

## International Commission On Irrigation And Drainage

### An Integrated Water Assessment Model for Future Scenario Studies of Sabarmati River Basin in India

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## Country Policy Support Programme CPSP

- Launched by ICID in 2002
- Supported by The Netherlands
- Integrated approach to water policy
  - Water for Food
  - Water for People
  - Water for Environment
- Basin Wide Holistic Integrated Water Assessment Model (BHIWA Model)

### Water Resource Assessment - Scope

- Basin/Regional/Country/Global scale
- Whether integrated and holistic
- Assessment and integration of sectoral demands of water including EFRs
- Impact of land and water use and climate changes on resources
- Development and analysis of scenarios to evaluate effects of water policies
- Linkages with socio-economic and environmental aspects

### Water Resource Assessment - Purpose

- Understanding resources and needs
- Analyze development and management options
- Creating and improving knowledge base for meaningful and transparent dialogue

## BHIWA Model

### BHIWA Model

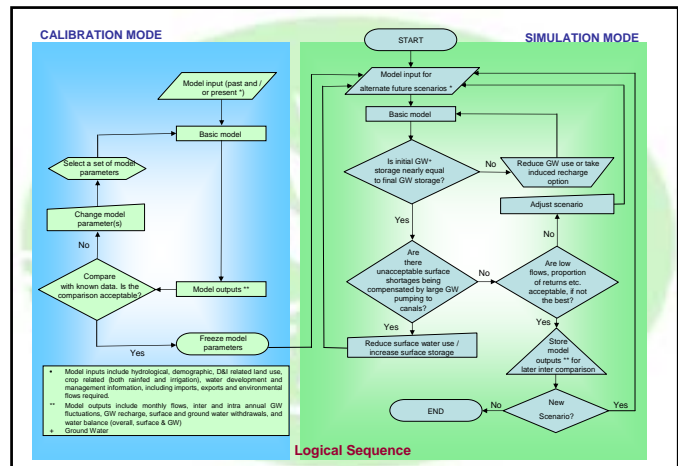
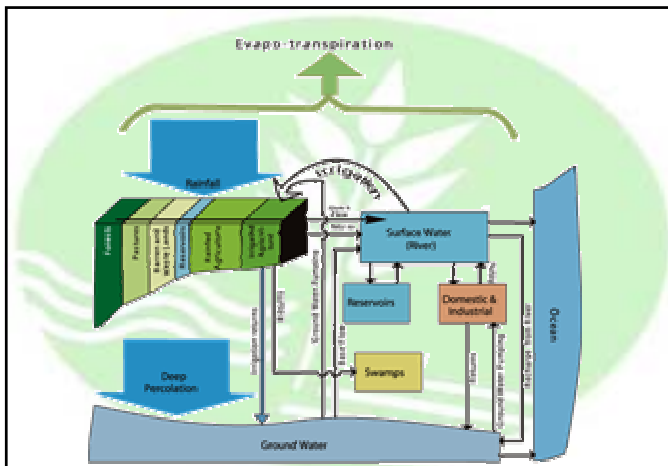
- Simple concept
- Deals with the entire land phase of the hydrologic cycle:
  - Precipitation
  - Evapo-transpiration
  - Outflow to sea
  - Withdrawals
  - Returns

## BHIWA Model

- Allows
  - Changes in land use
  - Water infrastructure development
  - Irrigation expansion
  - Changes in domestic and industrial withdrawals and consumption
  - Changes in water use efficiencies

## BHIWA Model

- Allows
  - Surface water balance
  - Groundwater balance
  - Surface water – groundwater interaction
  - Storage and withdrawals
  - Changing environmental flow requirements
  - Gradual changes in rainfall and evapo-transpiration (climatic changes)



## THE RATIONALE

- The need for depicting the entire land phase, stems from basic hydrologic premise (our view) that precipitation (and not river flow/ aquifer recharge) constitutes the primary resource.
- The evapo-transpiration management can increase the flows in rivers/ aquifers and hence will be a potential development strategy to be encouraged.
- This could be through policy intervention, either for improving river flows or the traditional resource base.

## Modules in the Model

- The natural module
- The module depicting hydrologic impacts due to anthropogenic influences.
- Modules for withdrawals, consumptive uses and returns for irrigation and D&I sectors.
- Module for accounting evapo-transpiration by "use sectors".
- Modules for separate and combined balances for river waters, ground waters and total sub-basin / basin.

## Capabilities

- Quantification and integration of sectoral needs
- Water Balances for Surface and Ground Water systems and for the overall basin
- Interaction between surface and Ground water system
- Effects of land use changes on supplies
- Impact of sectoral policies
- Maintenance of prescribed Environmental flows (EFR)

## Limitations

- Not a distributed hydrologic model
- Not a basin planning tool
- Need for additional modules to evaluate socio-economic impacts

## Information required for building scenarios

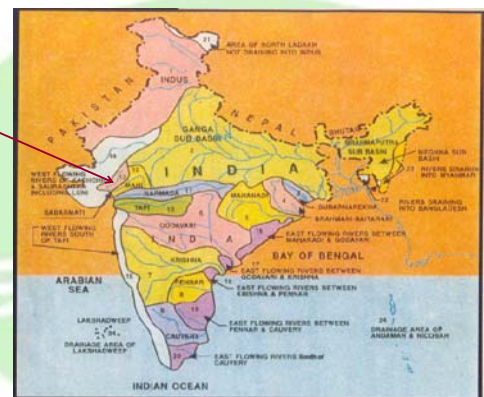
- Engineering possibilities for in basin development, and inter basin imports and exports, efficiency improvements etc.
- Population and demand projections.
- Land development potentials.
- Ecological and environmental considerations regarding land use changes, low flow regimes and water quality.

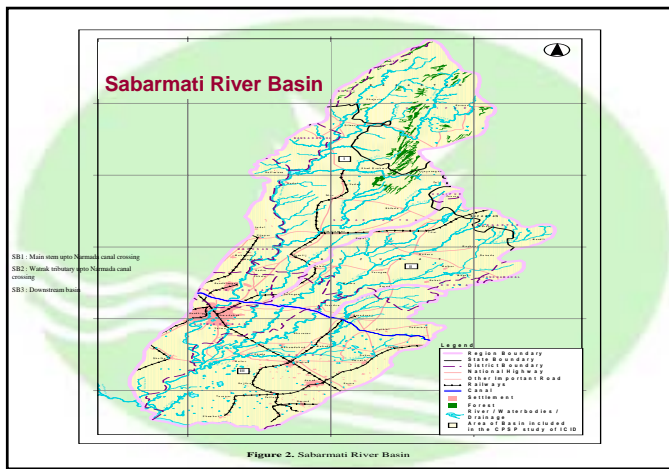
## Information required for building scenarios

- Agronomic possibilities in diversification, productivity improvements, changes in varieties etc.
- Possibilities and desirability's of industrial development.
- Possibilities and desirability of rain water harvesting, watershed management and insitu water conservation

## Sabarmati River Basin Study

Sabarmati River Basin





- ## Sabarmati River Basin
- Water deficient
  - Intensive agriculture
  - Industrial development
  - Large population density
  - Excellent farming and entrepreneurship skills

- ## Sabarmati River Basin
- Catchment Area – About 21,600 km<sup>2</sup>
  - Population (1995) – 11.4 million - 52% urban
  - Ave. annual rainfall – 750 mm
  - Renewable water resources – 48.5 million m<sup>3</sup> per year including groundwater
  - Per capita water availability – 413 m<sup>3</sup> per year (lowest among Indian river basins)

- ## Sabarmati River Basin
- Current Gross Cropped Area – About 1.5 million ha
  - Current Gross Irrigated Area – About 0.8 million ha, with predominance of groundwater irrigation
  - Inter-basin water transfer – Currently about 1,580 million m<sup>3</sup> from the adjacent Mahi River and
  - a plan to import up to 2,138 million m<sup>3</sup> of Narmada river waters is under implementation
  - Major Industries – Textile, Chemical, Dairy, Thermal power

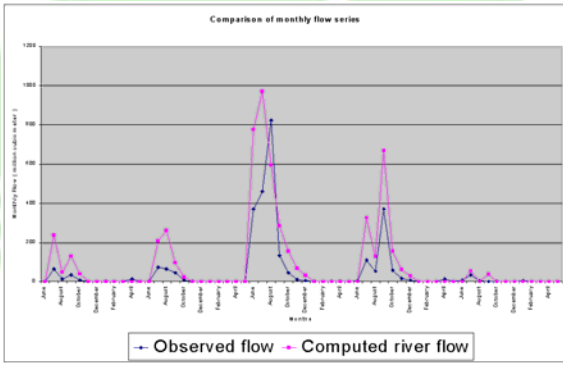
- ## Calibration of the model
- Rigorous calibration not necessary since model is meant to study relative impacts on basin hydrology. This was done by comparing the following:
    - Annual and monthly river flows
    - Natural recharge to groundwater as a percent of rainfall.
    - Groundwater fluctuations
    - Withdrawals from surface and ground waters

## Calibration of the model

Comparison of annual average flow based on five year sequential run (1995-1996 to 1999-2000)

Sub-Basin/ Basin	Average flow computed by the model (10 <sup>6</sup> m <sup>3</sup> /yr)	Observed average flow (10 <sup>6</sup> m <sup>3</sup> /rec)
SB 1	359	373
SB 2	1075	580
Total basin	1933	1711

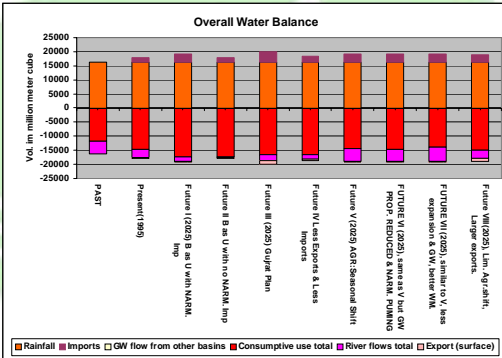
# Calibration of the model



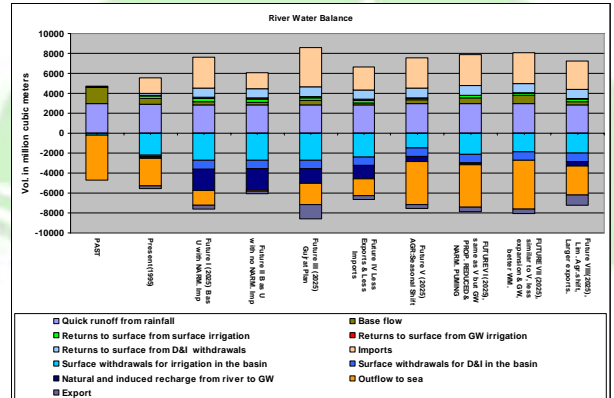
# Scenarios studied

Sr. No.	Name	Year	Abbreviation	Explanatory Notes
1	Past	1960	-	No water development
2	Present	1995	-	Considerable storage, groundwater and surface irrigation, and imports
3	Future I	2025	B AS U	Irrigation expansion with similar composition Additional Narmada Import
4	Future II	2025	B AS U, no Narmada import	Same as Future I, without Narmada Import
5	Future III	2025	Gujarat Plan	Larger imports and exports, pumping imported water in upper reservoirs
6	Future IV	2025	Less Imports and Exports	-
7	Future V	2025	Seasonal shift	Irrigation expansion mostly in wet season
8	Future VI	2025	-	Similar to Future V but groundwater irrigation reduced. Reduced pumping to reservoirs
9	Future VII	2025	-	Groundwater irrigation further reduced. Less irrigation expansion. Improved water management and more drip irrigation
10	Future VIII	2025	-	Smaller Seasonal Shift and improvements in water

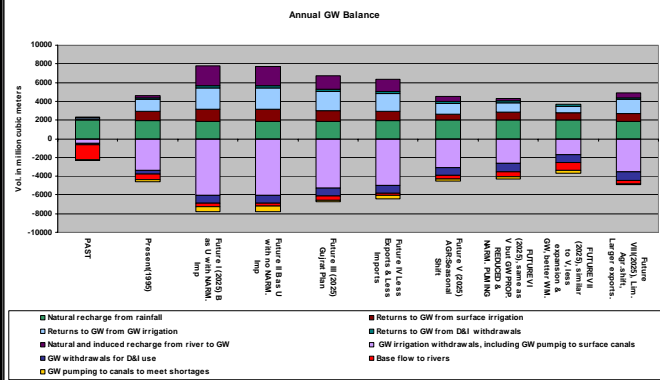
# Overall annual water balance



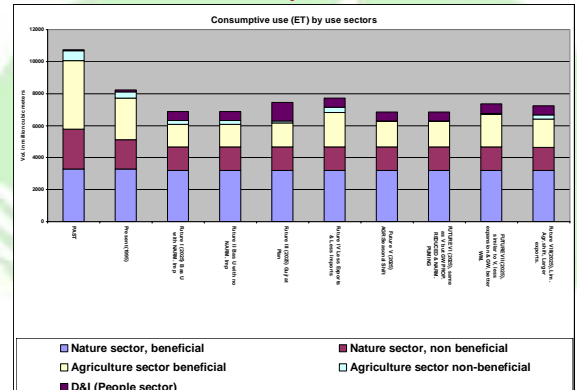
# Annual river water balance



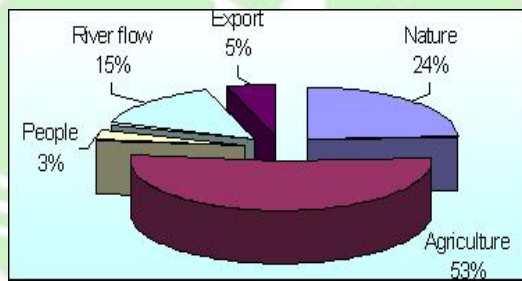
# Annual groundwater balance



# Consumptive use



## Utilization in Future VIII scenario



## Main Findings

- Non-beneficial ET in the nature and agriculture sectors exceeds quantum of annual river flow
- Reduction of non-beneficial ET through rain harvesting, soil and agriculture management is a potential strategy for improved water management

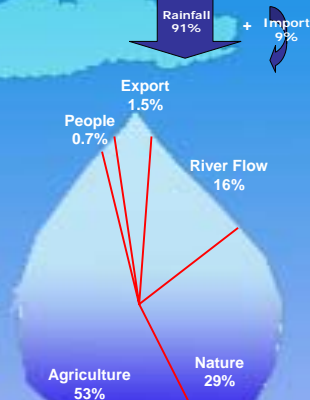
## Main Findings

- Import of Narmada water is necessary to sustain the present withdrawals and meet future needs, including that for improvement of low flows

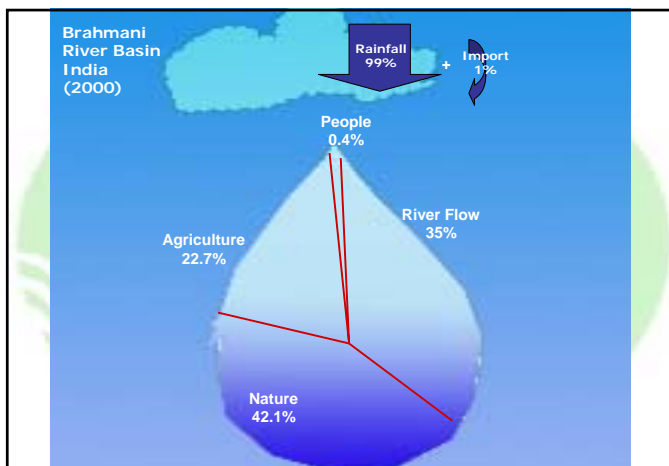
## Main Findings

- Present ground water use is unsustainable
- While the situation would improve slightly in future due to large additional Narmada imports, composition of return flow indicates much higher risk of ground water pollution

Sabarmati River Basin  
India  
(1995)



Location of Brahmani and Sabarmati River Basins



- ## Selection of Water Stress Indicators – Relevance ?
- Large **ground water use** as in India, rise the need for indicators for both surface and G.W resources
  - WSI proposed by Alcamo based on **withdrawals** out of which a substantial part may return. Multiple re-uses possibility ? How should we address it better?
  - Can an absolute and overriding priority for **environmental water** requirement (Smakhtin's) work in many water deficit basins?
  - ICID attempted to address the complex issue by objective modelling and the present efforts is just a beginning in this direction. More basin studies are to follow ....

## Suggested Indicators

Four indicators proposed for describing state of water resources

Indicator 1: Withdrawals/total input to surface water  
 Indicator 2: Returns/total input to surface water  
 Indicator 3: Withdrawals/total recharge to ground water  
 Indicator 4: Returns/total recharge to ground water

*Indicators 1&3- depict quantitative stress due to withdrawals  
 Indicators 2&4- depict hazard to water quality*

## ICID - IAH CPSP Study : Pt. 4

### Basin grouping by selected indicators

Class description	Value of indicator	Basin
a) Surface withdrawals	very high stress	Indicator 1>0.8 Pennar
	high stress	0.4 < Indicator 1<0.8 Cauvery
	Moderate stress	0.2 < Indicator 1<0.4 Indus, Ganga, Subarnarekha, Mahanadi, Tapi, Sabarmati
d) Surface water quality	low stress	Indicator 1<0.2 Brahmaputra, Godavari, Brahmani
	low stress	Indicator 2 < 0.05 All basins, in good
	moderate stress	0.05 < Indicator 2 < 0.1 Cauvery, Tapi, Sabarmati, Pennar
f) Groundwater withdrawals	very highly stressed through withdrawals	Indicator 3>0.7 Sabarmati
	highly stressed through withdrawals	0.4<Indicator3<0.7 Indus, Ganga, Subarnarekha
	moderately stressed	0.2<Indicator3<0.4 Mahanadi, Godavari, Krishna, Pennar, Cauvery, Tapi, Narmada,
j) Groundwater quality	Mahi	Indicator 4>0.8 None
	under very high threat	0.4<Indicator 4<0.8 Indus, Ganga, Subarnarekha, Krishna, Pennar, Cauvery, Sabarmati
	under high threat	under moderate threat Brahmaputra, Mahanadi, Godavari,
	0.2<indicator 4<0.4 Tapi, Narmada, Mahi, Brahmani	

## India Case Study -- Indicators

- Surface water resources

S. No	Basin	Total input 109m <sup>3</sup>	Total returns 109m <sup>3</sup>	Total withdrawal 109m <sup>3</sup>	Withdrawal/ Input (I1)	Returns/ Input (I2)
1	Indus	185	3	42	0.23	0.02
2	Ganga	525	19	146	0.28	0.04
3	Brahmaputra	633	1	12	0.02	0
4	Subarnarekha	12	--	4	0.33	0
5	Mahanadi	50	1	13	0.26	0.02
6	Godavari	126	3	21	0.17	0.02
7	Krishna	99	3	26	0.26	0.03
8	Pennar	7	1	7	1	0.14
9	Cauvery	28	2	19	0.68	0.07
10	Tapi	18	1	4	0.22	0.06
11	Narmada	51	1	7	0.14	0.02
12	Mahi	13	0	2	0.15	0
13	Sabarmati	7	0.7	2	0.4	0.09
14	Brahmani	17	0.6	2	0.14	0.04

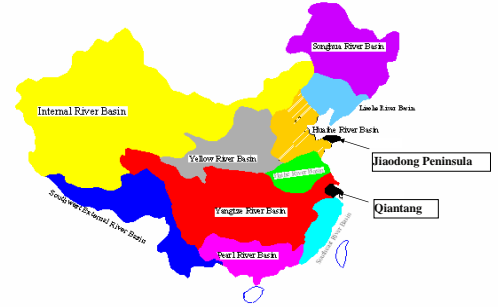
## India Case Study – Indicators... contd

- For Ground water resources

S. No	Basin	Total input 109m <sup>3</sup>	Total return 109m <sup>3</sup>	Total withdrawal 109m <sup>3</sup>	Withdrawal input to (ratio)	Return to input (ratio)
1	Indus	48	33	29	0.6	0.69
2	Ganga	251	115	118	0.47	0.46
3	Brahmaputra	33	7	2	0.06	0.21
4	Subarnarekha	4	3	2	0.5	0.75
5	Mahanadi	23	9	6	0.26	0.39
6	Godavari	49	15	12	0.24	0.31
7	Krishna	37	17	10	0.27	0.46
8	Pennar	9	5	2	0.22	0.56
9	Cauvery	22	13	8	0.36	0.59
10	Tapi	9	3	3	0.33	0.33
11	Narmada	15	4	4	0.27	0.27
12	Mahi	9	2	2	0.22	0.22
13	Sabarmati	5	2	4	0.87	0.54
14	Brahmani	6	1.5	1	0.11	0.3

## Findings of Extrapolation

- Inferences drawn from Sabarmati assessments are of much relevance to Pennar, Cauvery, Indus, Ganga, Subarnarekha, Mahanadi and Tapi in regard to surface water
- Ground water problems of Indus, Ganga, Subarnarekha, Krishna, Pennar and Cauvery have similarity with Sabarmati
- Problems of Brahmani resulting out of the high flows and low use of ground water have similar implications for Brahmaputra and Godavari



## Assessment for Qiantang basin - Main findings

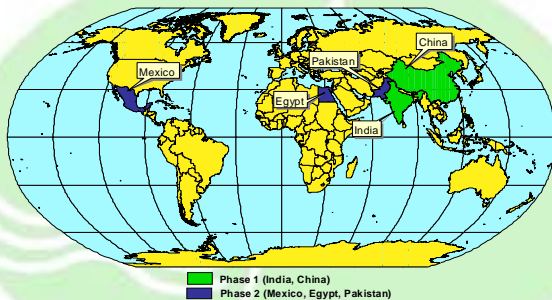
- Nature sector consumes major part of the primary resource ( rain water ).
- Consumptive use under nature sector is expected to increase significantly in future due to the expansion of forest area. This in turn would tend to reduce river flow. Part of this decrease can however be restored through better soil and water management.
- Due to abundant surface water resources almost entire irrigated agriculture including fisheries is presently dependent on surface water resources.
- Groundwater use is presently restricted to D & I sector. There exists a huge potential for groundwater development in this basin.
- Surface withdrawals constitute a small fraction of available supplies and seems to be constrained by availability of cultivable land.

## 7. Extrapolation of Qiantang assessment to other similar basins

### Basin Classification/grouping by water situation indicators

Class description	Indicator value	Basin
Low stress through surface withdrawal	Indicator 1 < 0.2	Yangtze, Zhujiang, Southeast, Southwest, Qiantang
Surface water quality, low stress	Indicator 2 < 0.05	Yangtze, Zhujiang, Southwest, Southeast, Inland, Qiantang
Groundwater low stressed through withdrawal	Indicator 3 < 0.2	Yangtze, Zhujiang, Southeast, Southwest, Inland, Qiantang
Groundwater quality under low threat	Indicator 4 < 0.2	Yangtze, Zhujiang, Southeast, Southwest, Inland

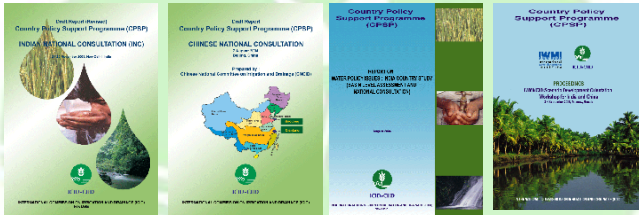
## CPSP Participating Countries



## In the end

- More studies are required to prescribe a certain specific demand for aquatic and other eco-system demands – work will continue.
- ICID's WG(Envt.) will address this aspect in a holistic manner; inputs are being made available
- On further action for works to be undertaken in Phase I as well as Phase II, we will consider them together after all the Presentations by CPSP Expert Team Leaders and National Committees of Mexico Pakistan and Egypt. Aim is to line up an 'Action Plan' to take the Project further, if of interest.
- Thank You for your listening!

## ICID CPSP Publications



# Thank You