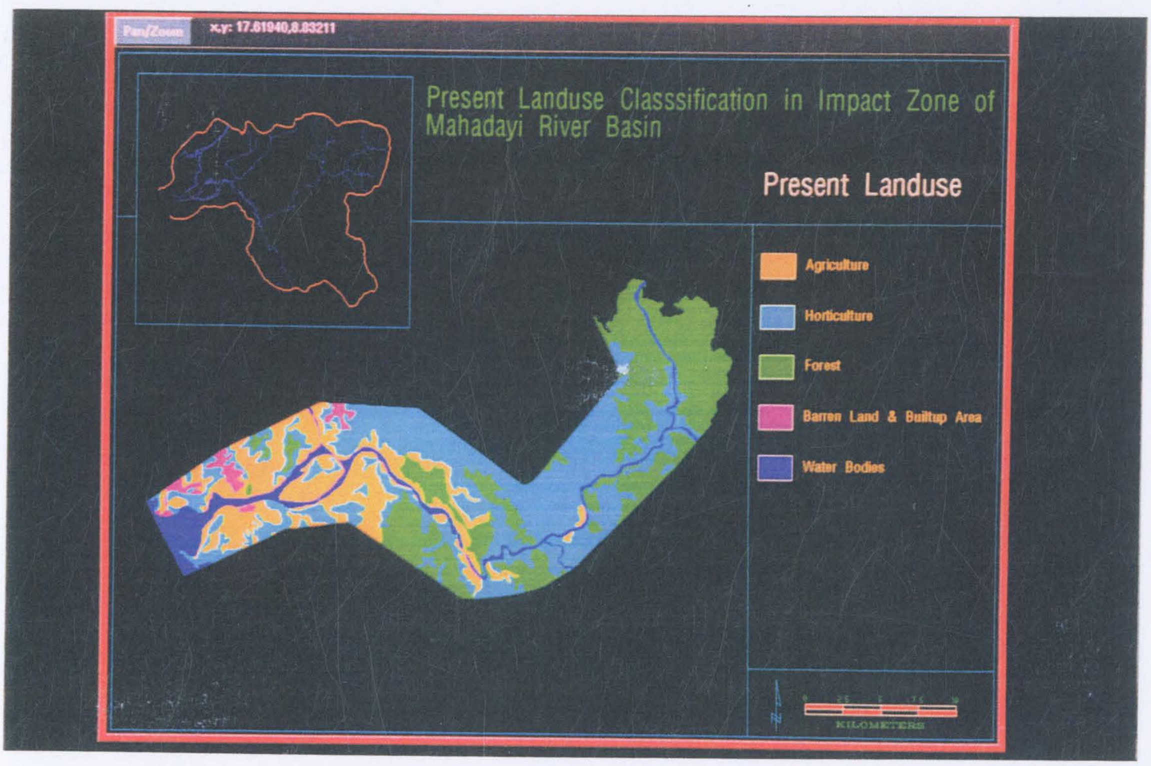
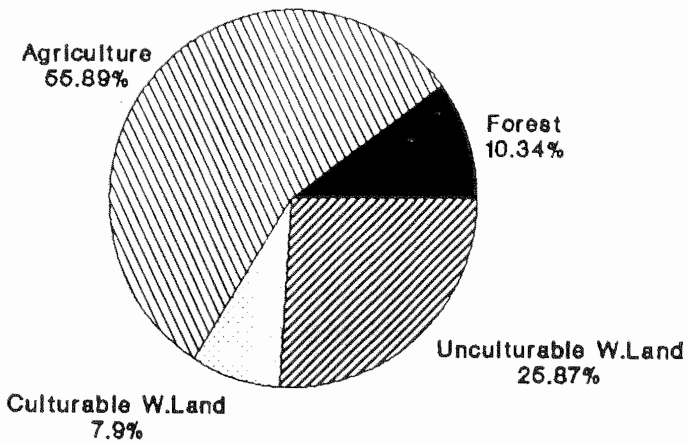
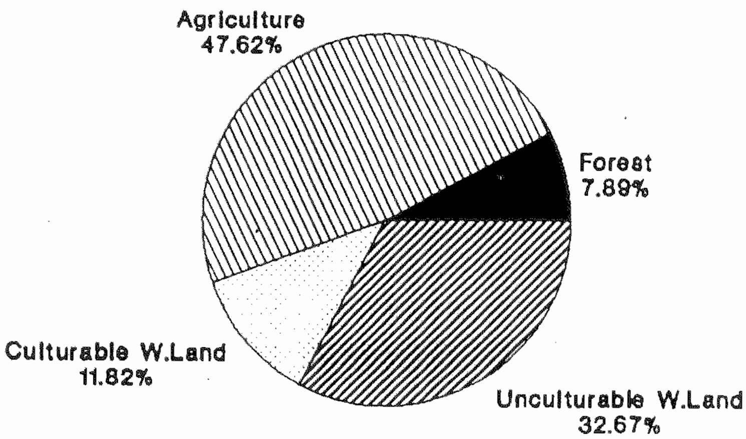

Pan/Zoom
x,y: 17.61940,8.83211
Present Landuse Classsification in Impact Zone of Mahadayi River Basin
Present Landuse
Agriculture
Horticulture
Forest
Barren Land & Builtup Area
Water Bodies
KILOMETERS

Plate 7



(1981)



(1991)

Fig. 4.23 : Land Use Pattern in the Study Area in Goa

iv) Saline soils are confined to the flood plains of both Zuari and Mandovi rivers in the Tiswadi, Ponda and Bardez talukas. The soils of Zuari series have slight salinity and fair amount of organic matter.

v) The soils in low-lying areas of Bardez taluka which are subjected to continuous flooding are classified as marshy soils.

The soil depth classification found in the region is given in **Plate 10** and presented in detail in **Annexure 4.5, Table 17**. Within the study area, deep to very deep soils (75 to 150 cm) are predominant and spread over 58.4% of the area (7436 ha) and the shallow soil covers only 18% of the total area.

The predominant soil texture in the region is clay loam to clay followed by sandy loam to sandy clay loam (**Plate 11 and Annexure 4.5, Table 18**).Within the study area (1000 meters wide), sandy loam, sandy clay loam, clay loam and clay soils are more predominant and spread over 78.7% (9486 ha) of the area.

The drainage pattern in the study area is depicted in **Plate 12** and is given in **Annexure 4.5, Table 19** . Most of the soils (51.5%) are well drained . Poorly drained soils account for only 1%.

Slight to moderate erosion problem is confined to over 10307 ha while severe erosion occurs in 1470 ha. The erosion pattern in the region is shown in **Plate 13** and the area covered under each erosion class is given in **Annexure 4.5 Table 20**.

4.6.2.4 Physico-Chemical Properties of Soils

Clay content of the soil varies from 5 to 45%. The soils have medium to good water holding capacity (8.6 to 30.2%) and the hydraulic conductivity varies from 20 to 88 mm per hour (**Annexure 4.5, Table 21**). The soils are slightly to moderately acidic in reaction (pH 5.1 to 6.2) (**Annexure 4.5, Table 22**), medium to high in organic carbon and of moderate fertility status (**Annexure 4.5, Table 23**). The soils have low to moderate adsorption capacity with the CEC varying from 3.37 to 28.20 meq/100g.

4.6.2.5 Land Capability and Irrigability Classification of Soils

The land capability classes of 15 dominant soil units have been grouped in 6 land capability classes (**Plate 14** and **Annexure 4.4, Table 24**) suitable for agriculture, forestry, pasture, recreation and rehabilitation. In the area 1000 m wide

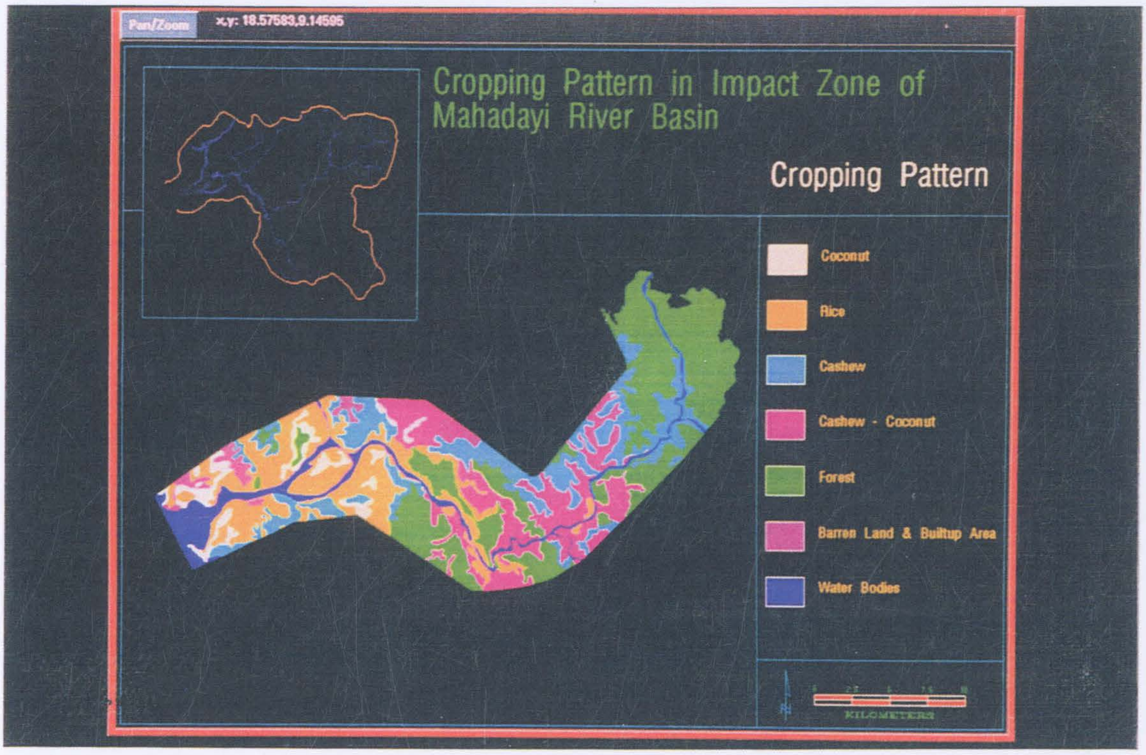

Pan/Zoom
x,y: 18.57583,9.14595
Cropping Pattern in Impact Zone of Mahadayi River Basin
Cropping Pattern
Coconut
Rice
Cashew
Cashew - Coconut
Forest
Barren Land & Builtup Area
Water Bodies
KILOMETERS

Plate 8

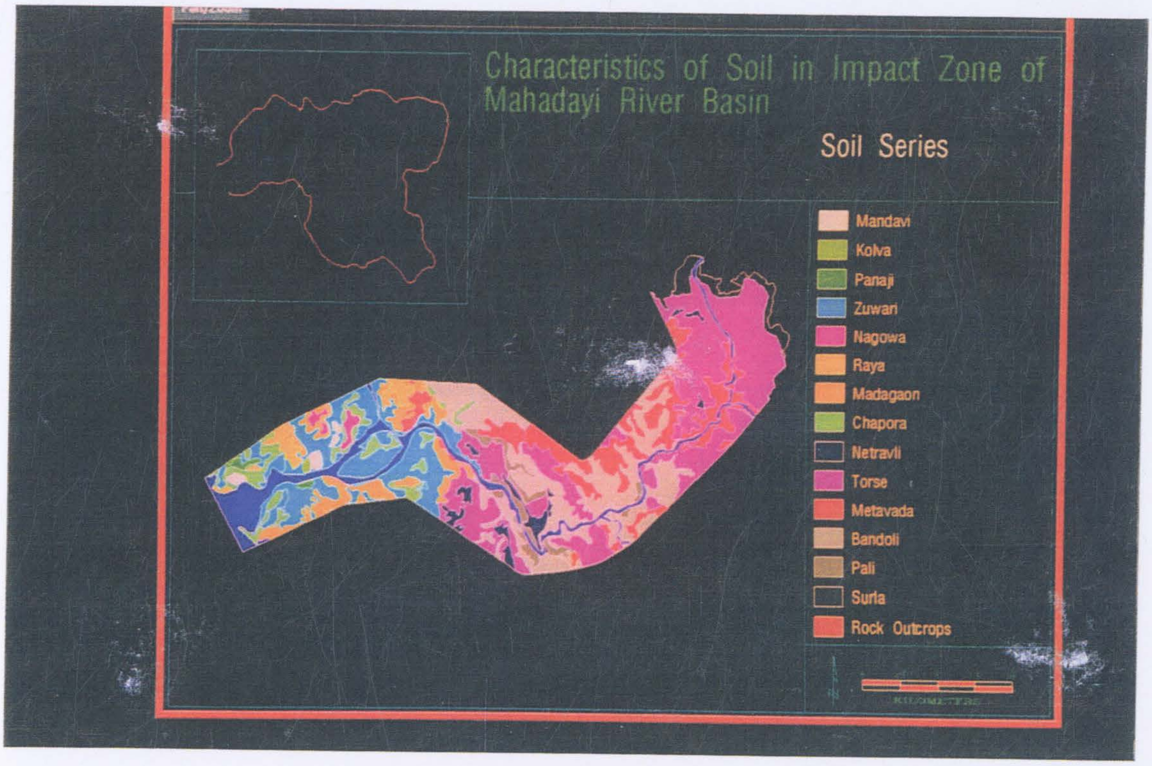

Characteristics of Soil in Impact Zone of Mahadayi River Basin
Soil Series
Mandavi
Kolva
Panaji
Zuwari
Nagowa
Raya
Madagaon
Chapora
Netravli
Torse
Metavada
Bandoli
Pali
Surla
Rock Outcrops

Plate 9

on both sides of the river, good to marginally good land covers an area of 6637 ha while land suitable for forestry and other purposes is spread over 2897 ha. About 66% land in the study area is suitable for agriculture while the remaining 34% area is classified as suitable for forest and other purposes.

The soils in the region are classified into 7 land irrigability classes as shown in **Plate 15** and presented in **Annexure 4.5, Table 25**. About 40% of the area is classified as not suitable for irrigation due to limitation of topography.

4.6.2.6 Khazan Lands

The physico-chemical characteristics of Khazan land along the Mandovi river upto Usgaon is examined to know the salinity status and possible degradation of land. Texturally the soils are clay loam and silty clay, the clay content varying from 36.8 to 44.8%(**Annexure 4.5, Table 26**). The hydraulic conductivity of the soil ranges from 0.68 to 1.34 cm/hr indicating poor drainability. The soil reaction(**Annexure 4.5, Table 27**) is strongly to moderately acidic. The total soluble salt (ECe) content from old Goa to Amone village is high (8.2 - 34.6 mS/cm) and is harmful for the growth of plants. The salinity in the stretch from Amone to Usgaon is low. It is also observed that the total soluble salt content decreases with depth indicating that the salinity in soils is due to the action of sea waves on the nearby land and not due to the pedogenesis. Also poor drainage in these soils is responsible for salinity problem as saline water irrigation of paddy crop may accumulate the salt in surface horizons. Among the cations and anions, sodium and chlorides respectively are found dominant in the saturation extract suggesting the influence of sea water on the soil. The organic matter content in the soil varies from 0.77 to 1.85% indicating medium to high status (**Annexure 4.5, Table 28**). The NPK values indicate moderate fertility status of the soils.

Data on total soluble salts (ECe) in Khazan lands(**Annexure 4.5, Table 29**) indicates that salinity near Old Goa is very high and decreases towards Usgaon. The average yield of local and improved varieties of paddy crop at farmers level of management is reported to increase as the salinity of the soils decreases. This is substantiated by the significant negative correlation obtained between the ECe and the yield of paddy, with correlation coefficient (r) value of 0.89 and 0.95 for local and improved variety respectively (**Figure 4.24**). The prediction of salinity changes indicate lowering of salinity in the Khazan land in Mandovi, and this would benefit the Khazan paddy cultivation.

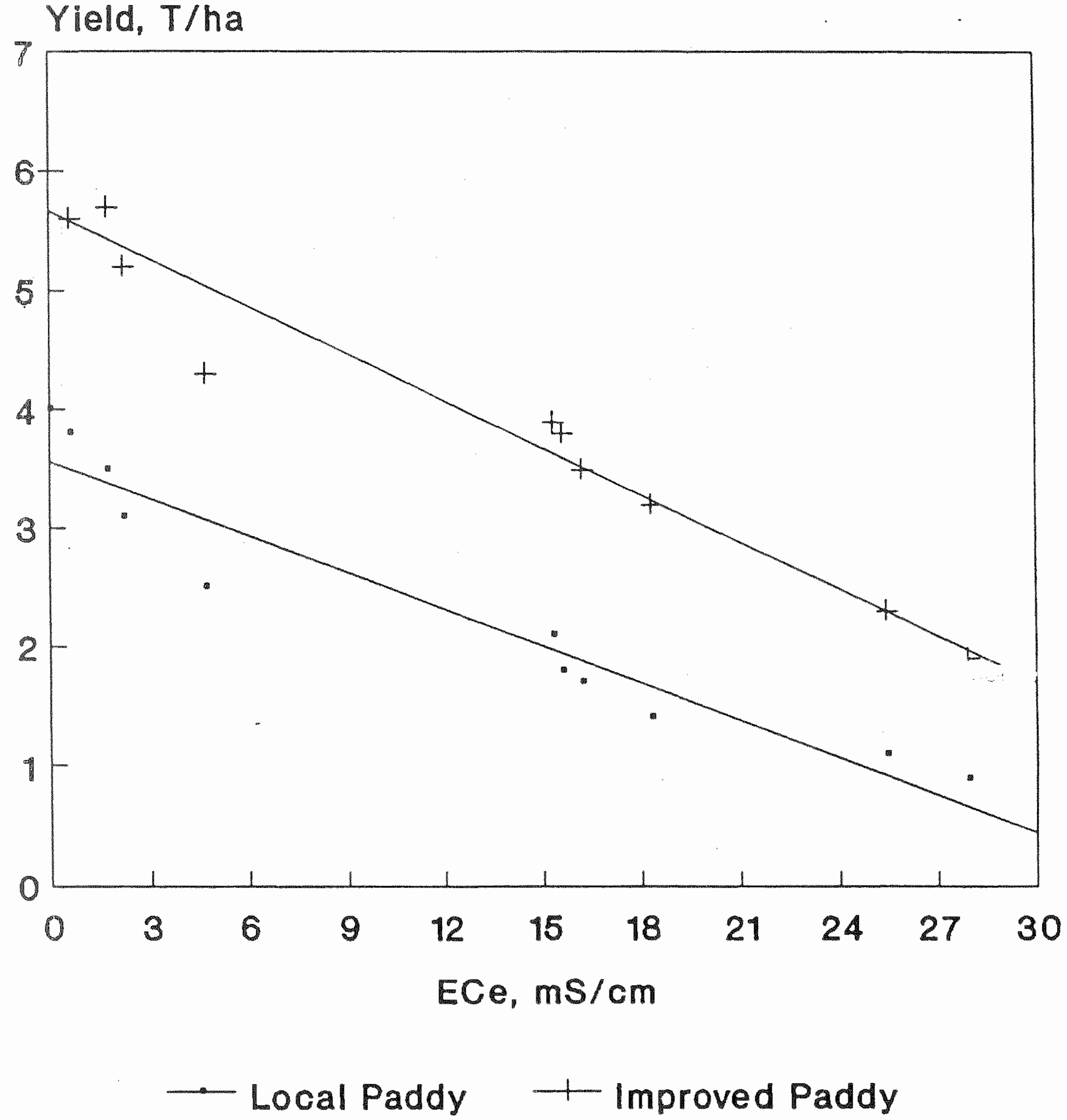
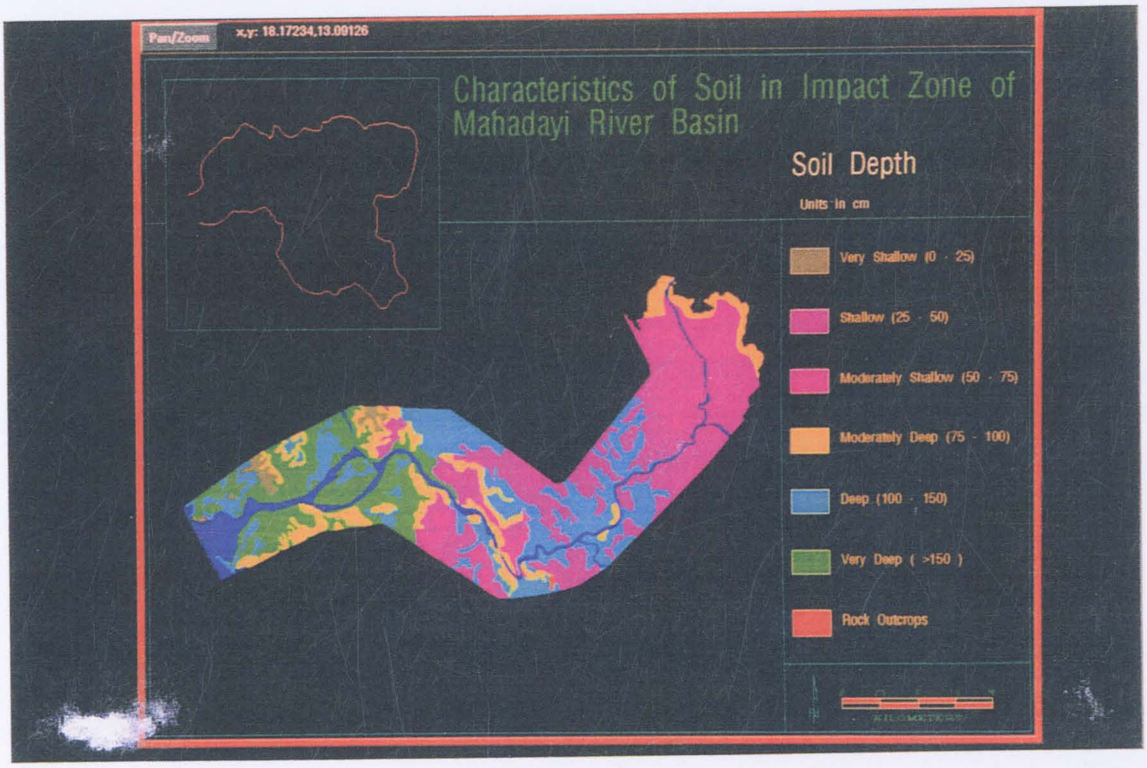


Fig.4.24 : Effect of Salinity on the
Local Improved Paddy Yields



Pan/Zoom
x,y: 18.17234,13.09126
Characteristics of Soil in Impact Zone of Mahadayi River Basin
Soil Depth
Units in cm
Very Shallow (0 - 25)
Shallow (25 - 50)
Moderately Shallow (50 - 75)
Moderately Deep (75 - 100)
Deep (100 - 150)
Very Deep (>150)
Rock Outcrops

Plate 10

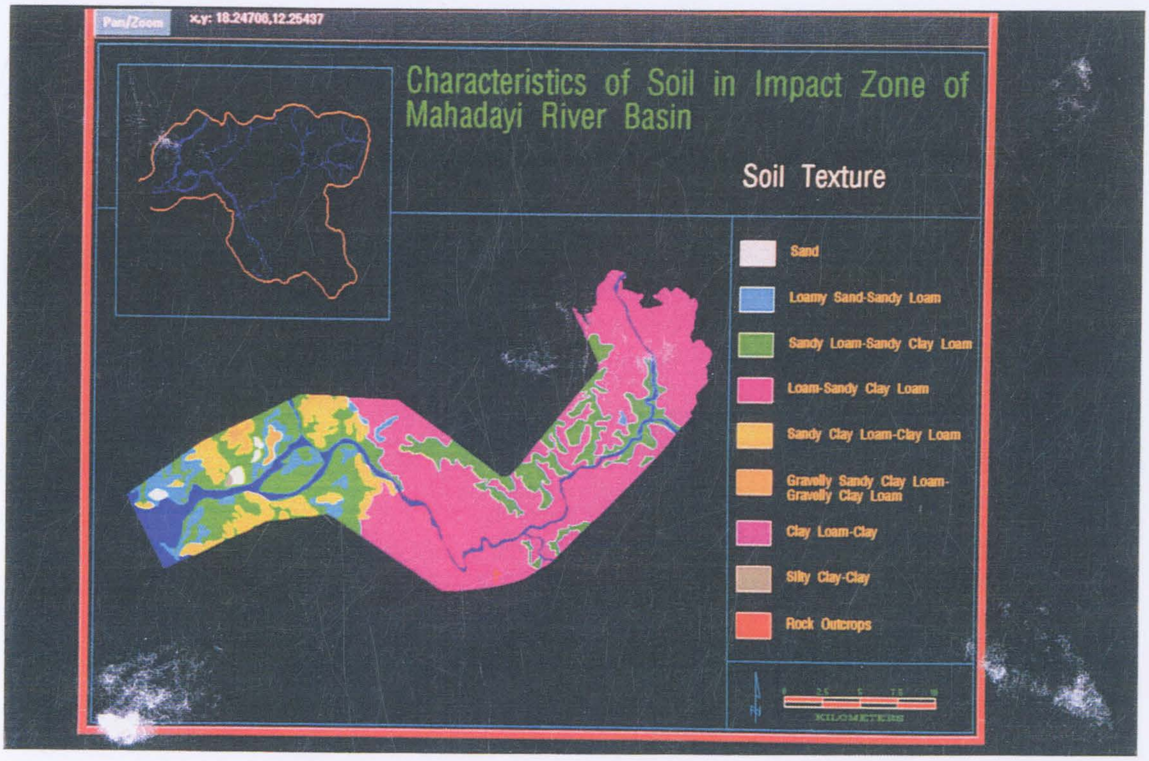

Pan/Zoom
x,y: 18.24706,12.25437
Characteristics of Soil in Impact Zone of Mahadayi River Basin
Soil Texture
Sand
Loamy Sand-Sandy Loam
Sandy Loam-Sandy Clay Loam
Loam-Sandy Clay Loam
Sandy Clay Loam-Clay Loam
Gravelly Sandy Clay Loam-Gravelly Clay Loam
Clay Loam-Clay
Silty Clay-Clay
Rock Outcrops
KILOMETERS

Plate 11

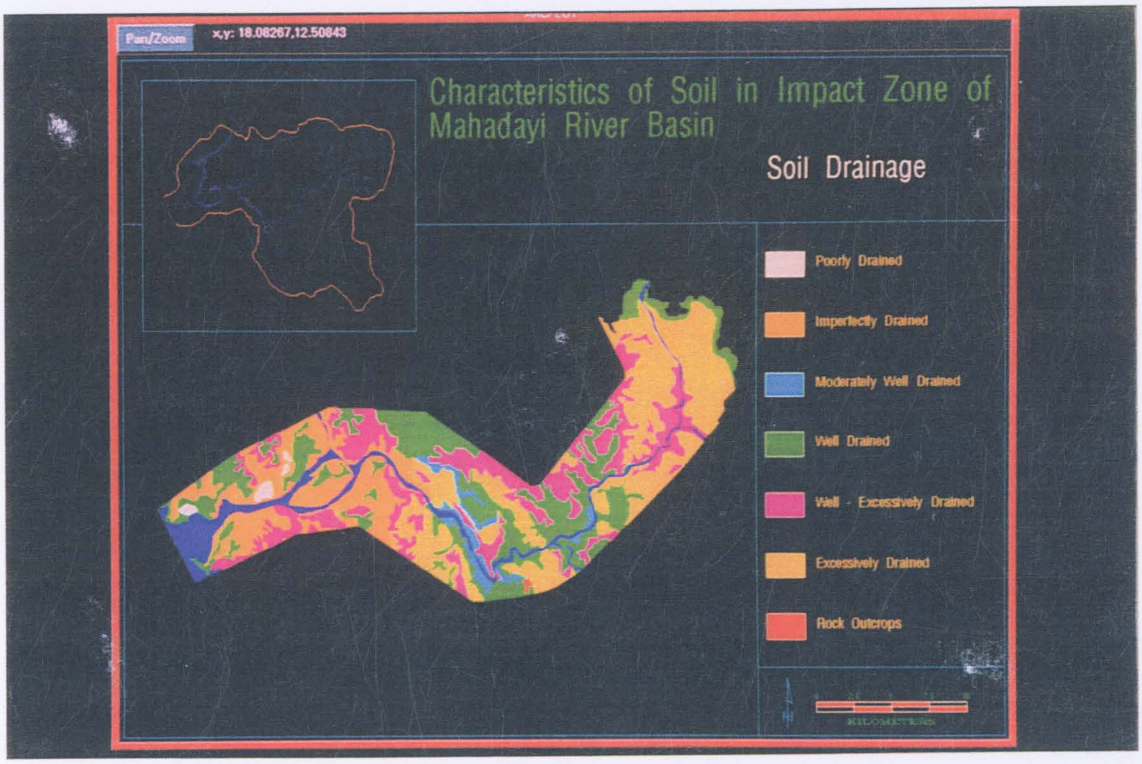

Pan/Zoom
x,y: 18.08267,12.50843
Characteristics of Soil in Impact Zone of Mahadayi River Basin
Soil Drainage
Poorly Drained
Imperfectly Drained
Moderately Well Drained
Well Drained
Well - Excessively Drained
Excessively Drained
Rock Outcrops

Plate 12

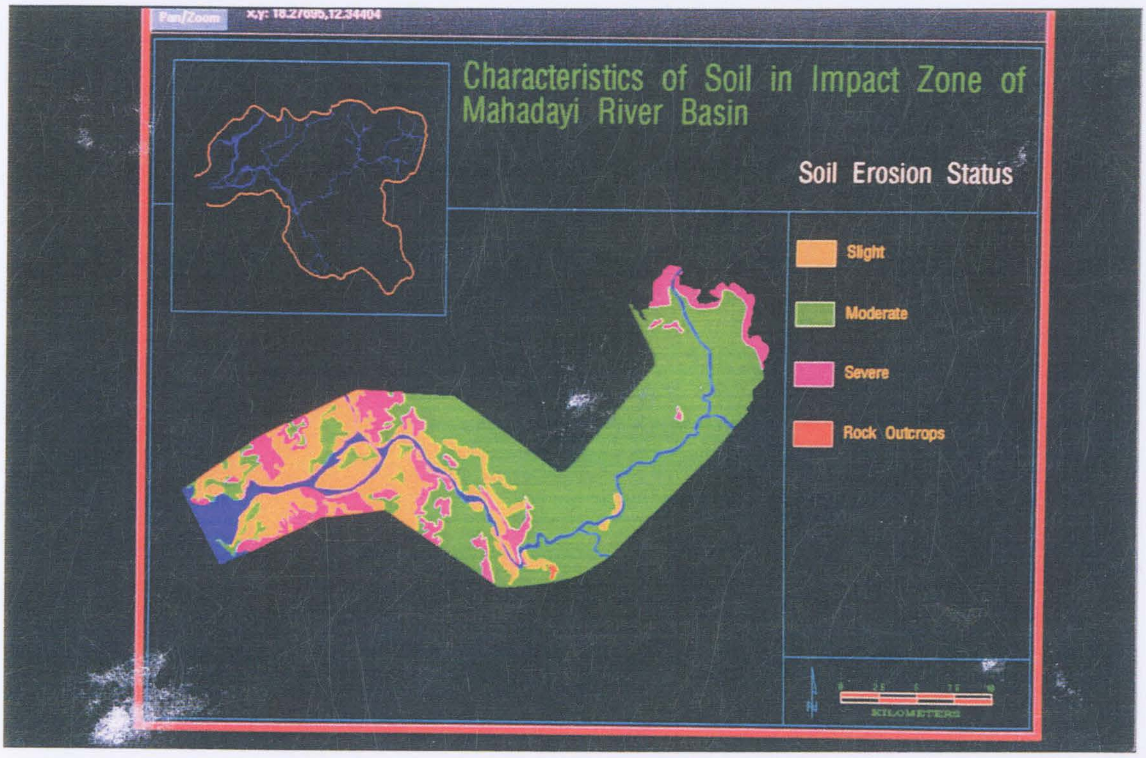

Characteristics of Soil in Impact Zone of Mahadayi River Basin
Soil Erosion Status
Slight
Moderate
Severe
Rock Outcrops
KILOMETERS

Plate 13

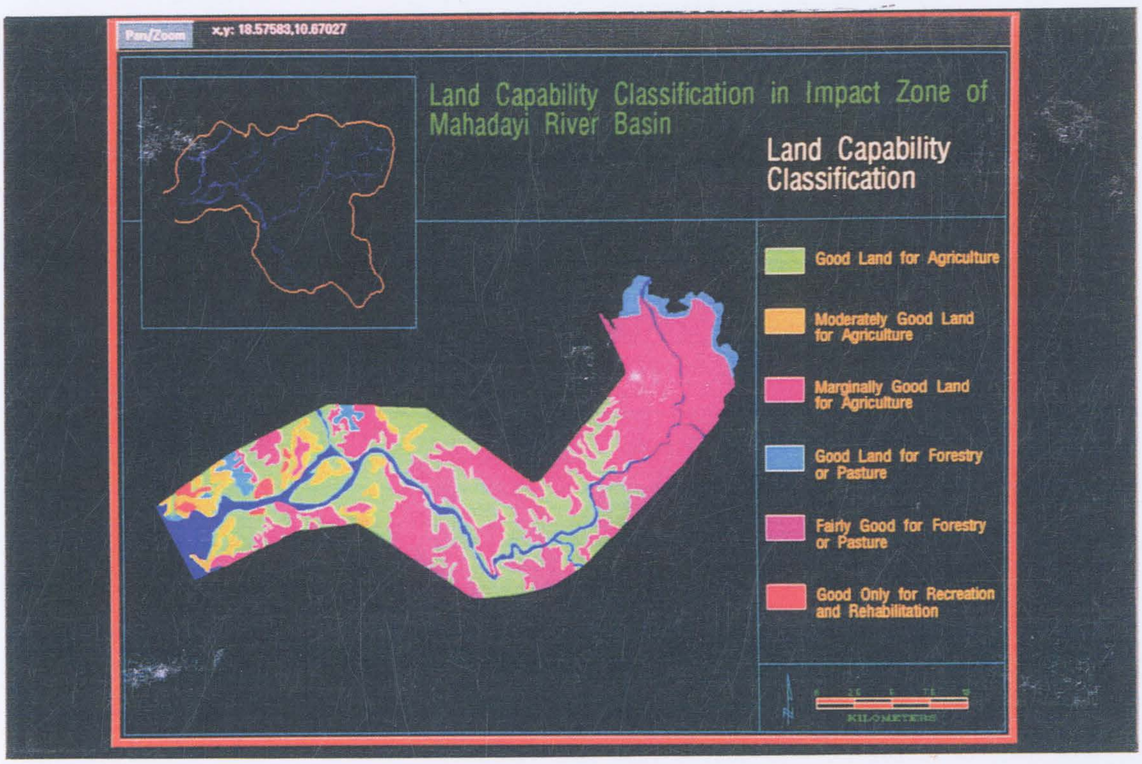

Pan/Zoom
x,y: 18.57583,10.67027
Land Capability Classification in Impact Zone of Mahadayi River Basin
Land Capability Classification
Good Land for Agriculture
Moderately Good Land for Agriculture
Marginally Good Land for Agriculture
Good Land for Forestry or Pasture
Fairly Good for Forestry or Pasture
Good Only for Recreation and Rehabilitation
KILOMETERS

Plate 14

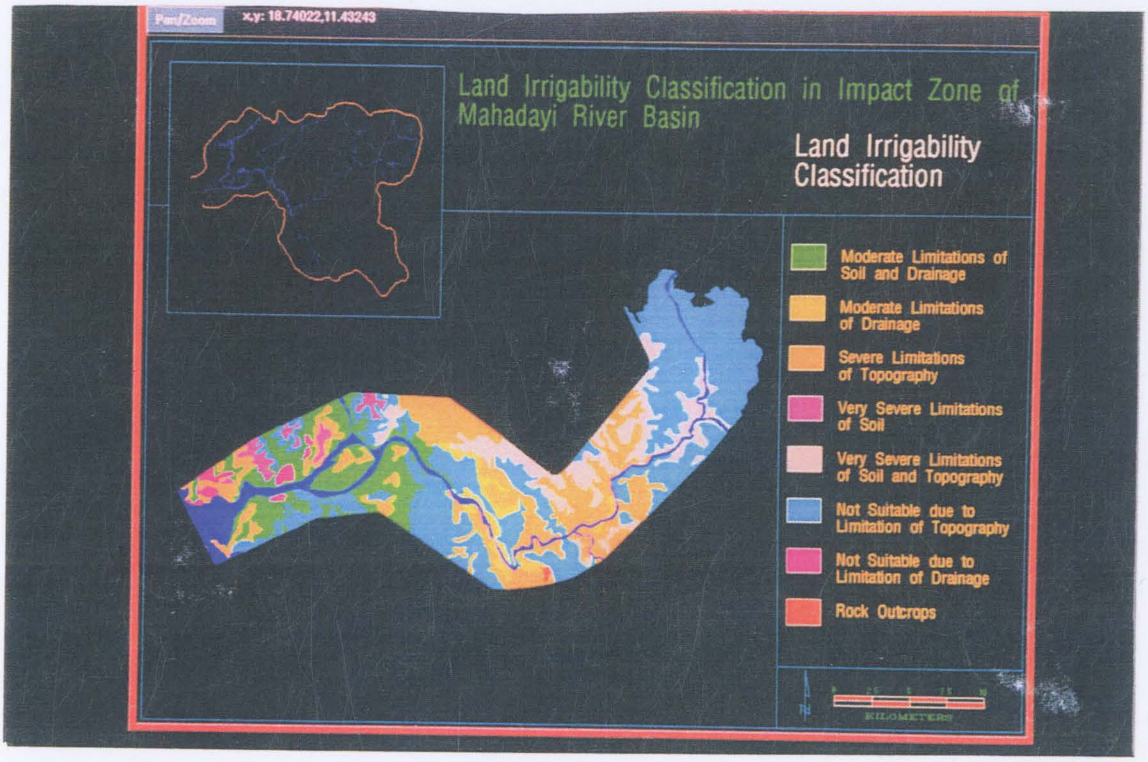

Pan/Zoom
x,y: 18.74022,11.43243
Land Irrigability Classification in Impact Zone of Mahadayi River Basin
Land Irrigability Classification
Moderate Limitations of Soil and Drainage
Moderate Limitations of Drainage
Severe Limitations of Topography
Very Severe Limitations of Soil
Very Severe Limitations of Soil and Topography
Not Suitable due to Limitation of Topography
Not Suitable due to Limitation of Drainage
Rock Outcrops
KILOMETERS

Plate 15

4.7 Biological Environment

4.7.1 Terrestrial Environment in Karnataka State

4.7.1.1 Floristic Composition

According to forest records (1996-97) Belgaum district possesses 1434.16 sq. km (10.7 % of district geographical area) which stands tenth in the state of Karnataka with respect to forest cover. According to 1991, forest survey of India (FSI) assessment, Belgaum district had 1078 sq. km of forest area which has increased to 1434 sq. km in 1997. The different forest types in the district are tropical semi-evergreen, tropical moist deciduous and scrub and thorny forests. The Climate Vegetation Productivity (CVP) based on potential productivity of the forests, (according to the Patersons Productivity Index) in Karnataka state is 32.23 Mcum/yr. This district fringes the western ghat range on south-west side with the highest elevation and rainfall. Therefore, the district has dense, semi-evergreen forest in the south west which merges into the tropical moist deciduous forest and then into the scrub thorny forest in the rest of the district.

The catchment area of the Mahadayi lies on the south-west part of Belgaum district consisting of forest ranges in Londa and Khanapur talukas at an altitude of 500-800 m. The soil in the area is reddish loam, quite often of lateritic or trap. However, humus rich alluvial soil is met near rivers and nalas in the valley. All these and the biotic factors have great influence on the nature of vegetation in the catchment area. This type of soil under good rainfall and moist climate supports medium size but dense forest in the area. Dense forest is found in the western catchment area while open forest with 10-40 % crown density is found in the eastern catchment area.

4.7.1.2 General Features of Forests

The forest of the tract corresponds to the following types of Revised Classification of Indian Forest Types by Champion and Seth. The different plant species at various locations in the Mahadayi catchment in Karnataka are listed in **Annexure 4.6, Table 1.**

West Coast Semi-evergreen Forests are found in Jamboti block and several compartments of Hemmadaga and Kanakumbhi area. However, the vegetation is confined to the river and stream banks in remote valleys, while on undulating plains, the vegetation is under intense edaphic and biotic pressure and is found to be displaced on account of felling, lopping, browsing and fires.

South Indian Moist Deciduous Forest (3B/C1) is present in compartments 1 to 5 of Hemmadaga block. It shows the absence of teak species but the presence of all its associates. This area constitutes the steep slope of Dongargay-gudda. Southern moist mixed deciduous forest (3B/C2) and southern secondary moist mixed deciduous forest (3B/C2/2S1) are found in Hemmadaga compartments 6 to 13, 29, 30, 32 to 35 and Kanakumbhi compartments 5 to 12. These types are found on undulating ground and they have been developed under climatic conditions suitable for semi-evergreen type but get degraded into 3B/C2 type due to edaphic and biotic factors.

Semi-evergreen forests (2AC2 type) are found to be developed to climax vegetation along the rivers and nallas in these forest blocks. The small patches of evergreen forests recorded in this area include the species of *Hopea wrightiana, Lophopetalam wigjtianum, Calophyllum apetalum, and Mysristica.* The typical west coast semi-evergreen forest is intermediate between tropical evergreen and tropical moist deciduous forest types. Its distinction may be rather difficult on account of the presence in patches or groups of species characteristics of two other types.

In physiognomy (external appearance), it forms dense forest with both deciduous and evergreen trees of large number of species. The height of canopy does not exceed 20-25 m. Accordingly, this type of forest is classified under Site Quality Class III. The biggest evergreen species are absent. The girth of the trees is found to be less than 1.5 m.

The upper canopy is found to be dominated by *Syzygium cumini, Lagerstroemia lanceolata, Terminalia paniculata, T.tomentosa, Cinnamomum zeylanicum, Holigarna arnotiana, Carallia brachiata, Euphoria longana, Mimusops elengi.* The second stratum is formed by *Memecyclon edule, Olea dioica, Diospyros montana, Symploca, Careya arborea, Emblica officinalis, Flacourtia montana, Diospyros candolleana, Mallotus phillipiensis.* The third stratum of shrubs is formed by *Glycosmis* species, *Atalantia racemosa*, and *Strobilantues.* Canes are found in wet pockets. Regeneration of species of *Memecylon edule, Olea dioica* and *Terminalia* is found to be abundant.

The degraded semi-evergreen forests are found to be replaced by tropical dry evergreen forests and tropical dry evergreen scrub. In the former type the upper canopy consists of *Diospyros* species, *Syzygium* species and *Xcanthium* species followed by second stratum of *Memecyclon edule* and *Ligustrum* sp., *Randia dumetorum, Atlantia racemosa* and *Flacourtia montana.*

South Indian Moist Deciduous Forest consists of upper canopy of *Terminalia* sp. *Lagerstroemia* species, *Dalbergia latifolia, Grewia tiliaefolia* and *Careya arborea, T. chebula, Cassia fistula, Diospyrous montana, Bridelia retusa* and *Macaranga peltata*. The third stratum of shrubs and climbers is formed by *Callicarpa lantana, Clerodendron infortunatum* and climber sp. of *Acacia, Caesalpaenia, Calycopteris floribunda, Spathobus roxburghii.* Regeneration of *Xylia* and *Terminalia* is seen. In mixed deciduous forests and secondary mixed deciduous forests, the forests are irregular on ridges and plains and consist of species like *Terminalia paniculata, Careya arborea, Dillenia pentagyna, Terminalia tomentosa, Emblica officinalis* and evergreen trees along relatively undisturbed areas, such as *Cinnamomum zeylanicum, Diospyros* sp., *Symploca canarana* and *Mangifera indica*. The maximum height of canopy recorded is 14 m.

4.7.1.3 Characteristics of Forest Vegetations in project sites

Kotni Dam Site

The Kotni dam site consists of hilly area with dense forest vegetation. The topography is undulating with deep valleys and mountains. The environment is, thus, wet and moist and suitable for the growth of evergreen species. The slope gradient towards the Mahadayi is steep with well grown forest. The valley portion is found to be covered by evergreen forests while the top of the hills shows some deciduous species along with evergreen species forming semi-evergreen forest. The vegetation is characterised by distinct strata. The canopy is dense, emergent and predominantly evergreen followed by small trees, shrubs and herbs. The climbers and woody lianas are abundant in the forests, climbing on shrubs or small trees. Woody lianas are found to grow to a great length encircling big trees also. The upper storey of the deep valley forest around the Mähadayi extends upto 30 m. The second storey of small trees varies between 10-15m, and the third storey of shrubs between 3 m to 10 m. The ground flora is seasonal and sparse in the forest and relatively dense in the marginal areas.

Around Kongla Upstream of Mahadayi River (Hemmadaga Section)

This forest is contiguous to the Kotni dam forest. It is also classified as 2AC2 Southern Tropical semi-evergreen forest (similar to West Coast semi-evergreen forest) according to Champion and Seth Classification. The forest in Kotni dam site and upstream area comes under Londa and Khanapur range which shows more or less homogeneous composition, which can be compared with 2AC2 West Coast evergreen forest. This range is found to be inaccessible due to dense growth of underground storey of shrubs,climbers and lianas. The downstream area is also undulating with hills and valleys and plain area on the outskirts. The vegetation is very much similar to the Kongla area in deep valley and mountains. However, on the slopes and on the plains, the broad leaved species are more dominant.

Bail nadi dam site is situated in a deep valley. The slopes of the hills are covered with dense evergreen forest species. The deciduous species are also recorded forming a top canopy. The upper hilly areas are covered by shrubby vegetation. Small pieces of agricultural lands are found at various places. The forest on the hills and plains is mostly of open type and consists of different species mixed with *Terminalia paniculata*.

Andher Nala Dam Site

The catchment area of this seasonal stream is undulating and is covered with dense forest. The forest type is closed and semi-evergreen and open moist deciduous vegetation. Many climbers are also recorded in the forest.

Pansheer Nala Dam Site

This area is not occupied by great hills and valleys but by small hills and undulating land. The bed of the nala is relatively broad with boulders.

Muruduhaul Nala Dam Site

This is a small stream by the side of the Pansheer stream on the south western side of Kotni catchment area. This area is again occupied by undulating land site.

Kalsa and Surla Nala Dam Site (Kanakumbhi Section)

Kalsa and Surla nala and their confluence are surrounded by undulating areas and small hills around. The nalas are seasonal with very small or no flow during summer season. The river bed is characterised by very big rocks and boulders.

Moist mixed deciduous forest (3 B/C2) and secondary moist mixed deciduous forest (3 B/C2/2S1) comes under Kanakumbhi compartments 5 to 12 with undulating ground and small hilly areas. This type of forest seems to be derived from evergreen forest due to human activity like shifting cultivation, grazing, burning, and deforestation. The forest is confined to hill, slopes and is irregularly distributed. On ridges, hill tops and level ground, vegetation of deciduous tree species occurs which is young and open, while it is comparatively old and dense in low lying areas. The dominant deciduous species on ridges, hill tops and level ground are *Terminalia tomentosa, T. paniculata, Careya arborea, Emblica officinalis, Dillenia pentagyna.* The banks of Kalsa and Surla nala showed the presence of few evergreen species like *Cinnamomum zeylanicum, Diospyros* sp., *Mangifera indica, Symploca canara.* The height of the canopy varies from 10-15 m. The teak was found at some places on the eastern side of Kalsa and Surla nala.

In most deciduous forest, the upper canopy was formed by *Terminalia paniculata, T. belerica, Dalbergia latitolia, Salmalia malabarica, Dillenia pentagyna, Lagerstroemia lanceolata, Syzigium cumini, Mangifera indica.* Second storey of vegetation was found to consist of *Bridelia retusa, Careya arborea, Memexylon edule, Olea dioica, Flacourtia montana, Randia dumetorum, Emblica officinalis, Terminalia chebula.* The third storey was found to consist of *Carirsa carandas, Clerodendron infortunatum, Helioteres isora, Glycomis pentaphylla* and the ground vegetation was formed by *Calycopteris floribunda, Acacia* sp. *Wagatea* sp.

Along the stream banks the vegetation was mixed with semi-evergreen species e.g. large gregarious patches of *Memexylon edule* and other species.

4.7.1.4 Area under Submergence and Construction Sites

The forest area coming under submergence including the river course is 2077.5 ha. The area required for project facilities like housing complex etc. is 330 ha. The details of the plantation cover under submergence are presented in **Table 4.15**.

4.7.2 Terrestrial Environment in Goa State

4.7.2.1 Floristic Composition

Goa has 32.9 % of forest cover to its geographical area. The forest area comprises dense forest (996 sq.km), open forest (254 sq.km), wet land - mangrove (3 sq.km) and scrub area (16 sq.km). The dense forest is present on the eastern side of Goa state on the Western fringe of western ghat range. The forest types are tropical wet evergreen, tropical semi-evergreen and moist deciduous forest with higher number of teak trees and cashew trees.

The Mandovi is surrounded by open forest near Sonali village. The trees near the river bed are, *Mangifera, Ficus religiosa, Mimusops, Sterculia foetida, Alstonia scholaris, Lagerstroemia parviflora, Artocarpus hirsuta, Ficus bengalensis, Tectona grandis, Anogeissus latifolia* etc. In the downstream areas, the river is surrounded by

Table 4.15

Details of the Forest Area under Submergence in Karnataka

Sl. No.	Description	Area (ha)
1.	Eucalyptus plantation	1040.50
2.	Under forest which forms the part of Heammadaga Jamboti Kanakumbhi fuel working circle of ghat forest of Belgaum district of the worked and unworked coupes (thick forest)	516.00
3.	Under unorganised forests (thick forests)	330.00
4.	Under river course	191.00
	Total	2077.50

Source : Asstt. Conservator of Forests, Khanapur Sub Division, Khanapur cashew plantations, with palms and coconut trees and other common trees as listed above. The estuarine portion of the Mandovi shows mangrove vegetation on its banks and island area.

4.7.2.2 Wetlands

Wetlands include areas of marsh, fen, peatland or water regardless of degree of salinity (natural or artificial, permanent or temporary, with static or flowing water), including marine waters upto 6 m in depth at low tide (UNESCO, 1982).

The wetland along Mandovi estuary consists of estuarine area, intertidal mudflats and rice paddies (Khazan land). These areas come under wetland type viz. 02 (estuarine); 06 (intertidal mudflats, sand mudflats) and 19 (rice paddies) as categorised by World Wide Fund for Nature, India and Asian Wetland Bureau (1993).

The wetlands comprises the Zuari and Mandovi rivers, their tributaries, and the inter connecting Cambarjua canal. They contain 90 % of the mangroves of Goa. The estuaries are divided by extensive intertidal mudflats and adjacent rice paddies. Panjim and old Goa are situated within this complex. Mandovi estuary and Cambarjua canal have 7 ha and 2 ha of mangroves, respectively, occurring along the banks.

Chorao island is located at the confluence of the Mapusa river flowing in from the north, and the Mandovi river from the south. Chorao Island, has now been declared as reserved forest and bird sanctuary. The low-lying areas of the island support mangrove swamps. The salinity varies from 0.9-28 ppt in Mandovi estuary surrounding this island. The central part of the island is hilly, the altitude ranging from 20 m to 93 m. A road runs some distance into the island. A ferry connects the island to the mainland. The estuary is an important spawning ground for various crustaceans and molluscs, together with many species of fish, the major ones being *Meretrix* sp., *Crassotrea* sp;, *Peneaus* sp., *Scylla serrata*, and *Mugil cephalus*. The commonly cultivated species are *Penaeus monodon*, P.*indicus*, and *Metapenaeus monoceros*. The site is also an important staging and wintering area for migratory ducks and shorebirds. *Anas acuta* occurs in particularly large numbers, e.g. over 30,000 were present in January 1987. The ducks roost on the estuary during the day and feed in surrounding rice paddies at night. Other water fowl present in January 1987 included :

100 *Egretta gularis*
25 *E. alba*
30 *T. nebularia*
1007 *E. garzetta*
150 *Tringa totanus*
50 *Actitis hypoleucos*

Water fowls are particularly good indicators of the general condition of wetland ecosystem; they are at or near the top of most wetland foodchains and are highly susceptible to wetland contamination and disturbance.

Contamination from industries upstream, city wastes, and sewage is increasingly threatening the Mandovi estuary. Mining activities are causing silting of the estuaries. The mangroves are being cut for fuel and green manure. The Konkan Railway, which is constructed through coastal Goa, is cutting across the estuarine complex. This is likely to impact the coastal wetland ecosystems of Goa. Mangrove vegetation in Chorao Island may also be affected due to changes in land use due to converting 24 ha. of Island into a fish farm.

Some poaching of birds has been reported in Chorao island. The island is a tourist attraction. The avifauna include migratory and residential species, such as lesser adjutant stork, painted stork, pintail, common teal, cotton teal, garganey, spotbill, shoveller, little grebe, white-necked stork, black-necked stork, egrets, herons, bittern, and fishing eagle. Other fauna include bats, jackals, water snakes, marsh crocodiles etc.. Common fish species are *Mugil cephalus, M.persica, Chanos chanos, and Lates calcifer.*

The estuarine area (depth < 6 m) is occupied by tree species of mangrove vegetation and the intertidal mudflats including Chorao island are occupied by shrubs and tree mangrove species. The wetland along the Mandovi estuary thus consists of mangrove vegetation occupying an area of 700 ha.

The mangrove wetland along Mandovi estuary is important for intense biological activity. Various phytoplanktons, crustaceans, and molluscs together with many species of finfishes and shellfishes viz. *Meretrix* sp., *Crassotrea* sp., *Penaeus, Scylla serrata* and *Mugil cephalis* use estuarine wetland for shelter, niches and spawning growing. Commercially important species are *Panaeus monodon, P. indicus* and *Metapenaeus monoceros*. Migratory birds and shore birds commonly visit the wetland during winter.

At Chorao Island, the mangrove wetland is vast and support a diverse avifauna such as migratory and residential species such as painted stork, lesser adjutant stork, common teal, pintail, spotbill, shoveller, little grebe, white necked stork, black necked stork, egrets, herons, and fishing eagle. Other fauna include bats, jackals, water snakes, marsh crocodiles etc.

Estuarine areas are used for fishing, fish farming, fodder collection, timber and medicinal plants.

Forest Department has undertaken mangrove afforestation programme. Chorao Island has been declared a bird sanctuary which is named after the late Salim Ali.

4.7.2.3 Wetland - Mangrove Vegetation in the Mandovi Estuary

The coastal area of Goa is drained by the major rivers Mandovi and Zuari linked by the Cumbarjua canal. The estuarine areas formed by these are suitable for the growth of mangrove vegetation. The tidal amplitude in Goa varies from 0.01 m to 2.44 m. During monsoon, the tidal currents may reach upto 4 to 5 m. The coastal strip of Goa is highly indented with sea cliffs, notches and promontories, alternating with rivers and estuaries. These estuaries have been confirmed to be drowned valleys. All the estuaries in Goa are classified as microtidal estuaries, as the tidal level is below 2 m. Mangrove vegetation along the Mandovi river in Goa is classified into two groups with associated major mangrove species as given below.

Mangrove Scrub: Type 4BTSI is recorded in isolated small areas along the banks of the Mandovi. The mangrove species comprising this vegetation are :

Stratum I/II	:	*Avicennia officinalis, Excoecaria agallocha*
Stratum III	:	*Acanthus ilicifolius*
Stratum IV	:	Grasses like *Cyperus*

Mangrove Forest : Type 4BTS2 is found on the sheltered portion of islands and river banks of the river Mandovi in limited area. The mangrove species recorded are :

Stratum I/II	:	*Rhizophora mucronata, R. apiculata, Bruguiera parviflora, Excoecaria agallocha, Sonneratia alba, Avicennia officinalis, S.caseolaris, Kandelia rheedii*
Stratum III	:	*Acanthus ilicifolius, Cyperus sp.*

A list of mangrove species recorded from Mandovi river is given in **Annexure 4.6, Table 2** and the species diversity and Importance Value Index in **Table 4.16.** The estuarine portion is 5 km wide at the mouth and 0.5 km wide at the upstream region. The Mandovi estuary has 700 ha of fringing mangroves. The mouth of the Mandovi is lined by rocky substratum with strong wave action and tidal currents. Owing to these factors, the Mandovi river mouth is devoid of mangrove vegetation. From the upstream area of Mandovi estuary, around 10 species of mangroves belonging to 8 genera are recorded.

Table 4.16

Importance Value Index and Shannon Weaver Index for Species Diversity of Mangrove Vegetation along the River Mandovi

Location	Mangrove Species	Abundance* (No/100 m^2)	Basal Area (m^2/100 m^2)	Relative Values in Percentage			Importance Value Index	Shannon** Weaver Index
				Dominance	Density	Frequency		
R6	*Sonneratia caseolaris*	18	4.3	100	100	100	100	0
R6A	*S. caseolaris*	9	3.2145	57.55	51.43	33.3	47.48	
	Cyperus sp.	6.5	2.3560	42.18	37.14	33.3	37.54	1.403
	Bruguiera parviflora	2	0.1520	0.27	11.43	33.3	1.5	
R7, R9, R10, R11	*Exocaecaria agallocha*	10.6	1.5267	33.1	35.9	21.4	30.13	
	Kandelia rheedii	6.3	0.4382	9.5	21.3	21.4	17.4	
	S. alba	4.3	0.659	14.3	14.6	21.4	16.76	2.365
	Rhizophora apiculata	3.3	1.1607	25.2	11.2	14.3	16.9	
	B. parviflora	3	0.5196	11.3	10.1	14.3	11.9	
	R. mucronata	2	0.3029	6.6	6.9	7.2	6.9	
R12, R14	*R. mucronata*	23.2	4.1319	84.8	93.2	47.6	75.2	
	R. apiculata	0.6	0.1836	3.8	2.4	19.0	8.4	
	Avicennia officinalis	0.6	0.1020	2.1	2.4	14.4	9.3	
	E. agallocha	0.4	0.1919	3.9	1.6	9.5	5	0.480
	S. alba	0.1	0.2642	4.4	0.4	9.5	4.76	
R8, R13, R15	*R. mucronata*	23.2	4.1319	91.7	95.9	62.5	83.36	
	S. alba	0.4	0.1919	4.3	1.7	12.50	6.17	0.287
	Acanthus ilicifolius	0.6	0.1836	4.0	2.4	25.0	10.47	

* Abundance = Average number of individuals per quadrant (100 m^2)

Mandovi River at Old Goa, Ribandar and Jetty

Mangrove vegetation starts in small patches along the right bank near Mandovi bridge. These patches are also found on the left bank and are mostly planted, protected and conserved. They consist mostly of *Rhizophora mucronata. Sonneratia alba* and *Acanthus ilicifolius* are also recorded from ditches and ponds by the side of the river in this area. In the stretch of Mandovi estuary from R8, R13 to R15 stations, the Importance Value Index (IVI) (Table 4.16) shows that *Rhizophora mucronata* was the most abundant among the mangrove vegetation. The Shannon Weaver Index in this stretch of estuary is low.

Chorao Island & Deewar Island

Further upstream in Mandovi estuary, the Chorao and Deewar islands (R12 and R14) are situated opposite Ribandar coast. The islands have grown in size due to accumulation of sediments carried by the river. Since the soil is fertile at Chorao island , it has been reclaimed for paddy cultivation. Some area is also used for fish farming. The beaches of these islands are now occupied by luxurient growth of mangroves, forming the largest single patch of mangroves in Goa. However, the distribution of mangroves has been checked by construction of bunds around mangroves for agricultural purposes and fish farming in both the islands. The bund construction around mangroves enhances siltation which deteriorates the nutrient status of soil and adversely affects the mangrove growth. The bunds also restrict the movement of mangrove seedlings and prevent regeneration of mangroves. The mangrove flora of Chorao island consist of about 5 different species viz. *Rhizophora mucronata, R.apiculata Excoecaria agallocha, Avicennia officinalis, Sonneratia alba*

The mangrove vegetation is found to be in the fringes upstream of Chorao island. The mangrove vegetation in Deewar island is present in small patches with species of *Rhizophora mucronata, A. officinalis* and *Sonneratia alba*. The data presented in Table 4.16 indicates that *Rhizophora mucronata* is dominant in the mangrove vegetation with IVI of 75.2. Other important species in the vegetation are *R. apiculata* and *Avicennia officinalis*.

Konkan Railway Bridge to Amone village

Mangrove vegetation is present in small patches in the area upstream of Konkan railway bridge (R7,R9, R10 and R11). In this area, *Rhizophora mucronata* is observed at all places along with other species such as *Kandelia rheedii* and *Rhizophora apiculata* In the tree vegetation (Table 4.16), *Excoecaria agallocha,* *Kandelia rheedii, Rhizophora mucronata, R. apiculata* and *Sonnuatia alba* were found to be dominant / subdominant species. The diversity index was found to be maximum in this area. It is a mesohaline zone and supports a large number of mangrove species.

Amone Village to Usgaon Pali Bridge

The mangrove vegetation becomes very sparse in this area (R6 and R6A), and is represented by a few trees at some places belonging to *Sonneratia caseolaris*,and *Bruguiera parviflora*. At Usgaon pali Bridge, mangrove is represented by a few trees of *S. caseolaris*. Mangrove vegetation is not recorded in the area upstream of Usgaon Pali bridge. The Importance Value Index indicates that *Sonneratio caseolaris* and *Cyperus sp.* were important in mangrove vegetation in this stretch of the estuary.

Distribution of Mangrove along Salinity Gradient

Mangrove derives its existence from a variety of plant families and genera. They are adapted to saline aquatic environment ranging from slightly brackish to highly saline as is found in sea water. Mangroves are characterised by their tolerance to various degrees of salinity by some or other mechanism. The mangrove plant species show distribution with respect to salinity levels. *Rhizophora mucronata* is found to have a wide tolerance range to the salinity. This is the mangrove species which was recorded almost from all the stations except for the upstream station i.e Usgaon Pali bridge.

In polyhaline areas of Mandovi river the dominant mangrove species recorded is *Rhizophora mucronata, Avicennia officinalis* and *Sonneratia alba*. In the mesohaline area, the mangrove species recorded are *Rhizophora mucronata, Rhizophora apiculata, Avicennia officinalis, Sonneratia alba*, and *Acanthus ilicifolius*. While in oligohaline area, the characteristic mangrove species are *Sonneratia caseolaris, Bruguiera parviflora* and *Cyperus sp.*

The diversity of mangrove species as evident from the total number of species recorded is more in mesohaline zone. The Importance values show that *E. agallocha, Kandelia rheedii, Rhizophora, Sonneratia* and *Bruguiera, Acanthus* play an important role in the estuarine mangrove vegetation of Mandovi estuary. As per the survey of forest department Panaji, distribution of mangroves along the Mandovi is given in **Fig. 4.25**. Mangrove vegetation in relation to salinity along the river Mandovi is given in **Fig. 4.26**. In the survey of Mandovi river, 10 species of mangrove vegetation have been identified in different salinity regimes. The species/groups of mangroves occurring in different salinity regimes (haline zone) are depicted in **Fig. 4.27**. In the

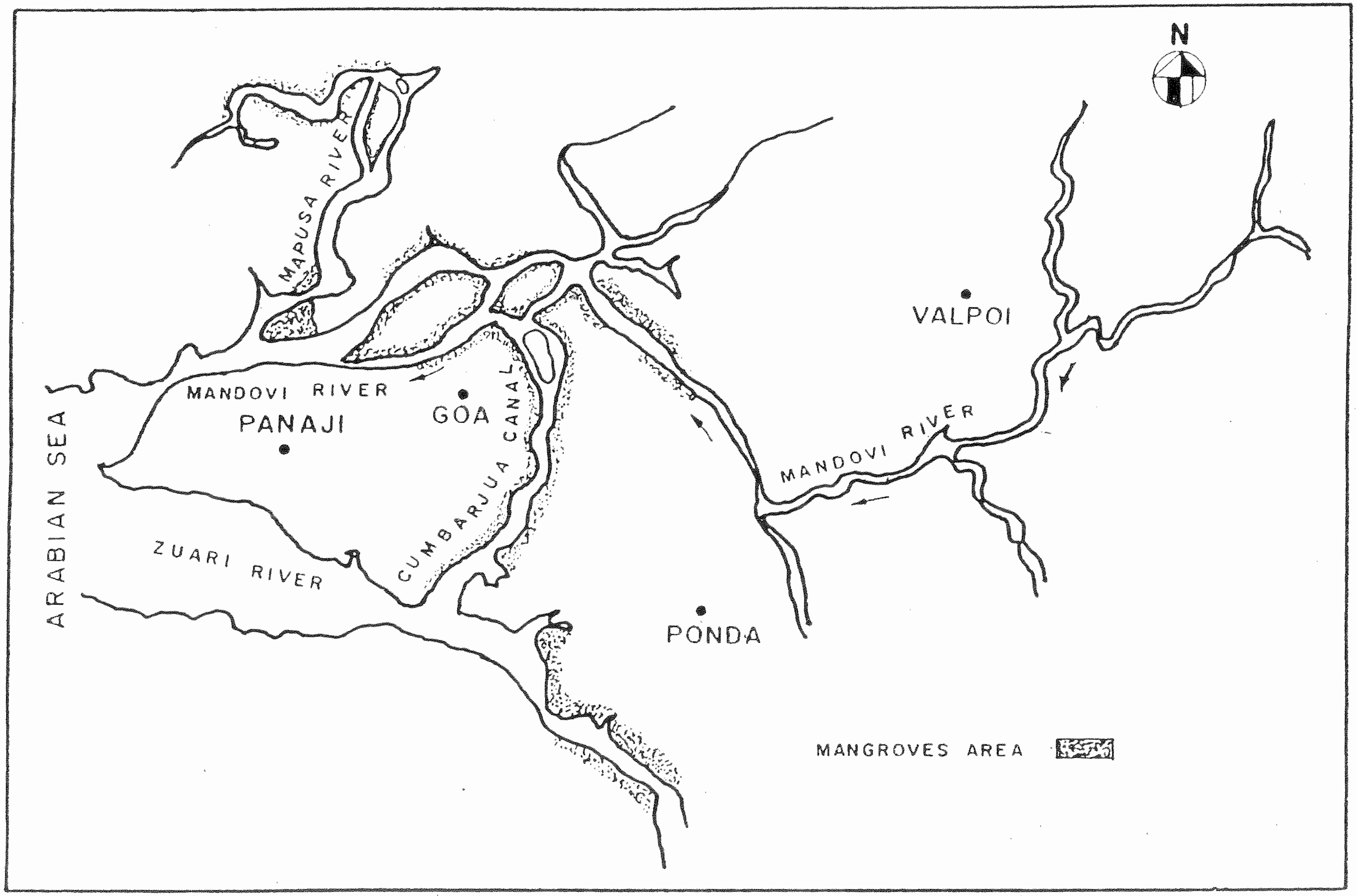


Fig. 4.25 : Distribution of Mangroves along the River Mahadayi (Mandovi) in Goa

Sl. No.	Mangrove Species	Salinity (ppt) Range			
		Limnetic (0-0.5)	Oligohaline (0.5-5.0)	Mesohaline (5.0-18.0)	Polyhaline (18-30)
1.	*Sonneratia caseolaris*				
2.	*Cyperus sp.*				
3.	*Bruguiera parviflora*				
4.	*Exocaecaria agallocha*				
5.	*Kandelia reheedii*				
6.	*Sonneratia alba*				
7.	*Rhizophora apiculata*				
8.	*Rhizophora mucronata*				
9.	*Avicennia officinalis*				
10.	*Acanthus ilicifolius*				

Fig. 4.26 : Mangrove Vegetation in Relation to Salinity along the Mandovi Estuary/River

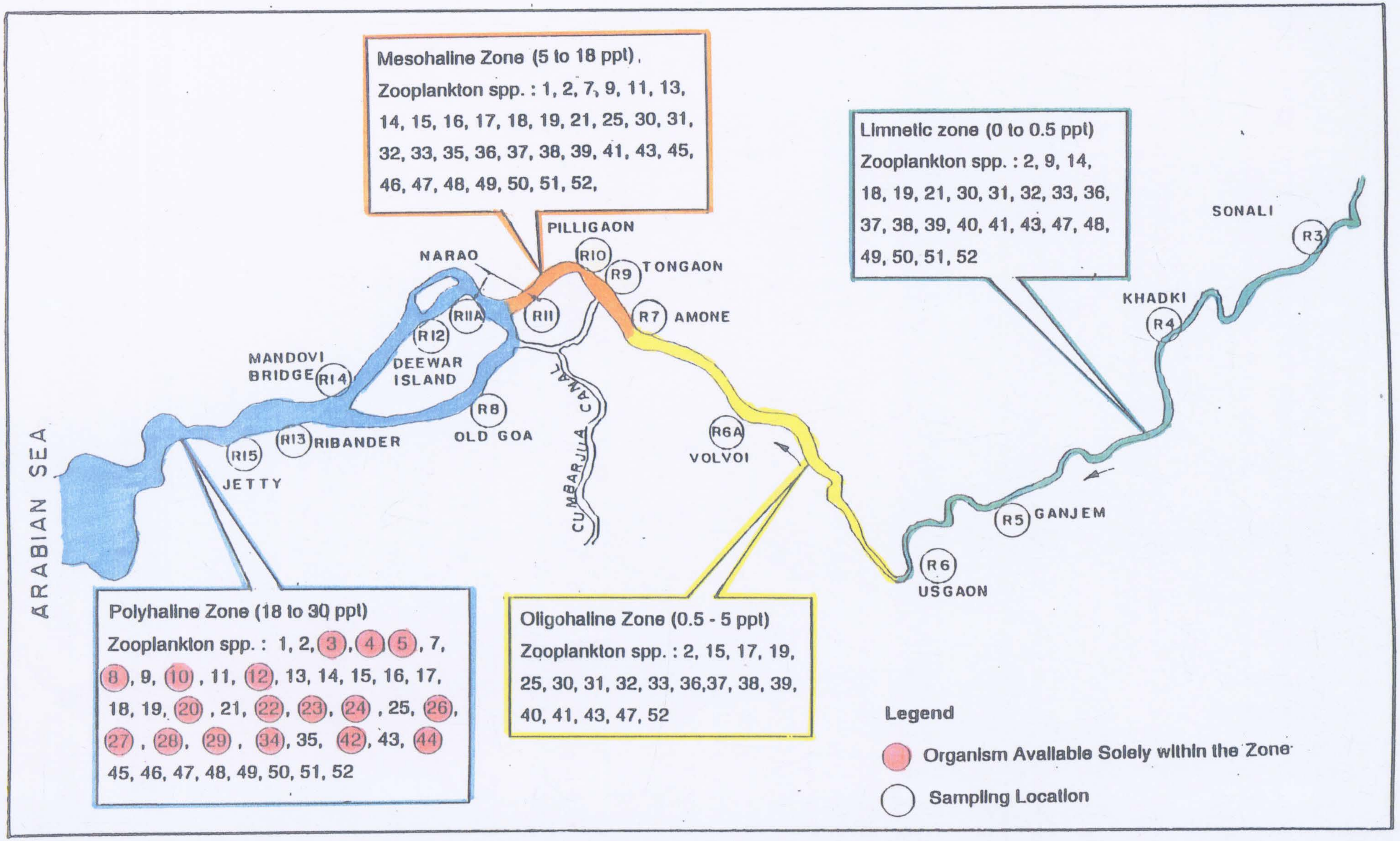


Fig. 4.28 : Occurrence of Zooplankton in Different Salinity Zones of Mandovi River during Winter Season (Key Numbers of Zooplankton Referred in Table 4.24)

polyhaline zone, 5 species were recorded (*Excoecaria sp., Sonneratia sp., Rhizophora sp., Avicennia sp., Acanthus sp.*). In mesohaline zone, 6 species were observed (*Sonneratia sp., Cyperus sp., Bruguiera sp., Excoecaria sp., Kandelia sp., Rhizophora sp.*). Only one species viz., *Sonneratia sp.* was observed in oligohaline zone.

The floristic composition of the vegetation around the Mandovi river in the state of Goa is presented in **Annexure 4.6, Table 3**.

4.7.3 Wildlife

Field observations of the birds at dam site, along the river and sea shore region were carried out with the help of 8x30 'Super Zenith' binocular in October, 1995. The counts of the birds were made by traversing the areas, and the species list was prepared by noting taxonomic position of each species encountered, relative abundance and absolute number in each specific area. The data was subjected to detailed analysis and the following indices were derived.

a) **Dominance index (D):** $D = (ni/N) \times 100$

where, ni = counts of individual species recorded
N = total counts of all species

b) **Census index (C):** $C = ni/M$

where, ni = counts of individual species recorded
M = area in sq. km covered at each site

Among the 14 locations studied for avifauna, a total of 42 birds as listed in **Table 4.17** were observed during the survey. Among the birds, black drongo, house crow, house sparrow, house swift, jungle crow, small green bee-eater were very common.

c) **Species richness index**

This is expressed as the total number of species recorded at each sampling site. While 12 and 4 species were recorded at Chorao island and Kotni dam site respectively, the remaining locations were represented by the species of birds ranging between these values.

Table 4.17
Occurrence of Common Birds at various places in the Mahadayi Basin

Common Name	Scientific Name	Kotni Dam Site		Jamboti Village		Chapoli Village		Kongla Village		Khanapur		Kanakumbi		Parwad		Sonali		Usgaon Pali		Khedki Bridge		Mandovi Bridge		Chorao Island		Diwar Island		Narao	
.		PD	CI	PD	CI	PD	CI	PD	CI	PD	CI	PD	CI	PD	CI	PD	CI	PD	CI	PD	CI	PD	CI	PD	CI	PD	CI	PD	CI
Blackbird	Turdus merula	-	-	-	-	-	-	6.2	5	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Black drongo	Dicrurus adsimilis	50	4	-	-	-	-	-	-	-	-	4	2.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10	5
Blue rock pigeon	Columba livia	-	-	-	-	-	-	6.2	5	-	-	-	-	-	-	-	-	-	-	4.4	5	-	-	-	-	-	-	-	-
Brahminy kite	Halliastur indus indus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	21.3	25	1.4	2	3.8	2.5	-	-
Brahminy myna	Sturnus pagodarum	-	-	-	-	30.7	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Brown shrike	Lanius cristatus	12.5	1	-	-	-	-	-	-	-	-	-	-	-	-	10	2.5	-	-	-	-	-	-	-	-	-	-	-	-
Brown headed gull	Larus brunicephalus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.3	5	5.7	8	-	-	-	-
Common iora	Aegithina tiphia	-	-	10	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Common myna	Acridotheres tristis	-	-	-	-	-	-	-	-	-	-	4	9	-	-	30	7.5	-	-	-	-	-	-	-	-	-	-	-	-
Common sandpiper	Tringa hypoleucos	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.5	5	11.5	7.5	10	5
Coucal	Centropus sinensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10	2.5	1.4	2.5	2.2	2.5	-	-	-	-	-	-	-	-
Dabchik	Podiceps ruficollis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8.5	12	-	-	-	-
House crow	Corvus splendens	-	-	40	4	7.7	5	12.5	10	15.4	10	28	17.5	22	20	20	5	-	-	4.4	5	17	20	13.5	19	30.7	20	25	12.5
House sparrow	Passer domesticus	-	-	-	-	3.8	2.5	12.5	10	7.7	5	20	12.5	11.1	10	10	2.5	-	-	-	-	-	-	-	-	-	-	-	-

Table 4.17 (Contd...)

House swift	Apus affinis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13.7	25	66.7	75	2.1	2.5	12	17	46.1	30	-	-
Indian robin	Saxicoloides fulicata	-	-	10	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Indian cliff swallow	Hirundo fluvicola	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.4	5	-	-	-	-	-	-	-	-
Jungle crow	Corvus macrorhynchos	25	2	10	1	-	-	50	40	38.4	25	8	5	16.6	15	-	-	1.37	2.5	4.4	5	2.1	2.5	-	-	-	-	-	-
Large egret	Ardea alba	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.1	2.5	17.1	24	-	-	5	2.5
Large green barbet	Megalaima zeylanica	-	-	-	-	-	-	-	-	-	-	-	-	5.5	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lesser coucal	Centropus toulou	-	-	-	-	-	-	-	-	-	-	4	2.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Little brown dove	Streptopelia senegalensis	-	-	-	-	-	-	-	-	3.8	2.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Little egret	Egretta garzetta	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	68.5	125	2.2	2.5	-	-	7.1	10	-	-	25	12.5
Little ringed plover	Charadrius dubius	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	2.5
Little stint	Calidris minuta	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.6	15	-	-	5	2.5
Pariah kite	Milvus migrans govinda	-	-	-	-	-	-	-	-	7.7	5	-	-	-	-	-	-	13.7	25	-	-	23.4	26.5	3.5	5	3.8	2.5	-	-
Pheasant-tailed jacana	Hydrophasianus chirurgus	-	-	10	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pied kingfisher	Ceryle rudis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.1	2.5	-	-	-	-	-	-
Pond heron	Ardeola grayii		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.1	2.5	1.4	2	-	-	-	-

Table 4.17 (Contd...)

Purple sunbird	Nectarinia asiatica	-	-	10	1	3.8	2.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Red spurfowl	Galloperdix spadicea	-	-	-	-	-	-	-	-	-	-	4	2.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Redvented bulbul	Pycnonotus cafer	-	-	-	-	-	-	-	-	19.2	12.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Redwattled lapwing	Vanellus indicus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	20	5	-	-	-	-	-	-	-	-	-	-	-	-
Reef heron	Egretta gularis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	21.2	25	15.6	22	3.8	2.5	10	5
Roseringed parakeet	Psittacula krameri	-	-	-	-	46.1	30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rufousbacked shrike	Lanius schach	-	-	10	1	3.8	2.5	-	-	-	-	-	-	-	-	-	-	-	-	4.4	5	-	-	-	-	-	-	-	-
Small blue kingfisher	Alcedo atthis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.2	2.5	-	-	-	-	-	-	-	-
Small green bee-eater	Merops orientalis	-	-	-	-	-	-	-	-	-	-	28	17.5	38.9	35	-	-	-	-	2.2	2.5	-	-	-	-	-	-	5	2.5
Tailor bird	Orthotomus sutorius	-	-	-	-	-	-	-	-	3.8	2.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
White wagtail	Motacilla alba	12.5	1	-	-	-	-	12.5	10	-	-	-	-	-	-	-	-	1.3	2.5	-	-	-	-	-	-	-	-	-	-
White breasted kingfisher	Halcyon smyrnensis	-	-	-	-	-	-	-	-	3.8	2.5	-	-	5.5	5	-	-	-	-	2.2	2.5	2.1	2.5	-	-	-	-	-	-
Whitebreasted laughing thrush	Garrulax jerdoni	-	-	-	-	3.8	2.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

PD : Percent Dominance; CI : Census Index

d) **Species diversity index(d) (Margalef 1951):** $d = (S-1)/\ln N$

where, S = total number of species recorded
N = total count of all species

The Mandovi river at Naroa having maximum varieties of birds, exhibited highest diversity index (2.67). Usgaon - Pali with 1.16 index value was poor in diversity **(Table 4.18)**. During the present survey, 42 species of birds were recorded, of which sandpipers and little stint are partially waders feeding often on crustaceans, molluscs etc. None of the recorded birds is endangered as per Schedule 1 of Wildlife Protection Act.

In addition to avifauna, other species observed in Karnataka were the giant millipede, pill millipede, land leech, Indian cobra & common green whip snake. Out of these species, land leech has the nuisance problem near Pansheer nala and at Kotni dam site. At the time of the survey, large number of leeches had assembled on the way at both the places. The snakes, Indian cobra and common green whip snake were observed near Jamboti village and Kotni dam site respectively.

Investigation from state forest departments reveal that 11, 102, 4 and 3 species of mammals, birds, reptiles, amphibians respectively are recorded within the forest division around the proposed dam site **(Annexure 4.6, Table 4)**.

The list of reptiles and birds available in the state of Goa is presented in **Annexure 4.6, Tables 5 and 6** respectively. As Goa has a rich heritage of wild life, extensive measures have been taken to protect the wildlife and its environment. For this purpose four game sanctuaries including a bird sanctuary at Chorao island have been set up in the state. The bird sanctuary, named after Dr.Salim Ali, is located along Mandovi river at Chorao island. Wide varieties of local as well as migratory birds frequently visit this area. The list of resident and migratory birds recorded in bird sanctuary and a comparative statement of the census of select mammals carried out in the sanctuaries of Goa are presented in **Annexure 4.6, Tables 7 and 8** respectively. The data reveals that the population of wild mammals has increased drastically (149 to 1033 per cent) in 1993 as compared to that in 1984.

4.7.4 Aquatic Environment

The baseline status of the aquatic environment with reference to flora and fauna in the Mahadayi/ Mandovi river has been critically studied in freshwater, oligohaline, mesohaline and polyhaline zones of the river. The monthly data for i) Nekton, ii) Phytoplankton, iii) Meiobenthos, iv) Macrobenthos at the 13 sampling

Table 4.18

Diversity and Dominance of Common Birds in the study area

Sl. No.	Location	Most Dominant Species	Diversity Index	Dominance Index	Species Richness	Total Density/ km^2
1.	Kotni dam site	Black drongo	1.44	50.00	4	8
2.	Jamboti village	House crow	2.60	40.00	7	10
3.	Chapoli village	Roseringed parakeet	1.84	46.15	7	65
4.	Kongla village	Jungle crow	1.80	50.00	6	80
5.	Khanapur	Jungle crow	2.15	38.46	8	65
6.	Kanakumbhi	House crow and small green bee-eater	2.17	28.00 each	8	80
7.	Parwad	Small green bee-eater	1.73	38.89	6	100
8.	Sonali	Common myna	2.17	30.00	6	25
9.	Usgaon-Pale	Little egret	1.16	68.49	6	183
10.	Khadki bridge	House swift	2.63	66.70	11	108
11.	Mandovi bridge	Pariah kite	2.60	23.40	11	118
12.	Chorao Island	Large egret	2.22	17.02	12	141
13.	Diwar Island	House swift	1.53	46.15	6	65
14.	Narao	House crow and Little egret	2.67	25.00 each	9	50

locations from village Sonali upto the mouth of river near Panaji city was collected from November 1995 to October 1996 and is presented as supplementary information in Volume II. The average values for the winter, summer and monsoon seasons are at **Annexure 4.6 (Table 10 to 14)**.

A widely accepted ecological concept is that communities with large number of species i.e. with high diversity will have high stability and thus, have the capability to resist adverse environmental influences to certain extent. Usually diversity increases with decrease in pollution and vice versa. Shannon Weaver diversity index (d) is a measure of diversity which takes into account the total count and the individual count in a water sample is expressed as

d = - ¯ (ni/N) $\log_2$ (ni/N)

where,

ni = number of individuals of each species in the sample

N = total number of individuals of all species in the sample

The values of 'd' in the range of 3 and above are generally considered healthy conditions of water. The values between 1 and 3, and less than 1 are believed to indicate semi or poor productivity respectively.

Palmer's Pollution Index is based on the pollution tolerant species of fresh water and not for saline water. Therefore, this index was applied to phytoplankton flora of Karnataka state only and not for the flora in Goa state.

4.7.4.1 Phytoplankton Flora

Water samples from Mahadayi river, its tributaries and dugwells / handpumps in the catchment area in Karnataka and Goa were collected for all the three seasons. The samples were preserved by adding Lugol's iodine (1% concentration) for enumeration of phytoplankton flora.

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The lists of algal species and the community structures of phytoplankton in surface and ground water samples with corresponding Palmer's Pollution Index and Shannon Weaver Index for the three seasons are presented in **Table 4.19** and **Annexure 4.6, Table 9**.

Table 4.19

Seasonwise Community Structure of Phytoplankton in Mahadayi Basin (Karnataka)

Season	Sampling Location	No. of Species Recorded	Total Algal Count (No./ml)	Percentage Composition of Different Algae				Shannon Weaver Index	Palmer's Pollution Index
				Cyano-phyceae	Chloro-phyceae	Bacillario-phyceae	Dino-phyceae		
Monsoon 95	R1	3	157	-	-	100	-	1.59	0
Summer 96	,,	5	1657	-	24	6115	2.292	6	
Post-monsoon 96	,,	4	340	59	24	17	-	1.625	4
Monsoon 95	R2	2	315	-	-	100	-	0.65	3
Summer 96	,,	10	1628	-	11	89	-	2.436	6
Post-monsoon 96	,,	4	260	38	54	8	-	1.572	4
Monsoon 95	T1	5	450	-	-	100	-	1.68	3
Summer 96	,,	2	318	-	50	50	-	1	3
Post-monsoon 96	,,	NR							
Monsoon 95	T2	4	340	-	-	100	-	1.7	5
Summer 96	,,	NR							
Post-monsoon 96	,,	5	202	66	8	26	-	1.588	2
Monsoon 95	T3	2	874	-	-	100	-	1.0	3
Summer 96	,,	3	67310	-	21	2	77	0.861	3
Post-monsoon 96	,,	6	435	50	38	8	4	2.956	4
Monsoon 95	T4	6	4260	-	-	100	-	2.31	8
Summer 96	,,	3	4770	-	-	84	16	1.458	3
Post-monsoon 96	,,	7	512	42	31	27	-	2.301	5
Monsoon 95	T5	7	1887	-	17	83	-	2.52	10
Summer 96	,,	NR							
Post-monsoon 96	,,	7	219	31	46	23	-	2.483	7
Monsoon 95	T6	2	475	-	-	100	-	1.76	8
Summer 96	,,	NR							
Post-monsoon 96	,,	NR							
Monsoon 95	T7	NR							
Summer 96	,,	Nil	-	-	-	-	-	-	-
Post-monsoon 96	,,	NR							
Monsoon 95	G1	Nil	-	-	-	-	-	-	-
Summer 96	,,	3	453	20	60	20	-	NA	NA
Post-monsoon 96	,,	3	133	50	25	25	-	NA	NA
Monsoon 95	G2	Nil	-	-	-	-	-	-	-
Summer 96	,,	Nil	-	-	-	-	-	NA	NA
Post-monsoon 96	,,	NR							

NR - Not Recorded

Mahadayi River : During monsoon season, the algal count in the Mahadayi river water was in the range of 157 to 315 algae/mL. The water samples were dominated by diatoms with low species diversity of 2 to 3. Based on this, the river water quality is classified as clean with less dissolved nutrients at sub-optimum levels.

During summer season, algal counts were higher, 1628 and 1657 algae/mL at Kotni dam (R2) and near Kongla village (R1) respectively. Species diversity was high at Kotni dam (R2) and the sample was dominated by diatoms. This indicates nutrient enrichment of river water resulting in the higher values of diversity index (Shannon Weaver Index 2.3 to 2.4) and total algal count.

During the post monsoon season, the phytoplankton count was found to be in the range of 260 to 350 algae/ml with the dominance of cyanophyceae and chlorophyceae species and low species diversity. This indicates low pollution alongwith sub-optimum level of nutrient enrichment in the river water.

Tributaries of Mahadayi River : The tributaries of Mahadayi river showed slightly higher level of enrichment as phytoplankton count was found to be higher than that obtained in Mahadayi river. In monsoon season, the phytoplankton count ranged from 340 to 4260 algae/mL. Among the tributaries, the Surla Nala (T4) was found to be more enriched as evident from the higher algal count and the higher value of Shannon Weaver Index.

In summer season, the phytoplankton count in the tributaries ranged from 318 to 67310 algae/mL. The phytoplankton count in Pansheer Nala (T1) was low i.e. 318 algae/mL with low algal diversity (e.g Shannon Weaver Index of 1) which may be due to the limiting nutrients in water and turbulent flow in the hilly stretch. Kalsa Nala (T3) showed high phytoplankton count i.e. 67310 algae/mL. The dominance of dinophyceae in the water sample was the effect of enrichment of certain nutrients due to degradation of forest litter in the nala. This was indicated by the low value (0.9) of Shannon Weaver Index. In summer season, the flow in Surla Nala (T4) was less with stagnant pools at some places. The phytoplankton count thus moderately increased upto 4770 algae/mL. However, the water is clean as indicated by the dominance of diatoms, low value of Palmer's Pollution Index (3) and moderate value of Shannon Weaver Index(1.5).

During post monsoon season, phytoplankton count in the water samples from tributaries was found to be in the range of 202 to 512 algae/ml with the dominance of chlorophyceae. The water samples showed sub-optimum / optimum availability of nutrient which is evident from the dominance of chlorophyceae, the increased diversity of phytoplankton flora i.e. 5 to 7 species per sample, and the higher Shannon Weaver Index values of 1.572 to 2.956.

Low values of Palmer's Pollution Index recorded in water bodies in the catchment area indicate the absence of organic pollution. Shannon Weaver Index values were relatively low which was mainly due to the low diversity of flora indicative of sub-optimum levels of nutrients in water.

The surface water bodies in Karnataka region of the study area are clean, unpolluted with sub-optimum level of nutrients in them. This is attributed, on one hand, to the short length of these water courses from the point of their origin, and on the other, to the fact that the water courses flow through the mountains away from human habitations. The only source of nutrients to these water bodies is leaching from the forest litter.

Ground Water : The phytoplankton count in ground water ranged from 0 to 453 algae/mL. The presence of algae in handpump water (G1) indicates contamination due to seepage of surface water into ground water. This handpump is situated near a small drain which may be responsible for the contamination of the ground water.

The absence of low phytoplankton count in ground water indicates that the ground water quality is, in general, good and uncontaminated except in Chapoli village where slight contamination of ground water was observed.

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The data on phytoplankton for the 3 seasons is presented in **Table 4.20 and Annexure 4.6, Table 10**. The total phytoplankton count was found to be increasing from upstream station (R3) of Mandovi river to the estuarine area (R15). This increase is an indication of more enriched water in the estuarine area. In upstream area, the phytoplankton count was low due to less nutrient enrichment and the turbulent flow of the river through hilly area strewn with boulders.

On the basis of phytoplankton count and the type of algal species, three zones could be identified in the Mandovi river. The first upstream zone (stations R3 to R5) with an average algal count ranging from 218 to 395 algae/100 mL; the second zone (stations R6 to R10) with an average phytoplankton count ranging from 541 to 659 (-1310) algae/100 mL; and the third zone (stations R11 to R15) with an average phytoplankton count ranging from 606 to 1680 algae/100 mL. These zones showed changes in biological quality of phytoplankton corresponding to upstream freshwater

Table 4.20

Seasonwise Community Structure of Phytoplankton Recorded in Mandovi River/Estuary (Goa)

Season	Sampling Location	No. of Species Recorded	Total Algal Count (No./100 ml)	Percentage Composition of Different Algae				Shannon-Weaver Index
				Cyanophyceae	Chlorophyceae	Bacillariophyceae	Dinophyceae	
Winter 95	R3	25	943	-	13.5	85.4	1.1	3.3454
Summer 96	,,	4	191	-	44	55.5	0.5	1.1538
Monsoon 96	,,	2	51	-	21.6	78.4	-	0.7522
Mean	,,	**10**	**395**	-	**26.4**	**73.1**	**0.5**	1.7505
Winter 95	R4	26	553	-	14.6	83.4	2.0	3.9392
Summer 96	,,	4	72	-	25.0	73.6	1.4	1.1421
Monsoon 96	,,	5	24	-	33.3	66.7	-	1.4969
Mean	,,	**12**	**218**	-	**24.3**	**74.6**	**1.1**	**2.1927**
Winter 95	R5	22	655	-	28.4	69.5	2.1	3.1749
Summer 96	,,	8	284	-	44.7	54.9	0.4	1.4195
Monsoon 96	,,	11	60	-	35.0	63.3	1.7	1.9240
Mean	,,	**14**	**333**	-	**36.0**	**62.6**	**1.4**	2.1728
Winter 95	R6	28	1174	5.5	1.1	91.6	1.8	3.8838
Summer 96	,,	11	353	24.4	0.8	74.5	0.3	1.8811
Monsoon 96	,,	11	97	-	39.2	59.8	1.0	1.9106
Mean	,,	**20**	**541**	**9.9**	**13.7**	**75.3**	**1.1**	**2.5585**
Winter 95	R6A	22	2539	9.6	-	86.3	4.1	3.5697
Summer 96	,,	NR	-	-	-	-	-	-
Monsoon 96	,,	5	81	-	33.3	66.7	-	1.5887
Mean	,,	**13**	**1310**	**4.8**	**16.6**	**76.5**	**2.1**	1.7195
Winter 95	R7	33	1217	0.2	1.6	96.1	2.1	3.7581
Summer 96	,,	14	330	0.9	0.9	97.9	0.3	1.5606
Monsoon 96	,,	15	105	-	29.5	68.6	1.9	2.1805
Mean	,,	**21**	**551**	**0.3**	**11.0**	**87.5**	**1.1**	**2.5064**
Winter 95	R8	35	1243	0.8	2.6	89.0	7.6	4.1851
Summer 96	,,	17	346	3.8	3.1	92.8	0.3	2.6734
Monsoon 96	,,	18	128	-	21.9	71.1	-	2.5383
Mean	,,	**23**	**569**	**1.5**	**9.2**	**86.7**	**2.6**	3.1323
Winter 95	R9	17	1185	-	20	79.3	0.7	3.1326
Summer 96	,,	18	592	-	13.2	86.0	0.8	2.5898
Monsoon 96	,,	19	140	-	13.6	83.6	2.8	2.3857
Mean	,,	**18**	**659**	-	**15.6**	**82.9**	**1.5**	2.7027

Table 4.20 (Contd...)

Season	Sampling Location	No. of Species Recorded	Total Algal Count (No./100 ml)	Percentage Composition of Different Algae				Shannon-Weaver Index
				Cyano-phyceae	Chloro-phyceae	Bacillario-phyceae	Dino-phyceae	
Winter 95	R10	17	1041	-	-	98.0	2.0	3.0378
Summer 96	,,	17	634	-	5.9	93.5	0.6	2.8280
Monsoon 96	,,	22	225	-	29.8	68.4	1.8	2.5107
Mean	,,	**19**	**633**	**-**	**11.9**	**86.6**	**1.5**	**2.7921**
Winter 95	R11	36	1821	3.2	0.9	87.4	8.5	4.0763
Summer 96	,,	25	700	-	0.6	98.8	0.6	3.1942
Monsoon 96	,,	22	160	-	15.6	83.1	1.3	2.8821
Mean	,,	**28**	**894**	**1.1**	**5.7**	**89.7**	**3.5**	**3.3908**
Winter 95	R12	32	1069	1.2	9.4	85.6	3.8	3.3844
Summer 96	,,	29	598	-	10.0	88.0	1.0	3.1775
Monsoon 96	,,	40	158	-	12.7	80.4	6.9	3.9765
Mean	,,	**34**	**606**	**0.4**	**10.7**	**80.5**	**3.4**	**3.5128**
Winter 95	R13	40	1849	1.9	-	88.6	9.5	4.3716
Summer 96	,,	46	937	8.5	0.5	80.2	10.8	4.5762
Monsoon 96	,,	46	228	-	3.5	89.9	6.6	4.4458
Mean	,,	**44**	**1005**	**3.5**	**1.0**	**86.2**	**8.3**	**4.4645**
Winter 95	R14	44	1102	-	0.3	94.6	5.1	3.8624
Summer 96	,,	46	808	2.0	-	91.6	6.4	4.6713
Monsoon 96	,,	48	416	0.2	0.7	89.9	9.2	4.4617
Mean	,,	**46**	**775**	**0.7**	**0.3**	**92.1**	**6.9**	**4.3317**
Winter 95	R15	48	2882	2.3	0.6	91.1	6.0	4.4600
Summer 96	,,	47	1480	4.8	-	88.0	7.2	4.7520
Monsoon 96	,,	48	678	0.1	-	92.8	7.1	4.5704
Mean	,,	**48**	**1680**	**2.4**	**0.2**	**90.7**	**6.7**	**4.5941**

NR - Not Recorded

zone, middle estuarine zone with intermediate salinity and terminal estuarine zone with higher salinity.

The Mandovi is marked, in general, with the following biological characteristics in the upstream stretch from village Sonali upto Ganjem.

- Less number of fresh water algal species ranging from 2 to 26 and low value of Shannon Weaver Index in summer and winter seasons (0.8-1.9) which is due to the sub-optimum level of nutrients in water, and higher index values (3.1 - 3.9) in winter season indicating clean water quality

- Low total phytoplankton count (24 to 943 algae/100 mL)

- Absence of blue-green algae; occurrence of diatoms and green algae as dominant and subdominant algal groups respectively; presence of dinophyceae and; algal species which are indicators of clean water quality.

The biological characteristics as above indicate that this zone of Mandovi river is an unpolluted freshwater zone. The algal diversity is low either due to the high turbulence of river or due to suboptimum levels of nutrients in the river water.

The intermediate zone from village Ganjem upto Palligaon shows, in general, the following biological characteristics.

- The total algal count has increased as compared to that in the upstream stretch.

- The number of algal species recorded and the Shannon-Weaver Index values have increased. This shows higher availability of nutrients for the algal growth.

- There was an increase in the count of blue-green algae, diatoms and dinophyceae. The algal species belonging to these groups are mostly tolerant to intermediate salinity of water.

The above observations indicate that the Mandovi is fairly enriched with nutrients in the intermediate estuarine zone and that the conditions are favourable for algal growth. Indicator algal species such as blue-green algae shows presence of slight organic matter. The algal species recorded in this zone are tolerant to intermediate salinity in the mixing zone of freshwater and marine water.

The polyhaline zone of the Mandovi shows, in general, the following biological characteristics.

- The number of algal species recorded in each sample considerably increased i.e. 22 to 48 and the Sahnnon-Weaver Index increased from 2.9 to 4.7.

- The algal count increased in this zone.

- The green algal species, which are mostly freshwater forms, were found to have decreased and the diatoms and dinophyceae members which are mostly brackish water forms were found to have increased.

The above biological characteristics show that the polyhaline estuarine zone of the Mandovi is enriched with increased marine algal forms and increased saline algal forms.

The freshwater algal forms recorded in the upstream river zone were *Ulothrix* and *Cosmarium*. Many genera have different species in freshwater and saline water. So, their continuous occurrence was recorded. Most of the diatoms and dinophyceae belong to this group. Some species have broader tolerance range for salinity. These occur in freshwater as well as in water of intermediate salinity. These algae are *Trichodesmium, Pediastrum, Spirogyra,* and *Zygnema*. The brackish water forms in polyhaline estuarine zone are *Bidulphia sinensis*, *Guinardia* sp. *Ditylum* sp. *Lithodesmium* sp., *Grannatophora* sp., *Eucampia* sp.,*Climacodium* sp. *Streptopheca* sp., *Thalassiosira* sp. *T. gravida*, *Thalassionema* sp., *Fragillaria oceanica*, *T. longissima*, *Asterionella japonica*, *Navicula* sp. (Diatoms) and *Prorocentirum* sp. *Peridinium* sp., *Ceratium* sp., *Pyrocystis fusiformis*, *Noctiluca miliaris*.

Phytoplankton population in Mandovi river showed considerable seasonal variation in quality and quantity of the flora. The density of phytoplankton, at all the sampling stations, was found to be maximum in winter season, followed by summer and monsoon seasons in the decreasing order. The effect of climatic conditions on the phytoplankton growth can be ascertained by studying the seasonal changes in the ratio of algal growth (winter/summer). The density of phytoplankton in winter season was found to increase by 4-8 times that in summer season in the upstream portion of Mandovi river from station R3 to R8. This fluctuation was found to be around 2 times at the downstream stations up to R9.

The influence of dilution differential in the river water during monsoon season on the phytoplankton density at different stretches of the Mandovi can be ascertained by comparing the ratio of winter phytoplankton density to monsoon phytoplankton density in the respective stretches of the river. In monsoon season, the phytoplankton growth when compared to that in winter season, was found to decrease by 18.2 - 23.04 times at stations R3 and R4, 9.7 - 12.1 (- 31.3) times at stations R5 to R8 and 2.6 - 8.5 (- 11.4) times at stations R9 to R15. Thus, the phytoplankton growth is highly variable in the upstream stretches (R3 and R4), less variable in the middle estuarine zone (R5 to R8) and least variable in estuarine zone (R9 to R15). Accordingly, the river stretch can be classified into 3 zones. The upstream zone is the river stretch where the phytoplankton growth is most vulnerable to the effects of dilution, the intermediate zone from Ganjem to Tongaon village showing medium level of fluctuations in the phytoplankton growth (10-12 fold) and the downstream zone from old Goa upto the mouth of the river least affected (2-9 fold) due to the fluctuations in dilution indicating tides have stabilizing effect on the biological quality of water in the second and third downstream zones of the river.

4.7.4.2 Zooplankton

This is an important group in the aquatic ecosystem, acting as the primary consumer and ultimately serving as a natural food source for many aquatic organisms including fishes. Zooplankton samples were collected separately by hauling a plankton net through water and filtering about 100 litres of freshwater through bolting silk plankton net # 20 mesh. The samples were collected both from the Mahadayi basin in Karnataka and Mandovi river/estuary in Goa during different seasons.

Zooplankton samples were collected from nine surface and ground waters of Mahadayi basin in Karnataka during monsoon'95, summer'96 and post monsoon'96. Seven groups were recorded, out of which protozoa, rotifera, cladocera, copepoda and diptera were dominating at different sampling points (**Table 4.21**). The diversity index varied from 0.81 to 2.08 in this region.

In Mandovi river/estuary in Goa, the samples were collected during winter'95, summer'96 and monsoon'96. Altogether 15 groups of zooplankton were recorded, of which copepoda was dominating in the majority of the samples. Amongst the three seasons, diversity index values varied from 0.46 to 4.42 (**Table 4.22**) and **Annexure 4.6, Table 11**. The zooplankton biomass recorded at the respective sampling points during the study period in Mandovi river/estuary in Goa is shown in **Table 4.23**. Freshwater forms, viz. the copepods (*Heliodiaptomus* sp., *Mesocyclops* sp., *Microcyclops* sp., and *Diaptomus* sp.), cladocerans (*Moina* sp., *Daphnia* sp. and *Macrothrix* sp.) and rotifers (*Brachionus* sp., *Keratella* sp. and *Polyarthra* sp.) were found in the upper stretch of the Mandovi in Goa (Sampling stations R3 through R6A).

Table 4.21

Seasonwise Community Structure of Zooplankton Recorded in Mahadayi Basin (Karnataka)

Sr. No.	Season	Sampling Location	Total Zooplankton No./m^3	Percent Composition of Organisms in Group							Shannon Weaver Index
				Protozoa	Rotifera	Cladocera	Copepoda	Ephemeroptera	Odonata	Diptera	
Surface Waters											
1.	Monsoon 95	R1	150	63.00	-	-	-	-	37.00	-	0.91
	Summer 96		500	60.00	40.00	-	-	-	-	-	0.97
	Post-monsoon 96		400	-	100.00	-	-	-	-	-	1.00
2.	Monsoon 95	R2	200	-	50.00	-	50.00	-	-	-	1.50
	Summer 96		400	-	75.00	-	25.00	-	-	-	1.50
	Post-monsoon 96		600	50.00	32.00	18.00	-	-	-	-	1.00
3.	Monsoon 95	T1	400	-	-	-	-	25.00	-	75.00	0.81
	Summer 96		300	-	66.00	-	34.00	-	-	-	0.92
	Post-monsoon 96		NR								
4.	Monsoon 95	T2	NR								
	Summer 96		NR								
	Post-monsoon 96		400	-	75.00	-	25.00	-	-	-	0.81
5.	Monsoon 95	T3	300	34.00	-	-	66.00	-	-	-	0.92
	Summer 96		400	25.00	50.00	-	25.00	-	-	-	1.50
	Post-monsoon 96		500	-	60.00	40.00	-	-	-	-	1.52

Table 4.21 (Contd...)

Sr. No.	Season	Sampling Location	Total Zooplankton No./m^3	Percent Composition of Organisms in Group							Shannon Weaver Index
				Protozoa	Rotifera	Cladocera	Copepoda	Ephemeroptera	Odonata	Diptera	
6.	Monsoon 95	T4	500	40.00	-	-	-	-	-	60.00	1.37
	Summer 96		NR								
	Post-monsoon 96		500	40.00	-	60.00	-	-	-	-	0.98
7.	Monsoon 95	T5	400	50.00	-	-	-	25.00	-	25.00	1.50
	Summer 96		1300	23.00	-	30.00	38.00	-	-	9.00	2.08
	Post-monsoon 96		600	-	50.00	50.00	-	-	-	-	1.00
Ground Water											
8.	Monsoon 95	G1	Nil	-	-	-	-	-	-	-	-
	Summer 96		Nil	-	-	-	-	-	-	-	-
	Post-monsoon 96		Nil	-	-	-	-	-	-	-	-
9.	Monsoon 95	G2	200	-	25.00	50.00	25.00	-	-	-	-
	Summer 96		Nil	-	-	-	-	-	-	-	-
	Post-monsoon 96		NR								

NR - Not Recorded

Table 4.22

Seasonwise Community Structure of Zooplankton Recorded in Mandovi River/Estuary (Goa)

Season	Sampling Location	Total Zooplankton (No./m^3)	Percent Composition of Organisms in Group															Shannon Weaver Index
			Ciliata	Foraminifera	Siphonophora	Anthozoa	Ctenophora	Rotifera	Polychaeta	Cirripedia	Cladocera	Copepoda	Brachiopoda	Gastropoda	Bivalvia	Appendicularia	Pisces	
Winter 95	R3	193	2.60	-	-	-	-	6.67	-	-	7.35	32.93	-	3.49	14.17	1.04	31.75	2.88
Summer 96		95	0.40	-	-	-	-	12.20	-	-	12.50	34.08	-	5.70	0.60	-	34.52	2.87
Monsoon 96		76	-	-	-	-	-	20.87	-	-	17.82	34.91	-	0.31	-	-	26.09	3.21
Mean		**121**	**1.00**	-	-	-	-	**13.25**	-	-	**12.56**	**33.97**	-	**3.17**	**4.92**	**0.35**	**30.79**	**2.99**
Winter 95	R4	147	-	-	-	-	-	7.41	-	-	10.34	63.27	-	6.64	-	-	12.34	2.98
Summer 96		74	0.66	-	-	-	-	13.35	-	-	17.35	46.49	-	5.98	0.52	-	15.65	3.46
Monsoon 96		45	-	-	-	-	-	20.96	-	-	20.93	35.74	-	0.97	-	-	21.40	3.19
Mean		**89**	**0.22**	-	-	-	-	**13.91**	-	-	**16.21**	**48.50**	-	**4.53**	**0.17**	-	**16.46**	**3.21**
Winter 95	R5	264	-	-	-	-	-	2.18	-	3.57	8.20	52.62	-	-	-	-	33.43	2.50
Summer 96		63	-	-	-	-	-	10.27	-	-	20.20	52.57	-	-	-	-	16.96	3.24
Monsoon 96		32	-	-	-	-	-	20.45	-	-	12.60	33.20	-	-	1.38	-	32.37	2.94
Mean		**120**	-	-	-	-	-	**10.97**	-	**1.19**	**13.67**	**46.13**	-	-	**0.46**	-	**27.59**	**2.89**
Winter 95	R6	141	0.43	-	-	-	-	2.04	-	1.03	7.86	66.73	-	0.46	-	-	21.65	2.43
Summer 96		71	0.63	-	-	-	-	4.70	-	1.27	9.51	53.99	-	0.43	-	-	29.47	2.79
Monsoon 96		26	-	-	-	-	-	12.33	-	-	18.62	28.79	-	1.08	-	-	39.18	2.69
Mean		**79**	**0.35**	-	-	-	-	**6.36**	-	**0.77**	**11.93**	**49.84**	-	**0.66**	-	-	**30.10**	**2.64**

Table 4.22 (Contd...)

Season	Sampling Location	Total Zoo-plankton (No./m^3)	Percent Composition of Organisms in Group															Shannon Weaver Index
			Ciliata	Forami-nifera	Sipho-nophora	Anth-ozoa	Cteno-phora	Roti-fera	Poly-chaeta	Cirri-pedia	Clado-cera	Cope-poda	Brachio-poda	Gastro-poda	Biva-lvia	Appendi-cularia	Pisces	
Winter 95	R6A	102	0.81	-	-	-	-	2.53	-	0.37	6.15	58.42	-	1.10	-	-	30.62	2.71
Summer 96		73	0.53	-	-	-	-	5.16	6.40	-	2.12	34.77	-	13.58	0.97	-	36.47	2.39
Monsoon 96		21	-	-	-	-	-	5.96	-	-	8.03	23.84	-	3.97	0.77	-	57.43	1.88
Mean		**65**	**0.45**	-	-	-	-	**4.55**	**2.13**	**0.12**	**5.43**	**39.01**	-	**6.22**	**0.58**	-	**41.51**	**2.33**
Winter 95	R7	80	2.20	-	-	-	0.47	0.40	-	-	1.66	62.98	-	5.08	1.70	-	25.50	3.03
Summer 96		46	3.04	-	-	-	-	-	-	-	-	45.04	-	1.63	4.07	-	46.22	1.98
Monsoon 96		15	-	-	-	-	-	-	-	-	-	7.50	-	11.33	1.50	-	79.67	0.73
Mean		**47**	**1.75**	-	-	-	**0.16**	**0.13**	-	-	**0.55**	**38.51**	-	**6.01**	**2.42**	-	**50.46**	**1.91**
Winter 95	R8	142	-	0.29	-	0.10	-	-	-	-	0.76	42.73	0.38	19.55	1.56	-	34.63	2.19
Summer 96		55	-	-	-	-	-	-	-	-	-	44.83	-	8.69	-	-	46.48	1.66
Monsoon 96		9	1.67	-	-	-	-	-	-	-	-	7.33	-	1.67	-	-	89.33	0.46
Mean		**69**	**0.56**	**0.10**	-	**0.03**	-	-	-	-	**0.25**	**31.63**	**0.13**	**9.97**	**0.52**	-	**56.81**	**1.44**
Winter 95	R9	136	3.66	-	-	-	-	-	-	-	-	43.13	-	0.48	-	-	52.73	1.90
Summer 96		102	0.69	-	-	-	-	-	0.69	-	-	49.23	0.35	0.39	2.57	-	46.08	2.08
Monsoon 96		24	-	-	-	-	-	-	-	-	-	21.85	-	4.80	0.41	-	72.94	0.94
Mean		**87**	**1.45**	-	-	-	-	-	**0.23**	-	-	**38.07**	**0.12**	**1.89**	**0.99**	-	**57.25**	**1.64**
Winter 95	R10	662	7.71	-	-	-	-	-	0.54	-	-	62.88	0.54	4.76	0.22	-	23.35	2.97
Summer 96		369	5.82	-	-	-	-	-	0.12	0.08	-	67.84	0.16	1.40	0.23	-	24.33	2.46
Monsoon 96		36	3.83	-	-	-	-	-	-	-	-	24.22	-	3.80	1.54	-	66.61	1.27
Mean		**356**	**5.79**	-	-	-	-	-	**0.22**	**0.03**	-	**51.65**	**0.24**	**3.32**	**0.66**	-	**38.10**	**2.23**

Table 4.22 (Contd...)

Season	Sampling Location	Total Zoo-plankton (No./m^3)	Percent Composition of Organisms in Group															Shannon Weaver Index
			Ciliata	Foraminifera	Siphonophora	Anthozoa	Ctenophora	Rotifera	Polychaeta	Cirripedia	Cladocera	Copepoda	Brachiopoda	Gastropoda	Bivalvia	Appendicularia	Pisces	
Winter 95	R11	703	3.26	-	-	-	0.08	-	-	0.99	0.99	74.90	-	2.60	0.11	-	17.07	2.76
Summer 96		471	6.58	-	-	-	-	-	-	1.30	0.78	69.56	-	0.63	-	0.05	21.10	2.70
Monsoon 96		38	4.87	-	-	-	-	-	-	-	-	38.25	-	3.35	-	-	53.54	1.80
Mean		**404**	**4.90**	-	-	-	**0.03**	-	-	**0.76**	**0.59**	**60.90**	-	**2.19**	**0.04**	**0.02**	**30.57**	**2.42**
Winter 95	R12	517	5.79	0.07	0.09	-	0.22	-	-	0.49	1.01	80.17	-	7.34	-	-	4.82	2.98
Summer 96		351	4.99	-	0.35	-	-	-	-	-	-	79.49	-	4.81	0.28	-	10.08	2.95
Monsoon 96		55	5.40	-	-	-	-	-	-	1.21	-	53.09	-	4.83	5.60	-	29.87	2.68
Mean		**308**	**5.39**	**0.02**	**0.15**	-	**0.07**	-	-	**0.57**	**0.34**	**70.92**	-	**5.66**	**1.96**	-	**14.92**	**2.87**
Winter 95	R13	328	5.35	0.08	-	0.28	-	-	1.18	0.81	0.75	59.09	1.64	4.72	-	0.59	25.51	3.31
Summer 96		200	7.81	-	0.20	0.44	-	-	0.62	3.19	0.85	61.40	-	4.07	0.80	0.20	20.42	4.42
Monsoon 96		81	3.69	-	-	-	-	-	1.73	1.04	0.52	65.69	0.23	3.88	2.30	-	20.92	3.33
Mean		**203**	**5.62**	**0.03**	**0.07**	**0.24**	-	-	**1.18**	**1.68**	**0.71**	**62.06**	**0.62**	**4.22**	**1.03**	**0.26**	**22.28**	**3.69**
Winter 95	R14	306	10.00	1.51	-	0.04	0.18	-	0.91	2.80	2.30	58.88	-	6.24	4.50	1.42	11.22	3.45
Summer 96		113	7.40	1.57	0.37	0.20	-	-	0.20	0.80	3.12	65.42	0.20	4.37	1.41	0.40	14.54	3.50
Monsoon 96		121	6.62	1.14	-	0.57	-	-	0.56	2.40	6.59	57.34	1.57	5.28	2.94	0.99	14.00	4.09
Mean		**180**	**8.01**	**1.41**	**0.12**	**0.27**	**0.06**	-	**0.56**	**2.00**	**4.00**	**60.55**	**0.59**	**5.30**	**2.95**	**0.94**	**13.25**	**3.68**
Winter 95	R15	578	7.76	0.39	0.76	0.35	0.08	-	0.34	2.07	2.70	59.93	1.00	4.96	1.30	1.20	17.14	3.98
Summer 96		224	7.11	0.80	1.39	0.97	0.21	-	1.20	2.57	2.27	58.92	0.71	4.71	1.75	0.65	16.74	4.30
Monsoon 96		188	4.38	0.94	1.25	0.62	0.56	-	0.65	2.07	3.76	61.19	0.88	6.30	1.85	1.24	14.33	4.32
Mean		**330**	**6.42**	**0.71**	**1.13**	**0.65**	**0.28**	-	**0.73**	**2.24**	**2.91**	**60.01**	**0.86**	**5.32**	**1.63**	**1.03**	**16.07**	**4.20**

\- Not recorded

Table 4.23

Zooplankton Biomass (mg/10m³)

Month	Sampling Location													
	R3	R4	R5	R6	R6A	R7	R8	R9	R10	R11	R12	R13	R14	R15
Nov 95	2.2	2.4	2.8	1.2	1.1	1.0	0.4	1.1	1.2	1.5	2.4	2.8	3.1	4.2
Dec	1.8	1.4	1.6	1.1	1.0	1.4	0.8	1.5	1.7	1.2	1.9	2.4	2.9	3.6
Jan 96	2.8	2.7	2.1	1.8	1.9	2.0	3.0	2.5	4.5	3.2	2.8	6.0	3.0	2.8
Feb	2.7	1.8	1.5	1.6	1.5	1.6	2.6	2.1	3.2	2.8	2.4	4.5	2.7	1.8
Mar	3.4	3.7	2.9	2.6	2.5	2.2	3.5	2.9	4.9	3.8	3.4	3.6	4.0	5.4
Apr	1.7	1.4	1.3	1.4	1.7	1.1	1.9	1.8	2.2	2.4	2.0	2.5	1.8	1.4
May	1.4	1.3	1.2	1.4	1.2	1.2	2.2	1.2	2.8	2.2	2.0	4.0	2.2	1.4
Jun	1.7	1.5	1.4	1.6	1.5	1.6	2.0	1.6	1.8	1.6	1.8	3.4	2.6	2.8
Jul	1.4	1.1	1.2	1.4	1.2	1.2	1.8	1.4	1.3	1.2	1.4	2.4	1.8	2.2
Aug	1.2	1.0	1.6	1.2	1.0	1.0	1.1	1.4	1.8	1.4	1.4	1.6	1.4	1.8

The foraminifera *Globigerina* sp., ctenophore *Pleurobrachia* sp., copepods *Undinula* sp., *Acartia* sp., *Eutemora* sp., *Oithona plumifera*, *Euterpina sp.*, *Centropages* sp., *Metridia* sp. *Candacia* sp., *Canthocalanus* sp., *Nannocalanus* sp., *Microcalanus* sp., *Parapontella* sp., *Oncaea* sp., cladocerans *Penilia* sp., *Evadne* sp. and larval forms of brachiopoda, polychaeta & *Arachnactis* sp. and a siphonophore were found in the lower stretch of the Mandovi where salinity was comparatively high.

Thus, a correlation between certain types of zooplankton species including their abundance, and salinity was noticed in the river. Similar correlations were not found in respect of species like *Favella* sp., *Temora* sp., *Paracalanus* sp., *Microsetella* sp., *Creseis* sp., *Oikopleura* sp., larval forms of copepoda, cirripedia, bivalvia and gastropoda, and fish eggs and larvae.

Enumeration of zooplankton species in different seasons revealed that the diversity and abundance were more in winter as compared to summer and monsoon seasons. In general, abundance was poor in monsoon season at most of the stations in the river.

The distribution of zooplankton during different seasons in different salinity zones of the river is depicted in **Fig. 4.28** through **Fig.4.30**. The key numbers of zooplankton given in these figures are listed in **Table 4.24**.

4.7.4.3 Benthos

In order to evaluate the benthic forms of selected water bodies, sediment samples were collected using Van Veen grab sampler and strained through a sieve of 0.5 mm mesh for isolation of macrobenthos. The quality and quantity of benthos are not only related to the nature of substrata but also to the depth, the kinds and quantity of aquatic plants and microbes present in such an environment. Their number and distribution also depend upon physico-chemical quality of water and the biological complexes such as food and other factors.

Data on seasonal occurrence of benthic fauna and their biomass at different sampling locations of the Mandovi in Goa is presented in **Annexure 4.5 (Table 12 and 13) and Table 4.25 and 4.26**. Macrobenthos were represented by 20 groups while 14 groups were recorded in meiobenthos. While polychaetes and worms outnumbered other macrobenthic fauna, diatoms and nematodes dominated amongst the meiobenthic species. Amongst macrobenthos, foraminifera, coelenterata, harpacticoida, cumacea, tanaidacea, amphipoda, ostracoda, stomatopoda and

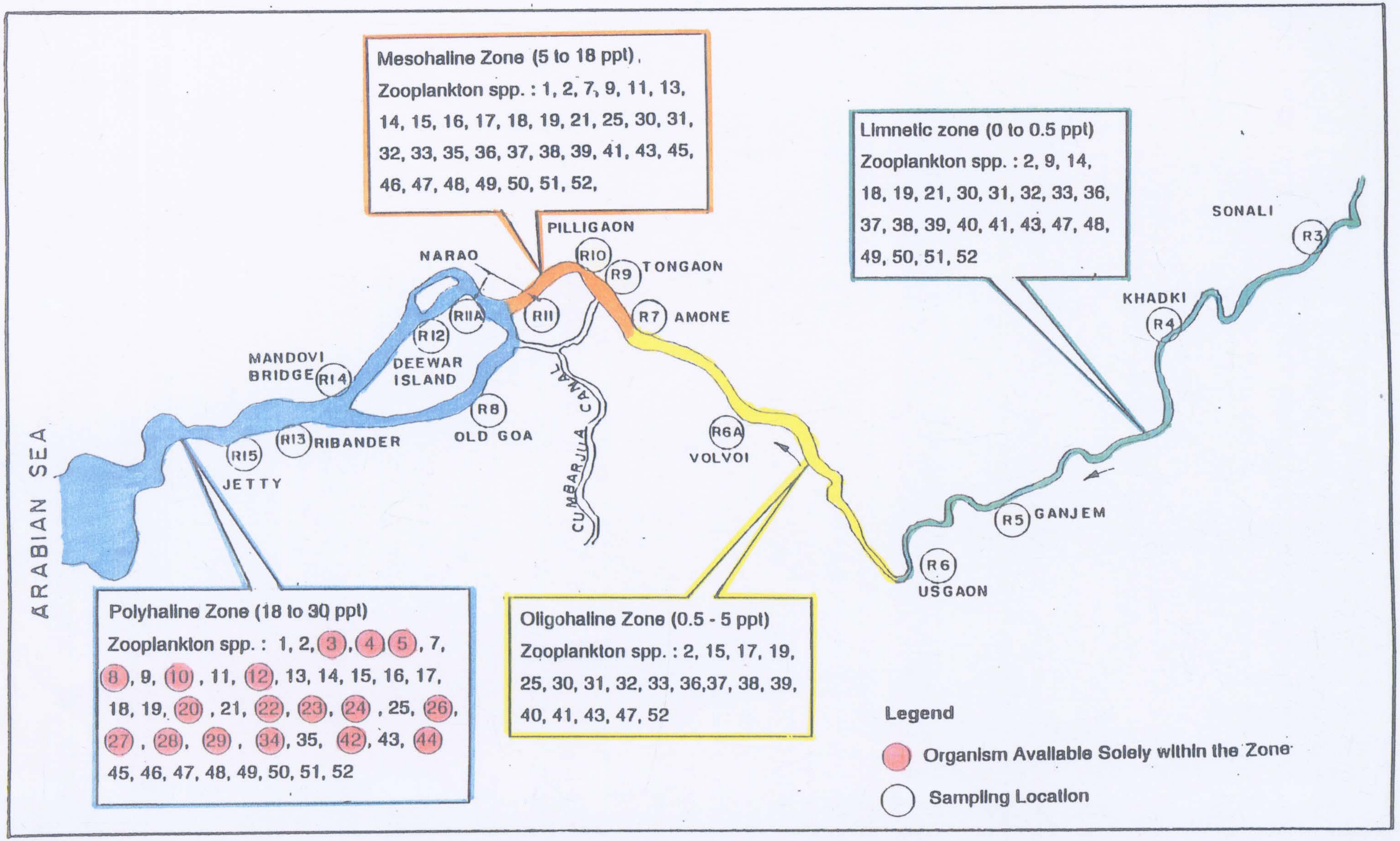


Fig. 4.28 : Occurrence of Zooplankton in Different Salinity Zones of Mandovi River during Winter Season (Key Numbers of Zooplankton Referred in Table 4.24)

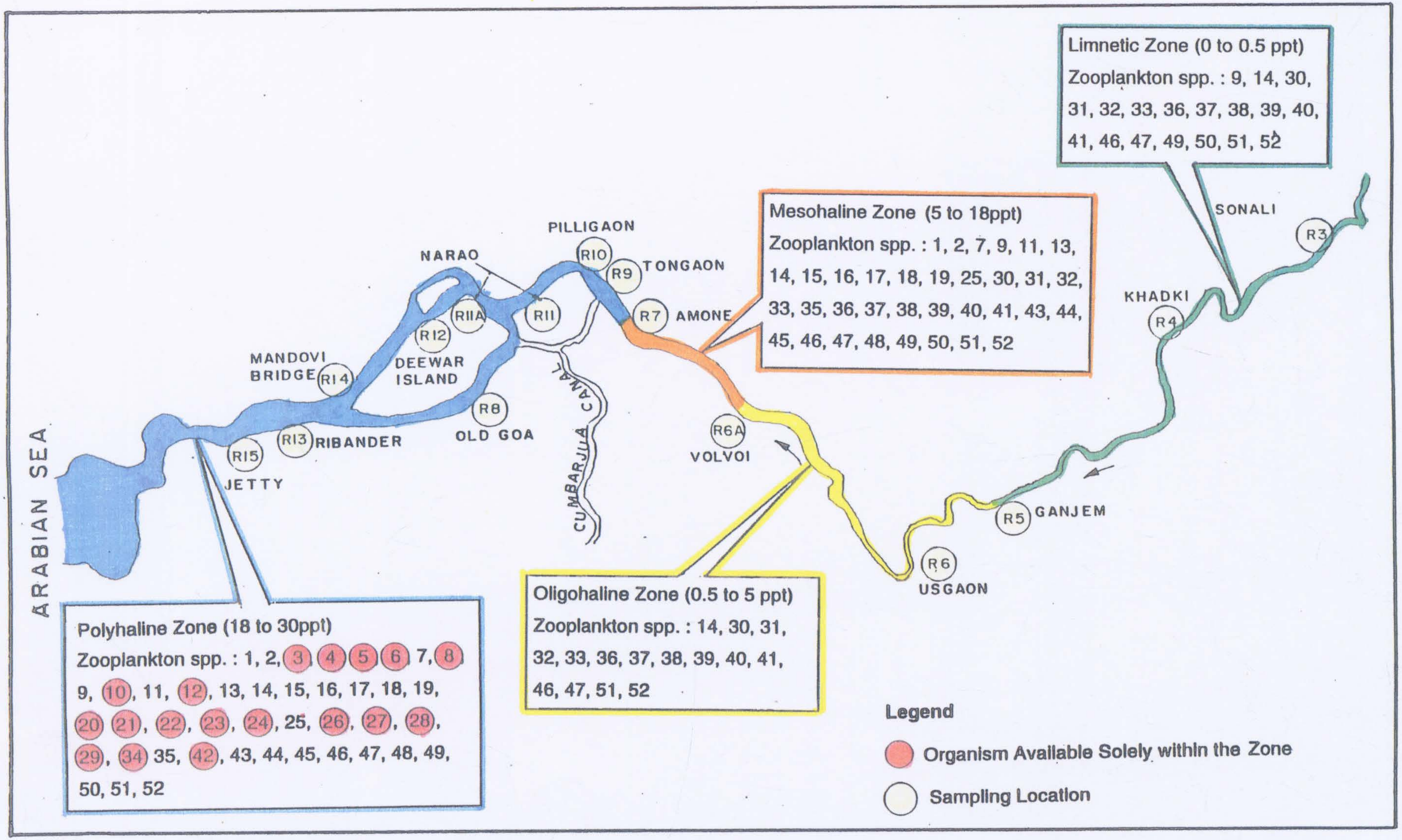


Fig. 4.29 : Occurrence of Zooplankton in Different Salinity Zones of Mandovi River during Summer Season (Key Numbers of Zooplankton Referred in Table 4.24)

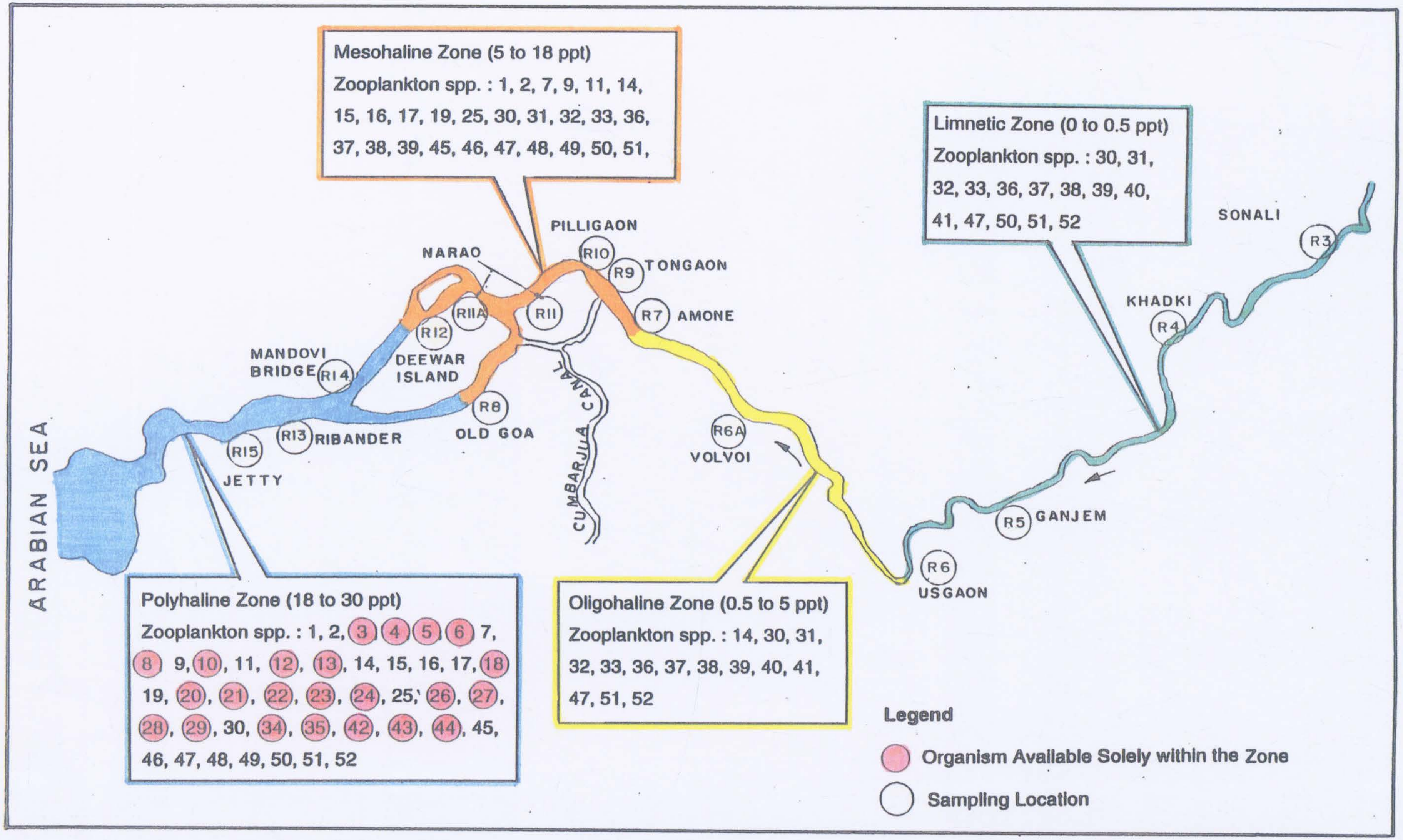


Fig. 4.30 : Occurrence of Zooplankton in Different Salinity Zones of Mandovi River during Monsoon Season (Key Numbers of Zooplankton Referred in Table 4.24)

Table 4.24

List of Zooplanktons Recorded in Mandovi River

Ciliata

1. *Tintinnopsis sp.*
2. *Favella sp.*
3. *Rhabdonella sp.*

Foraminifera

4. *Globigerina sp.*

Cnidaria

5. *Siphonophora sp.*

Ctenophora

6. *Pleurobrachia sp.*

Copepoda

7. *Undinula sp.*
8. *Acartia sp.*
9. *Temora sp.*
10. *Eutemora sp.*
11. *Oithona sp.*
12. *O. plumifera*
13. *Euterpina sp.*
14. *Paracalanus sp.*
15. *Eucalanus sp.*
16. *Centropages sp.*
17. *Pseudocalanus sp.*
18. *Macrosetella sp.*
19. *Microsetella sp.*
20. *Metridia sp.*
21. *Isias sp.*
22. *Candacia sp.*
23. *Canthocalanus sp.*
24. *Nannocalanus sp.*
25. *Rhincalanus sp.*
26. *Microcalanus sp.*
27. *Parapontella sp.*
28. *Labidocera sp.*
29. *Oncaea sp.*
30. *Heliodiaptomus sp.*
31. *Mesocyclops sp.*
32. *Microcyclops sp.*
33. *Diaptomus sp.*

Cladocera

34. *Penilia sp.*
35. *Evadne sp.*
36. *Moina sp.*
37. *Daphnia sp.*
38. *Macrothrix sp.*

Rotifera

39. *Brachionus sp.*
40. *Keratella sp.*
41. *Polyarthra sp.*

Pteropoda

42. *Creseis acicula*
43. *Creseis sp.*

Appendicularia

44. *Oikopleura sp.*

Larval forms

45. *Brachiopoda*
46. *Polychaeta*
47. *Copepod*
48. *Cirripede*
49. *Arachnectis*
50. *Bivalvia*
51. *Gastropoda*
52. *Fish eggs & Larvae*

Table 4.25

Seasonwise Variation in Biomass (mg wet wt./10 cm^2) of Meiobenthos Taxa in Mandovi River/Estuary

Season	Group	Sampling Location												
		R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15
Winter 95	Diatom	0.243	0.198	0.160	0.080	0.060	0.099	0.073	0.207	0.074	0.283	0.335	0.261	0.258
Summer 96	,,	0.356	0.270	0.056	0.082	0.017	0.166	0.143	0.266	0.089	0.090	0.461	0.306	0.268
Monsoon 96	,,	74.731	58.760	19.001	30.666	17.274	24.630	29.810	62.178	34.116	35.414	63.933	65.649	80.986
Winter 95	Foraminifera	0.042	0.022	0.004	0.025	0.088	0.091	0.005	0.056	0.060	0.070	0.074	0.100	0.091
Summer 96	,,	0.073	0.005	0.007	0.008	0.013	0.078	0.008	0.072	0.049	0.056	0.062	0.068	0.123
Monsoon 96	,,	1.769	-	-	-	-	0.004	1.764	0.882	7.060	11.500	9.260	17.635	24.262
Winter 95	Nematoda	0.676	0.338	0.184	0.165	0.181	0.722	0.199	0.496	0.759	0.390	0.496	0.830	0.514
Summer 96	,,	0.948	0.410	0.257	0.290	0.248	0.859	0.210	0.607	0.856	0.251	0.207	0.592	0.278
Monsoon 96	,,	57.026	60.575	49.878	67.669	248.20	176.29	55.184	110.37	199.45	110.39	62.318	85.508	109.069
Winter 95	Turbellaria	0.005	-	0.009	0.001	-	0.044	0.047	0.006	0.023	-	0.009	0.030	0.001
Summer 96	,,	0.010	-	-	-	0.012	0.070	0.039	0.009	0.025	-	0.013	0.007	0.006
Monsoon 96	,,	-	-	-	-	-	0.005	2.134	6.400	2.130	2.134	6.934	3.200	10.670
Winter 95	Polychaeta	0.921	0.297	0.058	0.210	0.398	0.681	0.503	2.118	1.219	0.682	1.494	1.081	0.539
Summer 96	,,	1.430	0.358	0.184	0.319	0.271	1.055	0.638	2.629	1.595	0.251	2.368	2.000	0.841
Monsoon 96	,,	58.084	0.011	17.394	-	11.619	75.382	5.867	138.97	203.17	324.82	173.94	394.45	188.555
Winter 95	Bivalvia	-	0.143	0.003	0.280	0.088	-	0.074	0.488	0.148	0.070	0.118	0.606	0.705
Summer 96	,,	-	-	0.020	0.090	0.110	-	0.110	0.470	0.260	0.100	0.150	0.420	0.770
Monsoon 96	,,	-	0.120	6.000	18.000	24.000	-	-	-	0.024	36.000	108.01	90.036	262.590

Table 4.25 (Contd...)

Season	Group	Sampling Location												
		R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15
Winter 95	Ostracoda	0.803	0.733	0.215	0.072	0.060	0.195	0.133	1.284	0.550	1.093	0.723	1.102	1.056
Summer 96	,,	1.234	1.166	-	-	0.041	0.293	0.121	1.152	0.884	0.657	1.058	1.702	1.812
Monsoon 96	,,	49.338	16.498	-	-	-	-	0.016	90.288	98.528	57.472	98.528	213.47	297.668
Winter 95	Amphipoda	-	-	-	-	0.055	0.105	0.130	-	0.154	0.014	0.154	0.231	0.014
Summer 96	,,	-	-	-	-	-	0.131	0.187	-	0.112	-	0.075	0.318	0.093
Monsoon 96	,,	-	11.176	-	-	-	-	5.597	5.586	33.516	16.756	78.215	100.54	153.618
Winter 95	Copepoda	0.128	-	0.039	0.133	0.117	0.399	0.399	0.067	0.218	0.178	0.111	0.167	0.178
Summer 96	,,	0.171	0.029	0.079	0.161	0.183	0.601	0.477	0.205	0.266	0.271	0.191	0.257	0.279
Monsoon 96	,,	110.017	145.235	167.20	88.000	176.00	61.640	154.052	224.400	88.000	30.813	61.617	88.000	187.044
Winter 95	Isopoda	-	-	0.007	-	-	0.017	0.011	-	0.028	0.008	0.016	0.044	0.014
Summer 96	,,	-	-	0.009	-	0.001	0.023	0.013	-	0.036	0.013	0.027	0.069	0.016
Monsoon 96	,,	-	-	-	-	-	-	-	-	0.003	11.200	0.024	9.603	14.000
Winter 95	Cumacea	-	-	0.405	-	0.350	0.250	-	-	1.000	0.500	-	-	0.050
Summer 96	,,	-	-	0.600	-	0.600	-	-	-	1.533	0.800	-	0.067	0.333
Monsoon 96	,,	-	-	-	-	-	0.040	-	40.000	-	240.08	320.00	360.00	450.050
Winter 95	Crustaceans	0.095	0.022	0.064	0.060	0.035	0.138	0.163	0.094	0.060	-	-	0.120	0.209
Summer 96	,,	0.123	0.021	0.107	0.091	0.029	0.189	0.168	0.101	0.072	-	0.005	-	0.307
Monsoon 96	,,	33.851	26.691	24.945	48.059	28.500	48.090	21.386	33.630	33.847	46.310	57.000	69.475	62.940

Table 4.25 (Contd...)

Season	Group	Sampling Location												
		R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15
Winter 95	Arachnactis (Anthozoa)	0.197	0.160	0.073	0.193	0.019	0.290	0.137	0.073	-	0.128	0.017	0.156	0.004
Summer 96	,,	0.043	0.003	-	0.040	0.020	0.052	0.140	0.083	-	0.017	0.030	0.003	0.032
Monsoon 96	,,	-	-	-	-	-	-	-	-	-	-	-	3.000	6.251
Winter 95	Fish egg mass	37.918	35.355	16.226	23.608	15.384	29.778	29.777	46.320	27.040	39.620	102.353	37.485	73.953
Summer 96	,,	26.880	22.933	24.483	35.730	23.157	45.655	42.353	58.228	9.263	58.893	170.050	65.505	131.007
Monsoon 96	,,	32162	65403	32160	40100	17906	14236	19060	12709	11116	15486	4376	27000	37227

- Not recorded

Table 4.26

Seasonwise Variation in Biomass (mg wet wt./cm^2) of Macrobenthos Taxa in Mandovi River/Estuary

Season	Group	Sampling Location												
		R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15
Winter 95	Foraminifera	-	-	-	-	-	-	-	-	-	-	0.421	-	0.537
Summer 96	,,	-	-	-	-	-	-	-	-	-	-	1.246	0.0003	1.513
Monsoon 96	,,	-	-	-	-	-	-	-	-	-	0.505	0.930	0.585	1.761
Winter 95	Porifera	-	0.075	0.023	0.075	0.075	0.015	-	-	0.075	-	-	0.150	-
Summer 96	,,	-	-	-	-	-	-	-	-	-	-	-	-	-
Monsoon 96	,,	-	-	-	-	-	-	-	-	-	-	-	-	-
Winter 95	Coelenterata (Cnidaria)	-	-	-	-	-	-	-	-	-	-	111.485	-	554.180
Summer 96	,,	-	-	-	-	-	-	-	-	-	-	1.687	-	6.307
Monsoon 96	,,	-	-	-	-	-	-	-	-	-	-	132.000	616.00	905.000
Winter 95	Nematoda	2.448	3.588	1.037	0.469	0.209	0.305	1.134	0.504	0.923	-	0.356	-	0.213
Summer 96	,,	0.192	1.985	2.464	1.792	0.704	0.736	1.888	2.433	1.184	0.768	0.288	1.312	1.056
Monsoon 96	,,	0.038	0.307	0.230	0.384	0.038	-	0.037	0.249	0.364	0.249	0.229	0.122	0.384
Winter 95	Gastrotricha	0.020	-	0.053	0.030	0.010	0.020	0.083	0.027	-	-	0.040	0.010	0.020
Summer 96	,,	-	-	-	-	-	-	-	-	-	-	-	-	-
Monsoon 96	,,	-	-	-	-	-	-	-	-	-	-	-	-	-
Winter 95	Polychaeta	4.021	5.887	13.417	9.670	4.123	26.428	32.747	15.132	13.664	0.113	6.173	15.506	7.982
Summer 96	,,	12.525	7.549	50.071	37.575	55.133	95.150	107.653	50.089	45.074	-	15.059	30.106	25.053
Monsoon 96	,,	2.996	1.498	16.478	26.960	49.430	34.460	55.410	37.450	22.500	1.498	4.494	19.470	20.600

Table 4.26 (Contd...)

Season	Group	Sampling Location												
		R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15
Winter 95	Gastropoda	12.715	-	-	11.385	-	7.590	-	-	-	1919.893	17.078	2678.891	4582.54
Summer 96	,,	5.313	0.506	-	-	-	-	-	-	-	20.493	-	25.805	54.142
Monsoon 96	,,	-	-	0.152	-	-	0.455	1.367	0.152	2.579	0.304	1.671	4.850	6.830
Winter 95	Bivalvia	26.565	11.385	5.693	39.848	-	-	639.714	-	-	5.693	763.543	6456.754	4178.061
Summer 96	,,	-	-	-	-	-	506.000	1012.440	2024.059	-	0.117	2531.143	13668.985	12148.454
Monsoon 96	,,	-	-	-	-	-	151.800	3795.000	303.640	2884.200	3795.000	5161.520	7590.000	13472.280
Winter 95	Harpacticoida	-	-	-	-	-	-	-	-	-	-	0.008	-	1.282
Summer 96	,,	-	-	-	-	-	-	-	-	-	-	0.001	-	5.054
Monsoon 96	,,	-	-	-	-	-	-	-	-	0.144	0.648	0.288	1.080	1.710
Winter 95	Cumacea	-	-	-	-	-	-	-	-	-	-	0.0005	-	0.0008
Summer 96	,,	-	-	-	-	-	-	-	-	-	-	0.333	-	0.417
Monsoon 96	,,	-	-	-	-	-	-	-	-	-	-	-	0.200	0.625
Winter 95	Tanaidacea	-	-	-	-	-	-	-	-	0.008	0.591	0.585	0.688	0.005
Summer 96	,,	-	-	-	-	-	-	-	-	-	1.567	-	2.087	0.391
Monsoon 96	,,	-	-	-	-	-	-	-	-	-	0.623	0.194	1.130	0.485
Winter 95	Isopoda	5.303	-	-	-	-	-	-	-	-	26.324	0.063	31.743	0.105
Summer 96	,,	7.049	0.067	-	13.987	-	0.105	-	-	-	64.110	6.993	105.969	8.286
Monsoon 96	,,	-	-	4.196	-	-	-	-	-	-	37.760	20.980	27.270	24.460

Table 4.26 (Contd...)

Season	Group	Sampling Location												
		R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15
Winter 95	Amphipoda	-	-	-	-	0.150	-	-	-	-	2.268	0.005	1.531	2.119
Summer 96	,,	-	-	-	-	-	0.0003	-	-	-	6.823	-	6.216	7.224
Monsoon 96	,,	-	-	-	-	-	-	-	-	0.240	5.400	1.560	2.160	10.650
Winter 95	Ostracoda	-	-	-	-	-	-	-	-	-	-	-	-	-
Summer 96	,,	-	-	-	-	-	-	0.001	-	-	-	0.001	0.005	0.008
Monsoon 96	,,	-	-	-	-	-	-	-	-	<0.0001	<0.0001	<0.0001	0.0006	<0.0001
Winter 95	Stomatopoda	-	-	-	-	21.250	-	-	-	-	-	-	-	-
Summer 96	,,	-	-	-	-	-	-	-	-	-	-	0.060	-	0.210
Monsoon 96	,,	-	-	-	-	-	-	-	-	-	-	-	<0.0001	0.0002
Winter 95	Mysidacea	-	-	-	-	22.500	-	-	-	-	-	1.868	225.000	521.933
Summer 96	,,	-	-	-	-	-	-	-	-	0.120	-	2.790	-	6.000
Monsoon 96	,,	-	-	-	-	-	-	-	-	-	-	-	198.000	450.000
Winter 95	Decapoda	0.900	-	-	-	-	-	-	-	-	1385.075	1706.610	-	2188.023
Summer 96	,,	0.988	-	0.141	-	-	-	-	-	-	11.250	16.505	0.423	22.126
Monsoon 96	,,	-	-	-	-	-	-	-	-	253.920	655.960	1438.800	423.200	2909.500
Winter 95	Pisces	-	-	-	-	396.250	-	-	-	-	-	-	-	6021.997
Summer 96	,,	1.323	-	-	-	1.323	-	-	-	0.662	2.647	13.233	3.970	91.310
Monsoon 96	,,	9528	5161	6749	7543	2382	3176	16764	7820	5468	8662	54786	17865	22331.250

Table 4.26 (Contd...)

Season	Group	Sampling Location												
		R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15
Winter 95	Prawn larvae	0.262	-	-	-	-	-	-	-	-	-	-	-	0.018
Summer 96	,,	0.608	0.049	-	0.097	-	-	-	-	-	0.195	0.243	0.414	1.801
Monsoon 96	,,	0.029	-	-	0.015	0.059	0.101	0.045	0.161	0.219	0.306	0.308	0.613	0.966
Winter 95	Worms & Others	3.177	6.361	3.180	7.950	4.741	1.589	6.354	-	3.186	-	11.119	6.356	4.804
Summer 96	,,	0.056	0.093	0.060	0.124	0.033	0.021	0.074	-	0.070	-	0.118	0.113	0.099
Monsoon 96	,,	22.660	28.980	7.560	27.720	10.080	18.900	25.200	12.600	11.340	31.500	59.220	44.100	72.425

- Not recorded

mysidacea were recorded only in the lower stretch of the Mandovi in Goa where the salinity was comparatively high. Such correlation with salinity could not be drawn for all the groups of meiobenthos and select groups of macrobenthos. Further, a definite correlation was not observed between abundance & biomass of benthos and different seasons.

Food Web

The food web is the feeding relationship between the species in a biotic community. All organisms sharing the same source of nutrition are placed in the same trophic level. Generally, 4 to 5 steps in food chains are found in a natural ecosystem. While the first trophic level is represented by the green plants as primary producers (P), the second trophic level is the primary consumers (C1) which are herbivores represented by zooplankton, meiobenthos and macrobenthos. Subsequent trophic levels in steps are denoted as consumer 2 (C2), consumer 3 (C3) and so on. In Mandovi river, the P is represented by 53 species of phytoplankton. The fauna in C1 are represented by 52, 14, 20 species/groups of zooplankton, meiobenthos and macrobenthos respectively. The small fishes, coelenterates, crabs, and prawns contribute as consumer 2(C2). Finally, shore birds dominated by brown headed gull, large egret, little egret, pied kingfisher, reef heron and certain large carnivorous fishes constitute C3 in Mandovi river.

4.7.4.4 Fisheries Activities

The study area in Khanapur taluka of Belgaum district, Karnataka has no fisheries activities; the area is not leased out to any society or private fishermen. No fishermen are living in the study area. Malaprabha river starts from Kanakumbhi village and flows towards Bailahongal and Saundatti talukas. It is a tributary of Krishna river and has a stretch of 26 km which is leased out for fishing rights to the fishermen society of Khanapur.

The Mahadayi was surveyed by KPCL and the Fisheries Department in March 1992. The trial netting conducted yielded only minor carps and catfishes. No bigger fishes were available in Mahadayi river. No endangered species of fish is recorded in the study area.

Specific data on fisheries in different stretches of the Mahadayi(Mandovi) in Goa is not available with the concerned departments. Hence, test netting by cast net was applied in different stretches of the river during different seasons. Altogether 28 and 13 varieties of fin fish and shell fish respectively were harvested during the survey. The occurrence of the fishes in different salinity regimes is depicted in

Fig. 4.31 through **Fig. 4.33** and **Table 4.27** and seasonal density of the fishes is presented in **Annexure 4.6, Table 14**.

Fish landing data as available with the State Fisheries Department of Goa for the last 4 years is presented in **Table 4.28**. The fish catch was maximum in 1993 followed by 1992, 1994 and 1995. In 1995 the fish catch decreased by 25.4%, 28.8% and 25% compared to that in 1992, 1993 and 1994 respectively. This decrease in the fish catch was due to sharks, wolf-herrings, sardines, anchovies, clupeids, perches, carangids, seerfishes, tunnies and barracudas. Certain groups of fishes like eels, shads, anchovies, Bombay duck and snappers, which were absent in earlier years, were harvested in 1994. Similarly, other tunnies which were present in 1992 could not be harvested in the last three years. A wide diversity amongst the different dominant groups of fishes was recorded in the last 4 years. The most dominant group was scads in 1992, and Indian mackerel in 1993, 1994 and 1995. In general, lesser sardines, ribbon fish, scads, carangids, mackerel, soles, penaeid prawns, stomatopods and cephalopods are common in this area.

There are five major fisheries cooperative societies in Goa with a total membership of 889 fishermen (**Table 4.29**). Of these, only one society has local traditional fishermen while the others comprise of boat owners. As this area is banned from trawling and siening operations these traditional fishermen catch fishes in the estuary and coastal waters with the help of stake nets, upto a distance of 3 km from the coast.

4.7.4.5 Aquaculture in Estuarine System of Goa

Two riverine systems, viz. the Mandovi and Zuari are used by the people of Goa for diverse activities and support a rich fishery resource in the coastal region. The estuarine complex provides 18,500 ha of low lying area, and traditional farming of Penaeus indicus has been practiced in about 400 ha of low lying area known as Khazans, in Bardez, Salcete, Tiswadi and Ponda talukas. In Mandovi, the shrimp farms are located in the Chorao Island. In order to improve Goa's poor share of 1.3 % of the West coast's total prawn catch, the state introduced schemes and facilities for prawn cultivation. The Brackishwater Fish Farmers Development Agency (BFDA) identified viable sites for prawn farms, and set a target of bringing 50 ha of brackishwater area under cultivation every year. During 1990-91, the BFDA cleared as many as 193 applications for 25 % subsidy and 75 % bank loan for setting up farms. So far only 17 farmers have benefited from the scheme. Thus, the total area under prawn farming covers only 600 ha.

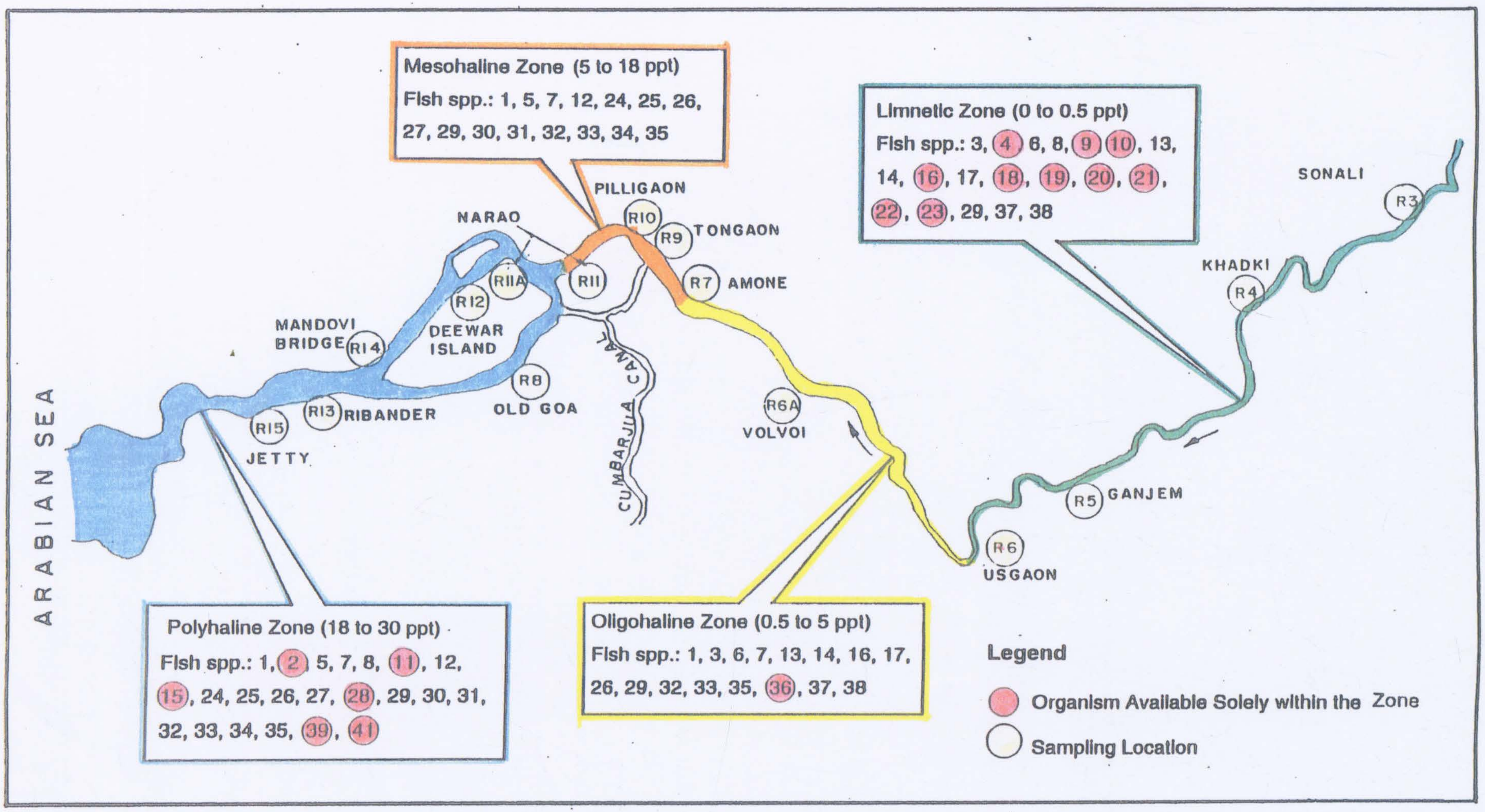


Fig. 4.31 : Occurrence of Fin Fish and Shell Fish in Different Salinity Zones along the Mandovi Estuary/River during Winter Season
(Key Numbers of Organisms Referred in Table 4.27)

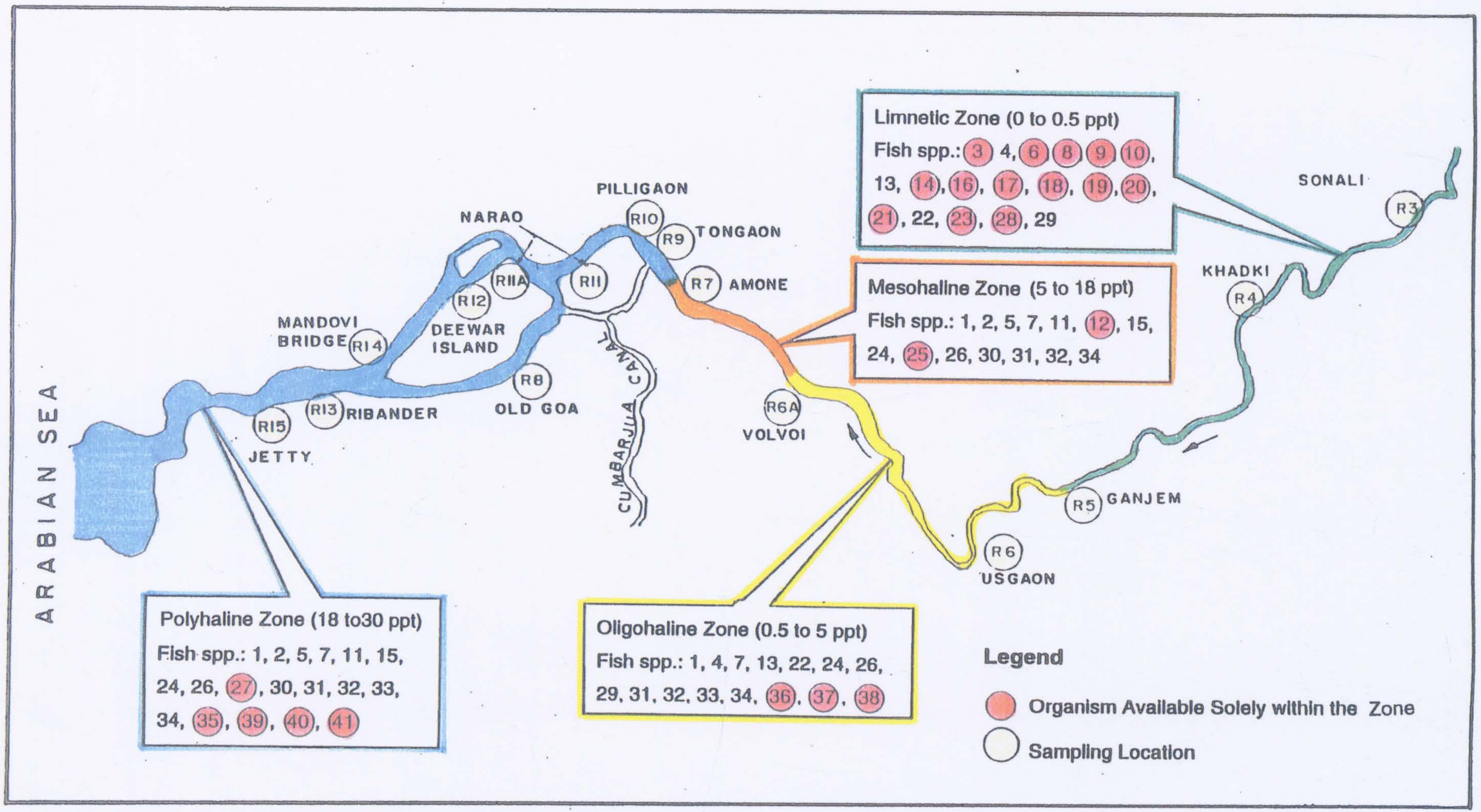


Fig. 4.32 : Occurrence of Fin Fish and Shell Fish in Different Salinity Zones along the Mandovi Estuary/River during Summer Season
(Key Numbers of Organisms Referred in Table 4.27)

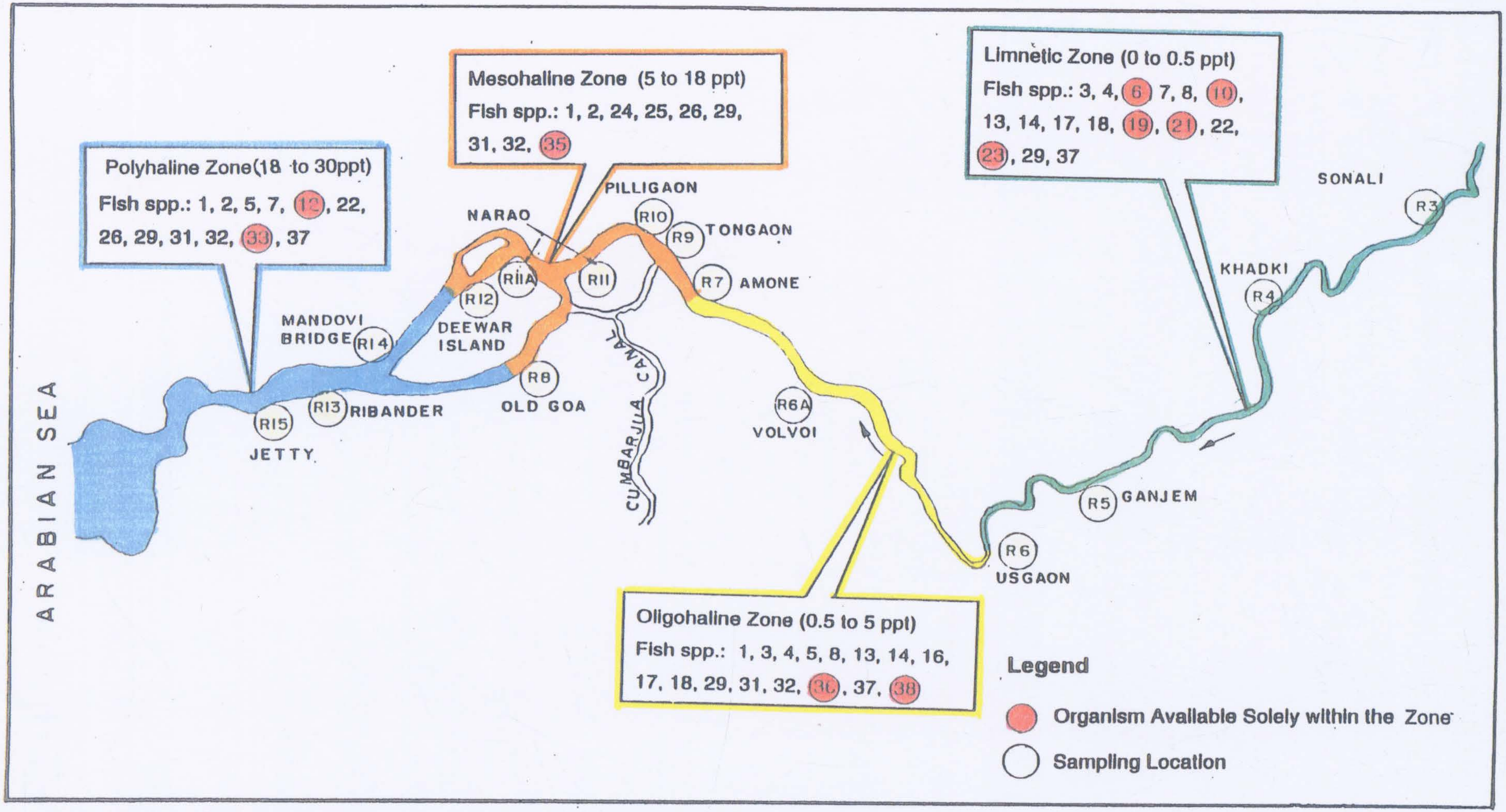


Fig. 4.33 : Occurrence of Fin Fish and Shell Fish in Different Salinity Zones along the Mandovi Estuary/River during Monsoon Season (Key Numbers of Organisms Referred in Table 4.27)

Table 4.27

List of Nekton Recorded in Mandovi River

Finfishes

1. *Ambassis commersonii*
2. *Ambassis dussumieri*
3. *Awaous grammepomus*
4. *Barilius evezardi*
5. *Cynoglossus puncticeps*
6. *Danio devario*
7. *Etroplus suratensis*
8. *Garra gotyla gotyla*
9. *Gonoproktopterus thomassi*
10. *Labeo kawrus*
11. *Leiognathus blochii*
12. *Mugil cephalus*
13. *Nemacheilus rubidipinnis*
14. *Osteobrama dayi*
15. *Pseudorhombus arsius*
16. *Parluciosoma daniconius*
17. *Puntius filamentosum*
18. *P.amphibius*
19. *P.nigrofasciatus*
20. *P.ophiocephalus*
21. *P.arulius*
22. *Rasbora neigherriensis*
23. *Sieyepterus graseus*
24. *Scatophagus argus*
25. *Sillago sihama*
26. *Stenogobius gymnopomus*
27. *Teuthis vermiculata*
28. *Chanos chanos*

Shellfishes

29. *Macrobrachium malcolmsoni*
30. *Metapenaeus affinis*
31. *M.monoceros*
32. *M.dobsoni*
33. *Penaeus marguiensis*
34. *P.indicus*
35. *Scylla serrata*
36. *Unidentified (small crab)*
37. *Macrobrachium rude*
38. *Villorita cyprinoides*
39. *Meretrix meretrix*
40. *M.casta*
41. *Paphia malabarica*

Table 4.28

Annual Marine Fish Catch in Goa State (Tonnes)

Sl. No.	Fish Group	1992	1993	1994	1995
1.	Sharks	115	314	201	26
2.	Rays	30	1	5	3
3.	Skates	-	-	-	1
4.	Eels	-	-	3	4
5.	Catfishes	123	772	687	1710
6.	Wolf herring	360	229	172	143
7.	Oil sardines	3330	877	210	79
8.	Other sardines	10761	2080	4160	1574
9.	Hilsa shad	-	-	2	-
10.	Other shad	-	-	3	-
11.	Anchovies	-	-	3	27
12.	Stolephorus	35	74	65	-
13.	Thryssa	11466	220	525	-
14.	Other clupeids	1113	319	321	269
15.	Bombay duck	-	-	2	-
16.	Lizard fishes	355	147	150	-
17.	Butter fish	-	-	-	96
18.	Halfbeaks & Fullbeaks	34	-	10	-
19.	Gofies	-	-	-	76
20.	Rock cods	2	-	3	2
21.	Milk fish	-	-	-	2
22.	Snappers	-	-	4	-
23.	Threadfin breams	8	5	25	21
24.	Other perches	566	684	912	-
25.	Goatfishes	-	1	1	-
26.	Croakers	851	644	1214	1006
27.	Ribbonfishes	2955	1420	2628	2181

Contd...

Table 4.28 (Contd...)

Sl. No.	Fish Group	1992	1993	1994	1995
28.	Horse mackerels	9329	283	805	-
29.	Scads	18211	13	2150	-
30.	Leather jackets	245	7	3	-
31.	Other carangids	4750	1511	1567	168
32.	Silverbellies	409	44	152	126
33.	Big-jawed jumper	304	118	198	-
34.	Black pomfrets	149	153	185	877
35.	Silver pomfrets	62	73	45	228
36.	Chinese pomfrets	4	7	3	-
37.	Indian mackerel	7733	57684	38230	42712
38.	Seer fishes	1673	380	3496	917
39.	Indian whiting	-	-	-	2
40.	Auxis sp.	2724	106	168	-
41.	Thunnus tonggol	14	80	75	-
42.	Other tunnies	87	-	-	-
43.	Barracuda	43	42	45	-
44.	Mullets	16	3	4	3
45.	Soles	891	3118	4213	3498
46.	Penaeid prawns	2997	3166	4355	5193
47.	Lobsters	1	4	3	2
48.	Crabs	332	890	1987	1649
49.	Stomatopods	12310	17057	17143	*
50.	Cephalopods	1096	6835	8996	7467
51.	Miscellaneous	847	1525	702	1142*
	Total	96407	101192	96726	71885

* In 1995, Stomatopods and miscellaneous fishes are recorded together

Source : Director of Fisheries, Goa

Table 4.29

Fishery Co-operative Societies in Goa

Sl. No.	Name of the Society	Year of Establishment	Membership	Major Activities
1.	Mandovi Fishermen Marketing Co-operative Society Ltd. Malim Jetty, Betim Bardaz, Goa.	1964	135	Boat Owners, Suppliers of High Speed Diesel, Maintenance of Fishlanding Centre
2.	Akhil Gomantak Harkari Sahakhari Samstha Society Ltd., Panjim, Goa.	1964	499	Local traditional fishermen
3.	Xaporae Boat Owners Co-operative Fishing Society Ltd, Xaphore, Bardez, Goa.	1990	45	Boat Owners, Suppliers of H.S.D
4.	Riosal Fishermens Co-operative Society, Sernabatim, Colva, Salcate, Goa.	1991	70	Boat Owners, Suppliers of H.S.D
5.	Cutbona Fisheries Co-operative Society Ltd. Cutbona, Velim, Salcete, Goa.	1991	140	Boat Owners, Suppliers of H.S.D

The state has a fishing population of 10,000. But in spite of the assured high returns from aquaculture and the availability of technical and financial assistance, there have been only a few fishermen to accept aquaculture to a large extent. One of the reasons for this, is the absence of clear titles to brackish lands. The initial investment on each hectare of farm averages nearly Rs. 4 lakhs, but without proper titles bank loans cannot be against mortgage of property.

Further, the Tenancy Act has led to the fragmentation of lands and does not allow purchase of large areas. Long term lease of such lands is allowed only for agricultural purposes, and aquaculture is not recognised as an agricultural activity. Besides, banks do not accept leased lands for mortgage. Lack of entrepreneurial spirit among Goa's land holding farmers, tardiness in processing loan applications and delay in disbursing subsidy are the other hindrances to prawn culture by small farmers. Another reason for the poor performance of the sector is the irregular supply and high cost of prawn seeds. The Government has set up in 1989 a prawn hatchery at Benaulim in south Goa with the capacity to produce 50 million seeds of tiger prawn. A private hatchery is also being set up at a cost of Rs. 120 lakhs to cater to the needs of farmers in the region.

4.8 Statistical Analysis

4.8.1 Zooplankton

Effect of salinity on the distribution of zooplankton species was assessed with recourse to correlation and cluster analysis. During the study period of November 1995 to October 1996 a total of 52 zooplankton species were recorded in the Mandovi estuary. Samples were collected at monthly intervals, from 14 fixed locations. The salinity in Mandovi estuary/river ranged from 0 to 34.67% depending on the season and the distance of the sampling location from the sea. November to February was considered as winter, March to May as summer and June to October as monsoon season. All the analyses were performed using SPSS package.

Correlation Between Salinity and Abundance of Species

As Pearsons Correlation Coefficient measures the linear association between the variables, the data on species density was transformed to $\log(x+1)$, where x is species density to ensure linearity of the data. The correlation coefficients for the three seasons, viz. winter, summer, and monsoon are given in **Table 4.30**. The values are highly variable. The correlation between any particular species say Tintinnopsis and salinity is 0.5457 followed by two stars. This means that, the probability that there is linear association between salinity and abundance of Tintinnopsis is 0.99.

Table 4.30

Correlation Coefficient Between Salinity and Log values of Abundance of Zooplankton

Sl. No.	Species	Season		
		Winter 95	Summer 96	Monsoon 96
Ciliata				
1	*Tintinnopsis sp.*	0.5457**	0.5915**	0.3876**
2	*Favella sp.*	0.6384**	0.6558**	0.5129**
3	*Rhabdonella sp.*	0.3055*	0.3307*	0.3508**
Foraminifera				
4	*Globigennia sp.*	0.4105**	0.3789*	0.2678
Cnidaria				
5	*Siphonophora sp.*	0.4446*	0.3986**	0.2678*
Ctenophora				
6	*Pleurobrachia sp.*	-	-	0.2252
Copepoda				
7	*Undinula sp.*	0.5493**	0.4953**	0.3645**
8	*Acartia sp.*	0.2927*	0.2537	0.5617**
9	*Temora sp.*	0.5280**	0.5150**	0.2556*
10	*Eutemora sp.*	0.3546**	0.3774*	0.5733**
11	*Oithona sp.*	0.5806**	0.7476**	0.6068**
12	*O. plumifera*	0.2000	0.3805*	0.4954*
13	*Euterpina sp.*	0.1160	0.4769**	0.6618**
14	*Paracalanus sp.*	0.5758**	0.5161**	0.4102**
15	*Eucalanus sp.*	0.3040*	0.2561	0.6118**
16	*Centropages sp.*	0.3936**	0.4281**	0.5247**
17	*Pseudocalanus sp.*	0.4806**	0.4864**	0.3728**
18	*Macrosetella sp.*	0.6161**	0.5101**	0.5491**
19	*Microsetella sp.*	0.4436**	0.4685**	0.4520**
20	*Metridia sp.*	0.1920	0.4257**	0.5793**
21	*Isias sp.*	0.3170*	0.5005**	0.5699**
22	*Candacia sp.*	0.4129**	0.3640**	0.5192*
23	*Canthocalanus sp.*	0.4596**	0.4159**	0.6243**
24	*Nannocalanus sp.*	0.3111*	0.3451*	0.5968**
25	*Rhincalanus sp.*	0.3790**	0.4806**	0.6261**

Table 4.30 (Contd...)

Sl. No.	Species	Season		
		Winter 95	Summer 96	Monsoon 96
26	*Microcalanus sp.*	0.3406*	0.3686*	0.5529**
27	*Paradontella sp.*	-	0.4648**	`0.5263**
28	*Labidocera sp.*	0.4680**	0.4043**	0.5003**
29	*Oncaea sp.*	0.3194*	0.2987	0.5961**
30	*Heliodiaptomus sp.*	-0.7284**	- 0.6122**	- 0.4821**
31	*Mesocyclops sp.*	- 0.7185**	- 0.6240**	- 0.4467**
32	*Microcyclops sp.*	- 0.7572**	- 0.7236**	- 0.4239**
33	*Diaptomus sp.*	- 0.6649**	- 0.6704*	- 0.4376**
Cladocera				
34	*Penilia sp.*	0.3781**	0.2201	0.5591**
35	*Evadne sp.*	0.4416**	0.3278*	0.5353**
36	*Moina sp.*	- 0.6616**	- 0.6405**	- 0.4520**
37	*Daphnia sp.*	- 0.6955**	- 0.5470**	- 0.4531*
38	*Macrothrix sp.*	- 0.6556**	- 0.5111**	- 0.4086*
Rotifera				
39	*Brachionus sp.*	0.6278**	- 0.7553**	- 0.4696**
40	*Keratella sp.*	- 0.5007**	- 0.6457**	- 0.4803**
41	*Polyarthra sp.*	- 0.5898**	- 0.7138**	- 0.4388**
Pteropoda				
42	*Creseis acicula*	0.4451**	0.2915	0.5455*
43	*Creseis sp.*	0.4904**	0.1817	0.5895**
Appendicularia				
44	*Oikopleura sp.*	0.4804**	0.1267	0.5433**
Larval Forms				
45	Brachiopoda	0.3644**	0.0730	0.6679**
46	Polychaeta	0.2591	0.1702	0.0152
47	Copepod	0.2683	0.1026	0.4720**
48	Cirripede	0.4129**	0.4506**	0.6000**
49	Arachnactis	0.2985*	0.1723	0.1246
50	Bivalvia	0.1811	0.1492	0.4349**
51	Gastropoda	0.4212**	0.1646	0.0862
52	Fish eggs & larvae	0.1793	0.2467	0.4668**

* Significant less than equal to 0.05
** Significant less than equal to 0.01

Similarly, the correlation coefficient values followed by single star indicate the probability that there is linear association between salinity and abundance of any species is more than 0.95.

Species with significant positive correlation to salinity indicate that salinity decrease would decrease their abundance and species with significant negative correlation to salinity indicate vice versa. Weak and insignificant correlation shown by certain species reflect their wide tolerance to salinity changes. The species which show significant negative correlation are *Heliodiaptomus, Mesocyclops, Microcyclops and Diaptomus among the copepods; Moina, Daphnia and Microthrix among the cladocera; and Brachionus, Keratella and Polyarthra* among the rotifera; Thus these species will be more abundant in fresh water. Protozoa, pteropoda, larval forms and a large number of copepods show positive correlation indicating their abundance decreasing with salinity decrease.

Results of Q technique of Cluster Analysis.

In the present analysis unweighted pair group method using arithmetic averages (UPGMA) and Average linkage within group (ALWG) methods of cluster analysis have been used. **Annexure 4.7** describes these methodologies. The dendrogram in **Annexure 4.7, Fig. 1** shows the presence of five stretches. These five stretches reflect the effect of salinity on the abundance of zooplankton in Mandovi estuary. The first stretch in general comprises sampling locations R7 to R14 which form high salinity stretch while the second group in general comprises of sampling locations R3 to R6A which form fresh water zone. The independent clusters found near the mouth of river (sampling locations R13, R14, R15) may be due to mere influence of sea fauna. The abundance of species collected from location R15 during the month of November is very high and therefore it forms a separate group. Similarly the data collected at sampling location R15 during December and R13 during November form separate groups. The salinity ranges between 10.4 to 32.8 at monitoring locations R7 to R14 and 0.0 to 8.6 at monitoring locations R3 to R7.

The dendrogram applied to the samples collected during summer season is presented in **Annexure 4.7, Fig. 2.** It shows the presence of four stretches, which support the results obtained for the winter season. The first stretch in general comprises location numbers R7 to R14 which form high salinity stretch while the second stretch comprises location numbers R3 to R6A which have a common characteristic of low salinity. Location R15 monitored during March and April form the third and the fourth stretch.

The results of Q technique applied to the samples collected during monsoon season are presented in **Annexure 4.7, Fig. 3**. It also supports the results of analysis done for winter and summer season.

The result of R-technique presented in **Annexure 4.7, Figs. 4, 5 and 6** for the three seasons shows the existence of two distinct groups of zooplankton species. Here the species are represented by species number for example Tintinnopsis is represented as Species no. 1, Favella is represented by species no. 2 etc. It is observed from the dendrogram that the species with positive correlation form one group while the second group comprises the species with negative correlation.

4.8.2 Phytoplankton

The correlation coefficient between salinity and abundance of phytoplankton after transforming the abundance of phytoplankton species density to log(x+1), where x is the species density, is presented in **Table 4.31**.

4.8.3 Fish

The correlation coefficient between salinity and abundance of fish after transforming the abundance of species density to log(x+1), where x is the species density, is presented in **Table 4.32**.

4.9 Socio-Economic Environment

This section presents the baseline status of socio economic profile in the area along the river basin in the two states. In Karnataka, where the construction of dams, diversions and power house would take place, the critical issues refer to :

* Submergence of 2145 ha of land due to construction of dams involving :
    - 1608 ha forest area (including 191 ha under river course)
    - 373 ha private land (inclusion of Kalsa and Haltar Diversions for irrigation purposes)
    - 164 ha waste and other Government land
* Change in land use pattern (Deforestation)

Table 4.31
Correlation Coefficient Between Salinity and Log values of Abundance of Phytoplankton

Sl. No.	Species	Season		
		Winter 95	Summer 96	Monsoon 96
Cyanophyceae				
1	Trichodesmium erythaeus	0.0943	0.3527*	0.3309*
Chlorophyceae				
2	Pediastrum sp.	0.1815	0.2439	- 0.4995**
3	Spirogyra sp.	- 0.3910**	- 0.4630*	- 0.2847*
4	Ulothrix sp.	- 0.2681	- 0.0190	0.0152
5	Cosmarium sp.	- 0.1596	- 0.0317	- 0.0677
6	Microasterias sp.	- 0.0377	0.1797	- 0.0657
7	Zygnema sp.	0.0009	0.0787	- 0.1755
Bacillariophyceae				
8	*Cosonidiscus sp.*	0.1739	0.3120	0.3748**
9	*Skeletonema sp.*	0.0742	0.0945	0.4878**
10	*Hemidiscus sp.*	0.1429	0.6396**	0.6452**
11	*Melosira sp.*	0.0113	0.5249**	0.6589**
12	*Stepanophyxis sp.*	0.3428*	0.3999*	0.6572**
13	*Triceratium sp.*	-0.0097	0.5051**	0.5809**
14	*Biddulphia sp.*	0.2496	0.5247**	0.6201**
15	*B.mobiliensis.*	0.3626**	0.5435**	0.6684**
16	*B.sinensis*	0.4503**	0.5832**	0.6481**
17	*Guinardia sp.*	0.5101**	0.4978**	0.5439**
18	*Bellerochea sp.*	0.1540	0.4371**	0.5871**
19	*Ditylum sp.*	0.4484**	0.4829**	0.6834**
20	*Lithodesmium sp.*	0.4444**	0.4297**	0.5679**
21	*Chaetoceros sp.*	0.4140**	0.6325**	0.7128**
22	*Grannatophora sp.*	0.4053**	0.4213**	0.5524**
23	*Canpylodiscus sp.*	0.0494	0.4069*	0.4379**
24	*Planktoniella sp.*	0.1536	0.4838**	0.5211**
25	*Bacteriastum sp.*	-0.0037	0.4280**	0.5654**
26	*Eucampia sp.*	0.1401	0.4532**	0.6387**

Table 4.31 (Contd...)

Sl. No.	Species	Season		
		Winter 95	Summer 96	Monsoon 96
27	*Climacodium sp.*	0.3739**	0.5540**	0.5388**
28	*Streptotheca sp.*	0.0886	0.4157**	0.5379**
29	*Thalassiosira sp.*	0.3216*	0.6464**	0.5458**
30	*T. gravida*	0.2613	0.4574**	0.6074**
31	*Thalassionea sp.*	0.3952**	0.5449**	0.5143**
32	*Rhizosolenia sp.*	0.3102*	0.6673**	0.5233**
33	*R. stolterfothii*	0.0814	0.4274**	0.5244**
34	*R. styliformis*	-0.1305	0.5526**	0.6767**
35	*R. hebatata*	0.0324	0.6023**	0.5494**
36	*Fragillaria oceanica*	0.2223	0.4495**	0.6168**
37	*Thalassiothrix sp.*	0.2770*	0.5251**	0.6312**
38	*T. longissima*	0.3036*	0.4742**	0.6905**
39	*Asterionella japonica*	0.3822**	0.5467**	0.6298**
40	*Gyrosigma sp.*	-0.0771	0.3859*	0.6619**
41	*Pleurosigma sp.*	-0.2725	0.5241**	0.6862**
42	*Navicula sp.*	0.1352	0.4433**	0.6019**
43	*Nitzschia sp.*	-0.1208	0.5239**	0.6608**
44	*N. longissima*	0.1035	0.4685**	0.7840**
Dinophyceae				
45	*Prorocentrum sp.*	0.1479	0.4555**	0.6719**
46	*Dinophysis sp.*	-0.0120	0.5422**	0.6073**
47	*Peridinium sp.*	0.2632	0.4982**	0.5619**
48	*Ceratium tripos*	0.0676	0.4676**	0.5416**
49	*C. fusus*	0.2801*	0.4289**	0.4891**
50	*C. massiliensis*	0.2081	0.5141**	0.4884**
51	*C. furca*	0.2625	0.5406**	0.6620**
52	*Pyrocystis fusiformis*	0.0137	0.4832**	0.6881**
53	*Noctiluca miliaris*	0.1273	0.3928*	0.4652**

* Significant less than equal to 0.05

** Significant less than equal to 0.01

Table 4.32

Correlation Coefficient between Salinity and Log Value of Abundance of Fish

Sl. No.	Species	Season		
		Winter 95	Summer 96	Monsoon 96
Fin Fish				
1.	*Ambassis commersonii*	0.2886	0.1192	0.2690*
2.	*Ambassis dussumieri*	0.2072	0.1330	0.0950
3.	*Awaous grammepomus*	-0.3139*	-0.2729	-0.3007*
4.	*Barilius evezardi*	-0.2417	-0.3046*	-0.1859
5.	*Cynoglossus puncticeps*	0.2248	0.1962	-0.1199
6.	*Danio devario*	-0.3819*	-0.3147*	-0.2791*
7.	*Etroplus suratensis*	-0.0537	0.1210	0.0870
8.	*Garra gotyla gotyla*	-0.2398	-0.2802	-0.2309
9.	*Gonoproktopterus thomassi*	-0.2330	-0.1957	-
10.	*Labeo kawrus*	0.1219	0.1446	-0.1562
11.	*Leiognathus blochii*	0.2581	0.2891	-
12.	*Mugil cephalus*	-0.1343	0.0162	0.1076
13.	*Nemacheilus rubidipinnis*	-0.3394*	-0.6501**	-0.3172**
14.	*Osteobrama dayi*	-0.4227**	-0.2794	-0.3313**
15.	*Pseudorhombus arsius*	0.1181	-0.0677	-
16.	*Parluciosoma daniconius*	-0.5122**	-0.4428**	-0.2254
17.	*Puntius filamentosus*	-0.3999**	-0.3348*	-0.3357**
18.	*P. amphibius*	-0.1719	-0.3380	-0.1685
19.	*P. nigrofasciatus*	-0.1719	-0.3874*	-0.1182
20.	*P. ophiocephalus*	-0.2455	-0.2802	-

Table 4.32 (contd...)

Sl. No.	Species	Season		
		Winter 95	Summer 96	Monsoon 96
21	*P. arulius*	-0.1719	-0.3660	-0.1642
22	*Rasbora neilgherriensis*	-0.1719	-0.5683**	-0.2966*
23	*Sieyepterus graseus*	0.2740	-0.3117*	-0.2073
24	*Scatophagus argus*	0.1710	0.0431	-0.0947
25	*Sillago sihama*	0.0957	0.0276	-0.1030
26	*Stenogobius gymnopomus*	-0.0120	0.0735	0.1980
27	*Teuthis vermiculata*	0.3439*	0.3496*	-
28	*Chanos chanos*	0.2706	-0.2802	-
Shell Fish				
29	*Macrobrachium malcolmsoni*	-0.4884**	-0.4979**	-0.4082**
30	*Metapenaeus affinis*	0.3134*	0.2251	-
31	*M. monoceros*	0.4127**	0.0800	-0.2023
32	*M. dobsoni*	0.1985	0.0788	0.2528*
33	*Penaeus marguiensis*	0.0771	0.1260	0.2757*
34	*P. indicus*	0.2125	0.0194	-
35	*Scylla serrata*	0.0640	0.2145	-0.1088
36	*Unidentified (small crab)*	-0.2981	-0.2685	-0.1182
37	*Macrobrachium rude*	-0.4545**	-0.1896	-0.2741*
38	*Villorita cyprinoides*	-0.3346*	-0.0179	-0.1956
39	*Meretrix meretrix*	0.2759	-0.0339	-
40	*M. casta*	-	0.2000	-
41	*Paphia malabarica*	0.2174	0.2011	-

* Significant less than equal to 0.05
** Significant less than equal to 0.01

Forest land - 330 ha (needed for other purposes, viz. roads, township etc.). Thus, the total forest area affected is 1938 ha (1608 + 330).

* Rehabilitation and Resettlement (R and R) of the PAPs

	1981 Census	1991 Census
Fully submerged villages :	3	3
Project affected Population (PAP) :	427	620
No. of affected households :	78	114

* Compensation to the project affected population (PAP) besides R & R.

* The other related issues are :

  - Effect on agricultural activities in the area due to submergence/ acquisition of agricultural land for the project

  - Employment opportunities and income generation leading to change in economy (auxiliary and ancillary industries due to power supply)

  - Health risks

  - Influx of migrant population and strain on existing infrastructure

  - Change in life style of the local people

  - Change in aesthetic and cultural attributes in the area

In Goa, where the Mahadayi/Mandovi flows for a length of 80 km before joining the Arabian Sea near Panaji, the critical issues with reference to the MHEP are :

* Effect on agricultural activity in the area due to changed flows arising from the impoundage and regulated release of water for power generation. This may lead to a change in existing irrigation practices in a few stretches, viz. saline to fresh water

* Change in the life style of the local people

4.9.1 Demography

Along Mahadayi river in Karnataka, there are 25 villages in Khanapur taluka of Belgaum district. The demographic details for these villages are presented in **Annexure 4.8, Table 1** and summarised in **Annexure 4.8, Table 2**. The significant observations are :

- Land area in these villages is 37953 ha
- Total population is 11080 with a density of 291 per sq.km
- Sex ratio is 992 (females per 1000 males)
- Scheduled Tribe population is not recorded in the census
- Scheduled Caste population is rather negligible, viz. 4.93% of the total population
- Literacy rate is 32%
- Employment rate is 50% of the total population **(Fig. 4.34)**
- Cultivators, agricultural labours and those engaged in live stock occupations constitute 94% of the total main workers
- Only 2-3% of the workers are engaged in occupation allied to trade and commerce, and industries

Along the river Mandovi in Goa there are 18 villages. The villagewise demographic details are presented in **Annexure 4.8, Table 3** along with a summary of the same in **Annexure 4.8, Table 4**. The significant observations are :

- These villages are spread over six talukas, viz. Ponda, Tiswadi, Satari, Panaji, Bicholim and Sanguem
- Total land area of these villages is 15997 ha
- Total population is 43809 with a density of 273 per sq.km
- Sex ratio is 954 (females per 1000 males)

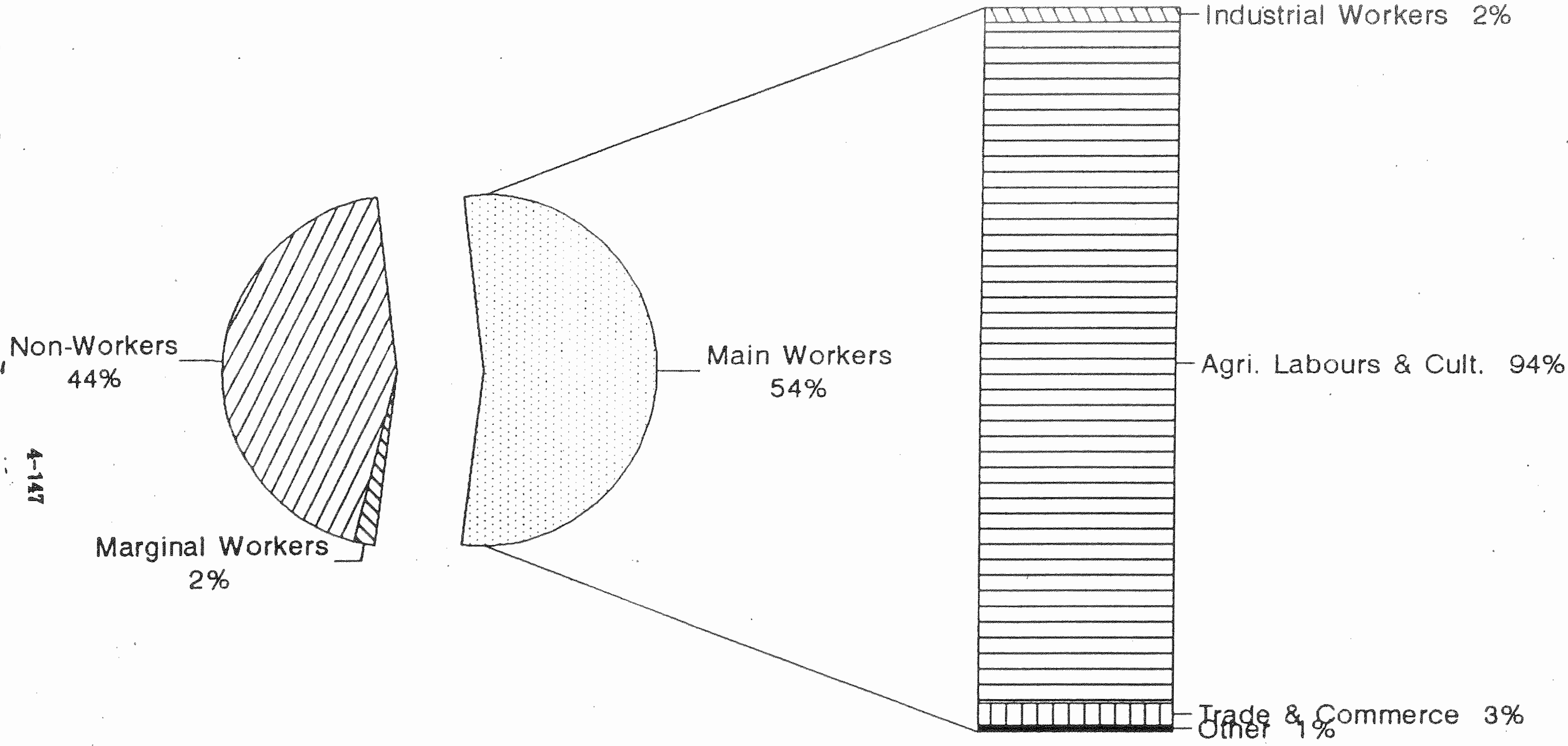


Fig. 4.34 : Employment Pattern in the Study Area
(Karnataka, Villages along the Mahadayi River - 1991)

- Scheduled Caste is 1.26 % of the total population

- Scheduled Tribe population is very negligible, only 2 individuals (1991 census) are recorded

- Literacy rate is 66.2% which is rather good

- However, the employment rate is only 34.29% indicating a mismatch between literacy and employment. The employed are evenly distributed, viz. 30% in agriculture, 18% in industries, 19% in trade and commerce and 23% in other fields such as fishing etc. **(Fig. 4.35)**.

4.9.2 Infrastructure

The main infrastructural support viz. transport, communication, market for the project is available at Khanapur, the taluka HQ on Belgaum-Panaji National Highway (NH4) and the focal point for access to the project site and Belgaum (the district place).

Khanapur is the nearest rail station on broad gauge, the South Central Railway. The nearest airport is Belgaum and the nearest sea port is Margoa. The infrastructure resource base of the villages within the study area of Mahadayi river is presented in **Annexure 4.8, Table 5.**

In Goa, at present the communication between urban and rural areas is satisfactory as the villages are closely connected to urban centres by efficient network of roads and transportation facilities. This facilitates good amount of marketing and other allied activities.

Tiswadi, Ponda and Satari talukas have good educational facilities. Facilities for higher technical education like engineering, medicine etc. are available only at Panaji.

4.9.3 Economy in the Region

In Belgaum district, for Khanapur taluka as well as in North Goa, agriculture is the main source of livelihood. Fishery is an important economic activity of the people of Goa. Fish forms the staple food for 90 % of the population of Goa and is always an added attraction for tourists.

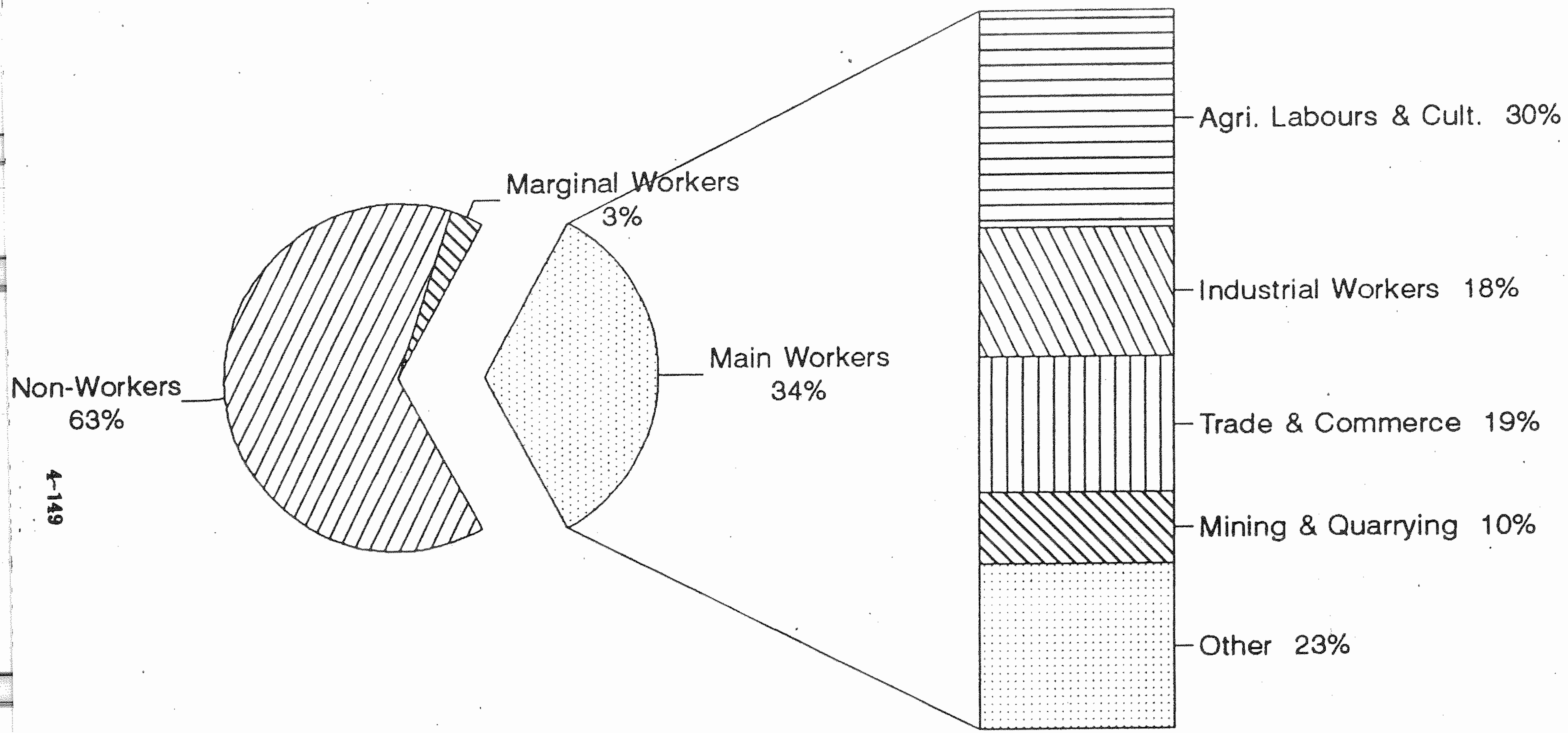


Fig. 4.35 : Employment Pattern in the Study Area
(Goa, Villages along the Mandovi River - 1991)

The harbour at Margoa provides employment as well as business opportunities to the local people.

In Goa, tourism is a very lucrative business and provides ample income sources for the local people. This percolates to the villages eventually. Forestry and mining are the other sources of income for villagers. Animal husbandry including poultry, piggery, dairy etc. which has been developed only during the post liberation period has a good potential for economic growth, and this has provided gainful supplementary source of income to the rural population.

Satari taluka, with its abundant water resources for green fodder cultivation, has the highest potential for dairy development in the North Goa district, followed by Ponda, Sanguem, Quepem, Bicholim and Canacona.

4.9.4 Health Status

The data on morbidity pattern in Kanakumbhi (Belgaum) is presented in **Annexure 4.8, Table 6**. However, the major health issues would refer to mosquito-borne diseases, viz. malaria and filaria by introduction of the vector due to influx of labour from different places during the construction phase though no cases for these diseases are recorded in the Public Health Centres.

In many of the villages and towns of Goa (**Annexure 4.8, Table 7**) waterborne diseases are endemic due to lack of necessary hygienic conditions, and potable water as reported during the survey.

4.9.5 Cultural and Aesthetic Attributes

In the study area no places of archaeological or historical importance are recorded excepting three small temples within the villages along the river.

The tribal population in the study area in Karnataka is negligible and as such does not call for any special mention.

In Goa, there are three wild life sanctuaries at Bondla, Mollem and Cotigoa with a total area of 353 sq.km representing nearly 33 % of the forest area and 10 % of the total geographical area. There are places of religious importance viz., temples and churches as well as attractive sea beaches. No negative impacts on these places are envisaged due to the project activities.

4.9.6 Socio Economic Survey

A socio-economic survey of the adult population was conducted in some representative Project Affected Villages (PAV) along the Mahadayi with the help of a pre-designed set of questionnaires (**Annexure 4.8**). The sampling was random stratified and proportionate. The field survey was addressed to the Quality of Life (QOL) of the people, their awareness, opinion, apprehensions and expectations from the proposed project. The methodology followed for evaluating the QOL is at **Annexure 4.8**. The Quality of Life is presented as an index (subjective and objective evaluation) (**Annexure 4.8, Table 8**).

The significant observations are :

* 100% awareness about the project amongst respondents

* The respondents opinion, inspite of the land acquisition and loss of agricultural land, is favourable in general, as 60-90% expressed 'Good' opinion about the project. This possibly is due to their aspirations about better job opportunities and infrastructure facilities due to the project **(Fig. 4.36)**

* The respondents expressed fear about loss of housing and other belongings, viz. fruit trees etc. due to the projects **(Fig. 4.37)**

However, the people in general aspire for betterment, and feel that an appropriate R & R would do so effectively.

The details of the project affected villages, fully submerged and partially submerged with reference to the status of land owners, total households and population affected are presented in **Annexure 4.8, Table 9 and Table 10**.

The employment pattern in the fully submerged villages need special consideration while designing the R & R package. Out of the total workers of 283 in the three villages approximately 44% are cultivators, 5% are agricultural labour. Non-cultivators (51%) are engaged in jobs other than agriculture. As such, nearly half of the affected population is dependent on agriculture.

Due to the rich forest in the area, people are engaged in forest based occupations such as collection of leafy vegetables, bamboo shoots and other forest produce, manufacturing agricultural implements from forest wood, acquiring

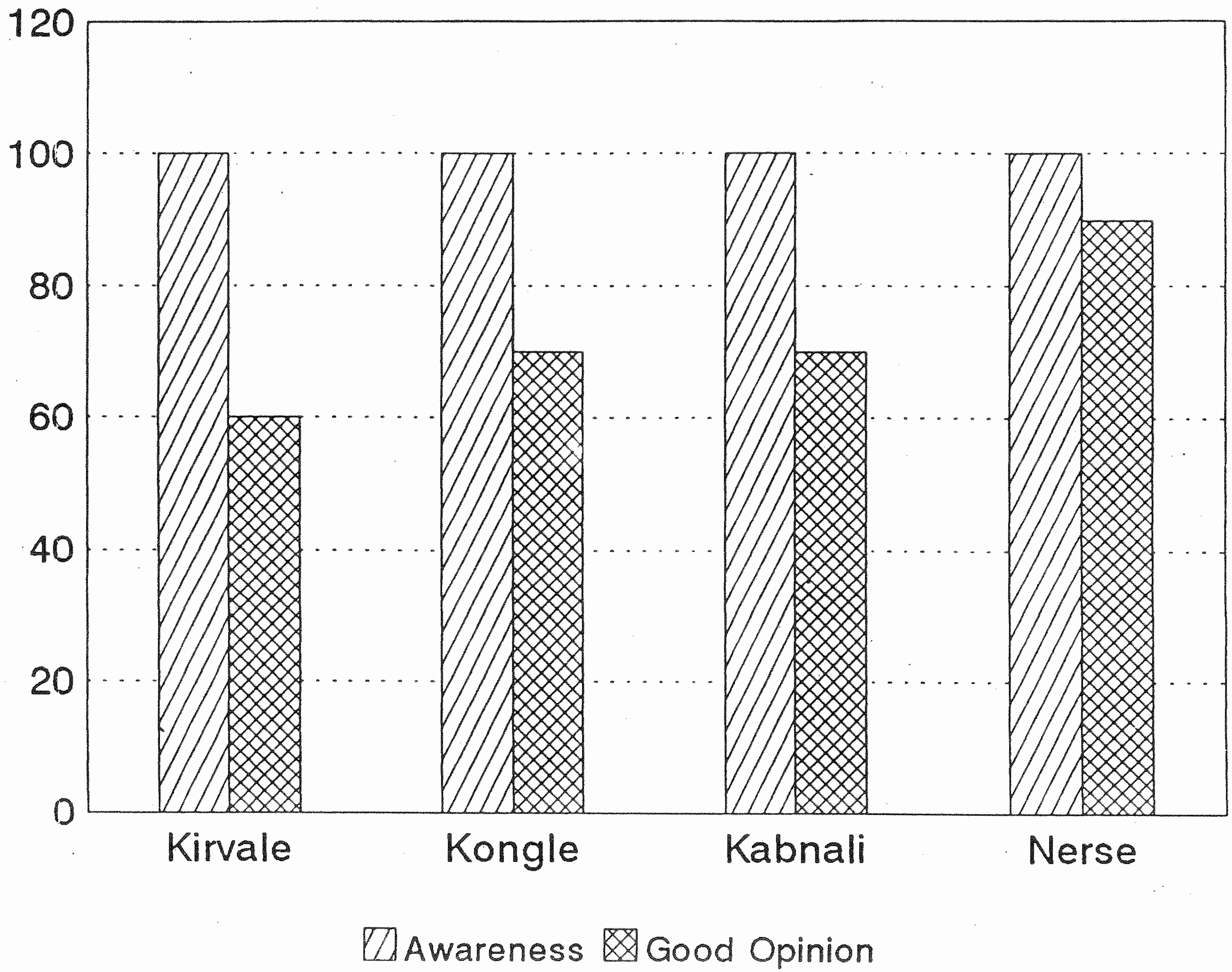


Fig. 4.36 : Opinion About the Project

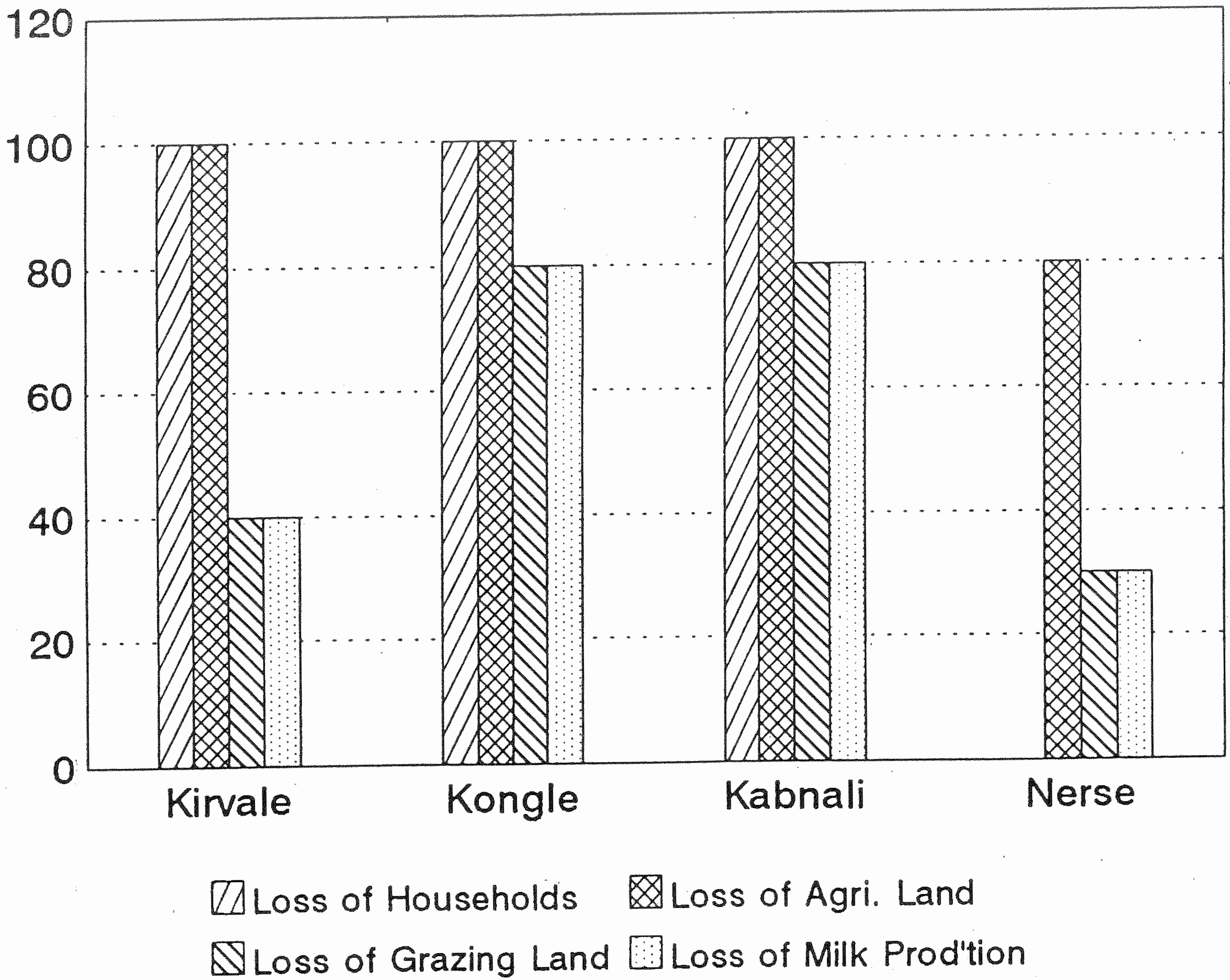


Fig. 4.37 : Adverse Impacts of the Project Activities

material for house construction as well as collection of fuel and fodder. Cattle, goat and sheep are the main livestock owned by the households.

Availability of infrastructure in the affected villages also needs to be looked into while designing the R & R package. The basic amenities are very scanty in these villages. The schools lack furniture, reading material, teaching staff etc. The same is the case with the PHCs.

4.9.7 Specific observations in the Project Affected Villages (PAV) along the Mahadayi river (Karnataka)

i. Kongla: This village would be fully submerged and all the households and agricultural land would be affected by way of land acquisition and displacement of population. Demands of the people are alternate land for the acquired land, housing and employment. Some people are willing for cash compensation against the acquired land.

Main occupation of the local people is agriculture. Paddy and sugarcane are the main crops. River water is used for irrigation. Due to the rich forest in the area, people are engaged in forest based occupation, viz. collection of honey and wood.

Basic amenities are available to some extent but still dissatisfaction prevails. Some people have encroached upon Govt. land (specific forest land) for agriculture.

ii. Nerse: This village would be partially submerged and only the agricultural land would be lost. The main demand of the people is alternate agriculture land since agriculture is the main occupation with canal as a source of irrigation. Paddy and sugarcane are the main crops, and the people are satisfied with the irrigation facilities. Water supply is also satisfactory. Basic amenities, such as education, medical and transport, communication are available to some extent but dissatisfaction prevails among the people. As regards ailments, no specific diseases were reported.

iii. Kirvale: This village would be fully submerged. As such loss of agricultural land and displacement of population are the critical issues. However, people are ready to shift to alternate location. Cultivation and agriculture are the main occupation of the people with paddy as the main crop.

Infrastructural facilities are very negligible, and dissatisfaction prevails amongst the people. Malaria and common fever are rampant in the village.

iv. Kabnali: This village would be fully submerged. All the households and population would be affected due to land acquisition and displacement of population. Households would be shifted to other places but the alternate location is not decided yet. People's demands are alternate land for land, house for house as well as employment.

Main occupation of the people is agriculture and cattle rearing. River water is used for irrigation. Paddy is the main crop and is harvested twice a year. Basic amenities are very negligible. There is no approach road to the village.

4.9.8 Specific observations in the villages along the Mandovi River (Goa)

i. Sonali: People are engaged in agriculture and business. Rice and cashewnut are the main crops and are harvested once a year. People reported that irrigation facility is not adequate. Approximately 30 to 40 per cent of land is rocky and is not under cultivation. Infrastructural facilities are available to some extent in the vicinity.

ii. Birondem : Main occupation of the people is agriculture and horticulture as well as other jobs, viz. transports, labours, services, shops etc. Paddy, banana, coconut and jackfruits are the main crops and the farmers get good revenue from agriculture. Basic amenities are available to some extent but dissatisfaction prevails amongst the people. The people reported about drinking water scarcity, particularly in summer.

iii. Sawarde: Agriculture and horticulture are the main occupations of the people. Paddy, coconut and banana are the main crops. Almost all the farming is rain dependent. Basic amenities are available in the vicinity (Voipoi) but dissatisfaction prevails amongst the people.

iv. Ganjem: Agriculture is the main occupation of the local population. Besides agriculture, people are engaged in various jobs and services. All infrastructure facilities are available in the vicinity but dissatisfaction prevails regarding communication and medical facilities.

People reported that Mandovi river water is used for drinking and agricultural purpose. The main crops in the area are paddy, chilly, onion, sugarcane, coconut, banana, supari which find a ready market in Panaji, Ponda, Satari and old Goa.

v. Usgaon: The local people get good revenues from mining, agriculture, fishing and other business. All infrastructural facilities are available in the village. People reported that the water quality is not good and there is air pollution in the mining area due to dust and noise.

vi. Volvoi: Main occupations of the villagers are agriculture, fishing and sand supply to Panaji and Ponda. Sand is dredged from river for use as building material. People started this business due to saline nature of river water. River water is not used for agriculture and drinking purpose. Rice, vegetables, chilly, coconut are the main crops. People opined that due to the project activities, water table of the Mandovi river may go down and will cause adverse impact on fishing. All infrastructural facilities are available to some extent in the village but are not upto satisfactory level.

vii. Beteui: Main occupation of the villagers is agriculture. Besides agriculture, people are engaged in business and service. Rice, vegetable, supari, coconut, banana are main crops. Irrigation facility is sufficient. All infrastructural facilities are available to some extent. People reported regarding air pollution and noise pollution due to industries. They also stated that Mandovi water cannot be used for drinking and irrigation as it is saline.

viii. Marsela: Main occupations of the villagers are business, and agriculture. Rice is the main crop and is harvested twice a year. All infrastructural facilities are available in the village but dissatisfaction prevails regarding drinking water and medical facilities.

ix. Old Goa: People are engaged in various jobs viz. agriculture, horticulture, service, fishing, transports, hotels, shops etc. People expressed satisfaction regarding income and employment, and the standard of living is good. Mandovi river water is not used for agriculture and drinking purpose as the water is saline. All infrastructural facilities are available in the vicinity. People reported that crime rate has increased in the area. Medical facilities are available in the area but dissatisfaction prevails among the people due to inadequacy and bad quality of services.

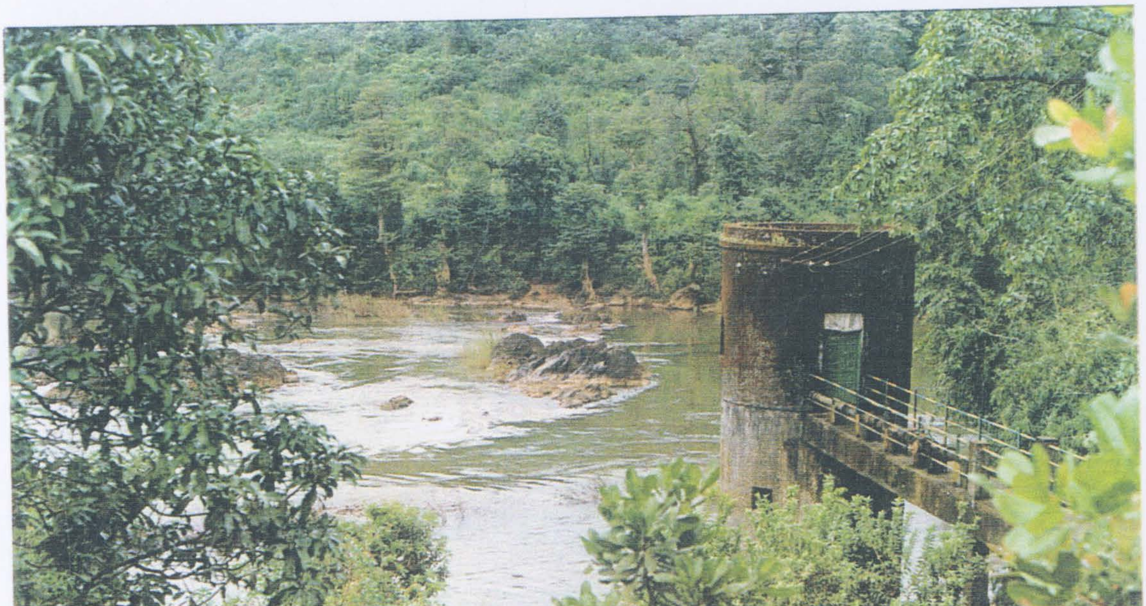
Photograph 1 : Thick Vegetation and Forest Cover in the Submergence Area of Kotni Dam

Photograph 2 : Water Sampling in the Mahadayi near Kotni Nala Confluence

Photograph 3 : Netting Operation for Fauna
in Mandovi (Goa)

Photograph 4 : Sampling in Mandovi Estuary

Photograph 5 : Mining Activity on the Right Bank of Mandovi in Goa



Photograph 6 : Bondla Water Supply Intake on Mandovi at Ganjem with a Natural Water Fall in the River Preventing Salinity Ingress Upstream

5. Identification of Impacts

5. Identification of Impacts

5.1 General

The major step involved in the process of environmental assessment is the identification of impacts as it leads to other steps such as quantification and evaluation of impacts. In order to identify and evaluate the impacts associated with the project, it is necessary to establish a general checklist and describe the existing environmental quality in the area under development, and the activities of the project which may cause environmental impacts. Although the impacts have been identified in general while describing the existing environmental status, it is necessary, at this stage, to identify for the various environmental components, the significant impacts that are likely to arise due to the Mahadayi Hydro Electric Project.

While a number of techniques like checklists, past incidents, interaction matrices and network method are available for identification of impacts, in the present case, the "Network Method" which involves understanding of the cause-condition-effect relationship between an activity and environmental parameters, has been adopted. This method has been basically advantageous in recognizing the impacts that would be triggered by the proposed activities and provides a "road map" type of approach for the identification of second and third order effects. The purpose is to account for the project activities and identify the type of impacts which would initially occur. The next step is to select each impact and identify the secondary and tertiary impacts which will be induced as a result. This process is repeated until all possible impacts are identified. The major advantage of this type of approach is that it allows identification of the impacts by selecting and tracing out the events as they are expected to occur.

5.2 Impact Networks

In the backdrop of data collected during the site visits, information furnished by the concerned authorities and the list of project activities described earlier in this report, the 'cause-condition-effect' networks have been generated for the various components of the project and presented in **Figs. 5.1** through **5.5**. In these illustrations, the lines are to be read as "has an effect on".

Pre-construction activities are those taken up prior to start up of the actual construction of the project and include land acquisition, and rehabilitation and resettlement. They may not have any direct impact on environment as such but may lead to socio-economic impacts from the local inhabitants who are likely to be

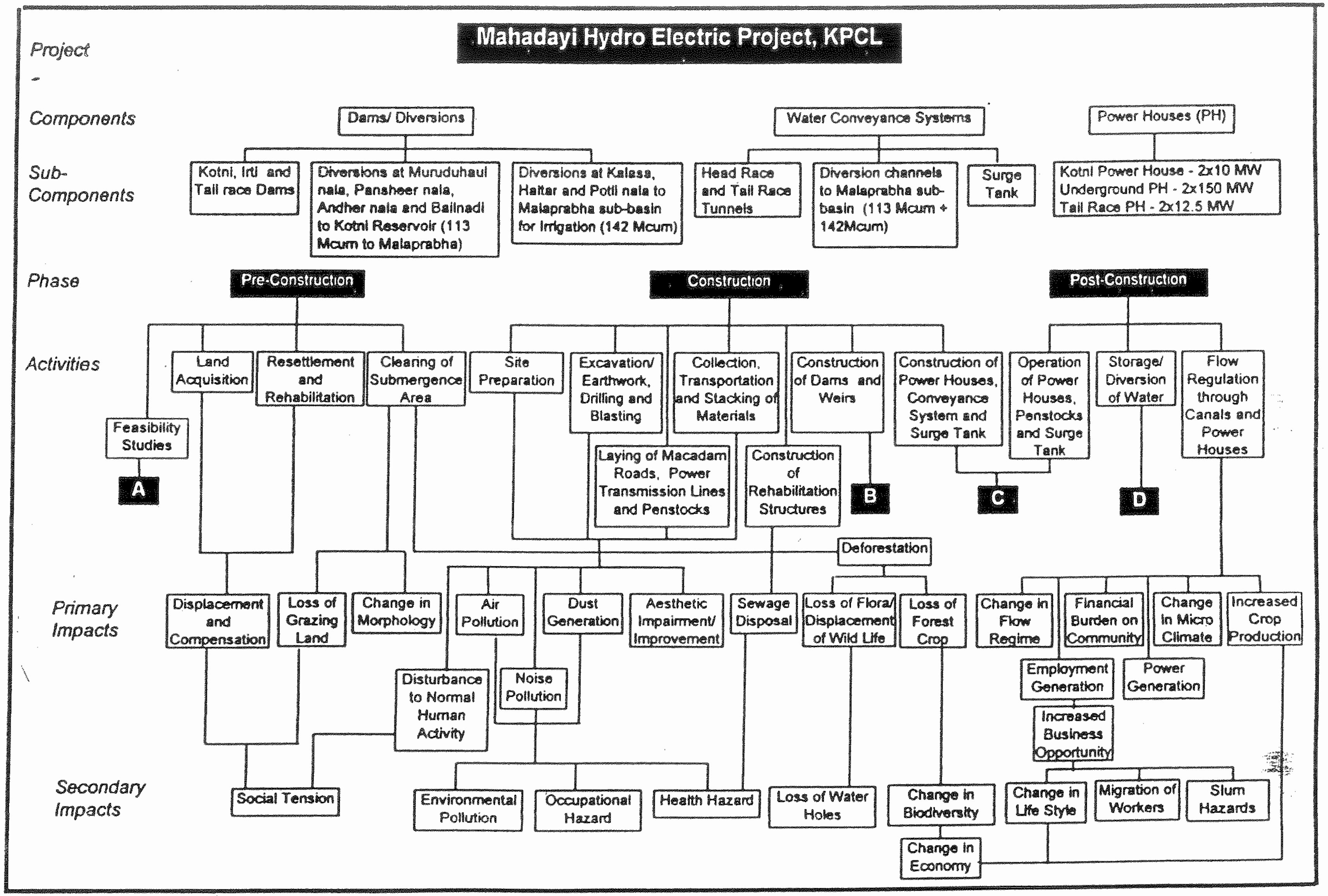


Fig 5.1: Environmental Impact Network

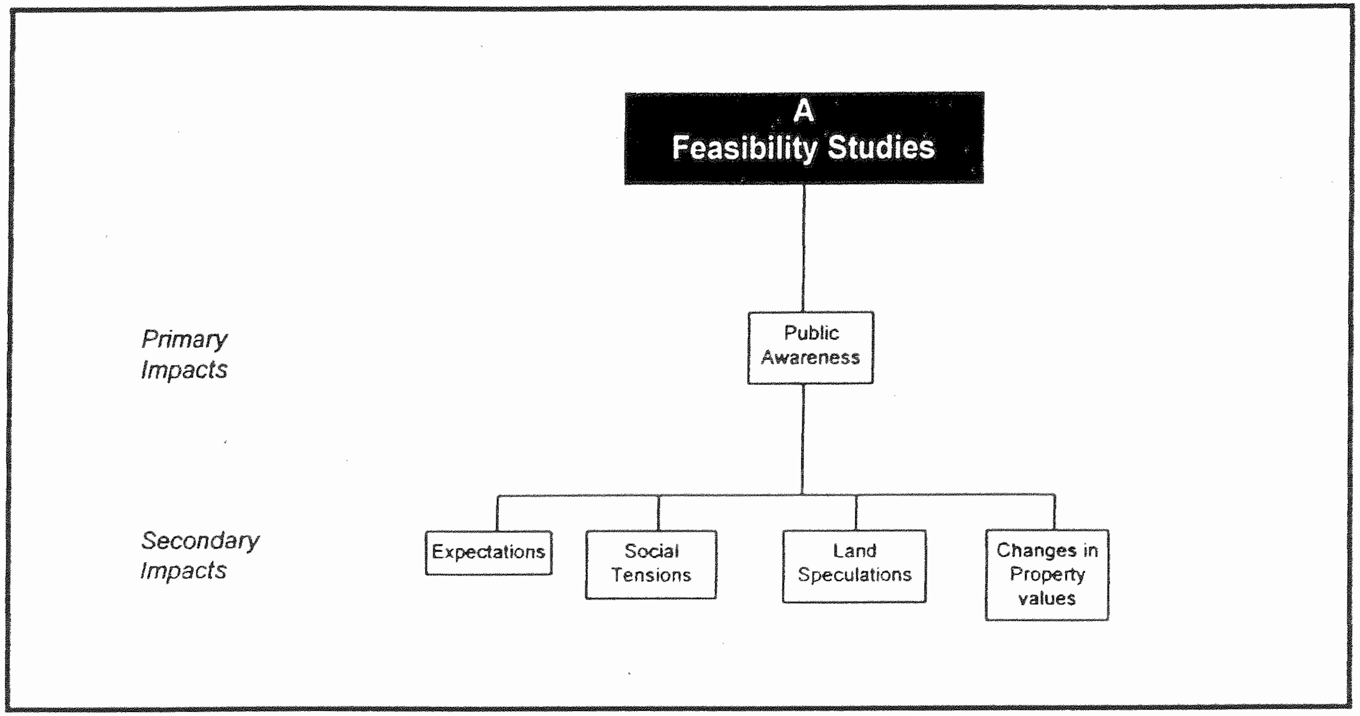


Fig. 5.2: Environmental Impact Network - Feasibility Studies

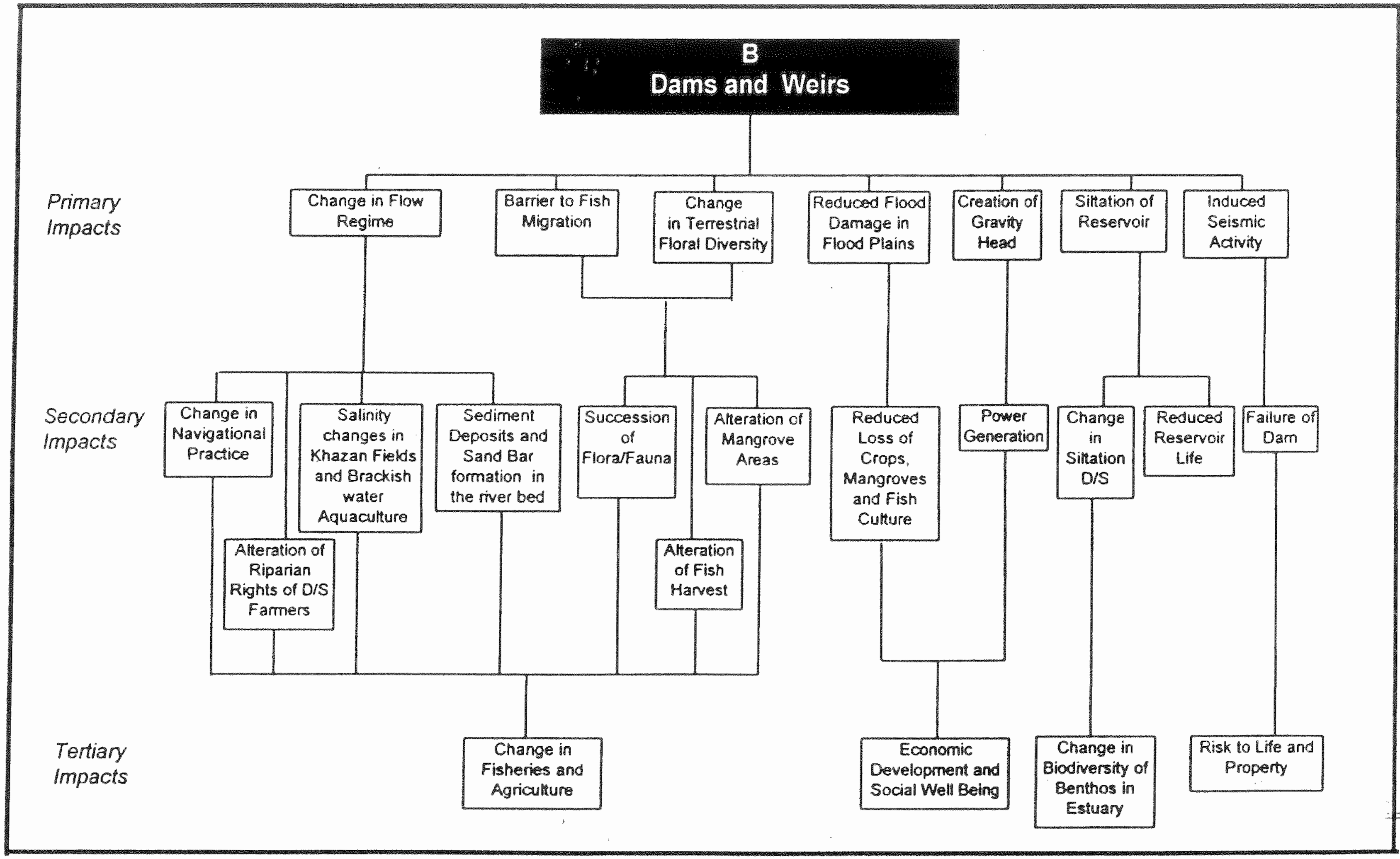


Fig. 5.3 : Environmental Impact Network - Dams and Weirs

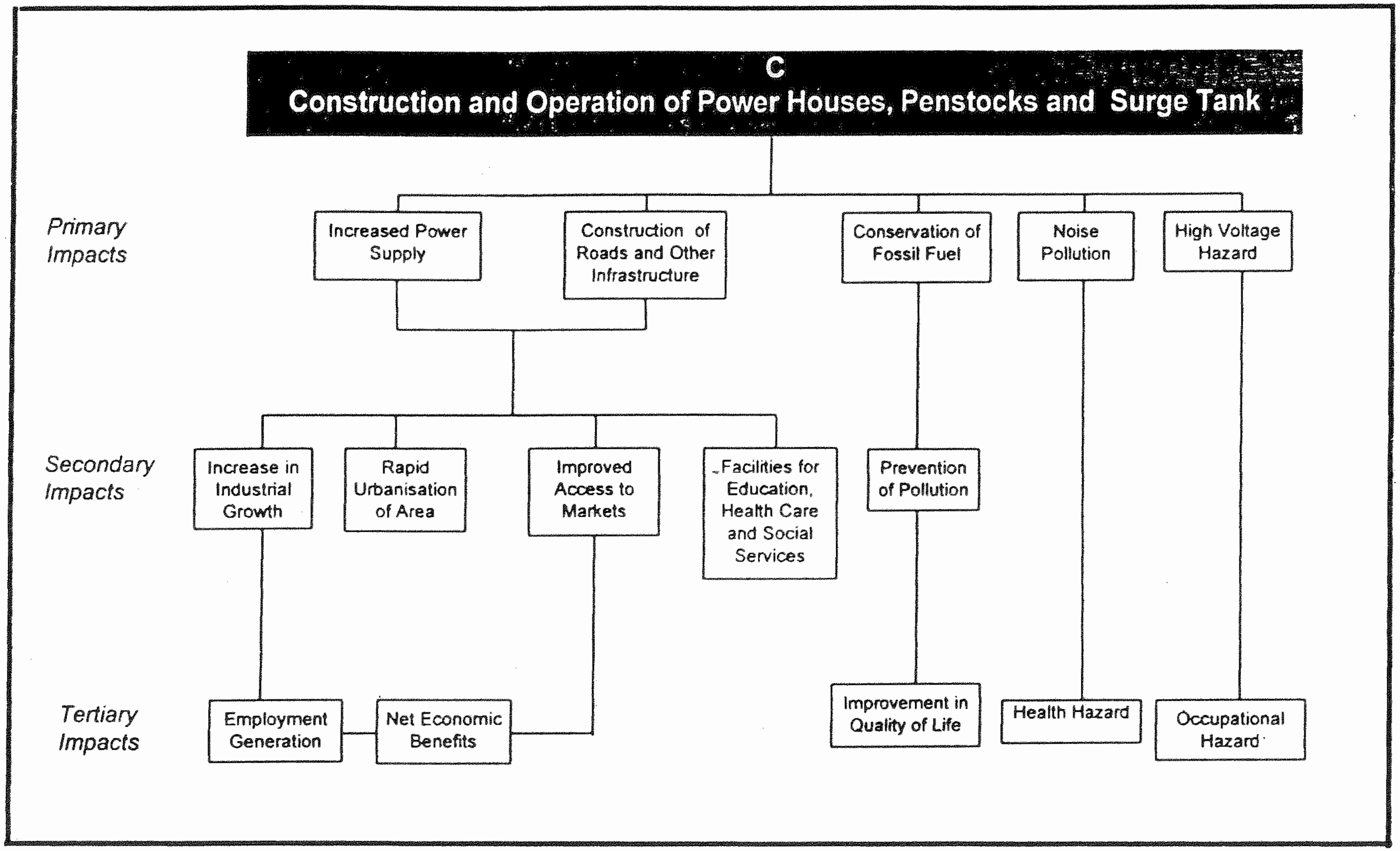


Fig. 5.4 : Environmental Impact Network - Construction and Operation of Power Houses, Penstocks and Surge Tank

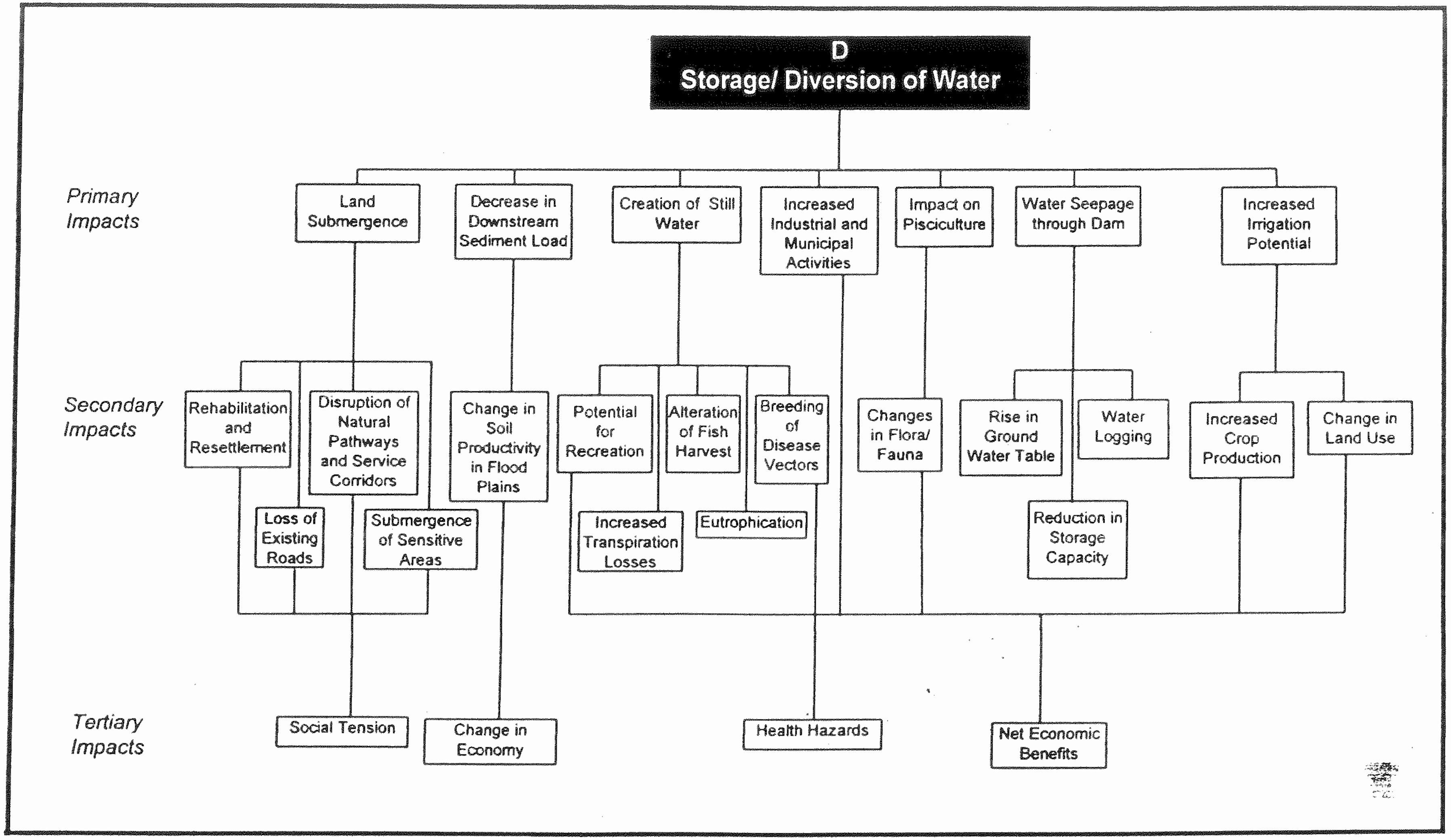


Fig . 5.5 : Environmental Impact Network - Storage/ Diversion of Water displaced and relocated or lose their properties due to land aquisting or submergence of the area.

Construction activities cause land alterations in accordance with the project design and a variety of physical-chemical, ecological, aesthetic and socio-economic impacts of varying duration and magnitude. Physico-chemical changes occur during construction mainly due to clearing of vegetative cover at the site thereby causing soil erosion resulting in turbidity in surface runoffs. Ecological impacts occur due to removal of forests and field habitat which result in destruction of terrestrial organisms. Socio-economic impacts that occur during construction relate to generation of employment, displacement of families, loss of natural resources coming under submergence etc.

Operation involves various activities and includes reservoir filling, flood control and other functions such as pumping, conveyance and release of water, generation of electricity, all of which can cause impacts on flow regime in the river, ecology, aesthetics, socio-economics and health.

5.3 Potential Environmental Impacts

The major components of the MHEP are works related to construction of dams and filling of reservoirs, construction of conveyance systems, creation of necessary infrastructure such as housing and other facilities for O & M personnel.

The environmental impacts due to the proposed project activities are broadly identified as under:

* Impact due to land acquisition, compensation thereof, resettlement and rehabilitation of project affected persons in the submergence area

* Alterations in terrestrial flora and fauna due to site clearance, construction of dams and formation of reservoirs

* Impact due to likely seismic activity due to the construction of dams and formation of reservoirs

* Siltation of the reservoirs with consequent change in the sediment supply downstream

* Moderation of floods due to reduction in peak floods

* Rise in noise levels due to the project activities

* Deterioration of air quality in the near viscinity during construction activities

* Micro climatic changes in the surrounding area due to formation of reservoirs

* Improvements in the infrastructural facilities like roads, communication and water supply

* Aesthetic improvement/impairment due to construction of dams

* Impact on social well being/ community

* Impact on the agricultural practices due to irrigation facilities

5.4 Significant Environmental Impacts

* Loss of forest area coming under submergence and construction of infrastructural facilities

* Change in the flow regime in river Mahadayi/Mandovi due to the construction of dams and regulated water release for power generation

* Changes in eco-system of river Mandovi in Goa and its surrounding areas due to change in the flow regime

* Impact on mangrove and Khazan paddy fields due to change in salinity in the river as a result of modified flow regime

* Improvement in the power supply leading to industrialisation, employment generation, housing etc.

6. Prediction of Impacts

6. Prediction of Impacts

6.1 General

Prediction of impacts is the most important component in environmental assessment studies. This helps to identify and implement the Environmental Management Plan (EMP) during and after the implementation of the developmental projects to minimise the deterioration in environmental quality.

The Mahadayi Hydro Electric Project aims at augmenting the existing power supply by 345 MW to mitigate the chronic power shortage experienced by the state of Karnataka. The project also envisages diversion of 255 Mcum of water from the Mahadayi sub-basin to Malaprabha sub-basin to augment the irrigation supplies in Belgaum district and parts of Dharwad and Bijapur districts. In this section, the most probable significant impacts on various components of the environment due to the proposed activities are predicted based on available information, the baseline status of the environment in the study area; and using scientific knowledge and techniques as appropriate.

6.2 Impact on River Hydrology

6.2.1 Construction of Dams/ Diversions

The impact of construction of dams and operation of large reservoirs can be two fold, (i) immediate/short term and (ii) long term effects. These can be grouped as (a) hydrological and (b) ecological effects.

The reservoir formed behind a dam has two significant effects on the river downstream (i) moderation of floods resulting in reduction of peak floods : the reservoir formed by the construction of the Kotni dam retains part of the flood flows as storage. Due to the large storage available upstream of the dam, the flood peaks get moderated (to 89% of the present average) resulting in reduction in peak floods downstream; (ii) cut off of sediment supply : due to considerable reduction in velocity of flow, the sediment load carried by the river gets settled in the reservoir, and relatively sediment free water flows over the dam spillway.

The Mahadayi river bed downstream of the tail race dam upto Ganjem being completely rocky in nature, the chances of it picking up additional sediment load from the river bed are meagre, particularly so during the lean flows.

6.2.2 Sediment Transport, Reservoir Sedimentation and Sand bar formation due to change in the flow regime

In order to examine, through mathematical modelling, the sediment deposition in the dam at Kotni, it is necessary that the river cross sections at various locations upstream of the reservoir are known. Since the available information is limited, the alternative to achieve this objective is to rely upon empirical equations. Accordingly, the following empirical equations have been used for computing the annual rate of sediment deposition in the Kotni reservoir.

1. Khosla Equation
2. Dhruva Narayan and Babu Equation
3. Garde and Kothyari Equation
4. Iso-erosion Rate Lines
5. Suspended Sediment Measurements
6. CWC Compendium

The detailed computations using these equations are presented in **Annexure 6.1**. The deposition of sediment load computed using these equations is given below:

	Equation	Sediment Deposition Rate (Vs) (Mcum/year)
1.	Khosla	0.103
2.	Dhruva Narayan and Babu	0.410
3.	Garde and Kothyari	0.059
4.	Iso-erosion Rate Lines	0.047
5.	Suspended Sediment Measurements	0.033
6.	CWC Compendium	0.316

It can be seen from the results that the value of sediment deposition rate (Vs), varies from 0.033 Mcum to 0.410 Mcum per year. The KPCL has provided for a dead storage in the Kotni reservoir up to R.L. 627.00. The elevation-capacity curve (**Fig. 6.1**) reveals that corresponding to R.L. 627.00 the capacity of the reservoir would be about 60 Mcum. Therefore, considering even the highest value of Vs equal to 0.410 it will take about 150 years to fill up the dead storage. Thus, it can be concluded that the useful life of the reservoir will be at least 150 years for generation of power as per the proposed plan.

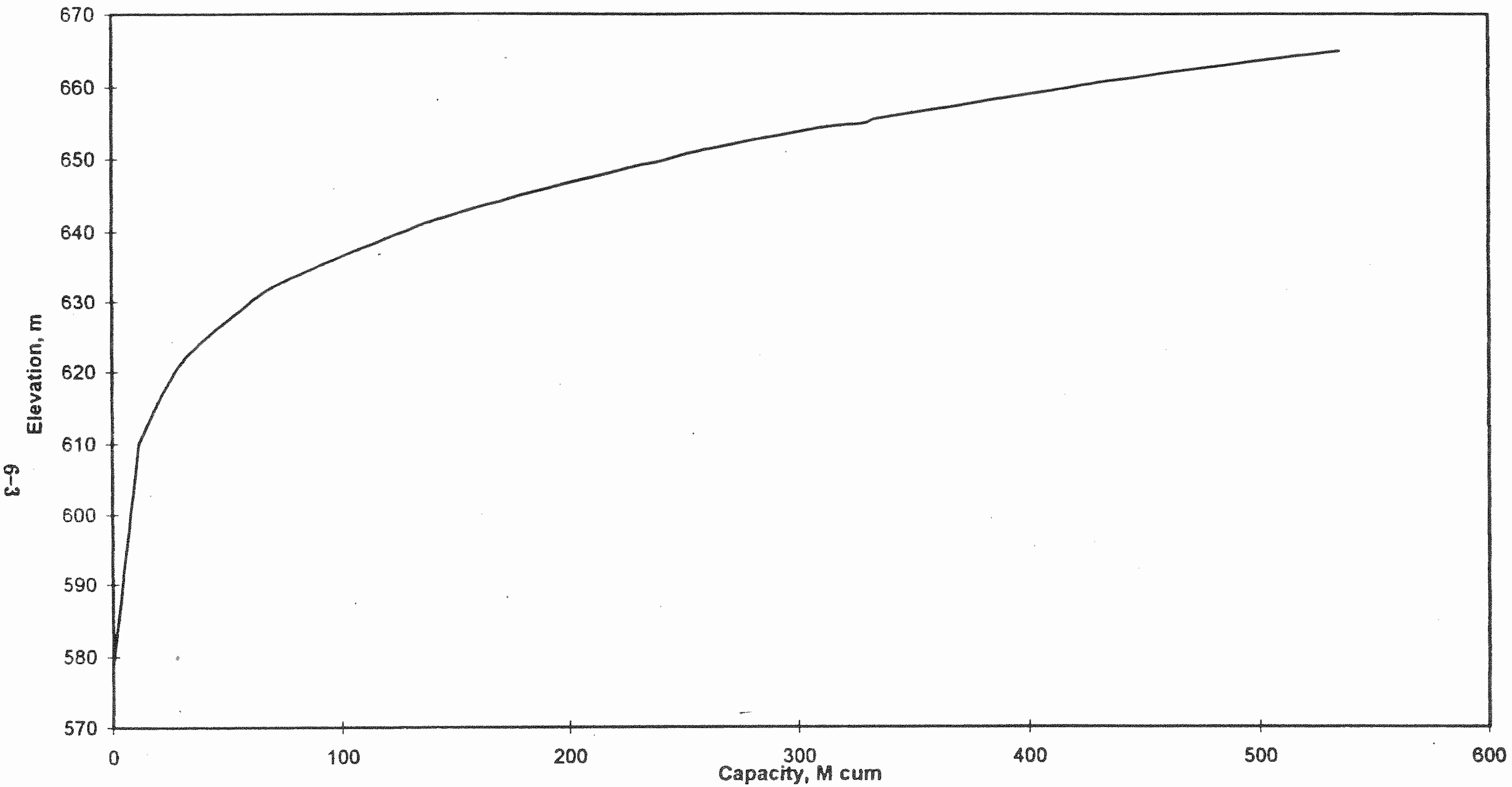


Fig. 6.1: Capacity curve for Kotni Reservoir

6.2.3 Flows in River Mahadayi at Ganjem

Data on the flows in the Mahadayi, measured by the CWC at Ganjem for the period 1979 - 1992, is presented in Table 4.6. In keeping with the operation schedule proposed by KPCL for release of water from Kotni dam, the pre and post project flows at Ganjem are presented in **Table 6.1**. The MHEP envisages diversion of only 4-5% of the runoff at Ganjem to the Malaprabha basin for irrigation use. If the total runoff for the entire Mahadayi basin is considered, the proposed diversion (255 Mcum) for irrigation purpose would work out quite insignificant (about 2 to 3%) because from Ganjem to Panaji an additional runoff of 40-50% would join the river Mahadayi before it joins the Arabian Sea. It is further evident from a comparison of the pre and post project flows in the Mahadayi that during monsoon (i.e. July and August) the flow in the river would be less by about 20%. This is desirable as it would moderate the peak floods which otherwise may cause inundation of the low lying areas in Goa. On the other hand, the flows during September and October would remain unaltered due to the release of water from Kotni reservoir for power generation. From November to May, the flows in the Mahadayi would be larger compared to that in the river during the same period prior to the construction of the MHEP. Eventhough the post project flows would be more during the lean season, they are not so high as to create problems of scouring the river bed. The flows in the river Mahadayi during summer in post project scenario would be of the same order as that in the river during October/November before construction of the dams. It is expected that during post monsoon period the water flowing in rivers is generally silt free due to absence of severe overland flow. During this period the rivers attain stable equilibrium and this state will continue till the subsequent monsoon due to the releases from the dams in Karnataka. Thus, it can be concluded that there would neither be erosion nor deposition in the river Mahadayi upto Ganjem due to the proposed project.

Fig. 6.2 depicts the logical water levels expected in river Mahadayi from the border of Karnataka to Arabian sea. It is reported that sand bar formation takes place somewhere around Amone. This material (i.e. sand) reaches the river Mahadayi from around Amone by the process of overland flow during monsoon especially through the mine spoil dumps from within Goa. This can be clearly seen in **Photograph 7** taken during the field visit. The forward velocities of the main flow in the river Mahadayi are not sufficient enough to keep it in suspension and transport the same further. Therefore, the same is being deposited somewhere around Amone (**Photograph 8**). It is noted from Fig. 6.2 that the backwater effect is upto Usgaon Pali which is slightly upstream of Amone. Due to this backwater effect, the forward velocities are expected to be sufficiently low as discussed in section 6.3 resulting in the deposition of the silt/sand around this place.

Table 6.1

Flows at Ganjem before and after the construction of Kotni Reservoir

Year/Month	Flows at Ganjem-CWC (Cumecs)	Total Inflow at Ganjem-CWC (Mcum)	Total inflow at Kotni using Correlation (Mcum)	Volume tapped at Kotni to built up storage (Mcum)	Volume released from Kotni for Power Generation (Mcum)	Volume diverted from Kotni for Irrigation (Mcum)	Volume flowing at Gangem after construction of Dam (Mcum)	Volume which will flow after construction of Kotni Dam in percent
1979-80								
June	54.62	141.58	50.0	50.0	0		91.58	64.68
July	325.4	843.44	154.0	154.0	0		689.44	81.74
August	509.5	1320.62	307.0	229.65	77.35		977.67	74.03
September	99.4	257.64	53.0	-20.05	73.05	113.3	277.69	107.78
October	53.5	138.67	24.0	-45.07	69.07		183.74	132.5
Nov-May		133.70	45.0	-246.53	291.53		380.23	284.39
Total		2835.65	633.0	122.0	511.0		2600.35	745.12
Volume which is not allowed to enter Goa = 3.995% **Volume which will enter Goa = 96.0%**								
1980-81								
June	220.78	572.26	155.0	155.0	0		417.26	72.91
July	629.16	1630.78	313.0	313.0	0		1317.78	80.81
August	591.32	1532.7	269.0	195.72	73.28		1223.68	79.84
September	120.33	311.9	60.0	-6.3	66.3	113.3	318.20	102.02
October	43.33	112.31	45.0	-15.02	60.02		127.33	113.37
Nov-May		81.99	67.0	-334.0	401.0		415.99	507.37
Total		4241.94	909.0	308.4	600.6		3820.24	956.32
Volume which is not allowed to enter Goa = 2.67% **Volume which will enter Goa = 97.33%**								
1981-82								
June	131.30	340.33	56.0	56.0	0		284.33	83.55
July	538.89	1396.8	290.0	290.0	0		1106.8	79.24
August	574.21	1488.35	313.0	239.44	73.56		1135.61	76.3
September	151.06	391.55	90.0	19.58	70.42	113.3	371.97	95.0
October	53.03	137.45	42.0	-23.02	65.02		160.47	116.75
Nov-May		96.38	56.0	-334.4	390.4		390.4	
Total		3850.87	847.0	247.6	599.4		3449.58	841.24
Volume which is not allowed to enter Goa = 2.94% **Volume which will enter Goa = 97.06%**								

Table 6.1 (Contd...)

Year/Month	Flows at Ganjem-CWC (Cumecs)	Total Inflow at Ganjem-CWC (Mcum)	Total inflow at Kotni using Correlation (Mcum)	Volume tapped at Kotni to built up storage (Mcum)	Volume released from Kotni for Power Generation (Mcum)	Volume diverted from Kotni for Irrigation (Mcum)	Volume flowing at Gangem after construction of Dam (Mcum)	Volume which will flow after construction of Kotni Dam in percent
1982-83								
June	100.19	259.69	43.0	43.0	0		216.69	83.44
July	680.02	1762.61	200.0	200.0	0		1562.61	88.65
August	702.07	1819.77	330.0	256.91	73.09		1449.56	79.66
September	83.29	215.89	36.0	1.6	34.4	113.3	214.29	99.28
October	32.45	84.11	33.0	-38.3	71.3		122.41	145.54
Nov-May		81.62	47.0	-320.0	367.0		401.62	492.06
Total		4223.69	689.0	545.79	545.79		3967.41	
Volume which is not allowed to enter Goa = 2.68% Volume which will enter Goa = 97.32%								
1983-84								
June	171.3	444.01	140.0	140.0	0		304.01	68.47
July	444.3	1151.63	220.0	220.0	0		931.63	80.9
August	512.3	1327.88	214.0	140.64	73.36	113.30	1073.94	80.88
September	211.0	546.99	87.0	16.08	70.92		530.83	97.06
October	62.4	161.74	27.0	-38.34	65.34		200.08	123.70
Nov-May		108.08	41.0	-320.0	361.0		428.08	396.08
Total		3740.25	729.0	570.62	570.62		3468.57	
Volume which is not allowed to enter Goa = 3.02% Volume which will enter Goa = 96.97%								
1984-85								
June	147.8	383.1	169.0	169.0	0		214.1	55.89
July	636.2	1649.0	275.0	204.22	70.78		1444.81	87.62
August	293.5	760.75	185.0	114.9	70.1	113.3	532.55	70.0
September	127.7	331.0	44.0	1.6	42.4		329.4	99.52
October	79.7	206.5	44.0	-28.4	72.4		234.98	113.74
Nov-May		110.15	42.0	-329.92	371.92		440.07	399.52
Total		3440.61	759.00	627.6	627.6		3195.91	
Volume which is not allowed to enter Goa = 3.29% Volume which will enter Goa = 96.71%								

Table 6.1 (Contd...)

Year/Month	Flows at Ganjem-CWC (Cumecs)	Total Inflow at Ganjem, CWC (Mcum)	Total inflow at Kotni using Correlation (Mcum)	Volume tapped at Kotni to built up storage (Mcum)	Volume released from Kotni for Power Generation (Mcum)	Volume diverted from Kotni for Irrigation (Mcum)	Volume flowing at Gangem after construction of Dam (Mcum)	Volume which will flow after construction of Kotni Dam in percent
1985-86								
June	174.5	452.3	99.0	99.0	0		353.3	78.19
July	323.3	837.99	165.0	165.0	0		672.99	80.31
August	393.2	1019.17	210.0	131.92	78.08		773.95	75.94
September	75.40	195.44	23.0	-47.3	70.3	133.3	242.74	124.2
October	100.6	260.75	37.0	-35.02	72.02		295.78	113.43
Nov-May		108.08	20	-185.7	205.7		293.78	271.82
Total		2873.74	554.0	426.1	1426.1		2632.54	
Volume which is not allowed to enter Goa = 3.94% **Volume which will enter Goa = 96.06%**								
1986-87								
June	126.4	327.63	166.0	166.0	0		161.63	49.33
July	288.3	747.27	216.0	129.2	86.8		618.07	82.71
August	395.3	1024.62	98.0	23.26	74.75		888.06	86.67
September	54.4	141.0	80.0	14.67	65.33	113.3	126.33	89.6
October	29.8	77.24	71.0	1.5	69.5		75.74	98.06
Nov-May		88.24	91.0	-282.55	373.55		370.79	420.21
Total		2406.01	722.0	669.92	669.92		2240.62	
Volume which is not allowed to enter Goa = 4.70% **Volume which will enter Goa = 95.29%**								
1987-88								
June	60.50	156.82	75.0	75.0	0		81.82	52.17
July	291.0	754.27	230.0	230.0	0		524.27	69.51
August	269.0	697.25	71.0	5.6	65.4		578.35	82.95
September	95.09	246.47	63.0	1.2	61.8	113.3	245.27	99.59
October	80.84	209.54	81.0	1.2	79.8		208.34	99.43
Nov-May		100.4	60.0	-185.7	245.7		286.1	284.96
Total		2164.75	580.0	452.7	452.7		1924.15	
Volume which is not allowed to enter Goa = 5.23% **Volume which will enter Goa = 94.77%**								

Table 6.1 (Contd...)

Year/Month	Flows at Ganjem-CWC (Cumecs)	Total Inflow at Ganjem-CWC (Mcum)	Total inflow at Kotni using Correlation (Mcum)	Volume tapped at Kotni to built up storage (Mcum)	Volume released from Kotni for Power Generation (Mcum)	Volume diverted from Kotni for Irrigation (Mcum)	Volume flowing at Gangem after construction of Dam (Mcum)	Volume which will flow after construction of Kotni Dam in percent
1988-89								
June	100.0	259.2	90.0	90.0	0		169.20	65.28
July	620.0	1607.04	439.0	360.22	78.78		1246.82	77.58
August	427.5	1108.08	86.0	11.13	74.87		983.65	88.77
September	251.8	652.67	169.0	95.3	73.7	113.30	557.37	85.4
October	74.73	193.7	97.0	20.57	76.43		173.13	89.38
Nov-May		82.82	102.0	-359.42	461.42		442.24	533.98
Total		3903.51	983.0	765.2	765.2		3572.41	

Volume which is not allowed to enter Goa = 2.90%
Volume which will enter Goa = 97.10%

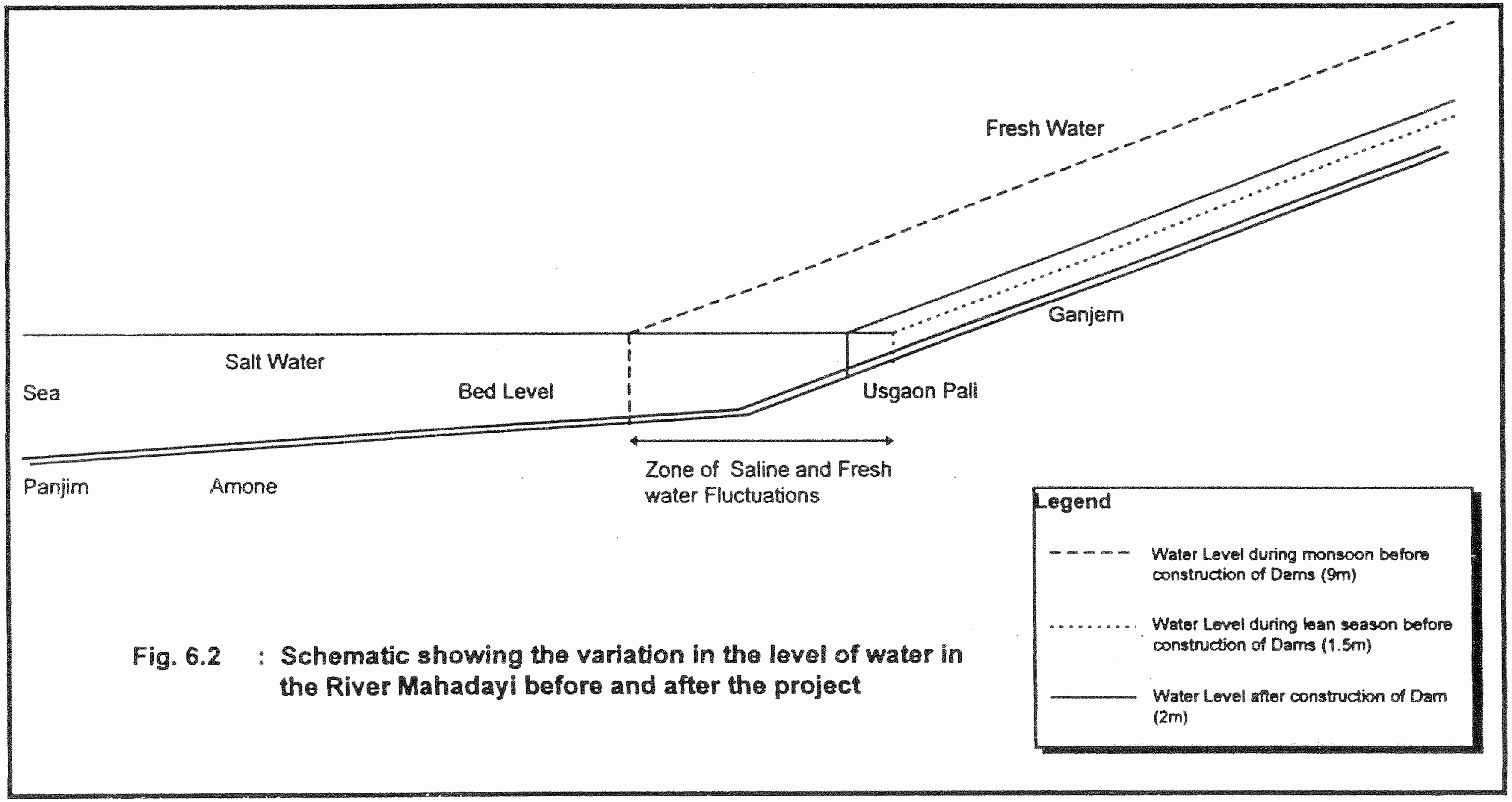


Fig. 6.2 : Schematic showing the variation in the level of water in the River Mahadayi before and after the project

At the mouth of river Mandovi there are no existing beaches excepting the Miramar beach which is of a small length. As discussed in hydrodynamic simulation, the change in the depth of flow as well as the associated velocity in the Mandovi estuary in the post project scenario will be very minimal. This small variation will not result in any impact on the existing Miramar beach ecosystem. Near the Cumburjua canal (stretch 17) changes in velocity of water in Mandovi due to MHEP are negligible, thus it is expected that the beach ecosystem of Zuari will also remain unaltered.

Since the Mandovi estuary is a well mixed system and the changes in flow and velocity in the estuarine region due to MHEP are small, the sedimentation and flocculation phenomenon will continue to behave in similar fashion.

The Mandovi river bed in its entire stretch from the Irti dam site to Ganjem is practically rocky in nature. This is also corroborated by the fact that the water samples collected even during the monsoon, when the flows are relatively large do not contain any significant amount of suspended matter. Furthermore, the vegetative cover in the catchment area along the river Mandovi is very dense and hence the runoff from the catchment area does not contain any sizable amount of sediment load. The heavy influx of total suspended matter during monsoons is essentially from the loose materials derived from mining activity in Goa region carried into the main stream by surface runoff. The major causes are lack of maintenance of mine rejects, dumping of ore alongside the banks of the rivers, inevitable losses of ore tailings directly to Mandovi. Thus the naturally established river regime upto Ganjem will not in any way alter. However, the sediment load contributed from the mining activities are essentially restricted to the state of Goa only, downstream of Ganjem.

It can thus be concluded that even after the construction of the proposed dams in Karnataka, the process of sand bar formation and other associated phenomena in Goa including the navigability of the river will remain unaffected.

6.3 Hydrodynamics of Mahadayi (Mandovi) River

Mahadayi (Mandovi) river, originating from Degaon village in Khanapur taluka in Belgaum district flows through north Goa district and meets the Arabian sea at Panaji, the capital of Goa. The river stretch in Goa is only about 82 km and depending on the river discharge the estuarine tidal influence is experienced upto about 30-40 km from the river mouth.

An estuary is a semi enclosed body of water, freely connected to the open sea. The hydrodynamics of an estuary is greatly influenced by the tidal action which

Photograph 7 : Sand Bar Formation in River Mandovi near Usgaon Village; Mine Dumps at the Background

Photograph 8 : Bottom Sediments in River Mandovi near Sonali Village varies widely in space and time. The water quality in an estuary is primarily governed by the physical processes which can be classified as stratified, partially mixed or well mixed. The classification can vary from season to season and from segment to segment of an estuary. In addition to tides, the mixing may also be affected by local wind stresses, bottom roughness and sediment types, channel geometry, coriolis forces etc.

The most influential characteristics in maintaining the depth of a navigable channel are velocity and the tidal volume which increases with the tidal range. The tidal range can not, however, be increased; but the direction and form of outlet into the sea can be regulated and the breadth limited in due proportion to the volume, and thus the depth may be increased. Dredging is only a palliative approach since it modifies the effect; however, it is valuable as an adjunct to training in preventing the formation of shoals and breaking up indurated bed.

In the estuary region, the Mandovi has split into three channels near Old Goa. The orientation prepose and the alignment of channel are very important. Tidal currents alone can maintain a channel in the estuary portion if it is sufficiently deep and favourable to the flood and ebb flow.

DYNHYD, the hydrodynamic model of WASP (Water Quality Analysis and Simulation Program), developed by USEPA (**Annexure 6.2**), estimates several space and time dependent parameters like channel flow, velocity, head, depth, flow direction etc. which, when fed to the water quality model, can estimate the chemical concentration for multiple, time dependent point discharges.

Based on flow ratio, $F = R/P$, where R is the river flow measured over one tidal cycle and P is the estuary tidal prism, Schultz and Simmons classified the estuaries. For F of the order of 1 or more, the estuary is normally stratified. Conversely, for $F = 0.1$ or less, it is well mixed. Flushing time, another common parameter, of a pollutant is determined as $T_f=V_f/R$, where V_f is the volume of fresh water in the estuary. The value differs for different segments of the estuary.

6.3.1 Problem Formulation

On completion of the MHEP, the flow regime will change due to regulated release of water from the proposed Kotni dam. The reported flows at the Ganjem site, upstream of the tidal region of the river, show that the variations in flow over the year during the pre and post project conditions are 1.35 - 824.11 cum/s and 18.31 - 724.01 cum/s respectively. During summer, the average flow is estimated to change from the present 1.3 cum/s to about 18 cum/s, an increase of about 12 fold. The reduction in flow during monsoon is of the order of 12% compared to the present maximum average flow.

It is normally expected that a change in river freshwater flow will change the river and estuarine hydrodynamics causing variations in saline water movement along the river. The change will be significant provided the freshwater volume is substantial in comparison to the tidal prism i.e. total volume of tidal water over a tide. Accordingly, the hydrodynamic simulation of the river was carried out to determine the volume of saline water entering any segment in one tidal cycle in relation to the freshwater flow.

The estuarine and river water quality is expected to be primarily governed by the relative volumes of tidal water from the sea and fresh water from the upstream of Mahadayi river. While the tidal volume at the mouth of the estuary remains unchanged for all practical purposes, the corresponding fresh water volume in each tidal cycle changes from summer to monsoon and from pre-project to post-project scenarios. Accordingly, to estimate the change in water quality, it is necessary to estimate their proportions in different segments in the estuary and the river under these four scenarios.

6.3.2 Simulation Results

For the purpose of hydrodynamic simulation, the stretch from the mouth of the river near Mandovi bridge to Sonali village was divided into 24 channels. The network configuration was suitably modified to accommodate the islands Chorao and Deewar between Ribander area and Tongaon village. The model was calibrated based on the observed depth, width and flow velocity at different segments of the river under known tidal conditions for the summer and monsoon seasons. The tidal elevation data on tidal heights under high and low tide conditions was collected from published literature for both summer and monsoon. **Fig. 6.3** presents the schematic of the network showing the channel or segment numbers.

The major flow contribution in the upstream of estuarine region is through Khandepar river, the flow in which is unaffected by the MHEP. For summer and monsoon conditions, the flows in Khandepar river have been taken as 0.3 and 3.0 cum/s respectively based on the CWC river flow data at Collem site. The effect due to Cumbarjua canal, meeting at the segment 15, could not be simulated due to the non-availability of required data related to time dependent flows, canal geometry, water quality for the canal as well as for adjoining Zuari estuary/river. If its effect is considered, it is expected to increase the salinity to some extent in the adjoining segments of Mandovi estuary.

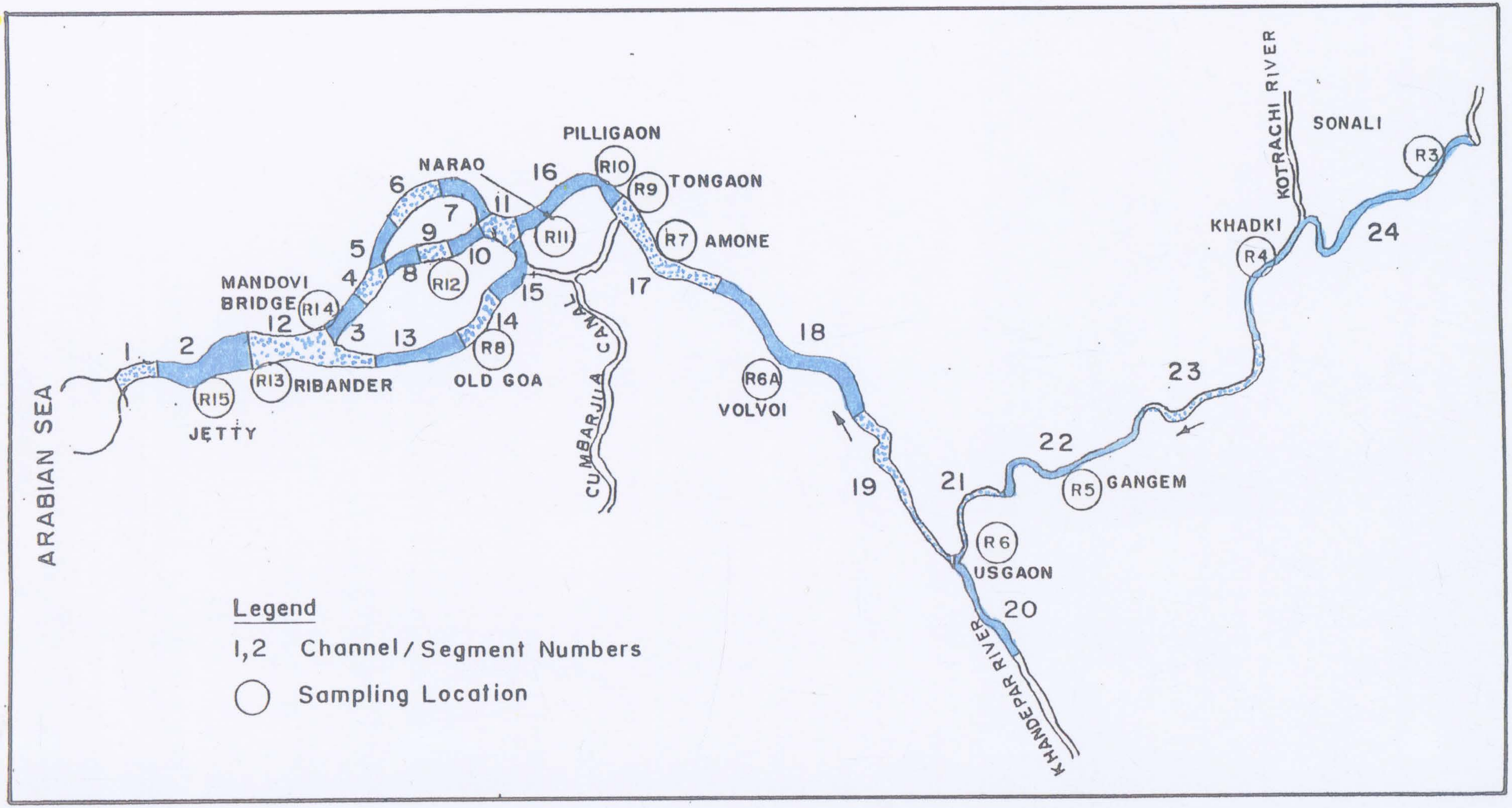


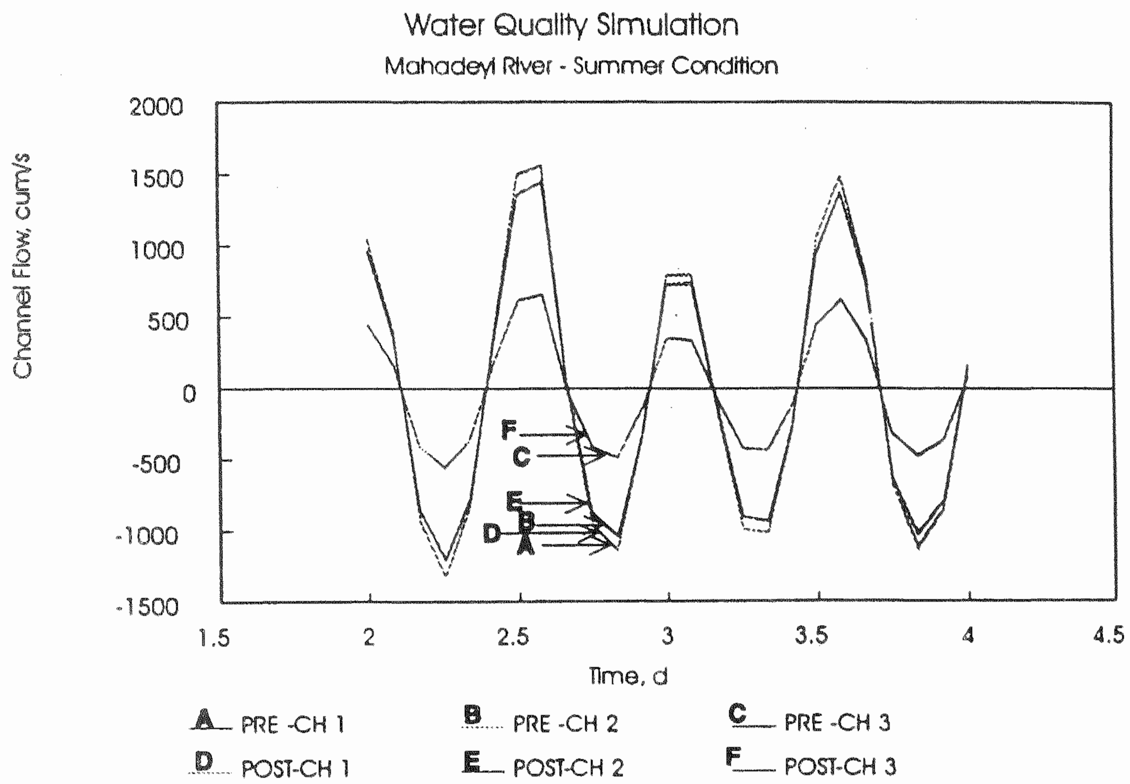
Fig. 6.3 : Schematics for Segment Numbers of Mahadayi Estuary

The upstream river flow data exhibits mostly summer time condition for about 8-9 months of the year while large volume of fresh water flows through the estuary under monsoon condition. The summer flow being only about 1% of the monsoon flow, the estuary behaves as an independent water body for most of the time of the year. The estuary also extends to the maximum extent landward due to the small river flow. However, during monsoon the large volume of fresh water pushes the tidal zone seaward. The effect is so prominent that the fresh water zone extends upto Old Goa and beyond. The natural variation in the river flow during a year is from 1.3 cum/s to 824 cum/s. In the post project scenario, the variation will range from 18.3 to 724 cum/s.

Figs. 6.4 and 6.5 present the channel flow variations between arbitrary second and third days of tidal simulation for pre and post project scenarios for summer conditions. For the pre and post project scenarios, comparison is made for curves A with D, B with E and C with F. The negative value indicates seaward flow and the positive value indicates landward flow in the simulation analysis. It is noted that the effect due to the project is insignificant upto channel 18, while channel 19 and 21 will be modified from oscillatory flow to seaward unidirectional flow. The channels 22 through 24 will maintain fresh water characteristics as observed at present. This indicates that during non-monsoon condition, the affected channels are only 19 and 21 which will become predominantly fresh water zone due to the MHEP. **Fig. 6.6** and **Fig. 6.7** present the channel flows under monsoon condition. The simulation indicates oscillatory motion upto channel 21 which is primarily affected by large volume of fresh water in the 18, 19 and 21 segments. Under post-project condition, flushing due to fresh water is lessened in the 19 and 21 segments and no significant variation is observed from 22 through 24 segments due to proportionally small change in the river flow for pre and post project scenario.

Figs. 6.8 and **6.9** present velocities during tidal cycles at the different segments for summer condition; **Fig. 6.10** and **6.11** present the same during monsoon condition. The channel velocities range from -0.3 to +0.3 m/s near the mouth of the estuary which is diminished in segments where the estuary is divided into multiple channels in segment no. 3 to 15 and again increases to about -0.4 m/s to +0.6 m/s beyond the confluence of these channels. In channels 22, 23 and 24 the velocity, as expected, is unidirectional and increases from -0.1 m/s to -0.3 m/s under pre and post project conditions. The change in velocity in other segments is not significant under the pre and post project conditions.

The flow velocity is significantly higher in monsoon ranging from -0.7 m/s to +0.7 m/s near the mouth dropping to about -0.4 m/s to +0.3 m/s in channels 3 to 15 and rising again from -0.6 m/s to +0.5 m/s beyond the confluence. The flow velocity


Water Quality Simulation
Mahadeyi River - Summer Condition
Channel Flow, cum/s
2000
1500
1000
500
0
-500
-1000
-1500
1.5
2
2.5
3
3.5
4
4.5
Time, d
F
C
E
B
D
A
A PRE -CH 1
B PRE -CH 2
C PRE -CH 3
D POST-CH 1
E POST-CH 2
F POST-CH 3

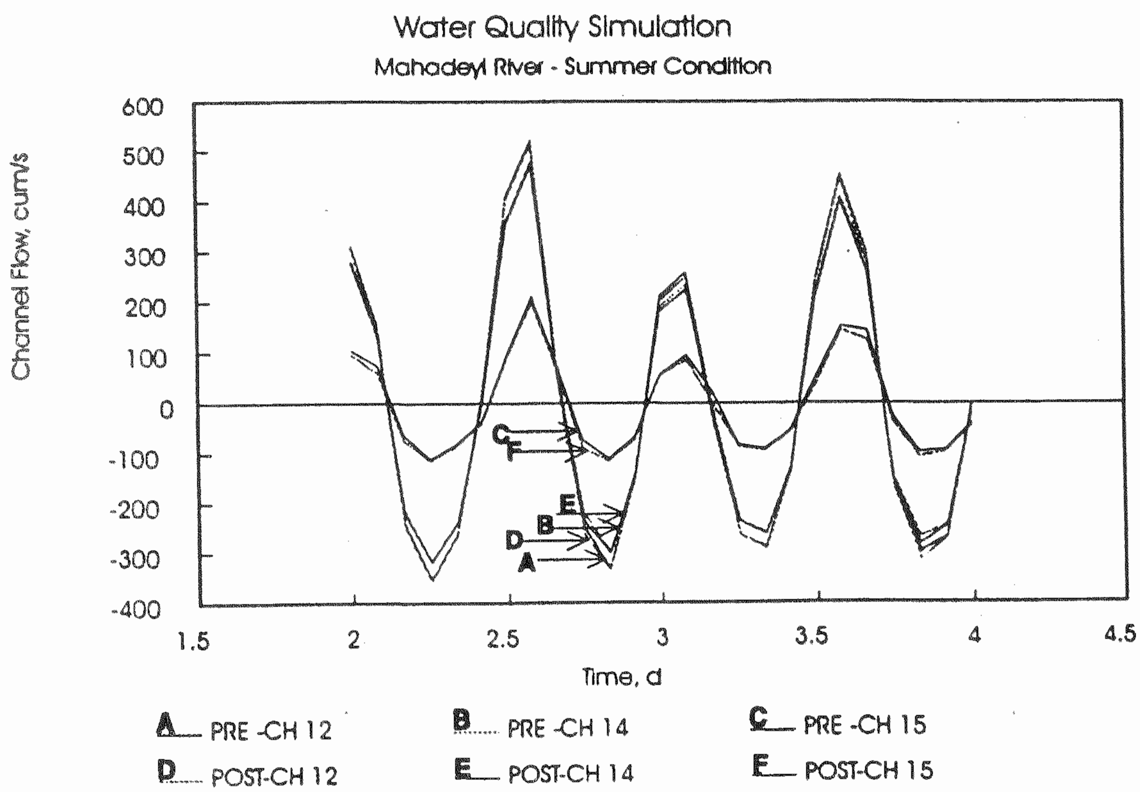
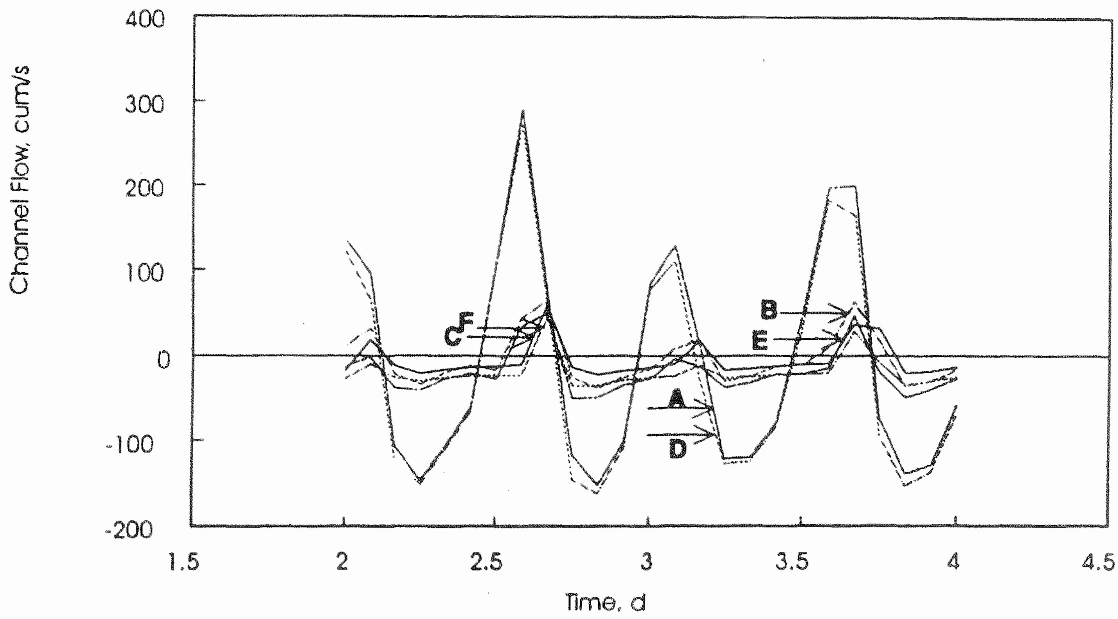

Water Quality Simulation
Mahadeyi River - Summer Condition
Channel Flow, cum/s
600
500
400
300
200
100
0
-100
-200
-300
-400
1.5
2
2.5
3
3.5
4
4.5
Time, d
C
F
E
B
D
A
A PRE -CH 12
B PRE -CH 14
C PRE -CH 15
D POST-CH 12
E POST-CH 14
F POST-CH 15

Fig. 6.4

Water Quality Simulation

Mahadeyi River - Summer Condition

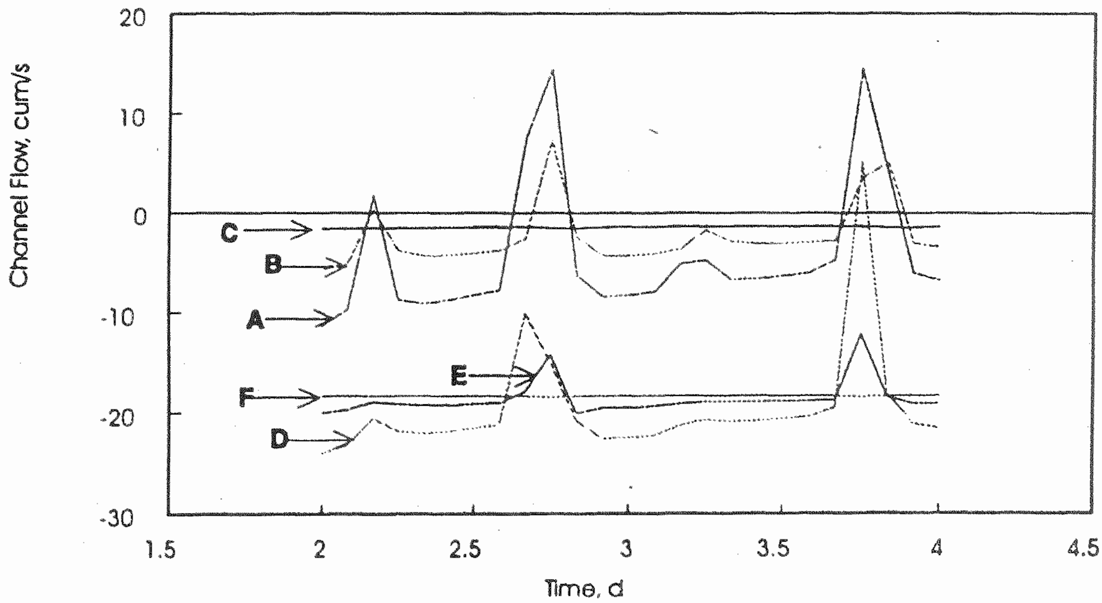


A...... PRE -CH 16   B...... PRE -CH 17   C___ PRE -CH 18

D...... POST-CH 16   E___ POST-CH 17   F___ POST-CH 18

Water Quality Simulation

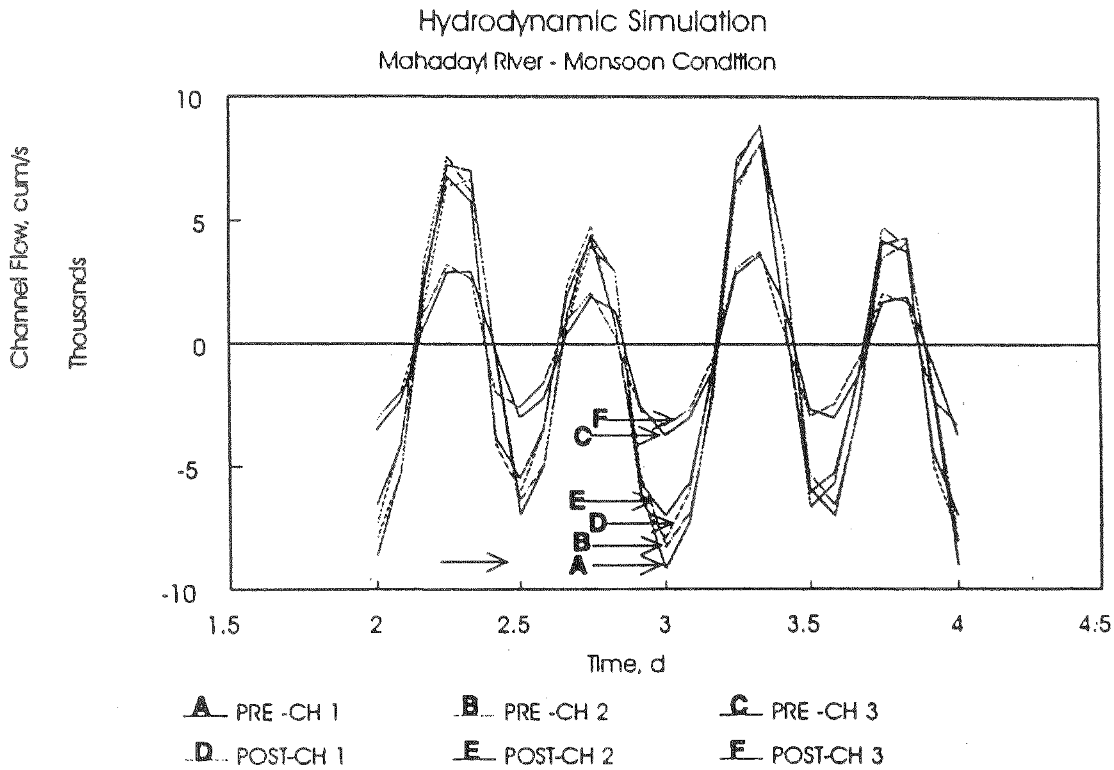
Mahadeyi River - Summer Condition



A...... PRE -CH 19   B...... PRE -CH 21   C___ PRE -CH 22

D...... POST-CH 19   E___ POST-CH 21   F...... POST-CH 22

Fig. 6.5


Hydrodynamic Simulation
Mahadayi River - Monsoon Condition
Channel Flow, cum/s
Thousands
10
5
0
-5
-10
1.5
2
2.5
3
3.5
4
4.5
Time, d
F
C
E
D
B
A
A PRE -CH 1
B PRE -CH 2
C PRE -CH 3
D POST-CH 1
E POST-CH 2
F POST-CH 3

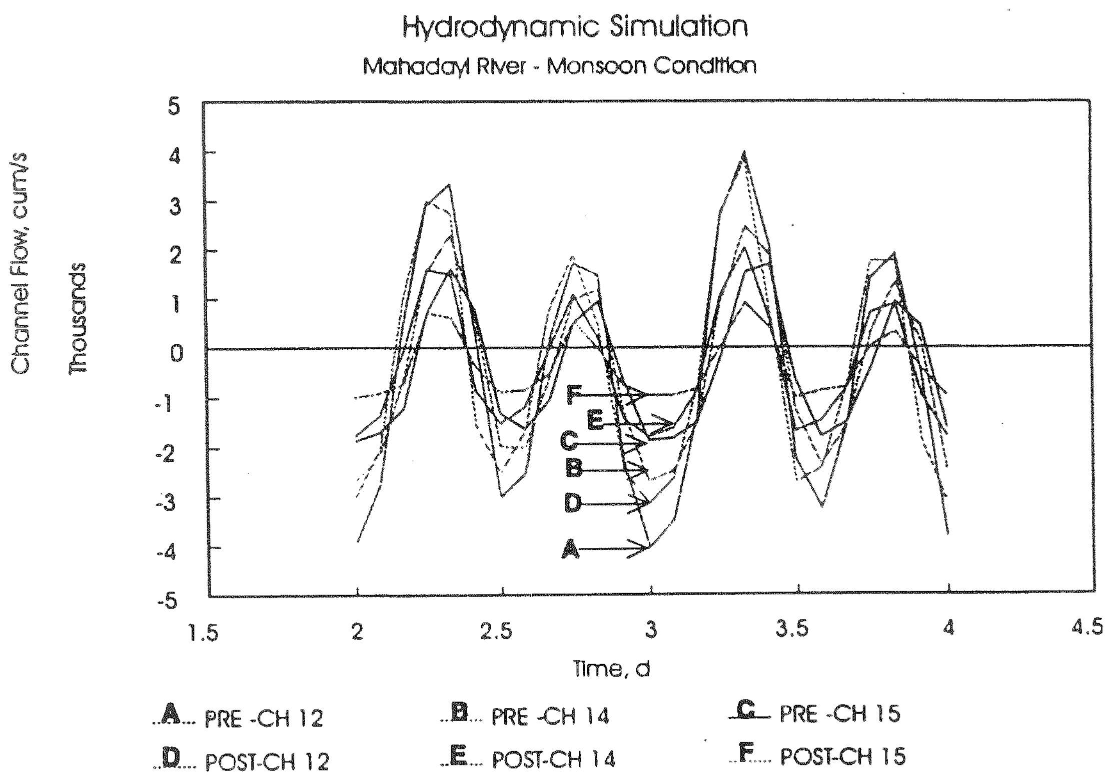
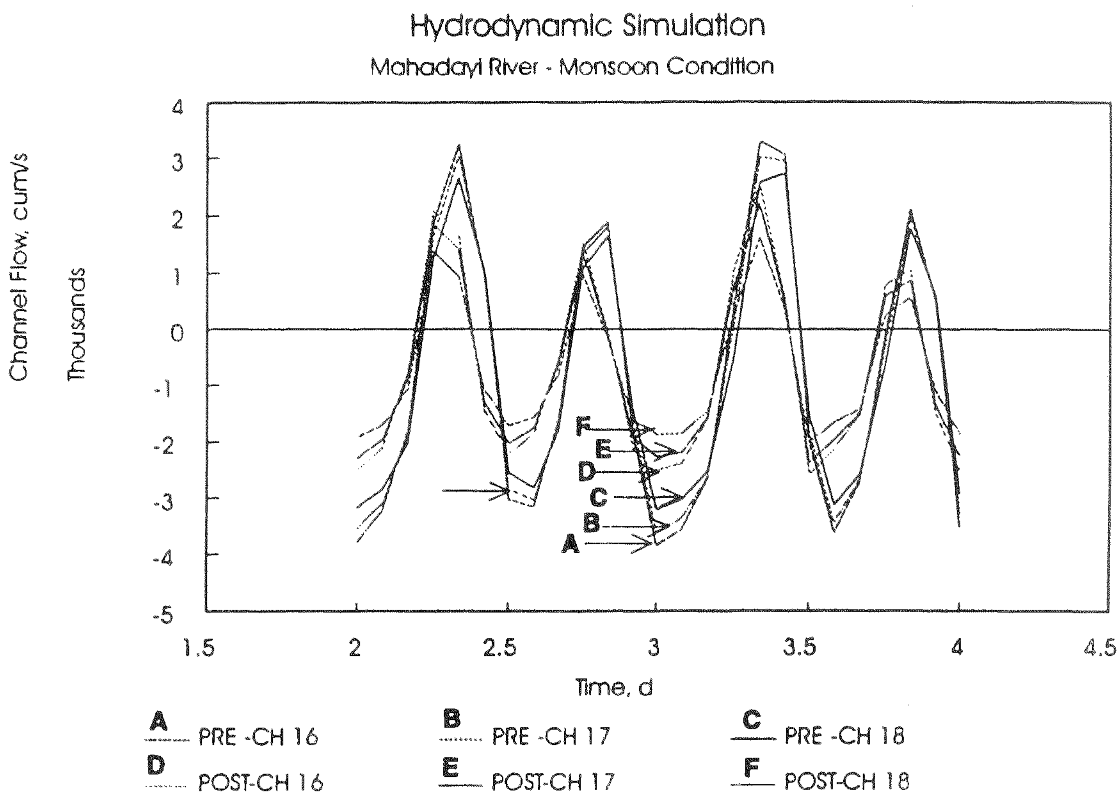

Hydrodynamic Simulation
Mahadayi River - Monsoon Condition
Channel Flow, cum/s
Thousands
5
4
3
2
1
0
-1
-2
-3
-4
-5
1.5
2
2.5
3
3.5
4
4.5
Time, d
F
E
C
B
D
A
A PRE -CH 12
B PRE -CH 14
C PRE -CH 15
D POST-CH 12
E POST-CH 14
F POST-CH 15

Fig. 6.6


Hydrodynamic Simulation
Mahadayi River - Monsoon Condition
Channel Flow, cum/s
Thousands
4
3
2
1
0
-1
-2
-3
-4
-5
1.5
2
2.5
3
3.5
4
4.5
Time, d
F
E
D
C
B
A
A PRE -CH 16
B PRE -CH 17
C PRE -CH 18
D POST-CH 16
E POST-CH 17
F POST-CH 18

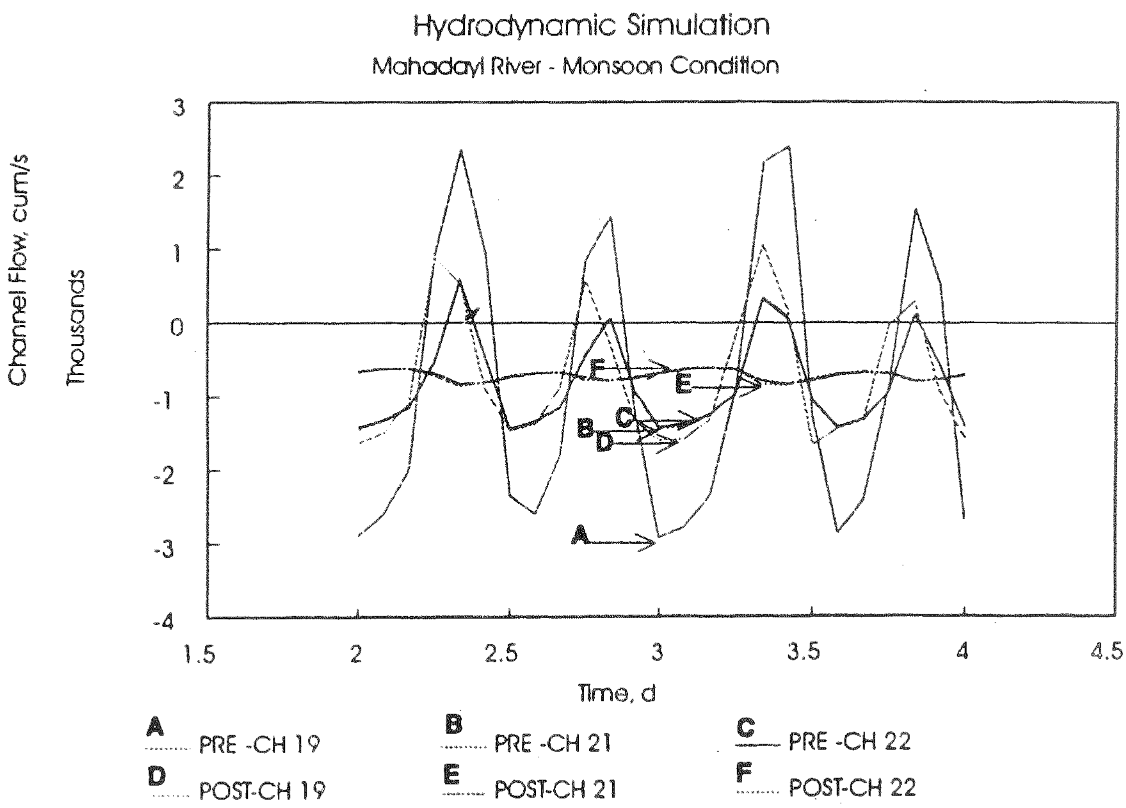
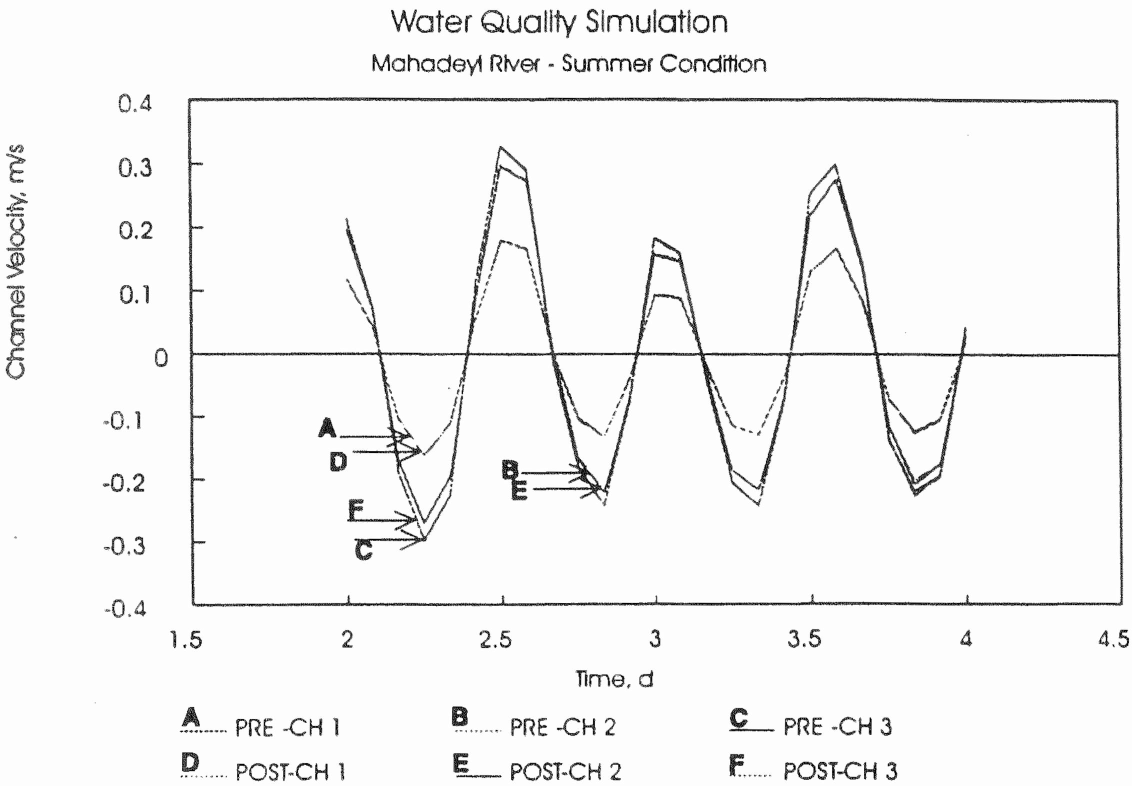
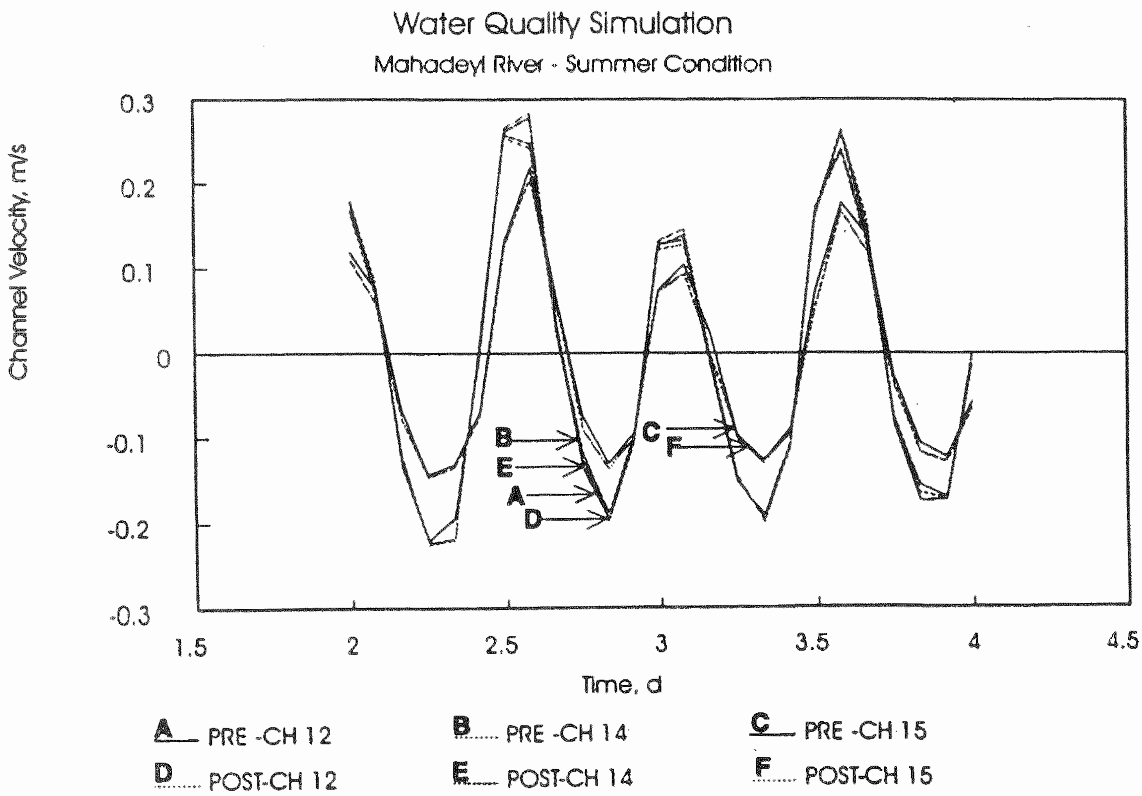

Hydrodynamic Simulation
Mahadayi River - Monsoon Condition
Channel Flow, cum/s
Thousands
3
2
1
0
-1
-2
-3
-4
1.5
2
2.5
3
3.5
4
4.5
Time, d
F
E
B
C
D
A
A PRE -CH 19
B PRE -CH 21
C PRE -CH 22
D POST-CH 19
E POST-CH 21
F POST-CH 22

Fig. 6.7

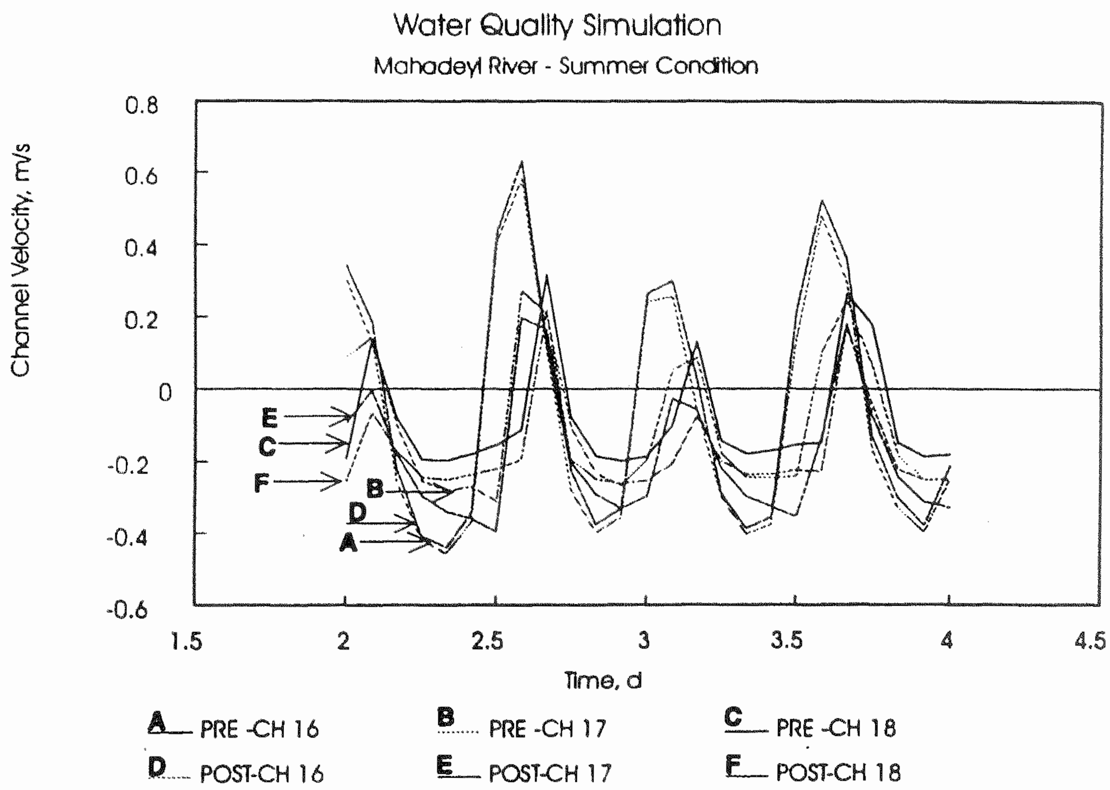


Water Quality Simulation
Mahadeyi River - Summer Condition
Channel Velocity, m/s
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
1.5
2
2.5
3
3.5
4
4.5
Time, d
A
D
F
C
B
E
A PRE -CH 1
B PRE -CH 2
C PRE -CH 3
D POST-CH 1
E POST-CH 2
F POST-CH 3



Water Quality Simulation
Mahadeyi River - Summer Condition
Channel Velocity, m/s
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
1.5
2
2.5
3
3.5
4
4.5
Time, d
B
E
A
D
C
F
A PRE -CH 12
B PRE -CH 14
C PRE -CH 15
D POST-CH 12
E POST-CH 14
F POST-CH 15

Fig. 6.8


Water Quality Simulation
Mahadeyi River - Summer Condition
Channel Velocity, m/s
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
E
C
F
B
D
A
1.5
2
2.5
3
3.5
4
4.5
Time, d
A PRE -CH 16
B PRE -CH 17
C PRE -CH 18
D POST-CH 16
E POST-CH 17
F POST-CH 18

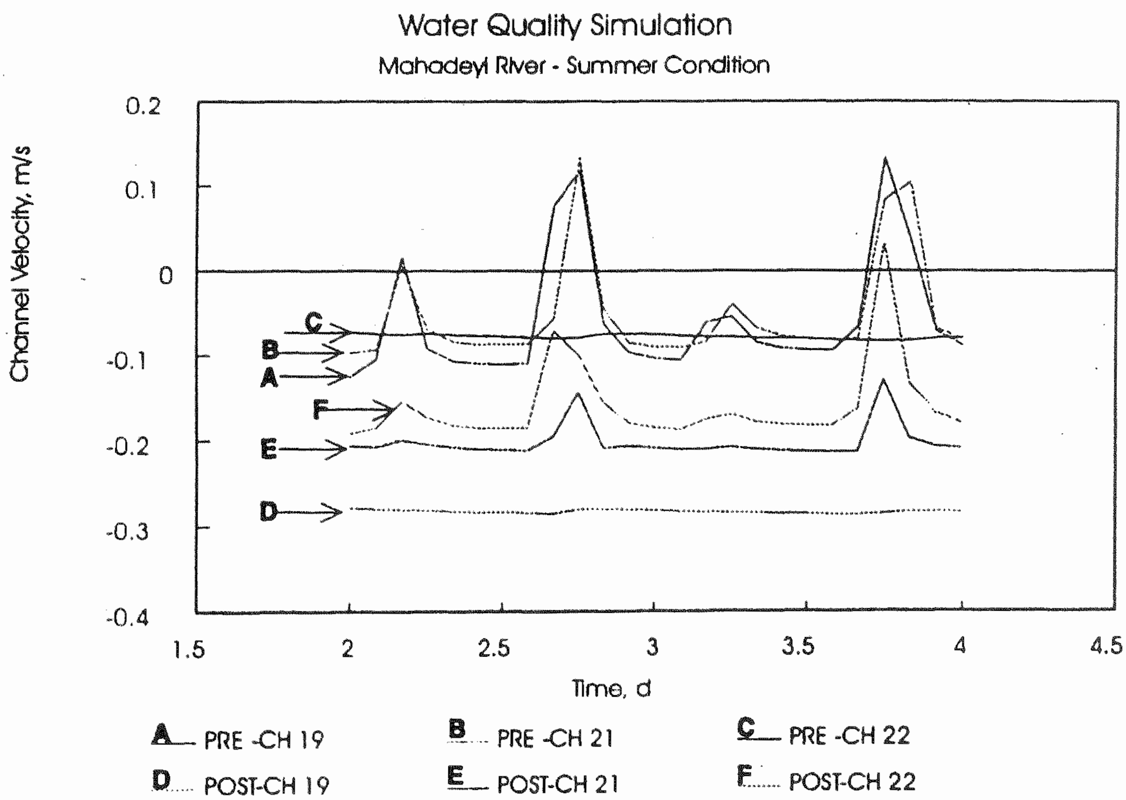
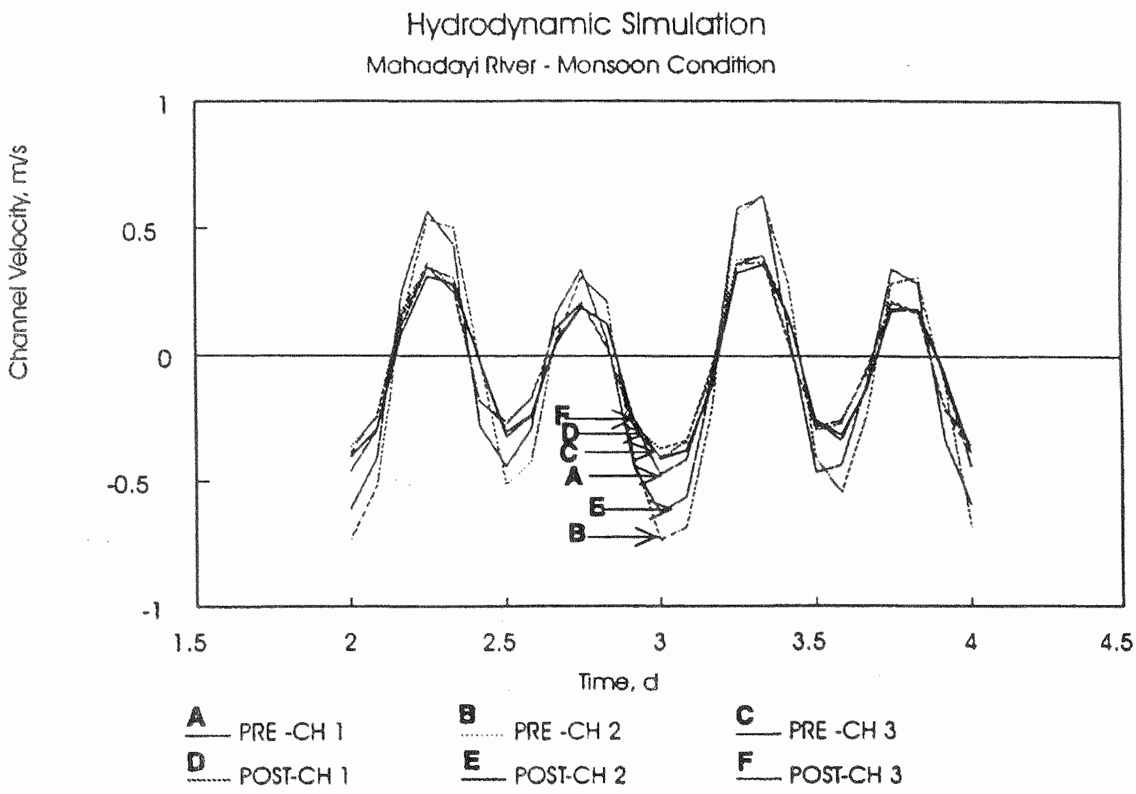
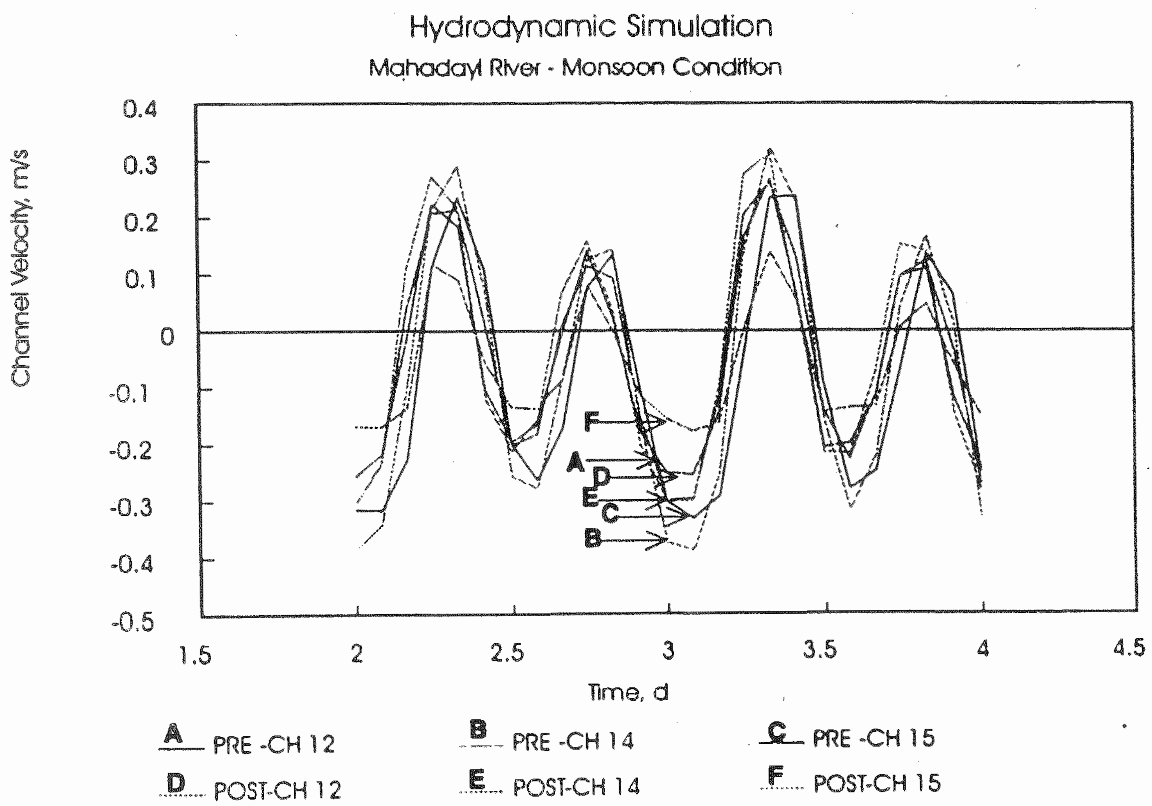

Water Quality Simulation
Mahadeyi River - Summer Condition
Channel Velocity, m/s
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
C
B
A
F
E
D
1.5
2
2.5
3
3.5
4
4.5
Time, d
A PRE -CH 19
B PRE -CH 21
C PRE -CH 22
D POST-CH 19
E POST-CH 21
F POST-CH 22

Fig. 6.9

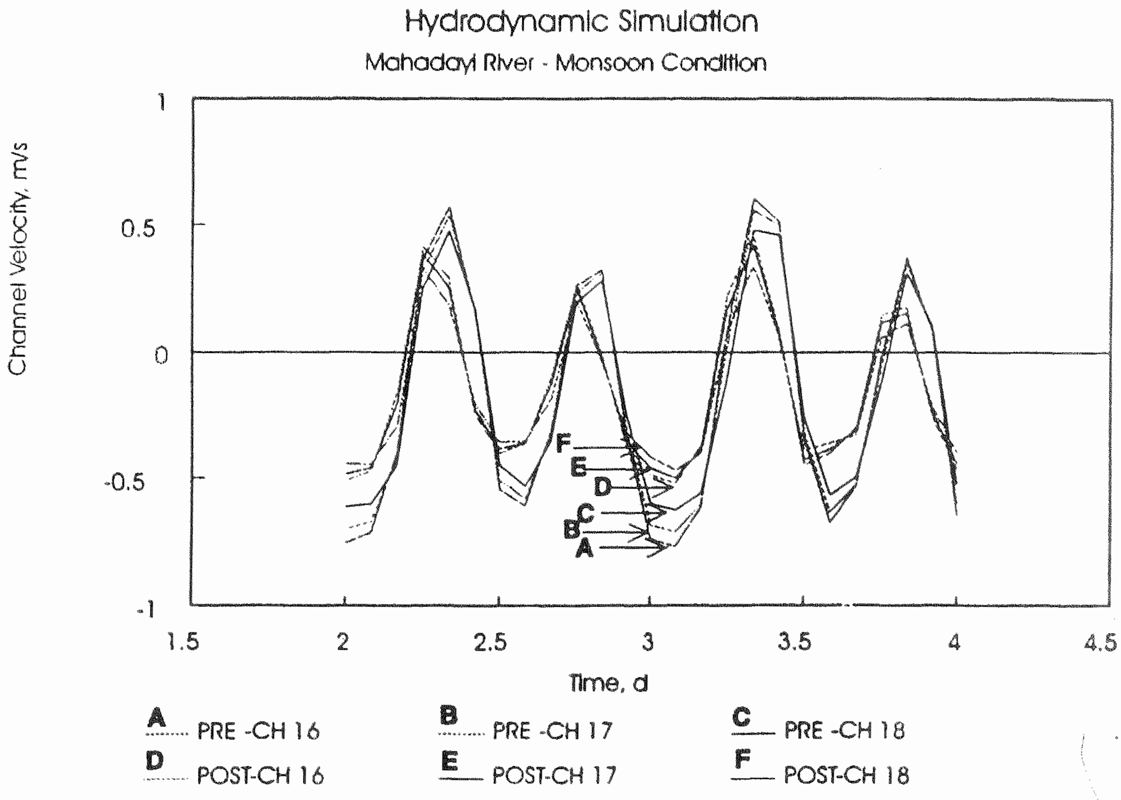


Hydrodynamic Simulation
Mahadayi River - Monsoon Condition
Channel Velocity, m/s
1
0.5
0
-0.5
-1
1.5
2
2.5
3
3.5
4
4.5
Time, d
F
D
C
A
E
B
A PRE -CH 1
B PRE -CH 2
C PRE -CH 3
D POST-CH 1
E POST-CH 2
F POST-CH 3



Hydrodynamic Simulation
Mahadayi River - Monsoon Condition
Channel Velocity, m/s
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
1.5
2
2.5
3
3.5
4
4.5
Time, d
F
A
D
E
C
B
A PRE -CH 12
B PRE -CH 14
C PRE -CH 15
D POST-CH 12
E POST-CH 14
F POST-CH 15

Fig. 6.10


Hydrodynamic Simulation
Mahadayi River - Monsoon Condition
Channel Velocity, m/s
1
0.5
0
-0.5
-1
1.5
2
2.5
3
3.5
4
4.5
Time, d
F
E
D
C
B
A
A PRE -CH 16
B PRE -CH 17
C PRE -CH 18
D POST-CH 16
E POST-CH 17
F POST-CH 18

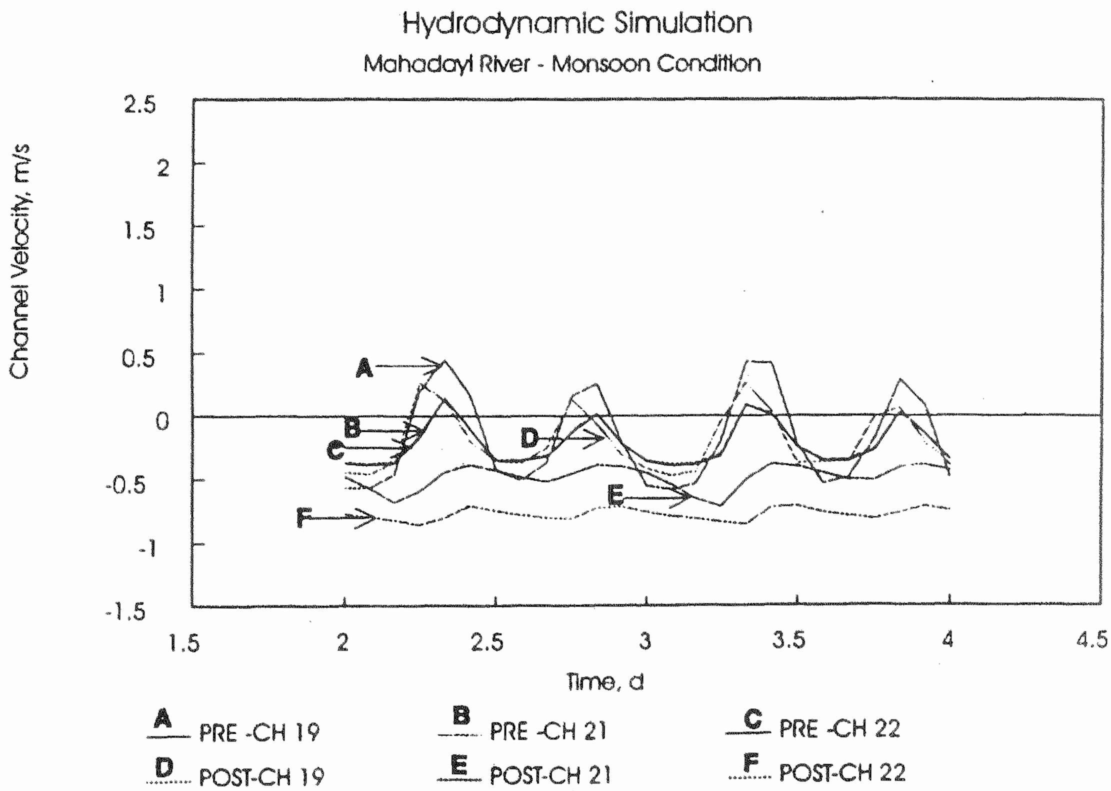

Hydrodynamic Simulation
Mahadayi River - Monsoon Condition
Channel Velocity, m/s
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
1.5
2
2.5
3
3.5
4
4.5
Time, d
A
B
C
D
E
F
A PRE -CH 19
B PRE -CH 21
C PRE -CH 22
D POST-CH 19
E POST-CH 21
F POST-CH 22

Fig. 6.11

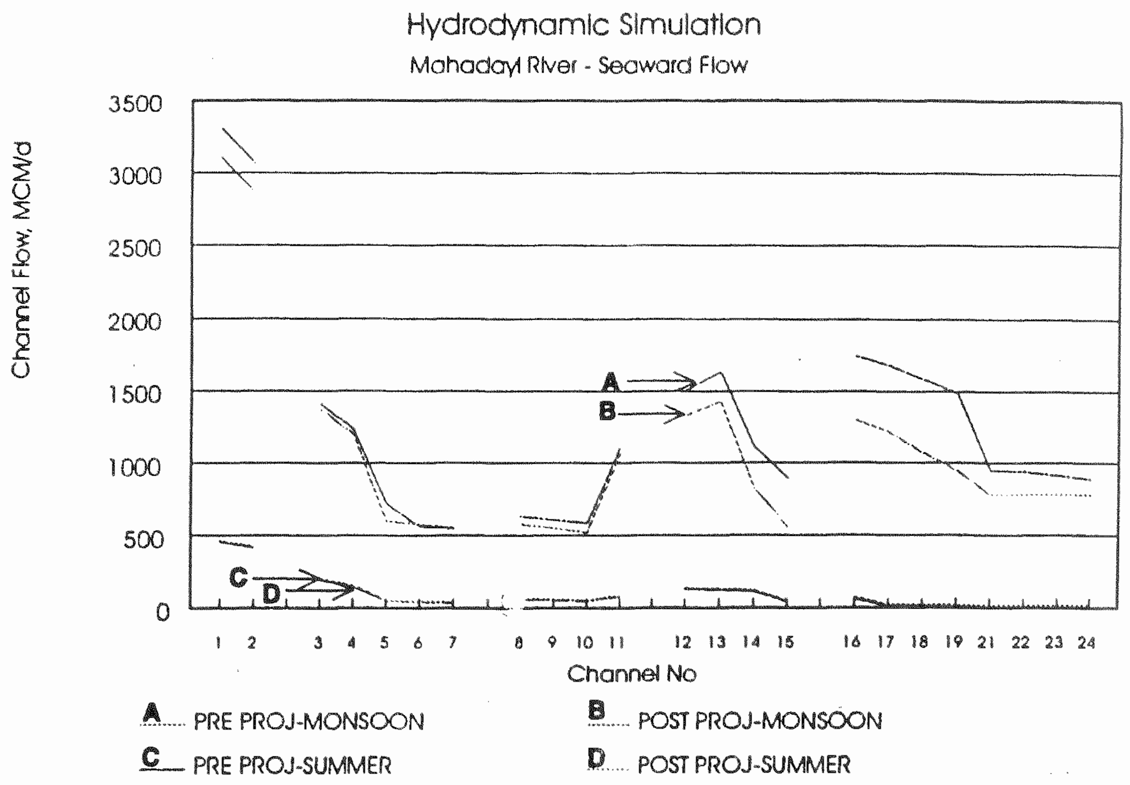
in the upstream segments 21 through 24 is predominantly unidirectional with a max of about 0.7 m/s in the limnetic stretch. The change in velocities from the pre to post project condition is significant only in these upper stretches where the velocity is expected to decrease by about 0.1 m/s.

Fig. 6.12 presents the seaward and landward flows in Mcum/d for both the seasons during the pre and post project conditions for all the channels. It is noticed that variation during summer in absolute values is insignificant throughout the estuary (**Table 6.2**). Under monsoon condition, however, the pre and post project values are significantly different for channels 16 to 19. **Fig. 6.13** presents the landward to seaward flow ratios for all the channels for the pre and post project conditions during monsoon and summer seasons. Channels 17, 18 and 19 exhibit considerable differences which implies that only these channels are susceptible to upstream fresh water flow variations.

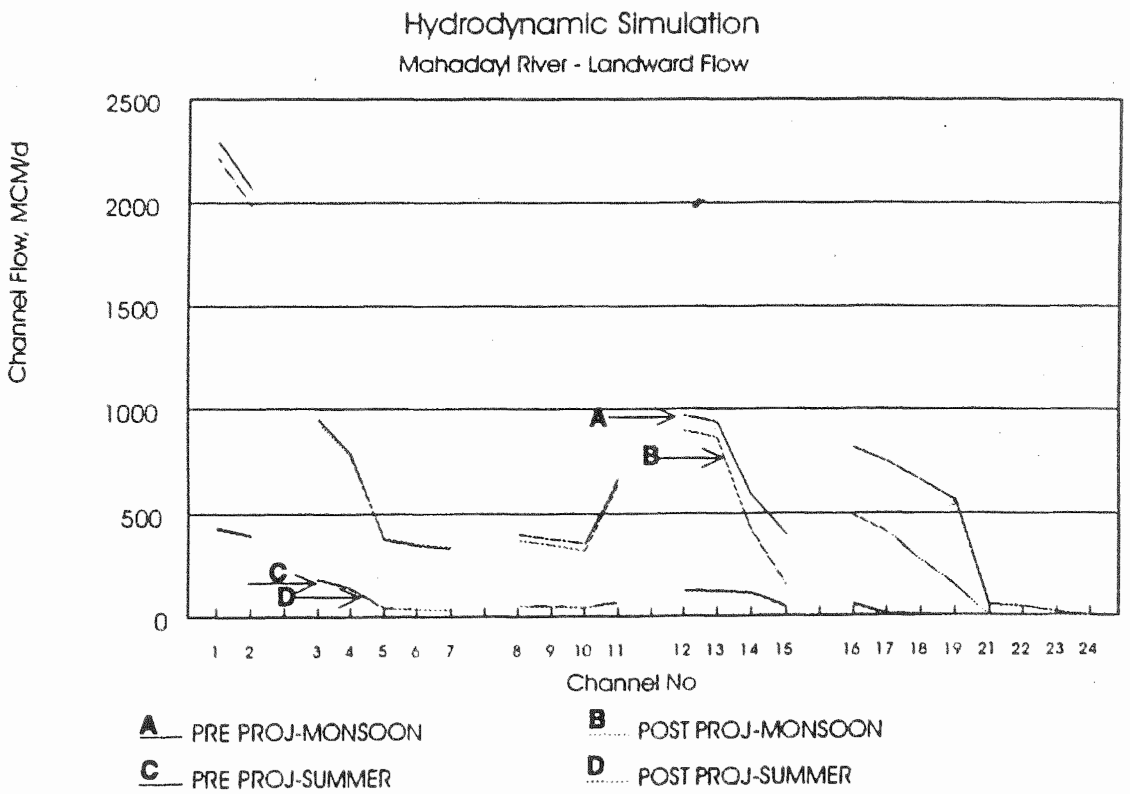
Figs. 6.14 and **6.15 (A&B)** are the results of simulation of total flow, channel volume and velocity and salinity in the estuarine region at various channels. **Fig. 6.15 A** shows the observed salinity values at various stations. **Fig 6.15 B** shows the predicted salinity values for the present situation. Figs. 6.15 A and 6.15 B fairly tally with each other indicating validation of the WASP model for the river Mandovi. Data, on salinity in the channels 8-11 is not available. During monsoon the observed salinity values are more than the predicted values in channel 16 to 18. The observed values at channel 16 are upto 4 ppt whereas the predicted value is below 0.5 ppt. This is expected because of the effect of Cumbarjua canal which could not be considered in the model studies due to the non-availability of baseline data. The literature indicates that in the Cumbarjua canal, the flow is towards Mandovi river during high tide and vice versa.

The effect on salinity in monsoon due to MHEP was observed insignificant while during summer, the variations in salinity are observed in channels 16 through 19. In channel 16, the salinity is expected to drop from about 28 to 18 ppt which would retain its polyhaline characteristics. The model indicates that channel 17 may be affected maximum where the salinity is expected to drop from about 20 to <5 ppt while in channel 18 it is expected to drop from about 10 ppt to 2 ppt. As a result, channels 17 and 18 may change from mesohaline to oligohaline during summer due to MHEP. The total length of channels 17 and 18 is about 12.5 km.

In summary, the change in salinity values along the various channels is marginal during the pre and post project scenario for both extreme situations obtained in summer and monsoon seasons.



Hydrodynamic Simulation
Mahadayi River - Seaward Flow
Channel Flow, MCM/d
3500
3000
2500
2000
1500
1000
500
0
A
B
C
D
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 21 22 23 24
Channel No
A PRE PROJ-MONSOON
B POST PROJ-MONSOON
C PRE PROJ-SUMMER
D POST PROJ-SUMMER



Hydrodynamic Simulation
Mahadayi River - Landward Flow
Channel Flow, MCM/d
2500
2000
1500
1000
500
0
A
B
C
D
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 21 22 23 24
Channel No
A PRE PROJ-MONSOON
B POST PROJ-MONSOON
C PRE PROJ-SUMMER
D POST PROJ-SUMMER

Fig. 6.12

Table 6.2

Summary of Flows (Mcum/day) in Pre and Post Project Conditions

Seg-ment No.	Monsoon						Summer					
	Pre Project			Post Project			Pre Project			Post Project		
	To Sea	To Land	Ratio	To Sea	To Land	Ratio	To Sea	To Land	Ratio	To Sea	To Land	Ratio
1	3309.2	2297.8	0.69	3110.1	2214.2	0.71	456.7	435.4	0.95	462.5	427.3	0.96
2	3065.9	2067.6	0.67	2864.6	1984.8	0.69	418.4	399.4	0.95	425.2	390.8	0.96
3	1408.3	952.1	0.68	1371.5	932.0	0.68	197.6	184.4	0.93	201.0	181.4	0.94
4	1240.2	789.7	0.64	1199.3	771.0	0.64	153.7	141.6	0.92	157.1	138.6	0.92
5	724.8	372.3	0.51	604.7	382.9	0.63	48.4	43.8	0.90	50.0	42.2	0.88
6	564.5	347.7	0.62	577.4	358.2	0.62	43.9	39.4	0.90	45.4	37.8	0.87
7	548.0	332.3	0.61	558.8	340.8	0.61	37.1	32.8	0.88	38.6	31.2	0.84
8	634.0	401.1	0.63	577.4	371.3	0.64	60.7	54.7	0.90	62.5	52.6	0.88
9	611.0	379.0	0.62	552.9	348.3	0.63	56.3	50.3	0.89	58.1	48.2	0.86
10	586.2	355.1	0.61	525.6	322.5	0.61	50.3	44.5	0.89	52.0	42.4	0.85
11	1118.3	671.9	0.60	1065.8	644.5	0.60	80.4	70.6	0.88	83.9	67.0	0.83
12	1503.5	968.4	0.64	1328.5	896.0	0.67	130.7	127.9	0.98	134.7	122.9	0.95
13	1637.4	938.1	0.57	1426.8	863.0	0.60	126.6	123.9	0.98	131.1	118.9	0.94
14	1107.3	592.1	0.53	831.7	417.0	0.50	117.6	115.4	0.98	122.0	110.6	0.94
15	896.3	397.1	0.44	558.8	154.8	0.28	44.8	46.4	1.04	48.6	41.0	0.88
16	1745.9	813.4	0.47	1301.0	487.9	0.37	65.2	59.9	0.92	73.0	51.5	0.74
17	1678.8	749.5	0.45	1216.3	408.4	0.34	16.0	11.6	0.73	26.4	5.7	0.23
18	1583.8	660.4	0.42	1070.5	273.3	0.26	12.7	7.1	0.56	24.5	3.2	0.13
19	1488.1	568.8	0.38	949.7	152.2	0.16	6.3	1.8	0.29	21.3	0.2	0.01
21	950.8	54.5	0.06	781.5	0.0	0.00	3.2	0.7	0.22	20.1	0.0	0.00
22	943.6	47.3	0.05	781.2	0.0	0.00	1.5	0.0	0.00	19.8	0.0	0.00
23	915.8	19.1	0.02	781.8	0.0	0.00	1.5	0.0	0.00	19.8	0.0	0.00
24	890.3	0.0	0.00	782.0	0.0	0.00	1.5	0.0	0.00	19.8	0.0	0.00
20*	311.9	299.9	0.96	90.8	83.7	0.92	2.0	0.4	0.18	1.6	0.7	0.48

Ratio # ratio of "To Land" to "To Sea" flows

* Segment in Khandepar river

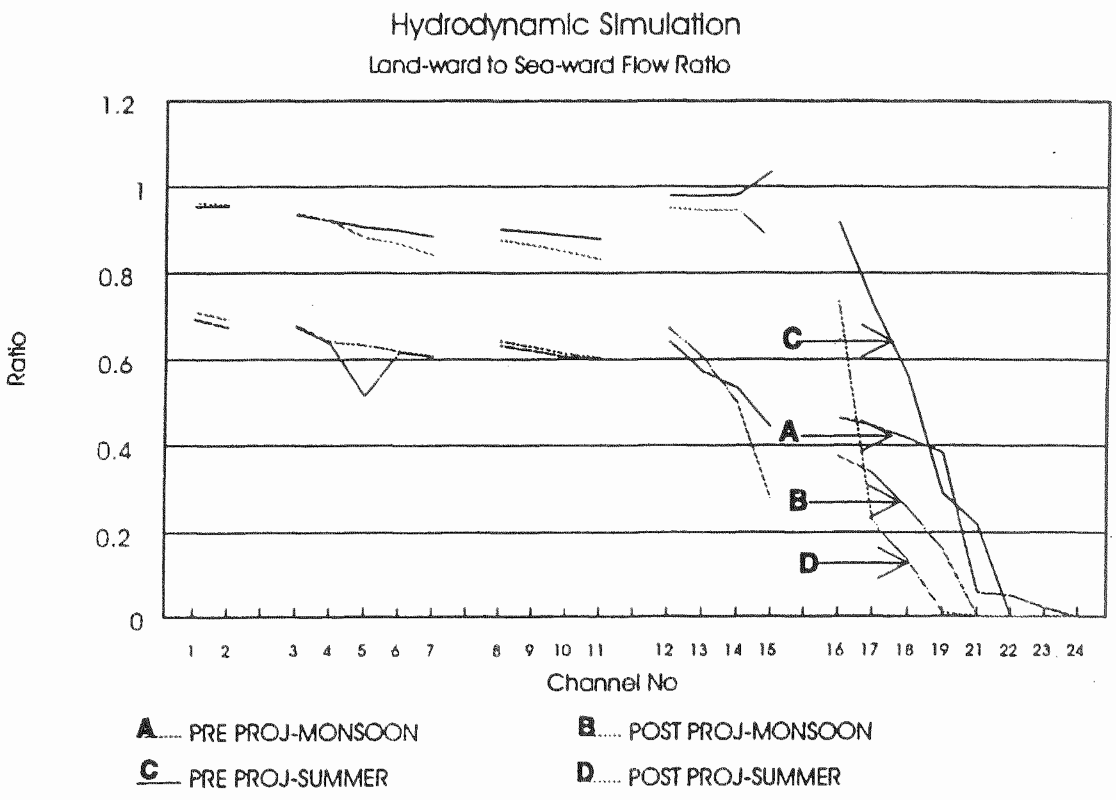
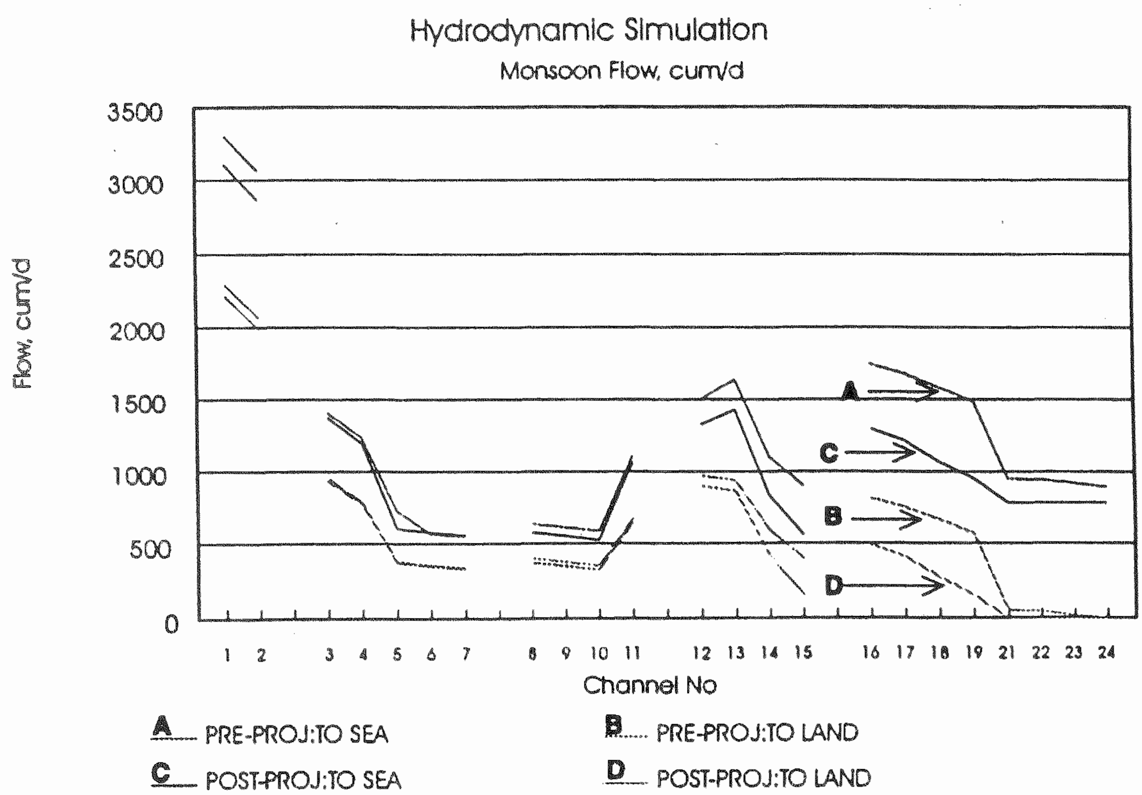

Hydrodynamic Simulation
Land-ward to Sea-ward Flow Ratio
Ratio
1.2
1
0.8
0.6
0.4
0.2
0
C
A
B
D
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 21 22 23 24
Channel No
A..... PRE PROJ-MONSOON
B..... POST PROJ-MONSOON
C PRE PROJ-SUMMER
D..... POST PROJ-SUMMER

Fig. 6.13


Hydrodynamic Simulation
Monsoon Flow, cum/d
Flow, cum/d
3500
3000
2500
2000
1500
1000
500
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 21 22 23 24
Channel No
A
B
C
D
A PRE-PROJ:TO SEA
B PRE-PROJ:TO LAND
C POST-PROJ:TO SEA
D POST-PROJ:TO LAND

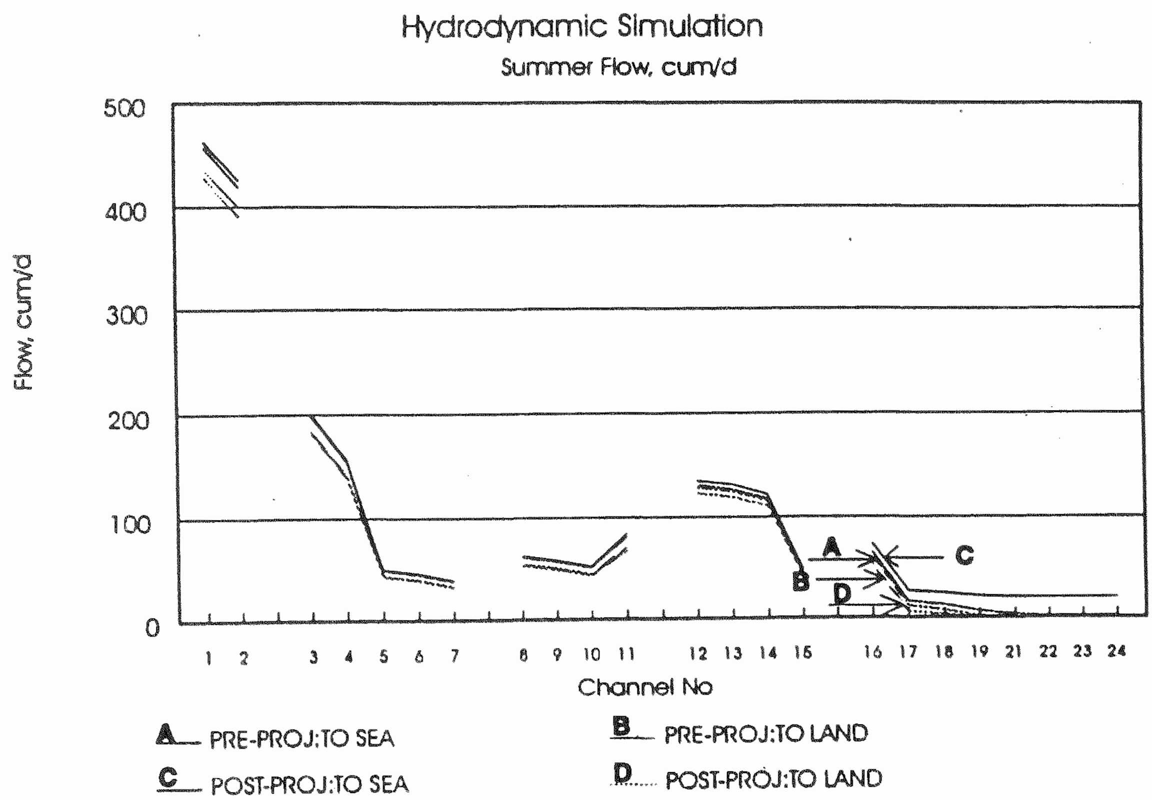
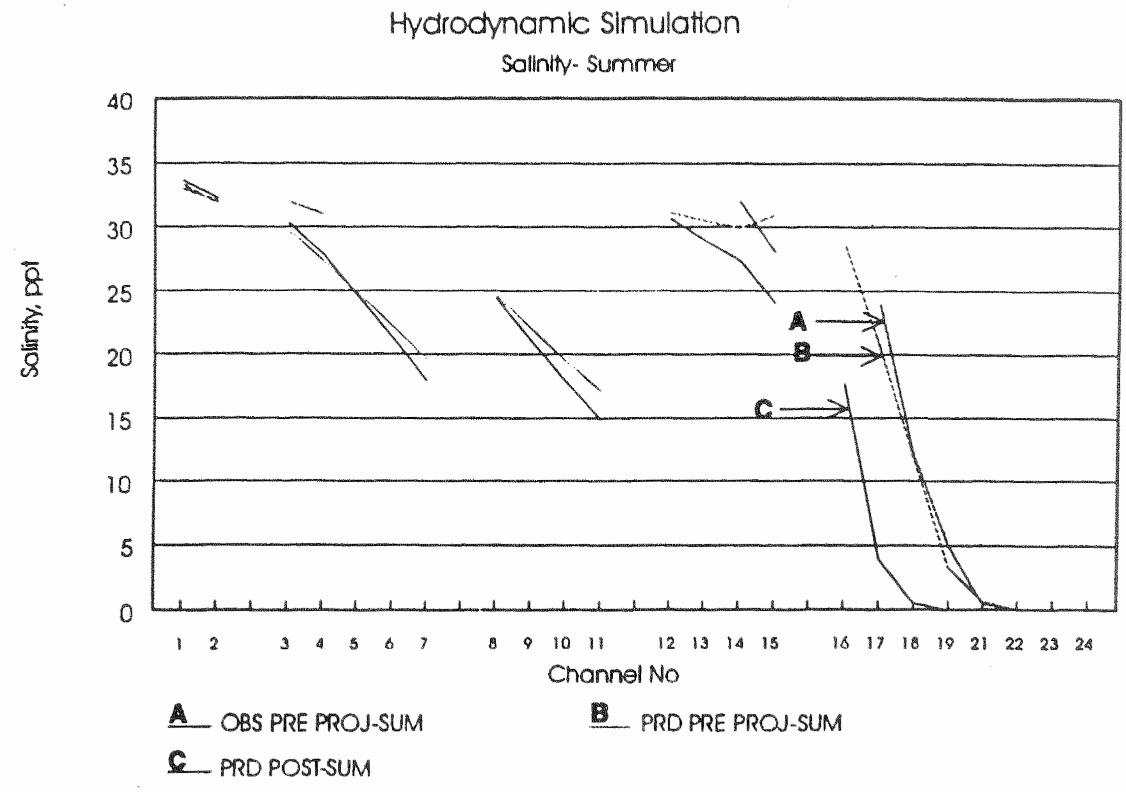

Hydrodynamic Simulation
Summer Flow, cum/d
Flow, cum/d
500
400
300
200
100
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 21 22 23 24
Channel No
A
B
C
D
A PRE-PROJ:TO SEA
B PRE-PROJ:TO LAND
C POST-PROJ:TO SEA
D POST-PROJ:TO LAND

Fig. 6.14


Hydrodynamic Simulation
Salinity- Summer
Salinity, ppt
40
35
30
25
20
15
10
5
0
A
B
C
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 21 22 23 24
Channel No
A OBS PRE PROJ-SUM
B PRD PRE PROJ-SUM
C PRD POST-SUM

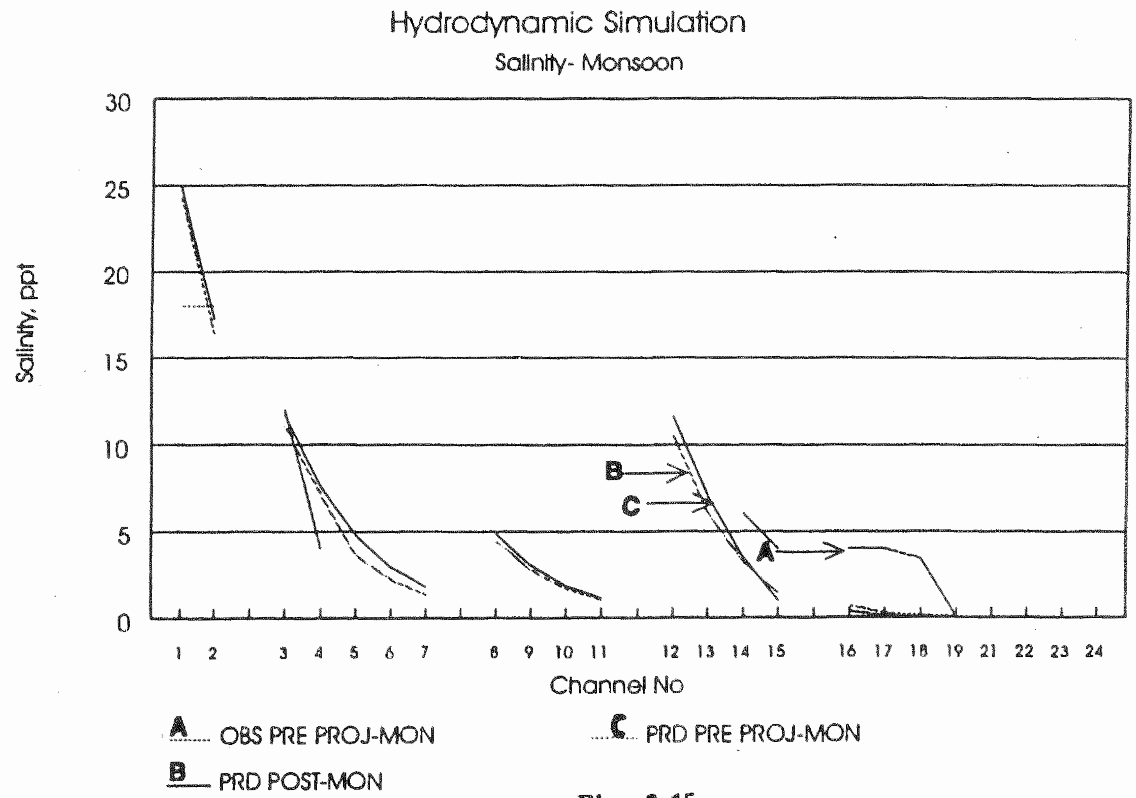

Hydrodynamic Simulation
Salinity- Monsoon
Salinity, ppt
30
25
20
15
10
5
0
B
C
A
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 21 22 23 24
Channel No
A OBS PRE PROJ-MON
C PRD PRE PROJ-MON
B PRD POST-MON

Fig. 6.15

6.4 Biological Environment

6.4.1 Loss of Forest Cover

The hydel power generation capacity in Karnataka constitutes 79.12 % of the total installed capacity in the state. There are no existing hydro electric projects in Belgaum district involving forest land. The present forest cover in Belgaum district has, as per the forest records, increased from 1078 sq.km in 1991 to 1434 sq.km in 1997. However, the forest cover was 2420 sq.km in 1981. The reduction in forest cover is mainly due to conversion of forest land into agricultural land (Fig. 4.21). The degradation of forest area in Belgaum district may be attributed to lack of water conservation measures and non conceiving of storage dams in the district. Storage of river water in dam helps in charging of ground water thereby having beneficial effect on forest vegetation. According to the 1991 Forest Survey of India (FSI) report, Belgaum district shows intensive biotic pressure on the forests of this region. The forest cover of Belgaum district would be reduced to about 12.85% after releasing the forest land (2077.5 ha) to the proposed Mahadayi Hydro-electric project.

The forest revenue of Belgaum division has increased from Rs. 63.49 lakhs in 1992-93 to Rs. 168.07 lakhs in 1996-97. At 1997 price level, the total revenue per annum lost from the forest cover in the submergence area would be around Rs. 2.9 lakhs. The one time revenue from the forest produce from the submergence area has been estimated at Rs. 28 crores in terms of direct cost (**Table 6.3**) apart from the loss of yearly revenue obtained by extraction of sustainable yield from the forest.

The vegetation in the Mahadayi catchment is a valuable climax evergreen forest harbouring species of economic importance such as *Terminalia* species, *Dalbergia latifolia, Dalbergia paniculata, Eugenia jambolana, Artocarpus lirauts, Hardwickia pinnata, Semicarpus anacardium, Machillus macranthus, Toona cielesta* etc. from which the forest department gets a revenue of Rs. 8 lakhs per ha through supply of forest products to industries. Apart from this, the forest contains many rare medicinal plants, endemic species along with some endangered flora and fauna. However, these species are available in the forest area of western ghats. Increase in human activity in the area would accelerate the rate of degradation of these natural forests.

6.4.2 Effect of Water Impoundment and Diversions on Flora and Fauna

The prediction of impacts on biological environment due to the construction of dam or any other activity is a relatively complex exercise because:

Table 6.3

Revenue Gained from the Forest Produce from the Submergence Area

Sl. No.	Particulars	Approximate yield	Approximate value (in Rs.)	Amount (Rs. in Lakhs)
1.	Yield from Eucalyptus plantation of an area of 1040.50 ha = 25658.186 tonnes	24.70 tonnes/ha	756/tonne	193
2.	Poles - Yield from Eucalyptus plantation of an area of 1040.50 ha = 53865 numbers per pole	52 nos./ha	40/no.	21.54
	I. Yield from standing free growth in an area of 982.50 ha pertaining to the thick forest area			
	1. Sissum	1325 Cum	19300/Cum	255.70
	2. Nandi	2980 Cum	7400/Cum	220.50
	3. Matti	3125 Cum	9200/Cum	287.50
	4. Kindal	2975 Cum	8000/Cum	238.00
	5. Niral(Jambul)	400 Cum	2600/Cum	10.40
	6. Miri	50 Cum	4300/Cum	2.15
	7. Hela	550 Cum	2500/Cum	13.75
	8. Other J.W.	40500 Cum	2500/Cum	1012.50
	II. J.W. Poles			
	I. I.	4183 nos.	375/no.	15.70
	II.	57815 nos.	250/no.	144.50
	III.	77447 nos.	250/no.	193.00
	III. Fire wood	318425.00 Cum	250/Cum	760.00
	IV. Bamboos	131345 nos.	10/no.	13.10
	V. Karvi	2914 trucks*	1500/truck load	43.70
	VI. Canes	24278 nos.	5/no.	1.2
	Total			**3212.30**
	Approximate Transportation cost			*400.00*
	Net Revenue			**2812.30**

* 1 truck load ≈ 4 tonnes

Source : Assistant Conservator of Forests, Khanapur Sub-Division, Khanapur

* Living organisms have natural variability both in time and space. Changes in species population and composition cannot always be directly attributed to the changes in the environment.

* Time is required for the changes to be visible. Usually, most of the impacts on either structure or function of a biological species or a population of an ecosystem take a long time to become fully externally visible.

Presently, the Mahadayi river in Karnataka is a small, shallow river while its tributaries and other nalas are seasonal water bodies with less flow of water except in monsoon season. In the absence of proper planning for harvesting of the valuable water resource most of the water flows to the sea. Construction of dam(s) would be helpful in conservation of water and recharge of ground water, thereby, creating a positive impact on the vegetation. Kalsa and Surla nala area has moist deciduous forest which is a degraded forest. The quality of this forest would be improved through water conservation by the construction of dam(s) on the river.

Diversion dams would be constructed on the seasonal streams/nalas. The stream water run off is wasted in monsoon and the stream bed becomes dry in late winter and summer season. These dams would be beneficial in the conservation of water and in the increase in ground water table. It would be available throughout the year for forest vegetation and wild life. Therefore, the diversion dams would be useful in promoting the forest vegetation and wildlife in the area.

The ground water table in the area surrounding the impoundments would rise. This would have a nourishing effect for the healthy growth of the surrounding forest area. The water storage and water spread would be beneficial in attracting migratory birds as well as for supporting wild life in the forest.

The fishery potential would be increased due to increase in the surface area of water bodies.

The marginally changed stream flow would not have pronounced effect on the downstream flora and fauna. The mangrove vegetation has a wide tolerance for salinity, and through proper management, their growth can be enhanced to suit marginal change in the flow pattern.

Due to flood control, the flora and fauna in the downstream reaches will be protected from destruction.

By Comparing the present observations of salinity with the past records along with other relevant parameters it has been predicated through mathematical modeling that, only at stations R6 and R7 the salinity in the critical season of summer may vary to the tune of 8-10 ppt to 2-5 ppt at R6 and 18-20 ppt to 10 ppt at R7 due to the construction of dam across the river Mahadayi. Stations R3, R4 and R5 are already in the freshwater zone and there is no question of impact on salinity. No change in salinity is predicted beyond station R7 (Amone area) towards the estuary.

Present observations as well as past records on the distribution and abundance of fauna and flora of Mandovi estuary have shown that their dominance is restricted upto the place (station R9) where the Cumbarjua Canal joins the Mandovi estuary, near St. Estevam, at the Tonga region. However, the predicted variation in salinity is only upto R7, which is well away from the region of faunal and floral abundance.

Sediment dynamics : An abrupt variation in the size fraction of sediment and organic matter content is visible from R6 - R7 zone to the R8 - R15 zone of Mandovi estuary. This indirectly shows that the R6 - R7 zone is already dominated by the limnetic features, and therefore, it is very unlikely that minor variations in salinity can bring about any drastic impact on the habitat (sediment) of bottom-living fauna or related flora (Mangroves).

Though the biotic elements of an estuarine environment are highly adaptable to a wide range of abiotic factors, including salinity, these prefer to inhabit a particular zone, which would suit their optimum tolerance limits. In case of change of salinity in certain stretches of the Mandovi river during the post project phase, the organisms which can move fast (e.g. fish) will migrate to adjacent stretches having favourable salinity for the inhabited fauna. Thus, the fauna will be redistributed within certain stretches of the river, and there will not be any loss or reduction of species diversity. The elimination of fauna from one stretch will be compensated by recolonisation of the fauna from the adjacent stretch of the river.

In case of organisms with lesser mobility such as demersal species or benthos, it would take longer time for them to colonise in the new salinity regimes. Because of their tolerance to a wide range of salinity, they will not disappear from their habitats Salinity tolerance levels of two demersal species viz., *Penaeus merguiensis* and *Metapenaeus monoceros* acclimatised to variable salinity, were determined in the laboratory for various size groups, (**Table 6.4**) and the results confirm the wide salinity tolerances of these slow-moving organisms.

Table 6.4

Salinity Tolerance of two Diversal Prawn at Variable Sizes and Acclimatisation Salinities

Species	Acclimation Salinity (ppt)						
		5		15		30	
	Size Group (mm)	Salinity Tolerance					
		Min	Max	Min	Max	Min	Max
Penaeus	10-15	4	20	5	30	10	42
merquiensis	30-35	3	30	5	30	10	44
Metapenaeus	10-15	3	35	5	35	10	40
monoceros	30-35	3	35	4	35	5	42

A brief discussion on the consequence of lowering of salinity in the mesohaline and oligohaline zones on various fauna and flora of Mandovi estuary is presented here under.

Fin Fish and Shell Fish : As many as 27 fish and shellfish species were recorded in the mid estuarine zone (stations R8 - R15) whereas at R6 and R7 28 species were observed, out of which only 3 were truly estuarine. Therefore, the predicted salinity variations may, at the most, redistribute these species to nearby zones.

Fish Breeding and Nursery Grounds : In general, the low-lying, productive mangrove zones of estuaries are used as nursery grounds by a variety of freshwater as well as marine organisms, as these areas provide food and shelter for larvae. The marine species breed in near shore waters and the larvae enter the estuaries to feed on the surplus organic matter available in the form of mangrove litter. When they become juveniles, they return to the sea. Similarly, some of the fresh water species such as the giant fresh water prawn, *Macrobrachium* sp., utilise estuaries as nursery grounds for their young ones. Therefore, the lowering of salinity as predicted in the present study (Fig. 6.14 and 6.15), at the most, may result in the redistribution of nursery grounds.

On the other hand, the truly estuarine fishes such as *Etroplus suratinsis*, *Scatophagus argus* etc., complete their entire life cycle in the estuarine zone. For them, a decrease in salinity means, shifting of breeding and nursery habitats within the limits of the newly demarcated mesohaline and oligohaline zones of the estuary.

Phytoplankton : Forty one Phytoplanktons were observed in the main estuarine zone (stations R8 - R15). At R6 only 11 species and at R7, 18 species were recorded. Minor variations in salinity may only induce the truly estuarine species to move towards the downstream. But simultaneously, a few species of low saline zones may invade R6 and R7, thus making the area equally productive in terms of primary production.

The phytoplankton species in the mesohaline zone (R6 & R7) of the estuary generally have wide tolerance range for salinity levels. On the contrary, it has been shown that the phytoplankton flora from R6 to R15 are less affected by the fluctuations in the river water flow. Therefore, it appears that the quality and productivity of phytoplankton species would only be marginally affected and would not cause any significant change in the flora of Mandovi estuary.

Zooplankton : Thirty four zooplankton species with eight larval forms were observed in the R8 - R15 regime of Mandovi. At R6 only 19 species and 4 larval forms and at

R7 only 25 species and 4 larval forms were present. Therefore, as in the case of Phytoplankton, one can expect only a temporary change in zooplankton dynamics, due to the predicted lowering of salinity.

Meiobenthos : Right from the fresh water zone (R3) to the estuary proper (stations R8- R15), the variation in number of faunal groups or their density is quite uniform. Such a uniformity in faunal distribution, across a wide range of salinity zones indicates that minor changes in salinity profile may not bring about measurable changes in future, due to impact of a dam.

Macrobenthos : Except at the R12 - R15 zone (high saline zone of the estuary), all the other stations exhibited relatively lesser faunal abundance. again, the R6 - R7 region is similar to the limnetic zone (R3 - R5) in terms of its macrobenthos distribution. Therefore, the lowering of salinity as predicted may not induce any further variation in macrobenthos distribution and abundance at R6 and R7.

Microbes : It can be said that there is no drastic variation in microbial load due to variation in salinity. Further, even at salinities as low as 0.036 ppt, the bacterial load was stated to be considerably high. However, the lowering of salinity predicted for stations R6 is well above these values, and therefore, it should not effect the bacterial production of the area.

Mangroves : After entering Goa state, the Mahadayi river continues to exhibit all limnetic (fresh water) features upto Ganjem (station R5). At Ganjem the slopy gradient of the river valley ends and the river water comes under the influence of tides. As only the highest high tide can reach this zone, only traces of salinity can be expected here at times, representing the Oligohaline zone of Pritchard's classification.

At Usgaon (station R6), the salinity remains at 8-10 ppt in summer season and the fringing mangroves make their appearance. The fringing nature continues upto Amone (station R7). The impact of lowering of salinity on mangroves would be felt in the oligohaline (0.5-5 ppt at R6) and mesohaline (5-18 ppt at R7) zones of the estuary. At present, two groups of mangroves are observed in the oligohaline and five groups in the mesohaline zone as depicted in Fig. 4.27. In the changed scenario of flows after construction of dam, a decrease in the species diversity of mangrove is expected in the stretch from R6 to R6A, where the salinity range falls below the tolerance capacity of the prevalent species. Therefore, the loss may have to be compensated by afforestation of the area with specific species which are tolerant to low salinity. Mangroves are very well distributed according to their salinity tolerance along the Mandovi estuary. Moreover, each mangrove sp. has got wide range of tolerance which is evident from their overlapping occurrence in various zones of

Mandovi estuary. In view of the very slight changes in salinity due to the dam construction in Karnataka and stabilising effects of estuarine zone from R7 to R15 as indicated earlier in case of phytoplankton flora, it appears that mangrove flora is well tolerant to these marginal changes and would not be affected.

Statistical Interpretation : The Pearsons Correlation Coefficients between species density and salinity for zooplankton observed in the Mandovi river in the three seasons do not show extreme positive or negative values (i.e. values nearer to ± 1). Significant positive correlation was observed in respect of 32 species and significant negative correlation was observed in respect of 8 species during winter season with absolute value ranging between 0.35 to 0.62. Other 12 species show their tolerance to salinity indicating that salinity variations do not affect their occurrence and distribution.

The regression equations were computed with only salinity as independent variable since the earlier study showed that other physico-chemical parameters like DO, turbidity did not show significant effect on the abundance of species in most of the cases. Multiple regression equation for all the zooplankton species are presented in **Annexure 6.3, Table 1**. These equations will help in predicting the abundance of a particular species with change in salinity, e.g. the number ciliate *Tintinnopsis* genera calculated using the regression equation with salinity values of 12 and 15 ppt will be 2, whereas with 30 ppt salinity the calculated number will increase to 4.

The statistical analysis indicates that most of the species have ability to tolerate wide salinity fluctuations. The largest fluctuation is observed in fish eggs and larvae. The value changes between 30 and 44 with change in salinity from 5 to 20 ppt. Thus, it is concluded that the distribution of zooplankton species in the river will not alter significantly and may get slightly redistributed according to their tolerance to salinity in the post project scenario.

Out of 53 phytoplankton genera observed in the Mandovi river estuary abundance of 28 genera does not show any significant correlation with salinity, and hence regression equations are not developed for these genera. Regression equations of abundance of the remaining 25 phytoplankton genera with salinity are presented in **Annexure 6.3, Table 2**. In case of the remaining 28 genera the observed regression coefficients are not high. The maximum change of abundance is expected in *Coscinodiscus* sp.. Based on regression equation $Y = 2.5624X + 139.746$, it is predicted that the abundance of the genera *Coscinodiscus* sp. will be 153 and 191 at salinity 5 and 20 ppt respectively. Thus it can be concluded that there will be insignificant change in abundance of phytoplankton genera with the post project scenario.

Regression equations of abundance of fish species with salinity is presented in **Annexure 6.3, Table 3**. Out of 41 fish species observed in the monitoring stations 18 species do not show any significant correlation coefficient with salinity and hence regression equations are not developed in these species. So in the post project scenario the distribution of these species will not get affected due to change in salinity. In case of other 22 species it is observed that regression coefficients are low. The maximum regression coefficient observed for *Macrobrachium ruda* is 0.0368. Based on regression equation $Y = 0.0368X + 1.0179$, it is predicted that the abundance of the species *Macrobrachium ruda* will be 1 and 2 at salinity 5 and 20 ppt respectively. Hence, there will be very insignificant change in the occurrence and abundance of these fish species with change in salinity.

The post project reduction in river flow in rainy season would be beneficial with respect to the following aspects.

* It would control the floods in Mandovi river.

* The germinating seedlings of the mangroves would not be destroyed due to submergence or washing away by the strong river currents.

* Mangrove flora will not be affected by reduction in the flow as the salinity change would be less as compared to the natural changes in the salinity.

* Aquatic life gets food and shelter in the mangrove belt, so the river fauna, especially fish species, would get protection from the mangrove vegetation, during low intensity flood conditions in rainy season.

The slight increase in river water flow in summer season would have the following biological impacts on river Mandovi.

* Mangrove vegetation shows presence of specific plant species in the estuarine portion according to the salinity gradient. The mangrove plants in these zones have wide tolerance range and can withstand the seasonal fluctuations in salinity. Therefore, the marginal fluctuations in salinity in summer season would not have any effect on the diversity and density of mangrove species present in the Mandovi estuary.

* The phytoplankton density may be slightly reduced due to the post project dilution of the Mandovi in summer season as compared to summer average values.

* The fish population and other aquatic fauna will not be affected by marginal change in salinity as they are capable of moving to a suitable zone of the river.

* Availability of more water in the upstream portion of Mandovi river in summer season would be beneficial for the surrounding forest vegetation as the level of ground water would be maintained in the area, which will support surrounding vegetation.

* Greater availability of water in summer season would be helpful for the aquatic and terrestrial fauna in the upstream of the Mandovi river to tide over water scarcity conditions .

The prediction of post project scenario salinity values in the Mandovi indicates that these values will be of the same order of magnitude as presently obtained. Thus, there will not be any significant difference in the distribution of zooplankton in the three groups identified.

In the light of the foregoing discussion, it can be concluded that the construction of dam(s) across the Mahadayi may bring about a temporary change in the distribution of fauna and flora of the estuarine system. They are likely to be redistributed in the area of salinity variation. In the process, the R6 - R7 zone may sometimes become biologically more productive due to colonisation of new life forms from the adjacent habitats.

Creation of a number of reservoirs will be beneficial for the development of fisheries. The major emphasis of the programme should be on adequate supply of seed and improvement in fish processing technology.

Increased availability of water vapour from the vast expanse of reservoirs, located in the forest area, will minimise the water loss from the forest plants by evapotranspiration. Thus, in the process, it will help reduce water deficit in the plants.

6.5 Impact on Land Environment

The direct environmental impacts due to the construction of dam and impoundment of water on land environment are i) flooding of land to form the reservoir and ii) alteration of water flow downstream. Some of the impacts such as flood control and improvement in fisheries potential are beneficial.

The dam's indirect effects on land include those associated with the construction , maintenance and operation of the dam (e.g. access roads, construction camps, power transmission lines) and the development of agricultural, industrial or municipal activities made possible by the dam. Deforestation, construction of roads and buildings would lead to the loosening of top soil and its subsequent transport during rains alongwith catchment washings resulting in deterioration of water quality in the rivers/nalas.

Water logging and salinity problems are expected to be insignificant due to steep valley, forest area and absence of canal networks downstream of the river.

Due to alterations in the river flow, the zone of sea water ingress in the estuary will be shifted seaward in wet as well as dry seasons. This, in turn, will change the salt concentration in river water. The zone of influence is from village Amone upto Usgaon (Pali) in Goa.

Due to increase in the river flow during dry months, salinity reduction in the river water is predicted in the stretch from village Usgaon Pali to Amone. In this area, the local salt tolerant variety of paddy is grown. The total soluble salts (ECe) of the Khazan paddy soils during the winter season are less than 0.4 mS/cm. Therefore, the chances of increase in salinity due to alteration in the water flow to exceed the critical limit of 4 mS/cm are remote. The salinity status of soils will not be affected due to the construction of MHEP. Thus, there will not be any impact on Khazan land fertility and productivity.

The existing irrigation in Mahadayi basin is mainly based on minor schemes. The total area irrigated (1980-81) was 3400 ha of which 2577 ha was from surface water and 823 ha from ground water. This is 3.1% of the culturable area of the basin. There will be an increase in the irrigated area due to this project.

The increased water storage can be utilized for perennial irrigation in the dry areas of Belgaum and part of Dharwad & Bijapur districts and for compensatory green cover development. The annual agriculture produce will increase to the tune of Rs 53 crores.

Due to diversion of water from the Mahadayi for irrigation, agro-based industries dealing in fertilisers, pesticides, farm implements and equipment, canning, cold storage etc. will be established. The increased production of fodder and grass may lead to development of cattle and dairy industry.

It will be possible to provide several lift irrigation schemes to serve the areas on the reservoir fringes and along the river upto Usgaon Pali due to the increased flow in the river during summer.

Slight changes in river flow between monsoon and nonmonsoon seasons will not have any influence on soil salinity of the Khazan land. However, the prediction of water salinity changes (Fig. 6.14 and 6.15) indicate a lowering of salinity in the Mandovi estuary which is beneficial to Khazan paddy cultivation.

6.6 Impact on climate, weather and noise

6.6.1 Impact of Water Impoundage on Micro-meteorology

The reservoir formed upstream of the proposed Kotni dam may slightly alter micro meteorological conditions. The micro meteorological parameters which may be affected are local winds, relative humidity, atmospheric temperature and atmospheric visibility. The seasonal change in submergence area will be marginal, hence the variation in local wind pattern generated by water body will remain almost the same throughout the year. The variation in relative humidity will mainly be governed by the evaporation losses.

The total quantity of evaporated water will increase after filling up of the reservoir, whereas transpiration losses will reduce due to clearing of forest land coming under submergence. The evaporation losses will be particularly significant during summer and winter seasons. The increase in evaporation losses will slightly increase the moisture content of the atmospheric layer existing above the water surface. This moisture will be ultimately transported to other places due to wind and turbulence. The evaporation process through reservoir will result in decreased day time temperature. The presence of large reservoir may result in increased night time temperature.

The existence of water body will cause the formation of lake breeze during day time and land breeze during night time. The lake breeze will enhance the natural upslope winds during day time, whereas land breeze will increase downslope winds during night time due to existing hills on the banks of the reservoir on both the sides.

There will be marginal increase in frequency of occurrence of fog in the project area ultimately reducing the visibility in the area. The frequency of fog occurrence depends on the difference in temperature between air and water body during night time.

6.6.2 Air

Major activities such as drilling, blasting, quarrying, transportation and dam construction in the study area would lead to an increase in concentration of air pollutants, particularly suspended particulate matter, oxides of nitrogen and hydrocarbons. Likewise, the NOx, CO and HC concentrations may also increase due to increased vehicular traffic.

The major dust emission sources during construction can be classified as follows :

* Quarrying and transportation of materials
* Road construction
* Dam and power house construction

The excavation and transportation of construction materials may cause increase in Suspended Particulate Matter (SPM) concentration levels but these increased levels will be sporadic and limited to construction phase only. Also, the existing concentration profiles indicate that the sporadic increases will also be well within the stipulated standards. The gaseous pollutants may include NO_x, HC and aldehydes emissions due to increased vehicular traffic during construction period. However, they will be within the limits due to the below detectable limit level as observed from the air quality monitored values in critical winter season.

6.6.3 Noise

The major sources/ activities of noise in the study area can be classified as follows:

- Stationary and mobile sources at quarry sites
- Transportation of construction materials
- Stationary and mobile sources at dam construction sites

The construction equipments and heavy machineries to be employed with expected noise levels at a distance of 2 m from the noise sources are presented in **Table 6.5**. The noise generated by these sources will not contribute to the background noise levels of the nearby human settlements, because these settlements are at a considerable distance from the quarrying and dam construction sites and surrounded by thick vegetation. Altogether it can be concluded that the noise levels in the nearby human settlements and at quarrying and dam construction sites will

Table 6.5

Noise Sources and Predicted Noise Levels

Source	Noise Level (dBA)
Scrapper	95
Loader	95
Shovel	83
Dumper (35 t Capacity)	90
Dumper (50 t Capacity)	97
Lorry	82
Dozer	96
Drill	85
Crusher (150 t /Hr)	80-82
Water tanker	85
Mixer	80
Blasting (charge 2000 kg)	120

remain well within the standards promulgated by World Health Organisation and Occupational Safety and Health Administration.

A) **Stationary Sources**

Dam construction is a one time activity and the noise generated during scraping, buldozing, drilling etc. will have a temporary impact on human settlements in the vicinity of the dam site.

The noise levels at various locations from the stationary sources can be estimated using the following model.

$$Lp_2 = Lp_1 - 20 \text{ Log } (V_2/V_1) - Ae_{1,2} \quad \text{.........} \ 1$$

Where Lp_2 and Lp_1 are the noise levels at distance V_2 and V_1 from the source and $Ae_{1,2}$ is the excess attenuation caused by environmental conditions.

The sound pressure levels generated by noise source decrease with increasing distance from the source due to wave divergence. An additional decrease in sound pressure level with distance from the source is expected due to atmospheric effect or its interaction with any object in the transmission path.

The cumulative impact of all the sources of noise at a particular distance is calculated by using the model :

$$Lp \text{ (Total)} = 10 \text{ Log } [10Lp_a/10 + 10\ Lp_b/10 + 10Lp_c/10 + ...] \ ...2$$

Where, Lp_a, Lp_b, Lp_c are the noise pressure levels at the sampling point due to sources a,b,c etc.

The impact of noise sources on nearby residential area due to power stations can be calculated using Eqns.(1) and (2). The proposed two units of 150 MW capacity will not have any impact on the population in the forest-village Krishnapur as the power station will be underground and the most modern "FRANICS-TYPE TURBINES" will be used in the power house.

The power station at Irti-dam site and tail-race dam site will have marginal impact on the surroundings due to noise sources in the power stations and the associated activities. The area surrounding these power stations is a dense forest, and there is not a single human settlement in a radius of 5 km.

B) **Wild Life**

During the dam construction activity, the noise levels at the construction sites will increase for a few hours of the day due to blasting, dumping and dozing activities and also due to heavy machinery like air-compressors, 30 tonnes capacity trailors, road rollers, motor graders, Vibrator rollers and heavy mobile cranes.

Using Eqns. (1) and (2), even if five stationary noise sources of 90 dBA are considered to be active at the dam-site for a few hours, the impact at a distance of 2 km from the site will be in the range of 42-44 dBA i.e. noise level sensitive to the external disturbance from the noise due to construction activity will increase hardly by 1-2 dBA for a short period. The existing wild-life in the surrounding forest area at the dam-site/power stations will migrate to safer sites in the dense forest.

C) **Transportation**

The vehicular traffic on the existing earthern road adjacent to the site in the forest area is comparatively low; but the construction of the dams will increase the traffic due to the dumpers, trucks, jeeps etc used in construction. The noise level estimated due to this activity can be determined using the following Federal Highway Administration Model :

$$Leq\,(h)_i = Loe_i + 10\log\left(\frac{Ni}{S_i * T_i}\right) + 10\log\left(\frac{15}{d}\right)^{(1+d)} + S_o - 13 \quad \dots .\ 3$$

Where

$Leq(h)_i$	- Leq at hour h due to ith vehicle type
Loe_i	- reference mean energy level for ith vehicle type
N_i	- number of class i vehicles passing during time T
S_i	- average speed for ith vehicle class in km/hr
T	-duration (in Hour) for which Leq is desired
d	- perpendicular distance (in meters) from the centreline of the traffic lane to the location where noise level is desired
a	- absorption factor
S_o	- shielding factor

The preceding equation (3) is used for light, medium and heavy vehicles separately and the total Leq at receptor is calculated using the following model :

Leq(h) [Total] = 10 Log [10Leq(L)/10 + 10Leq(M)/10 + 10Leq(H)/10]

Where Leq(L), Leq(M) and Leq(H) are equivalent noise levels for light, medium and heavy vehicles respectively. The noise levels due to existing traffic on major roads in the study area have been measured and the predicted noise levels using the above model are already presented in Annexure 4.3, Table 4.

D) Community

Community noise exposure is described from Leq(day) and Leq(night) noise levels and defined as hourly equivalent noise pressure level (Leq) averaged over 24 hours. Equivalent sound levels, Leq (Day) and Leq (Night) have been calculated for a few villages and sensitive receptors (Annexure 4.3, Table 3) noise exposure (ISO 1975).

The day and night equivalent sound levels measured for residential and sensitive areas are well within the standards prescribed by CPCB (Annexure 4.3, Table 5). There will not be any significant direct impact due to the proposed activities on the nearby settlements around the dam sites.

The CPCB damage risk criteria for hearing, stipulates that noise level up to 90 dBA is acceptable for eight hours exposure per day. The noise levels due to the likely sources of noise at the proposed site will be in the range of 80-95 dBA during construction activity and hence will not have any significant impact on occupational health.

The noise levels due to the noise generating sources at the proposed dam site will be in the range of 80-95 dBA and workers exposed to these noise levels (for 8 hours working shift) will not get adversely affected until they are exposed for longer times.

6.7 Socio-economic Environment

Analysing the baseline status of the socio-economic profile and visualising the scenario after actual project implementation, certain impacts on socio-economic environment are identified. The impacts would be of varied nature, viz. positive and negative, direct and indirect, local and regional and reversible and irreversible. The impacts have a reference to the area along the Mahadayi river. No specific impacts are envisaged for the area along the Mandovi river.

A) **Positive Impacts**

* The construction of dams/diversions would enable hydro-electric power generation. As such the existing water source would be effectively used for increasing the quantum of power generation.

* The project would generate direct and indirect employment at the construction sites. Indirect employment refers to the daily wage labour employed in transportation, supply of raw material and auxillary and ancillary works.

* The increased power supply would facilitate setting up of small and medium scale industries leading to employment generation.

* The availability of power supply would bridge the gap between demand and supply in the region satisfying the power demand for domestic, commercial and irrigation purposes.

* The improved irrigation facilities in Belgaum and Dharwad region would eventually lead to increased agricultural yield contributing towards economic upliftment specially in the agriculture sector.

* The project would set up a township with all infrastructure facilities. These facilities would be used by the local people also and would definitely help in the betterment and upliftment of the Quality of Life of the local people.

B) **Negative Impacts**

* Due to land acquisition for the project there would be a change in the land use pattern in the area. The project authority would acquire 1608 ha of forest area, 373 ha of private land and 164 ha of waste and Govt. land. At present, the private land for cultivation and waste land and Govt. land is used for grazing. As such due to land acquisition, there would be loss of agriculture and grazing land. This may lead to decrease in crop yield and milk production adversely affecting the employment and income of the local people.

* About 94% of the total main workers in study area (Fig. 4.34) are engaged in agriculture. Land acquisition may lead to a large scale change in the occupation pattern and loss of jobs to the villagers at the project site.

* Due to land acquisition the project would directly affect a population of 3743 in 10 villages (Annexure 4.8, Table 10) in Belguam district. Though these

villages would be either fully or partly submerged, the population would get affected due to loss of agricultural land, households as well as grazing land.

* It is understood that at present there are about 620 people to be evacuated in Kongla, Kirvale and Kabnali villages in Karnataka. The shifting may cause disturbance in their life pattern and eventual emotional stress.

* The cost of private land in places like Jamboti, Kanakumbhi, Chapoli etc. may go up due to the project. However, the rise is not likely to be significant in view of the area being tribal in nature with inadequate means of livelihood, and infrastructure.

* As regards impacts of the project in Goa, only people from Volvoi expressed an opinion that due to the project activities, water table of the Mandovi river would go down and cause adverse impacts on fishery which does not appear to have any scientific basis.

6.8 Seismic Impacts

All the structures envisaged under the MHEP such as the main dam at Kotni, the diversion dams, the power houses and the water conveyance systems fall in an area of about 10 x 10 km of the Mahadayi catchment in Karnataka. The Kotni dam site (longitude 74° 21' 10" and latitude 15° 37' 20") is located downstream of the confluence of Kotni nala with the Mahadayi river. The sites lie on the border between seismic zone III and II as per the seismic zoning map of India (Standard Criteria for Earthquake Resistant Design of Structures, IS : 1893-1984). It is generally understood, in the design of normal structures, that adequate safety would be achieved if the structures are designed as per the recommended IS code. The structures designed as per the recommended design parameters for this zone will generally prevent loss of human life and only repairable damage could occur. The recommended design parameters in IS : 1893-1984, however, are for preliminary design of dams, and it is desirable to carry out dynamic analysis for the final design in order to estimate deformations due to probable future earthquakes.

The site specific studies for the main Kotni dam were carried out for local and regional geological conditions, earthquake occurrences and seismotectonic set up of the region based on available literature. The maximum credible earthquake (MCE) has been evaluated on the basis of the above studies and recommended for adoption in the analysis (**Table 6.6**) of structures to ensure their structural safety. Based on these

Table 6.6

Seismic Sources and their Potential around the Kotni Dam Site

Epi Dis	Focal Depth	Mag	Dis to Eng Zone	Accer	Feature
8	12	6.0	10.00	0.18	Lineament A
15	12	6.0	16.15	0.13	Lineament B
50	12	6.0	50.35	0.05	Lineament C
30	12	6.0	30.59	0.08	Deep sealed fault

The attenuation relationship given by Abrahamson and Litehiser (1989).
In this case E and F are taken to be 0.

Lineament A, B and C are shown in Fig. 4.4.

studies (described in detail at **Annexure 6.4**), the following recommendations are made :

* The maximum credible earthquake for the site, as proposed in the study reported, be taken to be of magnitude 6.0 at an epicentral distance of 8 km from the site with focal depth as 12 km. The peak ground acceleration in horizontal direction (PGA-H) is conservatively taken as 0.18 g for MCE and 0.09 for DBE.

* For vertical component of earthquake, 2/3 of the value corresponding to the horizontal component be used for design purposes.

* Design Response Spectra values given in **Annexure 6.4, Table 4 and Table 5** are to be multiplied by 0.09 for DBE in horizontal direction and by 0.06 for vertical direction.

7. Environmental Management Plan

7. Environmental Management Plan

7.1 Preamble

In order to mitigate the adverse impacts likely to arise due to the construction of the proposed dams, diversions and powerhouses; and regulation of flows in the Mahadayi and its tributaries, an Environmental Management Plan (EMP) has been delineated for implementation by the project proponents during the pre-construction, construction and post construction phases. Some of the impacts may take place upstream of the proposed dam sites while some others on the downstream of the dams. An appropriate EMP would ensure smooth functioning of the project, enable the project proponent to allocate required funds for effective implementation and promote a secure socio-economic environment leading to the improvement in Quality of Life of the people.

7.2 Preconstruction Phase

The importance of public acceptance of developmental projects such as the MHEP at local, state and at national levels is increasing throughout the country. Public acceptance of a project should be mobilised prior to the start of the project activities. The promotional activities of the project should include a positive programme of information, effective communication and public education to prevent the spread of rumours or disinformation. The MHEP must be presented in the regional context to satisfy the general curiosity of the affected people and to address the qualms of likely pressure groups. In the background of the comprehensive impact studies, public consultation and information campaigns should be organised from the earliest possible stage of the project to dispel misgivings about the project and to successfully overcome the problem, if any, of non-acceptability.

The pre-construction phase would involve design of dam components, acquisition of land, and rehabilitation of villagers from the areas coming under submergence. The land for construction of dams and the proposed township belongs to Forest Deptt. of Govt. of Karnataka. Action on any proposal for acquisition / release of forest land should be initiated so as to obtain the clearance of the proposal by the competent authorities.

As such, it is necessary to ensure, in consultation with the PAPs, a proper rehabilitation and resettlement (R&R) package for the oustees in the construction/submergence areas in accordance with the existing policy guidelines of the Govt. of Karnataka. No such issues are envisaged in the villages in Goa excepting some anxiety regarding the possibility of some adverse effects on agriculture, fishing etc.

The following measures with respect to R&R are suggested as part of the EMP:

1. An inventory with following details should be prepared :

- persons affected by the project
- extent of the holding of the displaced persons
- extent of area wherefrom land is to be acquired for the project
- number of structures to be acquired for the project
- number of members in the family of each displaced person

While preparing the detailed inventory, the following aspects should be considered for designing and implementation of resettlement and rehabilitation plan:

* All the oustees above the age of 18, irrespective of sex, should be considered as separate individuals to be rehabilitated as per the State Govt. guidelines.

* The divorcees/ deserted women and widows with no source of livelihood should be duly considered for the purpose of rehabilitation.

* Physically and mentally retarded persons irrespective of age and sex should be treated as a separate family for the purpose of rehabilitation.

* Minor orphans who have lost their parents and land and have nobody to fall back upon, should be considered as a separate family for the purpose of rehabilitation.

* In deciding compensation rates and preparing rehabilitation and resettlement package, the local leaders (formal and informal) and NGOs should be consulted and their views duly considered. These local leaders should be included in the steering committee which will be constituted by the State Govt. or by the project proponents while deciding on the R&R strategy.

* For rehabilitation of the evacuated villages, three alternate sites should be identified from which the oustees could choose one site for resettlement. The whole village as a group should be shifted to one place or locality so as to protect the feeling of cohesiveness amongst the community.

* Alternate agricultural land for the land lost or alternate income source should be provided to those who have lost their land to the project.

* For the PAPs, a provision should be made for vocational, occupational training such as book binding, carpentry, poultry, and brick making. Also loans should be provided to the PAPs, so that they can start their own business.

* The value of standing crops in the field at the time of land acquisition, and the built up properties and other items of economic value should be included while deciding on the compensation package.

* At the rehabilitation site proper infrastructure viz., medical, education, water supply, electricity, road, transport and sanitation facilities should be provided to avoid strain on the existing facilities.

* If demolition of public utility and religious places at the PAVs is involved, it is necessary to build a temple for temple, mosque for a mosque at the new settlement site.

* Transportation charges or monetary compensation should be paid to the displaced people to carry their belongings to the rehabilitation site.

* Those who have encroached on Govt. land for house construction or agriculture, for earning their livelihood and are using the same for a considerable period (to be decided by the R&R committee) should be considered while preparing the compensation package.

* Social counselling centres should be opened to help and give guidance to the PAPs for buying land, property, setting up business jobs etc. and in proper utilisation of funds distributed by way of compensation. This is necessary to ensure that the funds are not misused in gambling, drinking etc. by the PAPs who are economically not very sound.

* For dam construction work raw materials would have to be brought to the area. Proper measures should be taken to mitigate adverse impacts arising from road accidents, noise and vehicular pollution, traffic problems etc. due to increase in transport activities.

2. The state government should establish a Directorate of resettlement consisting of Director, Joint Directors, Deputy Directors, Project Engineers and Resettlement Officers for the purpose, viz. advice and consultation for the

Resettlement and Rehabilitation of the project affected population. An advisory committee should be formed for the purpose of assisting the Directorate in the speedy resettlement of displaced persons by the State Government (Reference : The Karnataka Resettlement of Project Displaced Persons Act, 1987)

3. Assessment of land available for resettlement has to be done by the Joint Director. This would refer to proximity of alternative agriculture land, the availability of water sources in the new resettlement place, access to roads and suitability of land for constructing houses.

4. After the draft scheme for resettlement is finalised by the Joint Director, the Director should publish the draft scheme in the Official Gazette.

5. The draft scheme should call upon each of the displaced within forty-five days from the date of the draft scheme is published in the Official Gazette.

7.3 Construction Phase

The construction phase involves a preparatory phase during which the following activities have to be carried out.

* Cleaning and clearing of site for construction of offices/ residential quarters

* Erection of temporary site offices and staff quarters

* Construction of roads to the sites

* Provision of infrastructural facilities like water supply, sewerage, drainage, garbage removal, shopping centres etc. for the residential colony

* Employment of personnel and migration of staff to site

* Clearing and cutting of forests in the water spread area

* Transportation of heavy machinery and equipment and construction material

* Drilling, blasting, quarrying, and transporting of rock at the dam sites

For mitigating the adverse impacts during this phase, the following measures are suggested:

* Provision of cut off drains and holding tanks, growing different varieties of grass on the loose soils and on construction debris to prevent soil erosion and associated impacts

* Proper and adequate residential facilities with power, water supply and sanitation

* Proper supply of fuel needed by the labour to ensure that they do not cut trees in the region

* Treatment of domestic wastewater and garbage disposal

* Mobilisation of local NGOs to generate environmental awareness among the local people with specific reference to the project activities and to achieve their participation in the developmental project

With a view to mitigate the adverse impacts due to air pollution arising from the project activities and to improve the aesthetics of the area the following measures are called for:

* Protection of workers and staff against dust emissions from drilling, blasting and transportation activities

* Suppression of dust by spraying water on haul roads, overburden dumps, rocks and waste materials, etc.

* Growing native plant species along the roads

* Proper design of green belt over the waste dumps

* Improved maintenance of machineries, vehicles etc. at quarry and dam sites

To minimise adverse impacts due to noise, it is necessary to adopt the following measures.

* While procuring heavy machineries, equipments and vehicles proper care should be taken to check the measures taken by the manufacturers to minimise noise generation.

* Personnel working near heavy machineries and blasting sites should be provided with well designed ear muffs/plugs.

* Noise generating machineries and their platforms should be so maintained as to minimise vibrations and noise generation.

* The existing vegetation around the quarries and the dam construction sites should be well maintained to help in reduction of air pollutants and noise levels.

* The depth, charge, matrix of holes and delay may be optimized to minimise vibrations caused by blasting operations.

The adverse impacts of soil erosion and sediment transport leading to turbidity in water, loss of top soil and reservoir sedimentation caused by the construction activities including quarrying, transport etc. can be considerably mitigated by taking appropriate measures as listed below:

* Identification of critically eroded areas in the catchment and undertaking soil conservation measures.

* Restoration of construction sites, areas, work places by leveling, filling borrow pits, landscaping of open areas, planting of quick growing grasses, provision of cutoff drains and holding tanks, etc.

* Cutting and removal of all vegetation including roots of plants, shrubs and trees in the reservoir submergence area to minimise deterioration in water quality due to decay of organic matter and depletion in oxygen content at a later date when the reservoir gets filled up.

* Species of plants and trees tolerant to periodic inundation may be planted along the shoreline to improve the scenery, to mask unpleasant shore area and as protection against wind. Landing stages may be constructed and fitted into the reservoir landscape.

7.4 Post Construction Phase

7.4.1 Upstream of Dam

The increased human activities in the catchment area, improvement in transport facilities, better living conditions etc. may result in part urbanisation of the tribal areas, which in turn may affect the forest cover and deterioration of water quality in the river. Forests are the main stay of economy in the project area. In the interest of safe and sustained production there is a need for shifting the focus from exploitation forestry to conservation forestry. For compensatory afforestation programme in the valley the list of plant species are given in **Table 7.1**. In the context of safeguarding ecological concerns for present and future generation and to mitigate the adverse effects, the following strategies are identified.

* Periodic remote sensing studies to monitor the change in vegetation cover in the catchment area

* Hill tops and upper erosional/shoulder slopes should be maintained under permanent vegetation

* Treatment of critically eroded catchment area and adopting soil conservation measures

* Compensatory afforestation programme including the plant species lost in the submergence area

* No excess cutting be allowed even for meeting additional revenue demands

* Forest fires should be monitored regularly and suitable control measures executed at compartment levels

* Protection of catchment area from human activities

7.4.2 At Dam Site

The construction of dams will improve the quality of reservoir waters by intercepting the run off and through regulated release in the river Mahadayi.

The likely impacts which need to be addressed at the dam site include the following:

- Change in landuse pattern
- Effects on local flora/fauna
- Flood control
- Fishing practices and potential

The majority of the activities listed above have marginal adverse effects at dam site and these can be mitigated by adopting appropriate control measures as listed below:

Table 7.1

List of Plant Species for Afforestation

Botanical Name	Common Name
Acacia nilotica	Babul
Acacia senegal	Gum Arabic
Ailanthes excelsa	Maharukh
Albizia lebbeck	Siris
Azadirachta indica	Neem
Bambusa arundinacea	Kath Bans
Borarssus flabellifer	Tar, Todipalm
Bridelia retusa	Gondvi, Khaja
Caesalpaenia	Karkonda
Callicarpa lantana	-
Calophyllum apetalum	-
Calycopteris floribunda	Ukshi
Carallia brachiata	-
Careya arborea	Kumbhi
Carissa carandus	Karonda
Cassia siamea	Kassod
Cassia fistula	Amaltas
Casuarina equisetifolia	Vilayti jhau
Cinnamomum zeylanicum	Dal Chini
Clerodendrum infortunatum	Bhandira
Commiphora wightii	Gugul
Cordia dichotoma	Lasoora
Dalbergia latitolia	Pahari Sheesham

Table 7.1 (Contd ...)

Botanical Name	Common Name
Dillenia pentagyna	Karmal
Diospyros montana	Basendu
Emblica officinalis	Amla
Eucalyptus citriodora	Nilgiri
Eucalyptus umbellata	Nilgiri
Euphoria longana	-
Flacourtia indica	Talispatri
Glycomis pentaphylla	-
Grewia tiliaefolia	Dhaman
Helicteres isora	Murad Sheng
Holigarna arnotiana	-
Hopea wrightiana	-
Lagerstroemia lanceolata	-
Leucaena leucocephala	Subabul
Lophopetalam wigjtianum	-
Macaranga peltata	-
Mallotus phillipiensis	Shendi Kamala
Mangifera indica	Mango
Memexylon edule	Limba
Mimusops elengi	Maulsaro
Moringa oleifera	Sahaujna
Olea dioica	-
Orchlandra ebrateata	Kolanji
Pongamia pinnata	Papri
Prosopis chilensis	Vilayati Kikar

Table 7.1 (Contd ...)

Botanical Name	Common Name
Prosopis cineraria	Shami
Prosopis juliflora	Kabuli Kikar
Randia dumetorum	-
Salmalia malabarica	Semal
Santalum album	Sandal
Sesbania grandiflora	Basha(Agasba)
Spathobus roxburghii	-
Symploca canara	-
Syzygium cumini	Jamun
Tamarindus indica	Imli
Tamarix troupii	Jnau
Terminalia bellarica	Behera
T. chebula	Harde
T. paniculata	-
T.tomentosa	Asan sain (Maddi)
Thespesia populnea	Ran Pipal
Ziziphus mauritiana	Pemdiber

* Flexible shorelines are highly appreciated because of gradual transition from aquatic to terrestrial living communities; as feeding and nesting area for birds. Group of trees may be specially preserved or planted to improve the scenery or to mask unpleasant shore area. They may also serve as a protection against the wind. Landing stages and bathing places may be constructed and fitted into the reservoir landscape.

* Adoption of preventive and curative measures towards water borne/related diseases

* Protection of local biota and promotion of specific flora/fauna such as gaur, grey jungle fowl, jarul and teak.

7.4.3 Reservoir Operation

Efforts should be made to study the reservoir water balance using computerised mathematical model to assess the dependability of the project for power generation. The factors to be taken into account are rainfall - runoff correlation, monsoon and post-monsoon flows, regenerated flows from the upstream area inflow diverted from upstream reservoirs through canals, release from upstream reservoirs, raperian rights for water supply, lift irrigation, lake evaporation etc.

Reservoir operation optimisation model for MHEP needs to be developed and the reservoirs should be operated accordingly for the release and diversion of water from various dams. The highest priority for water release should be given to the downstream water requirements for water supply, and then to irrigation, hydropower, and flood control in that order.

Remote sensing studies should be carried out periodically for mapping of surface water storage, monitoring changes in command areas, flood affected areas and forest cover.

7.5 Mitigation Measures Downstream of Dam Site in River Mandovi

The predicted seasonal variation in the Mandovi river water quality and flow after the construction of MHEP and diversion dams in Karnataka appears to be beneficial for the protection of river system from the flood and conversation of aquatic and terrestrial fauna and flora in the area. Proper protection and conservation methods particularly in mesohaline zone should be implemented for mangrove propagation as outlined below

* Periodic monitoring of the status of mangrove vegetation

* Ban on indiscriminate cutting and clearance of mangrove vegetation by local people

* Plantation of suitable mangrove species in the estuarine zone. The suitable species are *Sonneratia caeseolaris* in the upstream estuarine zone; *S.alba, Avicennia* sp., *Kandelia* sp. and *Rhizophora* sp. in the intermediate estuarine zone and; *Acanthus ilicifolius, Avicennia* sp. *Bruguiera* sp. *Exocaecaria agallocha, Kandelia* sp. *Rhizophora* sp. and *Sonneratia alba* in the estuarine zone of Mandovi river.

In view of breeding of fishes mostly in monsoon season, fishing should be restricted during July to September in the estuarine zone. Bottom sediment in the estuarine zone is a good habitat for meiobenthos which are used as food by larval fishes and other macrofauna. Removal of sand from this region should be restricted. Intertidal regions, rich in mangroves are good nursery grounds for juvenile fishes. Plantation programme of mangrove vegetations in mesohaline and polyhaline zone should be undertaken. Salinity of soils in Khazan lands is due to poor drainage and non availability of fresh waters. Improved variety of paddy needs to be grown in such lands.

A comprehensive environmental mitigation and monitoring programme before the construction phase, and during the construction and operation of the project as detailed in **Table 7.2** is essential for minimising negative impacts and maximising beneficial impacts arising from the project. The monitoring for each project phase, to begin with, shall cover all environmental aspects related to the project. As factual information on the environmental impacts due to the construction and operational phases of the project becomes available through the proposed monitoring, the monitoring programme may be suitably modified, if necessary.

For effective implementation of the recommended environmental monitoring, it will be necessary to establish and develop adequate facilities for sampling and analysis. It will be desirable to set up an environmental monitoring cell at KPCL and ID, Karnataka with competent trained staff and adequate instrumentation support. Alternatively, the available infrastructure with the KPCB / authorised private laboratories may be assigned with the task of monitoring.

The implementation of the mitigation plan should be regularly reviewed by a high level committee consisting of members drawn from KPCL, ID, Karnataka and Goa, Pollution Control Boards, CWC, NWDA, and Forest Departments so as to ensure compliance with the recommendations.

Table 7.2

Environmental Mitigation and Monitoring Plan for MHEP

Environmental Issues	Action Taken / To be Taken	Responsibility
A. Pre-Construction Phase		
Public Acceptance	* Positive programme of information, effective communication and public education in the backdrop of the EIA report	KPCL IDK IDG
Land Acquisition	* Strict compliance of "The Karnataka Resettlement of Project Displaced Persons Act (August 1994)"	KPCL IDK
Social Disruptions	* Monetary compensation, and/or rehabilitation and resettlement of PAPs	PWD, KPCL, Revenue department
	* Organise public awareness programmes through audio visual aids and mass media	KPCL IDK IDG
B. Construction Phase		
Site Clearance	* Minimum damage to existing structures, flora & fauna, electricity and telephone lines and other infrastructural services, if any	KPCL IDK
	* Identify sites for stacking construction material and disposal of debris /refuse	PWD, KPCL IDK

PC : Prospective Contractor
IDK : Irrigation Department, Karnataka
IDG : Irrigation Department, Goa
ADK : Agriculture Department, Karnataka
TD : Traffic Department
HD : Highway Department
KPCB : Karnataka Pollution Control Board
MEF : Ministry of Environment & Forests
CWC : Central Water Commision
NWDA : National Water Development Agency
PWD : Public Works Department
FD : Forest Department

Table 7.2 (Contd ...)

Environmental Issues	Action Taken / To be Taken	Responsibility
Earth Work Excavation	* Ensure unobstructed natural drainage	PC
	* Dispose surplus excavated earth at identified sites	PC
	* Ensure minimum hindrance to normal local activities and business	PC
Loss of Natural Vegetation / Standing Crops	* Replantation on areas/ on the periphery of construction sites to minimise visual impact and soil erosion	FD, PWD, PC
	* Programme the work to avoid loss of standing crops in the submergence area	PC
Conservation of Ecological Resources	* Compensatory afforestation in appropriate locations in nearby areas to the extent of submergence area	FD, KPCL, IDK
	* Afforestation programme should include the plant species, lost in the submergence area	
	* Farmland and forest belts shall not be used as material borrow sites	PC
	* If excavation has to be done in arable land, top soil (30 cm) shall be preserved and returned after construction work is completed, so as to minimize impacts on ecosystem, agriculture and animal husbandry	PC
	* Education of construction workers to protect natural resources, wild plants and animals	PC

Table 7.2 (Contd ...)

Environmental Issues	Action Taken / To be Taken	Responsibility
Soil Erosion/ Sediment Transport/ Water Quality	* Catchment area treatment	ADK, PWD
	* Provision of cutoff drains and holding tanks	ADK, PWD, FD
	* Grow different varieties of grass on the loose soils	KPCL, FD
	* Removal of all vegetation including roots of plants, shrubs and trees in the submergence area	FD, PC
	* Ensure steps to prevent earth and stone from silting up the existing natural drainage systems	PC
	* Reasonable measures to prevent direct discharge of polluted waters from construction activities into water bodies	PC
	* Minimise exposure of soil types susceptible to wind and water erosion	PC
	* Runoff and erosion control through proper drainage channels and structures	PC
	* Plant along the shoreline of reservoir(s) species of plants and trees tolerent to periodic inundation	PC
Mangrove Vegetation	* Plantation of suitable mangrove species along the banks of Mandovi estuary	FD

Table 7.2 (Contd ...)

Environmental Issues	Action Taken / To be Taken	Responsibility
Soil Compaction	* Restrict traffic movements and use low ground pressure machines	PC
	* Preserve top soil to be replaced after completion of construction activity	PC
	* Avoid wet soils	PC
Road Construction	* Minimise interruptions to utility services through proper planning and scheduling of activities and inter-departmental co-ordination	PWD, PC, TD
	* Construction of temporary roads and diversion of traffic on Jamboti - Kanakumbhi - Panaji road and other interior roads	PWD, HD, PC
	* Preference to local labour /skill during construction, operation & maintenance	PWD, PC
Dust /Air Pollution	* Dust control through sprinkling/ washing of construction sites and access roads particularly in places near villages, towns	PC
	* Stock piles and storage areas shall be covered or watered to prevent dust pollution	PC
	* Trucks to transport construction materials shall be covered to minimise spills/accidents	PC
	* Preventive maintenance of construction equipment and vehicles to meet emission standards	PC

Table 7.2 (Contd ...)

Environmental Issues	Action Taken / To be Taken	Responsibility
Noise Pollution	* Where residences are located within 200 m from construction sites and in sensitive areas like hospitals, schools, zoological parks etc. noisy construction work shall be undertaken during day time only (0730 Hrs - 1800 Hrs)	PC
	* Ensure proper maintenance of machines and trucks to keep noise levels low	PC
	* Sound barriers shall be installed and trees shall be planted as appropriate, during the construction phase	PC
Construction Camps	* Adequate provision of septic tanks / sanitary pit latrines at the construction camp sites for sanitary disposal of excreta	PC
	* Provision of creches for working women labour	PC
	* Drinking water shall meet the national (CPHEEO) potable water standards	PC
	* Garbage shall be collected in garbage cans at fixed places & disposed of regularly	PC
Aesthetic Impairment	* Aesthetic enhancement through proper house keeping of construction sites	PC
	* Disposal of construction wastes at the approved disposal site(s)	PC

Table 7.2 (Contd ...)

Environmental Issues	Action Taken / To be Taken	Responsibility
	* Completing the construction activity by removing all temporary structures, restoring the project and surrounding areas as near as possible to the pre-construction condition	PC
Risk of Accidents	* Ensure worker / public safety and minimise accidents through efficient lighting and safety signs installed at work sites and temporary roads, and efficient traffic regulation	PC
	* Provide temporary crossings /bridges to facilitate normal life and business	PC
Cultural Relics	* If fossils, coins, artifacts of value or antiquity, structures and other remains of geological or archaeological interest are found, the local government shall be immediately informed of such discovery, and excavation shall be stopped until identification of cultural relics by the authorized institution of preservation is completed	PC
	* Protection of historical monuments and archaeological sites against possible damage	Archaeology Dept., PC
Traffic and Transportation	* Use major roads to avoid traffic congestion and insist on compliance by contractor	Traffic Police, PC

Table 7.2 (Contd ...)

Environmental Issues	Action Taken / To be Taken	Responsibility
	* Local construction materials shall be used as much as possible to avoid long distance transportation of construction materials, especially earth and stones	PC
	* Adequate actions to direct traffic shall be taken in consultation with highway and police departments when roads are jammed during the construction period	PC
	* Where sections of existing roads are used for transportation of construction materials, subsidiary roads shall be constructed as appropriate, so that the existing roads are not significantly congested	PC
	* Plan for transportation of construction materials shall be developed to avoid transport activities during hours of peak traffic especially for existing roads	PC
C. Post Construction Phase		
Reservoir Operation	* Design of operation rules with recourse to mathematical modelling and strict compliance of the regulation	KPCL, IDK
Water Contamination	* Regular reservoir water quality monitoring to facilitate treatment control	KPCL, IDK

Table 7.2 (Contd ...)

Environmental Issues	Action Taken / To be Taken	Responsibility
	* Judicious management of land and human activities within the watersheds to minimise pollution	Revenue Dept., FD, PWD, ADK
	* Protection of canal and bund slopes through appropriate measures such as stone /concrete pitching, turfing and planting goat foot creepers to minimise erosion	KPCL, IDK
	* Control weed growth in canals and reservoirs by mechanical harvesting	KPCL, IDK
Catchment Area Planning and Treatment	* Prioritization of watersheds in the catchment area using remotely sensed data and GIS tools	KPCL, RRSAC
	* Control and treatment measures related to runoff and soil loss	FD, ADK, PWD
	* Afforestation of degraded forest land and strict adherence to periodic updating	FD, PWD, Revenue Dept.
Fisheries Development	* Adequate production and supply of seed and improved fish processing technology	Fish Dept.
Others	* Implement a well planned programme of human resource development aimed at increasing the competence and capabilities of technical and administrative personnel to the project at all levels	KPCL, IDK

Table 7.2 (Contd ...)

Environmental Issues	Action Taken / To be Taken	Responsibility
D. Environmental Monitoring		
Air Quality Monitoring	Construction period (1)Monitoring items : SPM, NO_x, CO, SO_2 (2)Monitoring frequency : 3 times a year (January, May, & October) (3)Monitoring points : Near the construction sites and residential areas (4)Monitoring technical criteria : KPCB, MEF Standards /Guidelines	KPCB, KPCL
Noise Monitoring	Monitoring frequency : (a)Construction period : once in a month each time including day and night (b)Operation period : once in 3 months adhoc monitoring will be undertaken as appropriate Monitoring points : (a)Construction period : Near construction sites and sensitive areas (b)At Power Houses	KPCL, KPCB, PC
	Ensure compliance of prescribed : Standards /Guidelines	KPCB, MEF

Table 7.2 (Contd ...)

Environmental Issues	Action Taken / To be Taken	Responsibility
Water Quality/ Flow Monitoring	(1)Reservoir Water Quality (a)Monitoring parameters : Turbidity, pH, SS alkalinity, salinity, flora & fauna (b)Monitoring frequency : Once in three months (c)Monitoring points : Kotni dam, Tail race dam (d)Monitoring technical criteria : CPCB / BIS Standards	KPCL
	(2)River Water Quality (a)Monitoring parameters : Turbidity, pH, SS, Salinity, Flora & fauna (b)Monitoring frequency : Physico-chemical - Once in 3 months Biological (Flora & Fauna) - in each season	
	(3)River Flow - Weekly	CWC, IDG, NWDA

8. Environmental Impact Statement

8. Environmental Impact Statement

1. In order to relieve the chronic power shortage experienced by the Karnataka state, the KPCL has proposed the Mahadayi Hydroelectric Project on the river Mahadayi flowing through Karnataka and the downstream state of Goa before joining the Arabian Sea.

2. The project envisages construction of Kotni, Irti and Tail race dams; diversion dams across Andher nala, Bail nadi, Muruduhaul nala, Pansheer nala, Haltar nala, Potli nala, Kalsa and Surla nala, the associated water conveyance systems, and three power stations with a total installed capacity of 345 MW. All the project activities are located in Belgaum district of Karnataka.

3. The project also envisages diversion of 255 Mcum of water from the Mahadayi basin to the adjoining Malaprabha basin to augment the irrigation potential in Belgaum and parts of Dharwad and Bijapur districts of Karnataka.

4. The study area comprises the submergence areas of Kotni dam, diversion dams on Pansheer nala, Muruduhaul nala, Bail nadi, Kalsa-Haltar nala and the Mandovi in Goa over a stretch of 82 km upto the estuarine region in Panaji.

5. In the backdrop of existing environmental quality at the project site and in the downstream riparian state of Goa, and the statutory requirements from environmental considerations, this report analyses the environmental impacts associated with the various activities envisaged under the project.

6. The project activities during the preconstruction, construction and operational phases will have impacts, both positive and negative, on various environmental components.

7. The single, most significant impact due to the project is the change in the flow regime of the river Mahadayi (Mandovi) due to impoundment of the natural flow and its regulated release from the Kotni dam, and the diversion of 255 Mcum of water to the Malaprabha basin for irrigation in Karnataka.

8. Another significant impact is the submergence of 3 villages with a total population of 620 persons who need to be resettled and rehabilitated. Further, there will be a loss of 2145 ha of forest land and associated revenue (estimated at 168 lakhs per annum) from forest produce due to the submergence caused by the reservoirs formed.

9. The availability of increased irrigation water in Belgaum and parts of Dharwad and Bijapur districts will result in additional annual agricultural produce to the tune of Rs. 53 crores.

10. The groundwater table in the area surrounding the dams would rise which would have a nourishing effect for the healthy growth of flora. The water storage/spread would be beneficial for migratory birds, fishery production and will support wildlife in the forest.

11. Generation of 345 MW hydel power which will have a long term positive impact on the economy arising from the anticipated increase in industrial and agricultural activities and the associated socio-economic development and well being of the people. The net revenue accrual per annum will be of the order of Rs. 510 crores at the current rate of electricity tariff.

12. Computations for reservoir sedimentation based on empirical equations show that the useful life of Kotni reservoir will be about 150 years.

13. A study of the hydrodynamics of the Mandovi estuary using WASP-4 model has shown no significant difference in time dependent parameters like channel flow, velocity and flow direction between the pre and post project scenarios.

14. Under critical summer conditions, the post project flows in the Mahadayi/Mandovi will not alter the salinity upstream of Usgaon Pali and downstream of Amone village. However, there will be a marginal reduction in salinity in the stretch between Usgaon Pali and Amone village. During monsoon season, the pre and post project scenario in the flow conditions remain unaltered.

15. The post-project flows in river Mandovi may bring about a temporary change in the distribution of flora and fauna of the estuarine system. They are likely to be redistributed in the stretch of salinity variation. The stretch between Usgaon Pali and Amone may sometimes become biologically more productive due to colonisation of new life forms from the adjacent habitats.

16. Due to the post project change in the flow regime of the Mahadayi/Mandovi, no significant impact on the phenomenon of sand bar formation at the mouth of the river, the associated navigational activities and the beach ecosystem of Goa is anticipated.

17. Due to the construction of dams and impoundage of water, the flood peaks in river Mandovi will get moderated. The river flows during post monsoon would remain practically unaltered, while in summer the flows will not be that high as to cause floods and scouring of the river bed.

18. The water requirements for various uses in Goa state will be met effectively since additional flow will be available in the river during non-monsoon (November-May) period.

19. The predicted impact of salinity changes in the estuarine portion of the river Mandovi in Goa being marginal, the associated impact on Khazan paddy cultivation and on the mangroves of Goa will not be significant.

20. The mangrove vegetation has tolerance to a wide range of salinity and, through proper management, their growth can be enhanced to suit the marginal change in the flow regime and associated salinity.

21. The fertility and productivity of Khazan land will not be reduced since the soluble salts content (ECE) of the soils during post monsoon period is less than 0.4 mS/cm.

22. Due to the construction of the proposed dams on the Mahadayi and its tributaries in Karnataka, the potential for increase in fisheries exists. No significant impact on fisheries downstream of the river is likely.

23. Increase in human activity in the project area especially during the construction period will have a temporary effect on wild life of the area.

24. There are no mining activities in the construction and submergence areas which are likely to be affected as a result of the proposed project.

25. There are no monuments or structures of archaeological/ historical importance existing in the project area which are likely to be affected by the project.

26. Recreational and tourism potential in and around the reservoirs could promote tourism and water sports in the area.

27. The magnitude of maximum credible earthquake for the Kotni dam be taken as 6.0 at an epicentral distance of 8 km from the site with focal depth as 12 km. The peak ground acceleration in horizontal direction (PGA-H) be taken as 0.18 g for MCE and 0.09 for DBE in horizontal direction and 0.06 for vertical direction.

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