Water Resources Assessment of Brahmani River Basin, India

A document to analyse the future scenarios of a relatively water-rich basin as support to country water policies

Country Policy Support Programme (CPSP)

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INTERNATIONAL COMMISSION ON IRRIGATION AND DRAINAGE (ICID)
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International Commission on Irrigation and Drainage (ICID) was established in 1950 as a Scientific, Technical, Non-commercial, Non-Governmental International Organisation (NGO) with headquarters at New Delhi, India. The Commissions is dedicated to enhancing the worldwide supply of food and fiber by improving water and land management, especially the productivity of irrigated and drained lands. The mission of ICID is to stimulate and promote the development and application of the arts, sciences and techniques of engineering, agriculture, economics, ecological and social sciences in managing water and land resources for irrigation, drainage and flood management using research and development, and capacity building. ICID aims to achieve sustainable irrigated agriculture through integrated water resources development and management (IWRDM), ICID network spreads to 104 countries all over the world.

Country Policy Support Programme (CPSP) was launched by ICID in 2002 to contribute to develop effective options for water resources development and management to achieve and acceptable food security level and sustainable rural development. The programme is implemented in five countries viz. China, India, Egypt, Mexico and Pakistan and is funded by Sustainable Economic Development Department, National Policy Environment Division, The Govt. of The Netherlands as Activity No.WW138714/DDE0014311.

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The external boundaries of India as depicted on the map in this report are not political.

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ICID identified and assigned the key task of water assessment for selected basins to the Indian Association of Hydrologists (IAH). The IAH team comprising Mr. A D Mohile, former Chairman, Central Water Commission, and Mr. L N Gupta, former Executive Director, WAPCOS contributed to the development of the Basin-wide Holistic and Integrated Water Assessment (BHIWA) model which formed the basic tool in analyzing policy issues, first for the selected basins in India and subsequently for two sample basins in China. Their support in carrying out assessments and in further dissemination/ discussions of outcomes with stakeholders is greatly valued. In respect of specific Brahmani basin, the sharing of data and knowledge by the Central Water Commission, Water Resources Department, Government of Orissa, Dr. B.P. Das, former Engineer-in-Chief, Orissa State Water Resources Department and Mr. Subhadarshi Mishra of SPARC enabled the ICID to collect data, hold preliminary basin level consultations, and examine meaningful scenarios for detailed basin water assessments. Their contributions are greatly appreciated. A review by Prof. P.B.S Sarma, former Director, Water Technology Centre, IARI also helped in the editing task. At the Central Office, ICID, Dr. S.A. Kulkarni, Director (I) ably coordinated the execution of various CPSP activities since its inception and prepared the report for printing. Their contributions are duly acknowledged.

ICID acknowledges the donors for reposing their confidence in ICID in assigning the task of exploring strategic directions to support county level policy support addressing water supply and demand issues of all the three sectors in an integrated, holistic and sustainable manner with food security and rural development as the main focus.

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EXECUTIVE SUMMARY

Background to CPSP

The World Water Vision on Water for Food and Rural Development (WFFRD) for the year 2025 formulated through extensive consultations held in over 43 countries was facilitated by International Commission on Irrigation and Drainage (ICID) among others. The World Water Vision document was presented at the 2nd World Water Forum held at The Hague, The Netherlands in 2000. A substantial increase in the global water withdrawal, water storage and irrigation expansion for the pre-dominant "food sector", (largely consumptive), was apparent. These projections of larger increases were in the developing countries. However, the integrated overview vision did not quite reflect these conclusions. It also did not reflect quantification of water needs for the "people sector" (largely non-consumptive) and the "nature sector" (largely consumptive).

In order to integrate the supply and demand of all the three sectors, namely food, people and nature, ICID adopted a 'Strategy for Implementation of Sector Vision on Water for Food and Rural Development' in the year 2000. ICID also felt the need to mobilise strong international support for the strategies and policies after necessary independent assessments. In line with this, ICID launched a project titled "Country Policy Support Programme (CPSP)", with a funding support from the Government of The Netherlands.

China, Egypt, India, Mexico and Pakistan having 43% of the world population and 51% of the world irrigated areas were chosen as participating countries in the CPSP. Through CPSP an attempt was made for a detailed assessment of the water supply-demand situation for the three sectors. To begin with, two representative river basins of the two most populous countries of the world, viz., China and India were taken up for assessment, to be followed by Egypt, Mexico and Pakistan. Multi-stakeholder consultations at the respective basin and national levels were held and the findings from such consultations helped to identify desired interventions in the national policies related to water resources development and management.

For carrying out detailed water assessment, in India, a water-deficit basin on the west coast, namely the Sabarmati river basin, and a relatively water-rich basin on the east coast namely the Brahmani river basin, were chosen. A 'Basin-wide Holistic Integrated Water Assessment' (BHIWA) model has been evolved by the IAH Team and applied to these two basins. The results of the assessment for these two basins, extrapolation of the assessments and policy related issues emerging from the studies were presented in a National Consultation held in November 2003, at New Delhi. Subsequently, two more river basins in India – Tapi on the west coast and Pennar on the south east coast – were selected for similar assessments to have a broader representation.

This report covers the detailed water assessment of Brahmani river basin in India and is aimed to identify the key issues and evolve water policy options to address the future water issues in an integrated and holistic manner. Chapter 1 provides general water and land related details of the Brahmani river basin, while Chapter 2 deals with specific application of BHIWA model and discusses the results of these assessments, including abstraction of key results in form of simple indicators to describe the water situation under past, present and alternate future scenarios for year 2025. Chapter 3 briefly discusses basin specific policy interventions, and their relevance to similarly placed basins and extension to revisit by way of support to National Water Policy.

Overview of Brahmani Basin

Brahmani river is one of the east flowing rivers of India. The basin has a total drainage area of about 39,268 km^2 of which 22,516 km^2 lies in Orissa State, 15,405 km^2 in Jharkhand and rest 1,347 km^2 in Chhattisgarh State. The river has two main tributaries, namely the Sankh and Koel. The basin has a sub-humid tropical climate, with an average rainfall of 1305 mm most of which is concentrated in southwest monsoon season June to October. Rain-fed agriculture is predominant except in lower deltaic parts where irrigation plays a major role. Compared to national average, the basin has a higher proportion of both land under forests and culturable wastelands. In contrast to Sabarmati, the basin is almost double in size, with a much less population (about 8.5 million total habitants in 2001) and even lesser percentage of urban to total population and much less land under irrigation. Irrigated area in recent years has averaged only about 1.23 million ha against a total cropped area of 1.57 million ha.

The per capita water availability in the basin in 2001 was about 2,590 cubic meters per year considering the past estimates of annual renewable water resources of the basin at 21,920 million cubic meters per year, and the population of the basin at 8.5 million. The per capita water availability is much higher than the Falkenmark's water stress threshold of 1000 cubic metres per person.

The basin is abundant in mineral resources such as iron ore, coal and limestone. The Rourkela Steel Plants built in 1960 is one of the large steel plants with substantial ancillary industries in the Angul-Talcher area. There are two large thermal plants established by National Thermal Power Corporation and National Aluminium Company, besides coal-based fertilizer plants set up by the Fertilizer Corporation of India. Industrial activity in Jharkhand is also picking up substantially.

The basin is rich in forests occupying as much as 37% of the basin total area. Near the Brahmani-Baitarani delta are located mangrove ecosystems including the famous Bhitarkanika National Park and a Wild Life Sanctuary. About 215 sq.km of the mangroves in this region has been listed as RAMSAR SITE in November 2002. The basin has a considerable potential for development of inland fisheries in reservoir, ponds, tanks and canals.

The occurrence of floods, particularly in the deltaic region is a common feature and on an average a population of about 0.6 million and crop production of over 50,000 ha is affected annually. A large multi-purpose dam Rengali project completed in year 1985 has provided some relief to lower flood plains in this regard but its canal systems are not yet fully ready. Pollution of surface water of Brahmani and some of its tributaries below Rengali on account of discharge of industrial effluents continues to be a cause of concern despite some recent measures of the Orissa State Pollution Control Board made to improve the situation.

Water Assessments

The initial basin level consultations were held based on preliminary studies, primarily to help identify issues concerning water use for food, people and environmental sectors. The model was applied to derive responses to past, present and four future alternative scenarios using long term average rainfall. Apart from Business as Usual (B as U) Scenario (F-I), other future scenarios examined include:

- Large expansion of agriculture and irrigation (F-II) to harness much of its water and land potential.
- More industrialisation, considering the present base and its future growth (F-III)
- Lesser agriculture and industrial expansion with increased allocation of water to nature sector needs and navigation (F-IV).

In all the three cases, better water management through increasing of irrigation system efficiencies, recycling and reuse is assumed.

The aggregated results of the study and discussions of the results at the basin level are presented in the report.

To summarise, the total water input (rainfall and imports) to the basin is 51,586 million cubic meters. The major water outflow from the basin comprises consumptive use (69%) and river flows (31%). The total consumptive use (ET) at present (2000) situation is 34,138 million cubic meters comprising about 64% by nature sector (forests, pastures and barren lands), 35% by agriculture sector (rain-fed and irrigated agriculture) and 1% by people sector (domestic and industrial). The non-beneficial ET is about 28% of the total consumptive use.

Major Findings

The major findings of the assessment are:

1. Nature sector is by far the largest consumer of water.
2. Contribution of groundwater to base flow is increasing, indicating risk of waterlogging
3. Future withdrawal requirements would need full use of Rengali Dam storage as well as creation of additional storage in the basin.
4. Considerable land would remain rain-fed, and productivity increase may require watershed management of upper regions.
5. The basin would not have overall water shortage even in the projected scenario of increased agricultural and industrial water use.
6. To depict impacts of water use on water availability status both in quantitative as well as qualitative terms, four simple indicators were selected, two to depict the pressure of withdrawals and the other two to depict potential hazard to water quality, in the surface and groundwater systems. The water situation indicators in the Brahmani river basin in different scenarios studied are presented in the report for present conditions. Based on the classifications suggested for the indicators, the Brahmani river basin presently lies in the category of basins having little or no stress on account of surface water withdrawals

and it is very moderately stressed in groundwater withdrawal. It is in the category of low or no threat in respect of surface water quality and it is in the category of moderate threat in respect of groundwater quality.

Policy Related Issues

Some important policy related choices emerging from the Brahmani river basin assessments are:

- Shift in the concept of "water resources" : In order to consider impacts of nature sector use, terrestrial as well needs of aquatic eco-systems, impacts of rainfall harvesting, artificial recharge, and above all, for integration across the three sectors precipitation is to be considered as the primary renewable water resource
- Need for accounting return flows as additional water available for use
- Need for accounting water use by sectors, and their integration
- Need for recognising EFR and mainstreaming such requirements in to basin water management. Multi-purpose reservoirs like Rengali generating hydropower can indeed play a great role in maintaining or even improving low season river flows. However, the effects of any changes in the hydrologic regime, including improvement of flows, on the aquatic ecology needs to be studied and understood. There is a need for, an integrated management of land and water resources and integrating rural livelihoods.
- Need for a more balanced use of surface and ground water and provision of adequate drainage and relief from floods
- Improving water distribution and on-farm efficiencies through participation of beneficiaries, improved designs and O&M of structures, agriculture practices, waste water treatment technologies, etc
- Need for adopting a participatory approach, in regard to the choice of a strategy for flood control.
- Need for exploring the possibilities of 'Inland Navigation' in and near the delta, and the need for integrating the water needs for navigation (which may be compatible with EFR and hydropower), and of the consumptive uses. ■

ACRONYMS / ABBREVIATIONS

AIMO	Area Irrigated More than Once
ASMO	Area Sown More than Once
B as U	Business as Usual
BHIWA	Basin-wide Holistic Integrated Water Assessment Model
BOD	Biological Oxygen Demand
CPSP	Country Policy Support Programme
CWC	Central Water Commission
D&I	Domestic and Industrial
DO	Dissolved Oxygen
EFR	Environmental Flow Requirements
ET	Evapo-transpiration
ET0	Reference evapo- transpiration
FAO	Food and Agriculture Organisation of the United Nations
FCI	Food Corporation of India
G&D	Gauge and Discharge
GCA	Gross Cropped Area
GIA	Gross Irrigated Area
GoCH	Government of Chhattisgarh
GoO	Government of Orissa
GSA	Gross Sown Area
GW	Groundwater
GWP	Global Water Partnership
Ha/ha	Hectare
IAH	Indian Association of Hydrologists
ICID	International Commission on Irrigation and Drainage
IIT	Indian Institute of Technology
INCID	Indian National Committee on Irrigation and Drainage
IPTRID	International Programme for Technology and Research in Irrigation and Drainage
IUCN	World Conservation Union
IWMI	International Water Management Institute
IWRM	Integrated Water Resources Management
Km	Kilometer
lpcd	Liters Per Capita/Day

MAF	Million Acre Foot
MAR	Mean Annual Runoff
Mha	Million hectare
MCM	Million cubic meters (10^6 m^3)
MoEF	Ministry of Environment and Forests
MoWR	Ministry of Water Resources
MSL	Mean Sea Level
NALCO	National Aluminum Company
NCIWRDP	National Commission on Integrated Water Resources Development Plan
NIA	Net Irrigated Area
NIH	National Institute of Hydrology
OPCB	Orissa Pollution Control Board
SB	Sub-Basin
SPCB	State Pollution Control Board
SPARC	Spatial Planning & Analysis Research Centre
SW	Surface Water
WAPCOS	Water & Power Consultancy Services (I) Ltd.
WFFRD	Water For Food and Rural Development
WWC	World Water Council
WWF	World Wide Fund for Nature
WSI	Water Situation/Stress Indicator

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CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

BRAHMANI RIVER BASIN

1.0 Introduction

Background to CPSP

The World Water Vision on Water for Food and Rural Development (WFFRD) for year 2025, formulated through extensive consultations held in over 43 countries, was facilitated by International Commission on Irrigation and Drainage (ICID) and a few other International Organisations. The theme document presented at the 2nd World Water Forum in The Hague in 2000 projected a substantial increase in the global water withdrawal, water storage and irrigation expansion for the pre-dominant "food sector". (largely consumptive). A majority of these projections of large increases related to the developing countries. However, the integrated `Overview Water Vision' document scaled down these requirements in an attempt to consolidate conclusions and recommendation of various other themes. It also did not reflect quantification of water needs for the "people sector" (largely non-consumptive) and the "nature sector". Water needs of the food sector depend on the population, the changing dietary preferences and the income levels. Likewise, the water needs of the people sector also depend, apart from population, on the quality of life, income levels and the general economic growth including the industrial growth. The water needs of the nature sector, including the need of the terrestrial and aquatic eco-systems depend on the land use as also on the preferences of the society in trade offs between the uses and `non-use' of water.

In order to analyse the supply and demand issues of all the three sectors, namely food, people and nature in an integrated manner, ICID initiated a 'Strategy for Implementation of Sector Vision on Water for Food and Rural Development' initiative in the year 2000. It also felt the need to mobilise strong international support for strategies and policies in water sector to achieve food security and reduce poverty in developing countries through independent water assessments. In line with this, ICID launched a project titled "Country Policy Support Programme" (CPSP), with a funding support from the Government of The Netherlands.

China, Egypt, India, Mexico and Pakistan having 43% of the world population and 51% of the world irrigated areas were chosen as participating countries in the CPSP. To begin with, detailed assessments were planned and implemented for the selected sample basins for the two most populous countries of the world, viz.; China and India considering their population growth and rate of urbanisation which factors have strong bearing on water demands. Multi-stakeholder consultations at the respective basins and national level consultations were held to discuss the outcome of detailed assessments, including extrapolation to country level. Findings from such consultations were used to identify elements in the national policies requiring changes in the context of integrated and sustainable use of this vital natural resource. This experience in assessments was to be used for a similar exercise at a lesser scale in the remaining three countries.

As a first major step towards these initiative detailed water assessments for the past, present and future conditions were taken up for two sample river basins in India, namely the Sabarmati river basin, a water deficit basin on the west coast of the country, and Brahmani, a water-rich basin on the east coast. A simplified but more broad- based model called Basin-wide Holistic Integrated Water Assessment (BHIWA) model was developed keeping in mind the specific objectives of the CPSP and applied to each of these two selected river basins. The results of the preliminary assessment for these two basins were first deliberated at the basin level consultations in January 2003. Subsequently, the chosen model was amplified/fine tuned to help in carrying out detailed water assessments. Outcomes of these assessments including their approximate extrapolation to other major basins through selection of a set of water situation indicators and policy related issues emerging from the various studies were presented in a National Consultation held in November 2003. Subsequently, two more river basins of India – Tapi river basin on the west coast and Pennar river basin on the east coast were selected for similar detailed assessments. A location map of the two selected river basins is shown in Figure 1.

Figure 1. Location Map of the Brahmani and Sabarmati River Basins in India

Purpose and Scope of the Report

This report on Brahmani is prepared with the main objective of highlighting the water and water related issues of a typical water- rich basin and thereby deduces relevance and efficacy of the plausible policy options available for similar basins. With a view to support overall and countrywide water policy issues, the outcomes of the studies have been extended through selection of a set of water situation indicators to other major river basins. The report is based primarily on the use of the BHIWA model, which has been developed especially to consider and integrate supply and future requirements of all the three sectors for sustainable development and management. The report covers the use of the model to understand the availability and impacts of various land and water use policies under past, present and future conditions. The report covers the calibration of the model, which was based on the hydrologic data for a 3-year period (1998-2000) and land use data for 2000. The model simulation allows one to compare the future water regimes under alternate future scenarios, which depict alternate pattern of development and human interventions, under a similar (average) rainfall regime. The Past (1960) situation is studied essentially to serve as a pre-development baseline. This indicates, approximately a pseudo natural water regime, and in particular creates information about the pattern of dry season (Oct.-May) river flows.

Alternative scenarios about the future (year 2025) were formulated and analysed through the model, to explore the resulting regimes, and then to analyse the available various water policy options. Of these, the options, which seem to lead to a more acceptable balanced and integrated development, could then be chosen through a consultative process. A brief description of the BHIWA model is given in Annexure 1 to help the reader in understanding the capabilities and broad working of the BHIWA model. This model has been written in Microsoft EXCEL software. The model as developed and used herein is essentially a basin/ sub-basin level tool for broad water assessment with capabilities of quantifying and accounting human impacts on the water regime, through land use changes, storage, withdrawals, returns, and consumptive and non-consumptive water uses, for all three use sectors of the resources. It must, however, be noted that the model is not a water-planning tool for basin/sub-basin project planning.

Structure of the Report

Chapter 1 provides the background to CPSP and modelling approach used for detailed water assessments as a first step to explore policy options based on a comprehensive analysis of the selected sample basin. It covers the general description of the basin. The chapter also highlights water use related issues of the three main use sectors, based on the data collected by State level team. In Chapter 2 are given the details of the application of BHIWA model for assessing past, present and future conditions of the resource, the "present" condition being studied twice to explore sustainable use. Both calibration and simulation applications are covered giving salient information and aggregated results for a comparative study. Chapter 3 covers the basin specific findings as well as their extrapolation to other similarly placed basins and in the overall national context. The latter is based on abstracting of main results in the form of key water situation (state of resource and its use) indicators. The report needs to be studied along with the soft copy of the BHIWA Model containing basin- specific model by the water professionals to be able to understand the finer and sub- basin level details.

1.1 Brahmani River Basin – A Profile

General

Brahmani river basin is an inter-state river basin. It lies between Latitudes 20^0 28' North to 23^0 35' North and longitudes 83^0 52' East to 87^0 30' East latitudes. It is spread across the states of Chhattisgarh, Jharkhand and Orissa. Brahmani river is formed by its two major tributaries namely river Sankh and South Koel which originate in the state of Jharkhand. Brahmani River gets its name from below the point of confluence of river Sankh and river South Koel at Vedvyas in Sundargarh district in Orissa. The deltaic region starts at Jenapur. Here the river branches into numerous spill channels, criss-crossing with the spill channels of the adjacent Baitarani river and finally discharges into the Bay of Bengal. The total length of the river is 446 km. The map of Brahmani river basin is shown in Figure 2.

The basin has a total drainage area of 39,268 km^2 of which 22,516 km^2 is in Orissa State, 15,405 km^2 is in Jharkhand and 1347 km^2 in Chhattisgarh State. Details of the state and district wise distribution of drainage area of the Brahmani river basin are given in Table 1.

River System

Brahmani river is formed by its two principal tributaries the South Koel and the Sankh which have their origin in the upper state of Jharkhand. The river is referred as

Figure 2. Map of Brahmani River Basin

Table 1.
State and District Wise Distribution of Area and Population

State	District	Geographical Area (km^2)	Area within Basin (km^2)	Population 2001 (x10^3)		
				Rural	Urban	Total
1	2	3	4	5	6	7
Orissa	Sundargarh	9,712	5,717.77	680.98	588.06	1,269.042
	Keonjhar	8,303	1,743.56	166.32	56.83	223.145
	Sambalpur	6,657	1,371.05	81.36	0.00	81.36
	Deogarh	2,940	2,529.11	238.57	20.09	258.655
	Angul	6,375	4,235.38	760.29	147.00	907.294
	Dhenkanal	4,452	3,968.66	819.18	92.79	911.967
	Jajpur	2,899	1,836.14	932.90	37.61	970.509
	Kendrapada	2,644	1,114.41	439.26	74.13	513.388
	Orissa total	**43,982**	**22,516.08**	**4,118.86**	**1,016.50**	**5,135.36**
Jharkhand	Lohardega	1,490	625.60	169.75	46.20	215.954
	Simdega	8,820	3,927.34	569.32	33.96	603.282
	Gumla		4,420.23	773.60	39.79	813.39
	Ranchi	7,573	2,470.17	690.94	32.35	723.287
	W. Singhbhum	5,290	3,962.56	536.79	63.58	600.37
	Jharkhand Total	**23,173**	**15,405.90**	**2,740.40**	**215.88**	**2,956.283**
Chhattisgarh	Sarguja	22,337	196.00	70.91	0.00	70.91
	Jashpur	6,154	1,150.80	275.41	20.19	295.6
	Chhattisgarh Total	**28,491**	**1,346.80**	**346.31**	**20.19**	**366.5**
Basin Total		**95,646**	**39,268.78**	**7,205.57**	**1,252.57**	**8,458.14**

Brahmani below the confluence of the Sankh and Koel near Vedvyas, in Orissa at an elevation of 200 m above mean sea level.

The South Koel river originates near village Nagri in Ranchi district of Jharkhand at an elevation of about 700 m above MSL at Latitude of $23^0$20' N and Longitude $85^0$12' E. Karo river (a major left bank tributary that joins the South Koel river) at 221.25 km just south of Gudri in Singhbhum district. River Koel enters Orissa at RD 262 km. Another right bank tributary named Deo joins South Koel at 287.5 km in Orissa. The catchment area of Koel is 13,378 km^2 out of which 1438 km^2 lies in Orissa and 11,940 km^2 in Jharkhand.

The Sankh River rises near village Lupungpat in Ranchi district at an elevation of 1000 m above MSL, the latitude and longitude of origin being 23^0 14' N and 84^0 16' E respectively. The river traverses for a length of 67.5 km in Jharkhand before entering Chhattisgarh. It traverses a small length of about 50 km in Chhattisgarh before entering Jharkhand again and travels 77.50 km before leaving Jharkhand. The Sankh river in Orissa flows for a length of 45 km before meeting Koel. The total length of Sankh river is 205 km. The river drains an area of 7,350 km^2 out of which 1,422 km^2 lies in Chhattisgarh State 4,472 km^2 in Jharkhand State and 1,456 km^2 is in Orissa State.

Below the confluence, river Brahmani heads its way generally in southeast direction up to sea and traverses a total length 461 km. Below Jenapur, Brahmani river bifurcates into Brahmani (Kimiria) and Kharsuan its major deltaic branch on its left. Where as Brahmani maintains its geometry (channel width, depth & slope) on the main arm, Kharsuan has developed as a deeper and narrower channel. Although the two rivers join almost one hundred km in the downstream, Kharsuan is 15 km shorter in length and therefore is steeper and faster flowing channel. The river receives flood spills from the adjacent Baitarani, before finally discharging into the Bay of Bengal near Dhamra.

The length and drainage areas of two major tributaries of Brahmani river are shown in Table 2.

Table 2.
Drainage Area of Major Tributaries of Brahmani River

Tributary & Length (km)	Location	State	Area (km^2)
South Koel (304 km)	Left Bank	Jharkhand	11,940
		Orissa	1,438
		Total	**13,378**
Sankh (205 km)	Right Bank	Jharkhand	4,472
		Chhattisgarh	1,422
		Orissa	1,456
		Total	**7,350**

Climate and rainfall

The entire Brahmani river basin essentially falls under tropical monsoon climate zone. There are three well-marked seasons – winter, summer and rainy season. The climate in the small stretch close to the coastline is somewhat affected by sea, while that in the elevated areas of hills and plateau-tops becomes somewhat cooler due to altitude effect. The minimum temperature in winter is 4°C and the maximum temperature reaches as high as 47°C in summer.

The average annual rainfall of the basin is about 1305 mm, with minimum and maximum rainfall ranging between 969 mm and 1574 mm. Aggregate precipitation in the monsoon months (June to September) is sufficient to sustain crops and vegetation in the basin. During the months of November to February, the water deficit is moderate and may be generally met from the residual soil moisture from the monsoon months. However, during the months of March to May, the soil moisture deficit becomes rather large and shallow-rooted crops and vegetation cannot survive without irrigation. Due to the erratic and uneven time distribution of monsoon rainfall irrigation is required especially during periods of extended breaks in monsoon rainfall.

Soils

Soils in the basin can be broadly divided into two groups based on formation i.e. residual and transported soils. The soils of the upper basin which is part of Chhotanagpur Plateau lands are predominantly grouped under red gravely, red earth and red and yellow soil. Mixed red and black, red Loams dominate the Central Table land of Orissa while red loam lateritic and laterite soils are the main soils in the lower basin. The deltaic region below Jenapur is dominated by alluvial soils.

Land use

The land use statistics have been compiled using district level records collected from the co-basin States. The information has been processed sub basin wise as well as for the total basin. The land use data has also been verified from IRS-1D LISS III, satellite imageries collected from National Remote Sensing Agencies (NRSA, 2000), Hyderabad. The aggregated land use for the basin as derived from the latter analysis is presented in Table 3.

Table 3.
Land Use Pattern of Brahmani Basin (km^2)

Land use	Area
Geographical Area	39,268
Forests	15,101
Permanent pastures	1,323
Land not available for cultivation, waste and fallows	9,805
Land under reservoirs	607
Culturable land (Cultivated Land, Culturable wastes & Fallow)	21,805
Net sown area	12,432

Figure 3 shows the land use based on LISS III data imageries.

The basin is rich in forests which occupy about 38% of the area. Agriculture occupies about 55% of total basin area constituting the main source of rural livlihood and incomes.

The district wise distribution of arable and irrigated lands in the basin are depicted in Table 4.

Rice is the main food crop grown in the basin. Other food crops grown are wheat, millets, pulses, groundnut, mustard, ragi, maize etc.

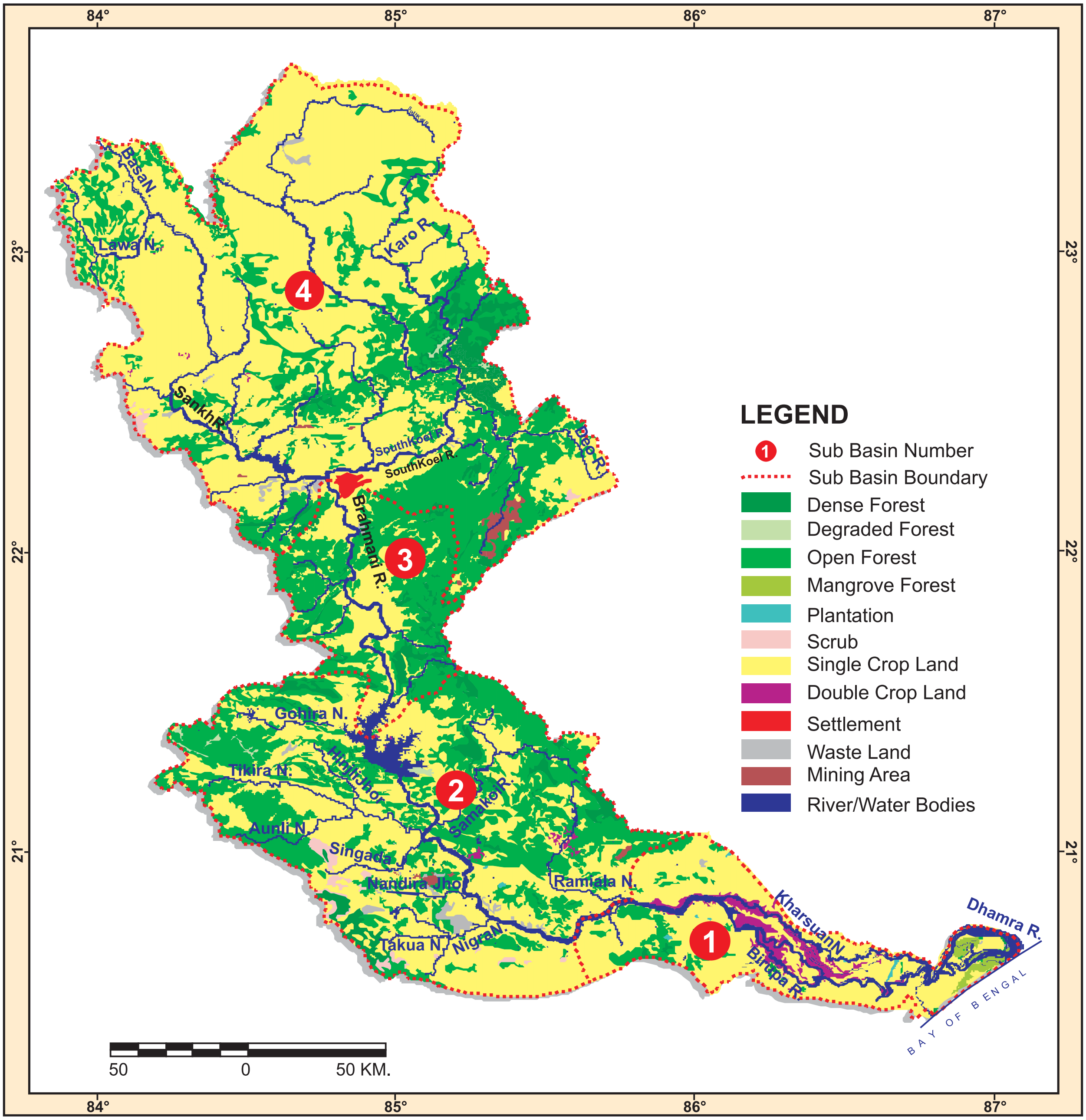

Figure 3. Land Use Map of Brahmani Basin

Table 4.
Arable Land and Irrigated Land in Brahmani Basin (km^2)

District	Geographical Area	Area within Basin	Agriculture Land	Irrigated land in Kharif
Sundargarh	9,712	5,786.08	2,589	197.32
Deogarh	2,940	2,512.37	682	118.66
Sambalpur	6,657	1,371.05	281	81.52
Angul	6,375	4,225.94	1,566	257.38
Dhenkanal	4,452	3,956.91	1,815	370.76
Keonjhar	8,303	1,723.48	401	72.11
Jajpur	2,899	1,824.75	1,047	458.44
Kendrapara	2,644	1,115.5	646	338.82
Sub Total	**43,982**	**22,516.08**	**9,027**	**1,895.01**
Ranchi	7,573	2,470.17	7,489	—
Lohardega	1,490	628.14	—	—
Gumla & Simdega	8,820	8,343.57	—	—
West Singhbhum	5,290	3,960.03	2,671	
Sub-total	**23,173**	**15,405.91**	**10,160**	**600.36**
Sarguja	22,337	423.70	46	0.7
Raigarh	6,154	923.10	747	16.6
Subi-total	**24,491**	**1346.80**	**793**	**17.3**
Total	**95,646**	**39,268.79**	**19,980**	**2,512.67**

1.2 Water Resources

A gauge and discharge (G&D) site exists on Sankh river at Tilga, (drainage area 3,160 km^2), and another on Koel river at Jareikela, (drainage area 9160 km^2). There are three G&D sites on the main Brahmani river at Panposh (drainage area 19,448 km^2) at Gomlai, (drainage area 21,950 km^2) and at Jenapur (drainage area 33,955 km^2). The location of the G&D sites are shown in Figure 4.

The Central Water Commission (CWC)[1] has estimated the annual renewable water resources of the basin as 21,920 million cubic meters. This includes surface and ground water resources. (CWC, 1988)

The annual renewable groundwater recharge has been assessed as 5,171 million cubic meters based on district wise estimates made by the Central Groundwater Board. Out of this, a recharge of 4,395 million cubic meters is considered utilisable for irrigation. The details are shown in Table 4 (CGWB, 1995).

1.3 Water Resource Development

Irrigation

Anicuts (diversion structures) were built at Jenapur on the river Brahmani and at Jokadia on the river Kharsuan in 1870-80 by the British for the purposes of irrigation, and also navigation along the coast. The Jenapur Anicut has gone into distress and has since become defunct. Old Anicuts built on Mahanadi and Baitarani Systems, as also

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[1] The Central Water Commission (CWC) is a premier technical organisation of India in the field of water resources and is charged with the general responsibility of coordinating and furthering in consultation with the State governments concerned, schemes for control, conservation and utilisation of water resources throughout the country, for purpose of flood control, irrigation, navigation, drinking water supply and hydropower development. The Commission inter alia, is involved in collection, collation and publishing of hydrological, hydro-meteorological, sediment and water quality data. The gauge, discharge and sediment sites indicated in Brahmani river basin, inter alia, form part of the overall network of the CWC.

Figure 4. Location of Gauge and Discharge Sites in Brahmani Basin

Table 5.
Annual Renewable Groundwater Resource in Brahmani River Basin (10^6 m^3)

State	District	Basin area (km^2)	Gross recharge	Utilisable recharge (85%) of gross recharge
Jharkhand	Ranchi, Gumla, Simdga, Lohardega	11,443.00	1,651.98	1,404.18
	Singhbhum	3,962.00	657.09	558.53
Chhattisgarh	Sarguga	196.00	20.65	17.55
	Raigarh	1,151.00	212.06	180.25
Orissa	Sundergarh	5,718.00	554.79	471.57
	Sambalpur	1,371.00	150.38	127.82
	Deogarh	2,529.00	226.42	192.46
	Keonjhar	1,744.00	154.35	131.20
	Angul	4,235.00	547.18	465.10
	Dhenkanal	3,969.00	481.53	409.30
	Jajpur	1,836.00	465.95	396.06
	Kendrapara	1,114.00	48.28	41.04
Total		**39,268.00**	**5,170.66**	**4,395.06**

parts of Orissa Canal system, are still functional and currently irrigate an area of 3,50,000 ha in adjacent Mahanadi and Baitarani basins and about 30,000 ha in Brahmani basin. The HLC range I and Pattamundai Canals are the main canals in the region.

Irrigation development has been accelerated with the advent of Five Year Plans. A number of medium and major projects including the Rengali multipurpose dam project were taken up. Completed in 1985, the Rengali Dam built on the main Brahmani intercepts about two third of total drainage area and is providing flood protection to the lower deltaic region besides generating hydropower. The dam has a live storage capacity of about 4,000 million cubc meters. The installed capacity of the powerhouse below Rengali dam is 250 MW. The irrigation potential of the project is, however, yet to be utilized fully as the construction of main canals off taking from the Samal Barrage, located some 35 km in the downstream of Rengali, is still in progress.

By the year 2000, 11 major and medium projects (7 in Orissa and 4 in Jharkhand) had been completed, and another five (2 in Orissa and 3 in Jharkhand) were under construction. In addition, there are 19 proposed major and medium irrigation projects in the Orissa state. Details of the existing, ongoing and proposed irrigation projects are furnished in the Annexure 2. Location of irrigation projects is shown in Figure 5.

1.4 Population and Urban Growth

The total population of the basin in 2001 was 8.457 million, of which 1.252 million was urban and 7.205 million was rural. District wise break up of basin population is given in Table 1. The live stock population was 3.818 million. By 2025, the population of the basin is projected to go up to 16.345 million, of which 5.970 million will be urban and 10.375 will be rural. The livestock population of the basin is estimated to be 4.936 million in 2025 (Census of India, 2001). The basin has witnessed rapid growth in the number of towns and total urban population and this could be attributed to the large mineral wealth and consequent industrial growth. A number of towns including Rourkela Steel city, Rourkela Municipality and its suburbs, The Talcher Thermal complex and its nearby urban areas like FCI township, Rengali Dam township, Dera Colliery township did not even exist in 1951. Even old towns like Rajganghpur, Dhenkanal, Birmitrapur received a great impetus for growth from industrial setups in and around these towns while mining activities boosted other centres like Talcher. Thus the growth, one sees in urban population, seems to be the result of specific and planned human politico-economic activities, and not due to the normal growth of population.

The exploding growth of urban centres and urban population started around Sundergarh before 1961 and

Figure 5. Location of Major and Medium Irrigation Projects

continues unabated. Somewhat similar growth seems to have started in Angul, Dhenkanal and Keonjhar districts since 1971 and may gather momentum in coming decades. This may have wide environmental implications and needs to be watched carefully.

1.5 Industries

The establishment, in the late 1950s, of an integrated steel plant at Rourkela in Sundergarh district, which included associated mines, ancillaries' by-products and down stream product units, opened the doors for wide scale industrialization of the area. The third and subsequent Five Year development plan of the country laid stress on industrialization of the country. The Brahmani basin with its rich minerals and cheap labour offered an ideal ground for establishment of industrial units. While the total number of industrial units registered with various licensing authorities presently run over a few thousands, a very dominant number of these are the labour intensive small-scale units, specifically encouraged by the Government. Most of these small-scale industrial units are engineering based units; they have no significant water requirement, wastewater generation and environmental implications.

Sundergarh and Angul and Dhenkanal have a major share of industries and have a reasonably well-diversified industrial pattern. Jute, textile and paper units that are located at Dhenkanal and the entire Angul-Talcher Industrial Complex have significant water requirements, wastewater generation and environmental implications, particularly due to their concentration in a few towns.

The number, size and variety of industrial units is bound to grow and such growth is likely to be much faster in the coming years. While metallurgical engineering and chemical units are likely to continue to dominate. Growth in consumer good and agricultural product processing units (i.e. rice, oil) is likely to be faster in the coming years due to growing demand for their product in this region.

1.6 Flood and Drainage

During floods, the river Brahmani turns into a large turbulent channel posing potential threat to the life and property of the population residing in the Basin. The maximum flood observed in the river has been recorded as 24,246 m^3/sec on 20 August, 1975 at Expressway Bridge site Pankapal gauging site. The Gauge level at the gauging site was recorded to be 24.78 meters against the danger level of 23.00 meters. Since then Rengali Multipurpose Project has come up and this is capable of moderating the flood in the lower reach covering an area of about 14,000 km^2. Of this, the deltaic stretch of 4000 km^2 is the most vulnerable. At some locations, raising and strengthening of flood embankments has also been taken up.

Brahmani River bifurcates into Brahmani (Kimiria) and Kharsuan below Jenapur. An anicut was built on the Brahmani arm another at Jokadia was built on Kharsuan (1890). On the left of the Kharsuan, a High Level Canal takes off for irrigation and navigation finally discharging into Baitarani. This canal has since become defunct, Brahmani, below Jenapur, branches out to Kimiria (the right arm), which joins Birupa, a branch of Mahanadi.

Initially Brahmani – Kharsuan doab was open except at densely populated villages protected by short embankments. Gradually with Kharsuan developing in width and depth, it conveyed 60 to 70% of the discharge in high floods. Embankments both on left and right were built on Kharsuan and three escapes Tantighai, Palasahi and Routra were provided on the right bank of Kharsuan to spill into the central low land. Another spill channel Kani takes off from kharsuan on its right 45 km below Jokadia and rejoins it after traveling 30 km.

The entire flood spill of the major rivers Brahmani – Kharsuan continue to the sea over a 10 to 20 km wide and 70km long flat flood plain. The entire delta of Brahmani-Kharsuan of 3500 km^2 is significantly flood prone. But to protect the very densely populated Aul area near Kharsuan – Kani and Brahmani, a 70 km long ring bund was constructed blocking a part of the flood plain and protecting 25000 ha of agriculture land and population of 1,50,000. The construction of embankments on the left of Kharsuan protecting the area between Khrasuan and Baitarani is substantially completed. Similarly the area between Birupa and Brahmani is also totally protected. This area receives irrigation through the Mahanadi-delta system.

It is the flood plains of 1500 km^2 in area between Kharsuan and Brahmani, which is substantially unprotected and experiences flooding of up to 1 to 2 m depth. When the river was not embanked, a discharge of 2,00,000 Cusec (5667.3 m^3/sec) at Jenapur would be conveyed without any major problem, and the flood wave passed in 2 to 3 days. But after construction of embankments to protect at least 250 villages (6,00,000 population) the submersion due to flooding become longer up to 30 days in the monsoon season (100 days). Figure 6 shows Annual Maximum Flood Discharge recorded at Jenapur. Rengali dam has moderated the high floods significantly and

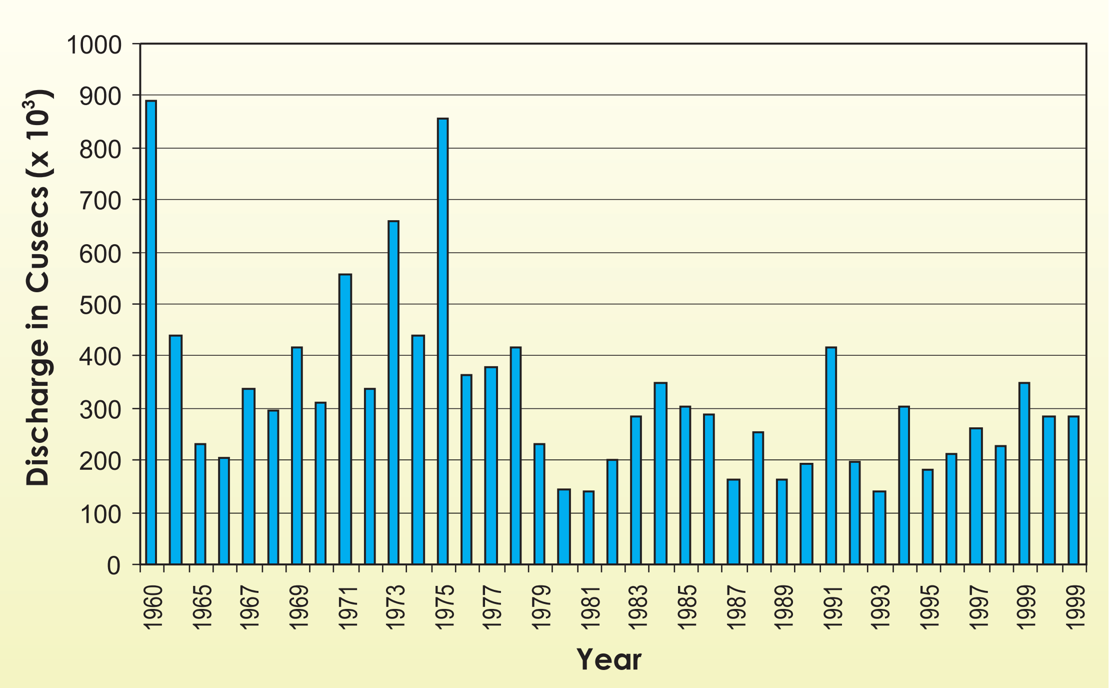

Figure 6. Annual Maximum Flood Discharge Recorded at Jenapur

provided much relief against floods. However, despite this protection, growing a Kharif crop in about 50,000 ha of low lands of elevation up to 10 m remains unviable due to prolonged flooding.

A comprehensive flood master plan for the delta needs to be prepared including the following:

a) A comprehensive drainage development, to make the central 1,00,000 ha area more productive, is necessary. The central drainage channel Dudhia need to be renovated fully. Some direct cuts may be required or channelisation has to be introduced to quickly dispose off the floodwater spilling in the central valley. Secondary and tertiary drains of 200 Km need to be renovated.

b) Since the Brahmani receives flood spill of the Mahanadi basin via Birupa (about 1500 m^3/sec) and spill of Baitarani basin via Budha join Kharsuan (about 1200 m^3/sec), a regulating structure has to be introduced to limit these spills.

c) The Rengali reservoir has to be operated in a way, which reduces the submersion of agricultural land, during the kharif crop season. Alternately, if this is not feasible,

d) Irrigated rabi cultivation by either through groundwater irrigation, or through diversion structures to be built on the Kharsuan, has to be planned.

1.7 Fisheries

Brahmani Basin has vast potential resources for development of Inland Fisheries in reservoir, ponds, tanks, and Canals.

The predominant species found in Brahmani river are Carps, Catfishes, Feather-backs, Forage fishes, Prawns and Hilsa. These species are potadromous and short-distance migrants from the upstream of the sea outfall to Panposh or a short distance up-stream. The entire stretch of Brahmani, Kimiria and Kharsuan has floodplain with over bank zones, which are sheltered locations for breeding. It is seen that Rengali Dam constructed about 300 Km upstream of outfall is not posing serious obstruction to fish migration of the native fish. The major fish catch used to be in the 100-150 km stretch from Kanika up to Kamakshyanagar. The Kharsuan arm supports a rich population of Hilsa (T Ilisa), which were observed migrating at the anicut at Jokadia (10km below Jenapur).

1.8 Mangroves of Bhitarkanika

The Bhitarkanika National Park and the Bhitarkanika Wild Life Sanctuary are famous for its mangrove ecosystems. These mangroves are situated at the terminal estuary of Brahmani river near the Bay of Bengal. The mangroves of Brahmani-Baitarani delta fall under the administrative control of the Orissa State Forest Department. Of these, a portion covering 215 km^2 has been listed as a RAMSAR SITE.

More detailed information about these mangroves is given in Annexure 6.

The sustainability of mangroves is crucially dependant on a delicate mix of abundant fresh water (riverine flow) and saline water, which the tides provide. The optimal salinity however is 5-15ppt for luxuriant growth and sustenance of mangroves.

A limited data available on water flows and salinity of water at the estuary is available (see Annexure 6). It appears that the estuarine salinity, which is slightly below the salinity in the seas, is not significantly affected by the head discharges in the river.

1.9 Navigation

Brahmani River traverses close to the Talcher-Kaniha area, which is the seat of large coal reserve and Daitari area, which has large iron ore reserve. Presently national highways NH-42 and NH-5A are being used for transportation of coal and iron ore and other industrial products. The old Orissa coast canal as well as link canals, which were used for inland navigation till about 1930's, is lying defunct. With good prospects of expansion of mining and other industrial activities in the basin, river navigation could offer a good and cheaper mode of transport. A brief note on possibilities of navigation in the lower Brahmani basin is included in Annexure 3.

1.10 Water Pollution

Brahmani, a mighty river during the monsoon, turns in the summer into more or less a stagnant pools of water held in deep gorges and pot holes in the river bed. The river becomes less capable of washing down the pollutants, which are discharged into it from the nearby industries, towns & villages located within the basin. Greater part of the river Brahmani (below Panposh and upto Rengali Dam) is found to be polluted. At present there is no arrangement for monitoring the heavy metal content and presence of radioactive material in the water. With the assurance of effluent treatment of industrial effluents, safe and clean drinking water in the river stream may be available.

1.11 Present Water Use and Future Requirement

Agriculture Use

The large majority of population in Brahmani basin depends mostly upon agriculture for its livelihood. At present (2000), the gross area under agriculture is 1.575 Mha of which 1.237 Mha is under rain-fed and the balance 0.338 Mha is under irrigation. The area covered under rice crop is 0.8 Mha and pulses and other crop cover an area of 0.167 Mha.

As per the quick estimates made for preliminary basin level consultations, the present (2000) water withdrawal for irrigation is roughly estimated at 3380 million cubic meters, by applying an assumed 'delta'[2] of one meter on the reported irrigated area. The net consumption for agriculture comes to about 2704 million cubic meters considering irrigation return as 676 million cubic meters (20% of withdrawal). The average delta value for minor irrigation schemes was taken as 0.65 m.

The Water Resources Department, Government of Orissa has a master plan for Brahmani river basin with the objective of utilising large irrigation potential. It is proposed to have an additional irrigation potential of 0.45 Mha from major and medium schemes and 0.12 Mha from minor irrigation schemes. Government of Jharkhand has proposed for irrigation of 0.56 Mha from major and medium projects and 0.10 Mha from minor schemes. It is proposed to provide irrigation for an area of 0.002 Mha from minor projects in Chhattisgarh state. The ultimate irrigation potential and water requirement by the year 2025 in Brahmani river basin is given in Table 6.

As per these preliminary estimates, total requirement for irrigation in basin from surface water based schemes will be 11,600 million cubic meters in term of withdrawals. The net consumptive use of water for irrigation will be somewhat smaller, on account of the return flows.

Domestic Use

Considering domestic water supply norm of 140 litres per capita per day (lpcd) for urban population of 1.252 million, 70 lpcd for rural population of 7.205 million and 50 lpcd for live stock population of 3.818 million, the total requirement for water for domestic use in 2001 was

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[2] delta is the term used to represent the average gross depth of irrigation water.

Table 6.
Ultimate Irrigation Potential and Water Requirement in Brahmani Basin by 2025

Projects	Orissa		Jharkhand		Chhattisgarh		Total basin	
	Area (ha)	Water requirement (10^6 m^3)	Area (ha)	Water requirement (10^6 m^3)	Area (ha)	Water requirement (10^6 m^3)	Area (ha)	Water requirement (10^6 m^3)
Major & Medium	4,49,326	4,493	5,65,234	5,652	Nil-	Nil	10,14,56	10,145
Minor	1,21,699	791	1,00,486	653	2,009	13	2,24,194	1,457
Total	**5,71,025**	**5,284**	**6,65,720**	**6305**	**2009**	**13**	**12,38,75**	**11,602**

324 million cubic meters. Considering 50% of water withdrawal as return flow, the net consumptive use of water for domestic use was estimated as 162 million cubic meters.

The water requirement for domestic use for the projected urban, rural and live stock population in the year 2025 is estimated as 671 million cubic meters considering the present norms for water supply. The net consumption of water would be 335 million cubic meters assuming return flow as 50% of total withdrawal.

Industrial Use

The basin has abundant mineral resources such as iron ore, coal and limestone. Rourkela steel plant built in 1960 is a large plant with substantial ancillary industries. The Angul-Talcher region has large thermal stations, aluminum smelter and fertilizer plants. Another major complex of steel plants at Duburi, close to the delta head is coming up fast. The industrial activity in Jharkhand state, which is not significant at the moment, is likely to pick-up substantially.

The present (2000) water requirement for industrial use as estimated in preliminary studies amount to 322 million cubic meters considering the water consumption pattern of the existing industries. The net consumption was estimated to be 170 million cubic meters considering return water from industries.

The future water requirement for the year 2025 for industrial use was estimated as 1282 million cubic meters considering the future industries likely to come up in the basin and water consumption pattern of the existing industries. A note on the status and issues of Angul-Talcher industrial complex is given in Annexure 4. List of existing and proposed industries and their water requirements are given in Annexure 5.

Forest Use

At present (2000) total forest area of the basin is 1.416 Mha comprising 0.529 Mha as dense forest, 0.496 Mha as degraded forest, 0.312 Mha as open forest and 0.078 Mha as plantation. Assuming annual water consumption of 500 mm per ha for dense forest and plantation, 400 mm per ha for open forest and 300 mm per ha for degraded forest, the total consumptive use of water for forest would be 5,757 million cubic meters per year.

It is proposed to maintain current level (38%) of forest coverage in the basin in the year 2025 and the consumption by forest thus would be the same as the present i.e. 5,757 million cubic meters per year.

Total water requirement

Preliminary estimates of total water requirements for different sectors in the year 2001 and 2025 are given in the Table 7.

Table 7.
Water Requirement for Different Sectors in the Year 2001 and 2025, Brahmani Basin (10^6 m^3)

Sectors	2001	2025
Agriculture (irrigation from surface and groundwater)	2,704	9,282
Domestic	162	336
Industry	170	679
Forest (from rainfall)	5,757	5,757
Total	**8,793**	**16,054**

1.12 Basin Level Consultations

In order to collect all water related data and identify the specific issues of water development and management, basin level consultations for Brahmani basin were held at Bhubaneshwar on 16-17, January 2003. Presentations were made by state organisations, NGOs and other participants on overall issues of integrated water resources development and management (IWRDM), rain-fed and irrigated agriculture, treatment and reuse of municipal and industrial wastewater, and water needs of forestry and mangroves, besides key presentations on assessments for the 'past', 'present' and 'future (2025) conditions based on preliminary studies, and initial formulation of alternative scenarios of the future. More than 55 professionals, non-governmental organisations (NGOs) Consultancy and representatives of Contributing Organisations (IWMI, FAO, IPTRID) participated in the consultations. The comments/suggestions received from the participants were used by the CPSP study team to develop and improve upon formulation of the model aimed at detailed evaluation of policy options in the context of Integrated and sustainable development. The initial consultations also helped to identify the main issues and expand database for detailed assessments and formulation of alternative meaningful scenarios for future (2025).

Some of the main sectoral issues based on these consultations are outlined below.

Water for Food

- There were conflicting suggestions in regard to future agricultural needs of water. Further irrigation development is needed because of the continued dependence on agriculture of the large rural population in the basin, particularly in the lower region. Even though the basin lies in semi humid zone, it was pointed out that because of frequent and extended breaks experienced in rainfall during the south-west monsoon season (June to October) and significant inter-year variability, large tracts of lands in the upper plateau region as well as lower flood plains require irrigation support for higher and stable crop production. On the other hand forest departments of the Orissa state in particular wanted to conserve forest resources at least at their present level, and if possible to promote afforestation in upper and central hilly regions. This is considered necessary as a part of the income of rural population also comes from use of forest produce.
- Due to the involvement of people, besides Water and Land Management Institute (WALMI) in projects like Pitamahal, Aarveli, Dadrahali & Dirjan there has been good progress regarding Participatory Irrigation Management (PIM). This can greatly help in improving irrigation system efficiencies. Participation of the local people need not be restricted to irrigation but also in extending and improving water and sanitation facilities in rural areas.

Water for People and Nature

- ❑ Domestic water supply norms used in preliminary studies are 140 and 70 lpcd for urban and rural areas, respectively. It was suggested that the norms recommended by National Commission (NCIWRDP, 1999) might have to be used in detailed assessment of domestic needs.
- ❑ The industrial water requirements are also expected to grow with the further expansion of mining and coal-based industries in the basin.
- ❑ The environmental needs of water of the basin require a careful consideration to maintain bio-diversity of the mangroves of Brahmani and Baitarani delta region specially Bhitarkanika Wildlife Sanctuary/National Park. About 215 sq.km of Bhitarkanika mangroves have been declared as a RAMSAR Site in year 2002 as a wetland of International importance. Fears were raised that progressive diversion of fresh water in the upstream in the years to come may disturb the interplay of sweet and salt water in the estuarine reaches of river delta which in turn may affect these fragile natural eco-systems. Useful information was provided on socio-economic benefits of mangrove forests and encroachment that has taken place in recent years. A brief information of mangroves of Bhitarkanika is given in Annexure 6.
- ❑ Development of navigation especially in the reach from Talcher down to Dhamra through Kharsuan branch needs to be looked into for transportation of iron ore, coal and other products from Talcher region.

Another important environmental concern voiced related to pollution of river waters due to discharge of industrial effluents into the Brahmani River. Owing to concentration of mining and industrial activities in Angul-Talcher belt, the river stretch near Kamalanga has been identified as one of the most polluted, though some improvements in water quality were reported as a result of measures taken by the Orissa State Pollution Control Board in recent years with the cooperation of the concerned industries.

The larger question of treating all effluents from D&I uses before these are discharged into the river systems was debated at length. While several industries have gone for zero effluent including many refineries, this issue needs to be looked into greater details from the viewpoint of water conservation.

The Rengali dam has significantly altered the hydrologic regime in the downstream. However, the larger releases in the downstream due to non-use of its waters for irrigation may impact on the flora and fauna in an around Bhitarkanika sanctuary. This scenario is likely to change in future especially with greater upstream abstractions and requirements of minimum releases in the downstream from Rengali dam for maintenance of ecology of the estuarine area.

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CHAPTER 2

APPLICATION OF BHIWA MODEL

2.0 Modelling Framework

A Basin-wide Holistic Integrated Water assessment (BHIWA) Model was especially developed to provide an integrated computational framework for a basin/sub-basin level assessment of water resources to evaluate water sector policies keeping CPSP goals in mind. The model considers the entire land phase of the hydrologic cycles and is capable of depicting human impacts such as changes in land and water use, as also impacts of water storage and depletion through withdrawals for various water uses and addition through returns/ inter-basin water transfers. The basic objectives of the model are:

- To consider the impact of changing land and water use on the resources, taking into account interdependencies between different elements of the land phase of the hydrological cycle,
- To quantify and integrate sectoral water uses, and
- To formulate and analyse scenarios to evaluate various policy options for development and management of water and related land resources.

The model can be used effectively for the following purposes:

a) Understanding resources and sectoral needs in an integrated manner considering sustainability of water for human use as well as environment,

b) Creating and improving knowledge base for meaningful and transparent dialogue.

The model is especially useful for assessing future water needs under different scenarios of development and management, and for analyzing impact of different policy options on the state of water availability for an integrated and sustainable use of the resource.

The model was calibrated based on data for present conditions and applied to identify main issues and challenges in basin water management and explore policy options though the analysis of alternate scenarios of the future (year 2025). The model uses water balance approach and prepares separate water balances for surface and groundwater systems as well as an overall water balance for the basin/sub-basin.

The model can be calibrated making use of data for the past or present conditions for the given basin. Once the model is calibrated, the user can proceed to simulate and analyze alternate scenarios of future development and management of resources. Scenarios can be developed in the model in terms of changes in land use, crop areas under rain-fed and/or irrigated agriculture, cropping patterns, irrigation efficiencies, imports and exports of water, surface (reservoirs) storage, proportion of surface and groundwater withdrawals, etc.

By simulating past conditions of limited water use in the basin, the model can also help the user in setting up minimum reference flows for maintenance and enhancement of river ecology and environment. Comparison of such flows with projected future status of balance river flows can help in setting limits on surface and ground water withdrawals, including extent of lowering of groundwater tables to meet prescribed "environment flow" requirements.

Figure 7 gives a schematic representation of the model. The salient features of the model, including its various computational modules, input and output data are outlined in Annexure 1.

2.1 Application of BHIWA Model to Brahmani River Basin

The model was run in calibration mode for the 'present'

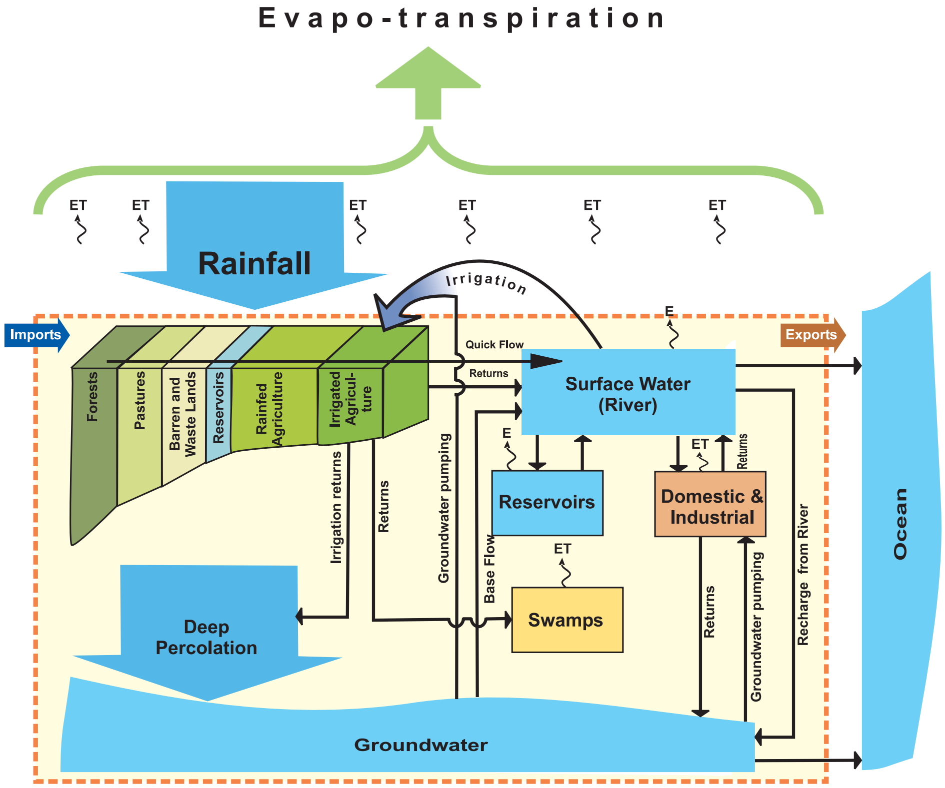

Figure 7. Schematic Diagram of BHIWA Model

(2000) conditions using short-term rainfall-runoff records for calendar years 1998-2000. Having selected the key parameters, it was then applied to derive responses corresponding to past, present and four alternative future (2025) scenarios using long- term averages of rainfall and ET_0 for the hydrological year June-May. Both calibration and simulations were done using sub- basin level data. The basin was divided into four sub- basins to allow grouping of areas having similar hydrologic and water use attributes. The sub basins short description as used in the studies is as follows:

- Sub-Basin A (SB4):	Catchments areas of Sankh and Koel Karo sub basins up to the confluence of Sankh and Koel Karo rivers (19,331 km^2).
- Sub-Basin B (SB3):	Catchments area from confluence of Sankh & Koel Karo up to Rengali Dam (3,880 km^2)
- Sub-Basin C (SB2):	Catchments area from Rengali Dam to head of delta at Jenapur (12,303 km^2)
- Sub-Basin D (SB1):	Lower Brahmani Delta below Jenapur (3,754 km^2)

The various sub- basins of the Brahmani river basin are shown in Figure 2.

2.2 Data Base

Hydrological Data

The following hydrological data collected from secondary sources was used in calibration of the model.

1. Sub-basin wise monthly rainfall for selected stations for the calendar years 1998 to 2000 (Annexure 7)
2. Available monthly observed runoff at CWC sites near sub-basin outlets namely Panposh, Gomlai, and Jenapur Sites for the selected period. These were adjusted for small differences in drainage areas to correspond to cumulative aggregation of sub-basin areas (Annexure 8)

3. Monthly reference evapo transpiration (ETo) for three key stations representing the lower, upper and middle parts of the basin computed from climatological data (Annexure 9)

Land Use, Crops and Irrigation Data

The available district-wise statistics of land use, crop and irrigated areas from surface and groundwater sources were used to derive sub-basin wise figures. Agriculture land use both rain-fed and irrigated was further subdivided using trial and error reflecting seasonal cropping cycles. In all, area of each sub basin was classified into 16 standard land use parcels. These included land parcels under forest and miscellaneous trees (P1), permanent pastures (P2), land not available for cultivation including waste and fallow lands (P3), land under reservoirs (P4) and a number of parcels for land under rain-fed and irrigated agriculture use. As mentioned before, The agriculture land use was further broken down to represent broadly seasonal cropping pattern cycles viz. perennial crops, two seasonal with a single crop and fallow in third season, lands that are under two separate crops in two seasons and fallow in one season, lands that are cropped only in one season and remain fallow in two other seasons, etc. Similarly, while land parcels under crops with more or less similar cropping season were grouped together, land under paddy, which has a different hydrological response and water requirement, was treated separately.

Based on the available land use data, cropping pattern details, and crop wise and source wise irrigated areas, individual parcel areas for sixteen standardised land parcels were derived by trial so as to approximately match the annual statistics on individual and total crop areas, for rain-fed and irrigated cropping for the calibration years. The sixteen standard land use parcels as adopted in the study are shown in Table 8.

The composition of land parcels and their temporal coverage is shown in Figure 8.

Domestic and Industrial (D&I) Water Use Data

The data provided by the state team during preliminary assessments has been made use of.

Some details of the early estimates are provided in Annexure 10.

Table 8.
Description of Land Use Parcels Used in BHIWA Model

Parcel Designation	Description
P1	Forest and miscellaneous trees
P2	Permanent pastures
P3	Land not available for cultivation, waste and fallow
P4	Land under reservoirs
P5	Rain-fed paddy in kharif and fallow in other seasons
P6	Rain-fed paddy, rain-fed rabi (other crops) and fallow in hot weather
P7	Rain-fed other crops in kharif and fallow in other seasons
P8	Rain-fed other crops in kharif and rain-fed other crops in rabi and fallow in hot weather.
P9	Fallow in kharif and rain-fed (other crops) crops in rabi and fallow in hot weather.
P10	Irrigated paddy in kharif and fallow in other season
P11	Irrigated paddy in both kharif and rabi and fallow in hot weather
P12	Irrigated paddy and irrigated other rabi crops and fallow in hot weather
P13	Irrigated other kharif crops and fallow in other seasons
P14	Irrigated other kharif crops, irrigated other rabi and fallow in hot weather
P15	Irrigated sugarcane (perennials)
P16	Fallow in kharif and irrigated other rabi crops and fallow in hot weather

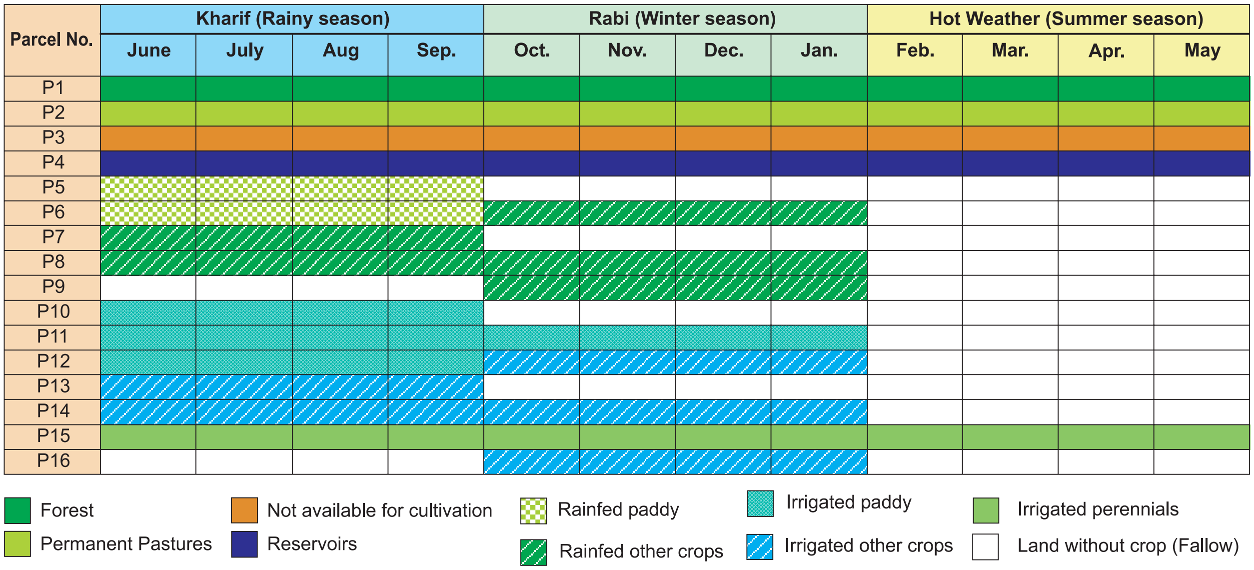

Figure 8. The Composition of Land Parcels and their Temporal Coverage

2.3 Formulation of Scenarios

The future scenarios studied were essentially based on emerging possibilities, developmental plans on anvil, expansion of irrigated agriculture based ion potential, improved soil and water management practices, etc. However, neither a major shift to commercial crops nor changes in the livelihood patterns of the people, etc. were considered in the present assessments. Nevertheless, the model can accommodate these factors as and when required.

The key attributes of the alternative scenarios studied are presented in Table 9 along with 'Past' and 'Present' conditions for ease of comparison.

A brief description of past, present and future conditions (under alternative scenarios) is as follows:

1. Past (1960)

- This reflects the past situation in which irrigation development consisted mainly from groundwater use and few small surface water projects. The area under agriculture was 0.898 Mha of which irrigated area was only 0.040 Mha. There was an import of 400 million cubic meters from Mahanadi river basin. This estimation of past condition can help setting up of reference for minimum flows for maintenance and enhancement of ecology and environment of the basin.

2. Present (2000)

- Area under agriculture in 2000 was 1.243 Mha with net irrigated area being 0.254 Mha and gross irrigated area as 0.359 Mha. The increase in irrigated area from 1960 conditions is mainly due to construction of several irrigation schemes including Rengali major multi purpose projects and about 14 medium irrigation projects in the basin. Import of water same as in the past. However, the full irrigation potential of Rengali has not been developed, and canal construction is continuing.

3. Future-I (B as U) 2025

- It is assumed that by 2025, all the ongoing irrigation projects, as well all of the proposed projects would be completed as planned. Similarly it is assumed that industrial growth as contemplated would also take place.

- It is estimated that with completion of planned schemes, land under agriculture would increase to 1.417 Mha against 1.243 Mha under the present (2000) condition through conversion of waste and fallow lands into crop lands.

- The planned irrigated and rain-fed lands have been projected to be 0.670 Mha and 0.747 Mha, respectively.

Table 9.
Key Attributes of the Scenarios for Simulation by BHIWA Model for Brahmani

S.No.	Scenarios	Key attributes	Brief description
1.	Past	Year 1960 conditions	Irrigation development mainly from groundwater use and few small surface water projects including past import of water from Mahanadi.
2.	Present	Year 2000 conditions	Major part of the water resources development took place due to construction of number of major and medium projects between 1960 and 2000.
3.	F-I	Year 2025 – Bas U	Expansion of area under irrigated agriculture by converting some rain-fed lands and bringing part of culturable waste and fallow lands under cropping, completion of all reservoirs as planned, no change in the volume of import of Mahanadi water and only a slight improvement in water management (system efficiencies).
4.	F-II	2025 – with larger expansion of agriculture and irrigation	With more emphasis on agriculture, including larger expansion of irrigation than under F-I, and assuming more reservoir storage than planned, slight shift in cropping pattern. Better water management including greater proportion of groundwater use to total.
5.	F-III	2025 - with more industrialization	Agriculture developments similar to F-I. Greater development of industries in the basin requiring 50% more withdrawal for industrial water use, and better water management.
6.	F-IV	2025- with less agriculture and industry	Lesser expansion of irrigation and industry, better water management and greater allocation of water for environment and navigation purposes.

- More reservoirs are expected to become operational. Reservoir area will be 0.088 Mha against 0.061 Mha under current scenario.
- The import of water will be same as past scenario.

4. Future-II (2025)

- It is assumed that much greater emphasis will be given to agriculture considering large rural population base, by bringing maximum possible area under irrigation through larger conversion of waste and fallow lands and rain-fed lands into irrigated lands.
- Land under cultivation will be increased to 1.575 Mha as against 1.417 Mha in F-I (BasU). Rain-fed as well as irrigated areas have been increased by converting waste and fallow lands.

More reservoirs will come up and the reservoir area will be 0.095 Mha as against 0.088 Mha in F-I (BasU) and 0.061 Mha in present scenario.

- ☐ Cropping pattern will be diversified
- ☐ Rabi intensity will be 70% for irrigated land and 10% for rain-fed land
- ☐ Water withdrawal for industrial purposes is same as BAsU.
- ☐ The import of water will be same as past scenario.
- ☐ There would be proportionately larger use of groundwater for irrigation, as compared to Future-I.

5. Future-III (2025)

- Under this scenario it is assumed that emphasis will be on industrial development considering rich mineral base of Brahmani, with irrigated agriculture being similar to that under F-I (BasU) scenario
- Industrial water requirements have been accordingly increased by 50% than estimated for F-I (BasU) scenario.
- Proportionately larger use of groundwater for irrigation as compared to Future-I.

6. Future-IV (2025)

- The import of water will be same as in year 1960
- Lesser emphasis on agriculture and industries and more water spared for environment and navigation.

- No addition of agricultural land from the 'present' level (1.243 Mha)
- Only a part of rain-fed land will be converted into irrigated land. Rain-fed land will be 0.692 Mha as against 0.990 Mha in the 'present' scenario. The irrigated land will be 0.552 Mha as against 0.254 Mha under the 'present' scenario.
- Additional provision for industries has been reduced by 50% as compared to Future-I (BasU) scenario.
- The import of water will be same as past scenario.
- Proportionately larger use of groundwater as compared to Future-I.

The areas in different land use parcels under past, present and various future scenarios are given in Table 10. The irrigation system variables and constants of surface and groundwater irrigation system are given in Table 11. Area Coverage by Natural Vegetation, rain-fed and Irrigated Agriculture is depicted in Figure 9. Net irrigated area by surface water and groundwater is shown in Figure 10.

2.4 Calibration of the Model

The BHIWA model has been calibrated using three years (1998-2000) of river flow data as available at gauge and discharge (G&D) sites near the sub basin outlets. The comparison of observed and computed monthly flows at the G&D site near Jenapur is shown in Figure 11.

The comparison of the annual river flows at the head of the delta, i.e., at the outlet of sub-basin C (SB-2) for the three years (1998-2000) is given in Table 12.

Table 10.
Areas of Land Parcels in Different Scenarios, (km^2)

Land Parcels	Past (1960)	Present (2000)	Future (2025)			
			F-I BAU	F-II	F-III	F-IV
P1	14,659	15,101	14,979	14,979	14,979	14,979
P2	1,348	1,323	1,293	1,293	1,293	1,293
P3	14,223	9,805	7,946	6,301	7,728	9,686
P4	63	607	880	945	890	880
P5	6,575	6,932	5,900	6,287	5,944	4,729
P6	0	783	335	357	338	543
P7	2,000	1,633	875	932	878	1,268
P8	0	500	330	352	331	349
P9	0	51	30	32	32	25
P10	400	1,335	2,760	3,209	2,817	2,709
P11	0	752	2,125	2,471	2,176	1,750
P12	0	251	630	732	645	622
P13	0	96	500	581	505	204
P14	0	50	350	407	360	117
P15	0	17	300	349	315	35
P16	0	32	35	41	37	79
Total	**39,268**	**39,268**	**39,268**	**39,268**	**39,268**	**39,268**

Table 11.
Irrigation System Variables and Constants

Components	Past	Present	F-I	F-II	F-III	F-IV
Proportion of return flows evaporating through waterlogged areas and swamps from surface irrigation	0.2	0.2	0.2	0.15	0.15	0.15
Proportion of residual return flows returning to surface waters from surface irrigation	0.25	0.25	0.25	0.2	0.2	0.2
Proportion of residual return flows returning to ground waters from surface irrigation	0.75	0.75	0.75	0.8	0.8	0.8
Proportion of return flows evaporating through waterlogged areas and swamps from GW irrigation	0.05	0.05	0.05	0.05	0.05	0.05
Proportion of residual return flows returning to surface waters from GW irrigation	0.1	0.1	0.1	0.095	0.095	0.095
Proportion of residual return flows returning to ground waters from GW irrigation	0.9	0.9	0.9	0.905	0.905	0.905
Surface water conveyance and distribution efficiency.	0.4	0.4	0.45	0.5	0.5	0.5
Ground water conveyance and distribution efficiency.	0.6	0.7	0.7	0.75	0.75	0.75
Proportion of additional evpo-transpiration needs which would be met through irrigation	1	0.9	1	1	1	1

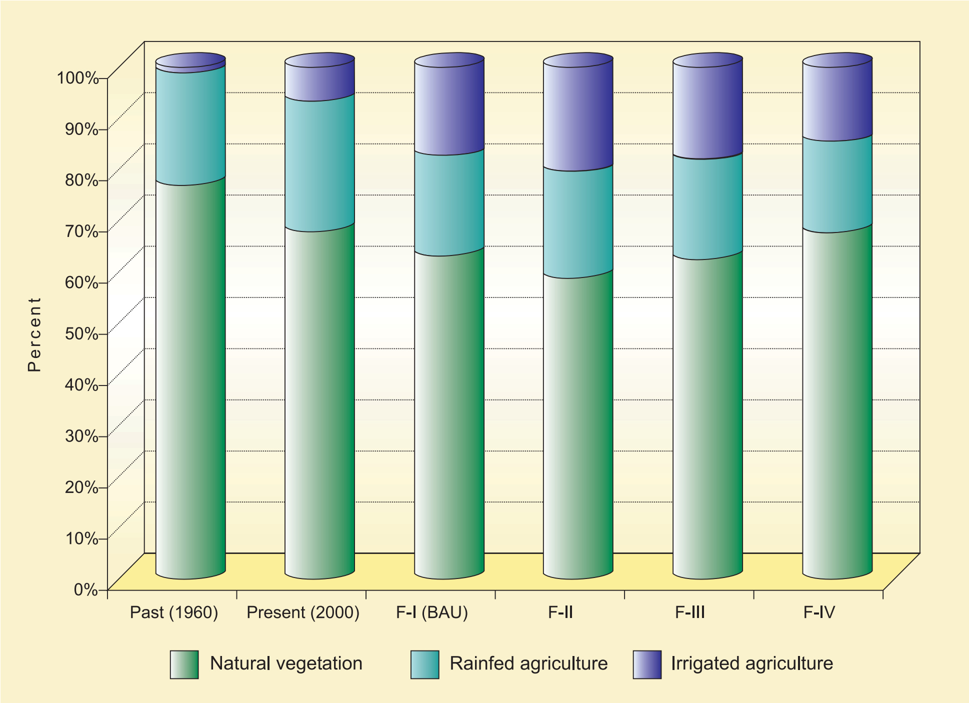

Figure 9. Area Coverage by Natural Vegetation, Rain-fed and Irrigated Agriculture

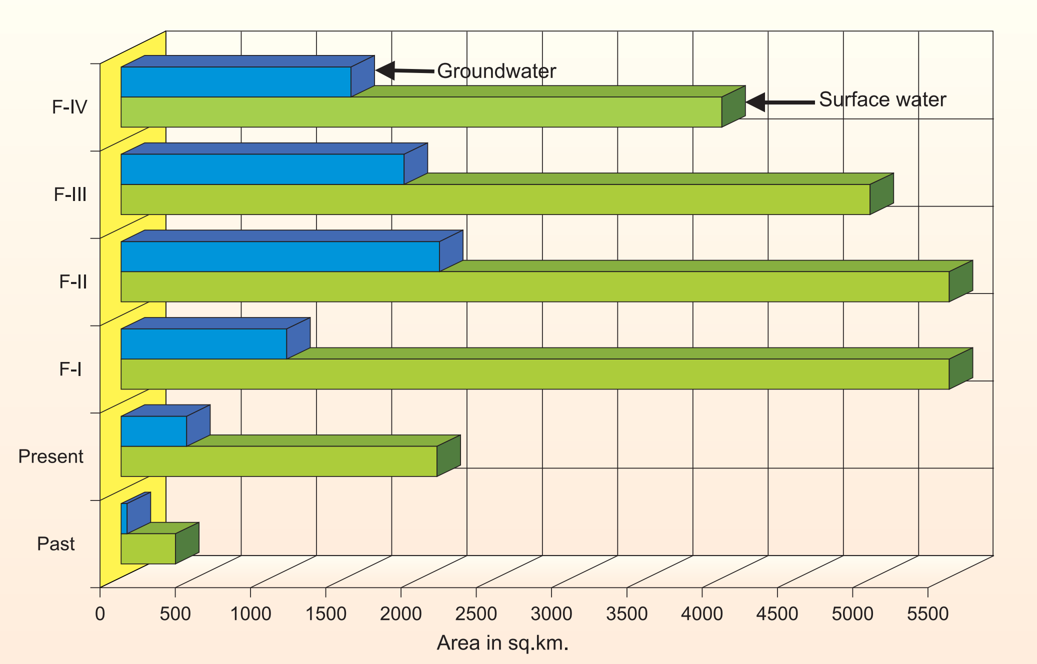

Figure 10. Net Irrigated Area by Source

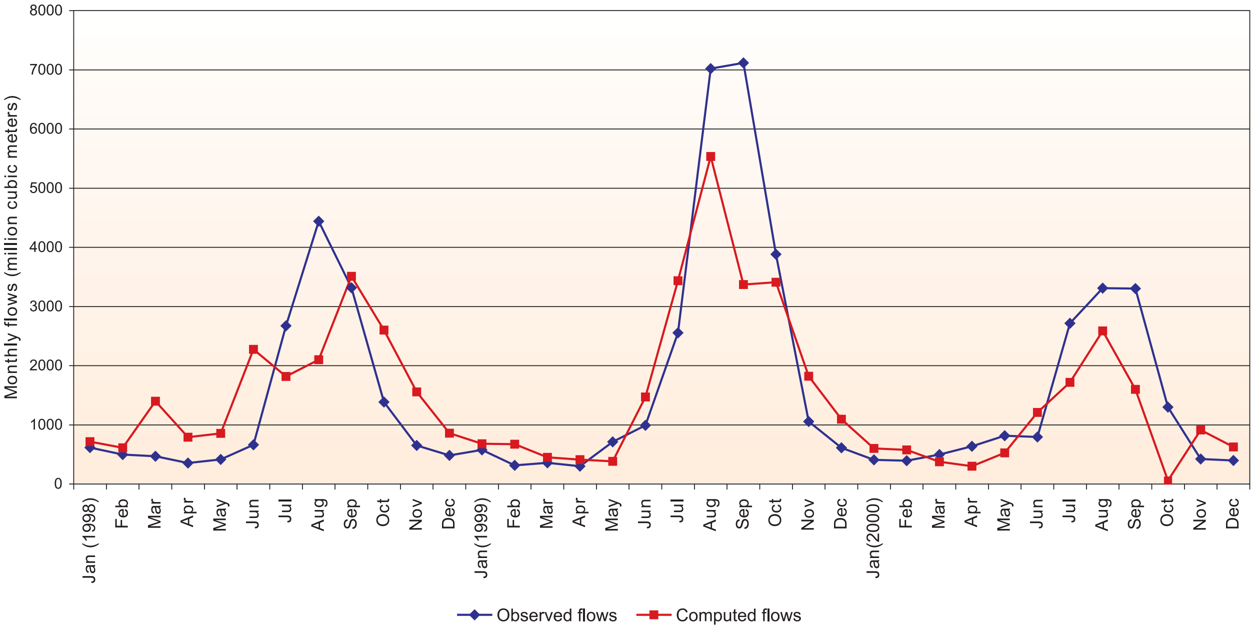

Figure 11. Comparison of Observed and Computed Monthly Flows at the G&D Site Near Jenapur

Table- 12.
Comparison of Annual River Flows, Brahmani river (10^6 m^3)

Year	Observed	Computed
1998	15,954	18,835
1999	25,492	22,454
2000	14,989	10,611
Average	**18,811**	**17,300**

The comparison of statistical parameters of time series of monthly flows at head of the delta is given in Table 13.

The groundwater recharge from rainfall works out to 6,375 m^3, which is about 12% of the average rainfall. This value is considered as reasonable and compares fairly with the general estimates.

Table 13.
Comparison of Statistical Parameters of time series of Monthly Flows, Brahmani River (10^6 m^3)

Parameters	Observed	Computed
Mean	1,567	1,441
Standard Deviation	1,765	1,213
Root mean square error	1,029	

The validation of the model has been accepted with values of model constants and soil moisture capacities as given in Tables 14 and 15.

2.5 Simulation of Past, Present and Alternative Future Scenarios

The calibrated model has been applied to study responses corresponding to the 'past' (1960), present (2000)

Table 14.
Values of BHIWA Model Constants, Brahmani Basin

Sl. No.	Model Constants	Calibrated values for sub basin			
		'A' (SB4)	'B'(SB3)	'C'(SB2)	'D'(SB1)
1	Proportion of excess rainfall which goes to quick runoff	0.75	0.65	0.65	0.7
2	Proportion of excess rainfall which goes to groundwater storage	0.25	0.35	0.35	0.3
3	Constant multiplier for soil moisture depletion	1	1	1	1
4	Recession co-efficient for groundwater reservoir	0.6	0.5	0.4	0.3

Table 15.
Values of Soil Moisture Capacity (mm)

Parcel	'A'(SB-4)	'B'(SB-3)	'C'(SB-2)	'D'(SB-1)
P1	200	225	200	200
P2	125	150	125	125
P3	50	50	50	50
P4	30	30	30	30
P5	125	125	125	150
P6	150	150	150	175
P7	100	100	100	100
P8	125	125	125	125
P9	150	150	150	150
P10	150	125	125	150
P11	225	225	225	225
P12	150	150	150	175
P13	125	125	125	150
P14	150	150	150	175
P15	200	200	200	200
P16	125	125	125	150

conditions and four alternative future scenarios for the year 2025. The simulation runs are made using average year rainfall based on long-term data and for sustainable use of resources. Present situation simulated here is different from that for model calibration. Only aggregated results at the basin level are presented herein. Annual overall water balance, as well as annual surface water and groundwater balance are presented in Tables 16, 17 and 18 and depicted in Figures 12, 13 and 14, respectively. The consumptive use (evapo-transpiration ET) by different sectors for the past, present and future conditions are summarized in Table 19 and depicted in Figure 15.

Monthly river flows at the basin outlet are shown in Table 20. The monthly river flows for the three selected scenarios are also shown graphically in Figure 16.

As stated earlier, the model does not have any module to estimate the environmental flow requirements for the aquatic ecosystem (EFR). However, it is capable of adjusting the surface and groundwater withdrawals and pumping, to adjust, to the extent possible, to the externally prescribed monthly EFR requirements. This was done for the scenario F-IV at the basin outlet. Table 21 shows the comparison of monthly river flows against the assumed environmental flow requirements (ecology, fisheries etc.) in the downstream i.e. at the outlet of the basin. The available river flows are much higher than the prescribed EFRs, and therefore, the model, in this case, would not have made any adjustments. Navigational requirements would be compatible with the EFR requirements. Although the navigational requirements, for any future scenario, which caters to navigational requirements, have not been estimated, these

Table 16.
Annual Overall Water Balance for Alternative Scenarios ($10^6 m^3$)

Component	Past 1960	Present 2000	Future (2025)			
			F-I (BAU)	F-II	F-III	F-IV
Inputs						
Rainfall (Long tem)	51,186	51,186	51,186	51,186	51,186	51,186
Imports	400	400	400	400	400	400
Groundwater flow from other basins	0	0	0	0	1	0
Total inputs	**51,586**	**51,586**	**51,586**	**51,586**	**51,587**	**51,586**
Outputs						
Consumptive use total	32,065	34,138	36,360	36,646	36,109	34,963
River flows total	19,515	17,381	15,220	14,933	15,471	16,618
Export (surface)	0	0	0	0	0	0
Groundwater flow to other basins *	0	0	0	0	0	0
Direct groundwater flow to sea *	0	0	0	0	0	0
Total output	**51,580**	**51,519**	**51,580**	**51,579**	**51,580**	**51,580**
Storage changes						
Soil moisture storage	5	5	5	5	5	5
Surface storage	0	0	0	0	0	0
Groundwater storage	1	0	0	1	0	0
Total storage change	6	5	5	6	5	5
Imbalance **	0	61	0	0	1	0

* Assumed values
** Could arise due to natural water transfers, which are assumed here as zero.

Table 17.
Annual Surface Water Balance for Alternative Scenarios (10^6 m^3)

Component	Past (1960)	Present (2000)	Future (2025)			
			F-I (BAU)	F-II	F-III	F-IV
Inputs						
Quick runoff from rainfall	13,805	12,839	12,177	11,804	12,119	12,600
Base flow	5,574	6,119	7,615	7,382	6,989	6,976
Returns to surface from surface irrigation	65	458	1,148	881	772	654
Returns to surface from groundwater irrigation	2	25	66	110	98	85
Returns to surface from D&I withdrawals	96	280	676	676	1,000	623
Sub-total, returns to surface	163	762	1,889	1,667	1,871	1,362
Imports	400	400	400	400	400	400
Total inputs	**19,943**	**20,121**	**22,081**	**21,253**	**21,378**	**21,338**
Outputs						
Surface withdrawals for irrigation in the basin	328	2,430	6,208	5,666	4,983	4,112
Surface withdrawals for D&I in the basin	100	309	653	653	923	609
Total surface withdrawals, for use in the basin	429	2,,739	6,861	6,319	5,907	4,720
Natural and induced recharge from river to groundwater	0	0	0	0	0	0
Outflow to sea	19,515	17,381	15,220	14,933	15,471	16,618
Export	0	0	0	0	0	0
Total output	**19,943**	**20,121**	**22,081**	**21,252**	**21,378**	**21,338**
Storage change	0	0	0	0	0	0
Imbalance	0	0	0	0	0	0

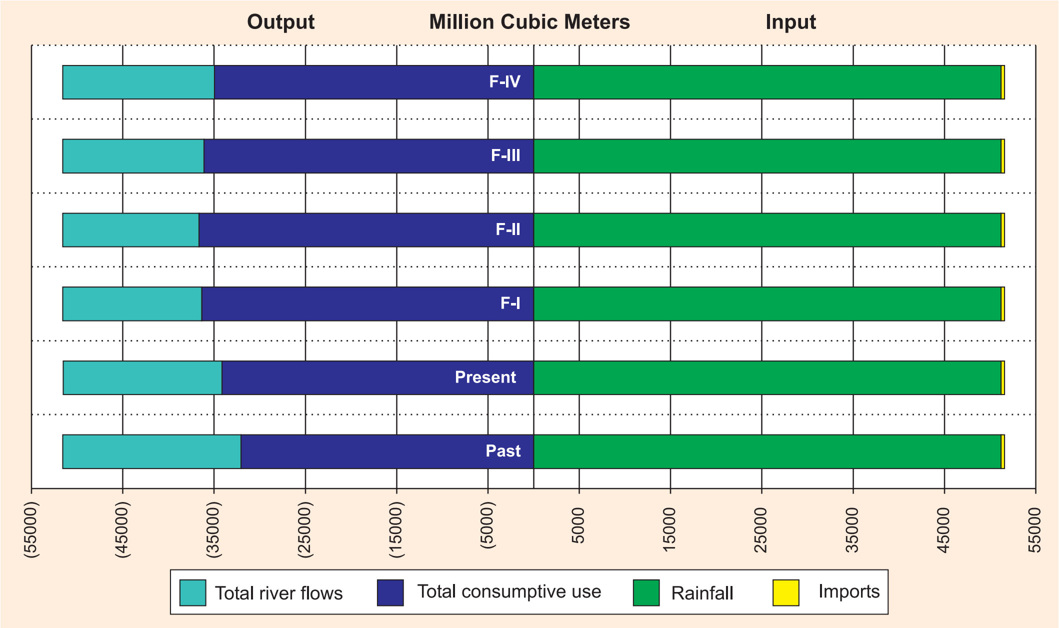

Figure 12. Annual Overall Water Balance, Brahmani Basin

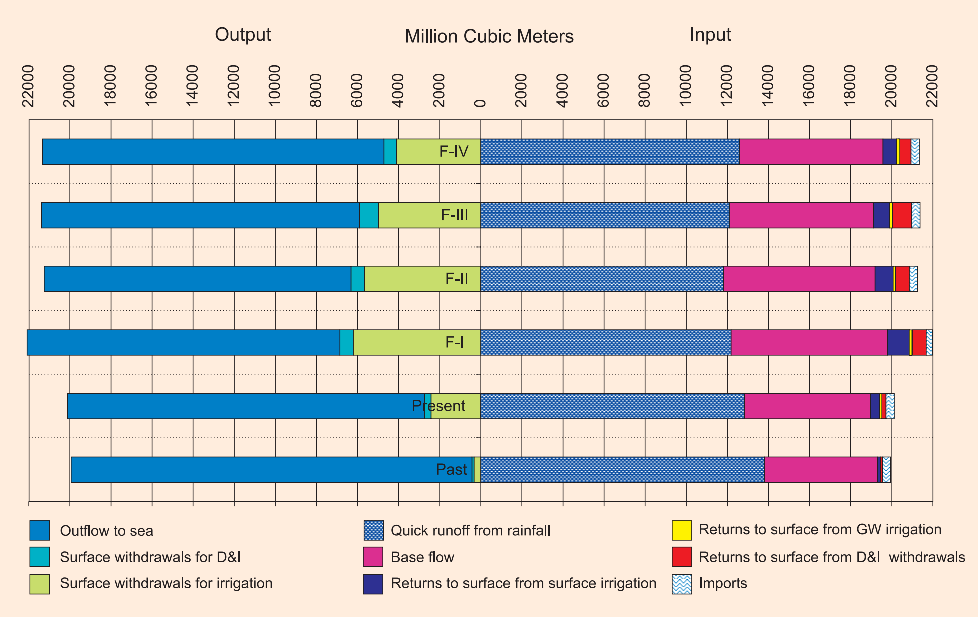

Figure 13. River and Surface Water Balance in Brahmani Basin

Table 18.
Annual Groundwater Balance for Alternative Scenarios (10^6 m^3)

Component	Past (1960)	Present (2000)	Future (2025)			
			F-I (BAU)	F-II	F-III	F-IV
Inputs						
Natural recharge from rainfall	5,451	5,054	4,779	4,623	4,754	4,965
Returns to groundwater from surface irrigation	196	1,373	3,443	3,523	3,090	2,618
Returns to groundwater from groundwater irrigation	21	221	590	1,051	935	811
Returns to groundwater from D&I withdrawals	55	155	224	224	260	218
Sub-total, returns to groundwater	272	1,749	4,256	4,798	4,285	3,647
Natural and induced recharge from river to groundwater	0	0	0	0	0	0
Groundwater flow from other basins	0	0	0	0	1	0
Total inputs	**5,722**	**6,803**	**9,035**	**9,421**	**9,040**	**8,611**
Outputs						
Groundwater irrigation withdrawals, including groundwater pumping to surface canals	24	289	841	1,459	1,290	1,085
Groundwater withdrawals for D&I use	122	394	580	580	760	550
Sub-total groundwater withdrawals	147	684	1,420	2,039	2,050	1,636
Base flow to rivers	5,574	6,119	7,615	7,382	6,989	6,976
Groundwater flow to other basins	0	0	0	0	0	0
Direct groundwater flow to sea	0	0	0	0	1	0
Total outputs	**5,721**	**6,803**	**9,036**	**9,420**	**9,040**	**8,611**
Groundwater storage change	1	0	0	1	0	0
Groundwater imbalance	0	0	0	0	0	0

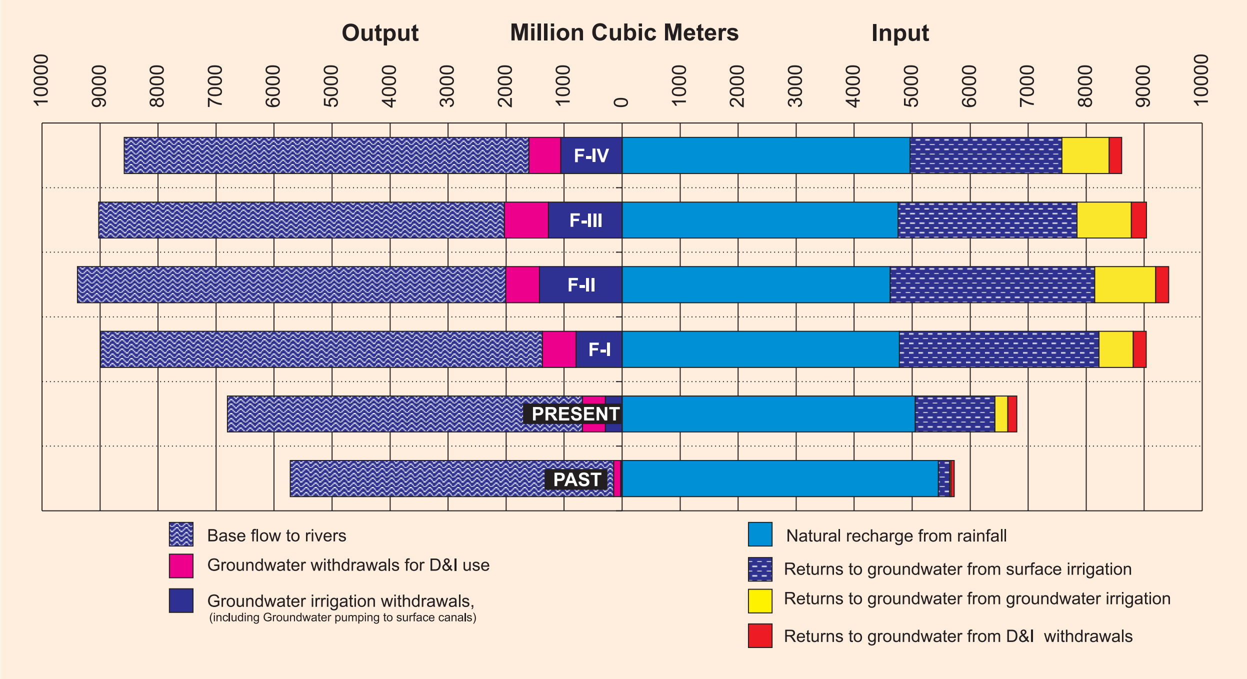

Figure 14: Groundwater Balance, Brahmani Basin

Table 19.
Consumptive Use (ET) by Different Use Sectors (10^6 m^3)

Sector	Past (1960)	Present (2000)	Future (BAU 2025)			
			F-I	F-II	F-III	F-IV
Nature sector						
Beneficial'	15,948	16,374	16,223	16,223	16,223	16,225
Non beneficial	8,424	5,808	4,684	3,703	4,536	5,737
Total (As a percentage of Grand Total)	24,372 (76%)	22,182 (64%)	20,907 (57%)	19,926 (54%)	20,759 (57%)	21,962 (62%)
Agriculture sector						
Beneficial	5,819	7,866	9,380	10,498	9,559	7,988
Non-beneficial	1,803	3,883	5,740	5,889	5,368	4,694
Total (As a percentage of Grand Total)	7,622 (23%)	11,749 (35%)	15,120 (42%)	16,387 (45%)	14,927 (42%)	12,682 (37%)
People sector						
D&I (As a percentage of Grand Total)	72 (1%)	207 (1%)	333 (1%)	333 (1%)	333 (1%)	319 (1%)
Grand Total	**32,066**	**34,138**	**36,360**	**36,646**	**36,019**	**34,963**

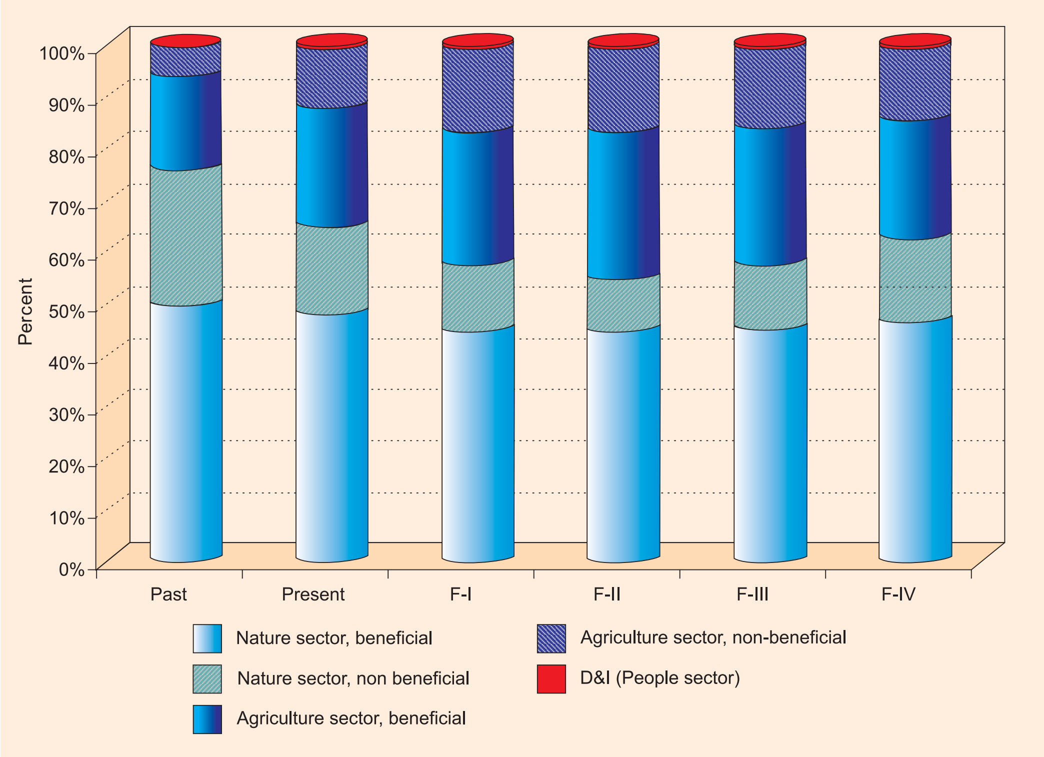

Figure 15. Consumptive Use (ET) by Use Sectors, Brahmani Basin

Table 20.
Monthly River Flows at the Basin Outlet (10^6 m^3)

Month	Past (1960)	Present (2000)	Future (2025)			
			F-I (BAU)	F-II	F-III	F-IV
June	1,615	999	672	553	689	860
July	4,454	2,982	2,293	2,194	2,362	2,564
August	6,677	4,944	4,473	4,414	4,531	4,706
September	3,793	1,629	1,261	1,230	1,318	1,452
October	1,408	1,304	1,483	1,475	1,488	1,534
November	681	1,058	1,473	1,457	1,416	1,417
December	362	949	970	970	965	1,002
January	209	834	725	741	757	827
February	132	854	626	647	665	748
March	91	735	375	402	433	594
April	28	760	533	542	562	632
May	64	332	337	307	287	282
Total	**19,515**	**17,381**	**15,220**	**14,933**	**15,471**	**16,618**

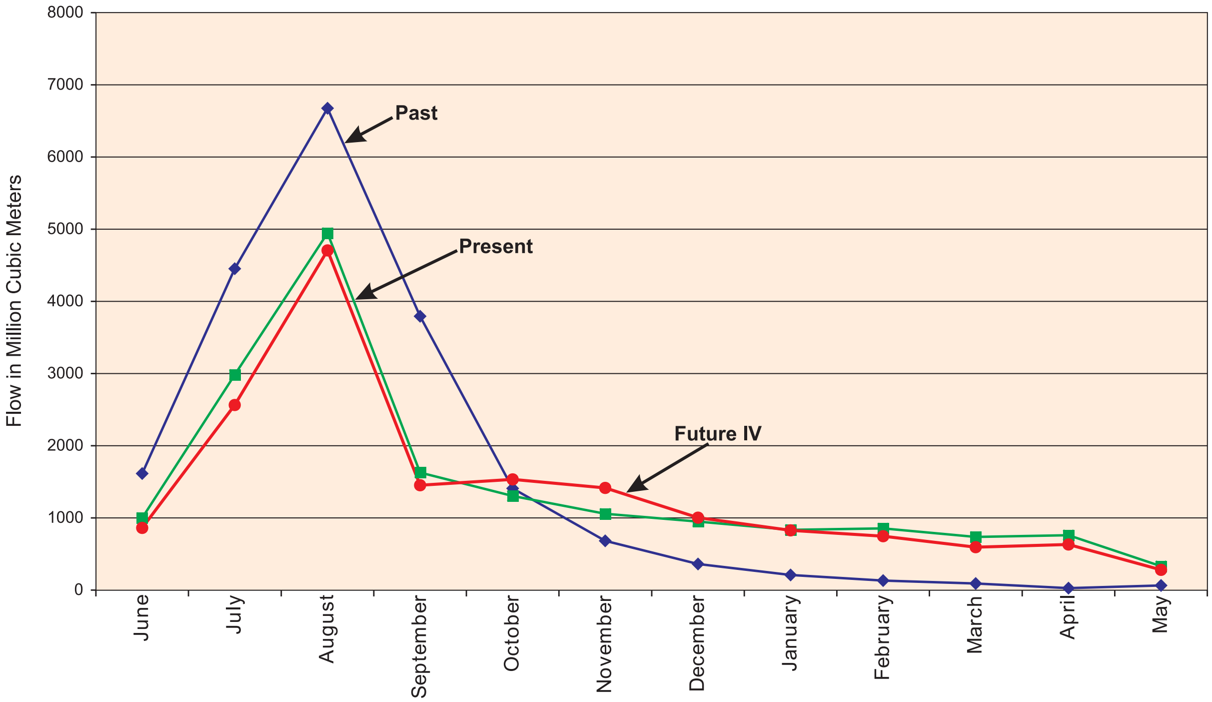

Figure 16. Monthly River Flows for the Selected Three Scenarios

could be in the range of 600 to 800 million cubic meters per month. If these are to be met, small additional releases, over and above the otherwise available river flows, would have to be met by adjusting the pattern of releases from Rengali, by tracking off some hydropower and irrigation demands.

During consultation it became apparent that migration of people from within and outside the basin and new settlements in the mangrove areas seem to be the main reason for the reduction of mangrove areas. The mangrove species prevalent in any area are likely to depend on the tidal range, the salinity levels in the estuary, and the salinity in the root zone soil moisture/ groundwater. Unfortunately, no relation between headwater discharge and estuarial salinity is available nor could be established from the available sparse data. However, future operation of Rengali reservoir may need to be looked into from the perspective of maintaining environment and ecology in the lower reaches of the river as well as near the estuary.

Composition of water withdrawals for past, present and alternative future scenarios is shown in Table 22 and depicted in Figure 17.

Table 21.
Comparison of Monthly River Flows with assumed EFR at the Basin Outlet (10^6 m^3)

Month	EFR	Monthly river flow (Scenario-F-IV)
June	300	860
July	600	2,564
August	600	4,706
September	600	1,452
October	600	1,534
November	400	1,417
December	350	1,002
January	350	827
February	250	748
March	250	594
April	200	632
May	200	282
Total	**4,700**	**16,618**

Table 22.
Composition of Water Withdrawals for Different Scenarios (10^6 m^3)

Month	Past (1960)	Present (2000)	Future (2025)			
			F-I (BAU)	F-II	F-III	F-IV
Surface water irrigation	429	2,739	6,905	6,351	5,582	4,747
Groundwater irrigation	147	684	1,376	2,007	2,032	1,609
Groundwater pumping to canals	0	0	44	32	18	27
Total irrigation	**576**	**3,423**	**8,281**	**8,358**	**7,614**	**6,356**
Domestic, from surface water	8	51	209	209	209	209
Industrial, from surface water	92	258	444	444	714	400
Sub-total, D&I from surface water	100	309	653	653	923	609
Domestic, from groundwater	99	272	284	284	284	284
Industrial, from groundwater	23	123	296	296	476	266
Sub-total, D&I from groundwater	122	395	580	580	760	550
Total D&I	**222**	**704**	**1,233**	**1,233**	**1,683**	**1,159**
Total withdrawals	**798**	**4,127**	**9,514**	**9,591**	**9,297**	**7,515**

Figure-17. Composition of Water Withdrawals

2.6 Discussion of Results

2.6.1 General

As mentioned earlier, the results of present conditions as predicted by the model are slightly different from that obtained from the calibration run. In the simulation run the rainfall data used relates to an average year and not the actual in the years of calibration. Unlike Sabarmati, there is no over-exploitation of groundwater at present. Hence no balancing of groundwater use for making present condition sustainable was needed (CPSP Report 1, 2005).

The monthly model output for the present situation seems to somewhat under estimated river outflows. Adjustments in river outflows as well as other outputs to account for variations arising due to daily and monthly working may have to be made to achieve a closer approximation.

2.6.2 Consumptive use of water

Under the present (2000) situation, the total consumptive use in Brahmani basin is 34,138 million cubic meters. It comprises 22,182 million cubic meters (64%) for nature sector, 11,749 million cubic meters (35%) for agriculture sector and 207 million cubic meters (1%) for people sector. Agriculture use is made up of ET from rainfall and soil moisture in rain-fed lands and irrigated lands as well as additional ET met from irrigation and reservoir evaporation. The consumptive use includes considerable non-beneficial ET. The total non-beneficial ET is 9,691 million cubic meters, which is 28% of the total consumptive use. The non-beneficial ET for the present scenario comprises 5,808 million cubic meters for nature sector and 3,883 million cubic meters for agriculture sector. The reduction of non-beneficial ET through soil and water management can therefore emerges as a key strategy that can lead to significant improvement in river flows. The consumptive use for all sectors will be 36,646 million cubic meters in the scenario F-II in which more area brought under agriculture and rain-fed as well as irrigated area, considered. This value is marginally more than the consumptive use in the present scenario.

The annual irrigation withdrawal requirements from surface and groundwater together are likely to increase from the present level of 3,423 million cubic meters to around 8,390 million cubic meters in the future (F-II). This would require full use of the Rengali dam storage as well as creation of additional storages in the basin.

The sub basins studied indicate a large disparity in irrigation coverage, varying from 5% in Jharkhand State to 20% in parts of Orissa State. To study this, the data for a typical district was seen. The Deogarh district has very large forest area and comparatively small culturable area per rural person is very low. The relevant statistical information is given below:

Deogarh District

Geographical area	2,940 km^2
Forest area	1,560 km^2
Culturable area	682 km^2
Irrigated area (kharif season)	118.66 km^2
Population: Urban (2001)	20,096
Population: Rural (2001)	2,54,012

It is obvious that for most of the rural and tribal population, forest produce and not agricultural produce, may be the mainstay for the livelihood. Due to this, the average per capita annual income from rain-fed agriculture is less than Rs.3,000. Increasing irrigation coverage will be a positive intervention to improve the income of the rural people to some extent, although irrigation alone may not be the main factor in poverty alleviation in this comparatively wet and forested area.

However, according to a recent policy initiative of the Ministry of Tribal Affairs, Govt. of India, each tribal household in a forest area is to be given rights on the minor forest produce, and in addition, could be allowed to cultivate a small patch of the forest land. If this were done, if the small patch can be allotted some water for irrigation, the poverty alleviation would improve.

2.6.3 Surface Water

Output for the present situation suggests that the monthly model seems to somewhat under estimate the river outflows. Adjustments in river outflows as well as other outputs to account for variations arising due to daily and monthly working may have to be made to achieve a closer approximation.

The total sustainable river flows and monthly distribution are shown in Table 20. The low flows (November-May) would be particularly affected by the pattern of development. A large river runoff of around 16,618 million cubic meters (F-IV scenario) would continue to flow to the sea, indicating that the basin would not have any overall water shortage.

The alternative future scenario (F-IV) examines the requirements of downstream flows for environment and ecology, fisheries and navigation. Since no methods of assessments of these requirements are yet available a subjective pattern of monthly requirements have been used as downstream constraints to demonstrate the computational framework provided in the model to consider in-stream flow (non-consumptive) requirements. It would be seen that from Table 21, these requirements could be met without any major difficulty if operational pattern of Rengali multi purpose reservoir is altered slightly.

2.6.4 Groundwater

The modelling exercise indicated that the flow from groundwater to river is increasing, from 5,574 million cubic meters per year in 1960, to 6,119 million cubic meters per year in the present scenario and going up to 7,615 million cubic meters per year in the future. This indirectly indicates increasing groundwater storage, which may lead to waterlogging.

2.7 Water Stress Indicators

Introduction

Water stress for a river basin is defined in terms of the degree of annual water use (water withdrawn from a surface or groundwater source for human purposes) as a percentage of the total water resources available in that basin. Water stress for a country is the summation of water stress for all its river basins. Water stress begins when withdrawals of freshwater rise above 10 percent of renewable resources. Medium to high stress is set to occur when water use exceeds 20 percent of renewable resources. Countries experience high water stress when water use exceeds renewable resource by 40% (ADB, 2004). At such levels, their patterns of use may not be sustainable, and water scarcity is likely to become the limiting factor to economic growth.

2.7.1 Water Situation Indicators (WSI)

A survey of indicators of water stress mentioned in International literature was made. The three main types recommended in recent years are:

(a) The water stress indicator (WSI) as per Alcamo, et.al, (2002), is defined as

WSI = Withdrawal / Mean Annual (natural) Runoff (MAR)

(b) Smakhtin, et.al, (2002) suggested a modification to account for water use for maintaining ecology and environment

WSI = Withdrawal / (MAR – Environmental water requirement for aquatic eco-system)

(c) At the 3rd World Water Forum in March 2003, ICID suggested the following relationship

WSI = Withdrawal / (MAR – Society's need for food, people and nature as evidenced by consumptive use)

The following indicators have been proposed in this study undertaken under CPSP in Indian basins.

The views of indicators is primarily aimed at abstracting the impact of human use on water availability and extend the outcome of sample basins to recommend policies on the basis of similarities and dissimilarities in the state of overall situation at the basin level. The following four indicators of the "water situation" are being used.

Indicator 1:	Withdrawals/ Total input to surface water
Indicator 2:	Returns/Total input to surface water
Indicator 3:	Withdrawals/ Total input to groundwater
Indicator 4:	Returns/ Total input to groundwater

These indicators have been considered more relevant to Indian situation due to the following reasons.

1. There is a large groundwater use in India. One needs indicators, which reflect water uses from both surface and ground water sources.
2. The WSI as defined based on 'withdrawals'; out of which a substantial part may return. Either one needs to consider the returns as an additional resource, adding to the natural runoff, or, one needs to consider the 'net consumptive use' rather than withdrawals.
3. The change suggested by Smakhtin et.al presupposes that the environmental water flow requirement for aquatic eco-system has an overriding priority, and only the rest of the water flow is available for any use for terrestrial natural eco-systems, food or people. This does not appear appropriate for many basins that are water-deficit or at a threshold level. The in-stream environmental use is inflow terms and not has consumptive nature as in other cases and can instead be considered as one of the requirements, competing with others. It just provides a habitat and remains un-consumed till it reaches the ocean.
4. The methodology for computing the MAR by

considering the withdrawals and returns has not been explained by Alcamo and Smakhtin. Since large land use changes can also affect the natural supply, this becomes more complex. Either a 'natural' land use, which does not allow for human interventions through agriculture, or a 'pseudo-natural' condition, where agriculture is allowed but irrigation is not, would have to be defined for this purpose. In case of Sabarmati basin, "past" conditions may correspond to a 'pseudo-natural' condition.

Instead of basing the indicator on gross withdrawals (numerator) and gross inputs (including human induced returns), these could also have been based on the net consumption (numerator) and the natural inputs (under the pseudo-natural conditions, without human interventions other than land use modification in the denominator).

The proposed indicators have been used to depict the water situations in Sabarmati basin in quantitative as well as qualitative terms. Indicators 1 and 3 depict the level of withdrawals as fractions of total water available in surface and groundwater systems, respectively, while indicators 2 and 4 depict the potential hazards to water quality in surface and ground water systems, respectively.

The indicators were sub divided into 3 to 4 classes each to represent the degree of water stress as given in the following Box 1:

Box 1.
Categories of Surface and Groundwater Indicators

(a) Indicator 1 - Surface water withdrawals
1. Very high stress – more than 0.8
2. High stress – between 0.4 and 0.8
3. Moderate stress - between 0.2 and 0.4
4. Low stress – less than 0.2

(b) Indicator 2 - Surface water quality
1. High threat - more than 0.2
2. Moderate threat – between 0.05 and 0.2
3. Low or no threat - less than 0.05

(c) Indicator 3 -Groundwater withdrawals
1. Very high stress – more than 0.8
2. High stress – between 0.4 and 0.8
3. Moderate stress - between 0.2 and 0.4
4. Low stress - less than 0.2

(d) Indicator 4 -Groundwater quality
1. Very high threat – more than 0.8
2. High threat - between 0.4 and 0.8
3. Moderate threat – between 0.2 and 0.4
4. Low threat – less than 0.2

2.7.2 Water Situation Indicator Values of Brahmani River Basin

Computed values of the water situation indicators for Brahmani river basin for past, present and alternative future scenarios are given in Table 23.

The value of Indicator 1 is less than 0.2 at present, and therefore the Brahmani river basin as a whole is a low stressed category in terms of surface water withdrawals. In future in the desirable scenario F-IV the value is about 0.22 indicating that basin may just about reach lower boundary of moderately stressed category.

The value of Indicator 2 is less than 0.05 at present and the basin thus comes under low threat. category in terms of surface water quality. However, the value of this indicator may rise to about 0.06 between 0.05 and 0.1 in F-IV scenario indicating only a slight change.

Table 23.
Water Situation Indicators

Indicator	Past (1960)	Present (2000)	Future 2025			
			F-I BAU	F-II	F-III	F-IV
Indicator 1	0.02	0.14	0.31	0.30	0.28	0.22
Indicator 2	0.01	0.04	0.09	0.08	0.09	0.06
Indicator 3	0.03	0.10	0.16	0.22	0.23	0.19
Indicator 4	0.05	0.26	0.47	0.51	0.47	0.42

Because of less use of groundwater resources, the value of Indicator 3 is less than 0.2 under present conditions, and even with assumed increase in groundwater use, the basin is expected to remain under the category of low stress. The value of Indicator 4 is lying between 0.2 and 0.4 in the present situation and scenario F-IV; the basin comes under moderate threat

2.8 Major Findings of the Assessment

Some of the key findings emerging from the study are:

1. Nature sector (forest and pasture lands) use in the basin is the largest among the three sectors, constituting 64% of the total consumptive use at present and 54 to 62% under four alternative of Future 2025 studied herein.
2. Owing to expansion of surface irrigation, contribution of groundwater to base flow is increasing, indicating risk of waterlogging. The situation will warrant increase in groundwater use, especially in canal commands.
3. Future withdrawal requirements would need full use of storage as well as creation of additional storage.
4. Considerable land would remain rain-fed, even in scenario stressing more agriculture and productivity increase may require watershed management of uplands.
5. The basin is not expected to have any water shortage on the whole even in the projected scenario of increased agricultural and industrial use i.e. F-II and F-III. Average annual river flows of 17,381 million cubic meters would reduce to about 16,618 million cubic meters under the assumed future scenario F-IV.

* * * * *

CHAPTER 3

POLICY RELATED ISSUES EMERGING FROM THE STUDY

3.0 General

The comprehensive assessment made through application of BHIWA model for past, present and future conditions gives a sound and much broader Knowledge Base (KB) to understand the state of water availability under alternative scenarios by different use sectors at the basin/sub basin level, source wise (surface and groundwater) and at the aggregate basin level. In particular, the scenario-based approach has allowed the testing of various plausible policy options for managing water and related land resources. While food sufficiency at the basin level and benefits of expanding irrigation to improve rural livelihoods requires setting of targets through socio-economic models and at country/global level, model such as BHIWA when applied to individual basin can consider constraints of 'within basin' availability of water and land, and help in assessing in-basin water storages, artificial recharge to groundwater and interbasin surface water transfers. The limited use of BHIWA to the water rich Brahmani basin has brought out important policy options that have application to similarly placed river basins and, through these to national water issues. The specific and overall conclusions relating to issues of three water use sectors emerging from Brahmani study in the context of IWRDM and sustainable water use are described in the following paragraphs.

3.1 Need for a Shift in the Concept of Water Resources

The nature sector water use needs to be accounted carefully as it affects water availability in the rivers and aquifers and is important for maintaining terrestrial as well as aquatic ecology. Similarly, harvesting of rainfall and local run off, over use of groundwater, etc. has large impact on availability of river waters. These considerations require that precipitation which is the primary source of all waters on land, rather than the terrestrial run off (surface and groundwater) is to be considered as the primary renewable water resource. BHIWA model evolved and used in water assessments provides a computational framework to account for impact of change in land use and soil and water management policies on surface and groundwater resources.

3.2 Accounting Water Use by Sectors and their Integration

- The consumptive uses of individual sectors (water for agriculture, people and nature) need to be assessed and integrated in order to understand the real impacts of land and water use and management policies. It is the consumptive use, which causes the depletion of the resource/water availability. Assessment of consumptive uses requires data on water withdrawals for irrigation, domestic and industrial and other uses. Such data are found to be inadequate and have been assessed indirectly using crop areas and irrigation statistics, supply norms etc. Similarly, data on efficiency in water use and returns are lacking in most cases. For better assessment of withdrawals and consumptive use and consequently state of water availability, it is necessary to improve the water related database.

Integration of sectoral water uses is made possible through application of model such as BHIWA and can help in taking a holistic view at the water needs and their impacts on the water availability.

- Maintenance of water accounts, in terms of withdrawals, consumption and returns, separately for the requirements of the food, the people and the nature sector leads to a better understanding of the water uses. For example, when the consumption of the rainwater by the terrestrial ecosystem is considered, the nature sector requirements become significant.

- The BHIWA Model, which considers the entire land phase of the hydrologic cycle, provides the necessary framework, including assessment and accounting for sector-wise withdrawals and consumptive use including their composition. The model considers the effect of land and water management policies on the magnitude as well as composition of consumptive uses of different sectors.

3.3 Accounting Return Flows

- ☐ The return flows from both point and non-point sources constitute a sizeable water resource.
- ☐ They could of different qualities, depending on the water management by each use sector.
- ☐ The return flows out of the withdrawals from surface and ground water are available for reuse, subject to proper treatment for ensuring water quality standard, as required. A better assessment of return flows and their impact on water availability can be made possible in cases where some information on returns is actually available for verifying the assumptions made in this regard while applying the model to Brahmani.

3.4 Consumptive Use Management

- The consumptive use management is to be treated as an integral part of water and land related resources management. In particular, the consumptive use could be reduced in nature sector by proper weed control, limiting the root zone depths and soil moisture holding capacities, for patchy barren lands, which seem to evaporate water withdrawal benefit to either the natural ecologies or to the food and the people sector.

- In the agriculture sector, reduction of non-beneficial consumptive use is possible through mulching (including use of plastic sheets), creation of moist microclimates, and use of micro irrigation etc. Increase in beneficial consumptive use is possible through conversion of wastelands or through watershed management and water development.

3.5 Integrating Surface Water and Groundwater Use in Irrigation in a Conjunctive Manner

A need for conjunctive use of surface and ground waters exists in surface water irrigated commands. Only about 15 - 25% of the current irrigation within the Brahmani basin is through groundwater. With expansion of surface water irrigation, the groundwater withdrawals need to be increased so as to minimize the risk of waterlogging in the canal commands. However, well thought of incentives and subsidies, encouraging ground water use, even when adequate surface water is available, have to be worked out and implemented.

3.6 Integrated Management of Land and Water Resources

- ❐ Appropriate choice of a cropping pattern with water requirements matching the availability of water and types of soil, is important. The land parcel and rainfall based working allows the flexibility for integrating the land and water resources development and management. With culturable waste forming a substantial part of land use, possibility of increasing rain-fed cultivation and conversion of rain-fed area into irrigated agriculture could be examined through application of the BHIWA model

- ❐ To provide livelihood to the rural population, productive and remunerative agriculture is a pre-requisite for generating local income and prevent migration. In the comparatively forested basins having a considerable rural population, such as Brahmani, rain-fed agriculture alone may not generate enough local incomes. Use of forest resources to supplement incomes including provision of minor irrigation facilities within forest lands may be required to enhance the carrying capacity of the land. The recent policy initiatives of the Indian Ministry of Tribal Affairs envisages the empowerment of tribals in forests by recognising such rights, and further allows cultivation of small patches of forest lands by the tribal people. The hydrologic and economic implications of these policies need to be studied. Allowing irrigation in such plots is another option, which can be considered.

3.7 Preventing Pollution of Natural Waters

A comprehensive study on overall water use and wastewater generation and treatment for all the industries could not be attempted so far.

Industrial/mining effluents of Angul-Talcher region have affected water quality of Brahmani River. River Nandira carries bulk of the industrial effluents and has become a highly polluted stream. Immediate effort is called for to treat all wastewater. Zero effluent is targeted to be achieved, failing which non-monsoon power generation at Rengali reservoir can be increased to supply the flushing needs at Kamalanga, just downstream of the confluence of Nandira River on the basis of 'polluter pays' principle.

Four tributaries to Brahmani – Tikra, the largest tributary in Orissa (3536 km^2), Singhdajhor (436 km^2), Banguru (131 km^2), and Nandira (595 km^2) have all the industrial and mining activities in their lower basins, a master plan for integrated management of waste water and its disposal to the surface waters of these parts of the basin needs to be drawn up through a special study.

In the highly industrialised Angul-Talcher belt of the Brahmani basin, the pollution hazards are very high. A river got heavily polluted when the industrial tailings accidentally slipped into the natural stream. Such accidental occurrences also are to be considered in developing the policies.

After discussion of these issues in the consultations, the acceptable view, which emerged was as follows:

a) Normally, each industry should treat their effluents, in accordance with the legal requirements, before discharging these into the national streams. Dilution should not be used as a method of effluent treatment.

b) However, considering the risks of accidental pollution, it would be preferable to keep a small sponge reserved for the abatement of such accidental pollution.

3.8 Watershed Development

Much of the land in the upper parts of the basin would require proper watershed development and management plans involving harvesting of the in-situ rainwater, as major and medium surface water schemes may not cover these parts. Watershed management can play an important role in poverty alleviations of the tribal population settled in the forested areas, and who are likely to be given the rights for cultivating some of these lands. Such local majors however have to be discouraged sometimes, where adverse effects on water availability in the downstream reservoirs are likely. However, in water rich basins like the Brahmani, such situations may be infrequent.

3.9 Water for People - Dimensions of Priority

- Domestic and industrial water needs constitute a significant part of the total water withdrawal requirements in case of the Brahman basin. While present assessments have been made externally an integrated, the policy issues in allocation of priority need to be looked into.

- National Water Policy accords first priority for drinking water, with industrial, environmental and navigational uses being given lower priorities than irrigation. The core water demands for drinking and those required for maintenance of rich bio-diversity of Brahmani delta and estuarine region may require to be given higher priorities.

3.10 Water for Nature - EFR

Stipulation of a desirable environment flow requirement (EFR) for riverine eco-system in water rich basins needs more investigation and proper substantiation. However, the EFRs need to be recognised as a valid requirement. Their estimation methods could be ad hoc and hydrology based, initially. Better methods based on water regimes required by different species as also based on the trade offs between environmental flow and uses, as preferred by the society, need to be evolved. The Brahmani case has provided and interested situation where requirements of fisheries in the lower (food sector), maintaining bio-diversity of he fragile mangrove eco-systems of Bhitarkanika and possibly river navigation below Talcher are to be met apart from irrigation requirements of the deltaic region. This needs a special study to establish if the existing Rengali reservoir operation could be modified to meet these complementary and competing uses.

3.11 Water for Navigation

Although this aspect could not be stated in detail, the importance of navigational water requirements in the comparatively water rich basins with physical possibilities of navigations, have been brought out. The navigational requirements would, in most cases, be compatible with the

EFR requirements. Where special releases for navigation, over and above the resulting river flows are necessary. Some adjustments and tradeoffs with other uses like irrigation and hydropower would be necessary, and these would require comprehensive studies.

3.12 Flood Control and Drainage

The Brahmani delta had considerable flood problems, and flood control was a stated objective of the Rengali reservoir. Although, in the post dam situation, the flood peaks have reduced remarkably, the duration of inundation of the low lands, at places, has increased. This, reportedly, is hampering the agricultural operations.

The implications of various flood mitigation strategies need to be discussed with the stakeholders, so that the limitations of each strategy are understood and then a choice is made through consultations.

* * * * *

ANNEXURES

ANNEXURE 1

BRIEF DESCRIPTION OF BHIWA MODEL

The Basin-wide Holistic Integrated Water Management (BHIWA) model as evolved for CPSP has 9 computation modules. The model is developed in Microsoft EXCEL software and has a number of spreadsheets. The model works, initially, in the calibration mode using the observed data. After obtaining a generally satisfactory calibration mode, it is worked as a tool for assessing the possible status of the basin, under different scenarios in the simulation mode. This process is depicted in Figure A1. For using the model, a river basin is first to be divided into hydrologically homogeneous sub- basins and each sub- basin into a number of land parcels each depicting a particular category/sub-category of land use. The model accommodates a maximum of 5 sub- basins and each sub- basin can be divided into a maximum of 25 land parcel types. The hydrologic computations are first performed for each land parcel in terms of water depth in millimeter over the area and then aggregated in volume units (million cubic meters) at the sub- basin level.

Natural (Hydrologic) Module 1: Computation of Actual ET, Quick Runoff and Natural Recharge

The model calculates water balances for the upper and lower zones viz. soil profile and groundwater system for each land parcel, given soil moisture holding capacity of the parcel, and area averages of rainfall, and reference evapo-transpiration for the sub-basin. The soil profile component of the model partitions the rainfall into actual evapo-transpiration (AET) and excess water. The actual ET is calculated as a function of potential ET and the actual moisture availability, as proportion of the root-zone soil moisture capacity for each land use type. These functional relations depict how the actual ET reduces with reduction of soil moisture availability, or indirectly the tension in the root zone. The excess water is further divided into deep percolation (natural recharge to groundwater) and quick runoff from land areas to the river. The quick runoff from all land parcels is aggregated into a single entity to represent natural contribution from rainfall to the river system. Likewise, natural recharge to groundwater under various land categories is lumped into a single groundwater entity representing the natural contribution of rainfall to the groundwater.

Module 2: Computation of Irrigation Withdrawal

This module calculates the requirement of additional water for each of the irrigated land parcels using data from previous module on shortfalls to meet the PET requirements. Net and gross irrigation requirements are computed source- wise using data on irrigation system efficiencies and proportion of surface water irrigation. For parcels having paddy crop, net water requirements are calculated taking into account user prescribed monthly percolation. Estimates of withdrawals for irrigation are arrived at finally considering "deficit irrigation" specified, if any.

Module 3: Computation of Irrigation Returns

These are computed separately for surface water and groundwater irrigation systems using user specified information on potential return from the total water withdrawn, in excess of the actual evapo-transpiration

(AET) and that part of the wasteful return, that will be lost as ET from swamps/waterlogged areas with in cropped lands. The difference between the potential and the wasteful return is further divided into the components returning to surface and groundwater system.

Module 4: Accounting for Evapo-transpiration (ET) by Sector

This module is designed for accounting ET by different use sectors. This is achieved through sectoral identification of each land parcel type. Agriculture land parcels are further divided into rain-fed and irrigated parcels. Parcel ET is designated as beneficial, if it is productive from consideration of sectoral water use. Otherwise it is classified as non-beneficial.

Module 5: Computation of Domestic and Industrial Withdrawals, Use and Returns

In calibration mode, this module is run on directly fed data. However, in simulation mode, D&I module is used first to project population and water requirements in the targeted "future" year from the user given information on base year, intermediate blocks, population growth rates and proportion of urban population to total population. Withdrawals are next computed in the model using rural and urban water supply norms and source-wise proportion of supplies. Information on consumptive use fraction and returns is used to calculate the total return as well as its components to surface and groundwater systems.

Module 6: Computation of the River Water Balance

It aggregates all inputs to the river including quick run off, base flow and returns from irrigation, D&I withdrawals and computes balance flow taking into account given values of storage changes and requirements of environmental flow. Provision exists to account for adjustments in surface water withdrawals through assumption of induced recharge from the river flow to groundwater in cases where the estimated groundwater withdrawal is found to be unsustainable. This module also has a provision to ensure that the river flow in any month is not less than the specified EFR, or zero, if no EFR is specified. This is achieved through extra pumping from groundwater reservoir to take part of the demands on surface water.

Module 7: Computation of Groundwater Balance

The input part of the module facilities aggregation of input from deep percolation from natural rainfall, return from irrigation and D&I withdrawals and as well as induce recharge if any required from the river. The output components of groundwater system include base flow to river and withdrawals through pumping from ground water reservoir as also pumping into canals to meet the surface water shortages, if there be any. In the simulation mode, the module is designed to achieve a stable groundwater regime under average conditions by adjusting the initial groundwater reservoir storage. Where the total annual input to groundwater is detected to be less than the estimated withdrawals including natural out flow (base flow) to the river, there exists a provision to manually balance groundwater through artificial recharge from surplus river flows for achieving a sustainable or balanced groundwater regime. Consequences of modifications in groundwater reservoir system are carried forward to modify the river water balance.

In addition to the above modules, there are worksheets to facilitate data inputs, and generation of aggregated results in the form of tables and charts.

The model runs on a monthly time step simulating average hydrological year. In the calibration mode, however, a model can be applied either to a single year (good, average or dry) or to a sequence of years (maximum length 5 years). ■

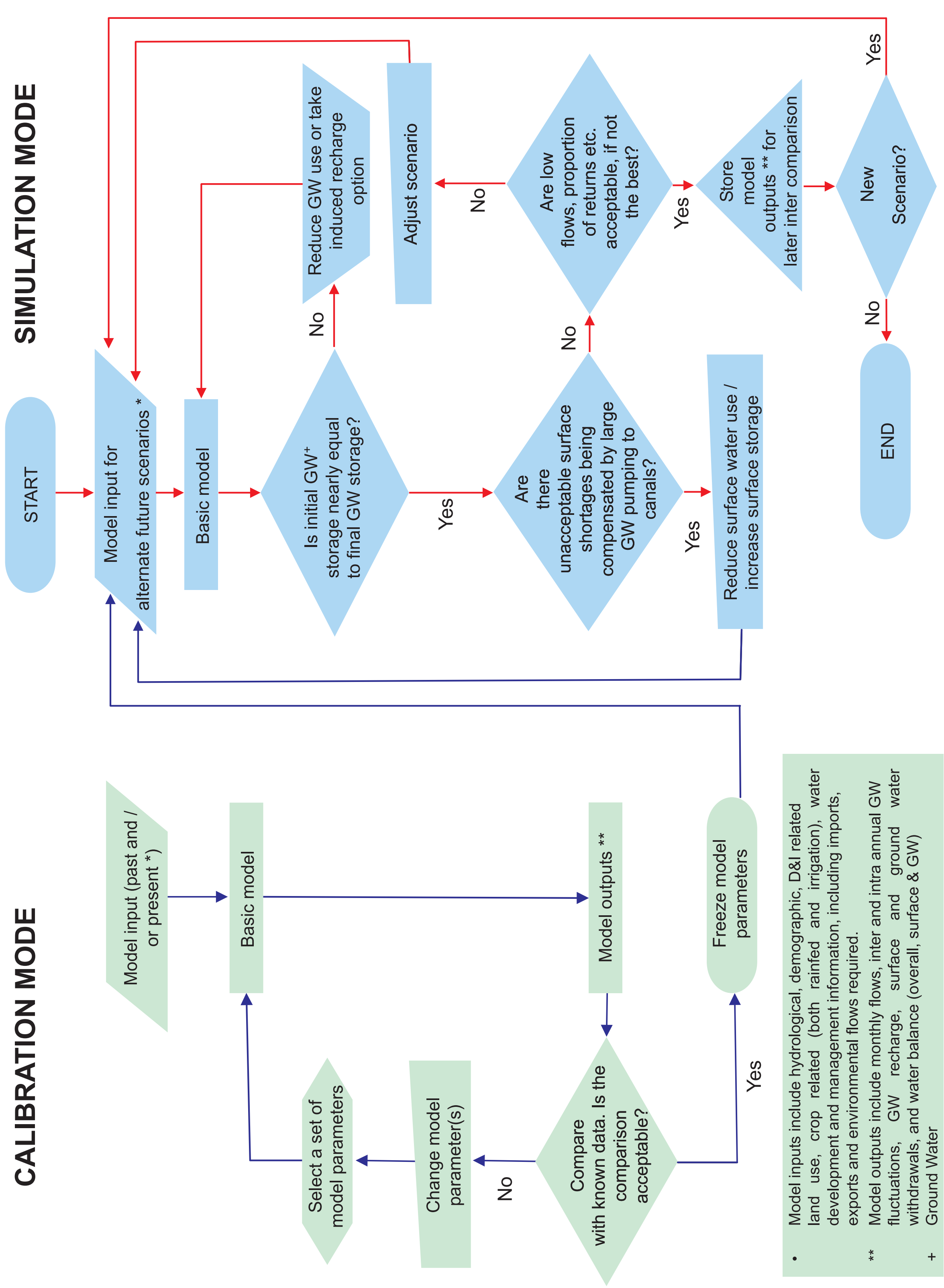

Figure A-1 Logical Sequence of BHIWA Model

- * Model inputs include hydrological, demographic, D&I related land use, crop related (both rainfed and irrigation), water development and management information, including imports, exports and environmental flows required.
- ** Model outputs include monthly flows, inter and intra annual GW fluctuations, GW recharge, surface and ground water withdrawals, and water balance (overall, surface & GW)
- \+ Ground Water

ANNEXURE 2

LIST OF EXISTING, ONGOING & PROPOSED IRRIGATION PROJECTS AND THEIR CULTURABLE COMMAND AREA (CCA) - BRAHMANI RIVER BASIN

S. No.	Projects	CCA (ha)
	Existing Major & Medium Project	
Orissa State		
1	Kansbahal	5,050
2	Pitamahal	2,644
3	Gohira	8,109
4	Aunli	1,188
5	Dadraghati	4,514
6	Derganj (Stg I)	6,478
7	Ramiala	9,600
Jharkhand State		
8.	Latratu	9,900
9	Kansjore	6,260
10.	Katri	4,970
11.	Banki	4,050
	Ongoing Major & Medium Projects	
Orissa State		
1	Rengali (Samal barrage)	2,52,425
2	Rukura	5,750
Jharkhand State		
3.	Dhansinghtoli	2,990
4.	Upper Sankh	4,228
5.	Ramrekha	2,400

S. No.	Projects	CCA (ha)
	Proposed Major & Medium Projects	
Orissa State		
1	Rengali dam (Durgapur canal)	3,000
2	Koel barrage (Orissa part)	1,0500
3	Hinjili	4,200
4	Derjang (stgge II)	1,922
5	Samakoi Barrage	7,200
6	Mankada	9,350
7	Chandri nalla	5,000
8	Barsuan	3,000
9	Kuradihi	5,000
10	Kutumgamurha	11,000
11	Suidihi	6,800
12	Kala	6,440
13	Antasira	7,200
14	Madalia	2,000
15	Singadajore	2,500
16	Takua Barrage	3,000
17	Tikira	4,0000
18	Champali Jor	3,965
19	Reconstruction of Brahmani Anicut	17,500
	Minor Irrigation schemes	
Orissa State		
	Existing	60,072
	Ongoing	7,873
	Proposed	1,21,699

ANNEXURE 3
NAVIGATION PROSPECTS IN BRAHMANI BASIN

Economic evaluation of navigation for transportation of minerals and other bulk cargo and product from manufacturing industries or end products in the basin is considered necessary. Brahmani river traverses close to the Talcher-Kaniha area, which is the seat of large coal reserve and Daitari area, which has large iron ore results. Figure A2 shows the approximate locations and river systems below Talcher, which could offer good river transport connectivity.

Presently, a National Highway (NH 42), which runs parallel to the river for almost 100 km and at a short distance away, from the river, is used for transportation of small consignment, which is found cheaper via road. Likewise, iron ore, being exported (primarily to Japan) from the OMC operated Daitari Mines; via the more or less captive Expressway (NH 5A) from Duburi to Paradeep port is able to cope with cargo and considered economical in today's situation. With good prospects of expansion of mining and other industrial activities in the basin, river navigation could offer a good and cheaper mode of transport.

Old Canal Navigation System

The British major Anicuts across Mahanadi, Brahmani and Baitarani linking these rivers through navigable high level canals from Cuttack in Orissa to Bhadrak in West Bengal, a distance of about 100 km. The last reach of canal, HLC III was utilized to transfer crafts to Salandi river, which in turn was transferring boats to Matei river and to the Orissa Coast Canal from Baitarani to West Bengal. The canal negotiated Kansbas, Budhabalanga and Subarnarekha rivers through locks. This Navigation system continued till about 1950 in all canals and rivers, except in HLC II, which had become defunct much earlier.

Proposed Navigation System

In recent years, possibilities of reviving Orissa coast canal system of navigation as well as navigation in lower reaches of Brahmani river have been studied by WAPCOS for the Inland Waterways and Navigation Department. The type of the vessels and its characteristics were studied by WAPCOS for the projected cargo from the area. These studies concluded that a canal with waterway of 45 m having a minimum water depth of 20 m might be needed in the short term. The vessel size, which fits to the above canal dimensions were accordingly arrived as follows:

For 45 m wide channel

• Capacity:	500 DWT
• Length:	40m
• Beam:	9m
• Draught (loaded):	1.67m

A two-way movement of vessels is considered in the canal under each of the phases. Suitable suggestions for deployment of navaids and type of vessels are also made for selection and deployment of suitable vessels for waterway.

The river navigation prospects (refer figure A2) basically comprised of two alternative routes, for conveyance of coal, iron ore and aluminum products, the principal cargo of Angul-Talcher-Duburi industrial region The loading point for coal, aluminum products is 'Talcher' and iron ore is 'Pankapal' on the river Brahmani.

Alternative A: Brahmani – Kharsuan path to Dhamra Port (proposed)

Navigation through Brahmani and over 95 km of riverine reach Kharsuan was found to be a feasible proposal for conveying 2 MT of iron ore to Dhamra, where a port is being proposed.

Two main features of this scheme are:

- River Brahmani between Talcher to Jenapur (a stretch of 140 km), which is the head of its delta, is currently carrying a discharge in the range 20 to 15000 m^3/sec, has a conveyance width of 300 m to 500 m and maximum depth of 8 m. But the deep channel, which is about 50 m to 70 m wide, has a minimum depth of 1.5 m to 2 m in the lean season (March-April-May) and may require augmentation from Rengali for flow navigation.
- The river bifurcates into Brahmani and its main deltaic branch - 'Kharsuan', which is 5 m to 6 m minimum depth and a width of 200 m to 500 m from Jenapur up to its confluence with Brahmani 95 km downstream. Thereafter, minimum depth available ranges 7-8 m in the remaining stretch of

the river for about 45 km and up to proposed Dhamra port.

Some constraints/requirements are as follows:

- ☐ Maintaining a minimum width of 100 m and depth of 5 m in Brahmani may need a minimum discharge as high as 300 m^3/sec, during March to June, which may become a limiting factor in the future,
- ☐ River training works utilizing short spurs for maintaining a navigable channel may become necessary,
- ☐ Developing an operational plan for multi-purpose operation of Rengali reservoir linked with the committed irrigation needs of the 2,00,000 ha command area below Samal barrage, so as to meet the additional requirements of flow in navigation in Brahmani/ Kharsuan,
- ☐ Providing a lock (100 m X 20 m) at Jokadia anicut on Kharsuan, and
- ☐ Providing necessary infrastructure including loading jetties on the bank of Brahmani at Talcher and at Pankapal.

Alternative B: Brahmani – HLC I – Birupa – Mahanadi – barrage pond – Taladanda canal – Paradeep Port (Existing).

The components of the scheme are:

- ○ Brahmani river 145 km up to Jenapur (from Talcher),
- ○ HLC Range I canal, Jenapur to Cuttack 50 km. This canal (with width of 20 m and depth 4 m) was used up to 1950-55 for small crafts (20 m X 4m) of draught 1.5 m. The canal had high-level bridges (100 year old, steel trusses), which however, have now been replaced with RCC bridges with no headway.

Constraints and some other requirements of this alternative are summarized below:

HLC I:

- The HLC I would need at least 20 new bridges with a singe span of 20 m and headway of 5 m.
- A lock at Jenapur and another lock at Birupa Barrage for entry into Mahanadi – Birupa /Barrage pond.

Talanda Canal:

- ■ Need for a lock at the head of Taladanda canal (90 km length) to negotiate from Mahanadi pond.
- ■ 10 Nos. locks along Taladanda canal up to existing Paradeep port.
- ■ 20 Nos. of high-level bridges on the canal.

Both these alternatives are shown on the map given in Figure A2. ■

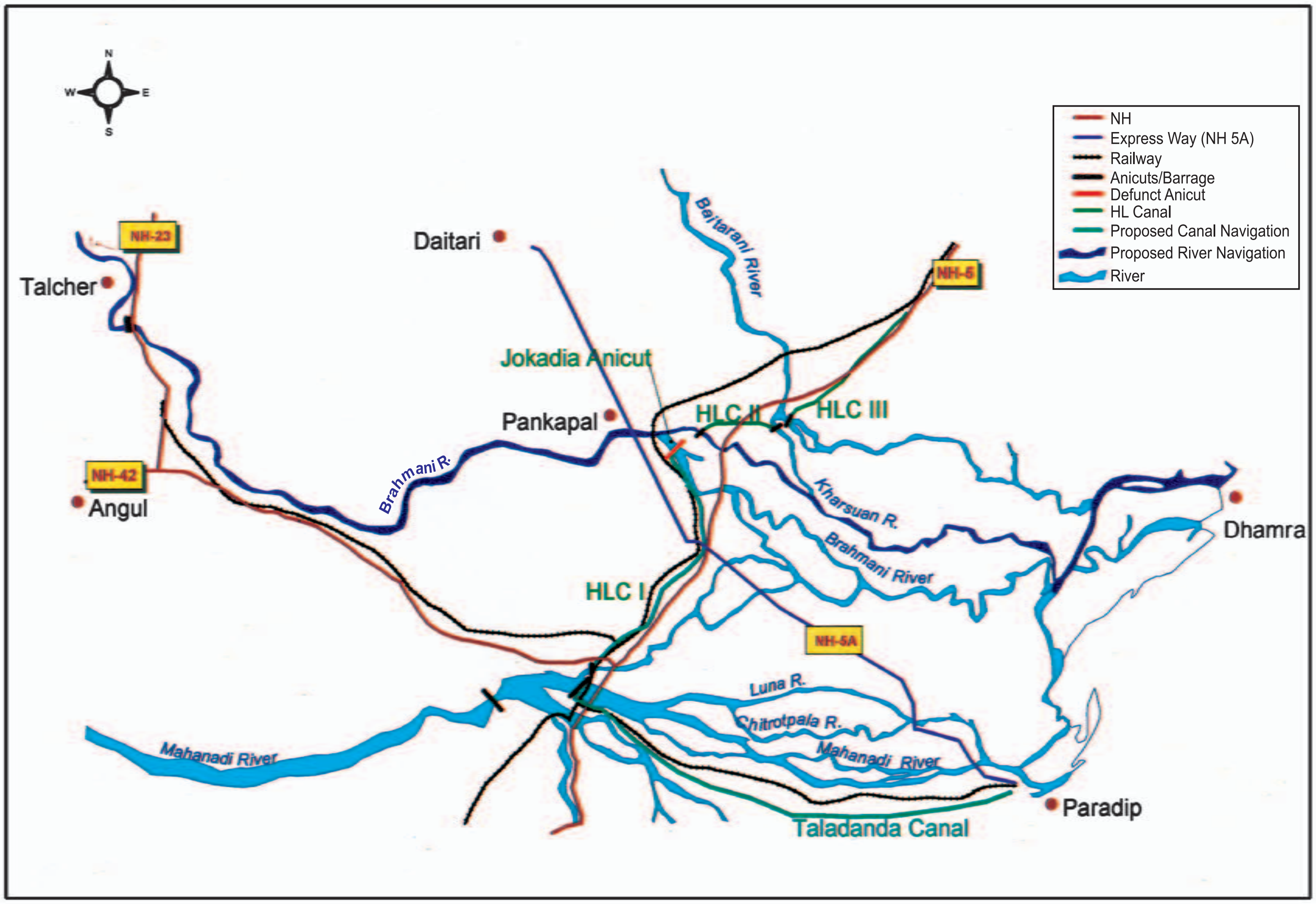

Figure A2. Proposed Inland Navigation in Brahmani River System

ANNEXURE 4
ANGUL-TALCHER INDUSTRIAL COMPLEX – STATUS AND ISSUES

Angul-Talcher region with 1813 km^2 of coal bearing area is one of the major industrial zones in the State of Orissa and in India. Angul-Talcher area lies between latitudes 20º 37' N to 21º 10' N and longitudes 84º 53' E to 85º 28' E. The area receives 1350 mm of average annual rainfall and is drought prone. A maximum temperature of 50.9º C has been recorded in the area. The area is fast emerging as a large source of coal, aluminium and thermal power in the country. About 711 km^2 area forms the core industrial zone. The land use pattern in this area broadly comprises of built up land (51.3 km^2), agriculture land (500.10 km^2), forest-lands (86.37 km^2), wasteland (34.11 km^2), mining areas (12.83 km^2) and water bodies (26.42 km^2).

The entire area is dissected by river Brahmani into two halves, while it traverses from northwest to southeast and drains directly into the Bay of Bengal. Water of Brahmani and its tributaries cater to the industrial/domestic need of this fast growing complex. The major part of the area forms the plains of river Brahmani and its tributaries like Nandira Jhor, Singada Jhor and Tikra River. The drainage network is controlled by river Brahmani. A rivulet Nandira, which flows centrally from west to east and meets Brahmani near the village Kamalanga. It is highly polluted carrying almost all the industrial effluents and also a sizeable load of domestic effluent from industrial townships, located on either sides of the river. Banguru Nallah originates from Satyabadi Sagar situated within the lease hold area of Kalinga Open Cast mine project and carries the waste water of different coal mines of Mahanadi coalfields joins Brahmani from north-west. Deojhar nallah flowing to Nandira rivulet carries the run-offs of mining area as well as waster water of South Balanda colliery.

The total reserve of coal in this area has been estimated to be 25,485.18 million-tons against India's reserve of 240,750 million tonnes. Out of the total reserve, 2,548.5 million tonne is superior grade coal (Grade A, B, C and D) and rest 22,936.68 million tonnes are power grade coal. The availability of coal in Talcher area and water of river Brahmani are responsible for growth of industrial activities. On the average 36 million tonnes of coal is being extracted annually. Raw water to the extent of about 86.26 million cubic meters/annum is drawn from the river for industry/mining activity, apart from other surface and ground withdrawals.

The industrial activities in Angul-Talcher area is primarily dominated by large scale coal based super thermal power plants established by National Thermal Power Corporation (NTPC) (2460 MW from industrial production units) and National Aluminium Company (NALCO) (720MW from captive power plant). Availability of good quality coal has also promoted the establishment of coal based fertilizer plant by Fertilizer Corporation of India (FCI). Two industrial estates in Angul-Talcher area are developed by Industrial Infrastructure Development Corporation, Govt. of Orissa.

The water withdrawal and wastewater generation by major industrial users are as follows:

Water demand and wastewater generation by major industries (10^3 litres/day)

S. No.	Industrial Unit	Water withdrawal	Wastewater generation
1.	NALCO		
	• Captive Power Plant	1,43,000	5,650
	• Smelter Plant	90,000	4,250
2.	Fertilizer Corporation of India	64,800	23,200
3.	Talcher Super Thermal Power Project		
	• NTPC, Kaniha	1,15,200	47,000
	• TTPS, Talcher	39,000	18,700

Mahanadi coalfields with 6 open cast mines and 4 underground mines have been operational using water from Brahmani and its tributaries like Tikra, Banguru Nallah along with substantial groundwater. The wastewater on which reliable quantitative information is not available is discharged into the streams after settlement in low-lying areas. The wastewater over flows to paddy fields en route to drainage channels. The industrial effluents with oil and grease are treated in settling tanks before cleaning through traps.

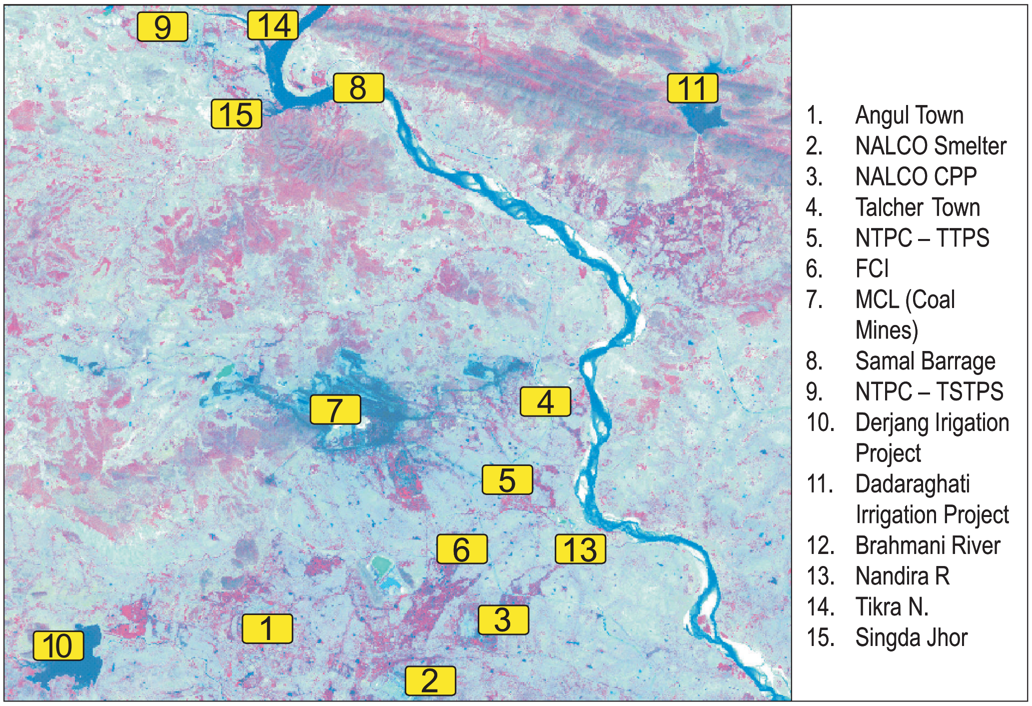

Figure A3. Angul-Talcher Industrial Complex

Some of the issues for consideration are:

- A comprehensive study on overall water use and wastewater treatment for all the industries has not been attempted so far. Assessment of water availability in this industrial region and planning for its optimal utilization, particularly for environmental protection has to be done urgently.
- Industrial/mining effluents of Angul-Talcher region have affected water quality of Brahmani river. River Nandira carries bulk of the industrial effluents and has become a highly polluted stream. Immediate effort is called for to treat all wastewater. Zero effluent is targeted to be achieved. In any case, the non-monsoon draft from power generation at Rengali reservoir is available to take care of any pollution and EFR needs at Kamalanga, just downstream of the confluence of Nandira.

Four tributaries to Brahmani – Tikra, the largest tributary in Orissa (3536 km^2), Singhdajhor (436 km^2), Banguru (131 km^2), and Nandira (595 km^2) have all the industrial and mining activities in their lower basins, a master plan for integrated development of these basins for nature, food and people sectors needs to be drawn up.

Industries need to be encouraged, through incentives to improve the wastewater management through recycling/reuse and adequate treatment. However, industries, which continue to violate the prescribed norms, need to be made to improve their water management by enforcing the "polluter pays" principle.

ANNEXURE 5

EXISTING AND PROPOSED INDUSTRIES, AND THEIR WATER REQUIREMENTS IN ANGUL TALCHER INDUSTRIAL AREA, BRAHMANI RIVER BASIN

Existing Industries (10^3 m^3/day)

S. No.	Name of the Industry	Products	Water consumption	Wastewater generation
1	Rourkela Steel Plant	Iron & Steel	2,65,580	1,20,000
2	Rourkela Steel Plant	Fertilizer (CAN)	28,807	7,920
3	Fertilizer Corporation of India	Fertilizer (Urea)	45,883	16,608
4	National Aluminium Company-Smelter Unit	Aluminum	5,066	4,900
5	National Aluminum Company – Captive Power Plant	Electric Power	1,35,000	90,000
6	ORICHEM Ltd.	Sodium dichromate, Basic Chromate Sulphate, Yellow Sodium Sulphate	170	10
7	Talcher Thermal Power	Electric Power	13,227	6,483
8	Talcher Super Thermal Power Plant NTPC, Kaniha	Electric Power	1,37,099	52,080
	Total		**6,30,832**	**2,98,001**

Proposed Industries (10^3 m^3/day)

S. No.	Name of the Industry	Products	Water consumption	Wastewater consumption
1	MESCO Iron Steel Ltd. Duburi	1.0 MT, Iron	84,840	40,078
2	MESCO Kalinga Steel Ltd. Duburi	4.5 MT, Steel	1,93,200	91,268
3	Bhusan Steel Ltd.	3.0 MT Iron & Steel	2,29,200	108,274
4	Neelachal Steel Ltd.	2.5 MT, Iron & Steel	1,75,200	82,764
5	Brahmani Steel, Duburi	1.0 MT, Iron & Steel	84,840	40,078
6	ORIND Steel Ltd.	1.0 MT, Iron & Steel	16,800	7,936
7	Other Steel Plants	3.0 MT Iron & Steel	2,88,000	136,051
8	Ancillary Industries		45,840	21,655
9	Kalinga Power	4 x 250 MW	3,36,000	1,58,726
	Total		**14,53,920**	**6,86,832**

ANNEXURE 6
MANGROVES OF BHITARKANIKA

Introduction

The Mangrove forest possesses manifold socio-economic potentialities. Local people make use of mangrove wood as fuel, for making charcoal, agricultural implements, as house building materials etc. Mangrove provides food for aquatic life forms. Many mangrove species possess medicinal value. Mangrove forest provides a breeding ground and serves as nursery for a majority of commercial fishes, prawn etc. The forest, meadows and swamps support a large number of resident and migratory birds. Good quality honey and other forest products are also available from these mangrove forests.

The mangroves of this region can be divided into two main formations: (a) the outer estuarine mangroves, and (b) the inner estuarine or riverine mangroves along the tidal flats.

a) Outer estuarine formation

Mangroves of this formation along the bank of river estuaries are influenced by open shore environment and are mainly dominated by Avecenia marina, associated with Sonneratia griffithii, Sonneratia alba, Aveceria alba, Lumnitzera racemosa, Ceriops tagal, Bruguiera Cylindrica, Bruguiera parriflora, Aegialitis rotundifolia and sometimes with Phoenic paludosa excluding the newly exposed areas covered with saline grass.

b) Inner estuarine formation

Best development of mangroves occurs in this formation and the flora becomes richer and diversified due to sheltered situation of these places and availability of some fresh water supply from the upper catchment compared to that of the river mouth formation.

Tidal flats are associated with a large numbers of creeks and channels along the upper part of the inner estuary formation where the salinity is lower than the outer estuaries. But tidal velocity of this region is higher due to presence of a number of creeks. These mangroves consist of Rhizaphora apiculata, Rhizaphore mucronata, Kandelia candel, Aegeras corniculatum associated with xylocarpus granatum, Excocaria agallocha, Bruguiera gymnorrhiza, Ceriops decandra, xylocarpus mekongensis, Avecenia officinalis, Phoenix paludosa, Merope angulata, Dalbergia spinosa and some climbers Finlaysonic obovata Derris scandens, Tylophora tenuis and Hoya parasitica form a typical mangrove formation.

Tidal flats along the middle part of the inner estuarine areas are away from Bay and near to fresh water flow, dominated by Heritieira fomes in association with Brownlowia tersa.

Sustainability of Mangrove Ecosystem

Mangrove eco-system depends on a balanced interplay of sweet and saltwater at the estuarine reaches of river deltas. Due to progressive diversion of fresh water in the rivers upstream, it is apprehended that the flow of fresh water into the mangrove swamps can diminish rapidly in the years to come. This can affect the salinity levels of the water in the mangrove eco-system resulting in their destruction.

The sustainability of mangroves is crucially dependant on a delicate mix of abundant fresh water (riverine flow) and saline water, which the tides provide. Presence of salinity at adequate level is the most desirable condition, as the absence of salinity will not enable the mangroves to survive. The optimal salinity however is 5-15ppt for luxuriant growth and sustenance of mangroves.

Low salinity is preferred to high salinity as was experienced in Indus delta where the mangroves in the estuarine region have been dying primarily due to massive fresh water abstraction. Bhakra Dam in India and Tarbela and Mangla Dams and large barrages in Pakistan have resulted in reduction of terminal flow from 140 MAF (1950) to 20 MAF currently. Thereby the salinity has gone up from 20ppt (around 1950) to 40-45ppt currently resulting in the reduction of delta mangroves extent from 3450 km^2 to 1585 km^2 (1990). An IUCN study emphasizes that 27 to 35 MAF of terminal flow must be ensured to sustain the whole eco-system of Indus delta (Menon, 2005).

A reversing trend is noticed in the Sunderban mangroves, covering 2500 km^2, the largest chunk in West Bengal, India. The mangroves were slowly perishing due to dearth of fresh water until the Farakka feeder canal was built (1970) bringing in 850 m^3/sec of fresh water perennially into Hoogly estuary reducing the salinity by 10-15 ppt. Not only the mangroves flourished due to decreased salinity but also the fishery production went up from 7,000 Ton (1970) to almost 70,000 Ton currently attributable to the healthy mangroves in the estuary.

Water Availability for Mangrove

In the current situation, the gross irrigation coverage is 0.34 Mha out of the total cultivated land of 1.48 Mha. The outflow to the sea is 17,320 million cubic meters. With larger irrigation coverage of the order of 0.98 Mha (anticipated by 2025) the outflow to the sea will reduce to about 15,000 million cubic meters.

The operation of the Rengali reservoir has changed the intra-annual flow regime. In the non-monsoon (November to June), the total river flow was around 650 million cubic meters in the Pre-Rengali (Pre 1987) period. This has now increased to around 3,000 million cubic meters. The consequent changes in the estuarine salinity could perhaps alter and improve the mangroves. However this needs further studies.

A limited data available on water flows and salinity of water at the estuary is available (see table below). It is interesting to note that even with a low flow of 350 m^3/sec in March 1999 and February 2000, the salinity was about 26 ppt, whereas in the monsoon (August 1998, a drought year) when the flow was 1000 m^3/sec, the salinity was 26.90 ppt. It appears that the estuarine salinity, which is slightly below the salinity in the seas, is not significantly affected by the head discharges in the river.

Preliminary Assessment of Impact of Increased Abstraction in Brahmani Basin

As is evident from the present water quality data at the estuary and flow at the head of the delta the fresh water need of the mangroves is adequately met. A review was

Water Quality Data of Bhitarkanika Mangrove System

Station	Maipua	Bhitarkanika	Gahirmatha	Gupti	Gahirmatha
Date	17 Feb. 2000 1999	17 March 1999	11 Dec. 1998	18 August 1997	10 Dec. ——
Depth	12.8 m	——	5.2 m	5.7m	——
High tide temperature	27° C	——	——	——	——
Suspended Solid (mg/l)					
• Surface	10.81	23.02	25.89	——	——
• Bottom	11.21	——	12.21	——	——
pH					
• Surface	7.78	8.05	8.15	8.05	——
• Bottom	8.14	——	8.19	——	——
DO (mg/l)					
• Surface	8.26	8.52	8.13	8.58	7.80
• Bottom	7.82	——	8.94	——	——
Salinity (parts per thousand)					
• Surface	26.98	24.70	25.98	26.90	27.96
• Bottom	27.12	——	28.12	——	——
BOD (mg/l)					
• Surface	2.00	——	0.64	1.54	1.84
• Bottom	1.84	——	2.52	——	——
Inorganic Phosphate (mg/l)					
• Surface	1.40	——	——	——	——
• Bottom	1.32	——	——	——	——
Total Nitrogen (mg/l)					
• Surface	38.7	42.60	29.8	34.40	——
• Bottom	42.0	——	24.6	——	——
Nitrate Nitrogen (mg/l)	——	2.42	——	——	——

made of the literature detailing the assessment of adequate environmental flow for basins in the US, Australia and South Africa. Often a 10-20 % of the mean annual flow (MAF) is being considered it sufficient as environmental flow, with a stipulation that it mimics the pre development scenario. In this context it is important to reckon that the mangroves, which need enough fresh water may face some deficit especially in the lean non-monsoon season, December through May.

Prior to construction of Rengali dam the lean season flow at the delta head was on the average 1,400 million cubic meters (1,000 million cubic meters in dry years to a maximum 2,000 million cubic meters in very wet years) out of the overall annual flow of 22,000 million cubic meters. With very little irrigation in the Rabi season, no return flow was available to the river. With a large terrestrial forest cover of 40% the ET need was getting drawn from the partly saturated root zone region. The monthly flow was progressively reducing from 400 million cubic meters in November to about 75 million cubic meters in May.

In contrast since 1986 the total lean season flow has been in the range 2,000 to 3,000 million cubic meters, the minimum in the month of May being 300 million cubic meters. This is the consequence of the perennial power release from Rengali hydro station. Further, as the BHIWA model demonstrates the additional withdrawal of 5,000 million cubic meters for the increased irrigation coverage of 6,70,000 ha in 2025 will return at least 1,000 million cubic meters between December to May. It is certain that the overall lean season flow will not go below 2,000 million cubic meters in the future which is 15% of the overall annual flow in the future scenario. In addition the densely forested Baitarani basin, which has a fresh water contribution of almost 1,000 million cubic meters in the lean season, has a direct contribution to freshwater for the estuary. From the water quality data it is obvious that current salinity is not increasing beyond 25 ppt in the summer, which shows that the saline wedge is not significantly affecting the fresh water upto 20 Km upstream.

The monthly river flows at the basin outlet, as estimated from the BHIWA model indicates that for any of the future scenarios, the average annual flow would be of the order of 15,000 million cubic meters or more. The lean season flows from December to May would also be of the order of 3,500 million cubic meters. Thus, there is no possibility of mangroves of Bhitarkanika facing dearth of fresh water, looking at the availability of additional water from Baitarani basin.

However a quantitative assessment of the need both for mangroves and fish, migratory in nature has to be carried out by adopting DRIFT (Downstream Response to Imposed Flow Transformation) or other suitable methodology and tested on a monthly basis against the available flow estimated on full irrigation and industrial development. ■

ANNEXURE 7

SUB-BASIN WISE MONTHLY RAINFALL (1995 AND 1998 TO 2002)

Year	1995				1998				1999				2000				2001				2002			
SB	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Jan	26	93	47	0	117	12	14	32	0	0	0	0	23	0	0	0	1	14	0	0	-	25	9	31
Feb	7	15	21	13	25	20	27	62	1	0	0	0	37	0	40	27	27	0	0	0	-	0	0	0
Mar	20	1	9	18	121	33	76	55	0	0	0	0	5	0	26	0	32	34	22	88	-	13	2	16
Apr	15	8	27	4	49	2	27	68	0	0	18	0	9	0	24	75	16	6	14	40	-	6	46	13
May	46	117	210	28	89	12	48	12	78	76	141	369	120	59	95	100	44	30	44	154	-	67	94	110
Jun	148	83	125	117	211	157	309	191	272	258	160	248	207	250	182	284	504	445	293	293	-	252	89	227
Jul	308	339	272	196	210	250	287	303	469	265	214	280	298	211	338	204	327	709	558	772	-	285	71	162
Aug	170	304	258	267	304	240	153	349	474	407	251	535	151	434	320	204	185	345	354	301	-	405	203	295
Sep	182	234	222	267	405	422	224	304	176	353	309	305	168	213	163	56	92	63	36	169	-	111	231	104
Oct	36	79	94	185	145	38	0	237	124	37	272	496	8	19	3	62	32	18	116	241	-	49	14	28
Nov	50	89	82	75	4	33	73	71	1	0	0	14	0	0	4	4	0	0	8	54	-	0	6	34
Dec	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0	0	0
Total	**1013**	**1360**	**1366**	**1170**	**1679**	**1219**	**1238**	**1682**	**1593**	**1396**	**1365**	**2246**	**1026**	**1184**	**1195**	**1015**	**1259**	**1663**	**1445**	**2112**	**0-**	**1212**	**763**	**1021**

Data was not available for 1996 and 1997.

ANNEXURE 8

AVAILABILITY OF MONTHLY OBSERVED RUNOFF (YIELD) AT PANPOSH, GOMLAI, JENAPUR G&D SITES, BRAHMANI RIVER BASIN (10^6 M^3)

Year	1995			1996			1997			1998			1999			2000		
Locn	**Panposh**	**Gomlai**	**Jenapur**	**Panposh**	**Gomlai**	**Jenapur**	**Panposh**	**Gomlai**	**Jenapur**	**Panposh**	**Gomlai**	**Jenapur**	**Panposh**	**Gomlai**	**Jenapur**	**Panposh**	**Gomlai**	**Jenapur**
Jan	NA	236.52	876.46	NA	109.30	432.17	180.88	81.81	472.77	377.72	158.76	588.11	292.6	109.69	550.43	NA	NA	390
Feb	NA	157.68	708.62	NA	72.86	349.41	92.48	54.54	382.24	193.12	105.84	475.49	149.6	73.13	300	NA	NA	375
Mar	NA	118.26	668.22	NA	54.65	329.49	32.64	40.91	360.45	68.16	79.38	448.38	52.8	54.85	342.82	NA	NA	475
Apr	NA	89.79	506.60	NA	41.49	249.80	49.64	31.06	273.27	103.66	60.27	339.93	80.3	41.64	287.94	NA	NA	610
May	NA	118.26	590.52	NA	54.65	291.18	45.56	40.91	318.54	95.14	79.38	396.24	73.7	54.85	680.29	NA	NA	780
Jun	NA	764.06	663.57	485.52	571.91	725.92	1013.88	1109.85	903.02	785.4	766.85	631.75	NA	Na	950	NA	NA	760
Jul	NA	2466.24	2684.94	1423.92	1846.03	2937.23	2973.48	3582.39	3653.8	2303.4	2475.26	2556.17	NA	NA	2443.86	NA	NA	2597
Aug	NA	3164.52	4462.64	2012.8	2368.70	4881.97	4203.2	4596.69	6072.98	3256	3176.09	4248.61	NA	NA	6716.93	NA	NA	3166.23
Sept	NA	2325.58	3333.19	1612.96	1740.73	3646.39	3368.24	3378.06	4535.97	2609.2	2334.08	3173.32	NA	NA	6811.07	NA	NA	3161.29
Oct	NA	694.23	1393.04	476.68	519.65	1523.94	995.42	1008.42	1895.72	771.1	696.77	1326.23	NA	NA	3716	NA	,A	1244
Nov	NA	250.98	652.85	253.64	187.86	714.19	529.66	364.56	888.42	410.3	251.89	621.53	NA	NA	1010	NA	NA	405
Dec	NA	120.43	484.27	134.64	90.14	529.77	281.16	174.93	659.02	217.8	120.87	461.04	NA	NA	585	NA	NA	380
Total	**NA**	**10506.5**	**17024.96**	**6400**	**7657.9**	**16611**	**13766.3**	**14464.2**	**20416**	**11191**	**10305.4**	**15266.8**	**649.0**	**334.2**	**24394.3**	**NA**	**NA**	**14343.5**

Source: CWC Water Year Book, Dept. of Water resources, Orissa.

ANNEXURE 9

SUB BASIN WISE MONTHLY REFERENCE EVAPO TRANSPIRATION (ETo), BRAHMANI RIVER BASIN

Sl.No.	Month	SB 1	SB 2	SB 3	SB 4,5,6
1	June	174.8	182.5	189.50	210.00
2	July	142.6	182.50	168.50	192.70
3	August	135.5	171.00	164.10	179.00
4	September	125.0	153.70	152.70	159.60
5	October	98.00	129.60	137.30	138.00
6	November	46.50	53.20	77.20	79.00
7	December	33.30	30.20	42.30	34.10
8	January	34.30	69.80	44.70	50.40
9	February	46.10	53.90	75.60	73.00
10	March	103.00	143.70	150.10	160.10
11	April	163.50	189.50	181.80	189.40
12	May	191.50	227.30	202.30	217.40
	Total	**1,294.10**	**1,586.90**	**1,586.10**	**1,682.70**

Note: Values computed from the climatological data of Cuttack, Sambalpur and Ranchi meteorological stations.

ANNEXURE 10

CURRENT DEMAND OF DOMESTIC AND INDUSTRIAL USE

As per the 2001 Census, population in the basin is 8.4 million, urban population is 1.2 million and rural Population is 7.2 million. Urban population is calculated by adding the population of urban areas falling in the sub-basins.

The rate of supply to different township varies from 70 lpcd to 220 lpcd. Domestic use is calculated @140 lpcd in urban area and 70 lpcd in rural areas. (Source: Public Health Engineers Division (PHED), Orissa)

Current withdrawals of water for domestic use

Sl.	Water Use Type	Per capita annual demand (Cubic Meter)	Total Population (in million)	Total annual withdrawals (in MCM)
DOMESTIC URBAN				
1	Municipal use (Urban area) @ 140 LPCD	51.10	1.25	63.98
	Total withdrawal for Urban Use			**63.98**
DOMESTIC RURAL				
1	Drinking water & sanitation needs (rural) @ 70 LPCD	25.55	7.21	184.09
2	Live stocks (Cattle & Buffalos) @ 50 LPCD	18.25	3.82	69.68
3	Other live stocks (pigs, sheeps, goats, etc.) @ 10% of livestock	-	-	6.97
	Total withdrawal for rural use			**260.74**

Current withdrawal of water for industrial use

Sl.	Industrial Water Use	Withdrawal (MCM)
1	Consumption of water by major industries, Orissa	230.32
2	Add 40% for other industries in the basin	92.13
	Total Withdrawal	**322.44**

(Source: Orissa Pollution Control Board)

Domestic & Industrial use in 1960

Population	1961 in Thousand		
	Rural	Urban	Total
Orissa	2400	150	2550
Jharkhand	1721	252	1973
Chhattisgarh	65	4	69
Total	4186	406	4592

Live Stock Population (Year 1966): 27,46,426
Drinking water need was minimal, being met from ground water mostly.
Domestic use is calculated @110 lpcd in urban area and 40 lpcd in rural areas.

Computation of Water withdrawal for domestic use in 1960

Sl.	Water Use Type	Per capita annual demand (Cubic Meter)	Total Population (in Million)	Withdrawals (MCM)
DOMESTIC URBAN				
1	Municipal use (Urban area) @ 110 LPCD	40.15	0.41	16.46
	Total withdrawal for Urban Use			**16.46**
DOMESTIC RURAL				
1	Drinking water & sanitation needs (rural) @ 40 LPCD	14.60	4.19	61.17
2	Add 50% for Live stocks			30.59
	Total withdrawal for rural use			**91.76**

There wasn't any major industry in the basin except Rourkela Steel Plant.

Computation of Water withdrawal for industrial use in 1960

Sl.	Industrial Water Use	Withdrawals (MCM)
1	Consumption of water by major industries	96.00
2	Add 20% for other industries in the basin	19.20
	Total Withdrawal	115.20

(Source: OPCB)

Domestic & Industrial use in 2025 (B as U)

Population projection by the year 2025 (x 10^3)

Year	2001	2011	2021	2025
Orissa portion	5,135	5,905	6,496	6,756
Jharkhand & Chatishgarh portion	3,319	3,927	4,438	4,682
Overall Basin	8,454	9,832	10,934	11,438

Projection of water consumption for domestic use

Domestic use is calculated @140 lpcd in urban area and 70 lpcd in rural areas.

Sl.	Water Use Type	Per capita annual demand (Mcum)	Total Population (in million)	Total Withdrawals (Mcum)
DOMESTIC URBAN				
1	Municipal use (Urban area) @ 140 LPCD	51.10	4.00	204.40
	Total withdrawal for Urban Use			**204.40**
DOMESTIC RURAL				
1	Drinking water & sanitation needs (rural) @ 70 LPCD	25.55	7.43	189.84
2	Live stocks (Cattle & Buffalos) @ 50 LPCD	18.25	4.94	90.08
3	Other live stocks (pigs, sheeps, goats, etc.) @ 10% of the livestock	-	-	9.01
	Total withdrawal for rural use			**288.93**

Projection of water consumption for industrial use (2025)

Sl.	Industrial Water Use	Consumption (Mcum)
1	Current Consumption of water by major industries	322.44
2	Future demand	530.68
3	Add 15%of (1&2) for other developments in the basin	127.97
4	Add for Jharkhand & Chhattisgarh (lumpsum)	300.00
	Total Withdrawal	**1281.09**

In all the alternative scenarios domestic use remained same as 2025 (B as U).

Alternative scenario:-I

The industrial use will remain same as 2025 (Bas U) scenario (i.e., 1281Mcum).

Alternative scenario-II

It is assumed that the industrial demand will grow by 50% more than the demands in 2025 B as U (i.e., 1281 x 1.5 = 1920 Mcum)

Alternative scenario:-III

Besides planned industries, additional provision for Industries as indicated in 2025 (B as U) scenario has been reduced by 50% (i.e. 322 + 530 + (128 + 300)/2 = 1065 Mcum)

* * * * *

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EXPLANATORY NOTES/GLOSSARY

Anicut: A barrier across a stream for the purpose of diverting part or all of the water from a stream into a canal is called 'anicut' (weir). It may incidentally store water for emergencies.

Aquatic: Growing in, living in, or frequenting water.

Aquifer: A porous geological formation, which can store an appreciable amount of groundwater and from which water can be extracted in useful quantities.

Arable: Land suitable for cultivation by ploughing or tillage, does not require clearing or other modification.

Arid: An area or climate that lacks sufficient moisture for agriculture without irrigation. According to Thornthwaite, areas having moisture index below –40 Thornthwaite moisture index.

Artificial groundwater recharge: Replenishment of groundwater storage by injection, deep percolation or surface flooding.

Base flow: Stream flow coming from ground water seepage into a stream.

Basin: Area drained by a river or its tributaries up to its common terminus.

Beneficial/Non-beneficial Evapo-transpiration: The evaporation, which provides goods and services to mainland through food production, or through support to ecosystems is considered beneficial. Where no significant goods and services are obtained as through evaporation from soils or from patchy barren lands, which may have few weeds etc. are, considered as non-beneficial.

Check dam: Small dam constructed in a gully or other small water course to decrease the stream flow velocity, minimize channel scour and promote deposition of sediment.

Consumptive use: That part of water withdrawn that is evaporated, transpired by plants, incorporated into products or crops, consumed by humans or livestock, or otherwise removed from the immediate water environment. Also referred to as water consumed.

Conveyance loss: Water that is lost in transit form a pipe, canal, or ditch by leakage or evaporation. Generally, the water is not available for further use; however, leakage from an irrigation ditch, for example, may percolate to a ground water source and be available for further use or may be recycled for reused.

Crop rotation: The practice of alternating crop types to maintain fertility levels, improve soil condition, avoid insect or disease infestations, etc.

Crop water requirement: The total water needed for evapo-transpiration, land preparation in the case of paddy and other requirements (leaching etc.) from planting to harvest for a given crop in a specific climate regime, when adequate soil water is maintained by rainfall and/or irrigation so that it does not limit plant growth and crop yield.

Crop-coefficient: It is the ratio coefficient between ET crop and reference evapo-transpiration ET_0. Crop coefficient varies with the stage of the growth of the crop and is also dependent on the humidity and wind conditions under which the crop is being grown.

Cropland: Land regularly used for production of crops.

Dead Storage capacity, or Dead Storage: The storage volume of a reservoir measured below the invert level of the lowest outlet and the minimum operating level.

Dependable yield: The value of yield for which water resource projects for water supply, irrigation and hydropower are designed.

Discharge site, Gauging site: A selected site on a stream for making observation of velocity and area of cross section with a view to determining the discharge.

Discharge, or Rate of flow: The volume of water, which flows past a particular cross section of a channel or conduit in a unit of time.

Domestic water use: Water used for household purposes, such as drinking, food preparation, bathing, washing clothes, dishes, and dogs, flushing toilets, and watering lawns and gardens.

Drainage area, Catchment area, Catchment Watershed: The area from which a lake, stream or waterway and reservoir receives surface flow which originates as precipitation. Also called 'watershed' in American usage.

Drainage basin: Land area where precipitation runs off into streams, rivers, lakes, and reservoirs. It is a land feature that can be identified by tracing a line along the highest elevations between two areas on a map, often a ridge. Large drainage basins, like the area that drains into the Mississippi River contain thousands of smaller drainage basins. Also called a "watershed."

Drainage: The natural or artificial removal of excess surface and ground water from any area into streams and rivers or outlets.

Drip irrigation: A method of irrigation where water s slowly drip onto crop root zone. Drip irrigation is a low-pressure method of irrigation and less water is lost to evaporation than high-pressure spray irrigation.

Dry farming: Agriculture practiced on non-irrigated land and dependent upon natural precipitation and its retention and distribution in the crop root zone.

Ecology: The study of the relationships of living things to one another and to their environment.

Effective rainfall: 1- Rain that produces runoff. 2- In irrigation practice, that portion of the total precipitation, which is retained by the soil so that it is available for use for crop production. 3- In geo-hydrology, effective rainfall is defined as that part of the total precipitation that reaches the groundwater (recharge).

Effluent: Water that flows from a sewage treatment plant after it has been treated.

Environment Impact: An effect of any kind on any component or the whole of the environment. Assessment of the impact generally involves two major elements – a quantitative measure of magnitude and a qualitative measure of importance.

Environmental Flow Requirement: Water needed for maintaining aquatic and terrestrial systems in a good health.

Environmental pollution: The contaminating or rendering unclean or impure the air, land, waters, or making the same injurious to public health, harmful for commercial or residential use, or deleterious to fish, bird, animal or plant life.

Estuary: A passage where the tide meets a river current; especially an arm of the sea at the lower end of a river; a 'firth'.

Evaporation: The process of liquid water, becoming water vapor, including vaporization from water surfaces, land surfaces, and snowfields, but not from leaf surfaces.

Evapo-transpiration, or Consumptive use of water: The quantity of water used by the vegetative growth of a given area in transpiration or building of plant tissue and that evaporated from the soil or from intercepted precipitation on the area in any specified time. It is expressed in water-depth units or depth-area units per unit area.

Excess rainfall: The difference over a period of time between the gains of water (rainfall, etc) and losses (evapo-transpiration) from the soil.

Exponential index for actual ET estimation: An index to slightly modify the decay of soil moisture through evaporation.

Fallow land: Land which (during the relevant period) has no crops.

Freshwater: Water with salinity less than 0.5 parts per thousand.

Groundwater balance or Groundwater budget: A systematic review of inflow, outflow and storage as supplied to the computation or groundwater changes.

Groundwater confined: Ground water under pressure significant greater than atmospheric, with its upper limit the bottom of a bed with hydraulic conductivity distinctly lower than that of the material in which the confined water occurs.

Groundwater recharge: 1- Replenishment of groundwater supply in the zone of saturation, or addition of water to the groundwater storage by natural processes or artificial methods for subsequent withdrawal for beneficial use or to check salt water intrusion in coastal areas. 2- Also the process of replenishment or addition, of the quantity of such water.

Groundwater table: Upper boundary of groundwater where water pressure is equal to atmosphere, i.e. depth of water level in borehole when ground water can freely enter the borehole.

Groundwater: The water that occurs in the zone of saturation, from which wells and springs or open channels area fed. This term is sometimes used to also include the suspended water and as loosely synonymous with subsurface water, underground water or subterranean water.

Groundwater recession co-efficient: The constant of proportionately which, when multiplied by the groundwater storage (above the 'no base-flow' datum) indicates the outflow from the groundwater. In BHIWA Model the groundwater storage is assumed to be a 'linear reservoir'. The recession co-efficient will have a dimension of T^{-1}.

Hot weather: Crop season from February to May.

Humid: An area or climate that has more moisture than the actual agricultural requirement and where drainage facilities are generally essential to get rid of surplus moisture. According to Thornthwaite, areas having moisture index above 10 Thornthwaite.

Hydrologic Cycle: The circulation of water from the sea, through the atmosphere, to the land, and thence, often with many delays, back to the sea or ocean through various stages and processes as precipitation, interception, runoff, infiltration, percolation, groundwater storage, evaporation and transpiration, also the many short circuits of the water that is returned to the atmosphere without reaching the sea.

Hydrological models: A simplified representation of a hydrological system leading to an acceptable simulation of the physical and other processes in hydrology.

Industrial waste: Any solid, semi-solid or liquid waste generated by a manufacturing or processing plant.

Industrial water use: Water used for industrial purposes in such industries as steel, chemical, paper, and petroleum refining.

Infiltration volume: Volume of infiltrated water.

Infiltration: 1- The flow or movement of water through the surface in to the soil body or ground. 2- The absorption of liquid water by the soil, either when it falls as rain, or when applied as irrigation or from a stream flowing over the ground. 3- Flow from a porous medium into a channel, pipe, drain, reservoir or conduit.

Integrated river basin management: The process of formulating and implementing a course of action involving natural, agricultural, and human resources of a river basin therewith taking into account the social, economic and institutional factors operating a river basin to achieve specific objectives. It signifies the interactions of components and the dominance of certain components in the particular area.

Intra-annual fluctuations: Fluctuation within a year.

Irrigation potential: Total possible area that has been brought under irrigation,in a river basin, region or country, from available water resources, with designs based on what may be considered as good technical practice known at the time of assessment of the potential.

Irrigation water use: Water application on lands to assist in the growing of crops and pastures or to maintain vegetative growth in recreational lands, such as parks and golf courses.

Irrigation: The controlled application of water for agricultural purposes through manmade systems to supply water requirements not satisfied by rainfall.

Kharif : Summer crop and Monsoon Crop - season from June to September.

Land-use pattern: The area design or arrangement of land uses, major and minor, and of operation units convenient for cultivation.

Live storage: That part of the conservation storage of a reservoir which is between the full reservoir level and the level of the lowest outlet to be operated for delivering water for any use.

Mean annual precipitation: The average over a sufficiently long period of years of the annual amounts of precipitation so there nearly true representative value of the mean is obtained.

Mean annual rainfall: The mean of annual rainfall observed over a period which is sufficiently long to produce a fairly representative mean value.

Mean annual runoff, Mean monthly runoff: The value of the annual volume of water discharged by the stream drainage of the area, the period of observation being sufficiently long to secure a fair mean; similarly 'mean monthly runoff'.

Micro-irrigation: A method of irrigation in which water is applied not to the land but to the plants in the root zone, in small but frequent quantities, in such a way as to maintain the most active part of the rootzone at a quasi-optimum moisture.

Natural Induced recharge: It is that portion of water, which gravitates to the zone of saturation under natural conditions. In the BHIWA model, a provision has been made for recharge from the river to the groundwater, either through natural or through force recharge. The provision is to be made by the user for balancing the groundwater regime; user may also change the irrigation area etc. for using this provision.

Net irrigation requirement: Irrigation requirement at the head of irrigation farm and is equal to consumptive use plus percolation minus effective precipitation, plus water needed for field preparation, leaching etc. or net duty of water when the latter is expressed in similar units.

Non-beneficial consumptive use: The water consumed by native vegetation, evaporated from bare and idle land surfaces and from water surfaces.

Per capita use: The average amount of water used per person during a standard time period, generally per day.

Percolation: The movement of water through the openings in rock or soil.

Perennial: The crop period extends in three seasons.

Potential evapo-transpiration: The amount of water that could pass into the atmosphere by evapo-transpiration if the amount of soil water were not a limiting factor.

Potentially utilizable water resource (PUWR): The amount of the AWR that is potentially utilizable with technically, socially, environmentally, and economically feasible water development program.

Precipitation: The total measurable supply of water of all forms of failing moisture, including dew, rain, mist, snow, hail and sleet; usually expressed as depth of liquid water on a horizontal surface in a day, month, or year, and designated so daily, monthly or annual precipitation.

Quick run-off: That part of the rainfall, which flows into surface stream without passing through groundwater. As used in BHIWA, the term also includes the interflow.

Rabi : Winter crop - season from October to January.

Rain: Precipitation in the form of liquid water drops greater that 0.5 mm.

Rainfall intensity: The rate at which rainfall occurs expressed depth units per unit time. It is the ratio of the total amount of rain to the length of the period in which the rain falls.

Rain-fed: Crops which are grown on natural rainfall.

Reference evapo-transpiration (ETo): The evapo-transpiration rate from a reference surface, not short of water is the reference crop evapo-transpiration or reference evapo-transpiration and is denoted as ETo. The ETo is climatic parameters and can be computed from weather data. ETo expresses evaporating power of the atmosphere at a specific location and time of the year and does not consider crop characteristics and soil factors.

Replenishable groundwater: A dynamic groundwater potential available in aquifer.

Reservoir capacity, Gross capacity reservoir, Gross storage, or Storage capacity: The gross capacity of a reservoir from the riverbed up to the retention water level. It includes active, inactive and dead storages.

Return flow: The drainage water from a particular withdrawal that flows back into the system where it can be captured and reused, or recycled within the system.

Runoff: 1- Portion of the total precipitation from a given area that appears in natural or artificial surface streams. 2- Also the total quantity of runoff during a specified period. 3- The discharge of water in surface streams above a particular point. 4. Runoff is the surface and subsurface flow of water.

Saline soil: A soil containing sufficient soluble salt to impair its productivity. The electrical conductivity of the saturation extract is greater than 2 mmhos per centimeter at 25° C. Crop plant growing is mostly inhibited in saline soils.

Saline water: Water, which contains moderate concentration of total dissolved salts.

Salinity: The relative concentration of salts, usually sodium chloride in given water. It is usually expressed in terms of the number of parts per million of chlorine (Cl).

Sewage effluent: The liquid and solid waste carried off with water in sewers or drains.

Soil moisture capacity: The capacity of the soil to hold the water within soil against gravitational force.

Sprinkler irrigation: A method of irrigation under pressure in which water is sprinkled in the form of artificial rain through lines carrying distribution components: rotary sprinklers, diffusers with permanent water streams, perforated pipes.

Stream flow: The water discharge that occurs in a natural channel. A more general term than runoff, stream flow may be applied to discharge whether or not it is affected by diversion or regulation.

Subarid or Semiarid: A term applied to an area or climate, neither strictly arid nor strictly humid, in which some selected crops can be grown without irrigation. According to Thornthwaite, areas having moisture index between –20 and –40 Thornthwaite moisture index are classified as semi arid areas. .

Subhumid, or Semihumid: A term applied to an area or climate that has on the whole sufficient moisture to support all crops but irregularity of precipitation during the year making it essential to provide irrigation facilities to raise better crops. According to Thornthwaite, areas having moisture index between +20 Thornthwaite moisture index are classified as sub-humid areas.

Swamp: Wet spongy ground with fully saturated subsoil.

Taluka: A subdivision of a district.

Transpiration: The emission or exhalation of watery vapour from the living plant.

Two seasonal: Crop period extends in second season.

Water balance, or water budget: A systematic review or inflow, outflow and storage as applied to the computation of changes in the hydrologic cycle. Always referred to a specific time period like day, week, month, season, or a year.

Water table: The upper surface of a zone of saturation, where the body of groundwater in not confined by an overlying impermeable formation.

Waterlogging: State of low land in which the subsoil water table is located at or near the surface with the result that the yield of crops commonly grown on it is reduced well below the normal for the land, or, if the land is not cultivated, it cannot be put to its normal use because of the high subsoil water table.

Wetcrop: Crop, which depends on high doses of irrigation for its growth.

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