Water Resources Assessment of Jiaodong Peninsula Basin, China

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

Country Policy Support Programme (CPSP)

Project funded by

Sustainable Economic Development Department
National Policy Environment Division
The Govt. of The Netherlands
(Activity No.WW138714/DDE0014311)

ICID•CIID

INTERNATIONAL COMMISSION ON IRRIGATION AND DRAINAGE (ICID)
NEW DELHI

AUGUST 2005

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.

ISBN. 81-85068-98-4

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

ACKNOWLEDGEMENTS

The study was conducted as part of Country Policy Support Programme (CPSP) initiated by the International Commission on Irrigation and Drainage (ICID) under the financial assistance of Sustainable Economic Development Department, National Policy Environment Division, of the Government of The Netherlands.

ICID acknowledges the support it received for the conduct of the various studies under CPSP from many water related International Organisations like IWMI, FAO, WWF, IUCN and GWP by way of participation in consultations and dialogues during the different phases of the study. During the initial basin level consultations and later at the National consultation many valuable suggestions and comments were received from several stakeholders which helped greatly in in-depth review of the analysis and results of the specific studies which contribution is gratefully acknowledged.

ICID acknowledges the constant guidance and support it received from President Keizrul bin Abdullah and President Honoraire Dr. Bart Schultz in overall implementation of CPSP activities in China, India and other three participating countries viz; Egypt, Mexico and Pakistan. The initiative of Dr. C D Thatte, Secretary General Honoraire enabled to conceptualise the activities and to give a further fillip to CPSP initiatives. His able organisation and piloting of activities till his relinquishment of the office of Secretary General in December 2003 is greatly appreciated.

A team comprising Mr. A D Mohile, former Chairman, Central Water Commission (India), and Mr. L N Gupta, former Executive Director, WAPCOS (India) contributed to the development of the Basin-wide Holistic Integrated Water Assessment (BHIWA) model and supported the Chinese National Committee on Irrigation and Drainage (CNCID) in its application to the Chinese basins. ICID acknowledges contribution of Dr.Upali Amarasinghe, IWMI for developing PODIUMSim Model and supporting the CNCID for its application to Chinese studies. A review by Prof. P.B.S. Sarma, former Director, Water Technology Center, Indian Agricultural Research Institute (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 inception and prepared the report for printing. Their contributions are duly acknowledged.

ICID gratefully thanks the CNCID and its members for carrying out assessment of river basins in China, especially to Mr. Li Daixin, Chairman, Dr. Gao Zhanyi, Vice Chairman and Secretary General, Ms. Wang Shaoli, Drainage Specialist and Ms. Jianxin Mu, Executive Secretary. Special acknowledgement is due to the Chinese Department of Irrigation, Drainage and Rural Water Supply and the Department of International Cooperation, Science & Technology and the Ministry of Water Resources for providing full support to CNCID in the study. ICID also acknowledges the invaluable data and advice provided by Zhejiang Provincial Water Conservancy Department, Survey and Design, Shandong Provincial water Conservancy Department, Qiantangjang River Basin Management Bureau, Yantai Municipal Water Conservancy Bureau, Weihai Water Conservancy Bureau, Zhejiang Provincial Institute of Water Conservancy Survey and Design, and Shandong Provincial Institute of Water Conservancy Survey and Design.

ICID acknowledges the donors for reposing their confidence in ICID in assigning the challenging and complex task of exploring strategic direction for addressing water policy issues considering needs of all sectors in an integrated manner, keeping food security and rural development as the main focus.

M Gopalakrishnan

August, 2005 *Secretary General*

PROJECT PARTICIPANTS

Coordination Committee

Mr. Li Daixin	Director General, Department of Irrigation, Drainage and Rural Water Supply; Chairman, Chinese National Committee on Irrigation and Drainage (CNCID)
Mr. Jiang Kaipeng	Deputy Director General, Department of Irrigation, Drainage and Rural Water Supply; Vice Chairman, Chinese National Committee on Irrigation and Drainage (CNCID)
Dr. Kuang Shangfu	Vice President of China Institute of Water Resources Hydropower Research Institute
Mr. Geng Fuming	Deputy Director General, Shandong Provincial Water Conservancy Department
Mr.Chu Jiafu	Deputy Director General, Zhejiang Provincial Water Conservancy Department

Project Team

Mr. Gao Zhanyi	Director, National Center for Efficient Irrigation Engineering and Technology Research (Beijing); Vice Chairman & Secretary General, Chinese National Committee on Irrigation and Drainage (CNCID)
Mr. Yan Guanyu	Chief, Division of Irrigation& Water Savings, Department of Irrigation, Drainage and Rural Water Supply, MWR; Deputy Secretary General, Chinese National Committee on Irrigation and Drainage (CNCID)
Mr. Liu Zhiguang	Chief, Division of Foreign Affairs, Department of International Cooperation, Science & Technology, MWR; Deputy Secretary General, Chinese National Committee on Irrigation and Drainage (CNCID)
Mr. Jiang Ping	Chief, Division of Irrigation and Drainage, Zhejiang Provincial Water Conservancy Department
Mr. Ma Chengxin	Chief, Division of Irrigation and Drainage, Shandong Provincial Water Conservancy Department

Study Team

Mrs. Mu Jianxin, Mrs. Wang Shaoli, Mrs. Liu Yu, Mrs. Han Yuling, Mr. Li Yunjin,

Mr.Yang Fuzhen, Mr.Liu Yufeng, Mr. Lin Binyan, Mrs.Xuan Weili,Mr. Zhang Jun, Mrs. Zhao Lin, Mr.Zhang Yangbo, Mr.Guo Jing

Consultation Committee

Prof. Feng Guangzhi, Prof. Jia Dalin, Prof. Tianyuoan, Prof. Cai Lingen,

Prof. Wang Hao, Prof. Li Yuanhua, Prof. Hu Heping, Prof. Xue Kezong

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 emrging from the studies were presented in a National Consultation held in August 2004, at Beijing. This report covers the assessment of Jiaodong Peninsula Basin in China. The Chapter-1 covers Introduction of CPSP and details of Jiaodong Peninsula Basin, Chapter-2 covers the aplication of BHIWA model for assessment of Jiaodong Peninsula Basin and Chapter-3 covers policy related issues highlighted from the study.

The Jiaodong Peninsula Basin has a total drainage area of 19,182 km^2. The river system, climate, land use, water resource and its development, water demand at present and projected water requirement in the year 2025 have been discussed in ithe report. The per capita annual water availability in the basin in the year 2000 was 492 cubic meters considering the estimated renewable water resources of the basin as 4,394 million cubic meters per year and 8.93 million as the population of the basin. This water availability is likely to be 454 cubic meters per year per capita in the year 2025 with the projected population of 9.67 million by 2025.

The Basin-wide Holistic Integrated Water Assessment (BHIWA) Model evolved by ICID, was applied to Jiaodong Peninsula basin to assess water use by different sectors for the present (2000) and future scenarios. The basin was divided into two sub basins, namely; Yantai and Weihai. The model was calibrated for the present conditions and applied to derive responses to the past and five future scenarios using monthly time set. Apart from Business as Usual Scenario (Future-I), other scenarios examined include:

- Without expansion of forest (Future-II)
- Better system management and reduced groundwater use (Future-III)
- Better system management and reduced groundwater use and adoption of drip irrigation (Future-IV)

- With soil and land management, import of more water and reduced groundwater use (Future-V)

The aggregate results of the study, discussions of result of the Jiaodong Peninsula basin assessment are furnished in this report.

The total water input comprises rainfall and import of water. The rainfall amount in the basin is 13,748 million cubic meters. At present there is no import and hence total water input is 13,748 million cubic meters. It was projected that an import of 147 million cubic meters in B as U, Future-II, III, IV scenarios and about 295 million cubic meters in Future-V scenario may be required. The major output consists of consumptive use and river flows. There is no export of water in any scenario.

The total consumptive use (ET) at present (2000) situation is 11,821 million cubic meters comprising about 52% by nature sector (forest, pasture and barren lands), 46% by agriculture sector (rain fed and irrigated agriculture) and 2% by people sector (D&I).

The major findings of the assessment are:

- Nature sector consumes major part of the primary water resource (rain water)
- Nature sector consumption for the past (1980), present (2000) and future (B as U) condition is estimated respectively as 5459, 6114 and 6601 million cubic meters. The increasing consumption in the nature sector (hence marked decrease in river flow in Future B as U scenario) is mainly on account of the land use shift between barren and forest land.
- Groundwater flow to rivers has decreased from 570 million cubic meters per year in the past to 230 million cubic meters at present. In future B as U scenario too, contribution from groundwater is likely to decline. For sustainable use, the groundwater withdrawal shall need to be reduced especially in Yantai area.
- To meet the additional future water needs, and to limit likely reduction in river flows, it will be necessary to import some water from outside the area, apart from improved management of soil and water resources.

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 possible integration of water supply and demand aspects of nature, food and people sectors. Policy interventions emerged from the study is discussed in the report.

ACRONYMS / ABBREVIATIONS

BHIWA	Basin Wide Holistic Integrated Water Assessment
BAU	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
FAO	Food and Agriculture Organisation of 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	Hectare
IAH	Indian Association of Hydrologists
ICID	International Commission on Irrigation and Drainage
IFPRI	International Food Policy Research Institute
IIUCN	World Conservation Union
IWMI	International Water Management Institute
IWRDM	Integrated Water Resources Development and Management
Km	Kilometer
lpcd	Liters Per Capita/Day
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

CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1
JIAODONG PENINSULA 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 from the studies were presented in a National Consultation held in August 2004.

In this report, water assessment of Jiaodong Peninsula basin for five scenarios in year 2025 have been presented. The Jiaodong Peninsula basin is shown in Figure 2.

1.1 Jiaodong Peninsula Basin

China has a large number of rivers. More than 50,000 small rivers cover a drainage area of over 100 km^2 and about 1500 rivers cover a drainage area of over 1000 km^2. The distribution of rivers over the country is uneven. The rivers of China are grouped into 9 basins viz., Songliao, Hai, Huai, Yellow, Yangtze, Pearl, Southeast Coastal, Southwest and the Inland River Basin. Jiodong Peninsula is part of the drainage area of Huaihe River Basin. Jiaodong Peninsula lies between north latitudes 36° 12' to 38° 24' and east longitudes 119° 33' to 122° 42". It borders on the Yellow Sea and Bohai Sea in the east, south and north, and

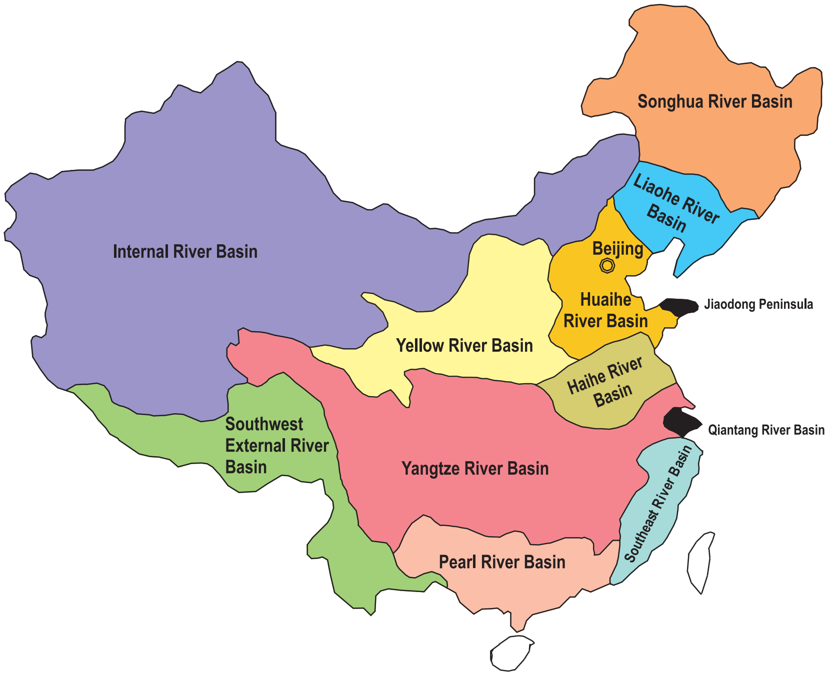

Figure 1. River Basin Map of China

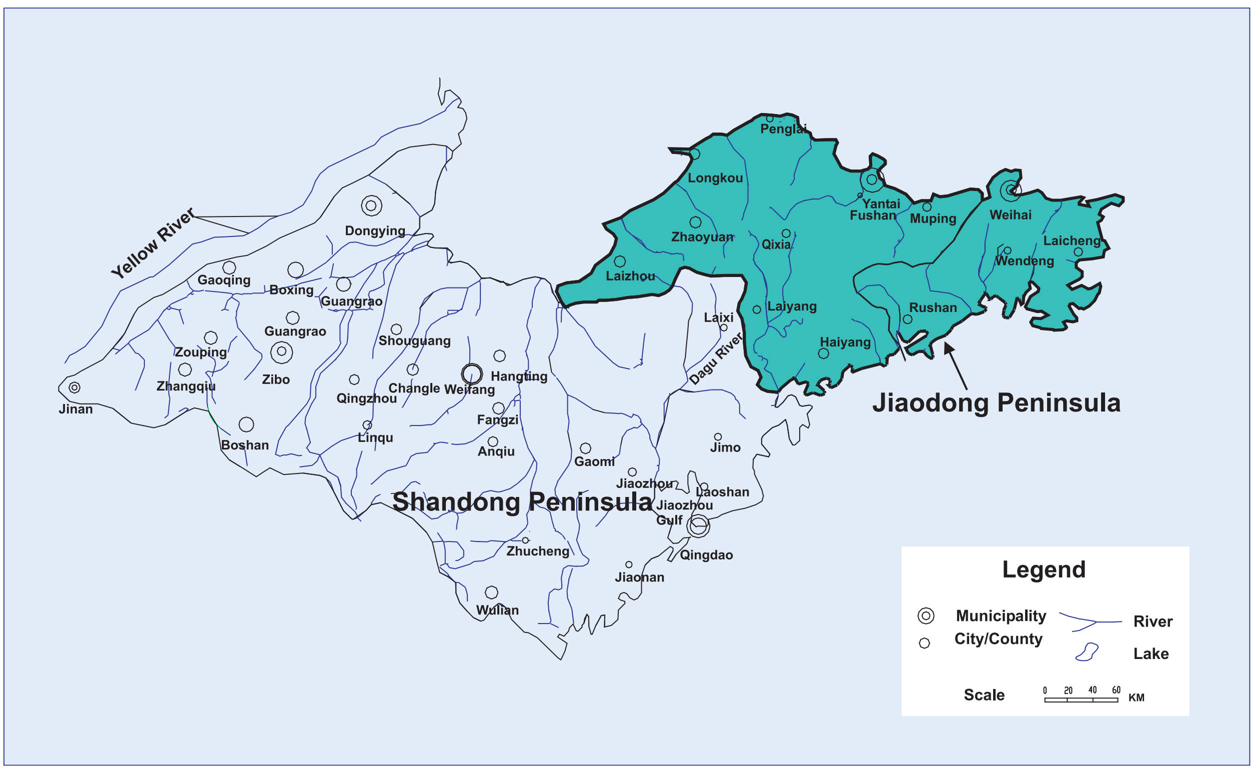

Figure 2. Location of Jiaodong Peninsula Basin

Weifang and Qingdao municipalities in the west. Yantai Municipality and Weihai Municipality are covered in the basin. The drainage area of the basin considered for the study is 19,182 km^2 . The basin has been divided into two sub basins, Sub basin-1 (SB-1) covering drainage earea of 13,746 km^2 falling within Yantai Municipality and Sub basin-2 (SB-2) covering drainage area of 5,436 km^2 falling within Weihai Municipality.

1.2 River System

All rivers flowing through Yantai sub basin are fed by monsoon-rain. The rivers flowing through Weihai sub basin are seasonal rivers.. The major tributaries of the basin are listed in Table 1.

Table 1.
Major Tributaries in Jiaodong Peninsula Basin

Sub basin	Tributary	Catchment Area (km^2)	Length (km)
Yantai	Wulong	2,652	124
	Dagujia	2,220	75
	Huanshui	983	53
Weihai	Mazhu	954	65
	Huanglei	652	69

1.3 Climate

The entire Jiaodong Peninsula comes under temperate continental monsoon climate, affected by sea. The average annual temperature in the basin is 11.5° C. It varies from about 1.6° C in the coldest month to 25.6° C in the hottest month. The average annual rainfall of the basin is 677.7 mm and the average annual evaporation is 1080.5 mm.

1.4 Land Use

The present land use pattern of Jiaodong Peninsula Basin is as shown in Table 2.

Table 2.
Land Use of Jiaodong Peninsula Basin

Land use	Area (km^2)		
	Yantai	Weihai	Total
Forest	4,373	1,560	5,933
Available cultivated area	4,439	1,722	6,161
Gross cropped area	6,552	2,993	9,595
Farm land irrigated area	2,815	1,198	4,013
Fruit irrigated area	687	228	915
Total Land Area	**13,746**	**5,436**	**19,182**

The basin has a large irrigation development. The farm land irrigated area in 2000 was 401,000 hectares, which was 65% of the cultivated area. It is estimated that the farm land irrigated area in 2025 will reach 460,300 hectares. The fruit irrigated area will increase by 21% in 2025 than in 2000. The major part of the irrigated agriculture is supported by groundwater development. The groundwater withdrawal for irrigation accounts for 67% of total use of water for irrigation. This has resulted in overexploitation of groundwater.

The main crops grown are wheat, maize and groundnut. The rotation pattern of winter wheat followed by summer maize dominates a large part of the area in the basin. In the past years, area under vegetable and melon has increased, while the area under grain crops has been decreasing.

1.5 Water Resources

The mean annual precipitation in Yantai and Weihai Municipalities based on the rainfall data from the rain gauge stations located in the area is 677.7 millimeters and 766.3 millimeters, respectively.

Surface water resources in Yantai and Weihai Municipalities have been estimated from the observed runoff data from 1956 to 1999 at the gauge and discharge (G&D) sites in the area.

The groundwater resource in Yantai and Weihai municipalities has been estimated separately for the hilly area and plain area. Total water resources in Yantai and Weihai municipality have been worked out after accounting for duplicating component. The details are shown in Table 3.

Table 3.
Water Resources of Jiaodong Peninsula Basin (10^6 m^3)

Municipality	Surface water	Ground-water	Double accounted amount	Total water resource
Yantai	2,580	895	610	2,865
Weihai	1,430	399	300	1,529
Total	**4,010**	**1,294**	**910**	**4,394**

It is proposed to import water to the extent of 383 million cubic meters from the eastern route of south-to-north water projects to meet the domestic and industrial needs.

Weihai and Yantai Municipalities are located on the sea coast. At present many industries are using sea water.

Table 4.
Main Projects to be Constructed and to be Extended

City	Project name	Controlled watershed (km^2)	Live storage (10^6 m^3)	Project function	Project status
Yantai	Laolan reservoir	-	120	Flood control	To be constructed
	Zhanjiagou reservoir	140	34	Irrigation	To be constructed
	Gaogezhuang reservor	140	30	Irrigation	To be constructed
	Wolong reservoir	240	16	Irrigation	To be constructed
Weihai	Boyu reservoir	159.2	47.5	Domestic water supply and irrigation	To be constructed
	Bahe reservoir	256	71.05	D&I water supply	To be extended
	Kunlongxing reservoir	136	32	D&I water supply, irrigation	To be extended
	Mishan reservoir	440	131	D&I water supply, irrigation	To be extended
	Longjiaoshan reservoir	277	59.16	Irrigation, D&I water supply	To be extended

The sea water utilization in Yantai Municipality is expected to reach 28 million cubic metres by 2005 and 73 million cubic metres by 2010. The sea water utilization in Weihai Municipality may reach 20 million cubic metres by 2005 and 50 million cubic metres by 2010.

1.6 Water Resources Development

In the Yantai Municipality, three large reservoirs - having an aggregate capacity of 533.1 million cubic metres, 24 medium reservoirs having 610.1 million cubic metres and 1078 small reservoirs having an aggregate capacity of 608.5 million cubic metres have been constructed by the year 2000. In the Weihai Municipality two large reservoirs having capacity of 385.2 million cubic metres, 14 medium reservoirs having capacity of 360.9 million cubic metres, 403 small reservoirs having capacity of 227.4 million cubic metres, and 3,307 ponds providing storage of 65.1 million cubic metres have been constructed by the year 2000. The projects that are planned to be constructed and extended for future scenario studies are shown in Table 4.

1.7 Population

The population of the basin in 2000 was 8.93 million and is estiamted to be 9.67 million in 2025.

The per capita availability of water resources in 2000 was 492 cubic meters, and it will be 454 cubic meters per year in 2025. The per capita availability of water resources of less than 1,000 cubic meters is considered as a critical value to maintain economic and social development. This value for the basin at present and in 2025 is far lower than the critical value.

The total cereal production in 2000 was 3.25 million tons. It is estimated that the total cereal production to meet the needs of the population of 2025 will be 3.71 million tons.

1.8 Water Demand

Present (2000) and projected (2025) water demand for different sectors for Jiaodong Peninsula basin is shown in Table 5.

Table 5.
Water Demand at Present (2000) and Projected for 2025

Sector	2000		2025	
	(10^6 m^3)	(%)	(10^6 m^3)	(%)
Irrigation	1,803	70	1,747	54
Industry	228	9	534	16
Domestic	378	15	615	19
Ecology	171	6	349	11
Total demand	**2,580**	**100**	**3,245**	**100**

CHAPTER 2
APPLICATION OF BHIWA MODEL

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, and

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 3 gives a schematic representation of the BHIWA model. The salient features of the model, including its various computational modules is Annexure 1.

2.1 Application of BHIWA Model to Jiaodong Peninsula Basin

The model was calibrated for the past (1980) and present

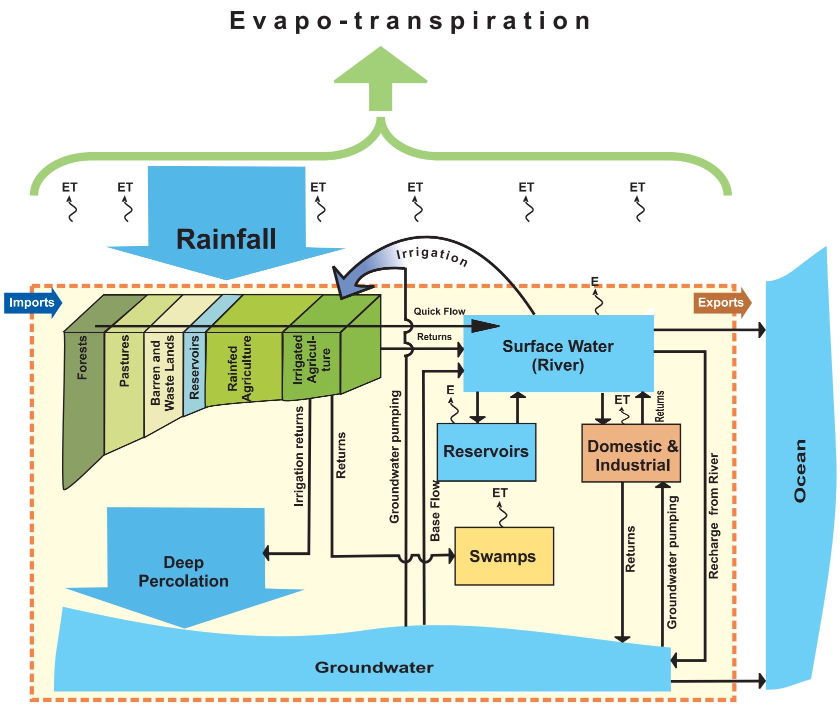

Figure 3. Schematic Diagram of BHIWA Model

(2000) conditions and applied to derive responses corresponding to past and future scenarios using monthly time steps. Studies are done at the sub basin level. The basin was divided into sub-basins on the basis of similar hydrologic and water use attributes. For modelling applications, the basin has been divided into two sub-basins as follows:

Sub Basin (SB 1): Drainage area lying in Yantai municipality – 13,746 km^2

Sub Basin (SB 2): Drainage area lying in Weihai municipality – 5,436 km^2

2.2 Data Used in Model Calibration

The following secondary data as per Annexure 2 have been used in the model study.

1. The monthly average rainfall for the period 1956-1999 observed at Yantai and Weihai rain gauge stations. (Table A2.1 of Annexure 2)
2. Monthly reference ET values in Yantai and Weihai Municipalities, estimated using ET values of Longkou station. (Table A2.2 of Annexure 2)
3. The crop coefficients for main crops grown in Yantai and Weihai Municipalities, estimated based on the results of Longkou station. (Table A2.3 of Annexure 2)
4. Crop coefficients of wheat grown in Yantai and Weihai Municipalities, estimated based on the results of Longkou station. (Table A2.4 of Annexure 2)
5. Water use for all sectors in the past and present conditions from 1984 to 2000 in Yantai and Weihai Municipalities. (Table A2.5 of Annexure 2)
6. Water requirements for D&I in the future (2025) in Yantai and Weihai Municipalities. (Table A2.6 of Annexure 2)

2.3 Land Use Parcels

Based on present (2000) land use statistics and crop rotation, 19 land use parcels have been considered as shown in Table 6. Parcels from P5 to P11 represent the rainfed agricultural land and parcels from P12 to P19 represent the irrigated agricultural land.

2.4 Scenario Development

Five scenarios have been studied for the year 2025. In various scenarios, irrigation expansion, variation of forest

Table 6.
Land Use Parcels in Jiaodong Peninsula 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 winter wheat and summer maize
P6	Rain-fed winter wheat and soyabean
P7	Rain-fed winter wheat and groundnut
P8	Rain-fed vegetables/melons
P9	Rain-fed fruit trees
P10	Rain-fed groundnut/potato
P11	Rain-fed winter wheat
P12	Irrigated winter wheat and summer maize
P13	Irrigated winter wheat and soyabean
P14	Irrigated winter wheat and groundnut
P15	Irrigated vegetables/melons
P16	Irrigated fruits trees
P17	Irrigated groundnuts
P18	Irrigated (sweet) potatoes/others
P19	Irrigated winter wheat

coverage, varying ratio of surface and groundwater irrigation, introduction of drip irrigation, and soil management aspects have been considered.

The description of the scenarios studied is given in Table 7.

The areas of land parcels for all the scenarios are shown in Table 8. Proportion of area coverage by natural vegetation, rainfed and irrigated agriculture in diifferent scenarios is shown in Figure 4. The net irrigated area (NIA) by source is shown in Figure 5.

The area under irrigated food grain crops in the past (1980) and present (2000) conditions as depicted in Figure 4 is the actual irrigated area, and accounts for 66 and 68 percent of the total irrigated areas, respectively. The total irrigated area for the future (2025) would be 1.16 times as large as that in the present condition. In the planting pattern of crops, the two-season wheat/maize and single-season crops dominates a large part of cropped area. For the future scenarios, the two seasonal crop area and the cropping intensity will be increased with the expansion of irrigated area. Due to limited sunlight and energy availability, there will be increase of cash crops and decrease of grain-crops, leading to decrease of overall cropping intensity.

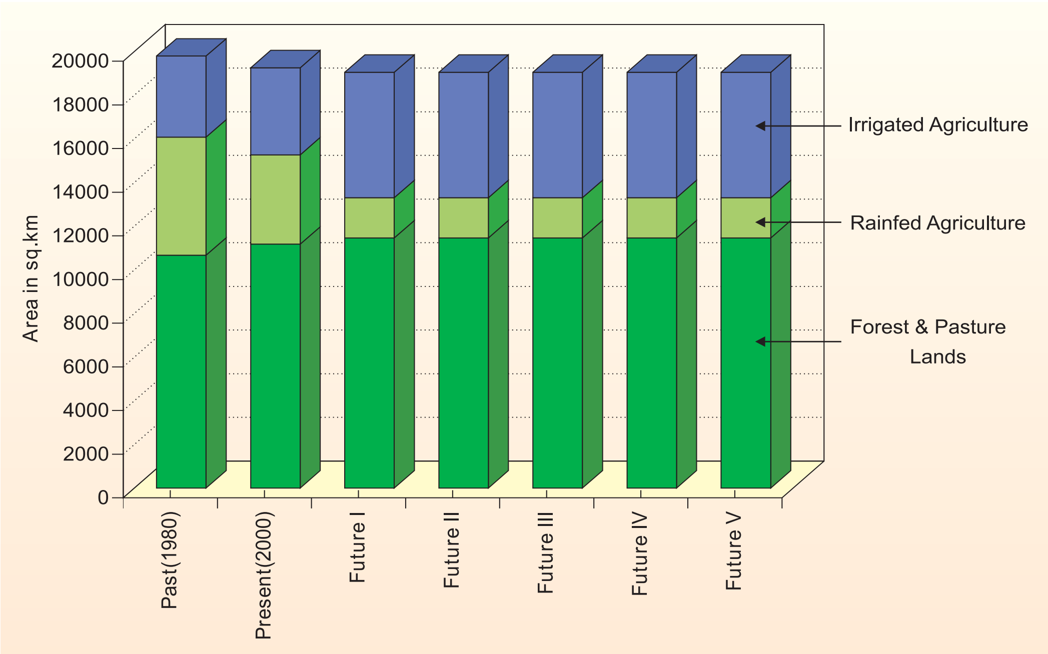

Figure 4. Area Coverage by Natural Vegetation, Rainfed and Irrigated Agriculture

Table 7.
Scenarios Studied in Jiaodong Peninsula Basin

Sl.No.	Scenario studied	Attributes	Description
1	Past (1980)	Around 1980	The land use, irrigated area, water use pattern represent the past conditions around the year 1980.
2	Present (2000)	Prevailing at 2000	The land use, irrigated area, water consumption , water use pattern as prevailed in the year 2000.
3	Future-I (2025)	Business As Usual	Irrigation expansion is based on local planning, the proportion of surface and groundwater irrigation same as at present, the covering rate of forest increases to 40% that of the present, and import of about 97 million cubic meters in Yantai and 50 million cubic meters water in Weihai.
4	Future-II (2025)	B as U without expansion of forest	Same as Future-I, but the rate of expansion of forest area is maintained at the present level.
5	Future-III (2025)	Better system management and reduced groundwater use.	Same as Future-II, but the ratio of surface irrigation to total irrigation increased from 0.3 at present to 0.5 in Yantai.
6	Future-IV (2025)	Same as Future-III with drip irrigation	Same as Future-III, but with adoption of more drip/micro-irrigation systems.
7	Future-V (2025)	Same as Future-III, more drip and soil management, more import of water and further reduction in groundwater use.	Same as Future-III, soil management in the barren lands, import 300 million cubic meters water, and further reduction in groundwater withdrawal.

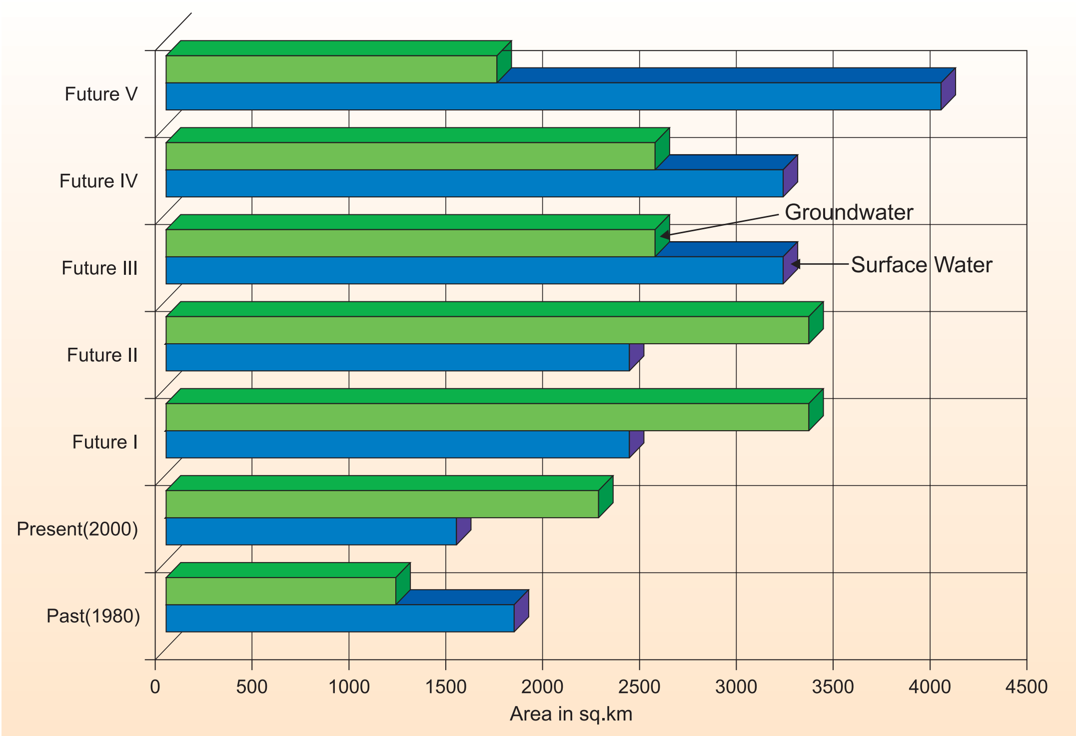

Figure 5. Net Irrigated Area by Source

Table 8.
Area of Land Parcels for the Various Scenarios (km^2)

Scenario	Past (1980)	Present (2000)	Future-I	Future-II	Future-III	Future-IV	Future-V
P1	3,837	5,934	7,673	5,934	5,934	5,934	5,934
P2	0	0	0	0	0	0	0
P3	6,840	5,242	3,789	5,528	5,528	5,528	5,528
P4	113	185	165	165	165	165	165
P5	1,738	1,283	541	541	541	541	541
P6	322	231	137	137	137	137	137
P7	52	334	91	91	91	91	91
P8	184	462	265	265	265	265	265
P9	809	643	410	410	410	410	410
P10	1,484	913	368	368	368	368	368
P11	820	223	34	34	34	34	34
P12	1,055	1,073	1,714	1,714	1,714	1,714	1,714
P13	195	193	433	433	433	433	433
P14	191	313	490	490	490	490	490
P15	111	386	788	788	788	788	788
P16	205	873	1,106	1,106	1,106	1,106	1,106
P17	505	520	750	750	750	750	750
P18	403	265	428	428	428	428	428
P19	319	108	0	0	0	0	0
Total	**19,182**	**19,182**	**19,182**	**19,182**	**19,182**	**19,182**	**19,182**

The water use proportion of surface irrigation to total irrigation in Yantai and weihai for different scenariois is shown in Table 9.

2.5 Calibration of the Model

The available data for past (1980) and present (2000) conditions were used for calibration of the model. The calibration was limited to match the observed and estimated values in the following situations:

1. Comparing the yearly outflow with the observed runoff in Yantai and Weihai sub basins. The observed runoff was estimated from available data provided by the local agency.
2. Comparing the yearly recharge to groundwater from natural rainfall and surface water as computed by the model with the estimates made by the local agency.

Table 9.
Water Use Pattern of Surface Irrigation to Total Irrigation in Different Scenarios

Scenarios	Proportion of surface irrigation to total irrigation	
	Yantai	Weihai
Past (1980)	0.6	0.6
Present (2000)	0.3	0.7
Future I (2025)	0.3	0.7
Future II (2025)	0.3	0.7
Future III (2025)	0.5	0.7
Future IV (2025)	0.5	0.7
Future V (2025)	0.7	0.7

Table 10.
Comparison of Calculated and Observed Results for Past and Present Conditions

Condition	Parameter	Sub basin	Calculated by the model	Observed	Variation (%)
Past (1980)	Yearly outflow (10^6 m^3)	Yantai	1528	1710	-10.6
		Weihai	1155	1100	5.0
		Total	**2683**	**2810**	**-4.5**
	Yearly total recharge to groundwater (10^6 m^3)	Yantai	858	895	-4.12
		Weihai	403	399	1.0
		Total	**1261**	**1294**	**-2.53**
	Groundwater fluctuation within the years (mm)	Yantai	362	401.4	-9.81
		Weihai	199	222.9	-10.59
Present (2000)	Yearly outlfow (10^6 m^3)	Yantai	1136	1165	-2.5
		Weihai	947	912	3.8
		Total	**2082**	**2077**	**0.3**
	Yearly total recharge to groundwater (10^6 m^3)	Yantai	668	NA	-
		Weihai	341	NA	-
		Total	**1010**	**-**	**-**
	Groundwater fluctuation within the years (mm)	Yantai	307	375.3	-18.1
	Weihai	169	141.9	18.9	

3. Comparing the groundwater fluctuation within an average year with the observed groundwater fluctuation.

4. Comparing irrigation water use with actual water use as observed by the local agency.

The comparison of items 1, 2 and 3 above is shown in Table 10.

It can be seen from Table 10 that the values calculated by the model fairly match with the observed ones. The model under-estimated the actual outflow and over-estimated recharge to groundwater slightly. The outflow and recharge to groundwater at present has a marked reduction than the past condition. The main reason might be due to the change in land use. The rate of forest coverage has gone up to 30 percent at present from 20 percent in the past. Consequently, the consumption of water by the nature (forest) sector has increased. The comparison of irrigation water use with actual water use is given in Table 11.

The calculated groundwater storage change within the years was mostly under-estimated compared to observed values. Due to non-availability of data, the groundwater

Table 11.
Comparison of Calculated and Actual Irrigation Water Use for Past and Present Condition (10^6 m^3)

Condition	Sub basin	Calculated by the model	Actual water with-drawal	Variation (%)
Past (1980)	Yantai	767	955	-19.6
	Weihai	237	251	-5.4
	Total	**1005**	**1205**	**-16.6**
Present (2000)	Yantai	687	827	-17.0
	Weihai	232	226	2.6
	Total	**919**	**1054**	**-12.8**

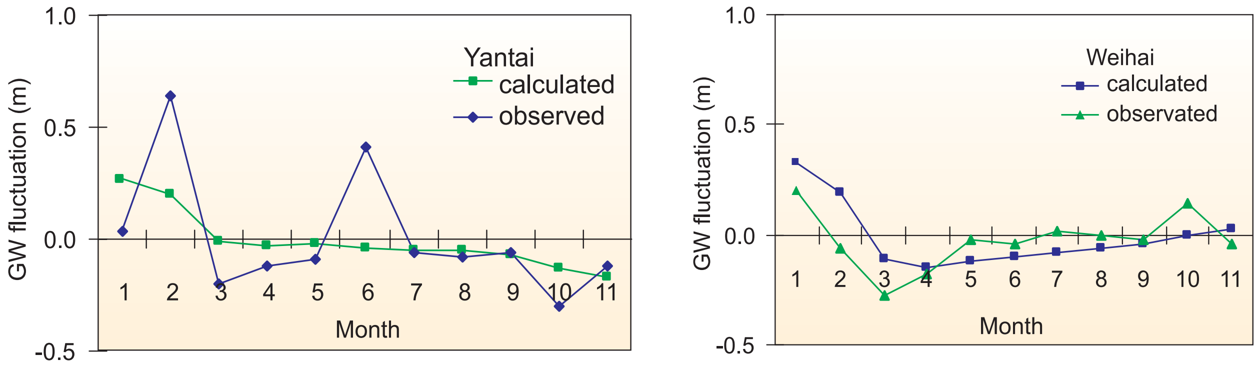

Figure 6. Comparison of Average Monthly Groundwater Fluctuation between Calculated and Observed Values

withdrawal given in the model was assumed to be uniform for every month, equal to the proportion of available yearly groundwater withdrawal, as a result the calculated groundwater fluctuates smoothly. However, the actual proportion of groundwater withdrawal is different among months. During the dry season and peak crop water demand, the groundwater withdrawal would constitute a large part of water use. This might be the main reason for the difference between calculated and observed groundwater storage change. However, precise matching in the model was not tried. Taking the difference of groundwater level variation between two consecutive months as groundwater fluctuation, Figure 6 shows the comparison of average groundwater fluctuation between calculated and observed values in the present (2000) condition.

The calculated results are in good agreement with the observed values.

It can be seen from Table 11 that the calculated irrigation water use was under-estimated, with larger differences occurring in Yantai. The difference may be due to the fact that the actual ET is over-estimated since the calculation time-step was one month, and therefore, the effective rainfall might have been overestimated. In general, the results calculated by the model are acceptable, and the results show that the selected crop parameters are suitable for local condition.

The calibration shows that the model is able to characterise the hydrological behaviour of Jiaodong Peninsula well, and can be used for predicting future hydrological cycle and water use situations. Based on the calculated results, the main parameters of the model were accepted with the following values.

1. The soil moisture storage capacity varies with land use: 150mm for forests, 60mm for agricultural lands and 40mm for bare lands or land used for other purposes. Generally, high storage capacity would lead to higher evapo-transpiration and lower flows after rainfall.
2. About 75 percent of excess water was assumed to contribute to surface flow (quick runoff) and the remaining 25 percent was assumed to contribute to groundwater. Under this assumption, reasonable outflow and recharge to groundwater were obtained.
3. In the calculation of actual ET, the exponential index, which represents the reduction of evapo-transpiration rate with the reduction of available soil moisture, was taken as 0.8.
4. A groundwater recession coefficient of 0.25 was adopted.

2.6 Simulation of Different Scenarios

The model was applied to simulate the responses for five future scenarios with average rainfall conditions. The abstracted results of annual overall water balance, annual river and surface water balance and annual groundwater balance are presented in the tables 12,13,and 14 respectively. These results are also shown in Figure 7, 8 and 9 respectively.

2.7 Discussion of Results and Findings

Based on the past and present conditions and average rainfall in Jiaodong Peninsula basin, the hydrological components and agricultural water use calculated by the model are seen to be in good agreement with the actual values. The observed groundwater status indicates that the calculated groundwater fluctuation within these years compares well with the observed results, and the variation

Table 12.
Annual Overall Water Balance (10^6 m^3)

Components	Past (1980)	Present (2000)	F-I	F-II	F-III	F-IV	F-V
Inputs							
Rainfall	13,748	13,748	13,748	13,748	13,748	13,748	13,748
Imports	0	0	147	147	147	147	295
Groundwater flow from other basins	0	0	0	0	0	0	0
Total inputs	**13,748**	**13,748**	**13,895**	**13,895**	**13,895**	**13,895**	**14,042**
Outputs							
Consumptive use total	10,956	11,796	12,723	12,361	12,353	12,352	12,277
River flows total	2,683	2,082	1,224	1,608	1,607	1,647	1,903
Export (surface)	0	0	0	0	0	0	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	**13,639**	**13,878**	**13,947**	**13,968**	**13,960**	**13,959**	**14,100**
Storage changes							
Surface storages	0	0	0	0	0	0	0
Groundwater storage	0	-54	0	0	0	0	0

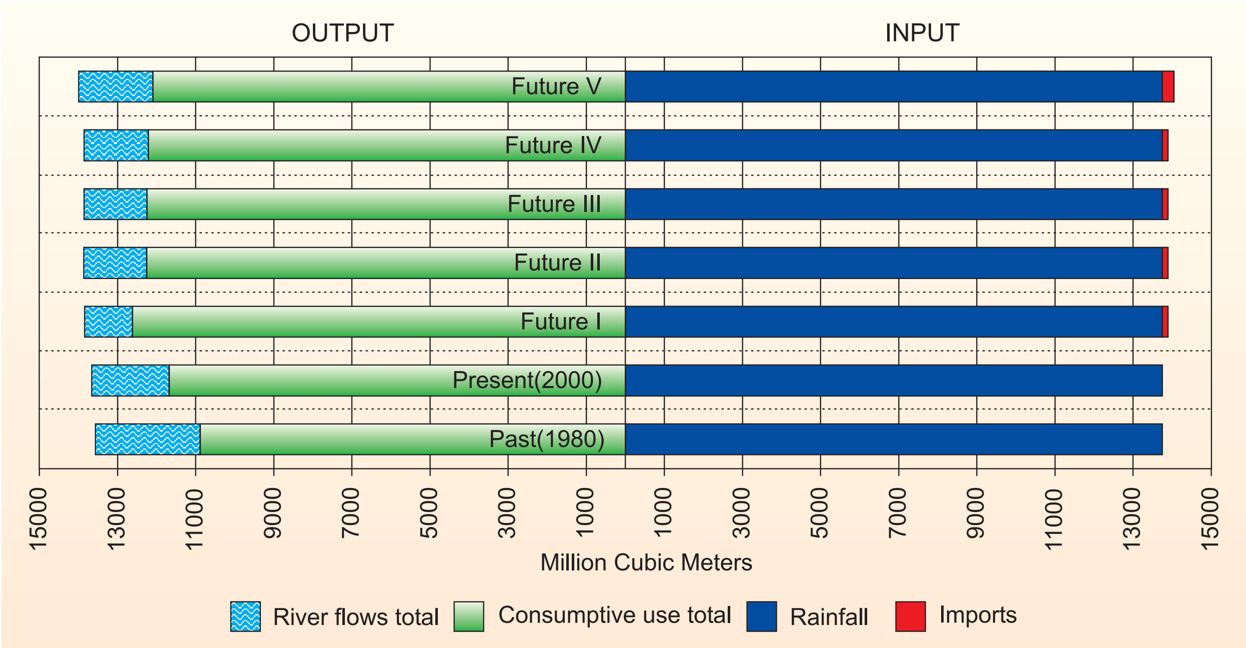

Figure 7. Annual Overall Water Balance

Table 13.
Annual Surface Water Balance (10^6 m^3)

Components	Past (1980)	Present (2000)	F-I	F-II	F-III	F-IV	F-V
Inputs							
Quick runoff from rainfall	2,645	2,173	1,833	2,108	2,108	2,108	2,173
Base flow	570	230	240	406	302	309	290
Returns to surface from surface irrigation	70	39	58	58	52	50	60
Returns to surface from groundwater irrigation	6	8	9	9	6	5	3
Returns to surface from D&I withdrawals	138	229	552	552	552	552	552
Sub-total, returns to surface	213	276	620	620	610	607	615
Imports	0	0	147	147	147	147	295
Total inputs	**3,428**	**2,680**	**2,841**	**3,281**	**3,167**	**3,171**	**3,373**
Outputs							
Surface withdrawals for irrigation in the basin	708	446	592	650	727	690	836
Surface withdrawals for D&I in the basin	37	137	424	424	534	534	534
Total surface withdrawals, for use in the basin	746	583	1016	1074	1261	1224	1370
Natural and induced recharge from river to groundwater	0	0	600	600	300	300	100
Outflow to sea	2,683	2,082	1,224	1,608	1,607	1,647	1,903
Export	0	0	0	0	0	0	0
Total output	**3,428**	**2,665**	**2,841**	**3,281**	**3,167**	**3,171**	**3,373**

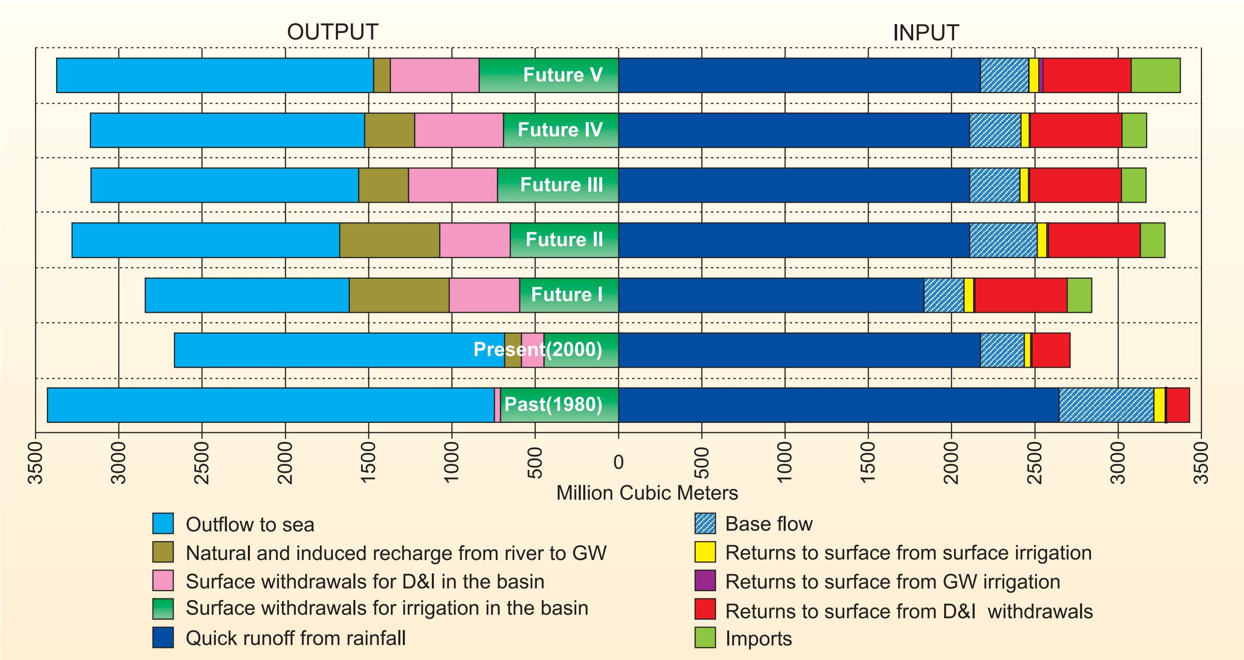

Figure 8 Annual Surface Water Balance

Table 14.
Annual Ground Water Balance (10^6 m^3)

Components	Past (1980)	Present (2000)	F-I	F-II	F-III	F-IV	F-V
Inputs							
Natural recharge from rainfall	852	682	552	660	660	660	682
Returns to groundwater from surface irrigation	281	157	234	234	209	199	241
Returns to groundwater from groundwater irrigation	107	149	178	178	105	100	64
Returns to groundwater from D&I withdrawals	21	39	97	97	97	97	97
Sub-total, returns to groundwater	409	346	509	509	411	395	402
Natural and induced recharge from river to groundwater	0	0	600	600	300	300	100
Groundwater flow from other basins	0	0	0	0	0	0	0
Total inputs	**1,261**	**1,028**	**1,661**	**1,769**	**1,371**	**1,356**	**1,184**
Outputs							
Groundwater irrigation withdrawals, including groundwater pumping to surface canals	296	473	715	657	465	442	286
Groundwater withdrawals for D&I use	257	409	725	725	615	615	615
Sub-total groundwater withdrawals	554	882	1,440	1,382	1,081	1,057	901
Base flow to rivers	570	230	240	406	302	309	290
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	**1,123**	**1,112**	**1,680**	**1,788**	**1,382**	**1,366**	**1,191**

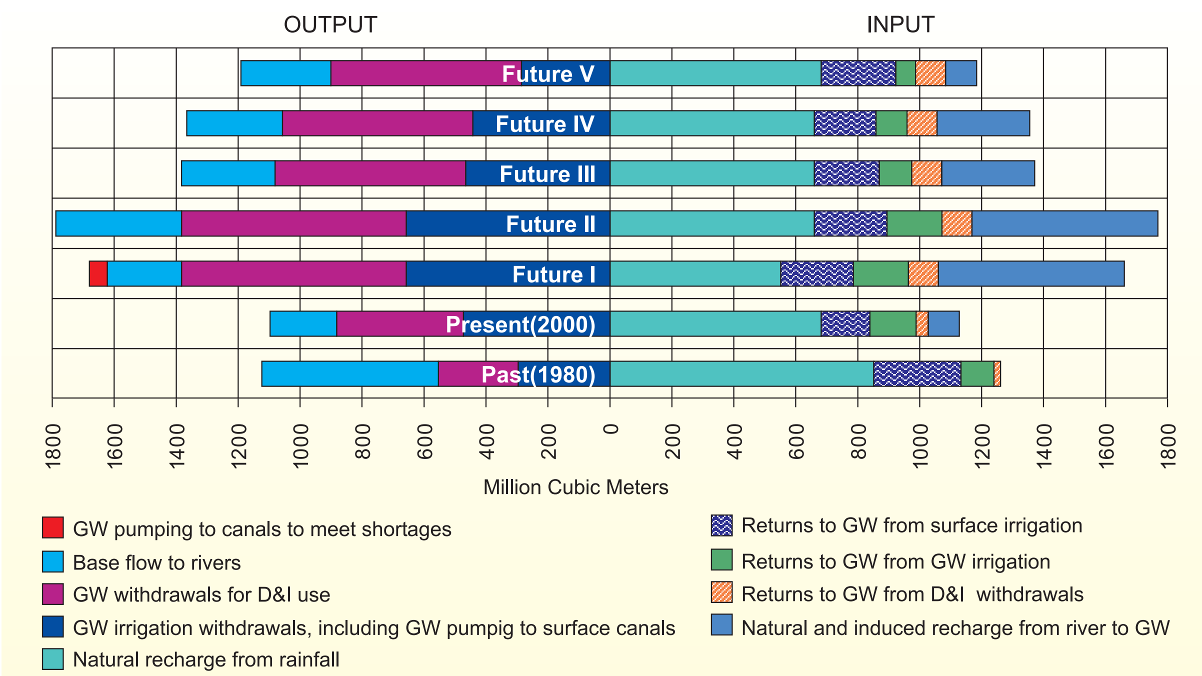

Figure 9. Annual Groundwater Balance

tendency of groundwater fluctuation matches with the observed values.

Compared to the past (1980) condition, the outflow and recharge to groundwater (2000) at present has reduced largely, in which the former has decreased by 22 percent and the later by 20 percent. The withdrawal of groundwater accounts for 44 percent of total groundwater inputs at past, and 86 percent at present, resulting in the reduction of the base flow to a great extent.

The model indicates that the total recharge to groundwater in the past was 1,261 million cubic meters, which is about 9 percent of the average annual rainfall of 13,748 million cubic meters. These values appear reasonable, and match the estimates made by the local agency.

The model displays extreme sensitivity for land use change, especially the shift between barren lands (or other unused lands) and forest area. When the forest coverage is extended from 30 percent to 40 percent, the consumptive use showed a marked rise, thus reducing the surface water availability.

In the present condition, the actual irrigated area is only 68 percent of total irrigable area, and the water withdrawal for irrigation computed by the model is 919 million cubic meters, which was a little lower than the observed values. With the expansion of irrigation in the future scenarios, the total irrigated area would be 1.16 times the present condition. The water requirement for agriculture under planned development condition (Future III) would reach 1,307 million cubic meters, an increase of 42 percent of water withdrawal over the available water. While the proportion of surface irrigation to total irrigation is maintained, of the total water requirement for agriculture and D&I, 1,074 million cubic meters is supplied from surface water and 1,440 million cubic meters from groundwater (Future-I). The capacity of surface water supply in scenario future-I (2025) will reach 1,611 million cubic meters, completely meeting the demand of surface water withdrawal, but the groundwater withdrawal would far exceed the recharge. Therefore, various water management measures, such as changing water use pattern of surface water and groundwater, further improving the efficiency of water use, import of more water, natural and induced recharge from river to groundwater or pumping water from groundwater to river to maintain the river and groundwater balance, need to be adopted.

2.8 Consumptive Use of Water

Future scenarios I to V considered the irrigated area as planned by the local agency. Due to expansion of the irrigated area and increased use of irrigation water, the agricultural consumptive use would go up compared to the past and present conditions, especially the additional consumptive use for irrigation. By adopting water saving measures such as improved irrigation efficiency, more area under drip/ micro irrigation and better soil management, the requirement of irrigation water for future scenarios has been reduced, as in Future IV and V.

For the present condition, the total consumptive use is 11,795 million cubic meters, including nature sector use of 6,114 million cubic meters, agricultural sector use of 5,404 million cubic meters and people sector (D&I) use of 277 million cubic meters. The agricultural sector use is made up of evaporation from soil moisture in rain-fed and from irrigated lands, additional ET met from irrigation, and reservoir evaporation. Non-beneficial consumption would be from reservoir, waterlogged areas, or from lands without crops in particular seasons. In the total consumptive use, non-beneficial ET is 2,291 million cubic meters in the nature sector and 686 million cubic meters in the agricultural sector. The beneficial ET in the nature sector changes obviously with the expansion of forest area or without it. Corresponding to 20, 30 and 40 percent of forest coverage for the past, present and Future I scenarios, the beneficial ET in the nature sector is 2,473, 3,823 and 4,946 million cubic meters respectively, and non-beneficial ET decreases accordingly. Total ET in the nature sector has increased by 12 percent over the past condition. If the forest coverage continues to expand in the same rate, the total ET in the nature sector would increase by 8 percent in future (2025) over the present condition.

In the agricultural sector, the non-beneficial ET at present (2000) is 12.7 percent. With the expansion of irrigated area and increase of cropping intensity for future scenarios, the proportion of non-beneficial ET reduces to 10 – 11.3 percent. In Jiaodong Peninsula basin, along with the adjustment of cropping pattern in which the grain-crop area reduces and cash-crop area rises, the potential of increasing cropping intensity is limited. To reduce the non-beneficial ET in the agricultural sector, proper soil and water management in the fallow lands can lead to an improved ET, such as in scenario Future V that envisaiges better soil management in the barren land. Non-beneficial consumption in the irrigated land would be reduced to12 percent.

Table 15.
Consumptive Use (ET) by Different Sectors (10^6 m^3)

Sectors	Past (1980)	Present (2000)	Future 2025				
			F-I	F-II	F-III	F-IV	F-V
Nature sector							
Beneficial	2,473	3,823	4,946	3,823	3,823	3,823	3,823
Non-beneficial	2,986	2,291	1,656	2,416	2,416	2,416	2,416
Total	**5,459**	**6,114**	**6,602**	**6,239**	**6,239**	**6,239**	**6,239**
Agriculture sector							
Beneficial	4,763	4,718	4,985	4,985	4,977	4,975	4,978
Non-beneficial	598	686	637	637	637	637	559
Total	**5,361**	**5,404**	**5,622**	**5,622**	**5,614**	**5,612**	**5,537**
People sector							
D&I	136	277	500	500	500	500	500
Total of all sectors	**10,956**	**11,795**	**12,724**	**12,361**	**12,353**	**12,351**	**12,276**

Compared to the present condition, the total irrigated area in the future scenarios increases from 4,92,800 ha to 5,70,900 ha, an increase of 16 percent. The agricultural consumptive use increases by about 3.5 percent and this consumptive use increase mainly comes from additional irrigation consumption. Owing to the adoption of water-saving measures, the increase in irrigation water use is not large. Consequently, increase in the agricultural consumptive use is less, especially in scenario Future V where the increase is only 2 percent.

The consumptive use (evapo-transpiration) by different sectors is shown in Table 15 and depicted in Figure-10.

2.9 Surface Water Use

Withdrawal of surface water in the past and at present is similar and equal to 22 percent of total inputs, but the return flows contribute 6 percent of total inputs in the past and 10 percent at present. Thus there is a more risk of pollution of downstream water at present than in the past. Also, the base flow availability reduced significantly at present due to more groundwater use.

In future scenarios, the estimated water requirement in the irrigated area is far larger than actual irrigation water use, and the water use for D&I is also very high. The withdrawal of surface water reaches to 33 – 41 percent of the total inputs. With reduced groundwater use in Yantai, the withdrawal to input ratio for scenarios Future III and IV reaches to about 41 and 40 percent, respectively, and return flows to input ratio approaches 19 percent. Compared to Future II, the withdrawal of surface water has a large increase, but return flows to input ratio increases only a little. With further reduced groundwater withdrawal and more import of water, scenario Future V has 41 percent of surface withdrawal to total inputs, and the return flows to input ratio is a little lower than that of other future scenarios.

In all future scenarios, the base flow and river outflows are affected by the pattern of development, and reaches the lowest value for scenario Future I. From scenarios Future I to Future V, the total river flows improve gradually. The monthly river flows for past, present and future IV are shown in Figure 11. The outflow to sea in scenario Future V approaches the available level and only 4 percent lower than that of the present condition.

The model output shows that the actual withdrawal of surface water at present is 583 million cubic meters. For Future I scenario, the withdrawal requirement for agriculture and D&I from surface water would reach 1,074 million cubic meters, and additional induced recharge to maintain the groundwater balance is 600 million cubic meters, reaching the maximum capacity of surface water supply.

2.10 Groundwater Use

In the Jiaodong Peninsula basin, extensive groundwater use has been practiced. In the past (1980), withdrawal of

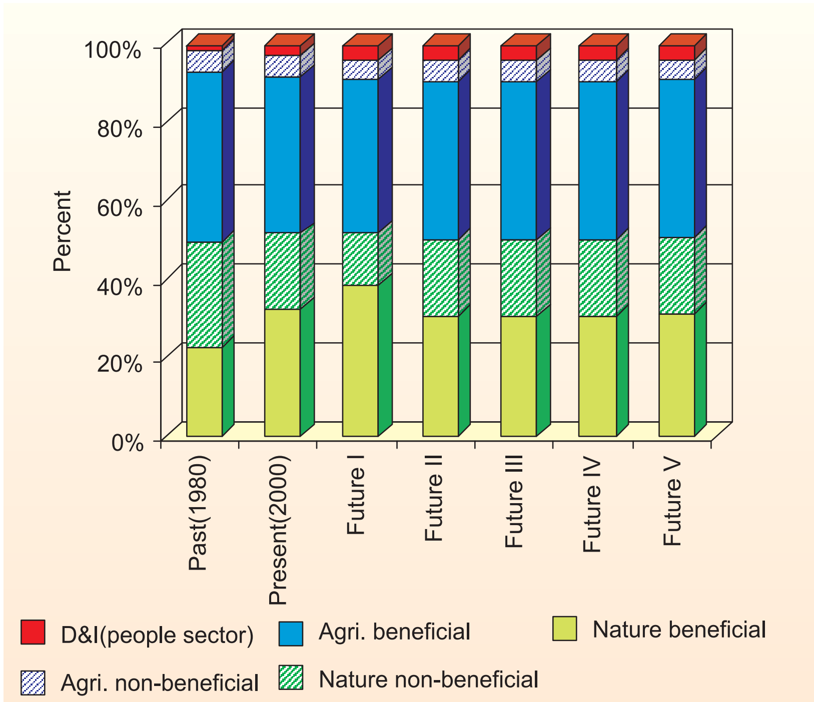

Figure 10. Consumptive Use (ET) by Different Sectors

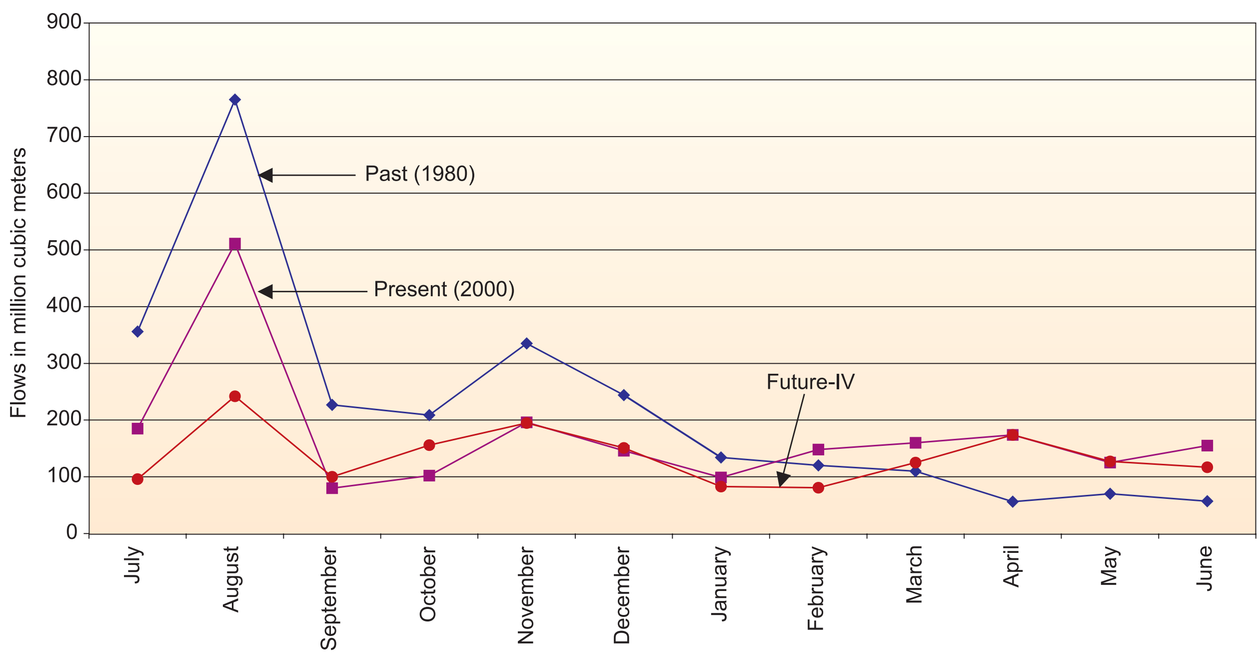

Figure-11. Monthly River Flows in Jiaodong Peninsula Basin

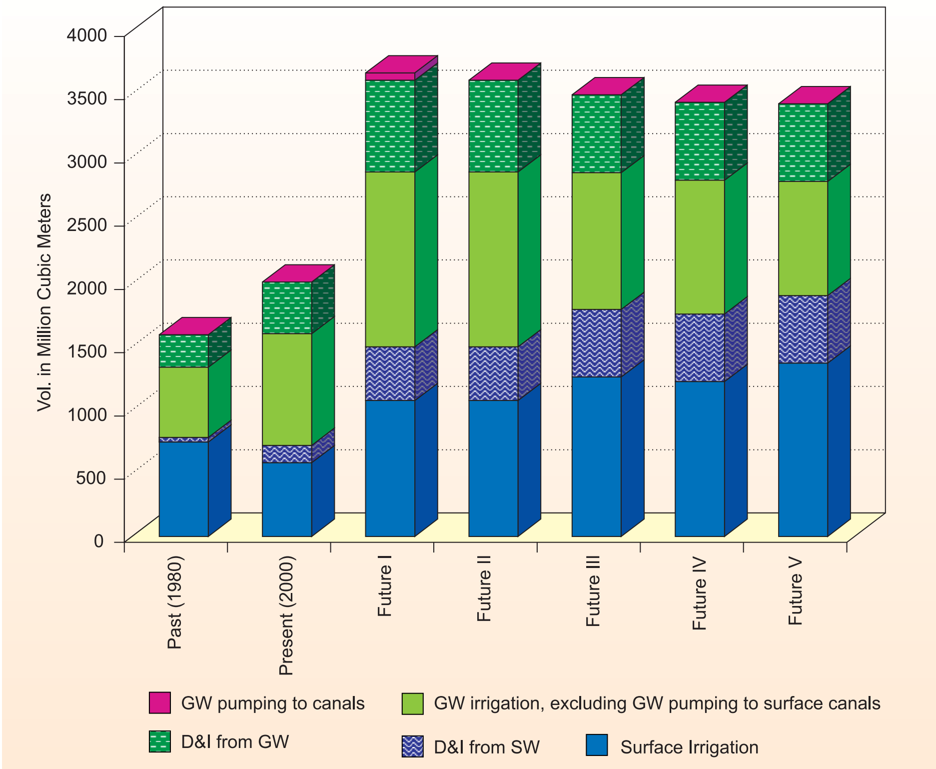

Figure 12. Composition of Water Withdrawals in Jiaodong Peninsula Basin

groundwater constituted 44 percent of the inputs and the return flow was 32 percent of the inputs. In the present (2000) condition, withdrawal of groundwater accounts for 86 percent of the inputs. The groundwater withdrawal at present has significantly increased. However, the return flows to input ratio has increased only marginally. The groundwater withdrawal exceeds the possible recharge rate, and indicates the unsustainable groundwater balance. For scenario Future I with business as usual, the withdrawal of groundwater is still 87 percent of the inputs and even though 600 million cubic meters is an induced recharge from river to groundwater, the return flows to input ratio is declining. If the forest cover is not expanded as in Future II, the withdrawal of groundwater decreases to 78 percent of the inputs with the same recharge from river to groundwater, and the base flow availability is improved.

In order to maintain the groundwater balance, the proportion of groundwater withdrawal should be reduced, especially for Yantai. When the proportion of surface irrigation to total irrigation in Yantai for scenario Future III is increased from 30 to 50 percent, the withdrawal remains similar to Future II but with 300 million cubic meters of induced recharge. With more drip irrigation (Future IV), further reduced groundwater use and more import of water (Future V), the withdrawals would constitute 78 and 76 percent of the inputs respectively. Whereas the induced recharge for Future V scenarios decreases to 100 million cubic meters, the return flow to input ratio increases slightly, and Future V scenario reaches an approximate balance state.

The composition of water withdrawals of both surface water and groundwater for different scenarios is shown in Figure 12. The irrigated cropped areas and withdrawals are shown in Figure 13. In the present and in the scenario with the planned irrigation expansion, the withdrawals depend mainly on the pattern of surface and ground water use.

2.11 Groundwater Pumping and Induced Recharge

The withdrawals from surface water and groundwater would be met from the available resources. When the surface water was not available, additional pumping from ground water to the surface canals was required to fulfil the

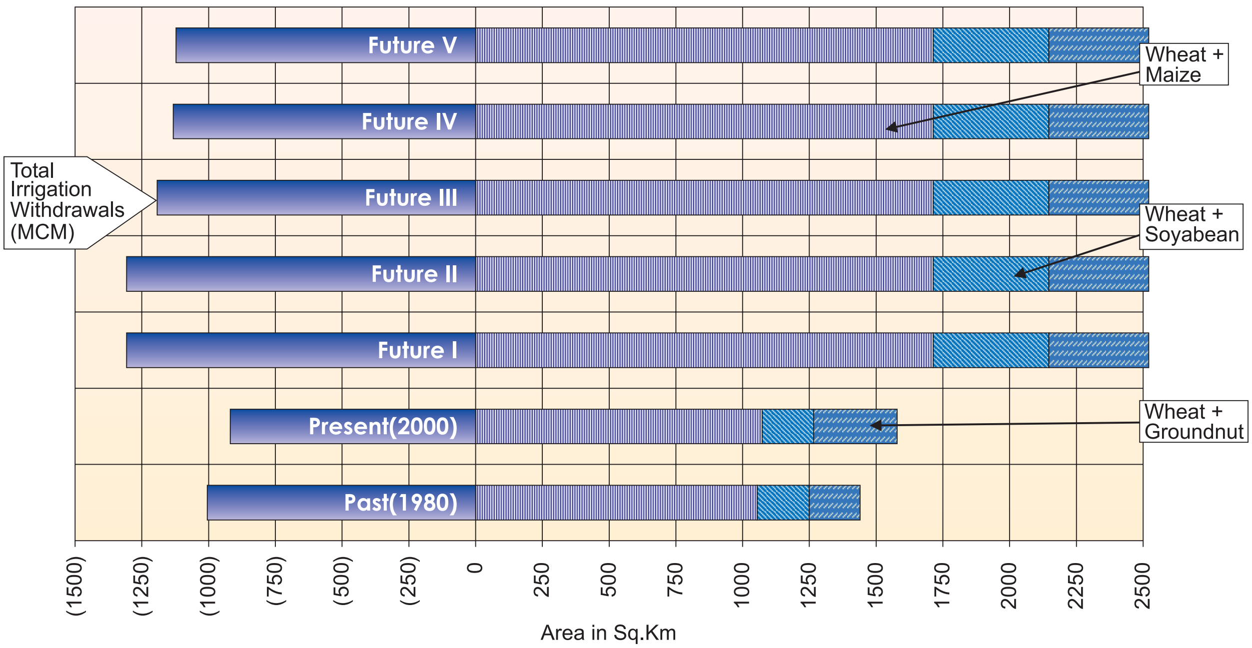

Figure 13. Irrigation Withdrawals and Irrigated Cropping Pattern (two seasonals)

surface water demands. Similarly, due to heavy groundwater withdrawals, the sustainability of the groundwater storage under the average recharge conditions would be disturbed, and the assumption of natural and induced recharge from surface to groundwater would be required. The demand for groundwater pumping into canals and natural and induced recharge for all scenarios are given in Table 16. The groundwater pumping to canals is required at the time when the river flow is low and the water requirement for crops is high. Whereas the natural and induced recharge from river to groundwater is mostly in the high flow months. Obviously, to maintain available 30 percent proportion of surface water irrigation to total irrigation, more natural and induced recharge from river to groundwater for scenarios Future I and II was needed as the groundwater was overexploited. While the proportion of surface water irrigation to total irrigation in Yantai increases to 50 percent such as in scenarios Future III and IV, the natural and induced recharge could be reduced, but the groundwater withdrawal approaches or exceeds the recharge rate, and the groundwater balance would confront crisis. If the proportion of surface water irrigation to total irrigation in Yantai is further increased to 70 percent and more water is imported, the groundwater withdrawal to input ratio can be maintained at the similar level and the natural and induced recharge could be reduced, and the groundwater could be maintained in an appropriate balance for a long time. Given surface storage filling and depletion for all future scenarios, the groundwater pumping to surface canals for meeting shortages in surface water irrigation would be zero except for Future-I in which 58 million cubic meters water is needed to meet the filling of surface

Table 16.
Requirements of Ground Water Pumping into Canals and Natural and/or Induced Recharge from River to Groundwater for all Scenarios (10^6 m^3)

Description	Past	Present	Future I	Future II	Future III	Future IV	Future V
Natural & induced recharge from river to ground water for balancing the groundwater	0	0	600	600	300	300	100
Groundwater pumping to surface canals for meeting shortages in surface irrigation	0	0	58	0	0	0	0

Table 17.
Water Situation Indicators in Jiaodong Peninsula

Indicator	Past	Present	Future I	Future II	Future III	Future IV	Future V
Indicator1	0.127	0.218	0.358	0.327	0.398	0.386	0.406
Indicator 2	0.062	0.103	0.218	0.189	0.193	0.191	0.182
Indicator 3	0.439	0.858	0.867	0.781	0.788	0.780	0.761
Indicator 4	0.324	0.336	0.306	0.288	0.300	0.292	0.340

storage. If other non-conventional water sources such as saline water, treated sewage water and seawater use could be developed to meet the shortages; the surface water and groundwater situation could be improved further.

2.12 Water Situation Indicators

Four water situation indicators were proposed to depict the level of water use (withdrawals) and potential of hazard (due to return flow) to water quality. The values of these indicators for Jiaodong Peninsula basin are presented in Table 17. Indicators 1 and 2 represent respectively, the proportion of surface withdrawal and return flows to the total surface water inputs. Indicators 3 and 4 represent respectively the proportion of groundwater withdrawal and return flows to the total groundwater inputs. It can be seen that the groundwater withdrawal in Jiaodong Peninsular basin was highly stressed than past condition, and groundwater quality was under moderate threat. With the utilization of surface water, the return flows to input ratio would increase largely compared to past and present conditions, indicating more risk of pollution for surface water resources, especially downstream water. Therefore, the related prevention measures must be adopted to lighten the pollution pressure as soon as possible along with the change of water use pattern.

2.13 Major Findings

1. The model output shows that the outflow to sea and recharge to groundwater decreased from the past (1980) to the present (2000). The yearly outflow to sea was 2,683 million cubic meters in the past and 2,082 million cubic meters in the present condition. The yearly total recharge to groundwater was 1,261 million cubic meters in the past, and 1,028 million cubic meters in the present. These results matched the observed values obtained by the local agency, thus giving a fairly good validation to the model.
2. The type of land parcels have a large impact on the consumptive use, thus influencing the total hydrological cycle, especially the area shift between barren land and forestland. Corresponding to 20, 30 and 40 percent forest coverage in the past, present and Future I scenarios, the consumptive use from the nature sector would be 5,459, 6,114 and 6,601 million cubic meters respectively, comprising beneficial consumption as 45, 63 and 75 percent of the total consumption, respectively. Total ET in the nature sector has increased by 12 percent over the past condition. If the forest coverage continues to expand at the same rate, total ET in the nature sector would increase by 8 percent in the future (2025). Therefore, maintaining the prevailing forestland and moderately developing the forest area in the future would be a sensible choice for sustainable water resources development.
3. The base flow from groundwater to river is decreasing from 570 million cubic meters per year in the past to 230 million cubic meters per year at present; indicating decreasing groundwater storage, and signifying the crisis of groundwater depletion. For Future I scenario with business as usual, the flow from groundwater continues to reduce.
4. The actual irrigated area at present is 68 percent of the irrigable area, and the actual water withdrawal computed by the model is 919 million cubic meters. With the expansion of irrigated area for future scenarios, the irrigable area would be 1.16 times the present condition. The model shows that the water requirement for agriculture under planned development condition (Future I) is 1,307 million cubic meters, increasing to 42 percent of water withdrawal. While the proportion of surface water irrigation to total irrigation is maintained at 30 percent, out of the total water requirement for agriculture and D&I 1,074 million cubic meters will be met from surface water and 1,440 million cubic meters from groundwater. The capacity of surface

water supply for future scenario (2025) will reach to 1,611 million cubic meters, fully meeting the demand of surface water withdrawal, but the groundwater withdrawal would far exceed the total recharge.

5. In order to sustain the groundwater balance, the groundwater withdrawal should be reduced, especially for Yantai. While the proportion of surface water irrigation to total irrigation increases from 30 to 50 percent and with better water and soil management is adopted, the groundwater withdrawal decreases to 1,081 million cubic meters and 1,057 million cubic meters for Future III and IV scenarios, respectively. With further reduced groundwater use, the groundwater withdrawal for Future V scenario would be 901 million cubic meters.

6. For Future I scenario with business as usual, the river outflow reaches the lowest of all scenarios, affecting the environmental water requirement to maintain the basic water demand of the river. By adopting different measures, the river outflow from Future I to V scenarios is improved gradually. Compared to Future IV scenario, with more water import and better soil and water management, the outflow to sea could be improved and approaches the available level - with only 4 percent lower than that of present condition.

7. The model output shows that Jiaodong Peninsular basin is likely to face a serious water shortage in the future. The groundwater withdrawal will be highly stressed than in the past condition. In order to mitigate the adverse consequences of groundwater withdrawal, the groundwater should be moderately exploited. With the utilization of surface water, the return flows to input ratio would inevitably increase in the future, indicating more pollution risk for surface water resources, especially in the downstream water bodies. Therefore, related measures must be adopted to reduce the pollution as soon as possible along with the change in water use pattern.

8. With the increase of industrial and domestic water use, the agriculture would confront with the crisis of water shortage. Enlarging the strategy of water-saving measures would enhance remarkably the efficiency of irrigation water use, and decrease the water withdrawal for irrigation. Water is also need to be imported from outside the basin to meet the domestic and industrial demands in order to reduce the confrontation between agriculture and D&I water use.

9. There would be a serious water shortage in the future, should the consumption by industries further expanded compare to the planned level. It is therefore highly essential to implement the optimal allocation and combined regulation of multi-water resources, increase the water use and re-use efficiency.

CHAPTER 3

POLICY RELATED ISSUES EMERGING FROM THE STUDY

3.0 General

The detailed hydrologic modelling and analysis of the basin for various scenarios has 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 ground water 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 policy 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 sustainable water resources use, the economic and social development requires to change perception of water continuously and promote water resources management at a better level. Following are the important aspects that need to be considered for better water management.

- Development of harmonious coexistence between man and nature to realize sustainable development;
- Change from 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, conservancy and protection while developing, utilizing and managing water resources;
- Strengthening the application of non-structural measures and emphasizing scientific management of water works;
- Shifting from supply-oriented water management to demand-oriented water management;
- Adopting pressurized irrigation and promoting efficient water use on larger scale;
- Realizing that water is a natural resource, structural measures should be taken up to turn water into a commodity;
- Proper management and monitoring of water quantity, water quality and hydropower, and multi-line management of water supply, use, drainage and reuse to integrated water allocation, distribution and management.;
- Promotion of re-use of poor quality waters.

3.2 Areas of Sustainable Use of Water Resources

3.2.1 Developing water resources and expanding the capacity of water supply

- Optimizing regional and sectoral allocation of water resources;
- Strengthening the evaluation on 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.

3.2.2 Increasing 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 with greater 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.

3.2.3 Protecting water resources and improving water environment

- Drawing up overall plans for the protection of water resources and water environment at basin scale;
- Strengthening the water environment monitoring;
- Strengthening water environment protection in urban and rural areas;
- Strengthening scientific research on the protection of water resources and on the improvement of water environment, popularizing new technologies of water environment control through experiments and demonstration;
- 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 resource macro control index;
- ■ Formulate water allocation schemes and indices as well as reliable measures at river basin, province and at national level;
- ■ Coordinate water for food, nature and people sectors based on total allocated water amount;
- ■ 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

- ❑ To formulate water resources protection program of major rivers;
- ❑ Rationally divide water function areas, specify the waste carrying capacity of river systems and the total discharge of various pollutants so as to realize total control on waste discharge;
- ❑ Establish an economic compensation system for water resources protection and ecosystem rehabilitation;
- ❑ Formulate GDP statistics index for pollution control; Specify water source protection zones;
- ❑ Guarantee safe drinking water for urban and rural population over 200,000;
- ❑ Readjust industrial structure and encourage clean production so as to control pollution at the source;
- ❑ Implement wastewater 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;
- ❍ Formulate national policies on water-saving;
- ❍ Increase waste water treatment and reuse, and industrial water reuse, develop water-saving measures in industry;
- ❍ Agriculture and domestic users to establish water-saving societies.

3.3.4 Appropriate development

- According to the water distribution and bearing capacity, under the precondition of conserving water, China will have to develop new sources appropriately to continuously improve distribution and water supply safety;
- Provide guaranteed drinking water supply to poor people for economic and social development;
- Construct water resources diversion and storage projects to make full use of local water resources;
- Develop inter-river basin and inter-region water transfer projects after overall planning and scientific research;
- Rationally utilize groundwater resources in potential areas;
- Increase utilization of rain and flood water;
- Speed up wastewater treatment and reuse, 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" and so on to establish and improve the legal system for water resources management;
- Promote the 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 ground water, the 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 Increased financial input

- Divide the rights and responsibilities between the central and local government, and among the government- market and beneficiaries; clarify the main investor 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 the 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). ■

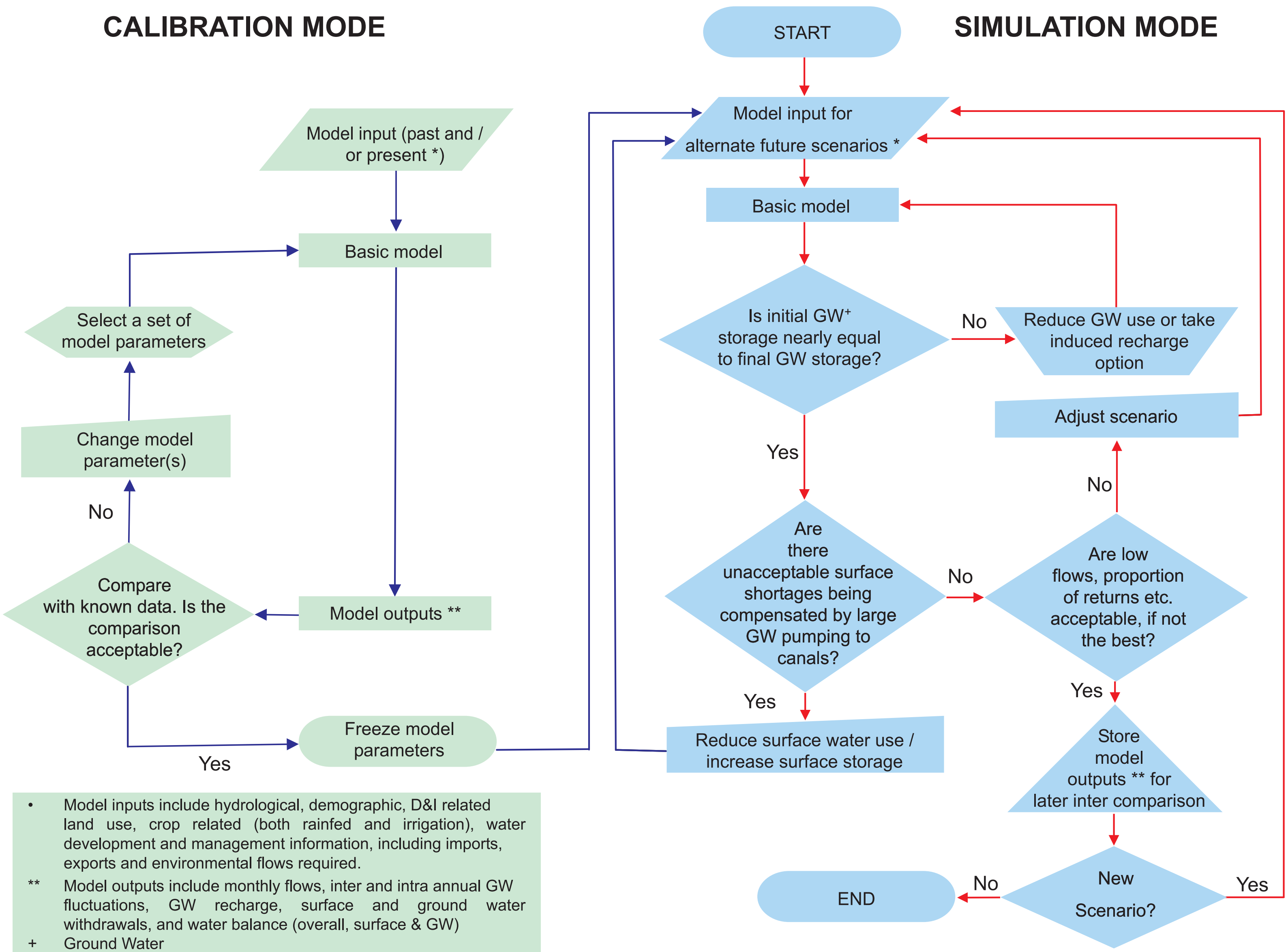

Figure A-1. Logical Sequence of BHIWA Model

ANNEXURE-2
BASIC DATA OF JIAODONG PENINSULA BASIN

Table A2.1
Monthly Average Rainfall in Yantai and Weihai Municipalities from 1956 to 1999 (mm)

Month	Yantai	Weihai
July	168.0	179.5
August	160.2	207.9
September	75.8	91.6
October	38.5	34.6
November	33.0	29.3
December	19.5	19.1
January	11.8	13.1
February	12.6	11.7
March	19.5	20.3
April	37.7	43.6
May	42.1	51.8
June	69.6	86.0

Table A2.2
Monthly Reference ET in Yantai and Weihai Municipalities from 1956 to 1999 (mm)

Month	Yantai	Weihai
July	127.9	125.2
August	106.2	104.1
September	106.3	104.1
October	82.8	81.1
November	50.9	49.9
December	36.1	35.4
January	31.9	31.2
February	39.1	38.3
March	72.5	71.0
April	113.1	110.8
May	143.9	141.0
June	143.8	140.9

Table A2.3
Crop Coefficients of Main Crops, Yantai and Weihai Municipalities

Crops		**Development stages**			
		Initial-season	**Quick development**	**Mid-season**	**End-season**
Summer Maize	Date	22 June~7 July	8 July~3 Aug.	4 Aug~3 Sep.	4~26 Sep.
	Kc	0.63	0.63~1.14	1.14	1.14~0.59
Groundnut	Date	5 April~1 June	2 June~7 July	8 July~4 Aug.	5~24 Aug.
	Kc	0.37	0.37~1.12	1.12	1.12~0.57
Soyabean	Date	19~30 June	1~14 July	15 July~24 Aug.	25 Aug. ~9 Sep.
	Kc	0.61	0.61~1.11	1.11	1.11~0.46
Sweet Potato (and Potato)	Date	7 April~3 May	4 May~3 June	4 June~17 July	18 July~12 Aug.
	Kc	0.4	0.4~1.14	1.14	1.14~0.71
Vegetables & Sugar beet	Date	5~30 June	1~30 July	31 July~27 Oct.	28 Oct.~6 Nov.
	Kc	0.45	0.45~1.18	1.18	1.18~0.7
Melons	Date	3~21 April	22 April~20 May	21 May~18 June	19 June~17 July
	Kc	0.45	0.45~1.01	1.01	1.01~1.0
Fruits	Date	1~20 April	21 April~27 June	28 June~22 Sep.	23 Sep~21 Oct.
	Kc	0.44	0.44~0.9	0.9	0.9~0.7

Table A2.4
Crop Coefficients of Wheat in Yantai and Weihai Municipalities

Development stages	**Seeding**	**Freezing**	**Soil frost**	**Reviving~ heading**	**Flowering-filling**	**Milking-harvest**
Date	28 Sep~ 30 Nov.	1~9 Dec.	12 Dec.~ 25 March	26 March~ 6 May	7 May~ 8 June	9~21 June
Kc	0.6	0.6 - 0.4	0.4	0.4 -1.17	1.17	1.17 - 0.4

Table A2.5 Water Use for all Sectors during the period 1984-2000, Yantai and Weihai Municipalities (10^6 m^3)

Year	Yantai			Weihai		
	Agriculture	Industry	Domestic	Agriculture	Industry	Domestic
1984	926.0	107.8	85.4	258.3	32.2	24.9
1985	954.6	141.9	96.2	182.0	36.3	25.7
1986	1042.5	159.7	100.2	328.1	46.5	26.4
1987	NA	NA	NA	292.3	55.4	28.3
1988	1014.0	147.6	133.1	373.7	58.0	33.3
1989	1006.8	148.8	106.5	286.6	56.8	37.0
1990	741.4	159.6	122.9	193.8	60.6	38.2
1991	965.9	162.8	143.4	249.1	70.3	45.8
1992	965.0	171.3	132.5	265.3	77.1	46.5
1993	913.1	214.5	135.2	237.1	83.2	50.9
1994	973.7	196.7	137.7	205.2	81.0	56.1
1995	900.2	210.1	133.8	203.5	87.3	65.3
1996	880.9	250.1	138.5	251.8	86.2	66.4
1997	913.0	231.4	144.6	262.5	92.3	66.2
1998	888.4	236.8	137.0	199.9	91.7	71.7
1999	856.0	251.2	170.1	265.8	92.0	77.1
2000	684.0	237.0	154.0	176.0	76.0	57.0
Average	**929.4**	**186.0**	**127.8**	**253.4**	**69.2**	**47.5**
Past (1980)	974.4	136.5	93.9	256.2	38.3	25.7
Present *	**844.4**	**241.3**	**148.8**	**231.2**	**87.6**	**67.7**

* The average value of five years from 1996-2000; NA – Information Not Available.

Table A2.6
Future (2025) Water Requirement for Domestic and Industrial Purposes, Yantai and Weihai Municipalities

Cities	Use sector	Requirement (10^6 m^3)
Yantai	Domestic, Rural	112
	Domestic, Urban	325
	Industrial	409
	Total	**846**
Weihai	Domestic, Rural	44
	Domestic, Urban	134
	Industrial	125
	Total	**303**

BIBLIOGRAPHY

Chinese National Committee on Irrigation and Drainage, (2004a): Water and Food Assessment in Jiaodong Peninsula and Qiantang River Basin (Draft Report).

Chinese National Committee on Irrigation and Drainage, (2004b): Draft Report of CPSP Chinese National Consultation, China.

Chinese National Committee on Irrigation and Drainage, (2004c): China's Irrigation Development Rational Allocation of Water Resources and Food Security (Draft Report).

International Commission on Irrigation and Drainage, (2005a): Water Resources Assessment of Sabarmati River Basin, India, CPSP Report 1.

International Commission on Irrigation and Drainage, (2005b): Water Resources Assessment of Brahmani River Basin, India, CPSP Report 2.

People's Republic of China, (2002): Water Law of the People's Republic of China.

Shandong Provincial Institute of Water Conservancy Reconnaissance and Survey, (2003): The Report of Overall Water Resources Planning in Jiaodong Peninsula, (Yantai and Weihai).

Weihai Municipal Water Conservancy Bureau, (1997): Synthesis Report of Million Mu of Water Saving Agriculture Demonstration Area, Weihai Municipality of Shandong Province.

Weihai Municipal Water Conservancy Bureau, (2001): The Planning Report of Urban Water in Weihai Municipality Resulted from the South-to-North Water Transfer Project within the Jurisdiction of Shandong Province.

Weihai Municipal Water Conservancy Bureau, (2002): Conclusive Report of Water Conservation in Weihai Municipality

Yantai Municipal Water Conservancy Bureau, (2002a): Conclusive Report of Water Saving Irrigation in Yantai Municipality.

Yantai Municipal Water Conservancy Bureau, (2002b): The Report on the Progress of Water Saving Agriculture Demonstration in Yantai Municipality.

Yantai Municipal Water Conservancy Bureau, (1994): Planning for Water Saving Agriculture Demonstration in Yantai Municipality.

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.

Crop-coefficient: It is the ratio coefficient between crop ET and reference evapo-transpiration, $ET_{0;}$ Crop coefficient varies with the stage of the growth of the crop and is somewhat dependent on the humidity and wind conditions under which the crop is being grown.

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).

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.

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

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.