Chapter 11.

Challenges of Water for Food, People and Environment – ICID's[1] Initiative on 'Country Policy Support Programme' (CPSP)

Mukuteswara Gopalakrishnan[2]

Introduction

Water is increasingly becoming scarce with ever rising and unabated growth rates of population, especially in developing and least-developed countries. Global food security can be assured only when a sizeable number of countries with a large population in these parts of the world can address to a meaningful extent their own national food security, if there is enough scope with available land and water.

The water challenge, though, apparently focusses more on the bi-polar aspects of water required for food production and water required for environmental security. It is important to recognise the role of water for the people sector. This includes the avowed water needs for drinking and other uses besides industrial needs. Both urban and rural requirements form part of them.

In the first phase of CPSP studies, detailed assessments in two countries, viz. China and India, were undertaken. Egypt, Mexico and Pakistan were also studied in a preliminary manner. One basin each in Mexico and Pakistan were also subsequently added using a similar approach; an intensive study of these basins and others was deferred for a future plan. These five countries were specifically chosen for the ICID studies because of the fact that they together cover 51% of irrigated area globally, and affect directly about 43% of the world population.

The study undertaken looks at the development and management of water, land and related resources, integrating the needs of various uses including vital needs of terrestrial and aquatic ecosystems.

In order to enable a rapid examination of the impacts of various future scenarios, a land and water use model, introduced with the acronym BHIWA, "Basin-wide Holistic Integrated Water Management", was developed. The aim was to handle an integrated computational framework for a basin-level assessment of water resources, keeping in view existing and other desirable options of water sector polices. This model was developed to consider the entire land phase of the hydrologic cycle; it is capable of

1. International Commission on Irrigation and Drainage – please visit the web page www.icid.org for more details of ICID, its mission and goals and other details.

2. International Commission on Irrigation and Drainage, New Delhi, India.

depicting human impacts such as changes in land and water use; also the impacts of water storage and depletion through withdrawals for various water uses, and inter basin water transfers. The model takes into consideration complex interaction between numerous factors including surface and groundwater, land use and natural water supply, storage and water withdrawals and returns, through separate water balances for surface and groundwater as well as an overall water balance.

To support the 'decision making', several scenarios were examined by a multifaceted hydrologic modeling which brings on board not only the hydrologic cycle, but also factors that are relevant for irrigated and rainfed agriculture, forestry and desirable flows in streams for the aquatic ecosystem.

The approach through modelling the entire land and water use of the basin, as developed, was found to be useful especially for understanding existing as well as future water availability; also for assessing future water needs under different scenarios, and for analysing the impact of different policy options for an integrated and sustainable development of resources. In a dynamic situation, one sees in the developing nations like India the conversion of barren lands either into forests or into irrigated or rain fed agriculture. Such actions tend to increase the evapo-transpiration, and in turn impact the river or stream flows adversely. Similarly, rainwater harvesting and soil and water conservation practices were also seen to influence the total as well as the inter-distribution of surface and groundwater. An impact of internal changes in land use invariably occurs in the long run. The changes in policies and programmes in regard to soil and water conservation can be properly tested only when the overall water balance for the entire land phase of the hydrologic cycle is studied. Dry season flow in rivers is contributed-to by shallow aquifers. Large-scale groundwater use for agriculture is becoming more common in some basins, particularly in India and Pakistan. Such use severely affects environmental interests and the sustenance of ecosystems, as the base flow in rivers vanishes, apart from depletion of the water table. The separate water accounts for the river-surface and groundwater systems enable a study of this in order to achieve integration of supply sources and to consider the natural and human-induced interaction between the surface and groundwater components. Nevertheless, one also sees that several hydrologic modelling solution techniques are available to study any basin in a detailed manner; but these are seen to be rigorous, and hence are more apt to evolve the best operational policies of existing systems that are developed fully. A quick and easier approach is to study the dynamics of different options where development actions are still being contemplated, as in India (and other developing countries). The impacts of such actions were required to help decision-making processes, and CPSP is one such attempt.

India was chosen for the detailed study alongside China, and this paper restricts its coverage to Indian studies only. Two typical basins were taken up. A water deficit basin in the west coast, namely the Sabarmati river basin, and a water rich basin in the east coast, namely the Brahmani river basin, were the candidates for this study. The location of these basins is shown in the India country map – (Annex Map 1).

For depicting the type of results emerging out of the CPSP, the example of Sabarmati is dealt with broadly in what follows.

Sabarmati River Basin

Sabarmati River Basin (Annex Map – 2) is one of the 24 river basins of India. This water deficit basin lies on the west coast of India between latitudes 22° N to 25° N and longitudes 71° E to 73° 30' E, and is spread across the States of Rajasthan and Gujarat. The river outfalls into the Arabian Sea (more specifically in the Gulf of Cambay, or Khambhat as it is well known locally). The basin has a total drainage area of 21,565 km^2. The basin has a tropical monsoon climate. The average annual temperature varies between 25 and 27°C. The rainfall occurs almost entirely during the monsoon months. The average rainfall of the entire basin is 749 mm. The rate of evaporation is maximum during April to June due to the rise in temperature and increase in wind speed. The average annual evaporation losses in the basin are in the order of 1500–2000 mm.

The total population in the basin (2001) is 11.75 million, of which 5.99 million is urban and 5.76 million is rural. The projected population of the basin for the year 2025 is 19.86 million, of which 10.81 million is urban and 9.05 million is rural.

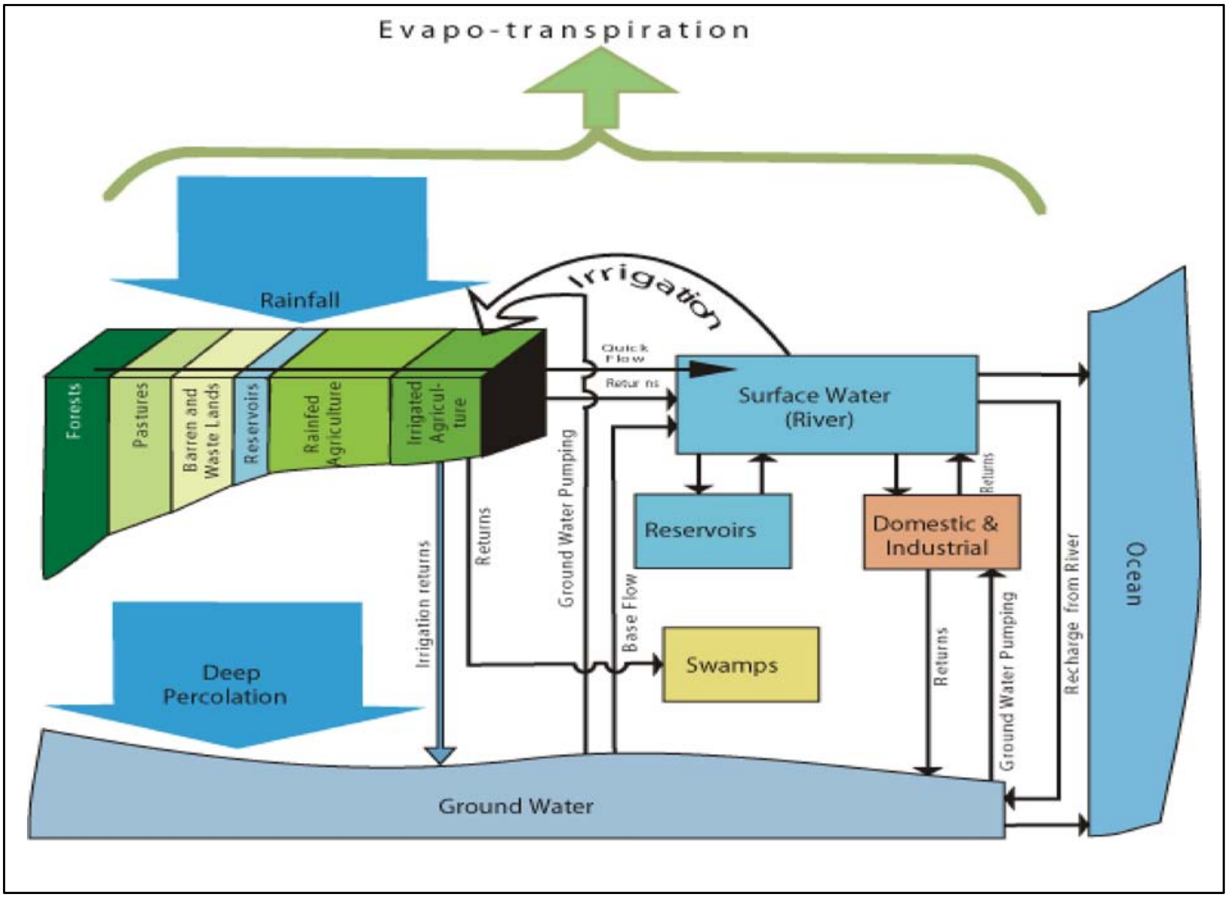
The annual mean water resource in the basin is estimated as 3,810 million m^3. Water consumption of surface water for irrigation has been estimated to be 3,465 million m^3 per year, including the Mahi command within the Sabarmati basin (1,663 million m^3). The groundwater contribution to agricultural use is estimated as 2,279 million m^3. The total demand for the year 2001 was in the order of 5,744 million m^3. The irrigation demands, considering the future expansion of areas and development of additional possible irrigable areas (with infrastructure like main canals ready), is about 4,554 million m^3. These are considered in some scenarios studied, which take into account inter-basin water transfer which has already been in place with an increasing provision in future. These include imports from the Mahi and Narmada rivers, which adjoin the study basin in its southern part. Since the basin suffers from overexploitation of groundwater, the groundwater demand for irrigation in the study has been restricted to the present use of 2,279 million m^3. Water requirements for humans and livestock in 2001 were 510 million m^3, which will increase by 2025 to 898 million m^3. The water requirement for the existing 20 industrial estates in the basin is 99.64 million m^3, and the demand is likely to be 245 million m^3 in 2025.

Basin-wide Holistic Integrated Water Management (BHIWA) Model

Figure 1 shows the schematic of the BHIWA model. The model covers the entire land phase of the hydrologic cycle, right from precipitation, and various water uses, river flow, groundwater recharge, returns, and outflow to the sea. The BHIWA model approach asks for a division of the entire river basin into sub basins and several homogeneous land parcels; depicting different land use categories such as forest land, pasture, waste land, wet land, land under infrastructure, land under reservoirs, rain-fed agricultural land, irrigated agricultural land, etc. is also necessary. The agricultural land can further be subdivided into parcels to represent broad seasonal cropping patterns (such as perennial crops, land with a single crop in two four-monthly seasons and not cropped in the third season, land under two different crops in two seasons and fallow in the third season, and land that is cropped only in one season and remains fallow in two seasons, etc.). The main inputs to the model include hydrological data, crop parameters, land use and land parcel areas, soil moisture capacity for each type of land parcel, irrigation system efficiencies, coefficients for return flow accounts, changes in reservoir storages, etc.

Giving due consideration to all the affecting parameters, such as monthly rainfall and the initial soil moisture content, soil moisture capacity, potential crop evapo-transpiration (etc.), quick runoff including interflow, ground water recharge, irrigation withdrawal and return, evapo-transpiration for nature and for agriculture sectors in each land parcel were worked out. The domestic and industrial withdrawals, use and returns were also accounted for.

Figure 1. Schematic Diagram of BHIWA model



The scenarios studied considered emerging possibilities, the developmental plans, and improved water and soil management plans etc. In Sabarmati River Basin, there is little possibility of additional dams and structures across the river, and there is no possibility of increasing the storage capacity. The available storage capacity in SB1 and SB2 is not fully utilised. There are plans for large imports from the Narmada River by inter-basin water transfer schemes. The Gujarat State Government, under whose jurisdiction the harnessing of Sabarmati River lies as per the Indian constitutional provisions, has evolved a plan for using monsoon (Indian rainy seasonal flows in rivers are from monsoons, as is well known) surpluses from the Narmada River, for pumping and filling up of the high level storages, including those in Sub Basin 1 and Sub Basin 2. Although there could be various pros and cons about these plans, their possibilities needed a quick evaluation. Similarly the possibility of constraints on imports due to inter-state issues (water, in a broader sense, being a state subject, as per the Indian Constitutions) also exists, and this needed a study. The present irrigation, with stress on post wet season (Rabi crops November-March) irrigation, was found to be causing a large reduction in river flows, and hence the idea of changing the emphasis and having increased irrigation in the wet season (Kharif crops: June-October) instead of post wet season, needed to be studied. Similarly, at present, groundwater is the predominant source of irrigation, and is already overexploited. If this trend continues, the situation may become totally unsustainable. Hence, a comparative reduction in groundwater use was studied in various scenarios. Improved water management through improving irrigation system efficiency and evaporation control, by adopting measures like mulching, weeding of barren areas and increasing the area under micro-irrigation, were also important strategies, which needed a study. The various scenarios are listed in Table 1.

Table 1. Scenarios studied in respect of Sabarmati Basin, India, in CPSP

No.	Scenarios	Description
1	Past (1960)	No water development
2	Present (1995)	Considerable storage, ground water and surface irrigation, and
3	Future I(2025)	Business as usual. Irrigation expansion with similar composition.
4	Future II (2025)	Business as usual. No Narmada import
5	Future III (2025)	Gujarat Plan. Large imports and exports, pumping imported water in
6	Future IV (2025)	Less expert and less import, to recognise competition amongst
7	Future V (2025)	Agriculture seasonal shift. Irrigation expansion mostly in wet season
8	Future VI (2035)	Similar to Future V, but ground water irrigation reduced. Reduced
9	Future VII (2025)	Similar to V, less irrigation expansion. Less ground water irrigation.
10	Future VIII (2025)	Smaller seasonal shift and improvements in water management

The types of policy support decisions that emerged out of these studies for future basin planning are quite revealing. The specific and overall lessons learned relate to issues of water use sectors, especially in the context of Integrated Water Resources Management. Given the fact that there are many water users and cross-cutting interests, any suggested action should not only be sustainable but also be attractive in a socio-politico-economic context (with a pro-poor and pro-woman leaning, a cherished goal in India). The study kept in view these aspects, which also came to the fore in the stakeholders' consultations and dialogues. A few such indicators are:

- Maintenance of water accounts, in terms of withdrawals, consumption and returns, separately for the requirements of food, the people and the nature sector, leads to a better understanding of water uses.

- The consumption levels of individual sectors (water for agriculture, people and nature) need to be assessed and integrated in order to understand the real impacts of land and water use and management policies. Consumption management is to be treated as an integral part of water and land related resources management.

- Nature sector water use needs to be accounted-for carefully, as it affects water availability in the rivers and aquifers and is important for maintaining the terrestrial as well as the aquatic ecology.

- The return flows from both point and non-point sources constitute a sizeable water resource. These could be of different qualities, depending on how the water is managed by each use sector. The return flows out of the withdrawals from surface and groundwater are available for re-use, subject to proper treatment to ensure the required water quality standard.

- Inter-basin surface water transfer is in some cases an inevitable option to meet the water needs of the basin for agriculture and for allowing restoration of the groundwater regime, and also for providing environmental flows required for the riverine ecosystem, besides improving river water quality through the re-use of effluents from domestic and industrial needs.

- Though watershed development/management enables more equitable use of land and water, and often involves harvesting of rain water where it occurs, watershed development upstream of the existing reservoirs could result, in some cases, in a considerable reduction in water availability, and should therefore be carefully analysed.

- Water requirements of the nature sector need to include both the requirements (mostly consumptive) of the terrestrial ecosystems like forests, grasslands, wetlands etc. and the water requirements (mostly non-consumptive) of the aquatic ecosystems. Both of these have to be decided through demand estimation, management, and tradeoffs.

- EFRs need to be recognised as a valid requirement. However, the stipulation of a desirable environment flow requirement for riverine eco-systems in water deficit basins needs more investigation and proper substantiation. Their estimation methods could be initially on an ad hoc basis, if rigorous methods are not available from Ecologists, and perhaps hydrology based. Better methods based on water regimes required by different species, also based on the tradeoffs between environmental flow and uses, as preferred by society, need to be evolved.

Brahmani Basin

The Brahmani River (Annex Map – 3) is one of the east-flowing rivers of India. The basin has a total drainage area of about 39,268 km² lying in different states of the Indian Union. The river has two main tributaries, namely the Sankh and Koel. The basin has a sub-humid tropical climate, with an average rainfall of 1305 mm, most of which is concentrated in the Indian southwest monsoon season of June to October. Rainfed agriculture is predominant, except in lower deltaic parts, where irrigation plays a major role. Compared to the national average, the basin has a higher proportion of both land under forests and cultivable wastelands. In contrast to Sabarmati, the basin is almost double its size, with a much smaller population (about 8.5 million total habitants in 2001) and an even smaller percentage of urban to total population. Relatively (in comparison to Sabarmati Basin) much less land is under irrigation. The irrigated area in recent years has averaged only about 1.23 million ha against a total cropped area of 1.57 million ha.

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

The basin is rich in forests which occupy as much as 37% of the basin's total area. Near the Brahmani-Baitarani delta are located mangrove ecosystems, including the famous Bhitarkanika National Park and a wildlife sanctuary. About 215 km² of the mangroves in this region was listed as one of the RAMSAR sites in November 2002. The basin has considerable potential for development of inland fisheries in reservoirs, ponds, tanks and canals. The occurrence of floods, particularly in the deltaic region, is a common feature, and on average a population of about 0.6 million and crop production of over 50,000 ha is affected annually. A large multi-purpose dam, the Rengali project, was completed in the year 1985, and has provided some relief to the lower flood plains in this regard, but its canal systems are not yet fully ready. Pollution of surface water of the Brahmani, and some of its tributaries below Rengali, on account of discharge of industrial effluents continues to be a cause of concern, despite some recent measures by the Orissa State Pollution Control Board to improve the situation.

Water assessments

The initial basin-level consultations were held based on preliminary studies, primarily to help identify issues concerning water use for the food, people and environmental sectors. The BHIWA model was applied to derive responses to

1. past,
2. present and
3. four future alternative scenarios using long-term average rainfall. These include:
    a) Business as usual (B as U) Scenario (F-I)
    b) Large expansion of agriculture and irrigation (F-II) to harness much of the water and land potential
    c) More industrialisation, considering the present base and its future growth (F-III)
    d) Lesser agriculture and industrial expansion with increased allocation of water to nature sector needs and navigation (F-IV).

In all three future cases (3b, c and d), better water management by best practices was presumed, and irrigation system efficiencies increased for the future scenarios; as well, recycling and reuse are also assumed.

The total water input (rainfall and imports) to the basin is 51,586 million m^3. The major water outflow from the basin comprises consumptive use (69%) and river flows (31%). The total consumptive use (in terms of evapo-transpiration — ET) at present (2000) is 34,138 million m^3 comprising about 64% by the nature sector (forests, pastures and barren lands), 35% by the agriculture sector (rainfed and irrigated agriculture) and 1% by the people sector (domestic and industrial). The non-beneficial ET is about 28% of the total consumptive use.

Major findings

The major findings of the assessment are:

- The nature sector is by far the largest consumer of water.
- The contribution of groundwater to base flow is increasing, indicating risk of waterlogging.
- Future withdrawal requirements would need full use of Rengali Dam storage, as well as creation of additional storage in the basin.
- Considerable land would remain rain-fed, and productivity increases may require watershed management of upper regions.
- The basin would not have overall water shortages, even in the projected scenario of increased agricultural and industrial water use.

Policy-related issues emerging out of Brahmani Basin studies

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

- A shift in the concept of "water resources": in order to consider the impacts of nature sector use, both terrestrial as well as the needs of aquatic eco-systems, impacts of rainfall harvesting, artificial recharge and, above all, for integration across the three sectors, precipitation is to be considered as the primary renewable water resource.
- The need to account for return flows as additional water available for use.
- The need to account for water use by sectors, and their integration.
- The need for recognising EFR and mainstreaming such requirements into basin water management;.
- The need for a more balanced use of surface and ground water and provision of adequate drainage and relief from floods.

- Improving water distribution and on-farm efficiencies through participation of beneficiaries
  - improved designs and O&M of structures, agricultural practices, waste water treatment technologies, etc.
- The need to adopt a participatory approach in regard to the choice of a strategy for flood control.
- The need for exploring the possibilities of 'inland navigation' in and near the delta, and the need for integrating water needs for navigation (which may be compatible with EFR and hydropower), and consumptive uses.
- Multipurpose reservoirs like Rengali, generating hydropower, play a great role in maintaining or even improving low season river flows. However, the effects of any changes in the hydrologic regime, including improvement of flows, on the aquatic ecology needs to be studied and understood.
- There is a need for the integrated management of land and water resources and the integration of rural livelihoods.

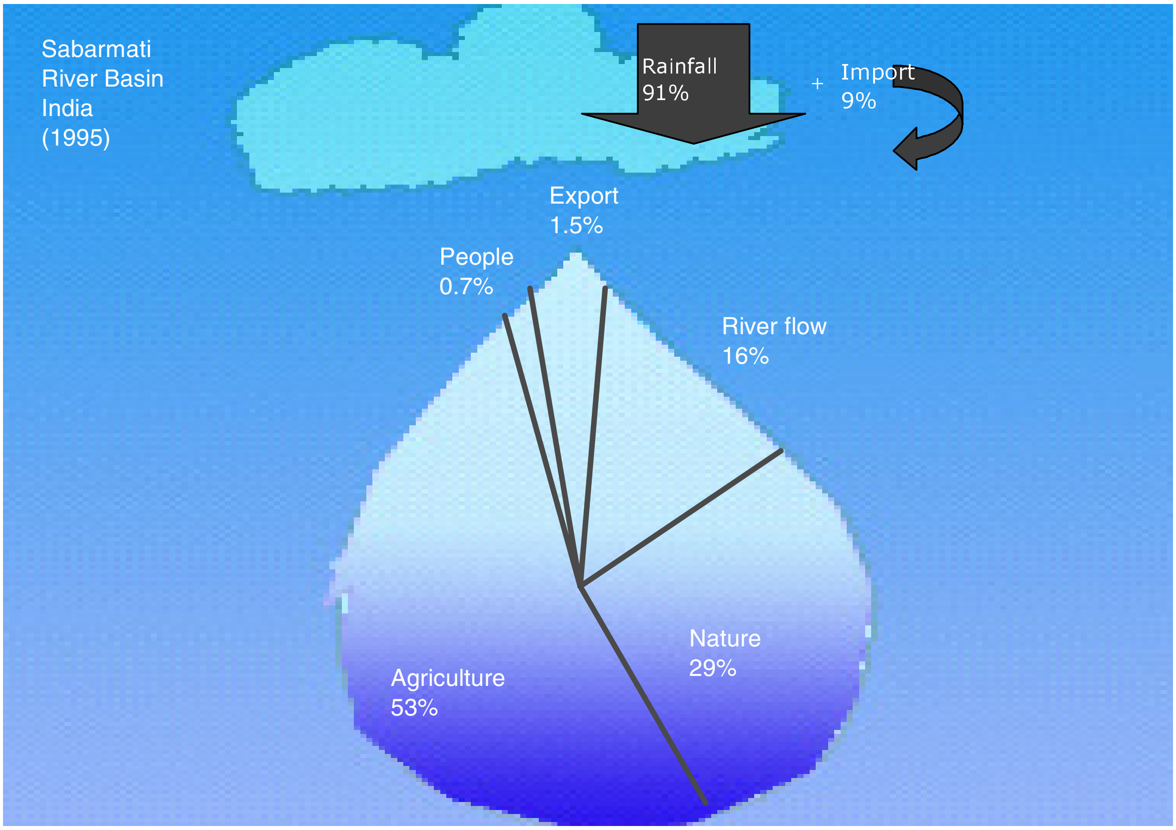
Allocation of available water in the respective basins

The types of studies carried out in respect of both Sabarmati and Brahmani basins in India yielded good insights on the sectoral allocation of water, and a scenario for each case is depicted in the text (Figure 2 and Figure 3).

These studies gave an insight into inter-allocation stress, if any, between different water users; essentially the people sector (both drinking and industrial), food sector (essentially agriculture) and the nature sector (terrestrial and aquatic ecosystem needs). In our study, forests were classified as of interest to the nature sector, and the allocations shown against them are depicted accordingly.

Water stress indicators were also evolved in an independent manner in the process, essentially in terms of withdrawals of surface water and groundwater (abstractions by pumping). Return flows were accounted for, which also gave an insight into the impacts on water quality. Having done this at basin scale, an extrapolation of a preliminary nature for all the basins was attempted, so as to sequentially order further detailed studies to investigate the possibility of severe stress, and the scope for inter-basin water diversions as a solution strategy. These are explained in what follows:

Figure 2. Water allocation for people sector, food sector (agriculture) and nature sector in respect of Sabarmati basin



Water situation indicators (WSI)

The following four indicators are proposed for the modelling framework used in detailed assessments for the purposes of describing pressure on resources due to withdrawals and threat to water quality:

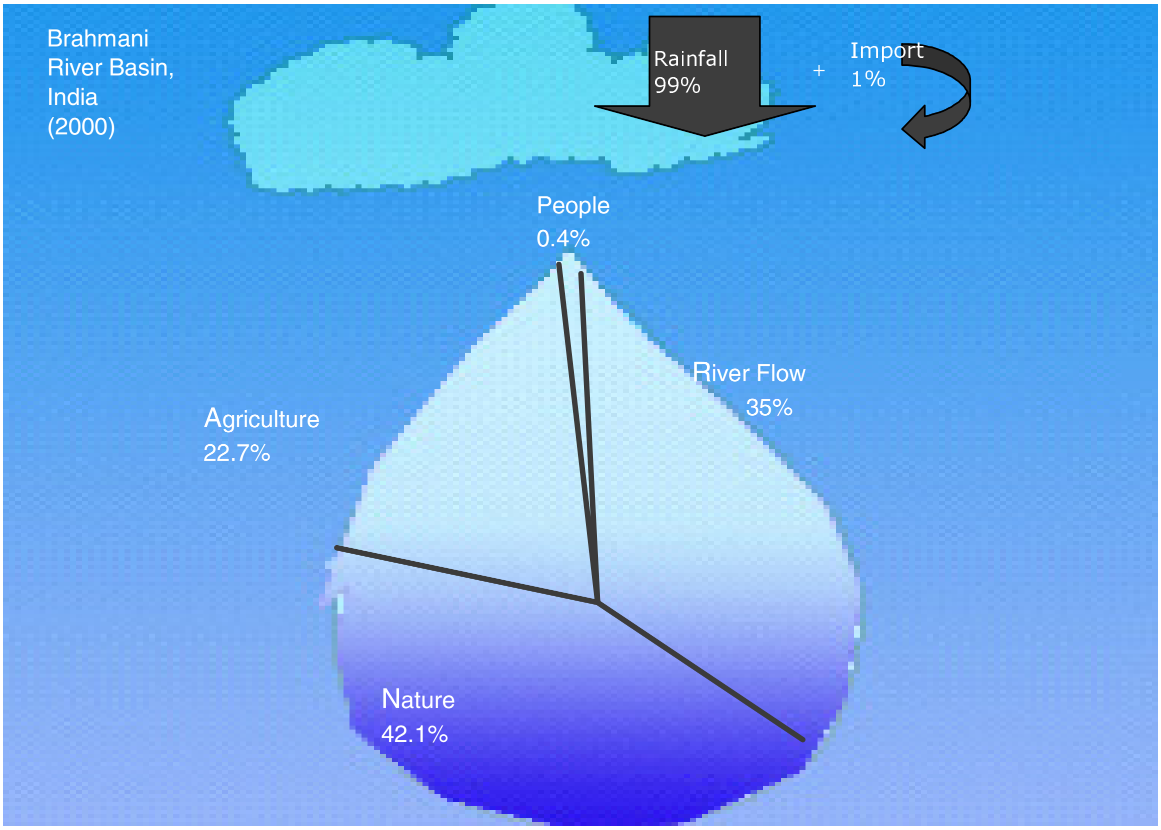
Indicator 1: Withdrawals/ total input to surface water

Indicator 2: Returns/ total input to surface water

Indicator 3: Withdrawals/ total input to groundwater

Indicator 4: Returns/ total input to groundwater.

Figure 3. Water allocation for people sector, food sector (agriculture) and nature sector in respect of Brahmani basin



These indicators have been considered more relevant to situations in developing countries like China, India and Pakistan for the following reasons:

1. A large amount of groundwater is used in India and Pakistan as well as China. One needs indicators which reflect water uses from both surface and groundwater sources.

2. The WSI, as defined based on 'withdrawals' by some authors earlier, does not account for the 'substantial part of the withdrawal' which would return (to surface or underground sources). Either one needs to consider the returns as an additional resource, adding to the natural runoff, or one needs to consider the 'net consumptive use' rather than withdrawals.

3. All use for terrestrial natural eco-systems, food or people is accounted-for on an equal footing, as it is desirable to have a prima facie look at what each such sector is drawing from the sources of water. For many basins that are water-deficit, or at a threshold level, a competing situation between such sectors arises and tradeoffs have to be looked into critically, and this approach is superior (to begin with such a review process in

allocation). The in stream environmental uses are not consumptive and can be considered as one of the requirements competing with others. It remains un-consumed, supporting aquatic ecosystems till it reaches the ocean.

4. Since large land use changes can also affect the natural supply, any other type of single prescription based on quantity ceilings may not be desirable. Either a 'natural' land use, which does not allow for human interventions through agriculture, or a 'pseudo-natural' condition, where agriculture is allowed but irrigation is not, would have to be defined for this purpose.

The proposed indicators depict the water situations in the basins in quantitative as well as qualitative terms. Indicators 1 and 3 depict the level of withdrawals as fractions of total water available in the surface and groundwater system, respectively. Indicators 2 and 4 depict the potential hazards to water quality in surface and groundwater systems respectively. These indicators are subdivided into four categories each to represent the degree of water stress (Table 2).

Table 2. Categories of surface and groundwater indicators

Indicator 1 – surface water quantity	1. Very high stress – value of indicator more than 0.8 2. High stress – value of indicator between 0.4 and 0.8 3. Moderate stress – value of indicator between 0.2 and 0.4 4. Low stress – value of indicator less than 0.2
Indicator 2 – surface water quality	1. Very high threat – value of indicator more than 0.8 2. High threat value – value of indicator between 0.2 to 0.8 3. Moderate threat – value of indicator between 0.05 and 0.2 4. Low or no threat – value of indicator less than 0.05
Indicator 3 – groundwater withdrawals	1. Very high stress – value of indicator more than 0.8 2. High stress – value of indicator between 0.4 and 0.8 3. Moderate stress – value of indicator between 0.2 and 0.4 4. Low stress – value of indicator less than 0.2
Indicator 4 – groundwater return flows (quality indicator)	1. Very high threat – value of indicator more than 0.8 2. High threat – value of indicator between 0.4 and 0.8 3. Moderate threat – value of indicator between 0.2 and 0.4 4. Low threat – value of indicator less than 0.2

Assessment for India in general by an extrapolation of Sabarmati and Brahmani Basin studies to understand water stress

The various rivers and river basins of India are seen in Annex 1.

After an assessment of indicators as above in respect of Sabarmati and Brahmani Basins, an upscaling was attempted.

On an analogy, the results of the Sabarmati River basin (water stressed basin) could be of relevance to the other Indian river basins of Pennar, Cauvery, Indus, Ganga, Subarnarekha, Mahanadi and Tapi in regard to surface water.

In regard to groundwater quality, the problems of Indus, Ganga, Subarnarekha, Krishna, Pennar and Cauvery could be similar to Sabarmati.

On the other hand, some problems of the Brahmani River basin (water rich basin) are attributable to high river flows and low use of groundwater. Brahmaputra, Godavari, Mahanadi, Tapi, Narmada and Mahi river basins in India could have similar groundwater-related problems, and therefore policies to increase groundwater withdrawals in future may be desirable.

The water resources availability both in respect of surface and groundwater are shown in Table 3.

An approximate insight for the present conditions in respect of other Indian basins

Grouping of various Indian river basins based on the foregoing criteria and values of water situation indicators are presented in Table 4.

Estimation of environmental flow needs

Fair and reasonable assessments of the riverine ecosystem needs posed difficulty throughout the exercise, in the absence of expert study inputs, and were largely based on consultations with stakeholders with some degree of arbitrariness.

Brahmani River has a considerable lean season flow, and sizeable fish numbers, particularly in lower reaches, supporting many livelihoods. Although the water development structures like Jenapur Dam (early 20th century) and Rengali Dam (late 20th century) caused some obstruction to free movement, fish catches and species are so considerable that an adverse impact situation does not currently appear.

Considerable areas of mangroves cover the mouths of the Brahmani, and other rivers have a common delta. The mangrove around Bhitarkanika is a well-known area of interest, especially for ecological interests. Migration of people from within and outside the basin and new settlements in the mangrove areas were identified as the main reason for the progressive and apparent reduction of mangrove areas. The mangrove species prevalent in any area are likely to depend on the tidal range, the salinity levels in the estuary, and the salinity in the root zone soil and moisture/groundwater. Unfortunately, no correlation between headwater discharge and estuarial salinity is available, nor could one be established from the available sparse data.

Of primary importance in the future would be a good response-based objective analysis, or studies projecting the realistic demand of minimum flows in different stretches of the rivers, not only for the Sabarmati and Brahmani, but also for all the riverine eco systems of India.

People sector requirements can be the first charge on fresh water. The study is a pointer to demonstrate that return flows after withdrawal for agriculture could also help (if duly treated, even for industrial and other uses) and sustains other aquatic ecosystems. Such an approach would ensure a win-win situation in both sectors, i.e. water for food and water for environment. Policy support suggestions are considered valuable if they are based on basin studies and bring in cross-cutting issues and interests.

Table 3. Water Potential of India by basin (Basin Map of India at Annex 1)

(Values are in Cubic Km/Year. A basin map of India is at Annex 1)

Sl No.	Name of river basin	Average annual potential in river	Total replenishable GW resources
1.	Indus (up to border)	73.31	26.49
2.	a) Ganga	525.02	170.99
	b) Brahmaputra Barak & others	585.60	26.55, 8.55[1], 10.83[2]
3.	Godavari	110.54	40.65
4.	Krishna	78.12	26.41
5.	Cauvery	21.36	12.30
6.	Pennar	6.32	4.93
7.	East Flowing Rivers Between Mahanadi & Pennar	22.52	
8.	East flowing rivers between Pennar and Kanyakumari	16.46	18.22[3]
9.	Mahanadi	66.88	16.46
10.	Brahmani & Baitarni	28.48	4.05
11.	Subernarekha	12.37	1.82
12.	Sabarmati	3.81	
13.	Mahi	11.02	
14.	West flowing rivers of Kutch, Sabarmati including Luni	15.10	11.23+ 7.19[4,5]
15.	Narmada	45.64	10.83
16.	Tapi	14.88	8.27
17.	West flowing rivers from Tapi to Tadri	87.41	
18.	West flowing rivers from Tadri to Kanyakumari	113.53	17.29[6]
19.	Area of inland drainage in Rajasthan desert	NEG.	
20.	Minor river basins drainage into Bangladesh & Burma	31.00	
	Total	**1869.35[7]**	**431.42[8]**

1. Meghna value assessment.

2. North East: a composite value

3. Madras and south of Tamilnadu

4. Kutch and Saurashtra composite

5. Cambai composite.

6. Western Ghat all-inclusive.

7. Official web site statistics of the Government of India 2005 (Surface Water Resources data). These data, given independently for surface and groundwater, have some differences in the basin categories and hence some readjustments have been made in the table to put GW under the corresponding row of a river basin in the table.

8. Official web site statistics of the Government of India 2005 (Ground Water Resources data).

Table 4. Water situation indicators of river basins in India

Class description	Value of indicator as proposed in the paper	River basin(s) of India (Annex 1 shows an 'India basin map' for reference)
	Indicator 1	
Very highly stressed through surface withdrawal	>0.8	Pennar
Highly stressed, through surface withdrawal	0.4 – 0.8	Cauvery
Moderately stressed, through surface withdrawal	0.2 – 0.4	Indus, Ganga, Subarnarekha, Mahanadi, Tapi, Sabarmati
Low stress, in regard to surface withdrawal	<0.2	Brahmaputra, Godavari, Brahmani
	Indicator 2	
Surface water quality, low stress	< 0.05	All basins
Surface water quality, moderate stress	0.05 – 0.2	Cauvery, Tapi, Sabarmati, Pennar
	Indicator 3	
Groundwater very highly stressed through withdrawals	>0.8	Sabarmati
Groundwater highly stressed through withdrawals	0.4 – 0.8	Indus, Ganga, Subarnarekha
Groundwater moderately stressed through withdrawals	0.2 – 0.4	Mahanadi, Godavari, Krishna, Pennar, Cauvery,Tapi, Narmada, Mahi
Ground water low stressed	<0.2	All other basins including Brahmani
	Indicator 4	
Groundwater quality under very high threat	>0.8	None
Groundwater quality under high threat	0.4 – 0.8	Indus, Ganga, Subarnarekha, Krishna, Pennar, Cauvery, Sabarmati
Groundwater quality under moderate threat	0.2 – 0.4	Brahmaputra, Mahanadi, Godavari, Tapi, Narmada, Mahi, Brahmani

Conclusions

Some of the interventions thrown up through by ICID's CPSP studies in India are of interest, though they are country specific. They relate to how best some of the provisions in the existing Country Water Policy could be reviewed in the context of individual basins. A few suggestions are listed below for the facilitation of the decision-making processes and mechanisms available in the region:

- Identify a time-bound programme for investments needed in the five year plans to meet the needs of 2025.
- Integrate surface water and groundwater.
- Aim for attaining equity, efficiency, economy and efficacy in all aspects of water resources development.
- Identify basin-wise contemplated storage schemes and undertake and complete them by 2025. Enhance useable waters simultaneously through special means, such as inter-basin transfers.
- Undertake watershed development and management in rain-fed areas through ample provisions.
- Maintain food security through 'sufficiency plus buffer stocks' and through governance towards 2025. Divert areas to cash crops if and when food production exceeds this threshold level.
- Collect, evacuate, treat and recycle all wastewater. Do not allow release of polluted water directly into rivers. Industry should only use make-up water.
- Implement drainage schemes to allow irrigated agriculture to convert non-point sources of pollution to point sources of collected drainage water, to enable treatment and re-use.
- Water resource development redistributes terrestrial waters to land from which it can run off, and hence can be considered as eco-friendly. Maximise the productivity of terrestrial eco-systems consuming significant quantities of waters. Quantify it.
- Assess the lengths of river systems presently supporting aquatic eco-systems. Try to sustain them. Assess goods and services provided by eco-systems for humans. Where possible, shift fisheries to reservoirs from flow systems.
- Stop encroachments on mangroves, assess freshwater need and provide it by pipelines, rather than through river channel, terming it environmental flow requirements (EFR). Dispassionately examine EFRs and minimum flow needs (MFN) based on realistic studies/needs. They are expensive, and do not reach targets if the needs of en-route human systems are left unattended.
- Assess and promote public awareness of flood amelioration provided by dams, including drought proofing and avoiding desertification.
- Adopt all science and technological interventions on a priority basis to bring about realisation of the objectives of Integrated Water Resources Development and management.
- Investment for addressing water needs for food, people and nature has many tacit returns. Quantify them independently and collectively, to help generate a propensity by policy makers and national governments to allocate these.[3]

3. The views expressed in this paper are the author's impression, and are not necessarily the opinion of the organisations which he serves, or has served in the past.

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Annex 1.

1. Indus
2. Ganga
3. Brahmaputra
4. Subarnarekha
5. Brahmani-Baitarani
6. Mahanadi
7. Godavari
8. Krishna
9. Pennar
10. Cauvery
11. Tapi
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15. West Flowing Rivers of Kachchh and Saurashtra Including Luni.
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17. East Flowing Rivers between Mahanadi and Godavari
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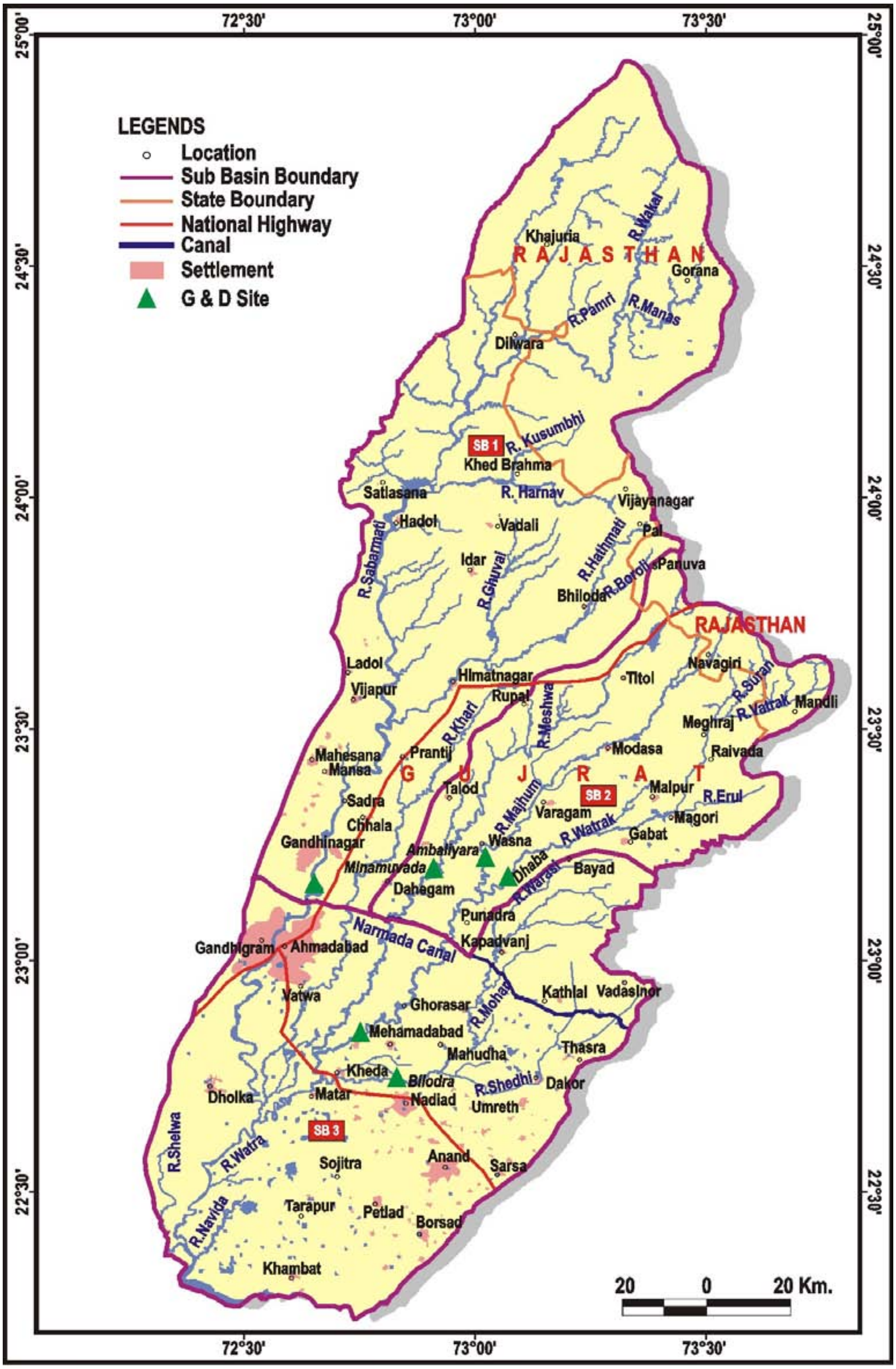
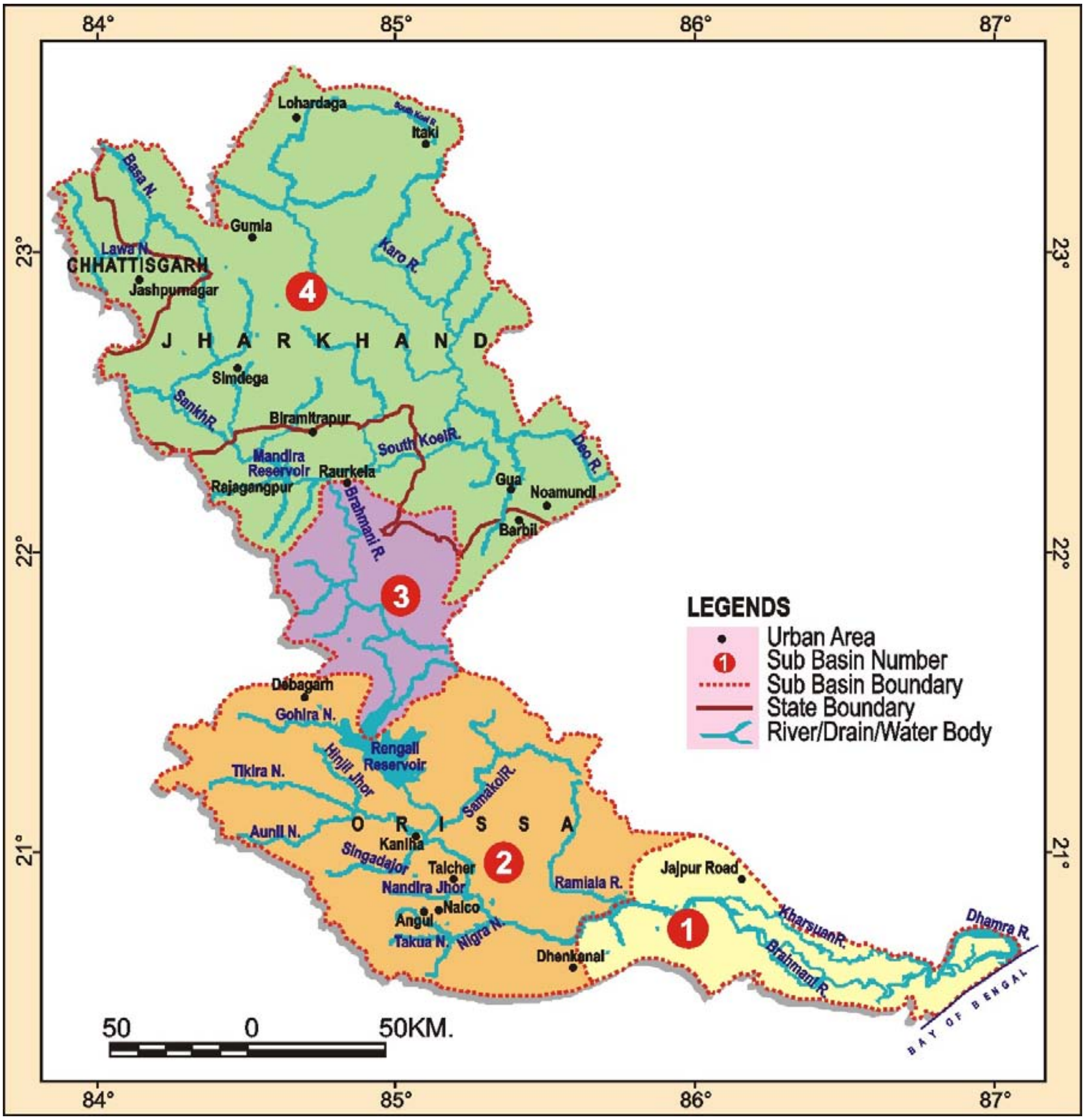
21. East Flowing Rivers South of Cauvery
22. Area of North Ladakh Not draining into Indus
23. Rivers draining into Bangladesh
24. Rivers draining into Mayanmar
25. Drainage Area of Andaman and Nicobar and Lakshadweep

Annex 2. Sabarmati Basin



Annex 3. Brahmani Basin



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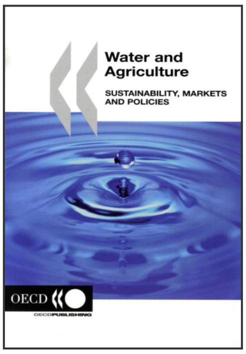

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