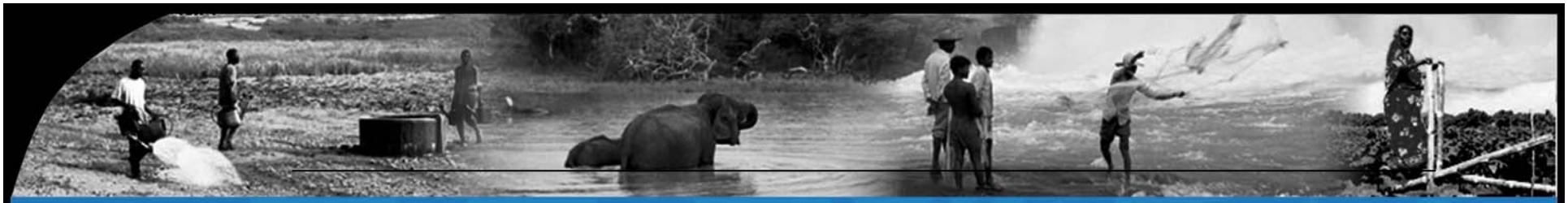


ENVIRONMENTAL FLOWS

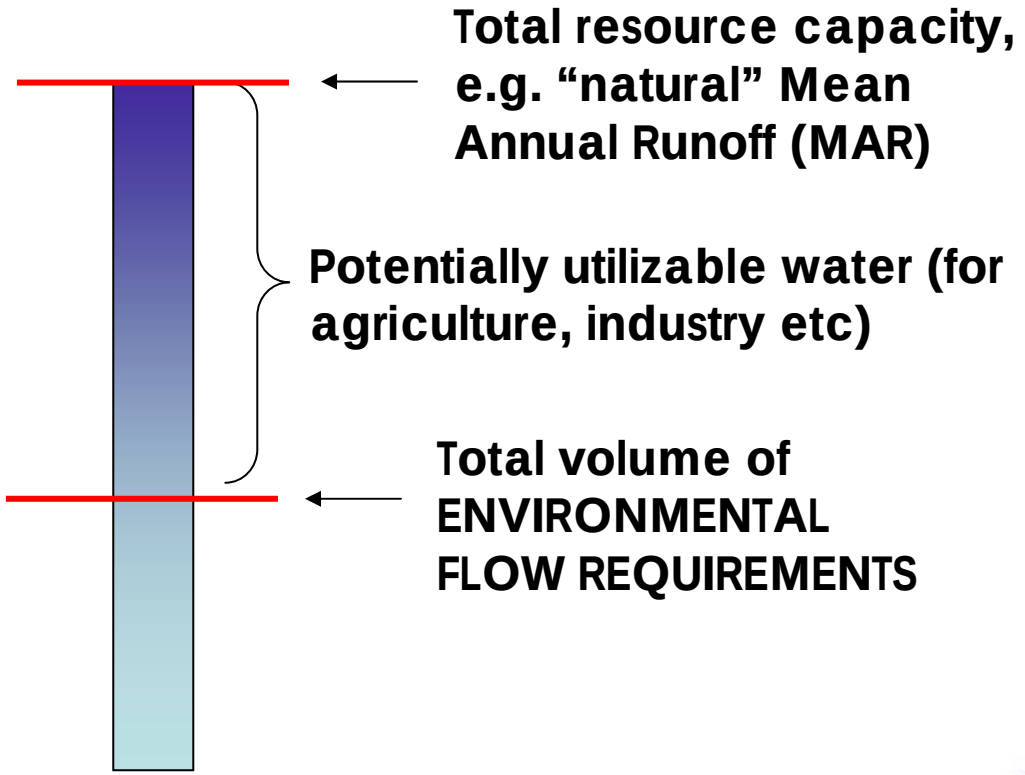
Peter G. McCornick, Ph.D., P.E., D.WRE.
Director, Asia
International Water Management Institute, Colombo, Sri Lanka

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

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:

  EWR = LOW FLOW REQUIREMENT + 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
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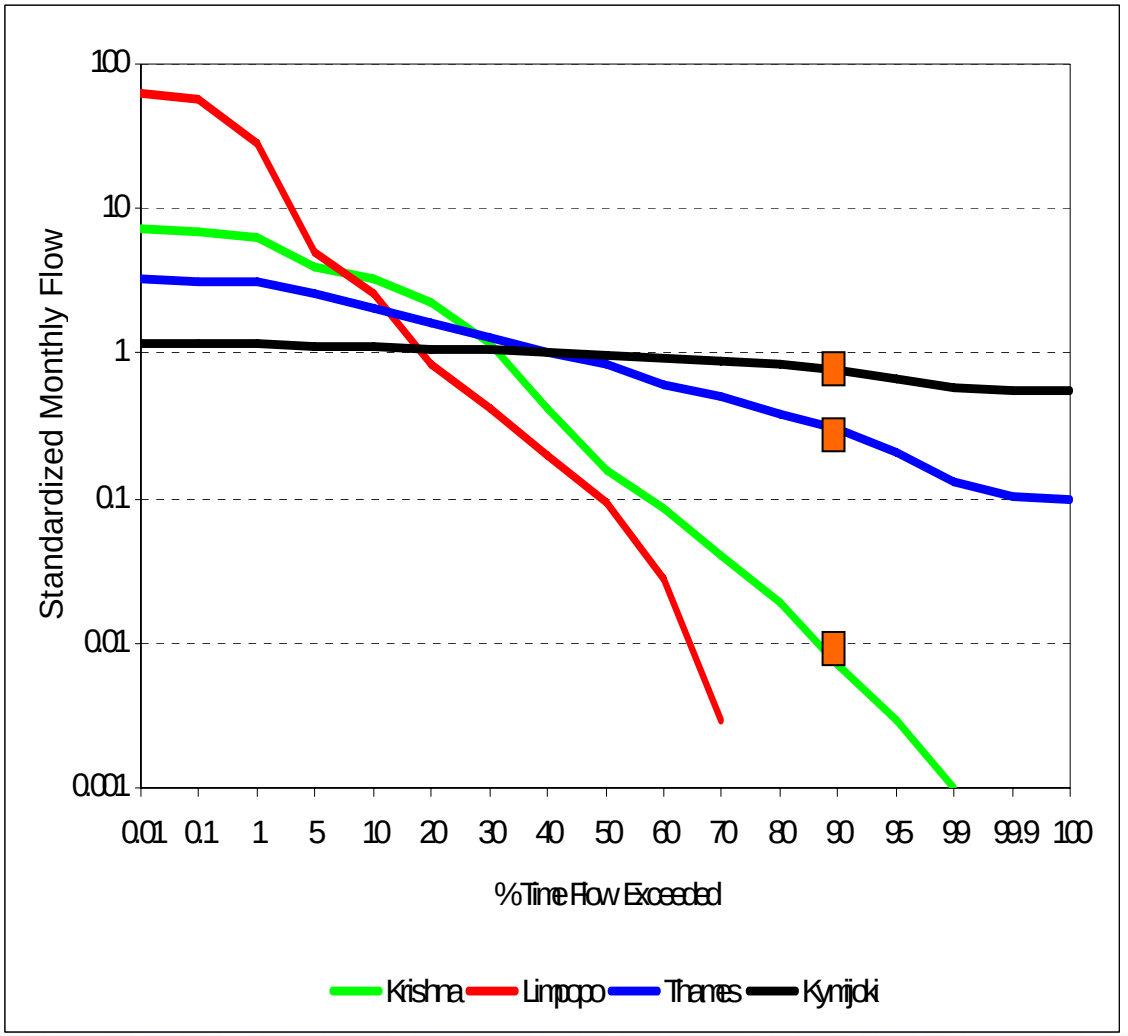
E: Seriously modified	Habitat diversity and availability have declined. A strikingly lower than expected species richness. Alien species invaded the ecosystem.	High human population density and extensive water resources exploitation.
F: Critically modified	Modifications have reached a critical level 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).

GLOBAL ENVIRONMENTAL FLOW ASSESSMENT: LOW FLOW REQUIREMENT (LFR)

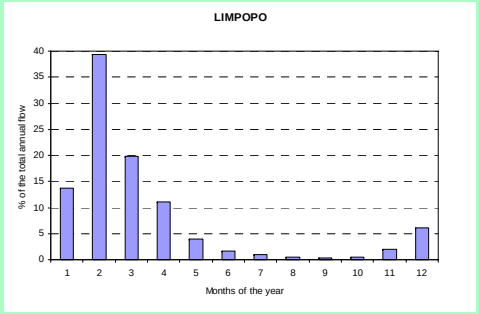
- FOR “FAIR” CONDITION (MODERATELY MODIFIED RIVERS), THE LFR IS SET TO Q90 - DISCHARGE, EXCEEDED 90% OF THE TIME ON A FLOW DURATION CURVE (FDC) - A CUMULATIVE PROBABILITY DISTRIBUTION FUNCTION OF FLOWS

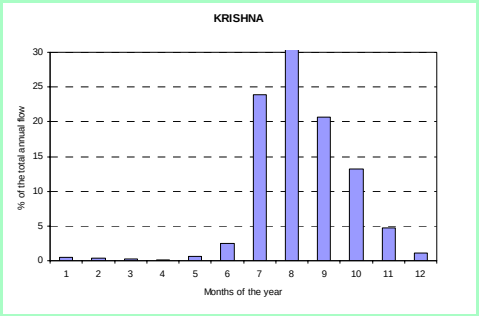
- FOR STABLE FLOW REGIMES, Q90 IS LARGE, COMPARED TO THE MEAN FLOW. FOR VARIABLE FLOW REGIMES, Q90 IS SMALL OR ZERO



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

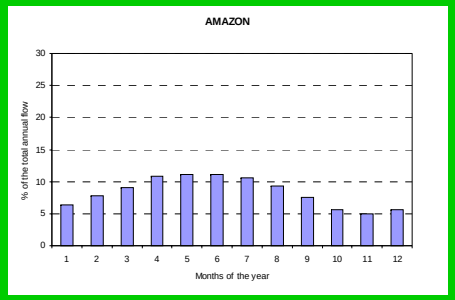


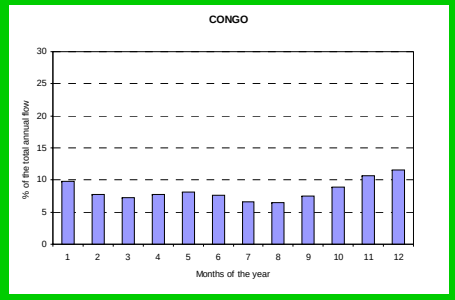


Less than 30% of river flow for the ecosystems

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

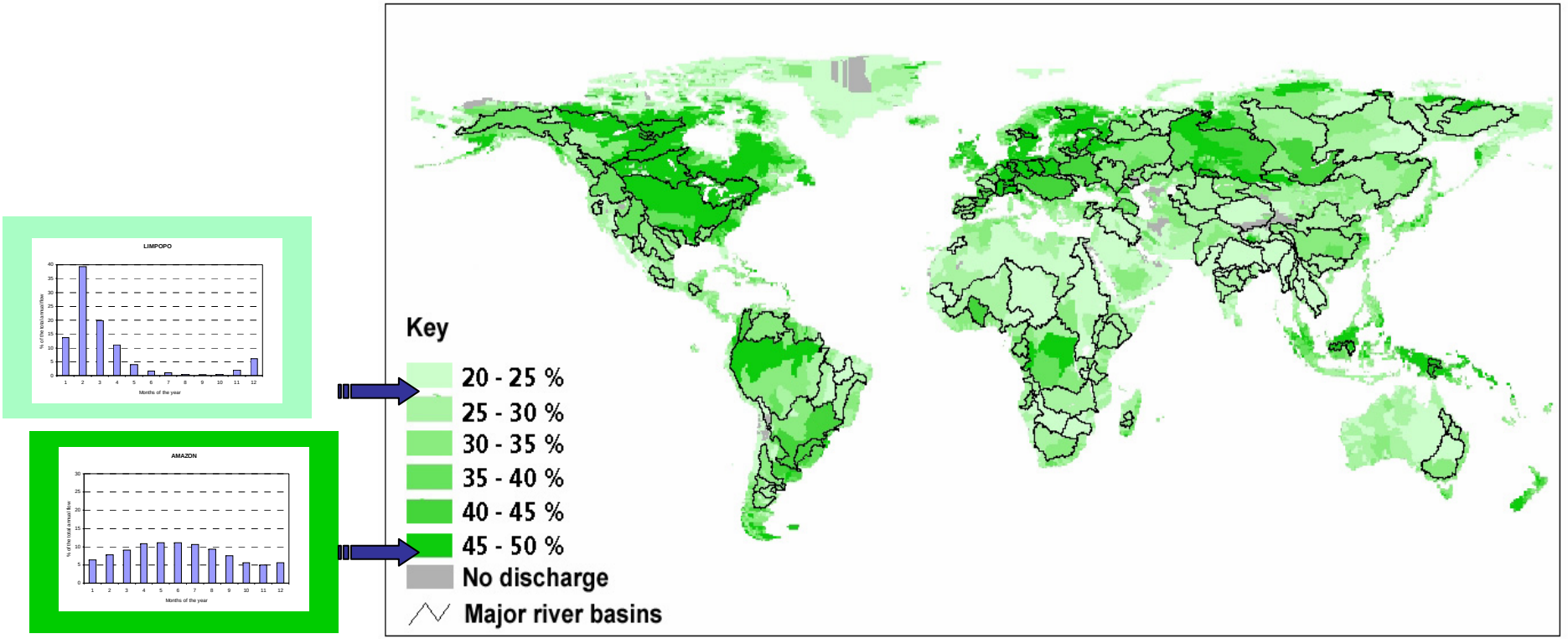
- AQUATIC LIFE IS MORE SENSITIVE TO FLOW REDUCTION
- ESTIMATES OF ENVIRONMENTAL WATER REQUIREMENTS ARE DOMINATED BY A PROPORTION OF BASEFLOW THROUGHOUT THE YEAR – BY LOW-FLOW REQUIREMENT: EWR = HFR + LFR





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

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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:

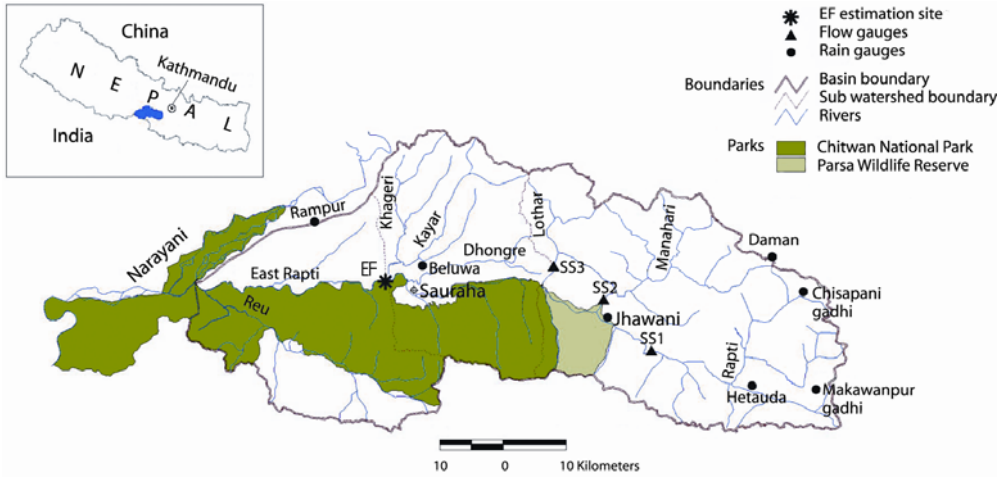
  - SIMPLIFIED RANGE OF VARIABILITY APPROACH (NEPAL AND SRI LANKA)
  - SHIFTING OF A FLOW DURATION CURVE ALONG THE PROBABILITY AXIS (SEVERAL MAJOR RIVER BASINS IN INDIA)
  - **MONTHLY TIME SERIES**

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 ± 1 Standard Deviation)
  - PARAMETER SELECTON IS ARBITRARY AND THERE IS LIMITED DIFFERENCE BETWEEN SOME OF THEM

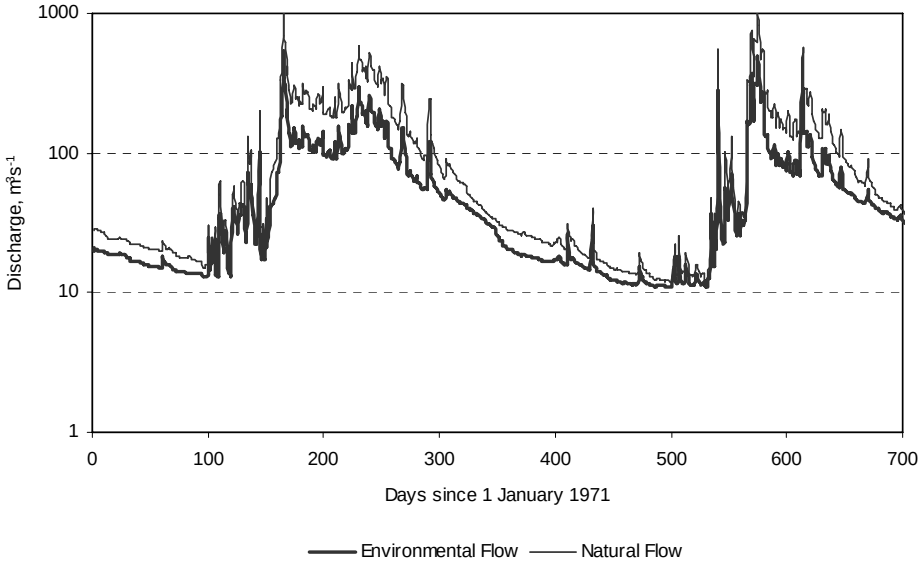
- SIMPLIFIED RVA:
  - REDUCES THE NUMBER OF PARAMETERS TO 16 or LESS
  - LOCATES THEM ALL ON A FDC
  - ACCEPTS DEFAULT RVA LIMIT OF 1 SD FOR EACH PARAMETER TO PRODUCE ENVIRONMENTAL FLOW DURATION CURVE, WHICH IS A SUMARY OF ENVIRONMENTAL FLOW REGIME AT A SITE
  - CONVERTS AN ENVIRONMENTAL FLOW CURVE INTO A COMPLETE ENVIRONMENTAL FLOW TIME SERIES

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



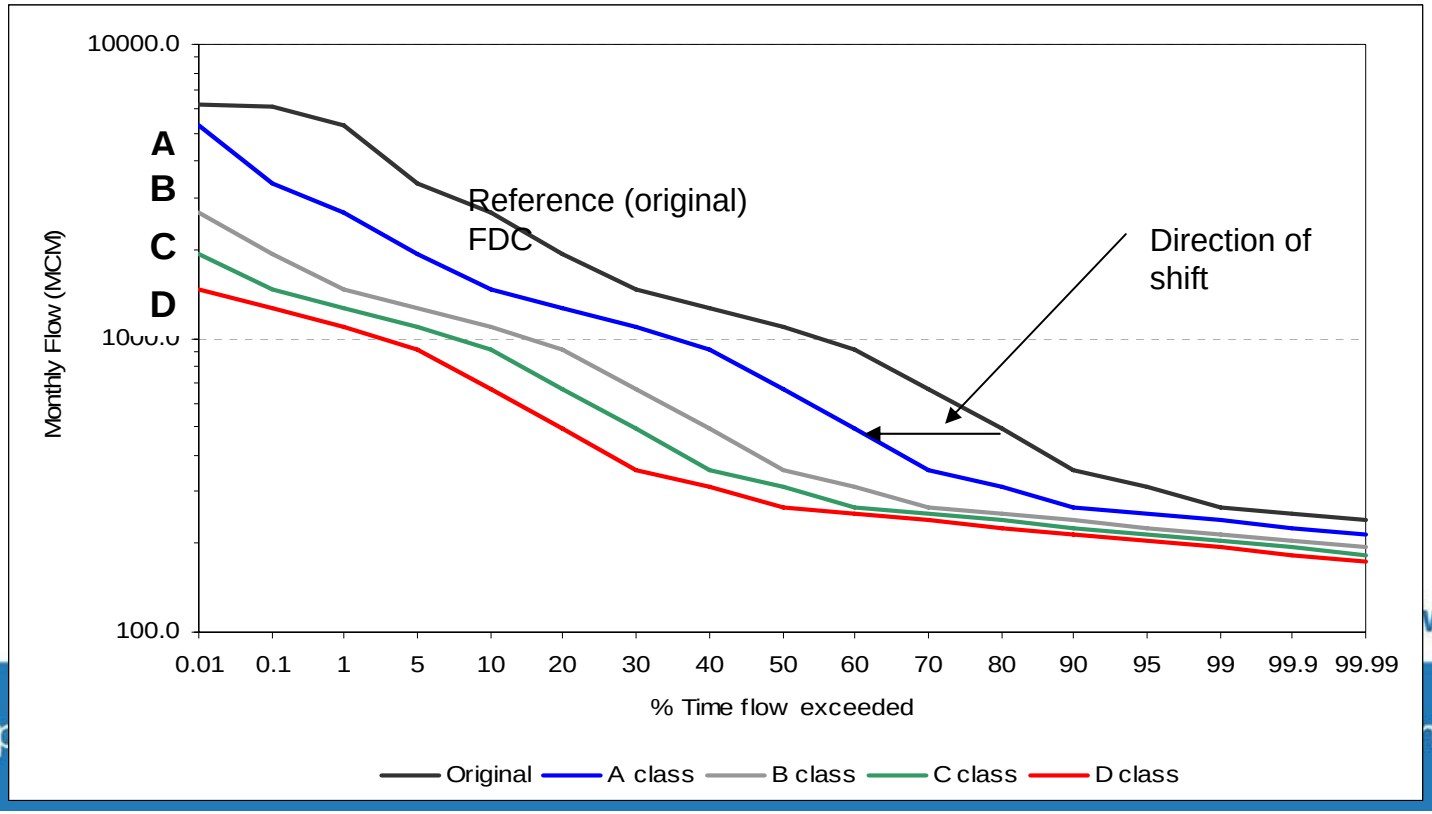
Natural and Environmental Flow Duration Curves

Natural and Environmental Flow Hydrographs

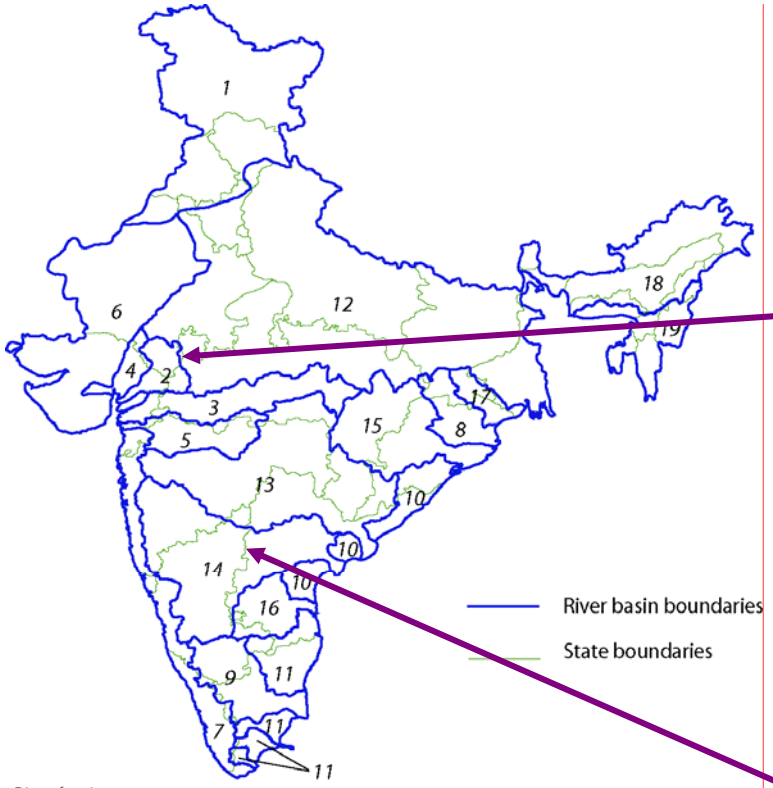


LATERAL SHIFT OF A FLOW DURATION CURVE

- 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’)

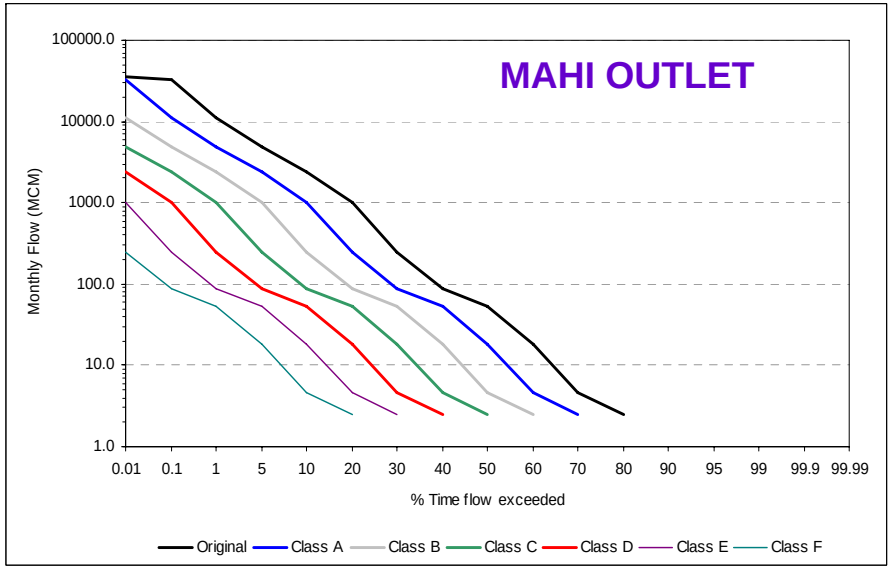


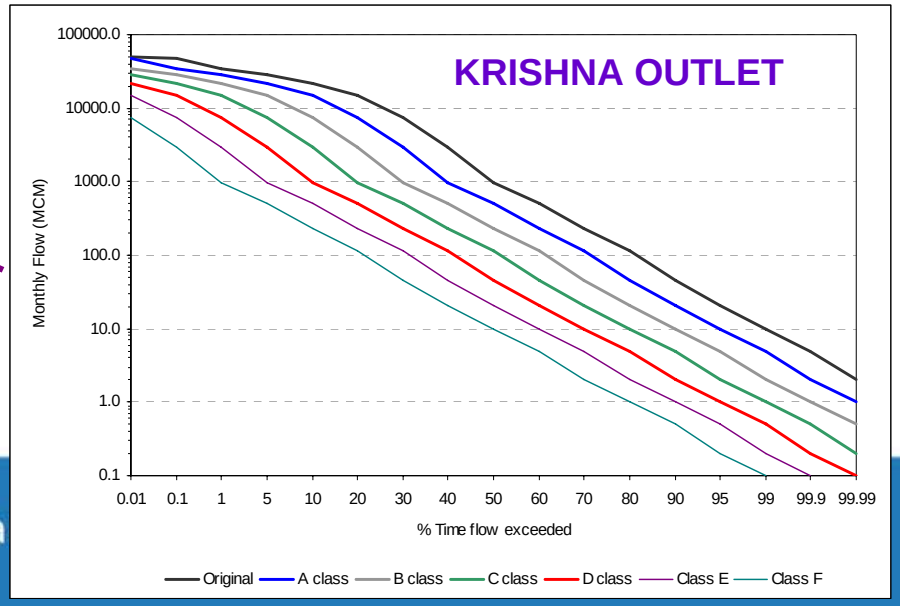
EXAMPLES OF ESTIMATED ENVIRONMENTAL DURATION CURVES



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





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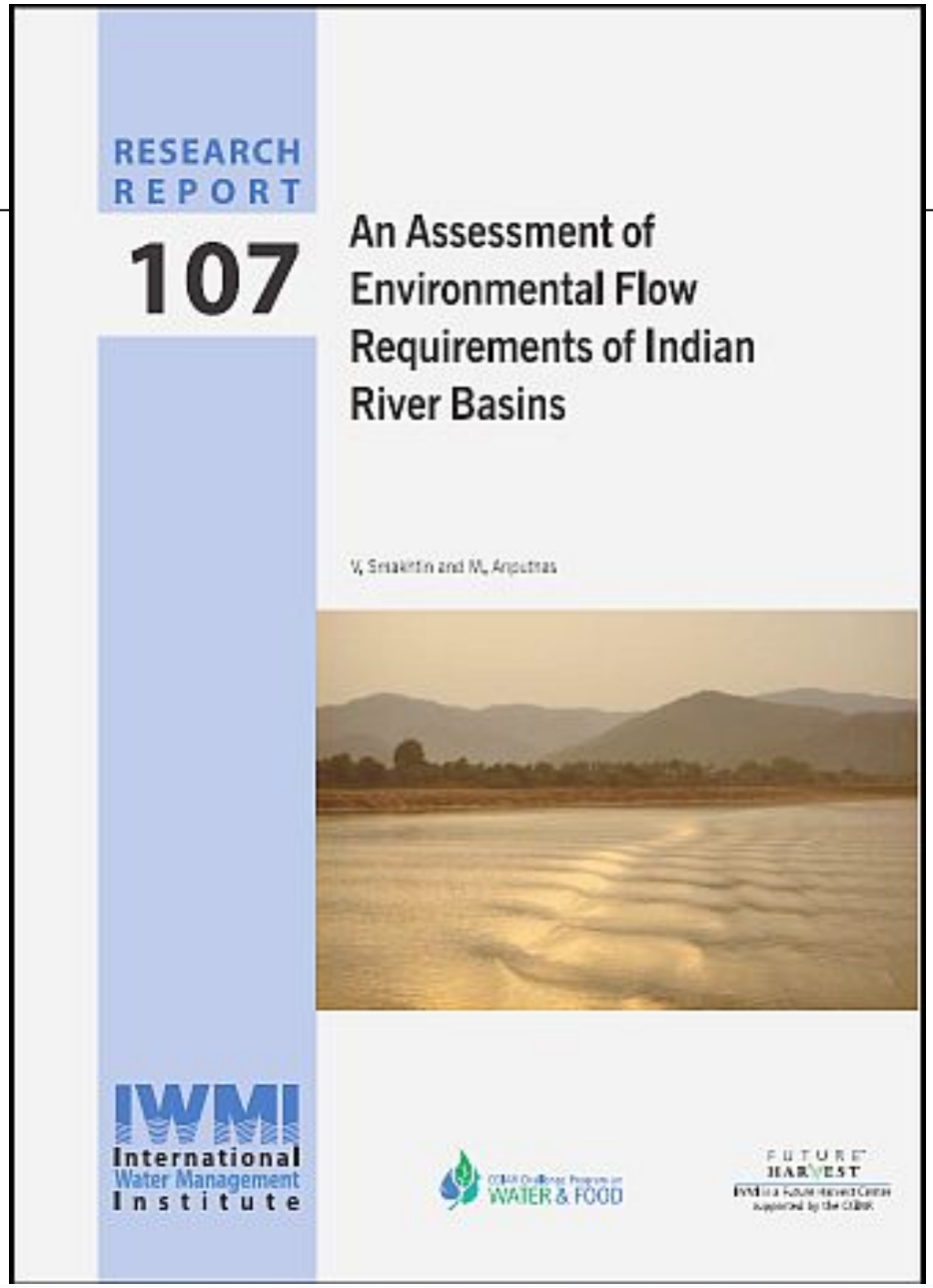

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ESTIMATES OF LONG-TERM EWR VOLUMES (% of natural MAR) for different environmental management classes

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

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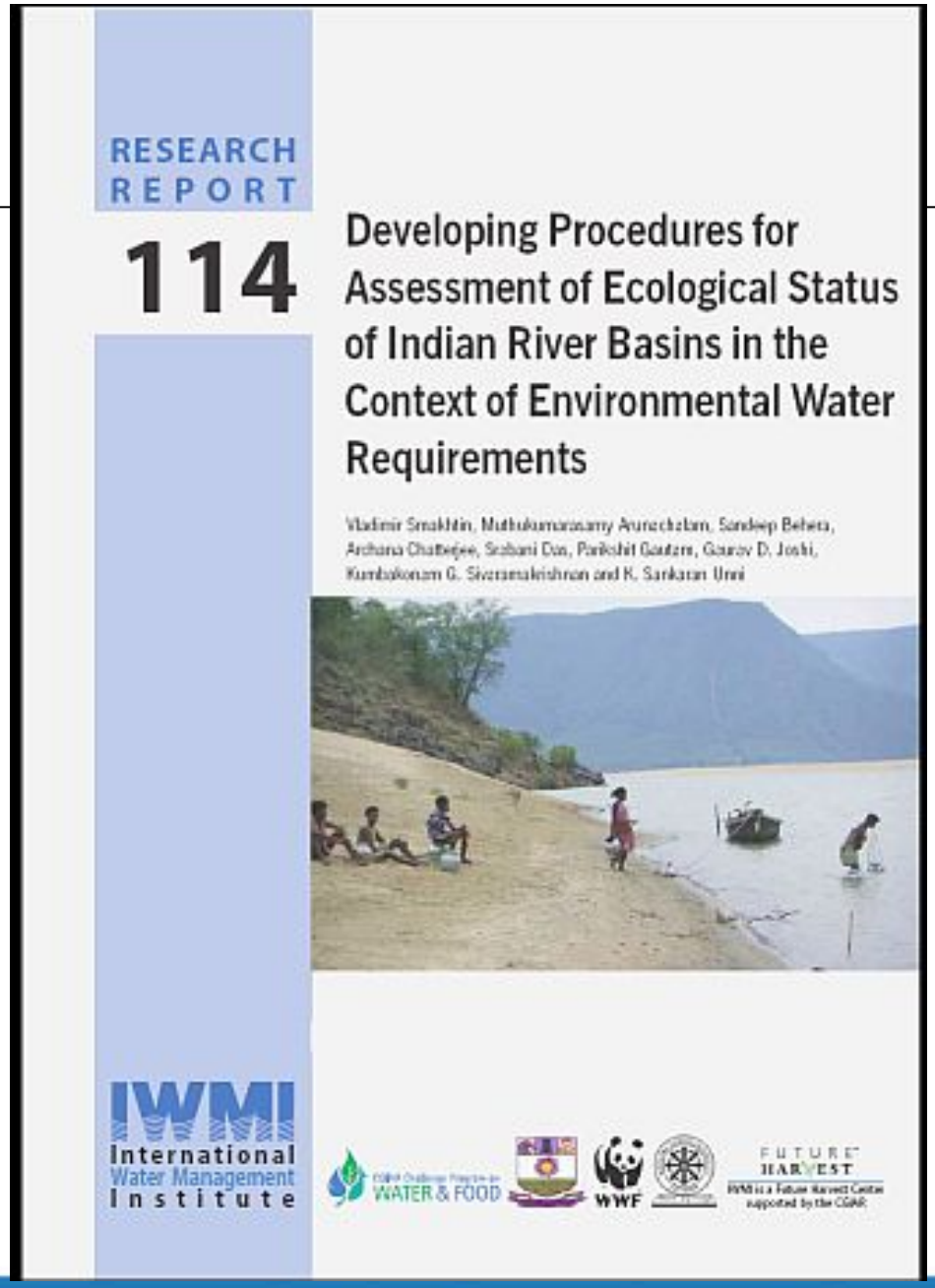

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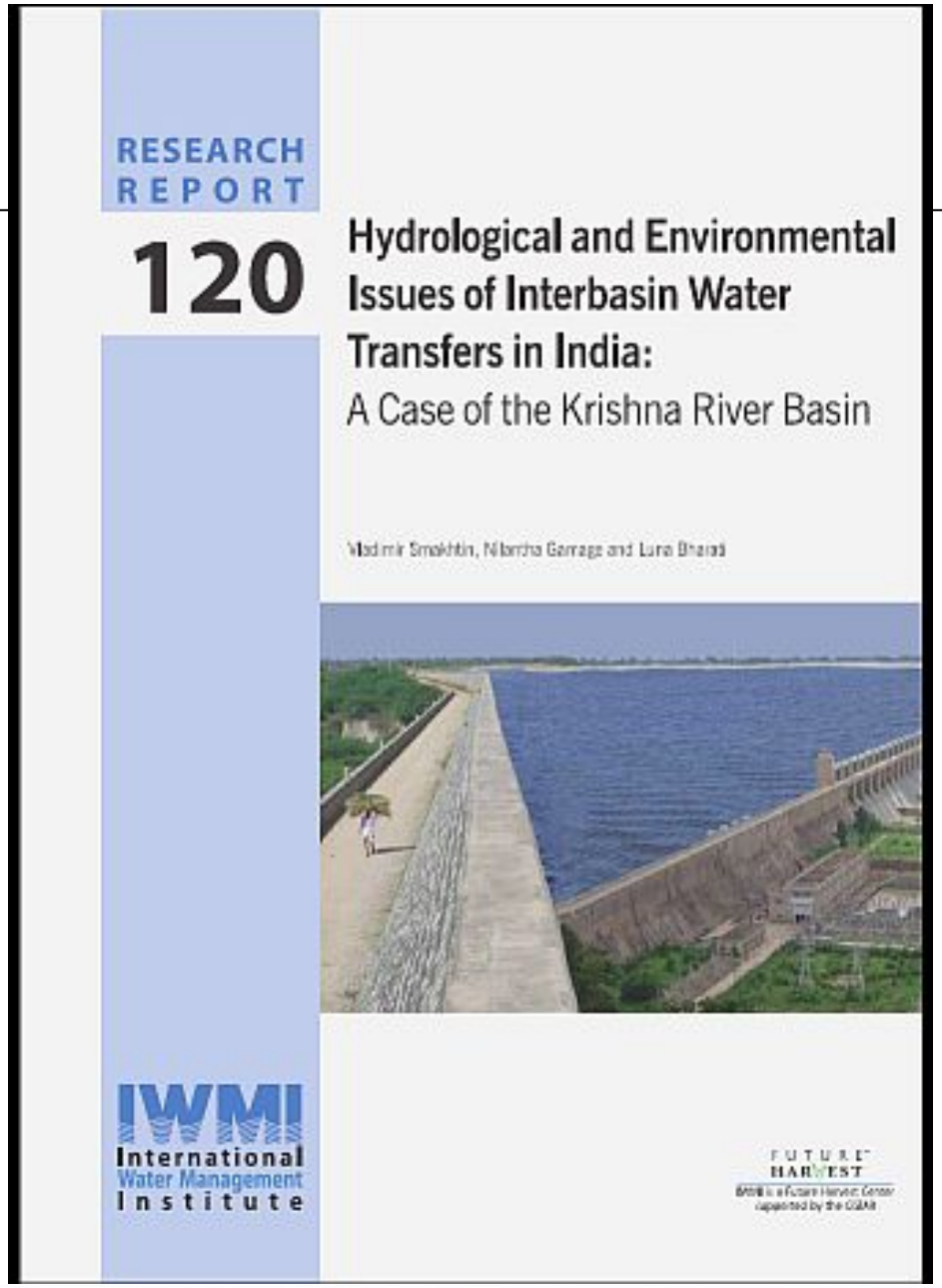

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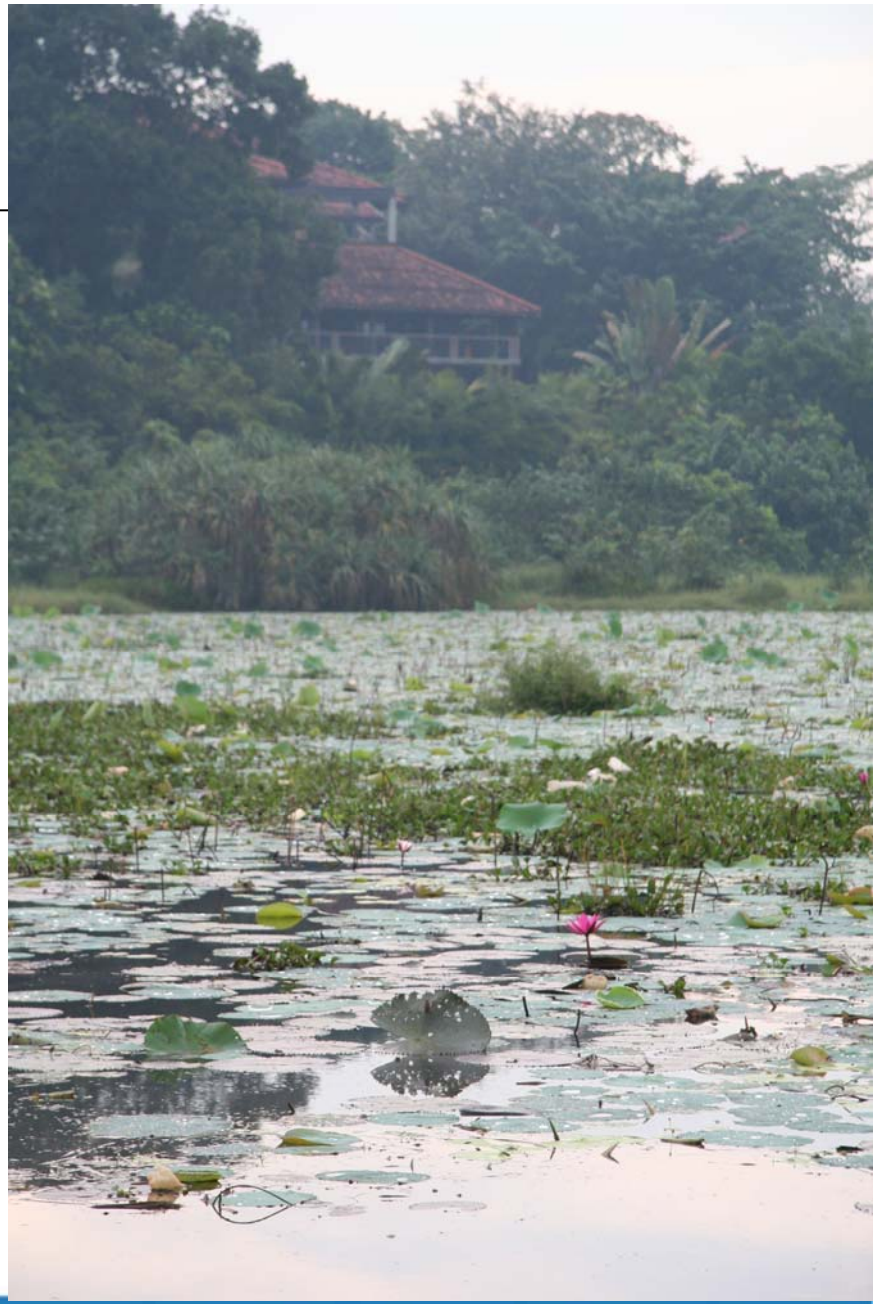
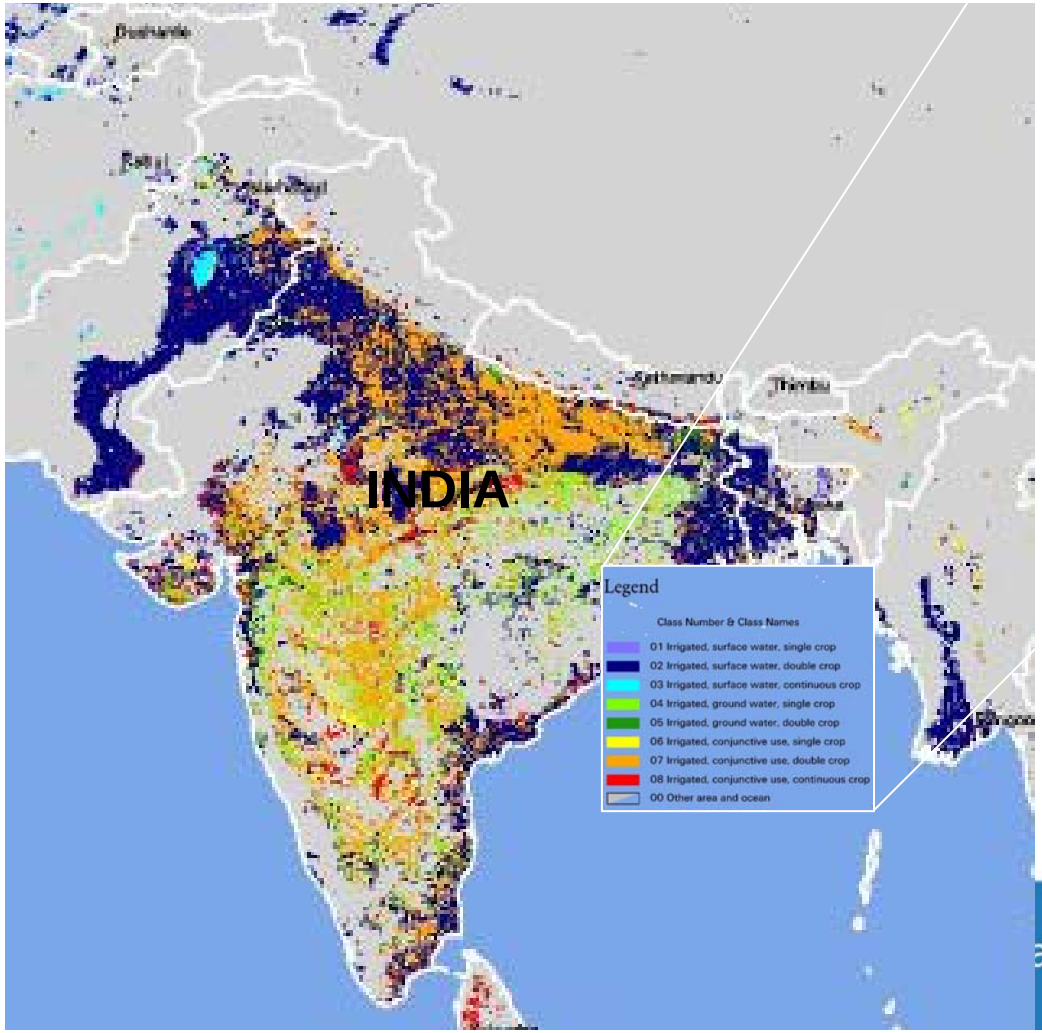
CONCLUSIONS ON E-FLOWS

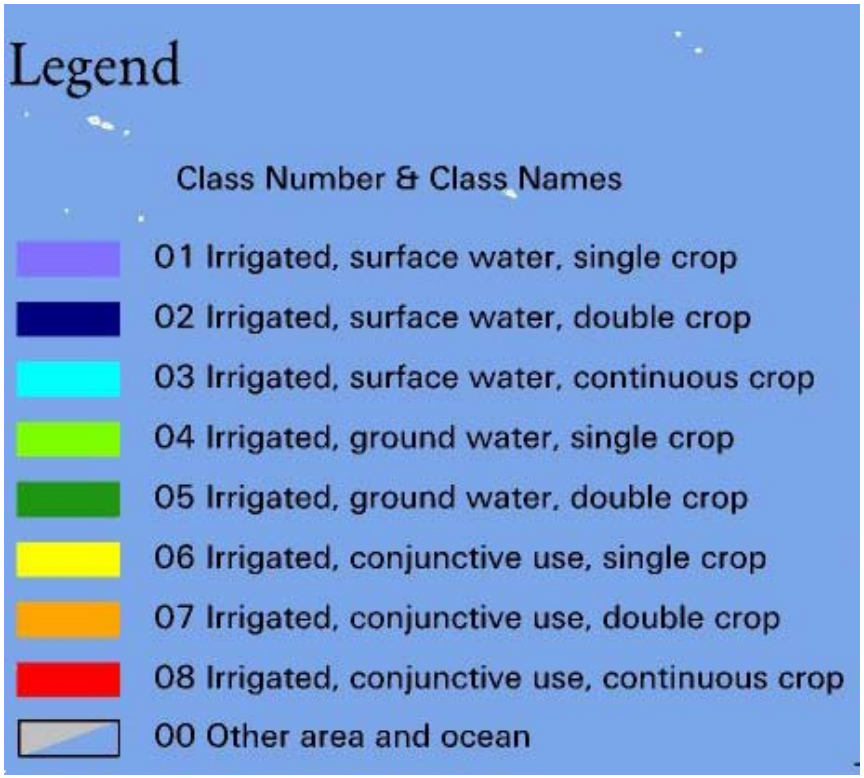
- HYDROLOGY-BASED METHODS OF ENVIRONMENTAL FLOW ASSESSMENT CAN PROVIDE FIRST, CRUDE ESTIMATES OF ENVIRONMENTAL WATER REQUIREMENTS – AT DIFFERENT SCALES: FROM GLOBAL TO SMALL RIVER CATCHMENTS
- APPLICATIONS OF SUCH METHODS (AS OPPPOSED TO MORE COMPLEX TECHNIQUES) MAY BE AN IMPORTANT FIRST STEP TOWARDS 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





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

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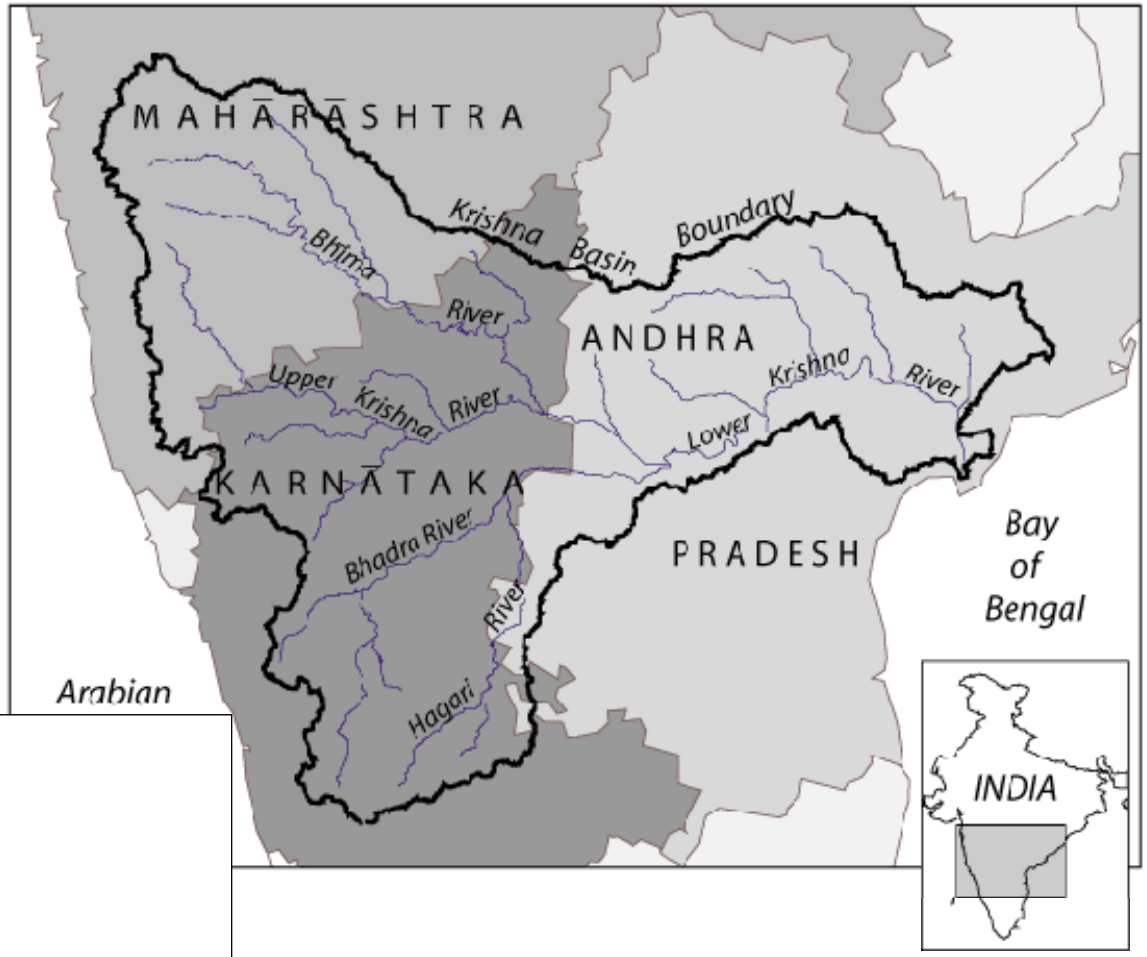
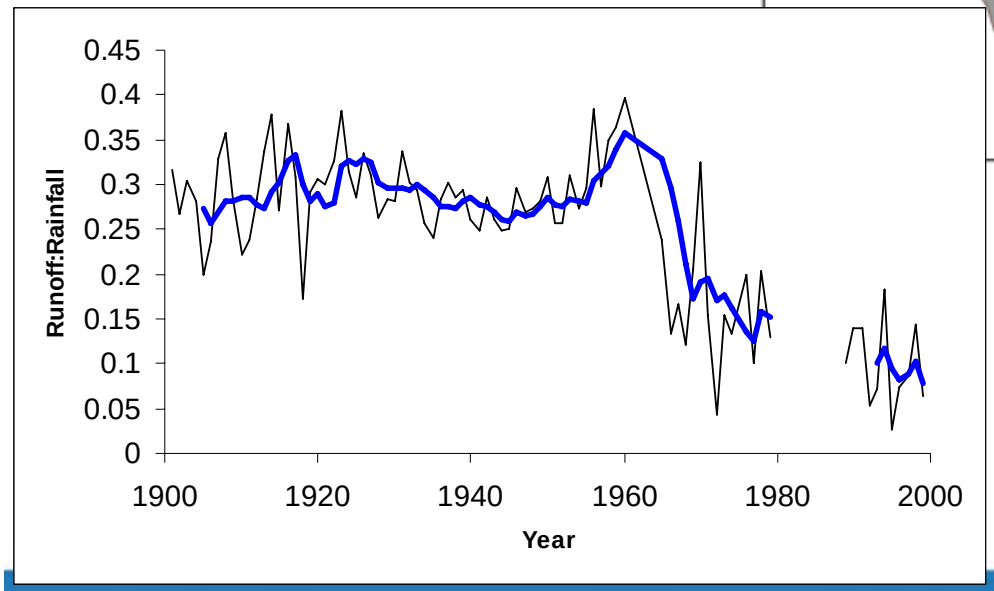
KRISHNA BENCHMARK BASIN





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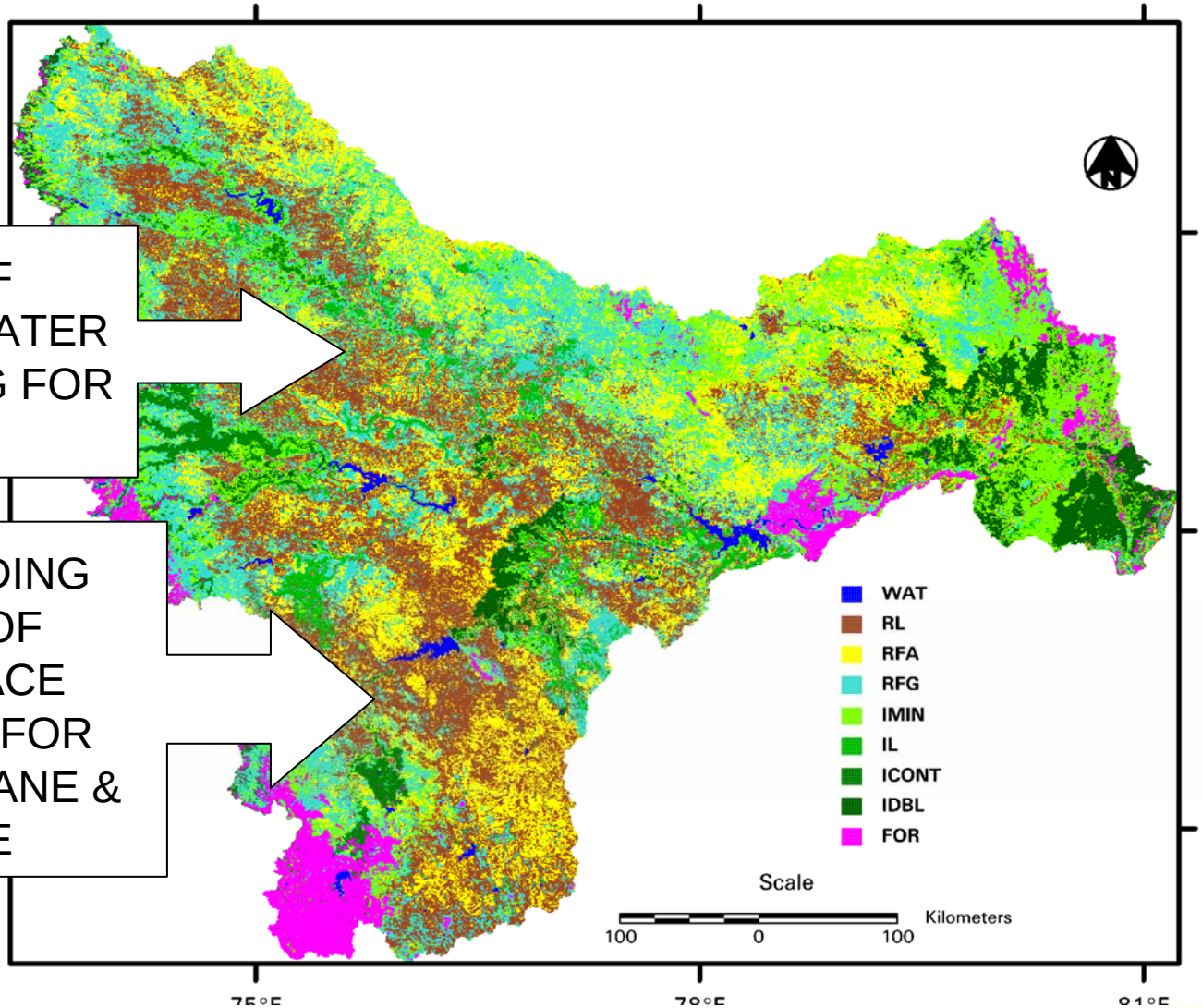
AGRICULTURAL WATER USE CHANGES IN THE KRISHNA

USE OF GROUNDWATER EXPANDING FOR DAIRY

EXPANDING USE OF SURFACE WATER FOR SUGARCANE & RICE



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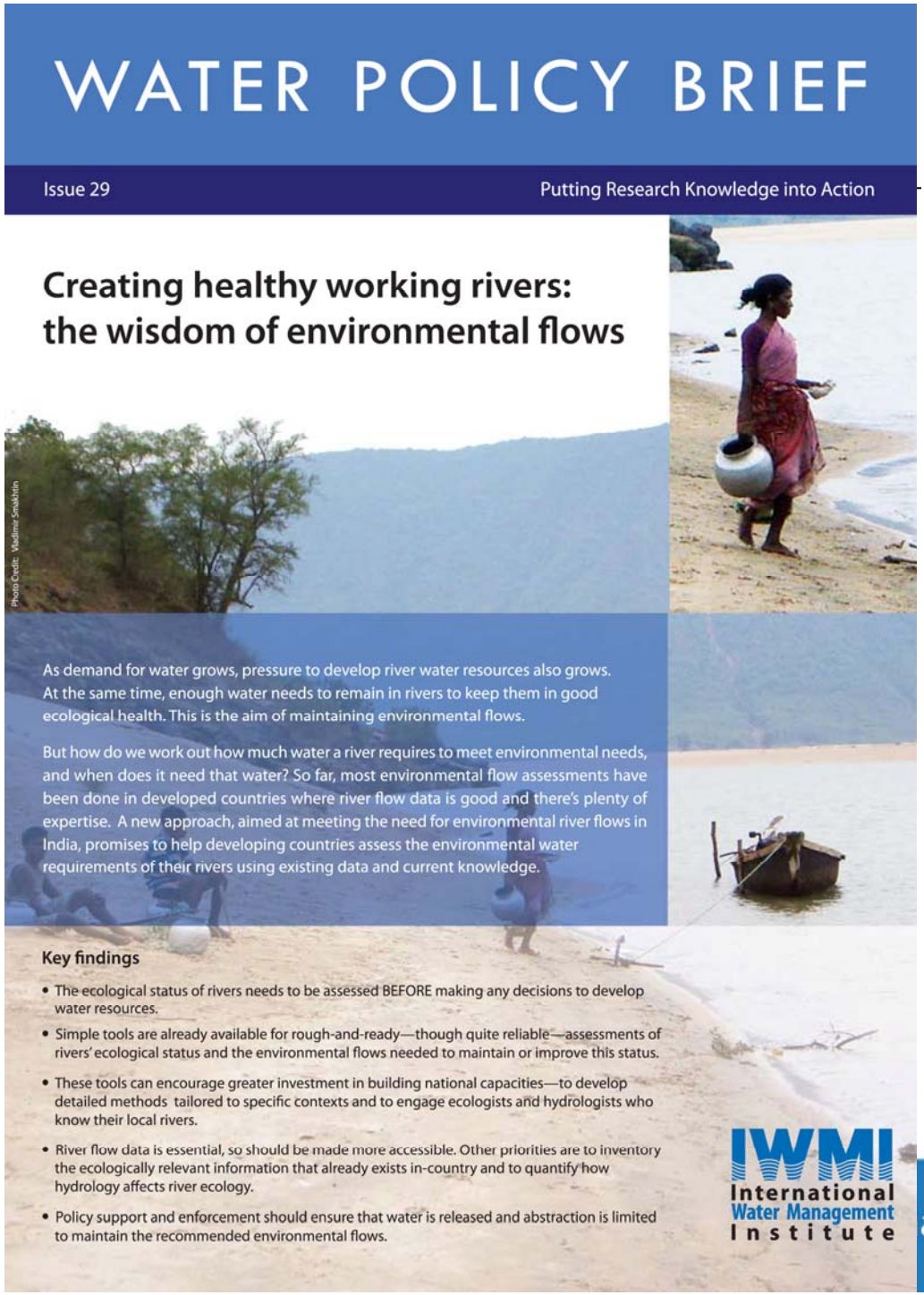

FURTHER INFORMATION

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