Water Resources Assessment of Qiantang River Basin, China

A document based on objective study aimed at 'Support to Development of Country Policies'

Country Policy Support Programme (CPSP)

Project funded by

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INTERNATIONAL COMMISSION ON IRRIGATION AND DRAINAGE (ICID)
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AUGUST 2005

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

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EXECUTIVE SUMMARY

Background

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 recommendations of various other themes. It also did not reflect quantification of water needs for the "people sector" (largely non-consumptive) and the "nature sector".

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. ICID 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 programme. The CPSP attempted a detailed assessment of the water supply-demand situation for the three sectors. To begin with a couple of representative river basins of the two most populous countries of the world, viz., China and India were taken up. This is 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.

For carrying out detailed water assessment, two sample river basins each in China and India were selected as indicated above. In China, a water-rich basin namely the Qiantang river basin on the south-east coast, and a water-deficit basin namely the Jiaodong Peninsula, on the east-coast, were chosen. A 'Basin-wide Holistic Integrated Water Assessment' (BHIWA) model evolved by ICID, was applied to these two basins. The results of the assessment for these two basins, extrapolation of the assessment and policy related issues emerging from the studies were presented in a National Consultation held in August 2004, at Beijing. This report covers the assessment of Qiantang River Basin in China. Chapter 1 provides details of Qiantang river basin, Chapter 2 deals with the application of BHIWA model for assessment of Qiantang river basin and Chapter 3 covers the policy related issues emerged from the study.

The Qiantang river basin has total drainage area of 55,558 km^2. For the present study drainage area of 35,500 km^2 in the upstream of Hangzhou Gate has been considered. The river system, climate, land use, water resource and its development, water demand at present and projected water requirement of the Qiantang basin in the year 2025 have been briefly discussed in the report.

The per capita water availability in the basin in 2000 was 3,621 cubic meter per year considering the estimated renewable water resources of the basin at 38.64 km^3 per year and the population of the basin at 10.67 million. The water availability is likely to be 3,389 cubic meter per year in the year 2025 with the projected population of 11.40 million by 2025.

The Basin-wide Holistic Integrated Water Assessment (BHIWA) Model, specially evolved by ICID, has been applied to Qiantang river basin to assess water use by different sectors for the present and future scenarios. The basin was divided into two sub basins. The model was calibrated for the present conditions and applied to derive responses to past situation and five future (2025) scenarios using monthly time set-up. Apart from Business as usual Scenario (F-I), other scenarios studied include:

- With no expansion of water infrastructure and better water management (F-II);
- With increased water infrastructure (including small import), and irrigation expansion (F-III);
- With increased water infrastructure, no irrigation

expansion, more industries, and export of water (F-IV);

- With increased water infrastructure, no irrigation expansion, more industries, and better water management (F-V).

The aggregate results of the Qiantang river basin assessment and related discussions are given in this report.

The total water input (rainfall and imports) to the Qiantang basin is 58,014 million cubic meters. The major output consists of consumptive use, river flows and exports. The total consumptive use (ET) at present situation is 25,322 million cubic meters comprising about 67% by nature sector (forest, pasture and barren lands), 29% by agriculture sector (rain-fed and irrigated agriculture) and 4% by people sector (domestic and industrial).

Four types of indicators have been suggested to depict status of water in regards to quantity as well as quality. Two indicators depict the level of withdrawals as a fraction of total water available in surface and groundwater system while other two indicators depict potential hazard to water quality in surface and groundwater system. The water situation indicators in the Qiantang river basin in different scenarios studied are presented in the report.

The major findings of the assessment are:

1. Nature sector consumes major part of the primary resource (rain water)
2. Consumptive use under nature sector is expected to increase significantly in the future due to the expansion of forest area. This in turn would tend to reduce river flow. Part of this decrease can however be restored through better soil and water management initiatives.
3. Due to abundant surface water resources almost entire irrigated agriculture including fisheries is presently dependent on surface water resources.
4. Groundwater use is presently restricted to domestic and industrial sectors. There exists a great potential for groundwater development in this basin.
5. Surface water withdrawal constitutes only a small fraction of available supplies and its further use for irrigation seems to be constrained by availability of cultivable land.

Detailed water assessment study of the basin for various scenarios has provided a greater insight into the understanding of water resources. The set of water stress indicators of the basin will help in understanding the current water scene for other basins of China. The study has helped in testing of various possible land and water use scenarios and allowed assessment and integration of nature, food and people sector. Policy interventions emerged from the studies are discussed in the report.

ACRONYMS / ABBREVIATIONS

BHIWA	Basin-wide Holistic Integrated Water Assessment
B as U	Business As Usual
CNCID	Chinese National Committee on Irrigation and Drainage
CPSP	Country Policy Support Programme
D&I	Domestic and Industrial
EFR	Environmental Flow Requirements
ET	Evapo-transpiration
ETo	Reference Crop Evapo-transpiration
FAO	Food and Agriculture Organisation of the United Nations
G&D	Gauge and Discharge
GW	Groundwater
GWP	Global Water Partnership
GIA	Gross Irrigated Area
GCA	Gross Cropped Area
GSA	Gross Sown Area
Ha or ha	Hectare
IAH	Indian Association of Hydrologists
ICID	International Commission on Irrigation and Drainage
IFPRI	International Food Policy Research Institute
IPTRID	International Programme for Technology and Research in Irrigation and Drainage
IWMI	International Water Management Institute
IWRDM	Integrated Water Resources Development and Management
Km	Kilometer
lpcd	Liters per capita per day
Mha	Million hectares
MAR	Mean Annual Runoff
MCM	Million cubic meters
MSL	Mean Sea Level
MWR	Ministry of Water Resources
NGO	Non Governmental Organisation

NIA	Net Irrigated Area
NCA	Net Cropped Area
NSA	Net Sown Area
SB	Sub-basin
SW	Surface Water
WAPCOS	Water and Power Consultancy Services (India) Ltd.
WHO	World Health Organisation
WWC	World Water Council
WWF	World Wide Fund for Nature
WFFRD	Water for Food and Rural Development
WRDP	Water Resources Development Plan

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CHAPTER 1
QIANTANG RIVER BASIN

1.0 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. ICID 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.

For carrying out detailed water assessment, two sample river basins in China viz; a water-rich basin namely, the Qiantang on the south-east coast, and a water-deficit basin namely, the Jiaodong Peninsula, on the east-coast, were selected. The location of the selected river basins is shown in Figure 1. A Basin-wide Holistic Integrated Water Assessment (BHIWA) model was developed and applied to Qiantang river basin and Jiaodong Peninsula Basin. The results of the assessment for these two basins, extrapolation of the assessment and policy related issues emerged for by the studies were presented at a 'National Consultation' held in August 2004 in Beijing.

In this report, water assessment of Qiantang river basin for the past, present and five scenarios for the year 2025 has been presented. The Qiantang river basin is shown in Figure 2.

1.1 Qiantang River Basin

China has large number of rivers. More than 50,000 small rivers cover drainage area of over 100 km^2 and about 1500 rivers cover drainage area of over 1000 km^2. The distribution of rivers over the country is uneven. The rivers of China are grouped into nine river basins viz; Songliao, Hai, Huai, Yellow, Yangtze, Pearl, Southeast Coastal, Southwest and the Inland river basin.

Qiantang river basin is a part of the drainage area of Yangtze River Basin and lies between east longitudes 118º to 121º and north latitudes 28º to 31º. It borders with the Xianxia Mountain and spreads into Min river of Fujian Province in the south, Huaiyu mountain and Lean river

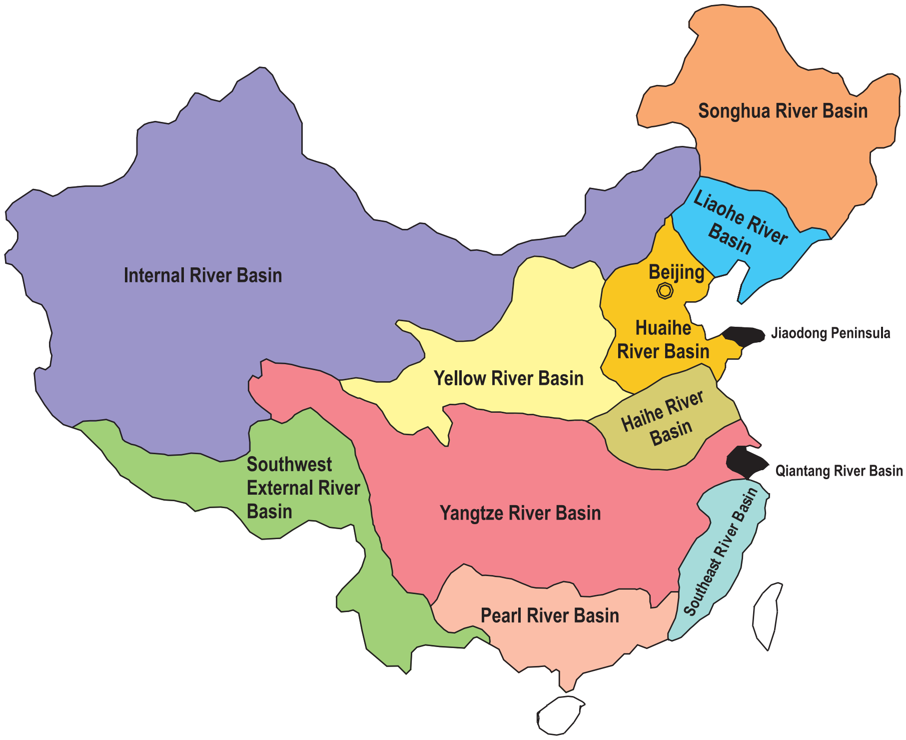

Figure 1. River Basin Map of China

and Xin river, water system of Poyang lake of Jiangxi province in the southwest, Huang mountain and Tianmu mountain and Qingyi river of Anhui province and Taihu lake of Zhejiang province in the north, Hangzhou gulf in the northeast. The catchment area of the basin is 55,558 km^2/drainage area. The drainage area of the basin considered in the study is 35,500 km^2 in the upstream of Hangzhou gate and within the boundaries of Zhejiang province that are under jurisdiction of Hangzhou, Quzhou, Jinhua, Shaoxing, and Lishui municipalities. For the present study, the basin has been divided into two sub basins, namely; Sub basin 1(SB-1): Upstream of Fuchunjiang river covering drainage area of 25,200 km^2 and Sub basin 2 (SB-2): Downstream of Fuchunjiang river covering drainage area of 10,300 km^2.

1.2 River System

Major tributaries of Qiantang river are listed in Table 1.

Table 1.
Major Tributaries of Qiantang River

Tributary	Area (km^2)	Length of the river (km)
Changchan river	3385	175.9
Qu river	11477	257.9
Lan river	19468	302.5
Fuchun river	38318	460.7
Xin'an river	11674	358.9
Wuxi river	2577	155.9
Dongyang river	3378	165.5
Wuyi river	2520	129.2
Jinhua river	6782	194.5
Fenshui river	3444	164.2
Puyang river	3452	149.7

1.3 Climate

Qiantang river basin comes under sub-tropical monsoon climate with well marked four seasons. The average annual rainfall in the basin varies between 1200 mm and 2200 mm. The rainfall is higher in mountainous area than in the rolling area; higher in the rolling area than in the plains. The rainfall is unevenly distributed inter-annually and the ratio between the maximum and the minimum varies from 2 to 3. The average annual evaporation is between 800

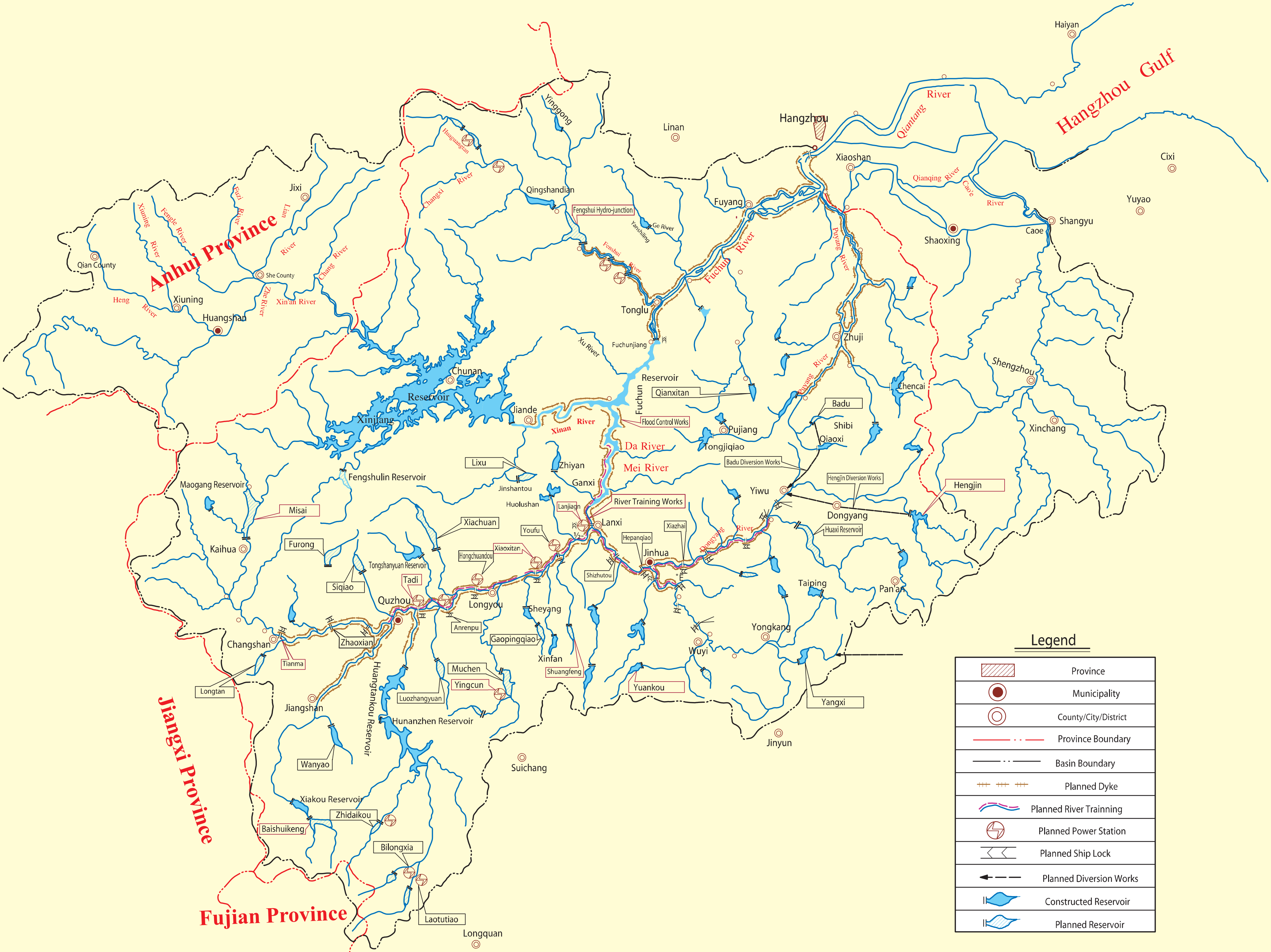

Figure 2. Map of Qiantang River Basin

Table 2.
Land Use of Qiantang River Basin in 2000 (10^6 ha)

Land Use	Upstream	Downstream	Total
Total land area	2.520	1.030	3.550
Available cultivated area	0.2888	0.1352	0.4240
Gross cropped area	0.5776	0.2704	0.8480
Farmland irrigated area	0.2679	0.1254	0.3933
Fruit irrigated area	0.1052	0.0256	0.1308
Forest area	0.9673	0.4527	1.4200

mm and 1000 mm. It is higher in the coastal areas than in inlands, and higher in plains than in mountainous areas. The average annual temperature ranges between 16.2º C and 17.7º C and is higher in the south than in the north, and higher in the plains than in the rolling areas.

1.4 Land Use

Qiantang river basin has favourable natural conditions and rich agricultural resources. The cultivable area of the basin in 2000 was 0.4240 million hectare accounting for 11.9% of the total land area and the area covered under the horticulture was 0.1309 million hectares, 3.7% of the total land area. The forest area in the basin is 1.42 million hectares.

The irrigated area is about 0.3933 million hectares, which is 93% of the cultivable area. Paddy, Wheat, Barley, Maize, Soyabean and Potato are the staple crops grown in the basin. Tea, Cotton, Sugarcane, Medicinal Plants are the cash crops grown in this basin.There are many varieties of crops, and cropping system and cropping intensity have been changed from time to time. Rice is a major crop in the basin and covers about 85% of the total cultivated area. The area under Rapeseed cultivation is about 12% of the total cultivated area.

The land use pattern of Qiantang river basin in the year 2000 is shown in Table 2.

1.5 Water Resources

The total water resources in Qiantang river basin (in Zhejiang province) is estimated as 38.64 km^3 including 7.71 km^3 of unconfined groundwater resources. Forty eight large and medium reservoirs and over 200 small reservoirs have been constructed in the basin. The large reservoirs in this basin include Hunanzhen, Tongshanyuan, Hengjin, Xin'an, Fuchuon and Wanyao reservoirs. The live storage capacity of medium and large reservoirs in the basin is 1,223.86 million cubic meters and storage capacity of small reservoirs is 886.46 million cubic meters. There are number of reservoir projects that are under construction and are proposed to be constructed. The live storage capacity of on-going and future projects is 985 million cubic meters. Two-third of the surface water storages are located in the sub basin 1. The sub-basin wise storage and water supply capacities of various projects are given in Table 3.

New projects that are under construction and are planned to be constructed are given in Table 4.

1.6 Population

The population of the basin in 2000 was 10.67 million comprising urban population of 3.557 million and rural population of 7.113 million. It is projected that population of the basin in the year 2025 will be 11.40 million. The

Table 3.
Storage and Water Supply Capacity of Existing Projects (10^6 m^3)

SB	Live storage of medium and large reservoirs	Live storage of small reservoirs	Water supply capacity of surface water projects	Water supply capacity of groundwater projects	Total live storage
SB 1	1,142.56	690.57	1,169.51	212.16	1,833.13
SB 2	81.30	195.89	729.39	72.89	277.19
Total	**1,223.86**	**886.46**	**1,898.9**	**285.05**	**2,110.32**

Table 4.
Projects Under Construction and Planned by 2025

Sub Basin	Name of the Project	Catchment area (km^2)	Live storage (10^6 m^3)	Main purpose	Project status
SB1	Misai Reservoir	797	146	Irrigation	to be constructed
	Furong Reservoir	126	72	Irrigation	to be constructed
	Longtan Reservoir	44.38	12	D & I water supply, flood control, power generation, irrigation	to be constructed
	Changgeng Irrigation District Water Diversion Project	2082	4.98	Irrigation	being constructed
	Wanraong Reservoir	——	——	Irrigation	being constructed
	Baishuikeng Reservoir	330	176	Flood control, power generation, irrigation	to be constructed
	Xiachuan Reservoir	221.4	106	Irrigation, domestic water supply	to be constructed
	Siqiao Reservoir	57	20	Flood control, irrigation, power generation	to be constructed
	Luozhangyuan Reservoir	76	13	Flood control, irrigation, power generation	to be constructed
	Muchen Reservoir	397	48	Flood control, irrigation, power generation	to be constructed
	Gaopingqiao Reservoir	64	21	Flood control, irrigation, D & I water supply	to be constructed
	Rehabilitation of Hengjin Reservoir	NA	increased by 28	D & I water supply, irrigation	to be extended
	Wangdian Reservoir	NA	5.2	D &I water supply	to be constructed
	Huaxi Reservoir	NA	160	Irrigation, D & I water supply, flood control, power generation	to be constructed
	Hengjin Water Diversion Project	NA	NA	D & I water supply	to be constructed
	Badi Water Doversopm Project	NA	NA	D & I water supply	to be constructed
	Rehabilitation of Yangxi Reservoir	NA	increased by 20	D & I water supply	to be extended
	Haoxi Water Diversion Project	NA	NA	D & I water supply	to be constructed
	Qianming Reservoir	304	59	D & I water supply	to be constructed
	Liuan Reservoir	48.5	25	D & I water supply	to be constructed
	Rehabilitation of Yuankou Reservoir	91	increased by 22.4	D & I water supply, irrigation	to be extended
	Rehabilitation of Xili Reservoir	31	increased by 10	D & I water supply, irrigation	to be extended
	Jiufeng Reservoir	120	52	Flood control, D & I water supply, power generation	to be constructed
	Dongxi Reservoir	21	10	D & I water supply, irrigation	to be constructed
	Rehabilitation of Andi Reservoir	NA	increased by 4.83	Irrigation, D & I water supply	to be extended
	Lixu Reservoir	33	10	Irrigation, D & I water supply	to be constructed
SB2	Wuliting Reservoir	2,630	60	Flood control, irrigation, power generation	to be constructed
	Qianxitan Reservoir	NA	12	D & I water supply, irrigation	to be constructed
	Nanshan Reservoir	NA	25	D & I water supply, irrigation	to be constructed

Table 5.
Socio-economic Conditions, Qiantang River Basin

Sub Basin	Population (million)			Cultivated area (km^2)			Orchard (km^2)	Equivalent sheep (million)
	Urban	Rural	Subtotal	Paddy	Upland	Subtotal		
SB1	2.41	4.93	7.33	2,403.52	484.82	2,888.34	1,052.59	9.00
SB2	1.15	2.19	3.34	1,200.66	151.21	1351.87	256.08	2.82
Total	**3.56**	**7.11**	**10.67**	**3,604.18**	**636.03**	**4,240.21**	**1,308.67**	**11.82**

per capita availability of water resources in 2000 was 3,621 cubic meters and projected to be 3,389 cubic meters in the year 2025. The population, cultivated area, orchard area and livestock population (equivalent sheep) in the two sub basins in 2000 are given in Table 5.

1.7 Water Requirement

Present and projected water demand for different sectors in Qiantang river basin is shown in the Table 6.

Table 6.
Present and Projected Water Demand for Irrigation, Domestic and Industrial Sectors (10^6 m^3)

Sector	2000	2025
Irrigation	7,040	6,458
Domestic & Industry (D&I)	1,407	2,623
Total demand (Irrigation and D&I)	**8,447**	**9,081**

CHAPTER 2

APPLICATION OF BHIWA MODEL TO QIANTANG BASIN

2.0 Modelling Framework

A holistic and integrated water assessment model called '(BHIWA)' 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 groundwater withdrawals, including extent of lowering of groundwater tables to meet prescribed "environment flow" requirements.

Figure 3 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 Qiantang River Basin

The model has been calibrated for the present (2000)

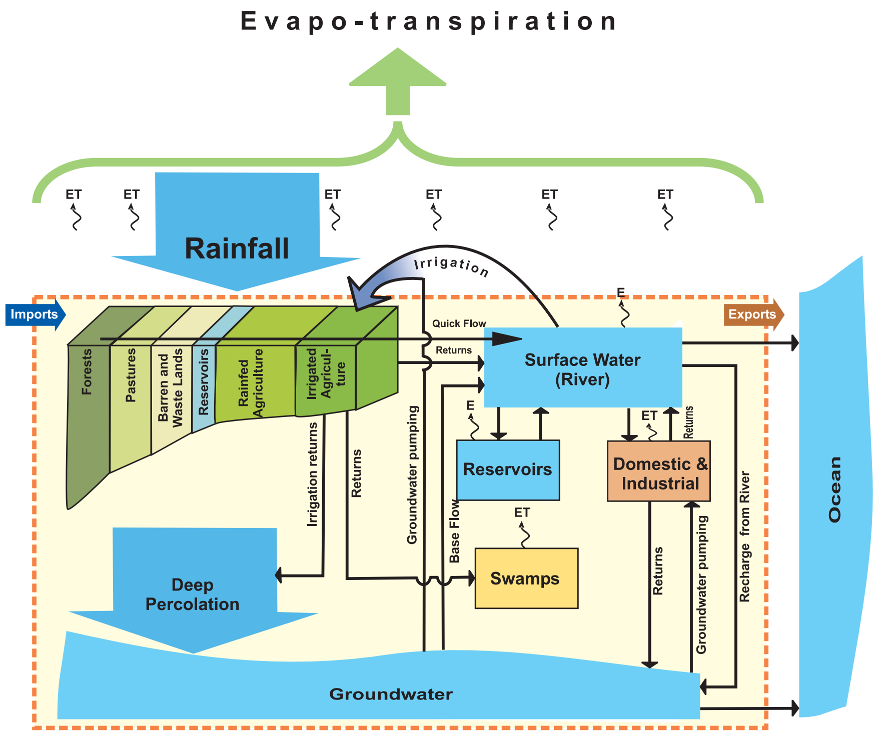

Figure 3. Schematic Diagram of BHIWA Model

conditions and applied to derive responses corresponding to past (1980) and future scenarios using monthly time steps. The studies were carried out at sub basin level. The basin area of 35,500 km^2 is divided into two sub-basins which allows segregation of areas having similar hydrological and water use attributes as follows:

- Sub Basin (SB 1): Upstream of Fuchunjiang River (Drainage area 25,200 km^2)
- Sub Basin (SB 2): Downstream of Fuchunjiang River (Drainage area 10,300 km^2)

2.2 Data Used in Model Calibration

The following secondary data have been used in the model study.

1. Monthly rainfall and evapo-transpiration data for the two sub basins (Annexure 2).
2. Average, maximum and minimum values of runoff observed at different gauge and discharge (G&D) sites (Annexure 3)
3. Net irrigation duty in each irrigation zone with 90% probability (Annexure 4).

2.3 Land Use Parcels

Paddy rice is the major crop grown in this basin, accounting for 85% of the total cultivated area. Fruits, rapeseed, cash crops, etc., are also grown. The area covered under rapeseed in 2000 was 733 km^2, amounting to 12% of the total cropped area.

Based on the present land use statistics and crop rotation, fourteen land use parcels have been considered in the model study as shown in Table 7.

2.4 Scenario Development

The water demand and supply scenarios developed for future 2025 are given in Table 8.

The key peculiarities of the future scenarios are shown in Table 9.

The areas of land parcels for all the scenarios are shown in Table 10. Proportion of area coverage by natural vegetation, rain-fed and irrigated agriculture in different scenarios is shown in Figure 4. The net irigated aea (NIA) by source is shown in Figure 5.

Table 7.
Land Use Parcels in Qiantang River Basin

Parcel Designation	Description
P1	Forest and miscellaneous trees
P2	Permanent pastures
P3	Land not available for cultivation, waste, & fallow
P4	Land under reservoirs
P5	Rain-fed soybean and wheat
P6	Rain-fed fruits
P7	Irrigated double cropping of rice
P8	Irrigated early rice and autumn maize
P9	Irrigated single cropping of rice and rapeseed/vegetables
P10	Irrigated sugarcane and barley
P11	Irrigated cotton and wheat
P12	Irrigated sweet potato and vegetables
P13	Irrigated vegetables
P14	Irrigated fruits

Table 8.
Brief Description of the Scenarios

S. No.	Scenarios	Description
1	Past (1980)	The socio economy developed quickly since the implementation of the reform and opening-up policies after 1980.
2	Present (2000)	Prevailing
3	Future I (2025) B as U	Business as Usual. With increased water infrastructure (and small import), Irrigation expansion with cropping pattern same as at present. Proportion of surface & groundwater irrigation same as at present
4	Future II (2025),	With no expansion of water infrastructure (and small import), shift in cropping pattern, better water management
5	Future III (2025)	With increased water infrastructure (and small import) and irrigation expansion, shift in cropping pattern, more groundwater use and better water management
6	Future IV (2025)	With increased water infrastructure (and small import), no irrigation expansion, shift in cropping pattern, more industries, more groundwater use, export of water and better water management
7	Future V (2025)	With increased water infrastructure (and small import), no expansion of irrigation, more industries, more groundwater, better water management

Table 9.
Key Peculiarities of Future Scenarios

Future Scenario	Additional water infrastructure	Expansion of irrigated area	Shift in cropping pattern	Industrial growth	Water management
Future-I (BAU)	Yes	Yes	No	Normal	As usual
Future-II	No	No	Yes	Normal	Better
Future-III	Yes	Yes	Yes	Normal	Better + More groundwater use
Future-IV	Yes	No	Yes	More	Better + More groundwater use +export
Future-V	No	no	Yes	Normal	Better + more groundwater use

Table 10.
Areas of Land Parcels for all the Scenarios (km^2)

Scenario	Past (1980)	Present (2000)	Future I	Future II	Future III	Future IV	Future V
P1	12,922	14,200	17,750	17,750	17,750	17,750	16,750
P2	8	9	9	11	11	11	11
P3	14,324	12,106	8219	8,554	7,939	7,765	8,944
P4	2,150	3,636	3,830	3,636	3,671	3,830	3,795
P5	206	177	134	177	158	194	1,90
P6	993	1,104	650	1,104	1,063	1,682	1,582
P7	1,207	1,041	1,197	623	716	623	623
P8	103	89	102	96	110	96	96
P9	2,871	2,475	2,846	2,762	3,176	2,762	2,762
P10	34	30	34	57	66	57	57
P11	48	42	48	51	59	51	11
P12	206	177	204	130	150	130	130
P13	244	210	242	221	255	221	221
P14	185	205	236	327	376	327	327
Total	**35,500**	**35,500**	**35,500**	**35,500**	**35,500**	**35,500**	**35,500**

2.5 Calibration of the Model

The Qiantang river basin is a water rich basin in which surface water is the major source for agricultural, domestic and industrial water requirements. Groundwater has not been exploited so far, except a little for domestic and industrial use. Consequently, there are no observed groundwater fluctuation data in this basin. The model was calibrated and validated by adopting the following steps with the available data computed by the model and estimated by Qiantang River Basin Management Bureau for the present conditions.

1. Comparing the total monthly outflow (surface runoff plus baseflow) of SB1 and SB2 with the observed monthly runoff.
2. Comparing the natural recharge to groundwater as in the model, as a percentage of rainfall, and to compare this percentage with the generally adopted norms.

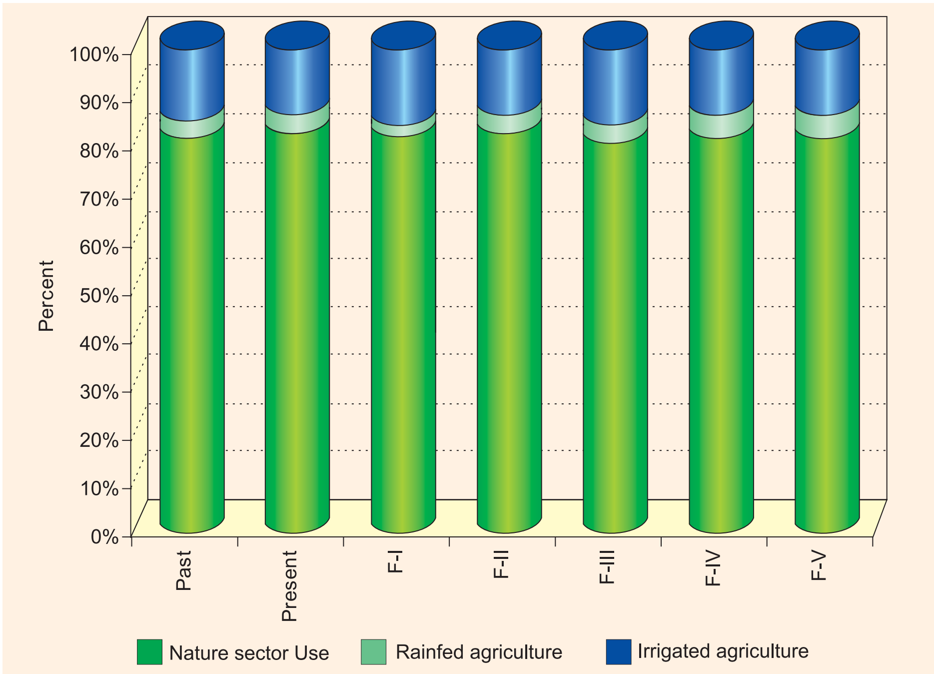

Figure 4. Area Coverage by Natural Vegetation, Rain-fed and Irrigated Agriculture

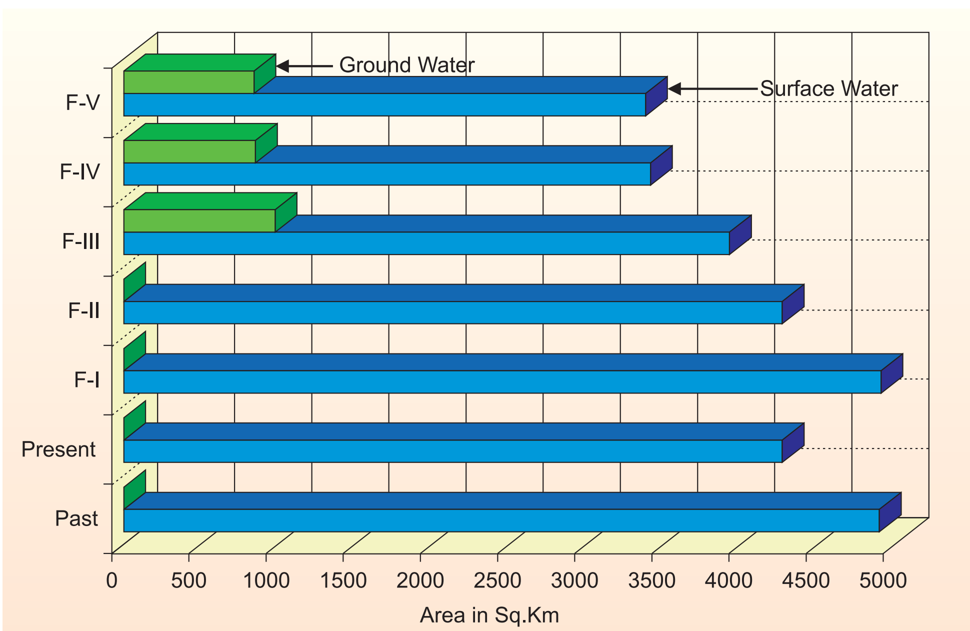

Figure 5. Net Irrigated Area by Source

Table 11.
Comparison of Computed and Observed Monthly River Flows (10^6 m^3)

Month	Computed by the model	As observed	Variation (%)
January	1,659	1,521	9.1
February	2,172	1,814	19.7
March	3,583	3,186	12.4
April	3,742	3,830	2.3
May	4,069	4,331	6.1
June	5,481	5,830	6.0
July	3,407	3,734	8.8
August	1,834	2,118	13.4
September	1,733	2,036	14.9
October	1,693	1,533	10.4
November	1,595	1,409	13.2
December	1,575	1,359	15.9
Total	**32,542**	**32,703**	**0.5 (Average)**

3. Comparing the total groundwater recharge and withdrawal, as computed by the model, with the estimates of the Qiantang River Basin Management Bureau.
4. Comparing the withdrawal for irrigation, and total withdrawal for irrigation and D&I, as computed by the model, with the estimates of the Qiantang River Basin Management Bureau.

As the boundaries of this river basin are dictated by the administrative units (municipalities) but not hydrologic units, therefore there could be natural inflows from outside the study area to the study area and similarly there would be some flows form the basin area which did not go to the sea and flows to other administrative units. In the assessment as made, this point has already been considered by using only the proportioned flow as generated from the study area.

In terms of monthly outflow to sea, this model has a very good match for the present conditions, where the difference between the total outflow computed by the model and observed by local hydrological stations is only around 0.5%. Table 11 gives the computed and observed average monthly values and also depicted in Figure 6. As can be seen in the figure, there is a good match between the observed and the computed values.

Regarding total recharge to groundwater and total withdrawals for irrigation and D&I, the differences between the computed and estimated values also is not very high, and is found to be 14.18% and 8.2%, respectively. Thus generally speaking, this model is found to be giving a good match under humid area condition. The main computed and estimated results for the present conditions are shown in Table 12.

Table 12.
Comparison of the Computed and Observed Results for the Present Conditions (10^6 m^3)

Particulars	Computed by the model	Estimated	Variation (%)
Percentage of groundwater recharge from rainfall (%)	9	8	10.92
Total Recharge to groundwater	7,451	6,525	14.18
Total outflow to sea	32,542	32,703	-0.5
Withdrawal for irrigation	4,497	5,028.8	-10.6
Withdrawal for irrigation and D&I	5,909	6,436.0	-8.2

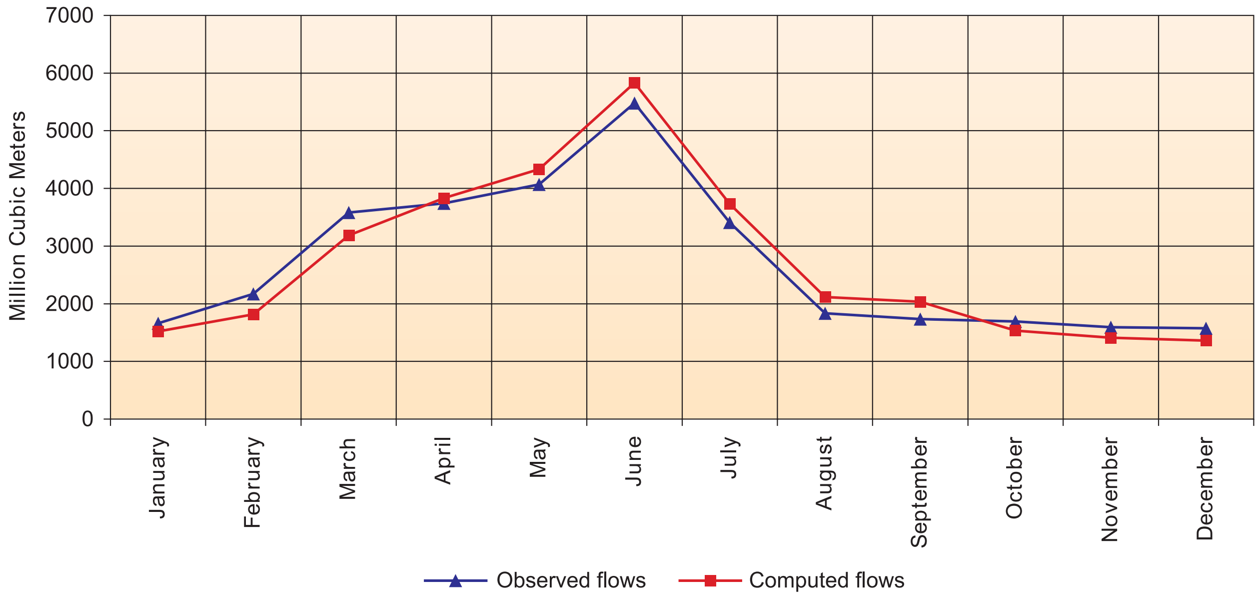

Figure 6. Comparison of Computed and Observed Average River Flows

With the above calibration, the general validation of the model was accepted with the following values of main parameters:

1. Qiantang river basin is situated in an humid area in the south of China, therefore soil moisture capacity used in the study is the initial value of the first month i.e. January, for each land parcel.

2. Assumed soil moisture storage capacity varied with soil type and land use: 200 mm for forests, 100 mm for pastures and fruit trees, 75mm for agricultural lands (but 150 mm for paddies) and 40 mm for bare lands or land put to other uses. Higher capacity values would lead to higher evapo-transpiration and lower flows after rainfall has ceased, thus giving a better calibration but values higher than these were not tried as such capacities were unlikely to be available.

3. The excess water was divided assuming that 85 percent contributed to surface and sub surface (or quick runoff) flow and the rest 15 percent to groundwater. With this assumption, reasonable annual recharge was realised.

4. The exponential index, depicting the reduction of evapo-transpiration rate with reducing availability of soil moisture in the relationship was kept at 0.6.

5. A groundwater recession coefficient of 0.27 allowed the persistence of good base flows. As there is not much groundwater withdrawals in this river basin, the base flows both in the prototype and in the model are very high, particularly from May to November.

2.6 Simulation of Different Scenarios

The model was applied to simulate the responses for five future scenarios with average rainfall conditions and reference evapo-transpiration (ET_0).

The abstracted results of annual overall water balance, annual surface water balance and annual groundwater balance are presented in Tables 13, 14 and 15, respectively. These are also depicted in Figure 7, 8 and 9, respectively. The consumptive use (Evapo-transpiration) by sector is given in Table 16 and depicted in Figure 10. The composition of consumptive use in agricultural sector is shown in Figure 11. Monthly river flows are shown in Figure 12. The composition of withdrawals and irrigated cropped areas and withdrawals are depicted in Figure 13.

2.7 Discussion of Results and Findings

Based on the present conditions and average rainfall the modified model response for sustainable water use conditions is briefly described as below:

The model indicates that the present average flows to the sea are as follows:

- SB1: 23,308 million cubic meters
- SB2: 9,234 million cubic meters
- Total basin: 32,542 million cubic meters

Table 13.
Annual Overall Water Balance, Steady State, Average Rainfal (10^6 m^3)

Component	Past (1980)	Present (2000)	F-I	F-II	F-III	F-IV	F-V
Inputs							
Rainfall	57,958	57,958	57,958	57,958	57,958	57,958	57,958
Imports	0	0	56	56	56	56	56
Groundwater flow from other basins	0	0	0	0	0	0	0
Total inputs	**57,958**	**57,958**	**58,014**	**58,014**	**58,014**	**58,014**	**58,014**
Outputs							
Consumptive use	24,913	25,322	27,077	26,514	26,760	27,150	27,274
River flows	32,990	32,542	30,861	31,423	31,178	30,518	30,664
Export (surface)	0	0	0	0	0	270	0
Groundwater flow to other basins	0	0	0	0	0	0	0
Direct groundwater flow to sea	0	0	0	0	0	0	0
Total output	**57,903**	**57,864**	**57,938**	**57,938**	**57,938**	**57,938**	**57,938**
Storage changes							
Surface storages	0	0	0	0	0	0	0
Groundwater storage	0	0	0	0	0	0	0

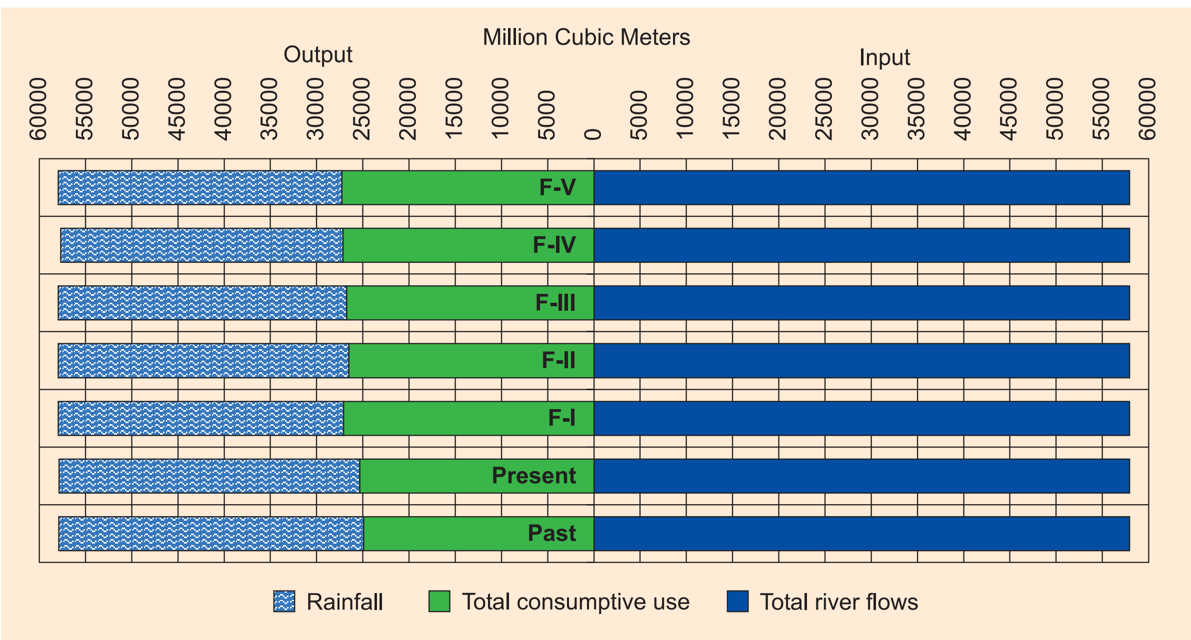

Figure 7. Annual Overall Water Balance

Table 14.
Annual Surface Water Balance, Steady State, Average Rainfall (10^6 m^3)

Component	Past (1980)	Present (2000)	(2025) F-I	F-II	F-III	F-IV	F-V
Inputs							
Quick runoff from rainfall	29,679	29,522	28,572	28,676	28,525	28,579	28,847
Base flow	7,980	7,341	7,387	6,550	6,242	5,999	6,603
Returns to surface water from surface irrigation	1,210	972	1,068	881	810	694	792
Returns to surface water from ground-water irrigation	0	0	0	0	26	22	24
Returns to surface water from D&I withdrawals	311	507	990	990	990	1,363	1,363
Sub-total, returns to surface water	1,521	1,479	2,058	1,871	1,826	2,079	2,179
Imports	0	0	56	56	56	56	56
Total inputs	**39,180**	**38,341**	**38,073**	**37,152**	**36,649**	**36,713**	**37,685**
Outputs							
Surface withdrawals for irrigation	5,370	4,497	4,701	3,218	2,960	2,477	3,573
Surface withdrawals for D&I	820	1,302	2,511	2,511	2,511	3,448	3,448
Total surface withdrawals	6,190	5,799	7,212	5,729	5,471	5,925	7,021
Natural and induced recharge from river to groundwater	0	0	0	0	0	0	0
Outflow to sea	32,990	32,542	30,861	31,423	31,178	30,518	30,664
Export	0	0	0	0	0	270	0
Total output	**39,180**	**38,341**	**38,073**	**37,152**	**36,649**	**36,713**	**37,685**

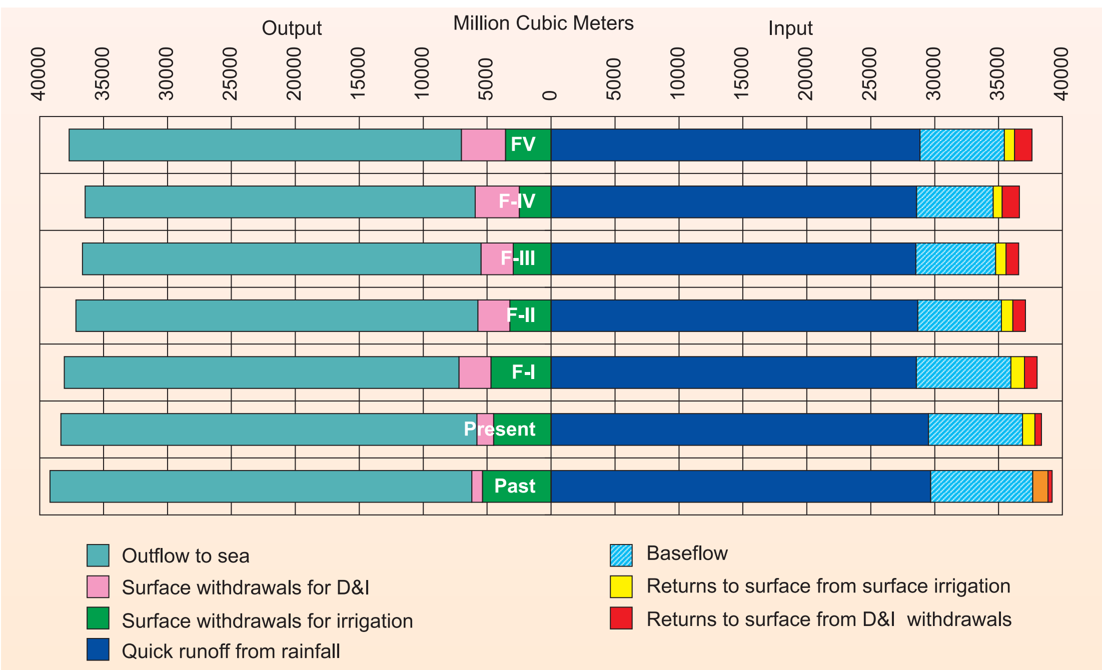

Figure 8. Annual Surface Water balance

Table 15.
Annual Groundwater Balance, Steady State, Average Rainfall (10^6 m^3)

Component	Past (1980)	Present (2000)	F-I	F-II	F-III	F-IV	F-V
Inputs							
Natural recharge from rainfall	5,182	5,143	4,966	4,984	4,958	4,967	5,015
Returns to groundwater from surface irrigation	2,824	2,268	2,491	1,636	1,505	1,289	1,848
Returns to groundwater from ground-water irrigation	0	0	0	0	491	422	457
Returns to groundwater from D&I withdrawals	14	40	40	40	40	77	77
Sub-total, returns to groundwater	2,838	2,308	2,531	1,676	2,036	1,788	2,382
Natural and induced recharge from river to groundwater	0	0	0	0	0	0	0
Groundwater flow from other basins	0	0	0	0	0	0	0
Total inputs	**8,020**	**7,451**	**7,497**	**6,660**	**6,994**	**6,756**	**7,397**
Outputs							
Groundwater irrigation withdrawals, including groundwater pumping to surface canals	0	0	0	0	641	537	574
Groundwater withdrawals for D&I use	40	110	110	110	110	220	220
Sub-total groundwater withdrawals	40	110	110	110	751	757	794
Base flow to rivers	7,980	7,341	7,387	6,550	6,242	5,999	6,603
Groundwater flow to other basins	0	0	0	0	0	0	0
Direct groundwater flow to sea	0	0	0	0	0	0	0
Total outputs	**8,020**	**7,451**	**7,497**	**6,660**	**6,994**	**6,756**	**7,397**

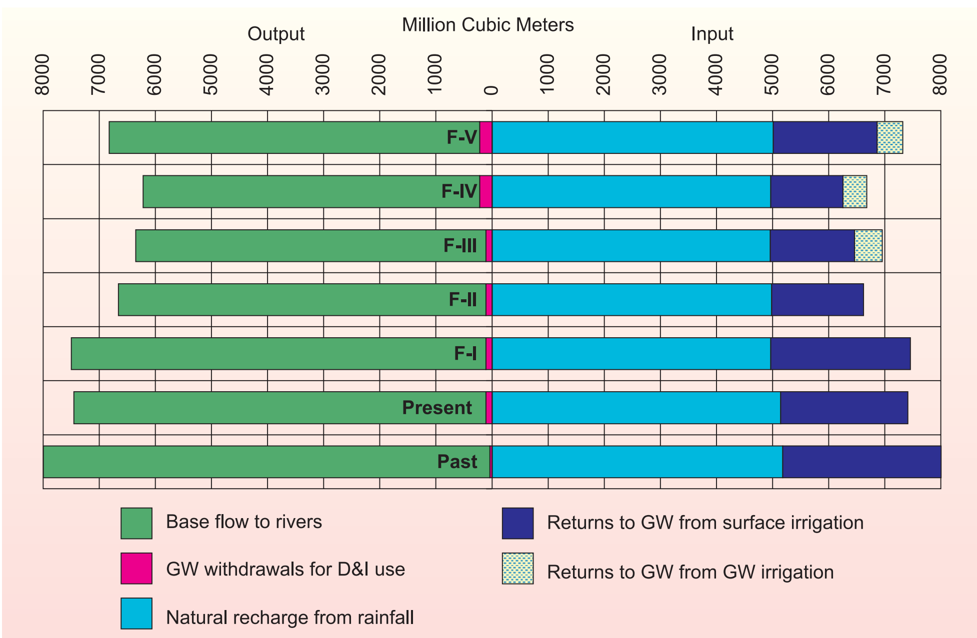

Figure 9. Annual Groundwater Balance

Table 16.
Consumptive Use (Evapo-transpiration) by Different Sectors (10^6 m^3)

Sectors	Past (1980)	Present (2000)	F-I	F-II	F-III	F-IV	F-V
Nature							
Beneficial	10,126	11,128	13,908	13,910	13,910	13,910	13,126
Non beneficial	7,102	6,003	4,075	4,241	3,936	3,850	4,435
Sub total	**17,228**	**17,130**	**17,983**	**18,151**	**17,846**	**17,760**	**17,561**
Agriculture							
Beneficial	4,647	4,207	4,368	4,207	4,667	4,615	4,515
Non-beneficial	2,503	3,147	3,136	2,565	2,656	2,548	2,969
Sub total	**7,150**	**7,353**	**7,503**	**6,772**	**7,323**	**7,163**	**7,484**
People							
D&I	535	838	1,591	1,591	1,591	2,228	2,228
Grand total	**24,913**	**25,322**	**27,077**	**26,514**	**26,760**	**27,150**	**27,274**

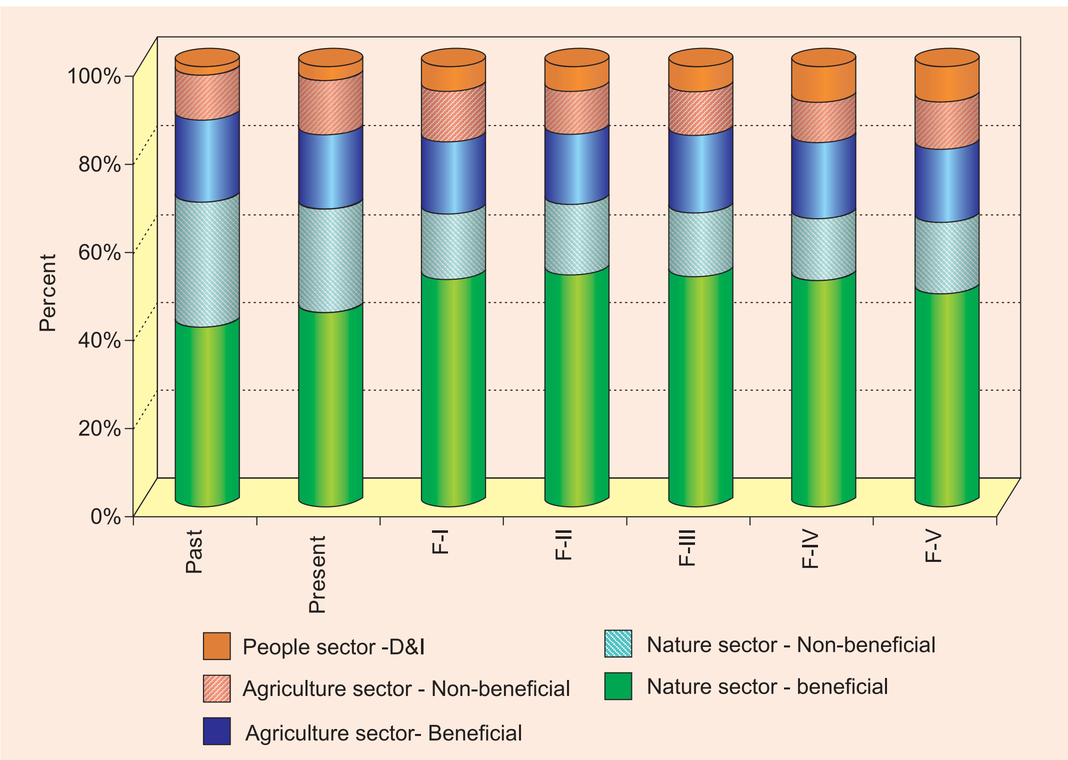

Figure 10. Consumptive Use (ET) by Different Sectors

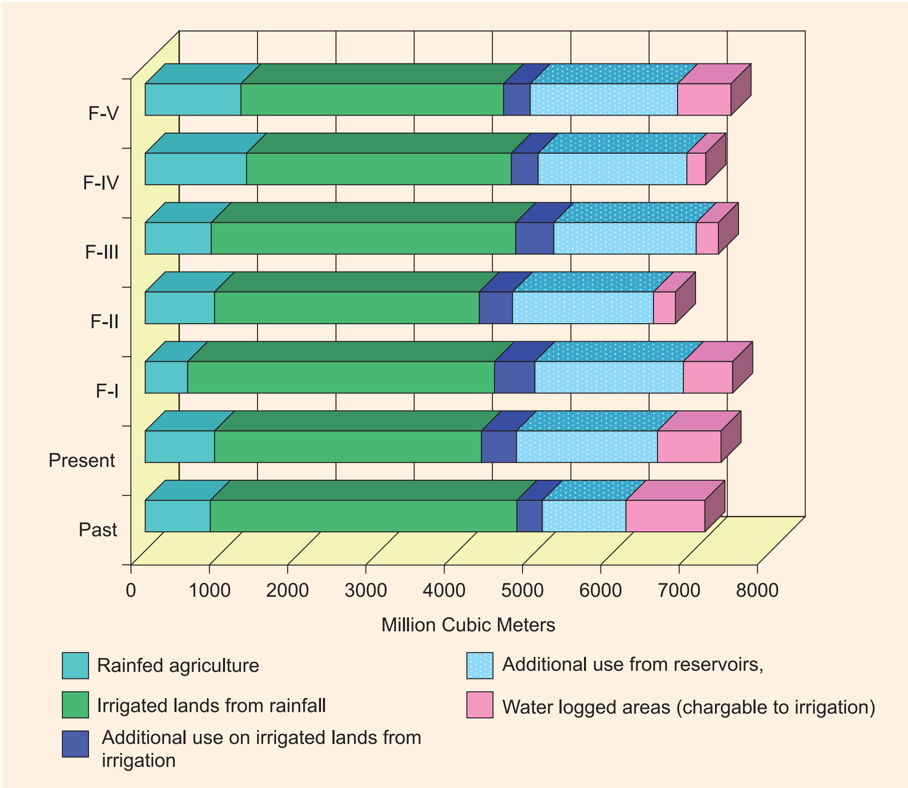

Figure 11. Composition of Consumptive Use in Agriculture Sector

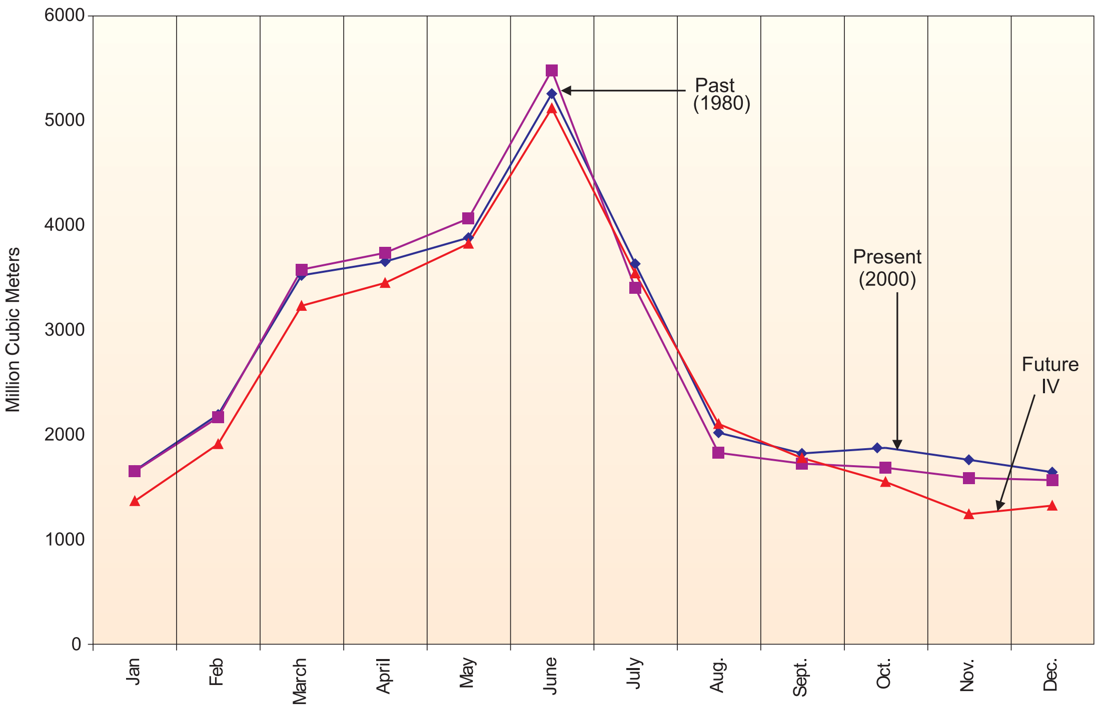

Figure12. Monthly Distribution of River Flows

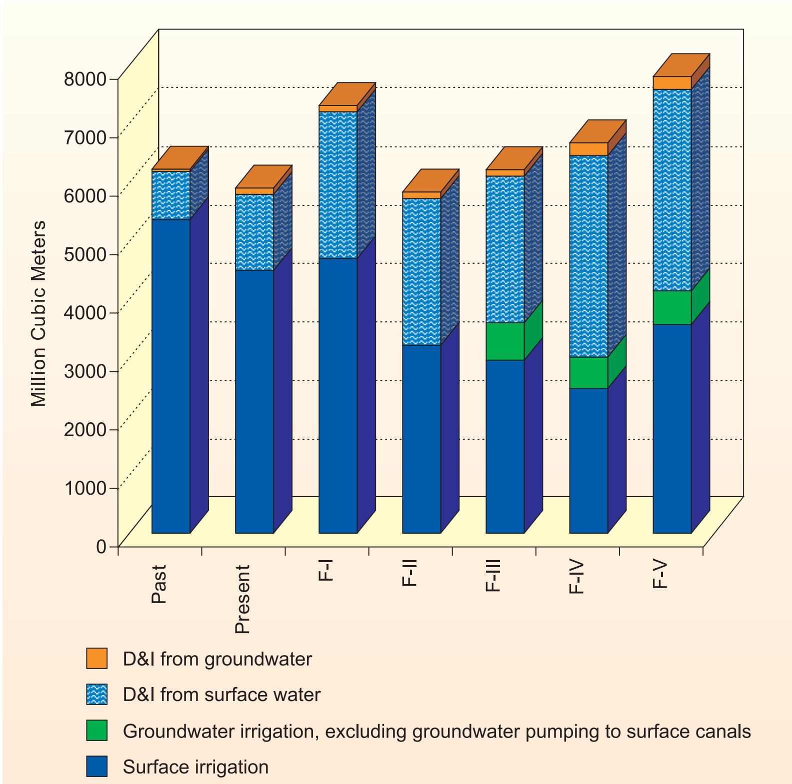

Figure 13. Composition of Water Withdrawals

The total flow computed by the model fairly matches with the observed one, which is 32,703 million cubic meters.

For the present condition, the withdrawal required for sustaining agricultural (irrigation) uses, which is entirely from surface water is 4,497 million cubic meters, and the withdrawals for D&I uses are 1,302 million cubic meters from surface water and 110 million cubic meters from groundwater, respectively. Therefore, there is huge potential for groundwater development in this basin. To sustain these current withdrawals, the surface storage filling and depletion of 7,680 million cubic meters contributes considerably.

The current total natural recharge from rainfall in the basin as computed by the model is 5,143 million cubic meters, which is about 8.9 percent of average annual rainfall of 57,958 million cubic meters as there is no groundwater use in irrigation in this basin so far, exploiting groundwater for both agricultural and D&I uses inevitably is a priority plan for local Integrated Water Resources Development and Management (IWRDM) so as to achieve sustainable development and use of water resources. Therefore, in Future III, Future IV and Future V scenarios, 20 percent of groundwater is planned to be exploited. Moreover, water export, which is 180 million cubic meters in the upstream and 90 million cubic meters in the downstream, together with better water management is also adopted in Future IV even though so far there is no plan for water export in this area.

2.7.1 Consumptive Use of Water

For the present condition, the total consumptive use is 23,519 million cubic meters, comprising 17,130 million cubic meters for nature sector, 5,551 million cubic meters for agriculture sector and 838 million cubic meters for people sector (D&I). The agricultural use is made up of ET in rain-fed lands (beneficial and inadvertent) as well as irrigated lands, additional ET met from irrigation and reservoir evaporation. The beneficial consumptive use of nature sector in the future five scenarios increased remarkably due to the expansion of forest area (the forest coverage is increased from 36.4% in 1980 to 40% in 2000 and 50% in 2025), but the non-beneficial ET is reduced due to the decrease of waste and fallow land area.

The scenario Future IV has been attempted to get the maximum practicable expansion, including more groundwater use, better management, water export and more industries. Even though the river flow is reduced slightly from 32,542 million cubic meters to 30,518 million cubic meters compared with the B as U Scenario, the total consumptive use is 26,610 million cubic meters, close to the value of B as U Scenario of 26,537 million cubic meters. Table 16 summarises consumptive use (ET) by sectors under different scenarios. Figure 10 depicts consumptive use estimates.

The composition of consumptive use in agricultural sector can be further classified by the status of the land (rain-fed or irrigated) as shown in Figure 11. Part of the consumptive use from irrigated land is met from rainfall and/or from irrigation waters. Non-beneficial consumption would be from reservoirs, waterlogged areas, and/or from land without crops in particular season.

2.7.2 Surface Water Use

From 1980 to date, surface water has been the major water source in Qiantang river basin. Particularly for agriculture, 100 percent of withdrawal is from surface waters. For Domestic & Industrial uses, only 5 percent of withdrawal was from surface water in the past and 7 percent is in the present conditions. In terms of total water withdrawal for agriculture, domestic and industry, only 0.6 percent was from surface water in the past and 1.8 percent at present. Therefore, the abundant surface water resources create superior conditions for local socio-economic development.

For the present condition, as computed by the model, the withdrawal of surface water was 10 percent of the total inputs, and return flow contributed only 2.5 percent of inputs, the baseflow was 7,341 million cubic meters, 12.6 percent of the total inputs available in all months. In the current situation, with average rainfall, total return flows contribute 6.5 percent of total inputs and total withdrawals are equal to 10 percent of the inputs.

In the future scenarios with average rainfall, even with more water consumption for agriculture, domestic and industry, the maximum withdrawals will be only 13.5 percent of the total inputs while the maximum return flows constituted 8 percent of the total inputs. Therefore, the sustainability of water resources in this area can be guaranteed. The monthly distribution of river flows is shown in Figure 12.

2.7.3 Groundwater Use

At present, very little groundwater, which is only 0.2 per cent of total inputs, has been exploited for domestic and industrial use. Return flow, natural and human together, constitutes only 4 percent of the inputs. Therefore, more groundwater use has been adopted in future three scenarios (F-III, IV, & V). At the same time, the abundant surface and groundwater resources also provide a scenario for water export. In Future IV scenario, 20 per cent of groundwater is planned to be used and totally 270 million cubic meters of water is planned to be exported to other water deficit basins. But even then, the total withdrawal from groundwater is only 1.3 percent of the total inputs and the return flow would constitute about 3 percent of the inputs. The potential for groundwater development therefore is huge in this basin.

The withdrawals for both surface and groundwater for different purposes and for different scenarios are shown in Figure 13. As paddy is the biggest water consumer and still the major crop in this basin, surface water withdrawal for irrigation was reduced remarkably due to the cutting down of paddy area in the last four scenarios. However, with the rapid growth of population and quick development of industrialization and urbanization, the withdrawal for D&I use is nearly doubled in Future I, II and III scenarios and increased by 160 percent in Future IV and V scenarios. The ratio of irrigation withdrawal to total withdrawal is reduced from 86 percent in the past to 76 percent at present and even to 45 percent in Future IV scenario.

2.7.4 Groundwater Pumping and Induced Recharge

The agricultural and D&I water demand are met both from surface water and groundwater. As the surface water resource in this river basin is high enough to meet local water demand as well as the base flow even in dry seasons, groundwater pumping into canals to meet the deficits in surface water is not required. Similarly, as only a small groundwater has been developed, natural and induced recharge to balance groundwater table also is not required.

2.8 Water Situation Indicators

In the model, four water situation indicators have been proposed to depict the level of water use (withdrawals) and potential of hazard (due to return flows) to water quality, as follows:.

Indicator 1:	Total surface water withdrawal/ Total surface water inputs,
Indicator 2:	Total returns to surface water/ Total surface water inputs,
Indicator 3:	Total groundwater withdrawals/ Total groundwater inputs, and
Indicator 4:	Total returns to groundwater/ Total groundwater inputs

Discussion about these indicators is given in CPSP Reports 1,2, and 6 (ICID, 2005). The indicators were further categorised into 3 to 4 classes each to represent the degree of water stress and quality threat as shown in Box 1:

Box 1

Indicator	Water source and type	Category	Value
1	Surface water withdrawal	Very high stress	>0.8
		High stress	0.4 – 0.8
		Moderate stress	0.2 – 0.4
		Low stress	<0.2
2	Surface water quality	High threat	>0.2
		Moderate threat	0.05 – 0.2
		Low threat	<0.05
3	Groundwater withdrawal	Very high stress	>0.8
		High stress	0.4 – 0.8
		Moderate stress	0.2 – 0.4
		Low stress	<0.2
4	Groundwater quality	Very high threat	>0.8
		High threat	0.4 – 0.8
		Moderate threat	0.2 – 0.4

Values of these indicators for Qiantang river basin are given in Table 17:

It can be seen from the Table 17 that surface water withdrawals are only a small part of the total surface water inputs. Even in future scenarios, indicator 1 varies between 0.15 and 0.19. In groundwater withdrawal, the ratio varies from 0.005 in the past to 0.01 at present and to 0.11 in the last three future scenarios, even with more groundwater use. However, it should be specially noted that GW return flow is very high in all the studied scenarios, even it was slightly reduced in future II to IV scenarios due to better water management. Therefore, efforts should be made to reduce the threat to groundwater quality.

2.9 Major Findings of the Assessment

- Qiantang river basin is rich in water resources. However, there is a variation in the water availability in different regions of the basin. In some regions there is a shortage of water. Therefore, the construction of reservoir for storage purposes and water saving measures to reduce water losses should be taken up to better utilize the basin water resources and reduce the water shortage;
- As there is no groundwater use in irrigation in this basin so far, conjunctive use of surface water and groundwater should be adopted for both agricultural and D & I uses. But as much of the shallow groundwater in this river basin is return water, this is also the reason why there is not much groundwater use at present.

Table 17.
Water Situation Indicators, Qiantang River Basin

Indicator	Past (1980)	Present (2000)	Future I	Future II	Future III	Future IV	Future V
Indicator 1	0.16	0.15	0.19	0.15	0.15	0.16	0.19
Indicator 2	0.04	0.04	0.05	0.05	0.05	0.06	0.06
Indicator 3	0.005	0.01	0.01	0.02	0.11	0.11	0.11
Indicator 4	0.35	0.31	0.34	0.25	0.29	0.26	0.32

- Meanwhile, to guarantee the stability of river bed for flood control, the total withdrawal from rivers should be within 12 per cent of the total river runoff.
- Possibilities to explore the potentials of the current projects should be exploited to increase water supply;
- Recycling of industrial water should be encouraged to minimize the fresh water supply to industries;
- Inter-basin water transfer projects need to be formulated to transfer water from rich areas to water short areas, such as Yongkang and Yiwu etc.
- Some reservoirs need to be rehabilitated to increase their regulation capacity to increase water supply;
- Water-saving technology in paddy grown areas should be strengthened in the basin as rice is the major staple crop and consumes highest water;
- Qiantang river basin is water rich and located in developed area of southeast China. Structural and non-structural flood control measures should be taken up to safeguard the people's life and property;
- Nature sector consumes major part of the primary resource (rain water);
- Consumptive use under nature sector is expected to increase significantly in the future due to the expansion of forest area. This in turn would tend to reduce river flows. Part of this decrease can however be restored through better soil and water management initiatives.

CHAPTER 3

POLICY RELATED ISSUES EMERGING FROM THE STUDY

3.0 General

The detailed hydrologic modelling and analysis of the Qiantang basin for the various scenarios have provided a greater insight into the understanding of the water resources. The holistic view of the assessments taken through the modelling gives a sound and much broader basis to describe the state of water availability and the likely water use under different sectors and various future scenarios at the basin / sub-basin level; source-wise surface and groundwater separately and interaction between the two. Modelling has been used to develop a set of indicators, which help in understanding the current water scene for other basins of China. Similarly, the modelling has allowed the testing of various possible land and water use scenarios, in regard to their hydrologic implications, and allows assessment and integration of the individual water use sector. Following is a summary of key issues that have emerged, and may need to be studied further for suitable modifications in the Water Law of China adopted in 2002 (People's Republic of China, 2002).

3.1 Change in the Perception of Water Resources

Improvement of water management has become a common concern of all people in China. From the perspective of the economic and social development, it would be necessary to change perception of water resource availability by promoting water resources management at a better level. The following important aspects need to be considered for better water management.

- Developing harmonious coexistence between man and nature for sustainable development;
- Change in the perception that water is inexhaustible to the recognition that freshwater resources are limited;
- Paying special attention to the prevention of human damage to water while preventing water damage to mankind;
- Shifting focus on water development, utilization and management to water allocation, conservation and protection while developing, utilizing and managing water resources;
- Emphasizing water works construction to strengthen non-structural measures and scientific management of water works;
- Matching water supply according to demand and water demand according to supply;
- Developing pressurized irrigation systems and promoting efficient water use;
- Realizing water as a natural gift, structural measures should be taken for its optimum utilisation;
- Management of water quantity and quality in all uses;
- Promoting re-use of poor quality waters;
- Integrating water allocation, distribution and management.

3.2 Areas of Sustainable Use of Water Resources

3.2.1 Increasing the water use efficiency and saving water

- ❑ Strengthening water conservation and management;
- ❑ Formulating national and local level, middle and long term plans for water supply and demand;
- ❑ Extending water-saving irrigation practices with enhanced vigour;

- Promoting water saving practice in industry;
- Promoting water saving measures in municipal use;
- Publicizing vigorously water saving practices through news media like radios, television and newspapers to mobilize public participation.

3.2.2 Developing water resources and expanding the capacity of water supply

- Optimizing regional and sectoral allocation of water resources;
- Strengthening evaluation of water resources development and utilization;
- Constructing a number of water resources development and utilization projects;
- Promoting the comprehensive use and multi-purpose development of water resources;
- Developing alternative water resources.

3.2.3 Protecting water resources and improving water environment

- Drawing up overall plans for protection of water resources and water environment in all the river basins;
- Strengthening water environment monitoring;
- Strengthening water environment protection in urban and rural areas;
- Strengthening scientific research for protection of water resources and improvement of water environment, popularising new technologies of water environment control through experiments and demonstrations;
- Publicizing the importance of water resources protection and water environment improvement, mobilizing the public support and participation.

3.3 Measures for Sustainable Use of Water Resources

3.3.1 Optimal allocation

- Formulate water resources planning, specify water resources macro control index;
- Formulate water allocation schemes and indices as well as reliable measures at river basin, province, and at the national level;
- Coordinate domestic, crop production and ecosystem water use based on total allocated water amount;
- Implement total water use control and quota management for different sectors and different water users,;
- Implement water-drawing permit, formulate contingency water supply plan during dry seasons and prioritize water uses;
- Development of contingency policies and measures to guarantee water use safety;
- Optimize inter-river basin and inter-region water allocation on the basis of scientific research and analysis;
- Formulate water rights and rotation systems suitable for the country's situation and market economy.

3.3.2 Effective Protection

- Formulate water resources protection program of major rivers;
- Rationally divide water function areas, specify amount of waste and total discharge of various pollutants in the river system so as to realize total amount of control for waste discharge;
- Establish an economic compensation system for water resources protection and eco-system rehabilitation;
- Formulate GDP statistics index for pollution control;
- Specify water source protection zones for providing safe drinking water for urban and rural population over 200,000;
- Readjust industrial structure to encourage clean production so as to control pollution at the source;
- Implement waste water discharge permit.

3.3.3 Effective utilization

- Formulate national policies on water saving;
- Designate micro water use quota for different areas, different sectors and different products specifying water use index of 10,000 yuan GDP of various sectors, and water-saving evaluation index;
- Develop and utilize water-saving technology and equipments;

- Increase waste water treatment and reuse of industrial water;
- Develop water-saving industry;
- Establish water saving society in cities to improve water use efficiency.

3.3.4 *Appropriate development*

- Develop new sources appropriately to improve distribution and water supply safely for conserving water;
- Solve drinking water problem in poor areas and guarantee water supply for economic and social development;
- Construct storage projects to make full use of local water resources;
- Develop inter-river basin and inter-regional water transfer projects after overall planning and scientific research;
- Rationally utilize groundwater resources in areas with potential;
- Increase utilization of rain and flood water, speed up wastewater treatment and reuse of industrial and domestic water, sea water desalination and direct use, and other non-conventional water utilization.

3.3.5 *Scientific management*

- Revise "Water Law" and formulate "River Basin Law", "Water-Saving Law" to establish and improve the legal system for water resources management;
- Promote water management system with integrated urban and rural water management;
- Establish an integrated, authoritative and efficient water resources management system for major rivers and develop sound water project operation mechanism to realize effective combination of river basin management and regional management;
- Coordinate the use of surface water and groundwater, use of local water resources and water transferred from other areas to achieve effective and efficient uses;
- Establish real-time monitoring system, distribution system and management information system in water resources.

3.3.6 *Increase financial input*

- Divide the rights and responsibilities between the central and local governments, and among the government, market, and beneficiaries and investors of water projects;
- Implement active fiscal policies to increase government input in water resources development and utilization;
- Establish a rational water pricing mechanism and make full use of the market system to raise funds for water projects;
- Mobilize public to participate in water resources development and management through policies and measures.

ANNEXURES

ANNEXURE 1
BRIEF DESCRIPTION OF BHIWA MODEL

The Basin-wide Holistic Integrated Water Management (BHIWA) model as evolved for CPSP has nine 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).

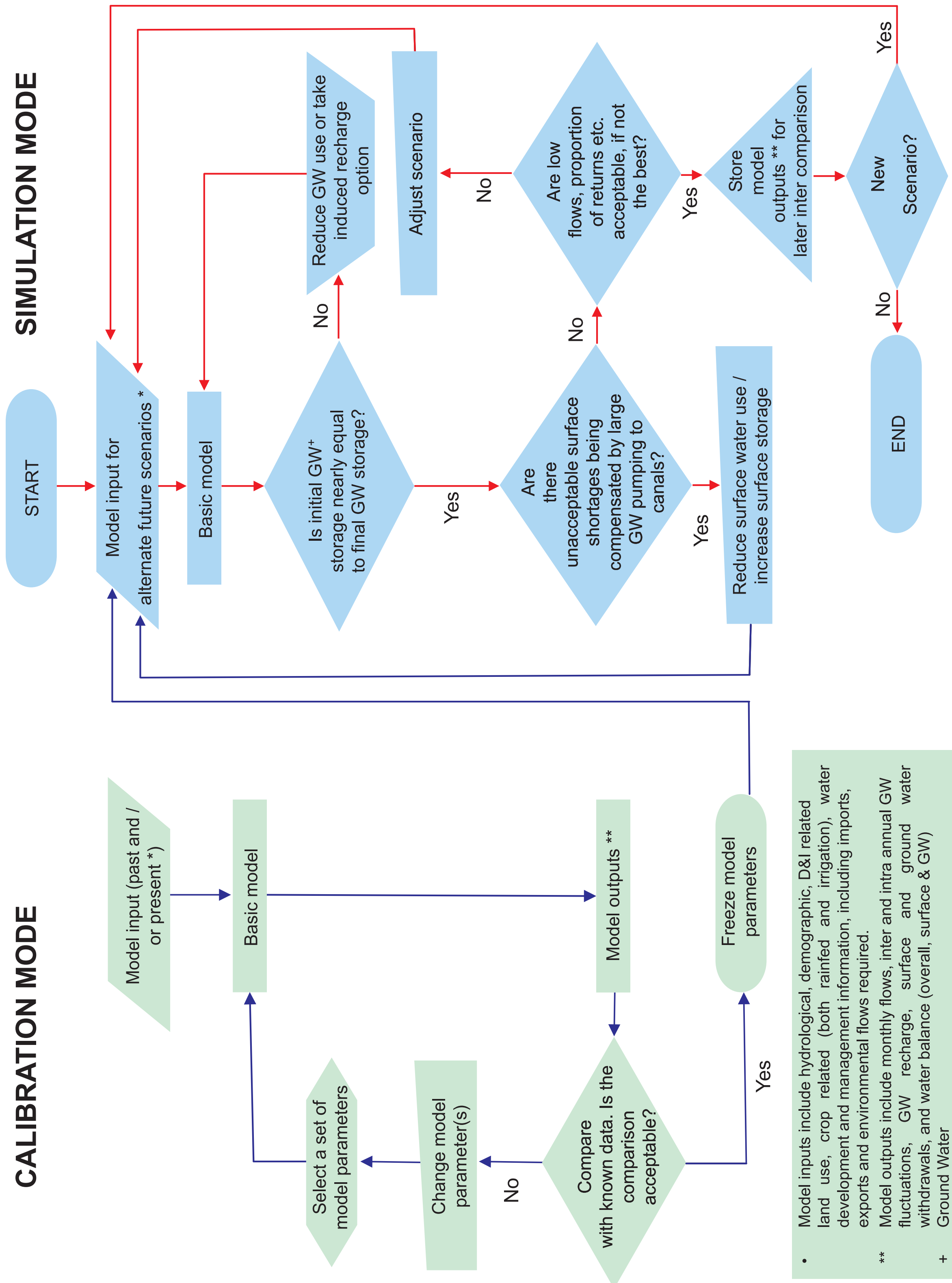

Figure A-1 Logical Sequence of BHIWA Model

ANNEXURE 2

SUB-BASIN WISE MONTHLY RAINFALL AND REFERENCE EVAPO-TRANSPIRATION (ETo)

Month	Rainfall (mm)		ETo (mm)	
	SB1	SB2	SB1	SB2
January	77.79	77.79	289	28.9
February	113.36	113.36	24.9	24.9
March	200.2	200.2	40.1	40.1
April	215.51	215.51	60.4	60.4
May	230.34	230.34	113.2	113.2
June	292.05	292.05	80.4	80.4
July	135.05	135.05	154.7	154.7
August	83.16	83.16	126.8	126.8
September	96.07	96.07	100.8	100.8
October	71.52	71.52	70.8	70.8
November	63.95	63.95	37.4	37.4
December	53.62	53.62	33.0	33.0
Total	**1,632.62**	**1,632.62**	**871.40**	**871.40**

ANNEXURE 3

AVERAGE, MAXIMUM AND MINIMUM RUNOFF VALUES AT DIFFERENT G&D SITES

River	Station	Catchment area (Km^2)	Average value (10^6 m^3)	Maximum runoff		Minimum runoff		Max/min ratio
				Runoff (10^6 m^3)	Year	Runoff (10^6 m^3)	Year	
Qu	Quzhou	5,424	6,590	9,910	1954	3,090	1978	3.20
Lang	Lanxi	18,233	17,800	28,400	1954	7,570	1978	3.75
Xin'an	Yuankou	687	646	1,140	1973	327	1979	3.49
Jinhua	Jinhua	5,953	4,530	6,970	1954	1,720	1978	4.05
Puyang	Zhuji	1,719	1,220	2,100	1954	500	1978	4.20
Cao'e	Dongshafu	3,302	2,510	3,530	1954	1,120	1978	3.20
Fuchun	Qililong	31,645	20,100	54,300	1954	17,300	1979	3.14

ANNEXURE 4

NET IRRIGATION DUTY IN EACH IRRIGATION ZONE WITH 90% PROBABILITY (M^3/HA)

	Zone	Paddy	Upland Crops	Garden crops
Upstream	Changshan	9,495	2,835	2,130
	Jiangshan	9,795	3,000	2,250
	Qubei	10,110	3,165	2,370
	Qunan	10,110	3,165	2,370
	Dongpan	9,390	2,715	2,040
	Yiwu	9,435	2,895	2,175
	Yongkang	9,240	2,595	1,950
	Wuyi	8,955	2,565	1,920
	Jinwulan	9,825	3,060	2,295
	Shouchang	8,070	2,550	1,920
	Fuchun	7,575	2,535	1,905
Downstream	Fenshui	7,260	2,460	1,845
	Luzhu	8,985	2,055	1,545
	Huyuan	8,700	2,010	1,515
	Main stream of Fuchun River	9,300	2,145	1,605
	Puyang	9,840	2,445	1,830

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EXPLANATORY NOTES/GLOSSARY

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.

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

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, 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.

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

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).

Evapotranspiration, 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.

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.

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.

Irrigation efficiency, or Overall efficiency: The ratio or percentage of the irrigation water consumed by crops to the water diverted from the source of supply, at different levels of the irrigation system such as the farm or the entire system.

Irrigation potential: Total possible area that can be 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: Water artificially applied to soils in the process of irrigation. It does not include precipitation.

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

Mean annual precipitation: The average over a period of years of the annual amounts of precipitation.

Natural recharge: It is that portion of water, which gravitates to the zone of saturation under natural conditions.

Potential evapo-transpiration: It is that portion of water, which gravitates to the zone of saturation under natural conditions.

Precipitation: The total measurable supply of water of all forms of falling 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.

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

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

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

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 resources: 1- Water available, or capable of being made available, for use in sufficient quantity and quality at a location and over a period of time appropriate for an identifiable demand. 2- Supply of water in a given area or basin interpreted in terms of availability of surface and underground water.

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