

ENVIRONMENTAL FLOWS

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Director, Asia

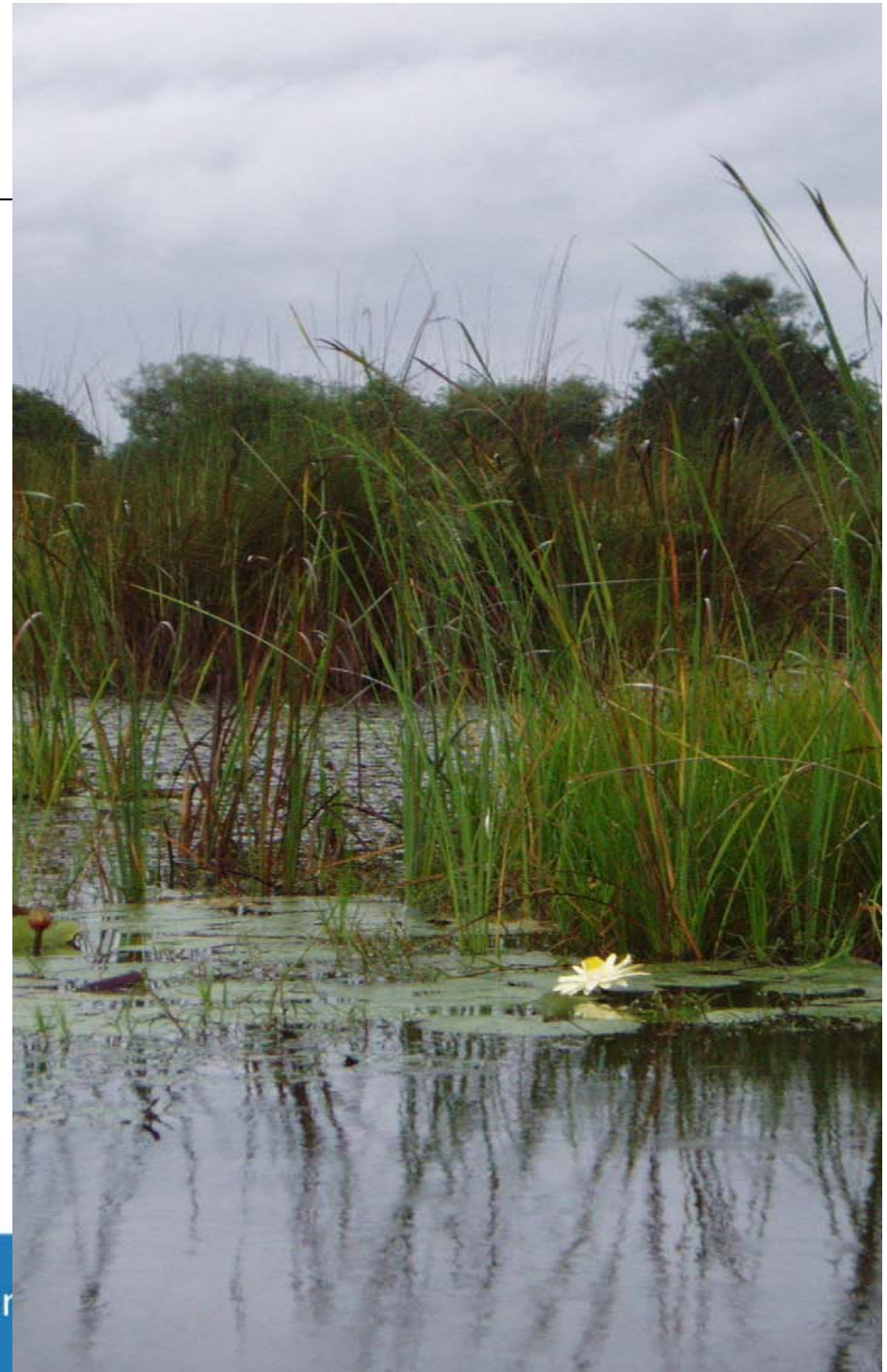
International Water Management Institute, Colombo,
Sri Lanka

*Stakeholder Consultation, Basin Development Plan for the
Lower Mekong. 12-13 March 2008, Vientiane, Lao PD*

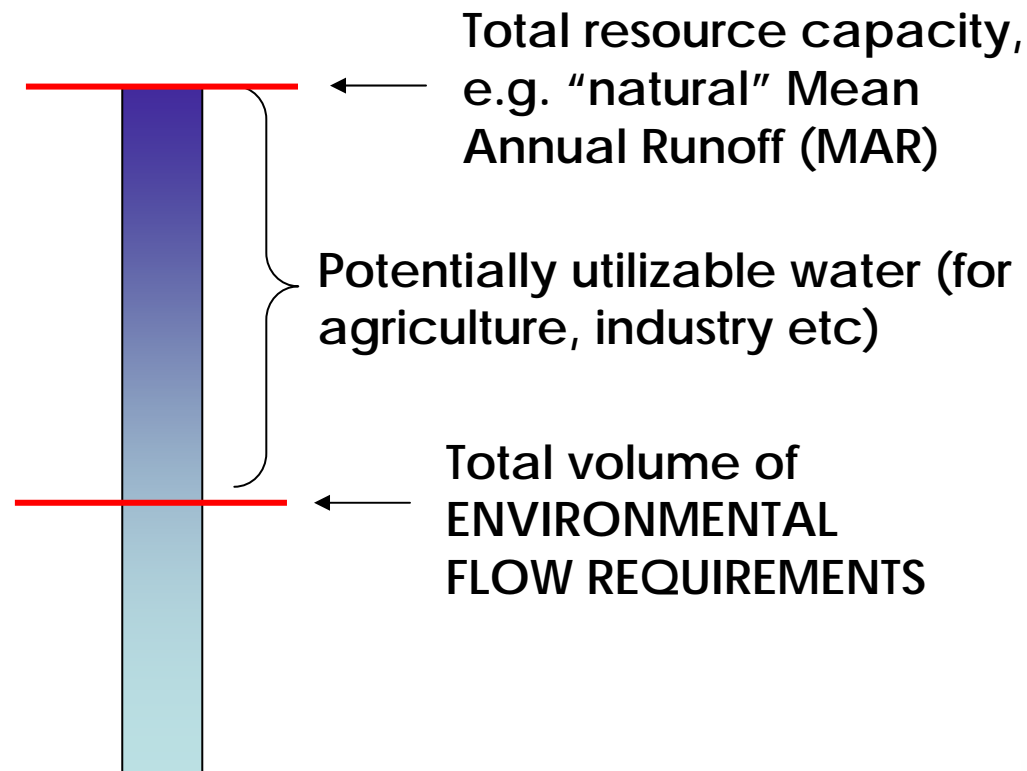
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BACKGROUND

- Aquatic ecosystems provide water for development, but they also need water to maintain the aquatic life and biodiversity
- For the majority of the world's river basins estimates of the environmental water requirements (EWR) are yet to be developed
- As the competition for water and other pressures grow, environmental water requirements need to be appropriately accounted for, even before other uses.



ENVIRONMENTAL FLOW REQUIREMENTS AS PART OF AVAILABLE WATER RESOURCES



GLOBAL ENVIRONMENTAL FLOW ASSESSMENT: HYDROLOGICAL “RULE OF THUMB”

- OUR KNOWLEDGE AND DATA ON THE IMPACTS OF CHANGING FLOW ON AQUATIC ECOSYSTEMS IS LIMITED : THE ESTIMATION HAS TO BE DRIVEN BY HYDROLOGICAL DATA AND ECOLOGICAL HYPOTHESES
- ASSESMENT AND MAINTENANCE OF ELEMENTS OF NATURAL FLOW VARIABILITY IN A MODIFIED FLOW REGIME SHOULD BE THE MAIN GOAL OF ENVIRONMENTAL FLOW MANAGEMENT
- BASEFLOW AND QUICKFLOW ARE THE PRIMARY PARTS OF NATURAL HYDROLOGICAL REGIME. THEIR TIMING, DURATION, FREQUENCY AND MAGNITUDE ARE IMPORTANT FOR MAINTAINING KEY ECOSYSTEM PROCESSES
- FOR COARSE GLOBAL ASSESSMENT, ENVIRONMENTAL REQUIREMENT WAS ASSUMED TO BE COMPOSED OF TWO REQUIREMENTS - ONE FOR LOW FLOW AND ONE FOR HIGH FLOW:
$$\text{EWR} = \text{LOW FLOW REQUIREMENT} + \text{HIGH FLOW REQUIREMENT}$$
- BOTH REQUIREMENTS VARY DEPENDING ON FLOW REGIME



ENVIRONMENTAL MANAGEMENT CLASSES (EMC)

TOTAL ENVIRONMENTAL REQUIREMENT DEPENDS UPON THE CATEGORY OF ENVIRONMENTAL PROTECTION – THE MORE PRISTINE THE DESIRED MANAGEMENT CLASS - THE HIGHER THE REQUIREMENT

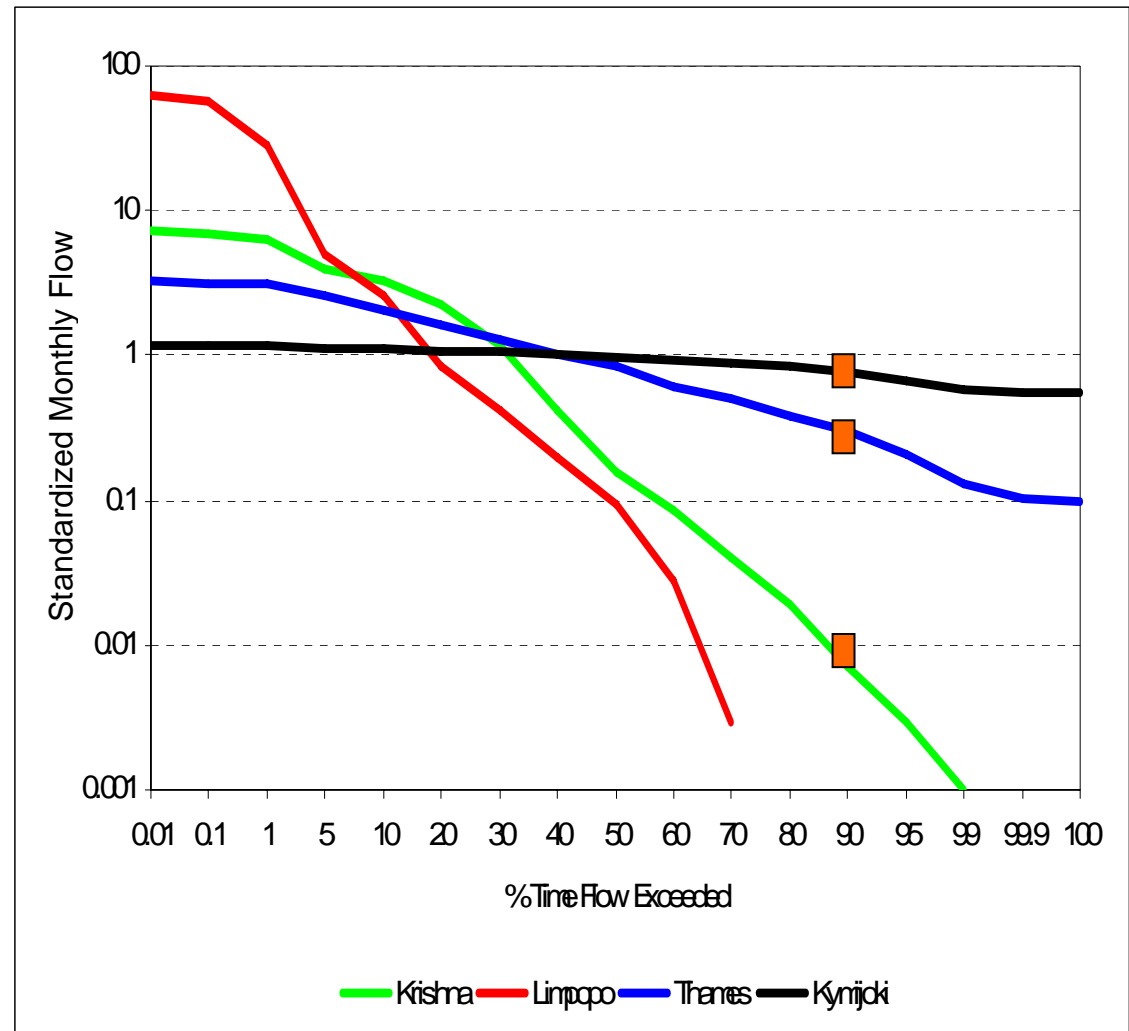
EMC	ECOLOGICAL DESCRIPTION	MANAGEMENT PERSPECTIVE
A: Natural	Pristine condition or minor modification of in-stream and riparian habitat	Protected rivers and basins. Reserves and national parks. No new water projects allowed.
B: Slightly modified	Largely intact biodiversity and habitats despite water resources development and/or basin modifications.	Water supply schemes or irrigation development present or allowed.
C: Moderately modified	Habitats and dynamics of the biota have been disturbed, but basic ecosystem functions intact.	Multiple disturbances associated with the need for socio-economic development, e.g. dams, diversions, etc
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E: Seriously modified	Habitat diversity and availability have declined. A strikingly lower than expected species richness. Alien species invaded the ecosystem.	High human population density and extensive water resources exploitation.
F: Critically modified	Modifications have reached a critical level and ecosystem has been completely modified with almost total loss of natural habitat and biota.	Status is not acceptable. Management interventions are necessary to restore flow pattern, river habitats etc (if still possible / feasible).

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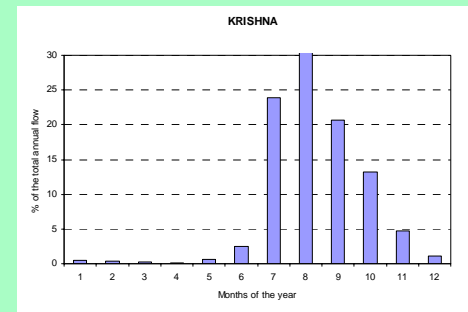
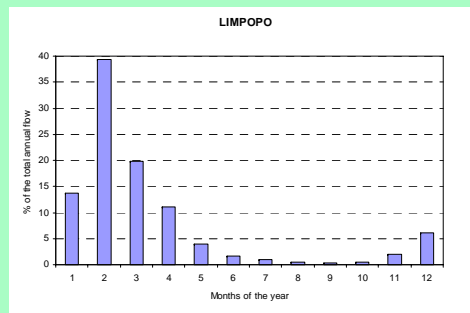
GLOBAL ENVIRONMENTAL FLOW ASSESSMENT: LOW FLOW REQUIREMENT (LFR)

- FOR “FAIR” CONDITION (MODERATELY MODIFIED RIVERS), THE LFR IS SET TO Q90 - DISCHARGE, EXCEEDED 90% OF THE TIME ON A FLOW DURATION CURVE (FDC) - A CUMULATIVE PROBABILITY DISTRIBUTION FUNCTION OF FLOWS
- FOR STABLE FLOW REGIMES, Q90 IS LARGE, COMPARED TO THE MEAN FLOW. FOR VARIABLE FLOW REGIMES, Q90 IS SMALL OR ZERO



HIGHLY VARIABLE HYDROLOGICAL REGIMES: A LOWER PROPORTION OF NATURAL RUNOFF FOR THE ECOSYSTEMS

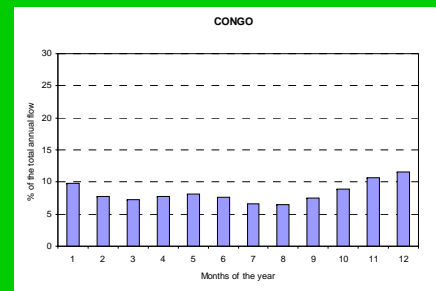
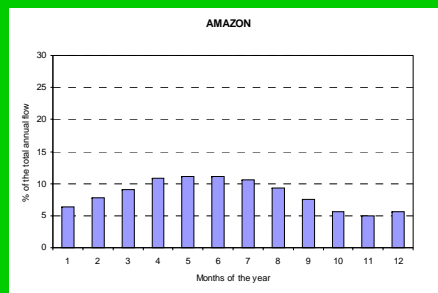
- AQUATIC LIFE IS USED TO THE EXTENDED PERIODS OF LIMITED OR NO FLOW
- ESTIMATES OF ENVIRONMENTAL WATER REQUIREMENTS ARE DOMINATED BY A PROPORTION OF HIGH FLOWS OF THE WET SEASON – BY HIGH FLOW REQUIREMENT: $EWR = HFR + LFR$



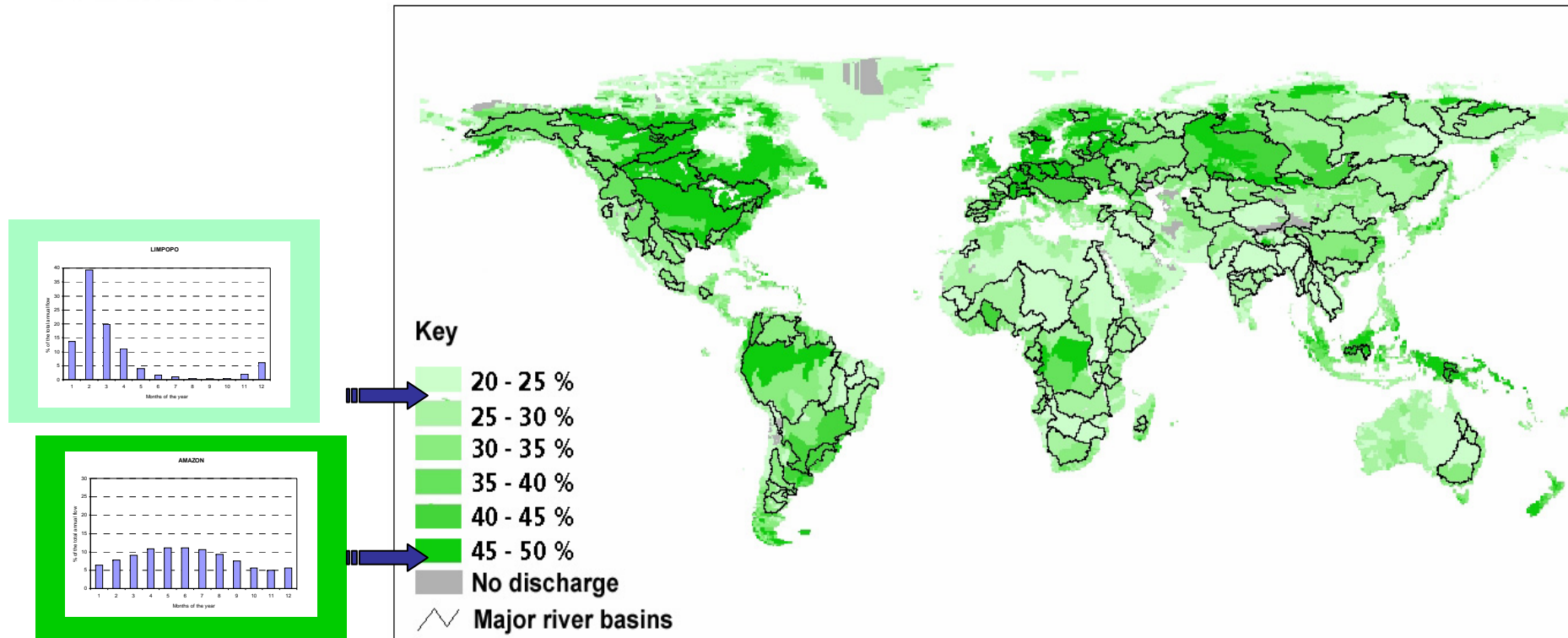
Less than 30% of river flow for the ecosystems

STABLE HYDROLOGICAL REGIMES: A HIGHER PROPORTION OF NATURAL RUNOFF FOR THE ECOSYSTEMS

- AQUATIC LIFE IS MORE SENSITIVE TO FLOW REDUCTION
- ESTIMATES OF ENVIRONMENTAL WATER REQUIREMENTS ARE DOMINATED BY A PROPORTION OF BASEFLOW THROUGHOUT THE YEAR – BY LOW-FLOW REQUIREMENT: $EWR = HFR + LFR$



ESTIMATED ENVIRONMENTAL WATER REQUIREMENTS (Percentage of the annual river flow needed for ecological purposes)



- Globally the estimated EWR range from 20 to 50% of the mean annual river flow
- As a general, broad-brush, rule of thumb, at least 30% of the flow in a river needs to be allocated to maintain a fair ecological condition in a river

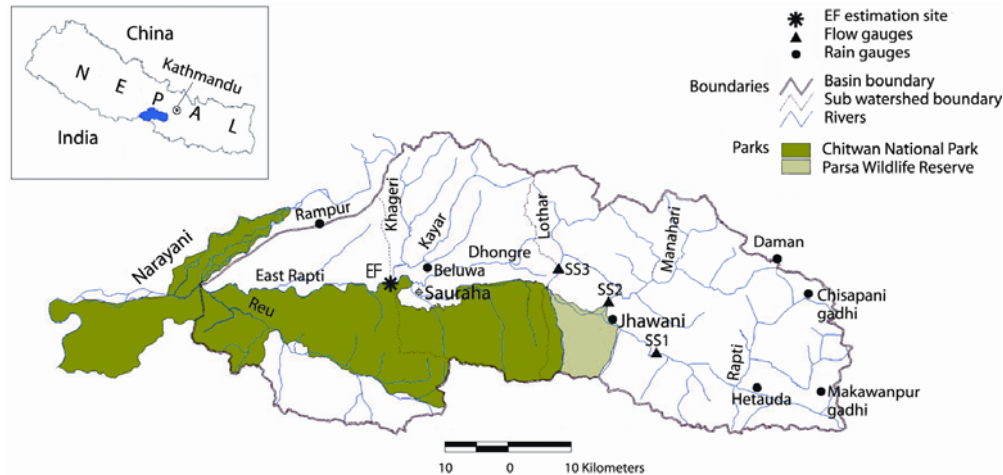
BASIN-SPECIFIC STUDIES IN ASIA

- GLOBAL ASSESSMENT IS TOO COARSE FOR ENVIRONMENTAL WATER ALLOCATION PLANNING IN INDIVIDUAL RIVER BASINS. ALTERNATIVE ESTIMATION TECHNIQUES ARE REQUIRED
- THEY MAY STILL BE PRIMARILY HYDROLOGY-BASED, BUT SHOULD MORE EXPLICITLY INCLUDE TIME SERIES ANALYSIS AND HAVE ENVIRONMENTALLY ACCEPTABLE FLOW REGIME AS OUTPUT
- RECENT BASIN-SPECIFIC APPLICATIONS IN ASIA:
 - SIMPLIFIED RANGE OF VARIABILITY APPROACH (NEPAL AND SRI LANKA)
 - SHIFTING OF A FLOW DURATION CURVE ALONG THE PROBABILITY AXIS (SEVERAL MAJOR RIVER BASINS IN INDIA)
 - **MONTHLY TIME SERIES**

SIMPLIFIED RANGE OF VARIABILITY (RVA) APPROACH

- ORIGINAL RVA:
 - HAS 32 PARAMETERS, WHICH REFLECT VARIOUS ECOLOGICALLY RELEVANT ASPECTS OF FLOW REGIME (e.g. means of 1, 3, 7, 30, 90-day annual minimum and maximum flows).
 - IN A MODIFIED FLOW REGIME, THESE PARAMETERS ARE ALLOWED TO VARY WITHIN THE LIMIT OF: (mean \pm 1 Standard Deviation)
 - PARAMETER SELECTION IS ARBITRARY AND THERE IS LIMITED DIFFERENCE BETWEEN SOME OF THEM
- SIMPLIFIED RVA:
 - REDUCES THE NUMBER OF PARAMETERS TO 16 or LESS
 - LOCATES THEM ALL ON A FDC
 - ACCEPTS DEFAULT RVA LIMIT OF 1 SD FOR EACH PARAMETER TO PRODUCE ENVIRONMENTAL FLOW DURATION CURVE, WHICH IS A SUMMARY OF ENVIRONMENTAL FLOW REGIME AT A SITE
 - CONVERTS AN ENVIRONMENTAL FLOW CURVE INTO A COMPLETE ENVIRONMENTAL FLOW TIME SERIES

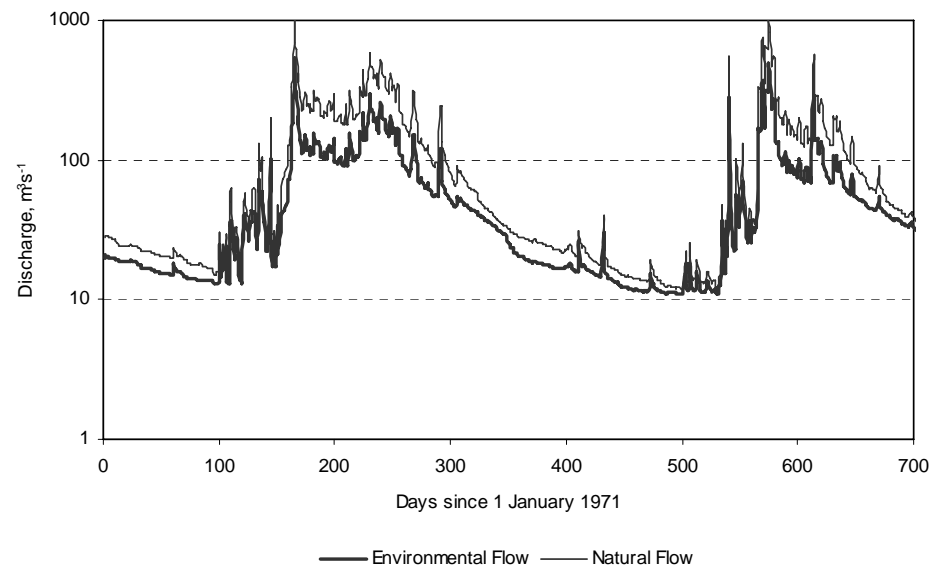
SIMPLIFIED RANGE OF VARIABILITY APPROACH APPLICATION IN E.RAPTI BASIN, NEPAL



Natural and Environmental Flow Duration Curves

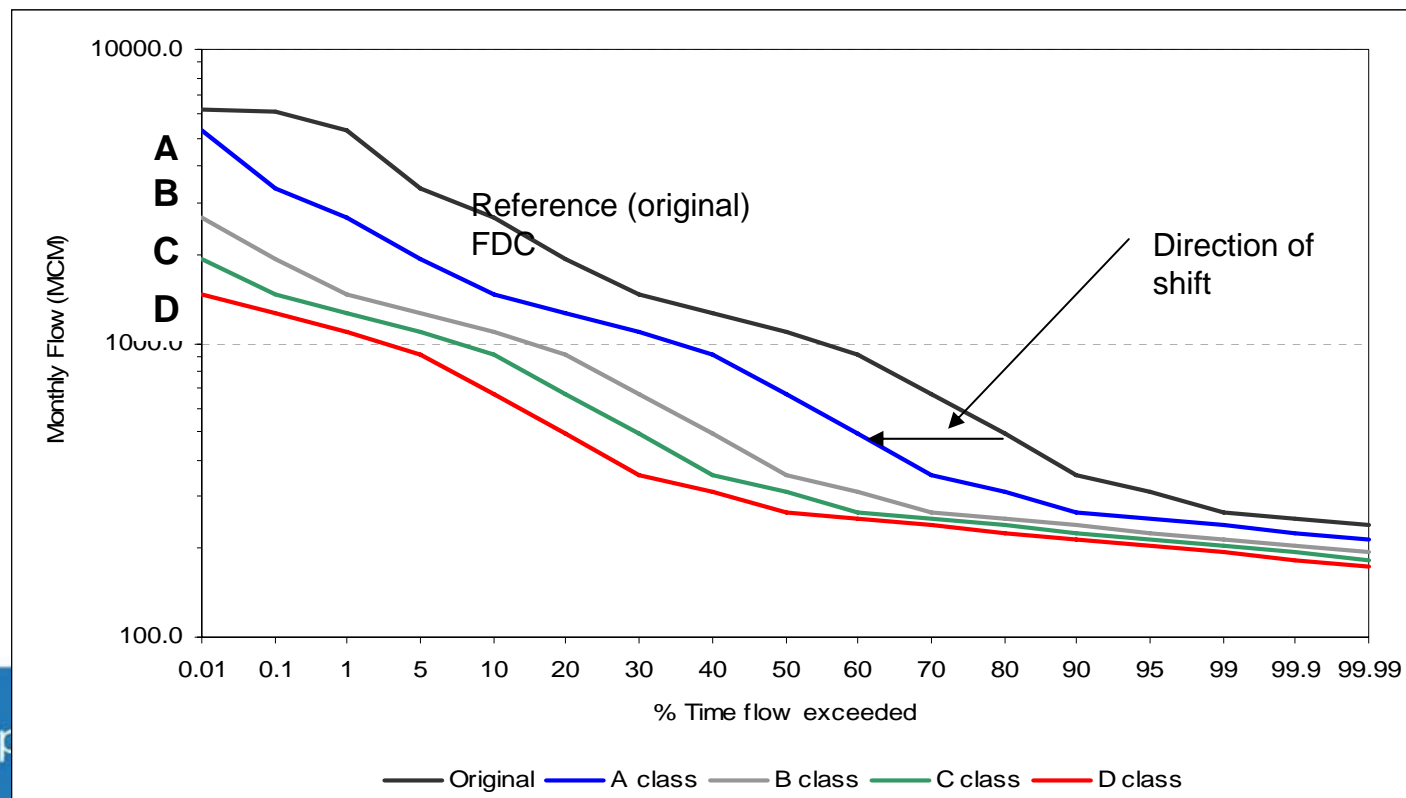


Natural and Environmental Flow Hydrographs

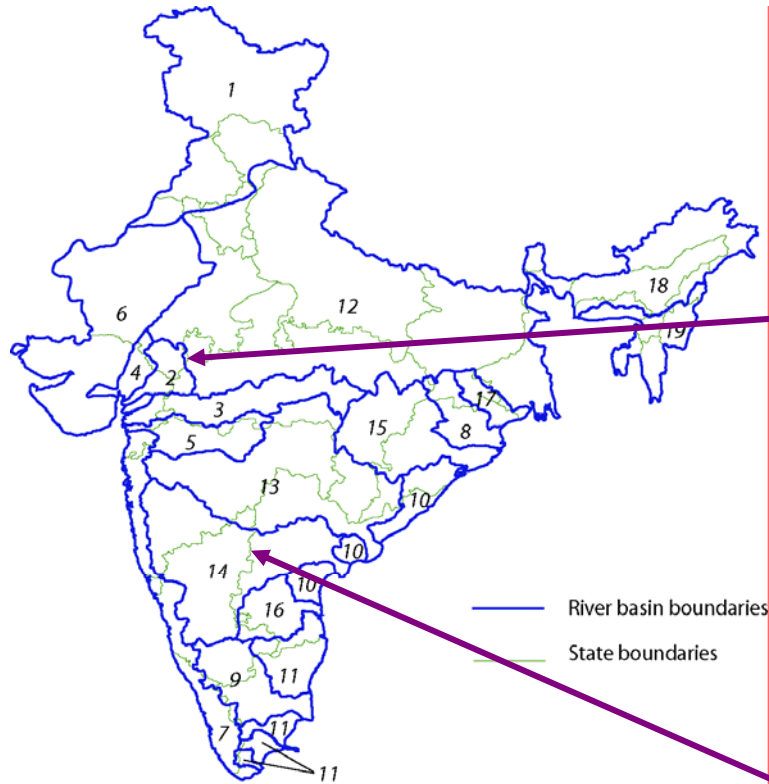


LATERAL SHIFT OF A FLOW DURATION CURVE

- MONTHLY FLOW TIME SERIES TO ESTABLISH A NATURAL – REFERENCE FDC
- SHIFT IS PERFORMED USING 17 FIXED PERCENTAGE POINTS, WHICH COVER THE ENTIRE RANGE OF FLOWS
- A SHIFT OF 1 STEP IS EQUIVALENT TO “MOVING” A RIVER FROM A HIGHER ENVIRONMENTAL MANAGEMENT CLASS TO THE NEXT (LOWER) ONE (e.g. from Class ‘A’ to Class ‘B’)

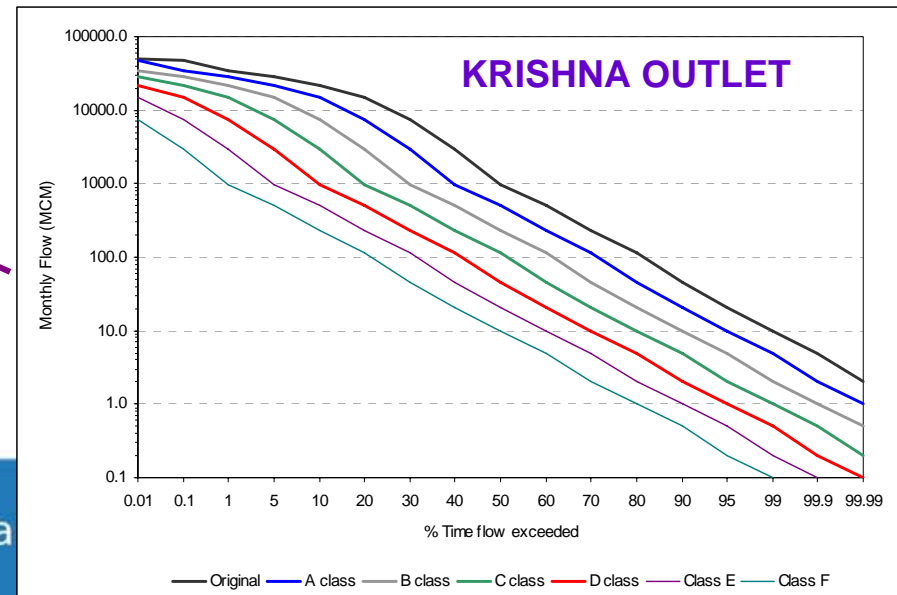
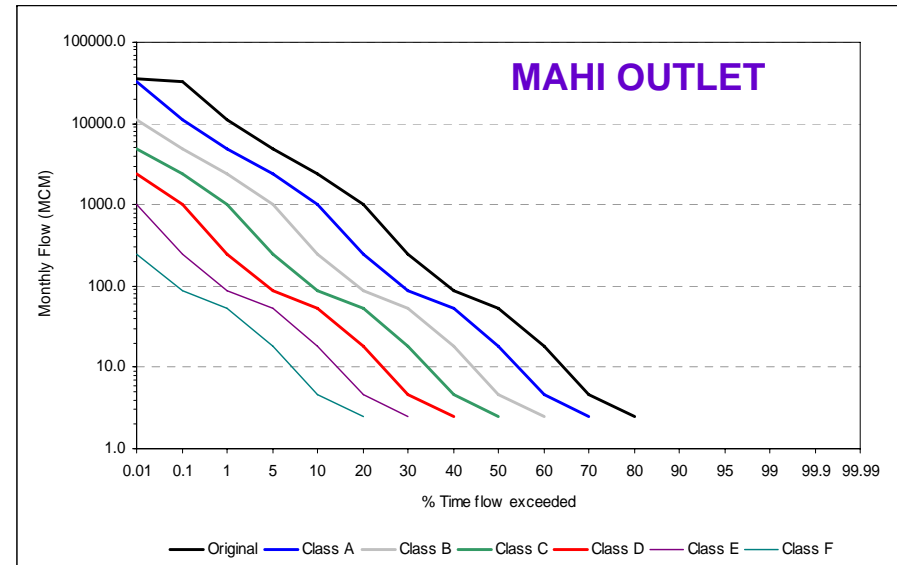


EXAMPLES OF ESTIMATED ENVIRONMENTAL DURATION CURVES



River basins

- | | |
|-----------------------------------|------------------------------------|
| 1 Indus | 10 Easterly flowing rivers-Group 1 |
| 2 Mahi | 11 Easterly flowing rivers-Group 2 |
| 3 Narmada | 12 Ganga |
| 4 Sabarmati | 13 Godavari |
| 5 Tapi | 14 Krishna |
| 6 Westerly flowing rivers-Group 1 | 15 Mahanadi |
| 7 Westerly flowing rivers-Group 2 | 16 Pennar |
| 8 Brahmani and Baitarani | 17 Subarnarekha |
| 9 Cauvery | 18 Brahmaputra |
| | 19 Meghna |



An Assessment of Environmental Flow Requirements of Indian River Basins

V. Srinivasan and N. Arputras



ESTIMATES OF LONG-TERM EWR VOLUMES (% of natural MAR) for different environmental management classes

River	Natural MAR, BCM*	EWR estimates (% natural MAR)					
		Class A	Class B	Class C	Class D	Class E	Class F
Brahmaputra	585	78.2	60.2	45.7	34.7	26.5	20.7
Cauvery	21.4	61.5	35.7	19.6	10.6	5.8	3.2
Ganga	525	67.6	44.2	28.9	20.0	14.9	12.1
Godavary	110	58.8	32.2	16.1	7.4	3.6	2.0
Krishna	77.6	62.5	35.7	18.3	8.4	3.5	1.5
Mahanadi	66.9	61.3	34.8	18.5	9.7	5.6	3.6
Mahi	11.0	41.9	17.1	6.5	2.3	0.8	0.3
Narmada	45.6	55.5	28.8	14.0	7.1	3.9	2.5
Pennar	6.3	52.7	27.9	14.3	7.3	3.8	2.0
Tapi	14.9	53.2	29.9	16.6	9.0	4.9	2.6
Periyar	5.1	62.9	37.3	21.2	12.1	6.9	3.9
Sabarmati	3.8	49.6	24.2	12.1	6.6	3.7	2.1
Subarnarekha	12.4	55.0	29.9	15.4	7.4	3.4	1.5

Developing Procedures for Assessment of Ecological Status of Indian River Basins in the Context of Environmental Water Requirements

Vladimir Smakhtin, Mathukumaranamy Anurachalam, Sandeep Behera,
Arghana Chatterjee, Srabani Das, Parikshit Goutam, Garov D. Joshi,
Kumbakonam G. Sivaramakrishnan and K. Sankaran Unni





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RESEARCH
REPORT

120

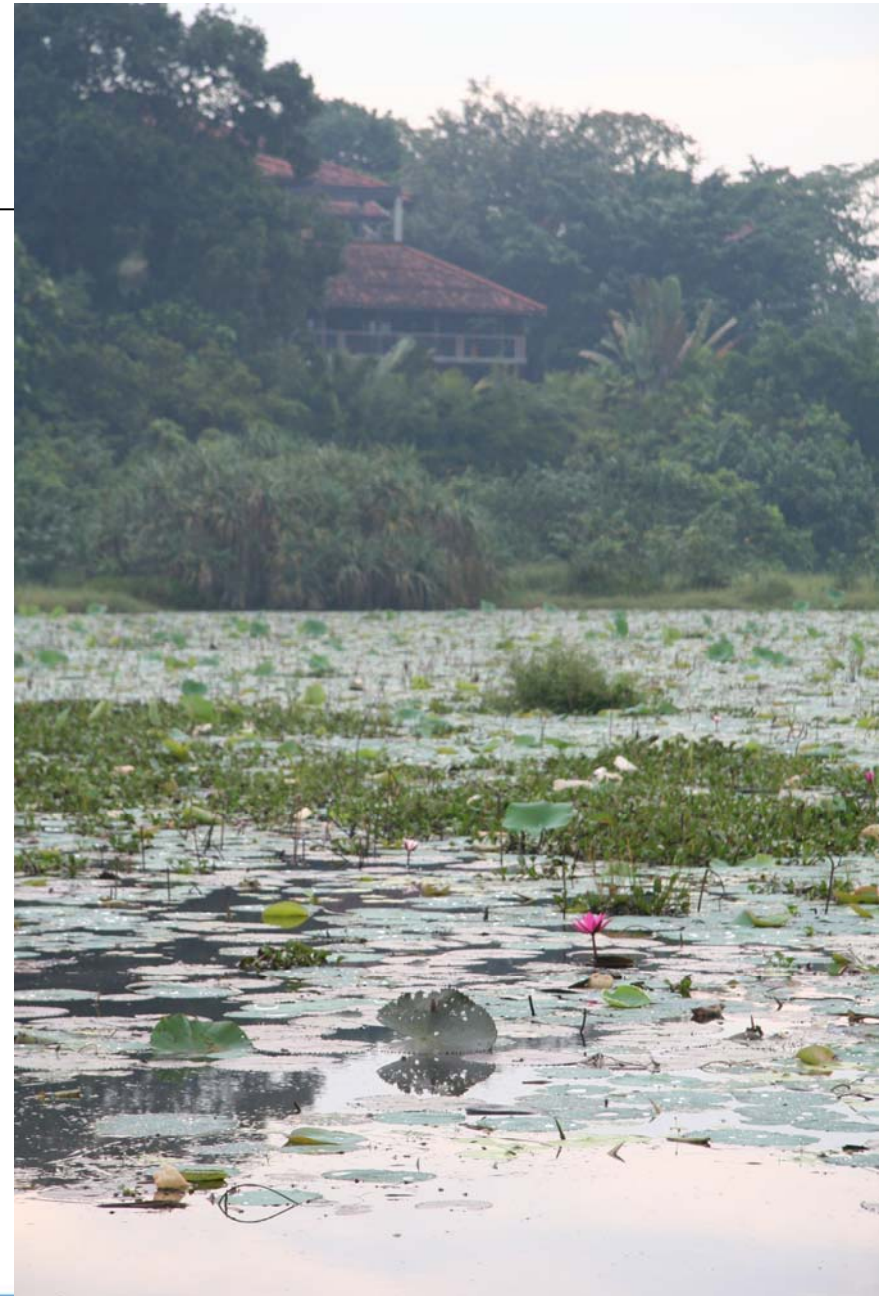
Hydrological and Environmental Issues of Interbasin Water Transfers in India: A Case of the Krishna River Basin

Madimir Smakhtin, Nilantha Garrage and Luro Bharad



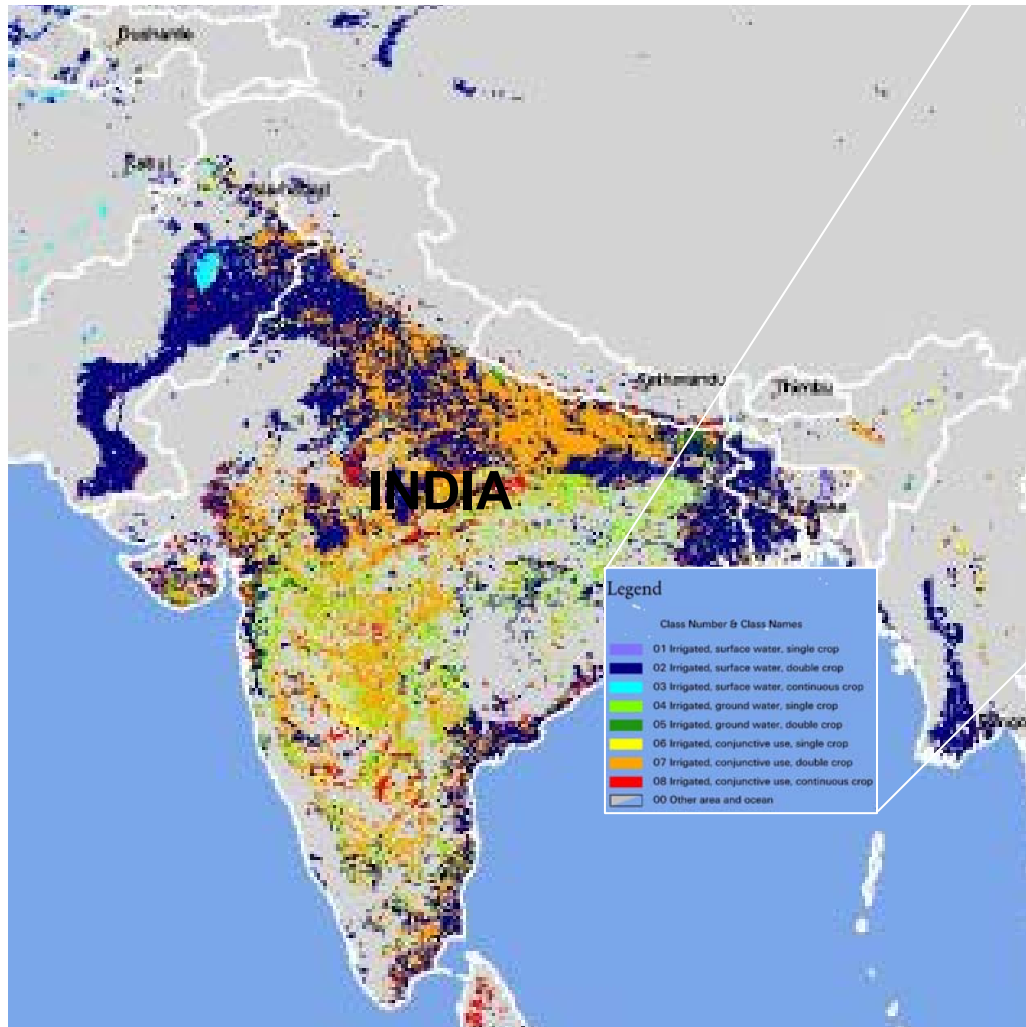
CONCLUSIONS ON E-FLOWS

- HYDROLOGY-BASED METHODS OF ENVIRONMENTAL FLOW ASSESSMENT CAN PROVIDE FIRST, CRUDE ESTIMATES OF ENVIRONMENTAL WATER REQUIREMENTS – AT DIFFERENT SCALES: FROM GLOBAL TO SMALL RIVER CATCHMENTS
- APPLICATIONS OF SUCH METHODS (AS OPPOSED TO MORE COMPLEX TECHNIQUES) MAY BE AN IMPORTANT FIRST STEP TOWARDS ENVIRONMENTAL FLOW MANAGEMENT IN ASIAN COUNTRIES
- A REQUIREMENT FOR BETTER ECOLOGICAL JUSTIFICATION OF HYDROLOGICAL METHODS REPRESENTS AN OPPORTUNITY TO INITIATE COMPREHENSIVE ENVIRONMENTAL FLOW ASSESSMENT STUDIES AND FEED THEIR MORE SOUND ECOLOGICAL OUTPUTS INTO HYDROLOGICAL (DESKTOP) METHODS
- ACTUAL ENVIRONMENTAL FLOW PROVISIONS ARE NOT THE SAME AS ENVIRONMENTAL WATER DEMAND ESTIMATES. NO MATTER HOW ADVANCED AND ACCURATE THE EFA IS, ITS OUTPUT WILL REMAIN ON PAPER IF NO ACTUAL RELEASES ARE MADE OR IF THE PRESCRIBED LIMIT OF WATER RESOURCE EXPLOITATION IS VIOLATED












IRRIGATED AREAS OF SOUTH ASIA

Global map @ 10km
India map @ 500m



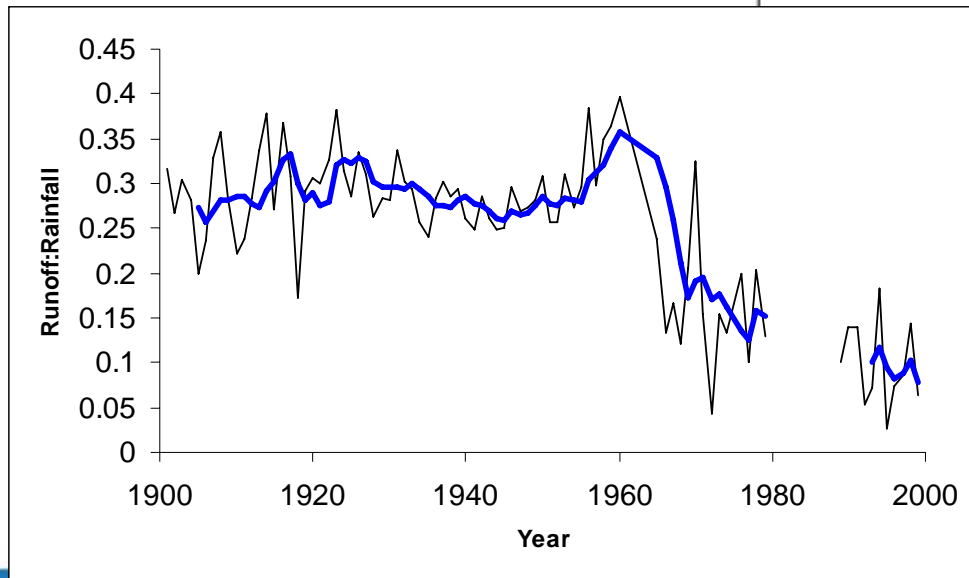
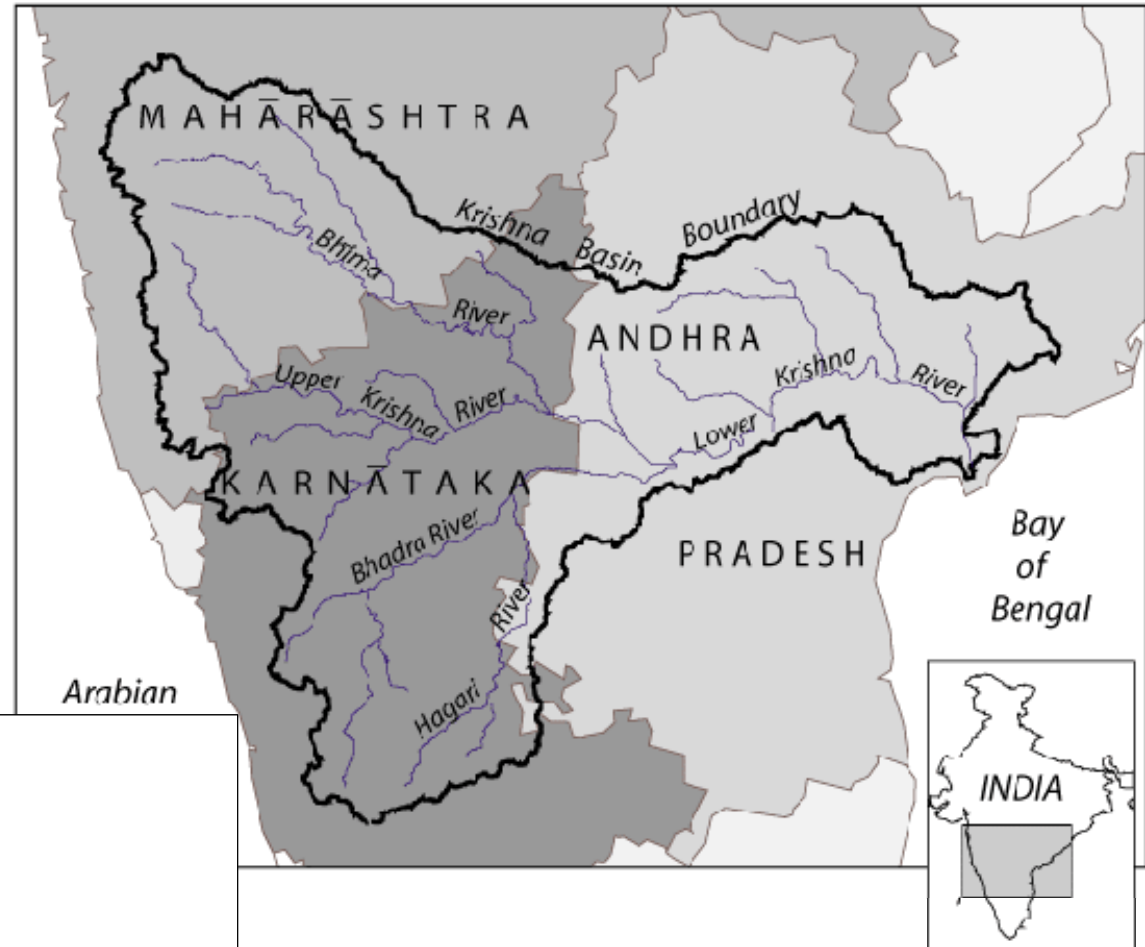
Legend

Class Number & Class Names

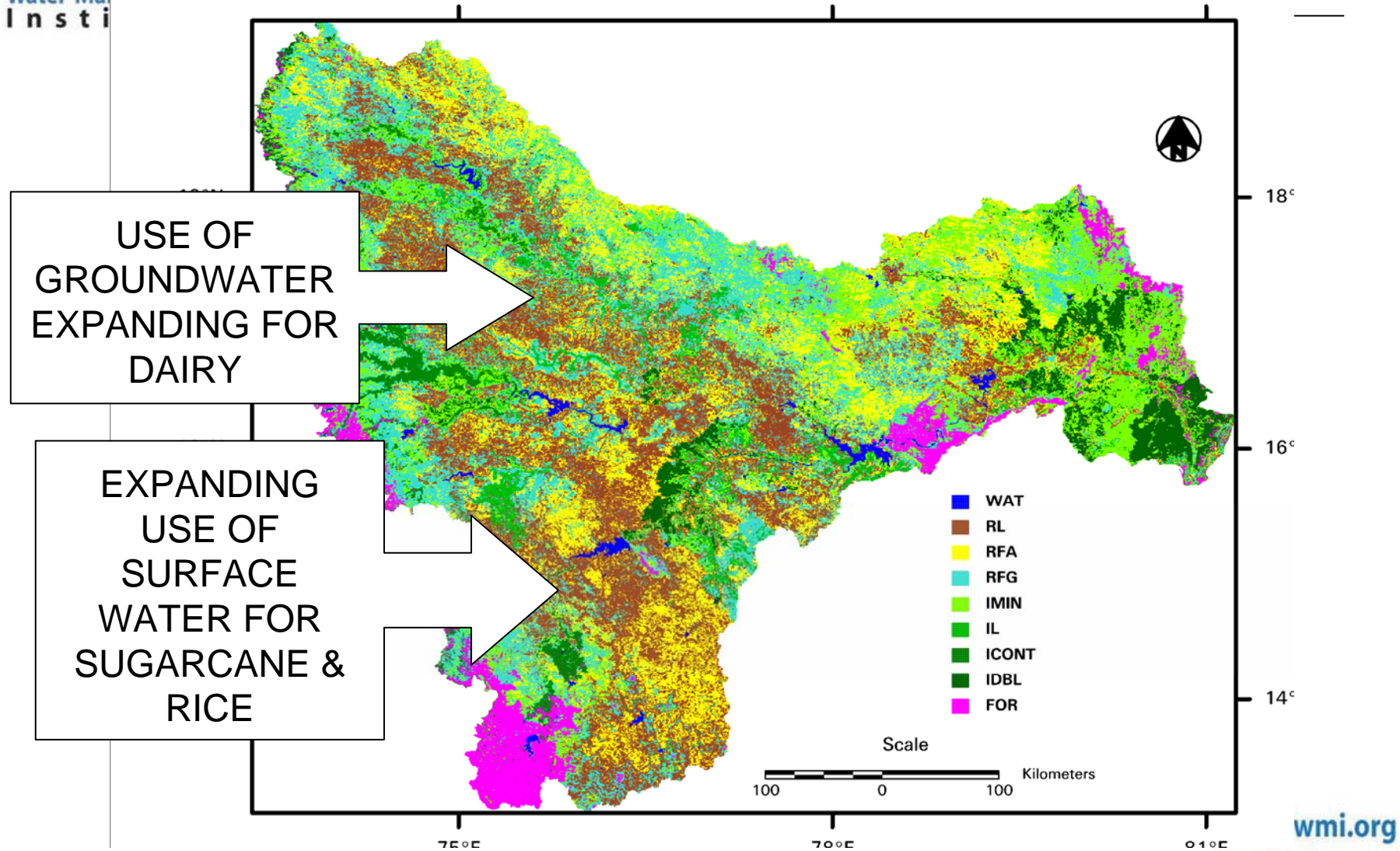
-  01 Irrigated, surface water, single crop
-  02 Irrigated, surface water, double crop
-  03 Irrigated, surface water, continuous crop
-  04 Irrigated, ground water, single crop
-  05 Irrigated, ground water, double crop
-  06 Irrigated, conjunctive use, single crop
-  07 Irrigated, conjunctive use, double crop
-  08 Irrigated, conjunctive use, continuous crop
-  00 Other area and ocean

Country	Season 1	Season 2	Continuous	Annualized
India	66,051,953	48,967,675	5,383,295	120,402,923

KRISHNA BENCHMARK BASIN



AGRICULTURAL WATER USE CHANGES IN THE KRISHNA



WATER POLICY BRIEF

Issue 29

Putting Research Knowledge into Action

Creating healthy working rivers: the wisdom of environmental flows



Photo Credit: Vladimir Smakhtin

As demand for water grows, pressure to develop river water resources also grows. At the same time, enough water needs to remain in rivers to keep them in good ecological health. This is the aim of maintaining environmental flows.

But how do we work out how much water a river requires to meet environmental needs, and when does it need that water? So far, most environmental flow assessments have been done in developed countries where river flow data is good and there's plenty of expertise. A new approach, aimed at meeting the need for environmental river flows in India, promises to help developing countries assess the environmental water requirements of their rivers using existing data and current knowledge.

Key findings

- The ecological status of rivers needs to be assessed BEFORE making any decisions to develop water resources.
- Simple tools are already available for rough-and-ready—though quite reliable—assessments of rivers' ecological status and the environmental flows needed to maintain or improve this status.
- These tools can encourage greater investment in building national capacities—to develop detailed methods tailored to specific contexts and to engage ecologists and hydrologists who know their local rivers.
- River flow data is essential, so should be made more accessible. Other priorities are to inventory the ecologically relevant information that already exists in-country and to quantify how hydrology affects river ecology.
- Policy support and enforcement should ensure that water is released and abstraction is limited to maintain the recommended environmental flows.



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International
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FURTHER INFORMATION

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agement for food, livelihoods and nature