Water Resources of India

Problems & Perspectives

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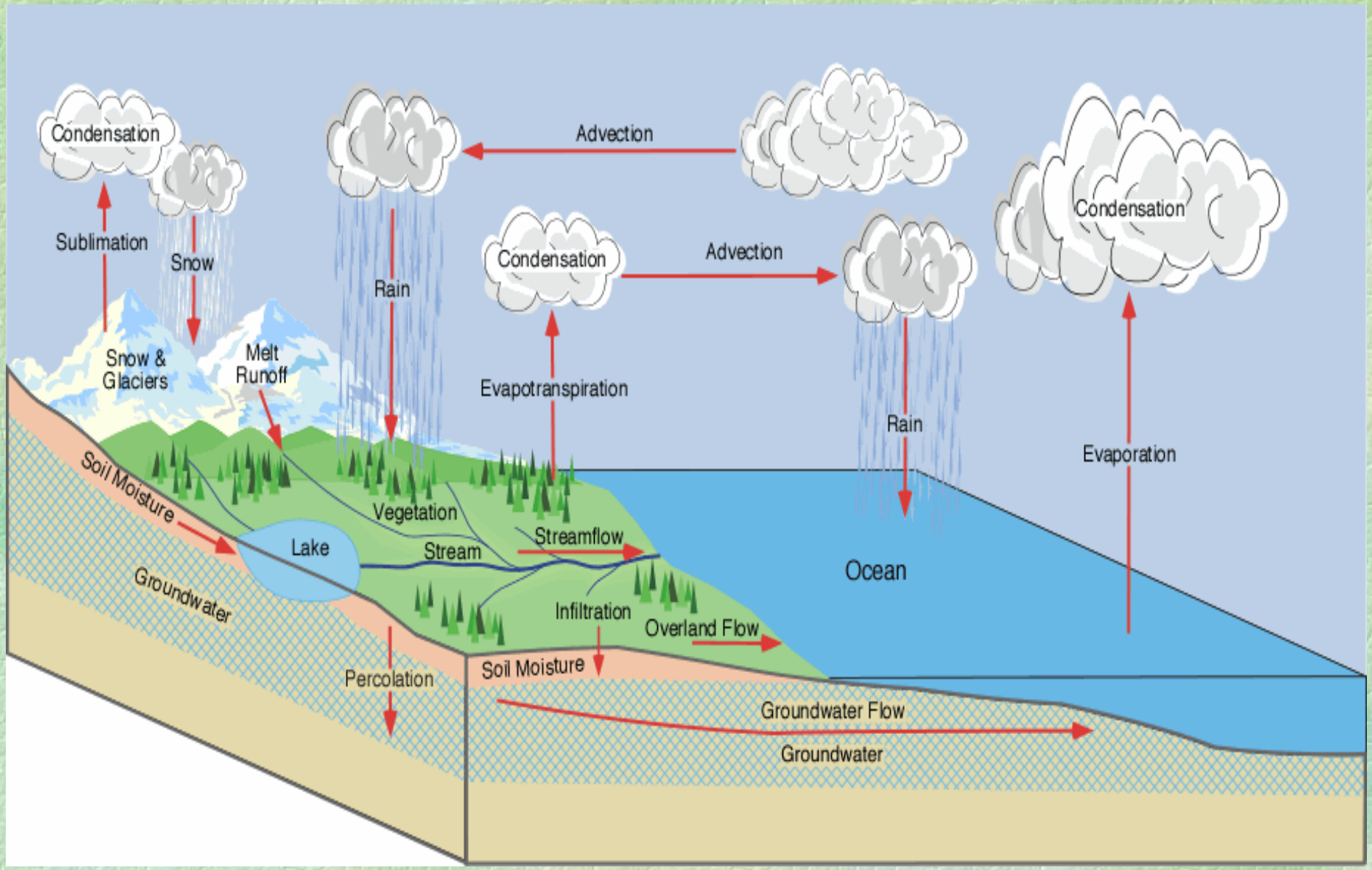
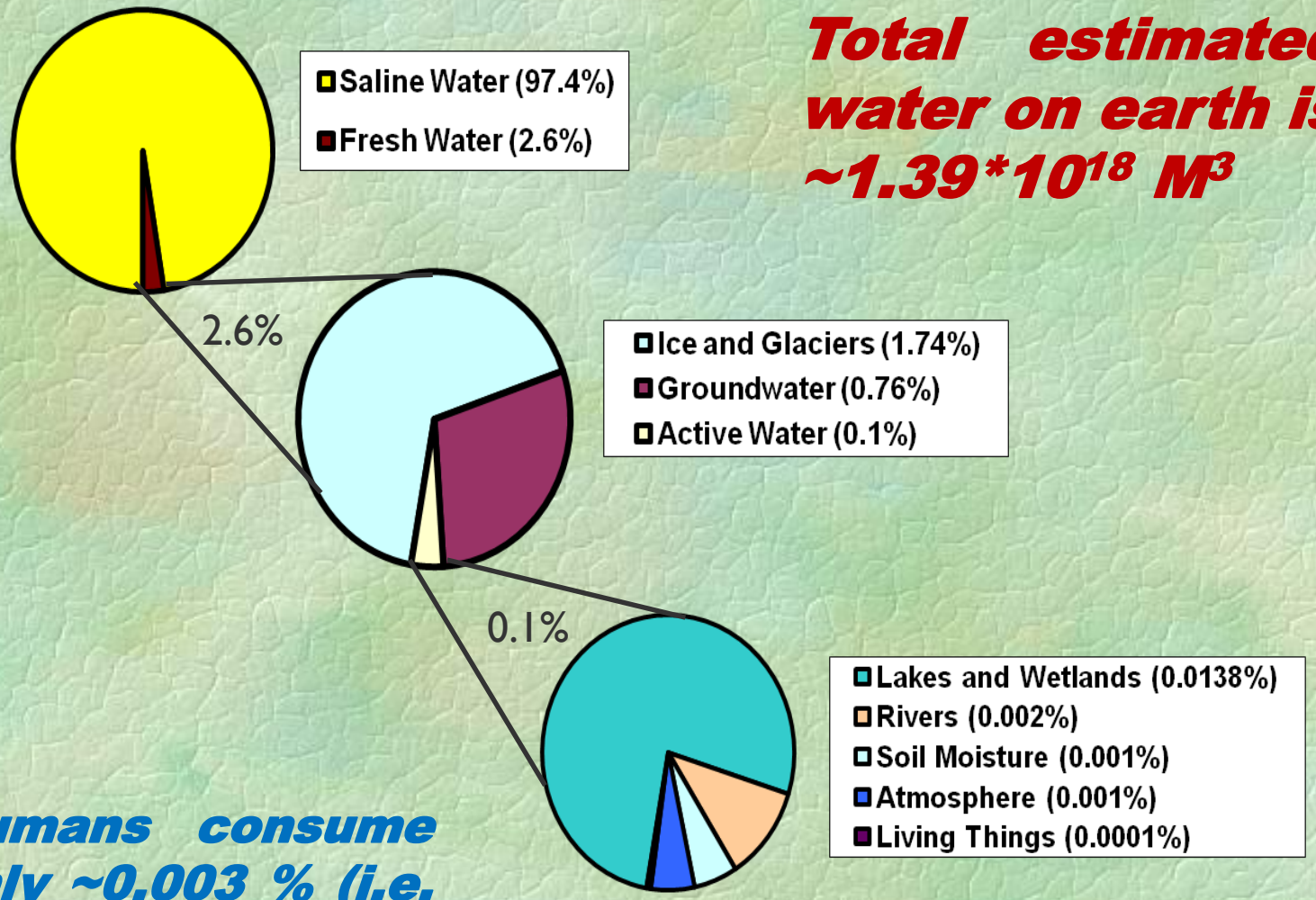
Hydrologic Cycle

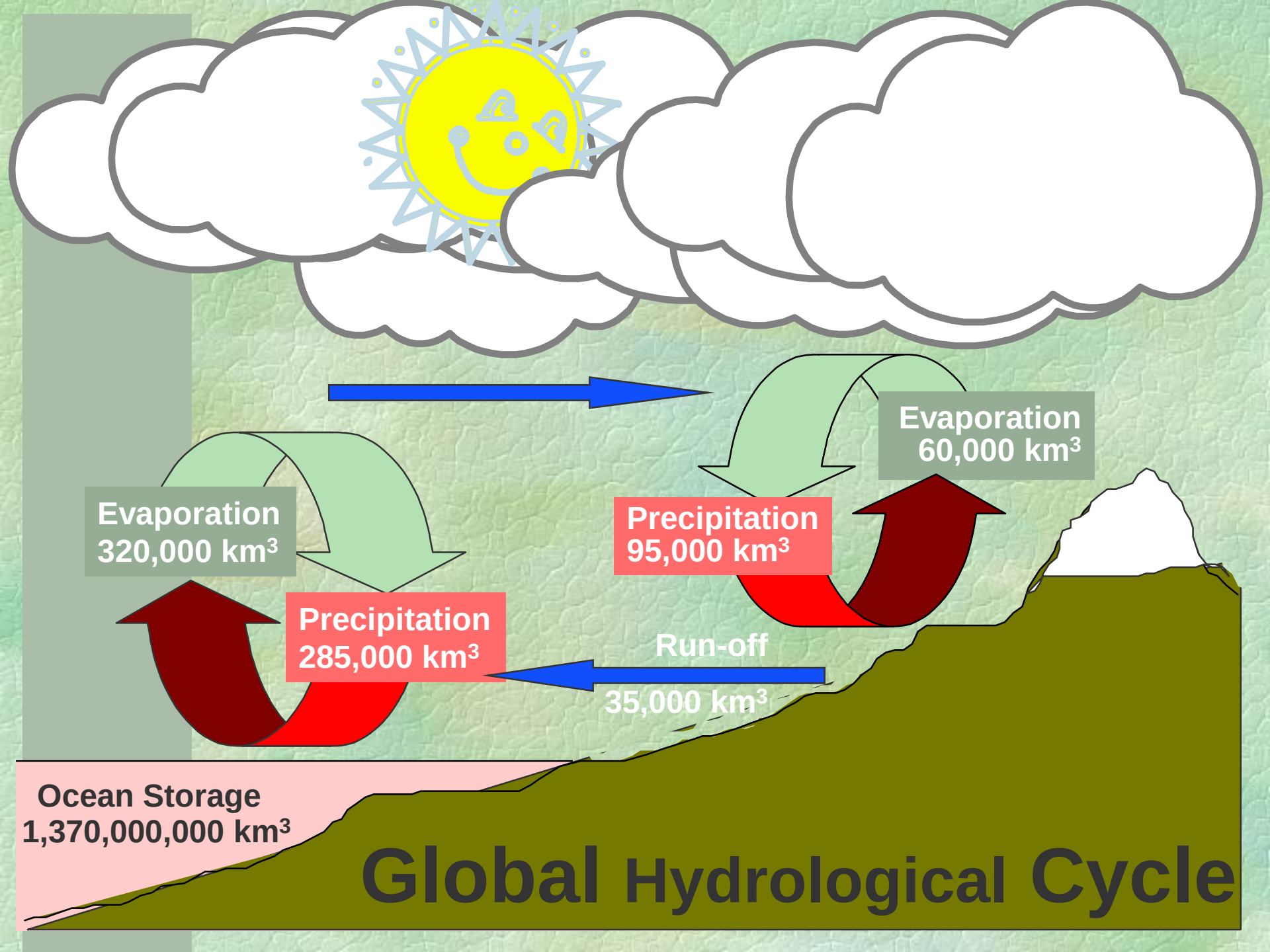


GLOBAL WATER DISTRIBUTION



Total estimated water on earth is ~1.39*10^{18} M^3

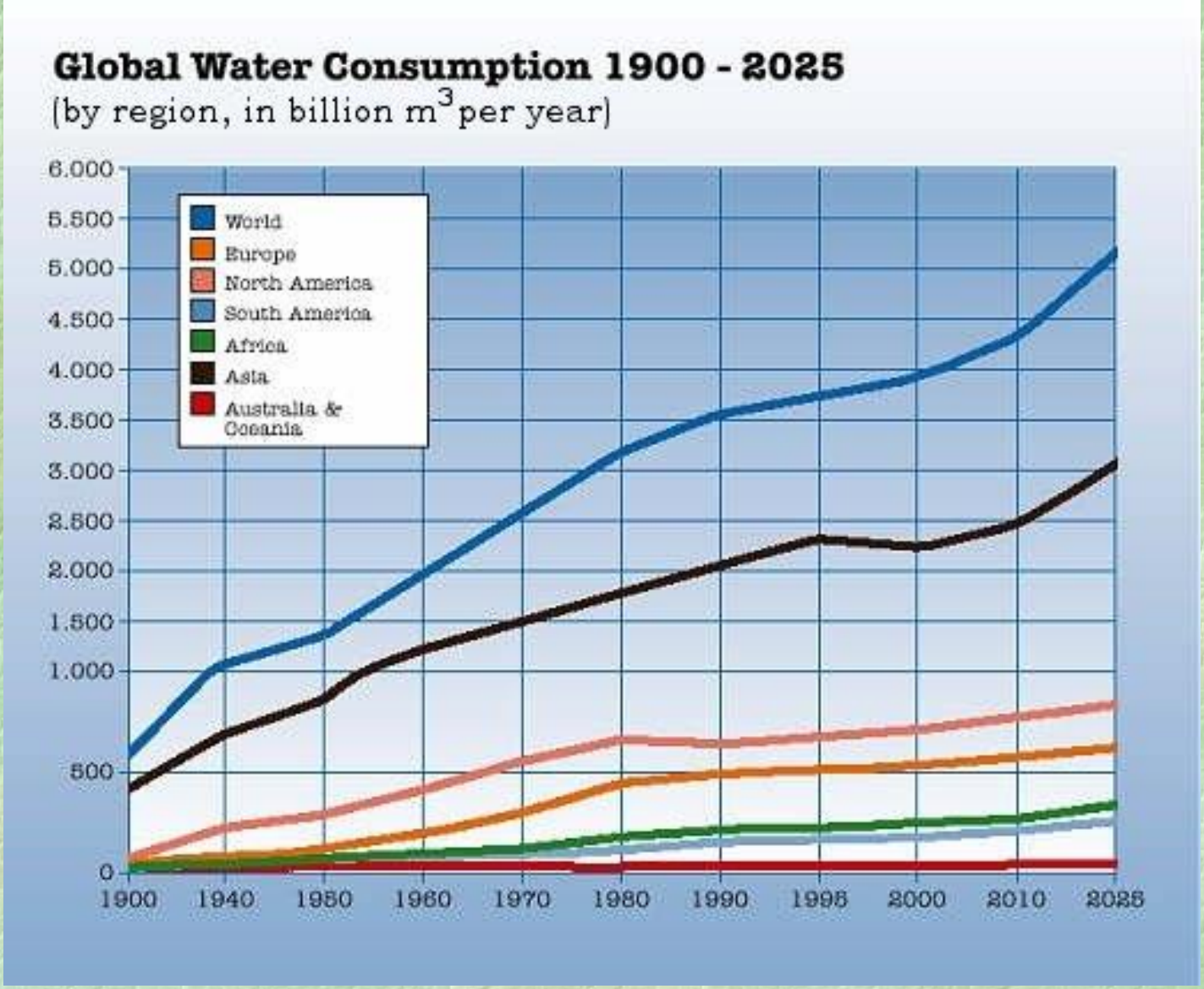
Humans consume only ~0.003 % (i.e. ~4*10^{13} M^3)


Evaporation
60,000 km3
Precipitation
95,000 km3
Evaporation
320,000 km3
Precipitation
285,000 km3
Run-off
35,000 km3
Ocean Storage
1,370,000,000 km3
Global Hydrological Cycle

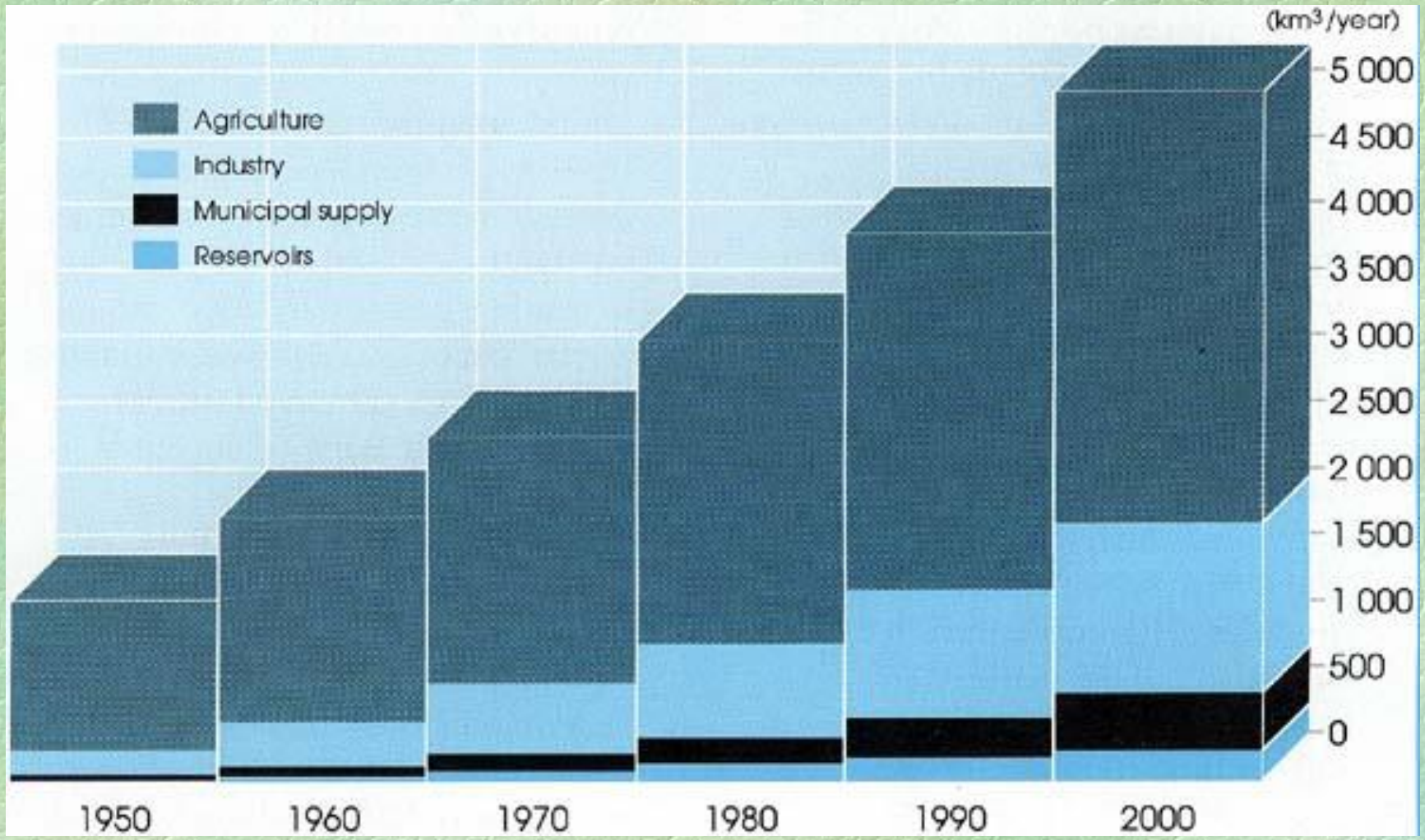
FRESH WATER RESOURCES

Item	Area 10^6 km^2	Volume Km^3	% of total water	% of fresh water
Oceans	361.3	1,338,000,000	96.5	-
Groundwater:				
Fresh	134.8	10,530,000	0.76	30.1
Saline	134.8	12,870,000	0.93	-
Soil moisture	82.0	16,500	0.0012	0.05
Polar ice	16.0	24,023,500	1.7	68.6
Other ice & snow	0.3	340,600	0.025	1.0
Lakes:				
Fresh	1.2	91,000	0.007	0.26
Saline	0.8	85,400	0.006	-
Marshes	2.7	11,470	0.0008	0.03
Rivers	148.8	2,120	0.0002	0.006
Biological water	510.0	1,120	0.0001	0.003
Atmospheric water	510.0	12,900	0.001	0.04
Total water	510.0	1,385,984,610	100	-
Fresh water	148.8	35,029,210	2.5	100

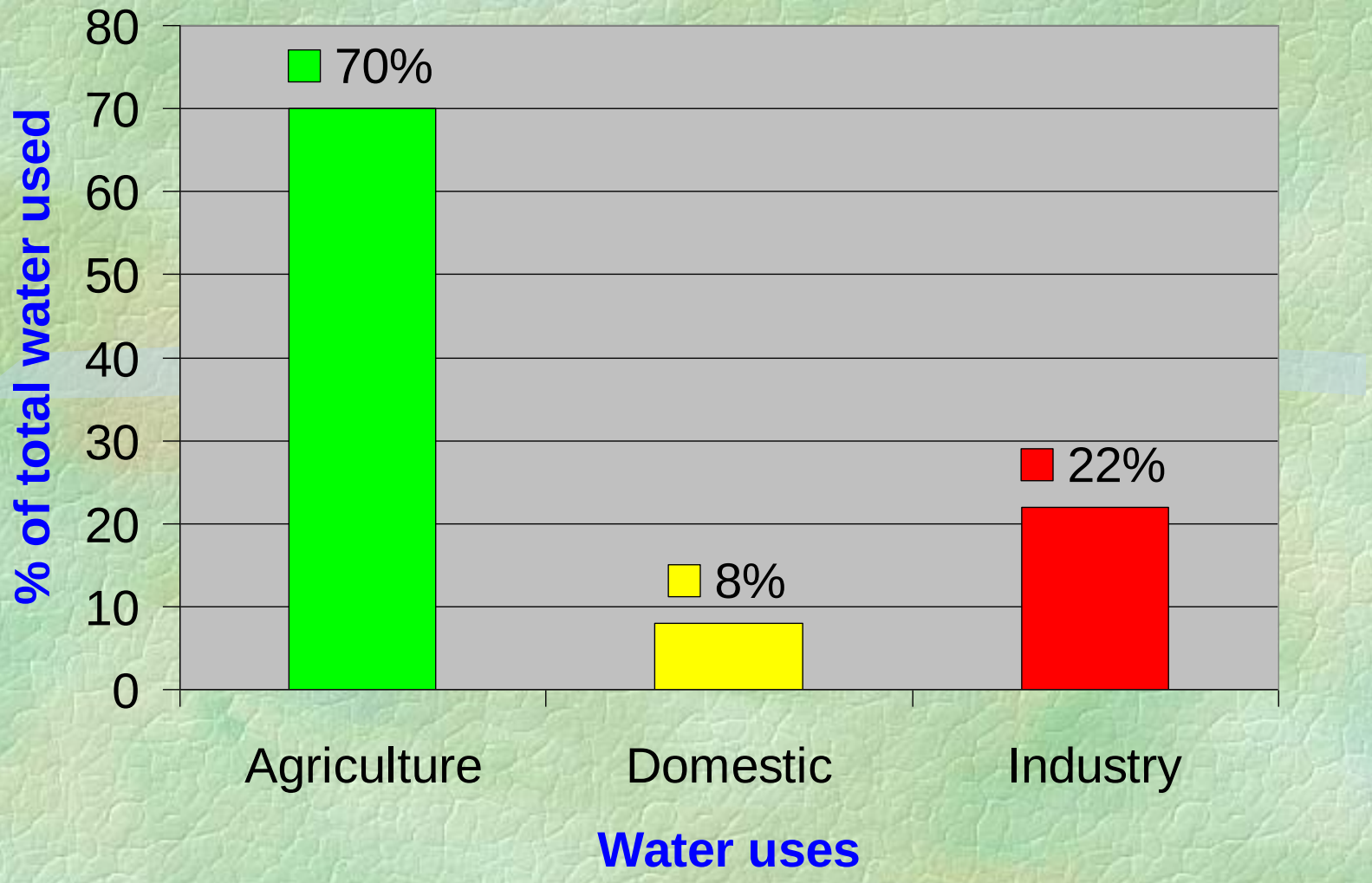
GLOBAL USE OF WATER

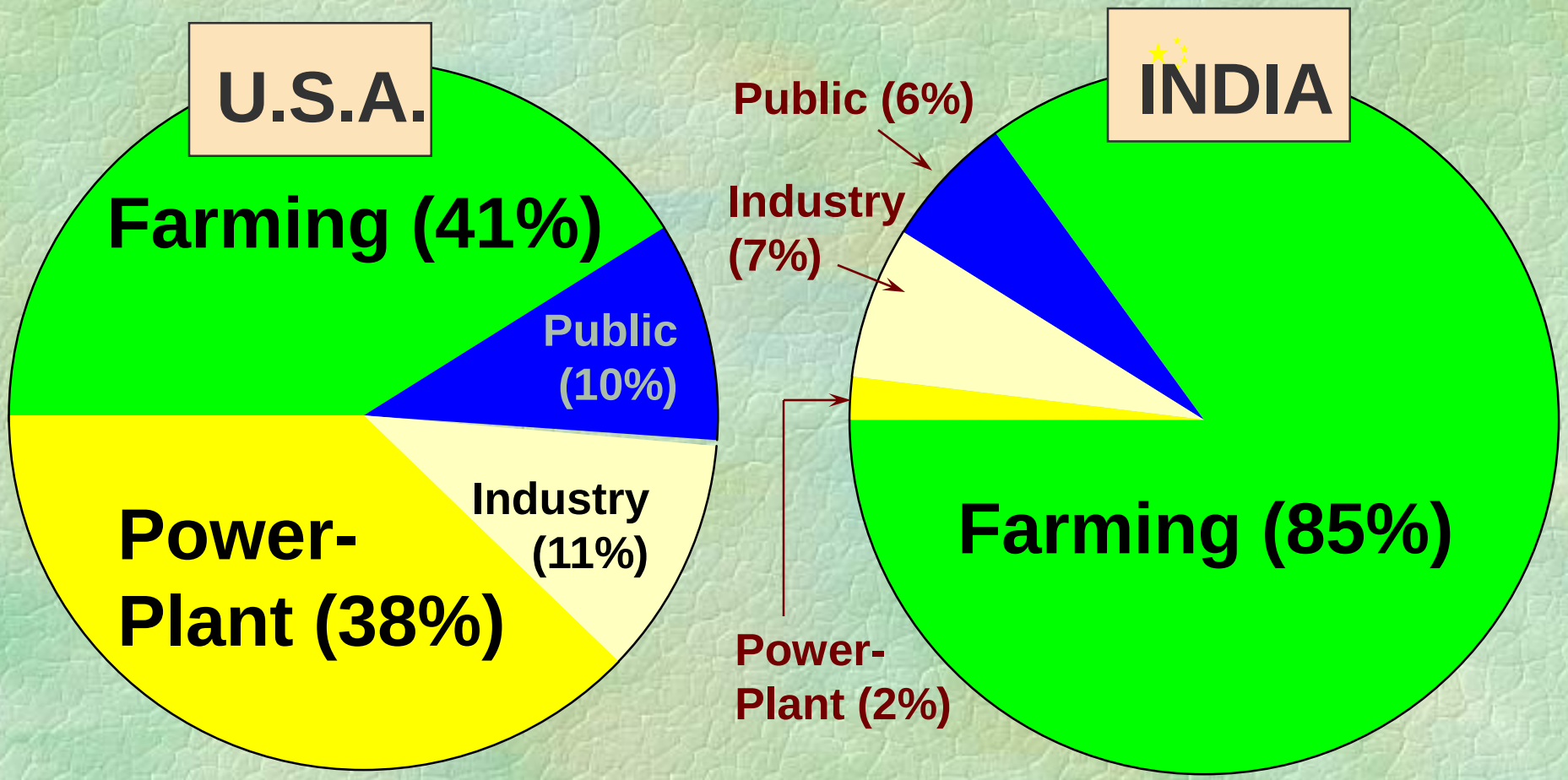


GLOBAL USE OF WATER



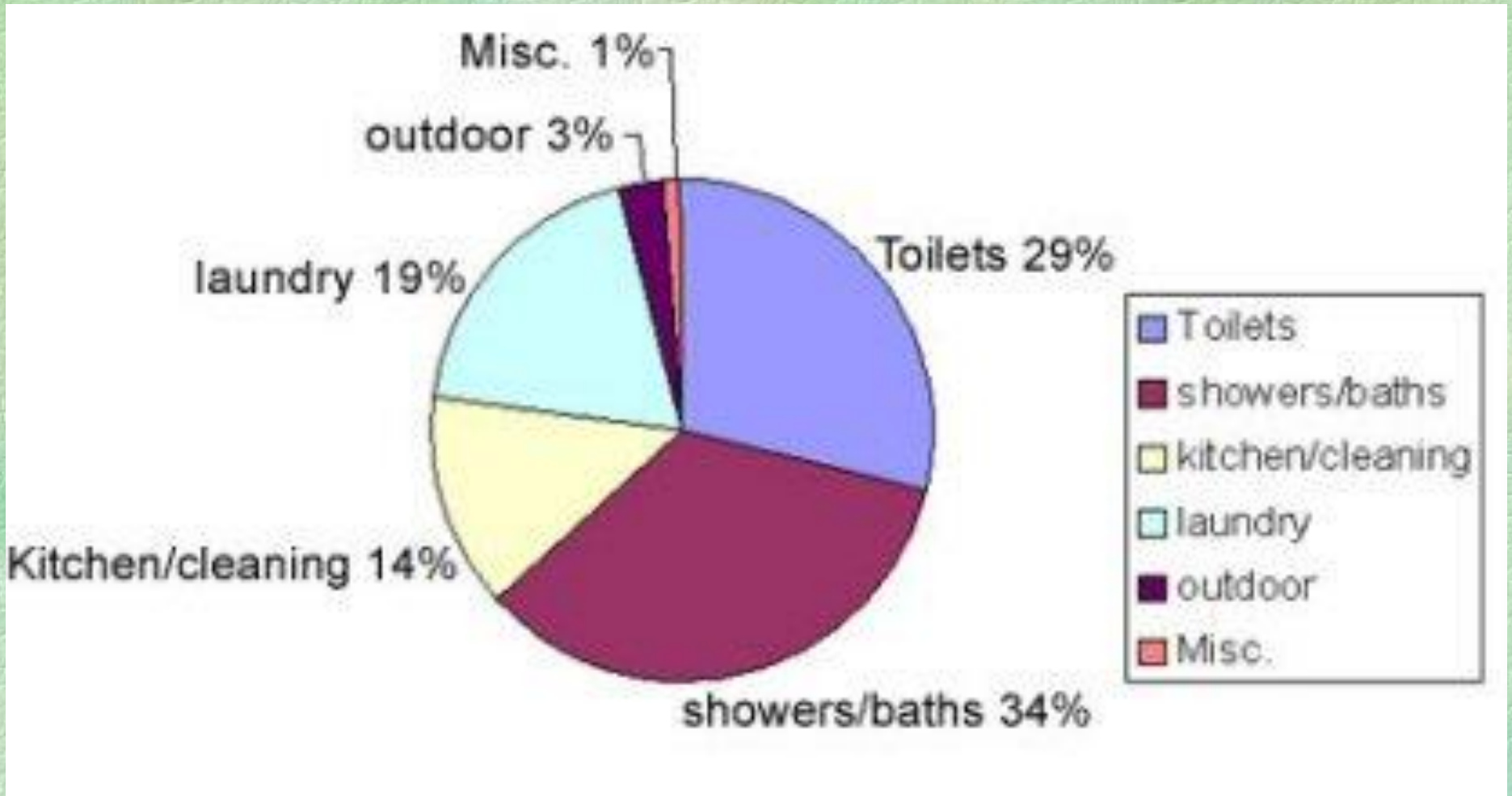
World Water Uses

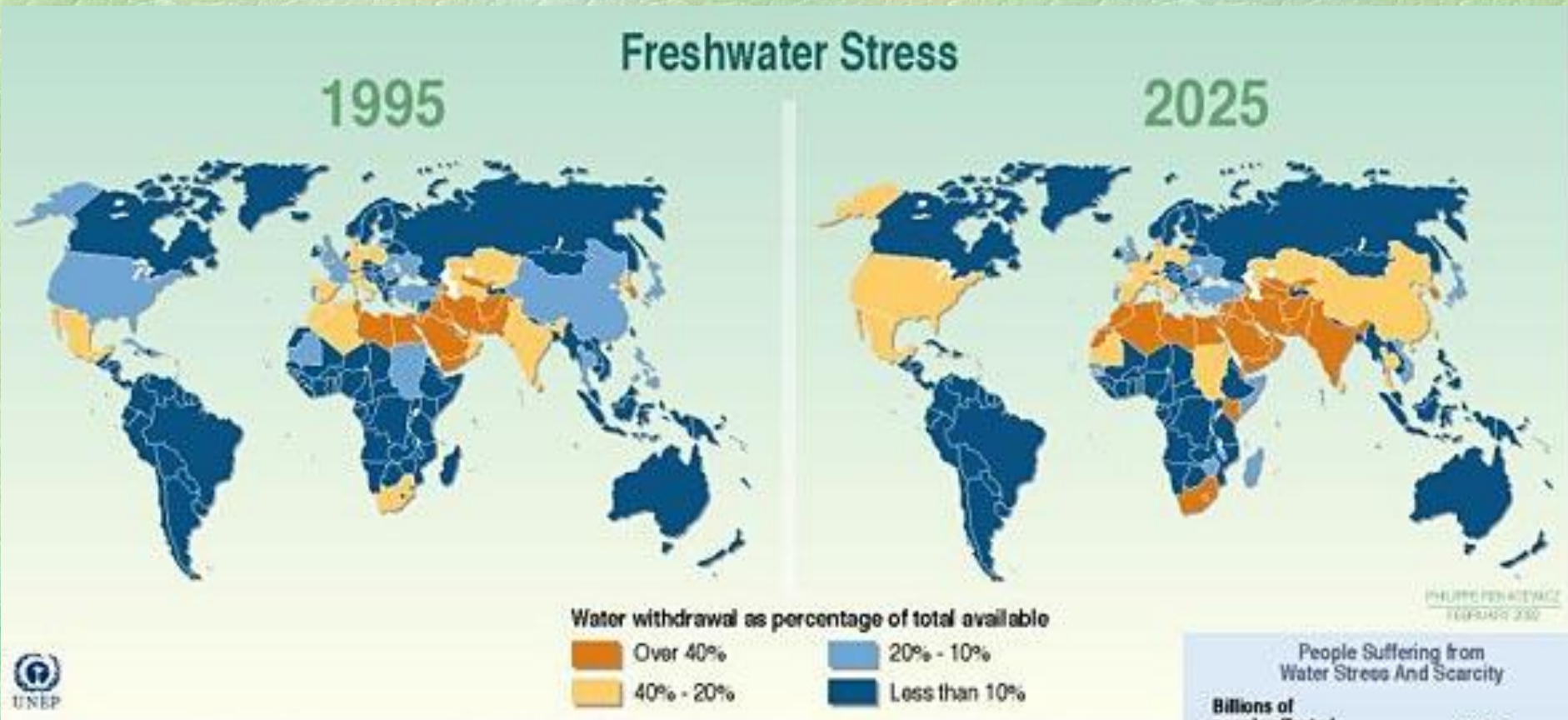




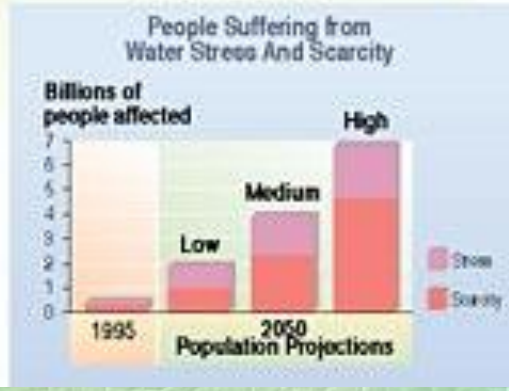
this comparison of U.S. and India shows how economic growth necessitates increased use of water for nonagricultural purposes.

MUNICIPAL WATER USE



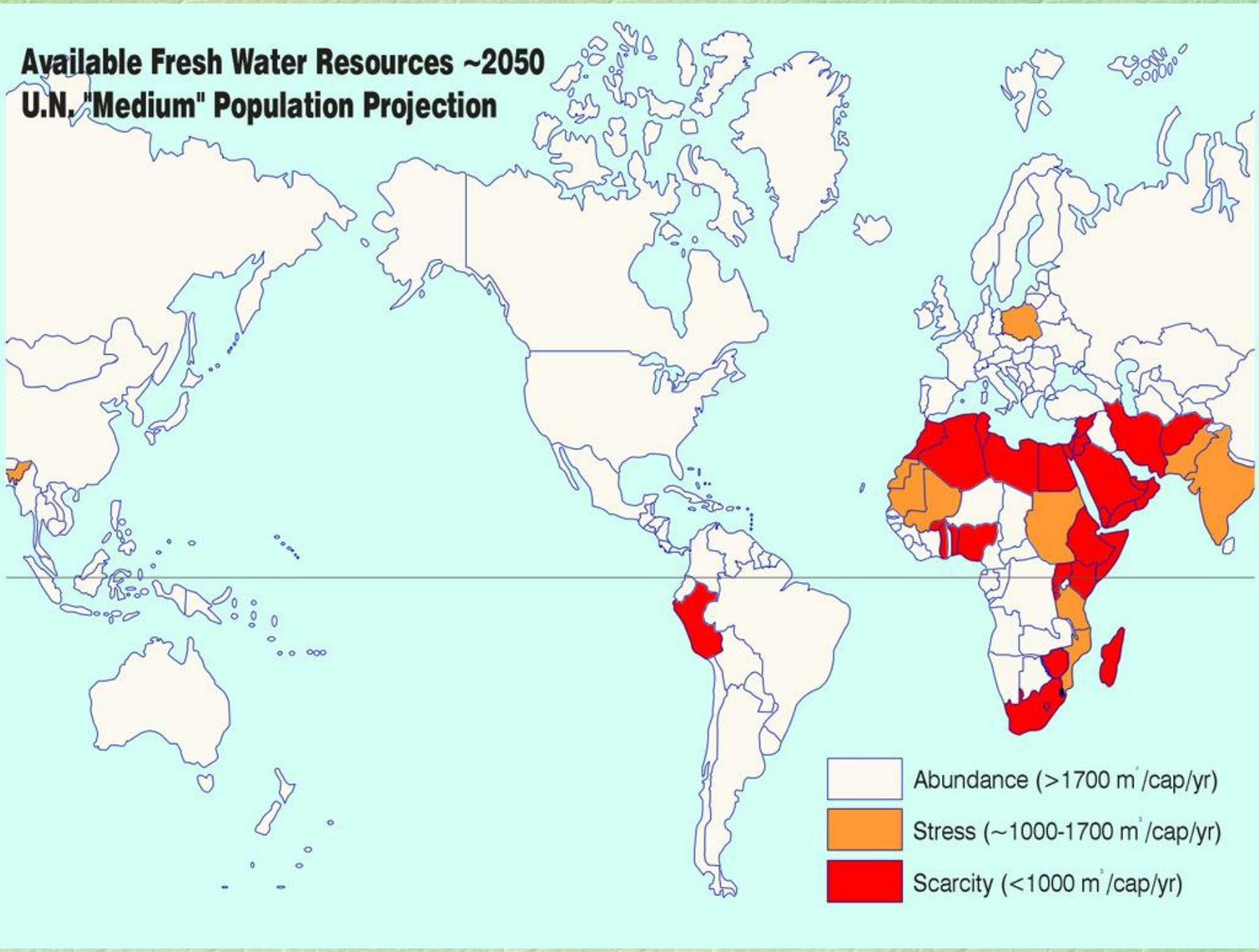


Source: World Meteorological Organisation (WMO), Geneva, 1996; Global Environment Outlook 2000 (GEO), UNEP, Earthscan, London, 1999.



Per Capita Availability < 1700 Cubic Meter per year • **Water Stressed**

Per Capita Availability < 1000 Cubic Meter per year • **Water Scarce**


Available Fresh Water Resources ~2050
U.N. "Medium" Population Projection
Abundance (>1700 m³/cap/yr)
Stress (~1000-1700 m³/cap/yr)
Scarcity (<1000 m³/cap/yr)

Water – Some General facts

Water is a basic natural resource which nurtures life.

- **2 Billion people have no access to clean drinking water and 2.9 billion have no access to sanitation**
- **By 2025, 40% of the World's population, or about 3 billion people will live in countries where it is difficult or impossible to get enough water to satisfy basic needs**
- **80% of all illness and death in developing world due to contaminated water**
- **A child dies every 8 seconds from drinking contaminated water**

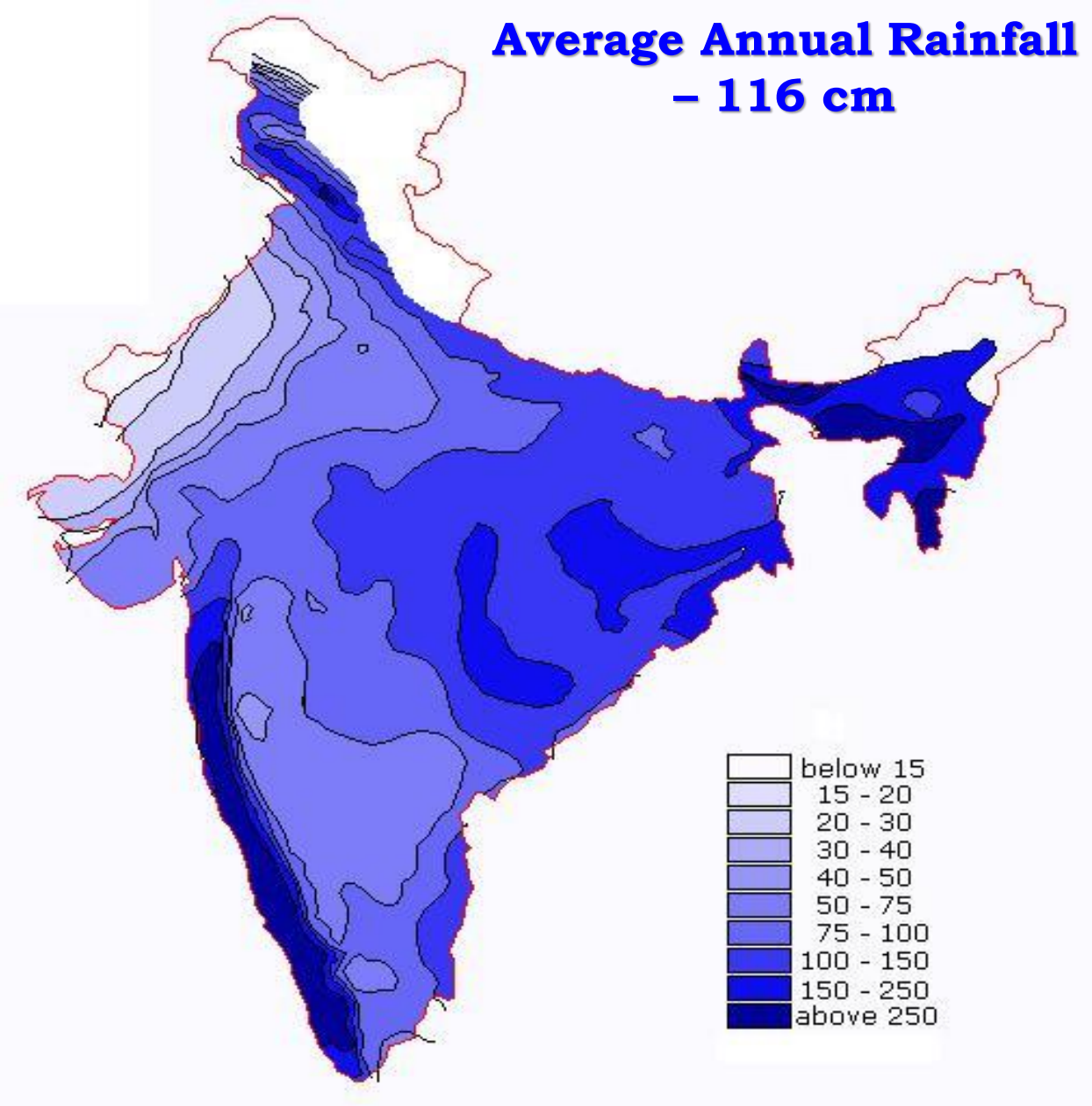
India's Land Resources

Geographical Area	329 mha
Non-cultivated Area Barren/Waste Land	7% 23%
Forested Area	23%
Cultivated Area (CA)	47%
Irrigated Area (produces 55%)	37% of CA
Rainfed Area (produces 45%)	63% of CA

India – A Comparison with the World

India's Land Resources	2.4% of the World
India's Freshwater Resource	4% of the World
India's Population	18% of the World
India's Cattle Population	10% of the World

Spatial Variation of Rainfall in India



RAINFALL PATTERNS IN INDIA

Long-term average annual rainfall is 1160 mm.

Highly Variable in space (about 11,690 mm at Mousinram near Cherrapunji in Meghalaya and 150 mm at Jaisalmer)

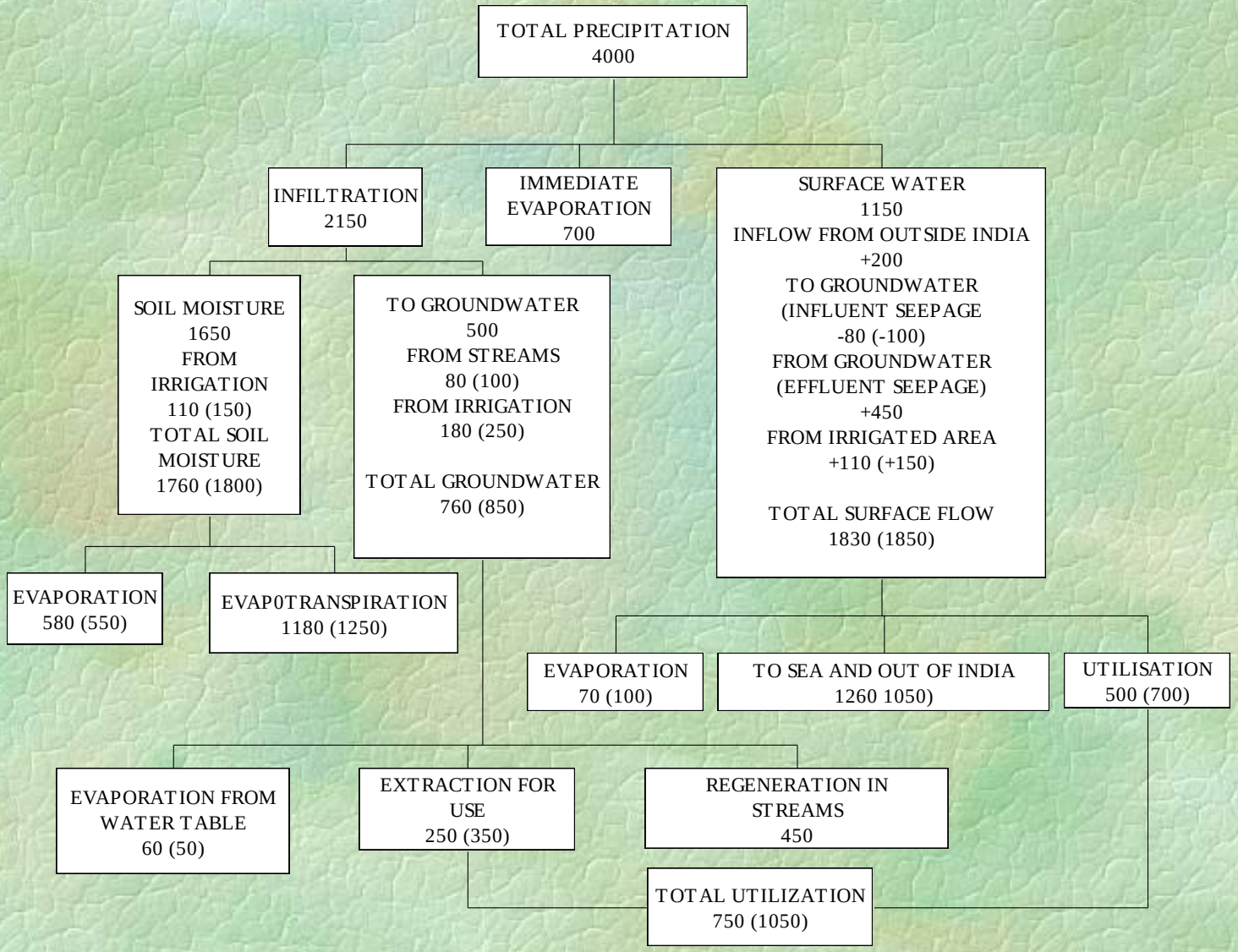
Highly Variable in time (Three-quarters of the rain in less than 120 days during June to September)

Average number of rainy days in a year is 40

Temporal Variation of Rainfall

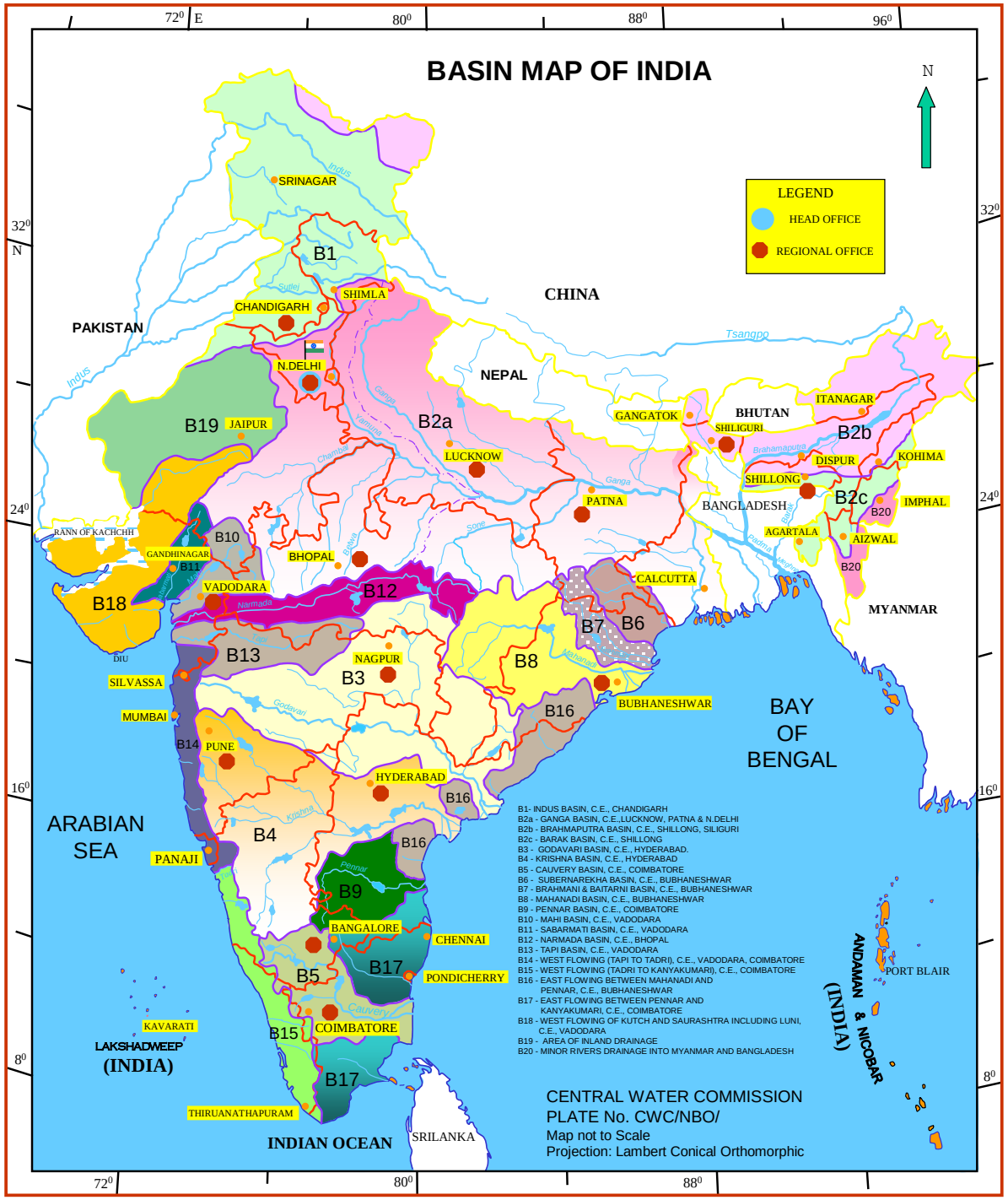
Month	Annual Avg. Rainfall (%)
Jan	1.24
Feb	1.33
Mar	2.12
Apr	3.46
May	6.03
Jun	15.42
Jul	23.76
Aug	19.89
Sep	14.19
Oct	7.69
Nov	3.45
Dec	1.42

Approximate Annual Water Resources of India in 2000 and 2025 AD (km^3)



Annual Water Availability in India

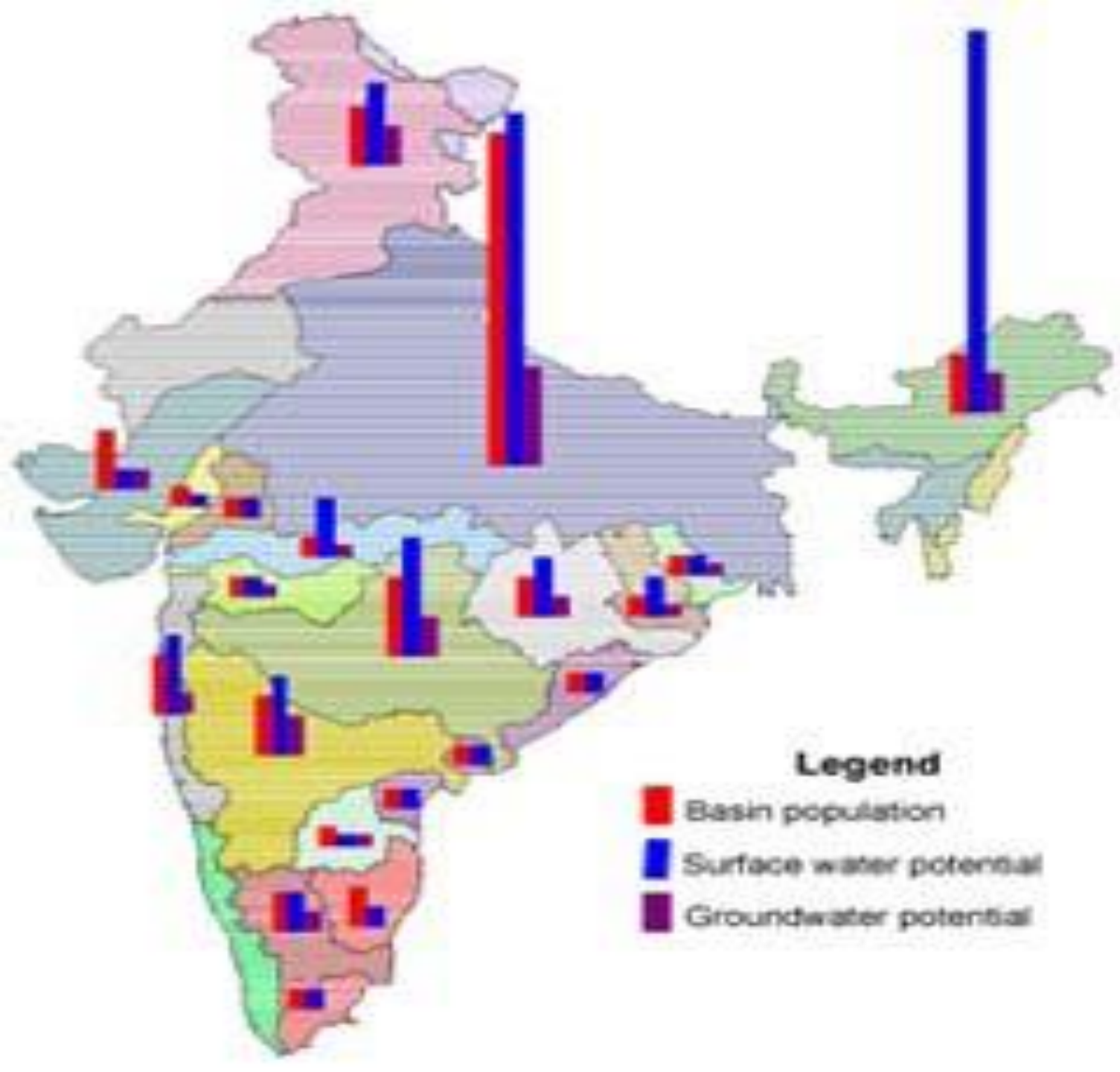
Total precipitation	**4000 BCM**
Annual water availability (after accounting for losses in the form evaporation etc.)	**1869 BCM**
Utilizable water (the available water cannot be fully utilized due to topographical and hydrological constraints and the need for allowing certain amount of water to flow in the river for maintaining the river regime.)	**1123 BCM**
- **Surface water** - **Ground water**	**690 BCM** **433 BCM**



Major River Basins of India

Basin-wise Average Annual Water Availability

S. No.	River Basin	Average Annual Water Availability (BCM)
1.	Indus	73.31
2.	Ganga-Brahmaputra-Barak	
	a. Ganga sub-basin	525.02
	b. Brahmaputra & Barak sub-basin	585.60
3.	Godavari	110.54
4.	Krishna	78.12
5.	Cauvery	21.36
6.	Pennar	6.32
7.	East Flowing Rivers between Mahanadi and Pennar	22.52
8.	East Flowing Rivers between Pennar and Kanyakumari	16.46
9.	Mahanadi	66.88
10.	Brahmani and Baitarni	28.48
11.	Subarnrekha	12.37
12.	Sabarmati	3.81
13.	Mahi	11.02
14.	West Flowing Rivers of Kutchh, Saurashtra including Luni	15.10
15.	Narmada	45.64
16.	Tapi	14.88
17.	West Flowing Rivers from Tapi to Tadri	87.41
18.	West Flowing Rivers from Tadri to Kanyakumari	113.53
19.	Area of Inland Drainage in Rajasthan Desert	Negligible
20.	Minor River Basins Draining into Bangladesh and Myanmar	31.00



Basin-wise Water Potential

Ground Water Resources

Annual potential natural ground water recharge from rainfall is about 342.43 BCM, which is 8.56% of annual rainfall.

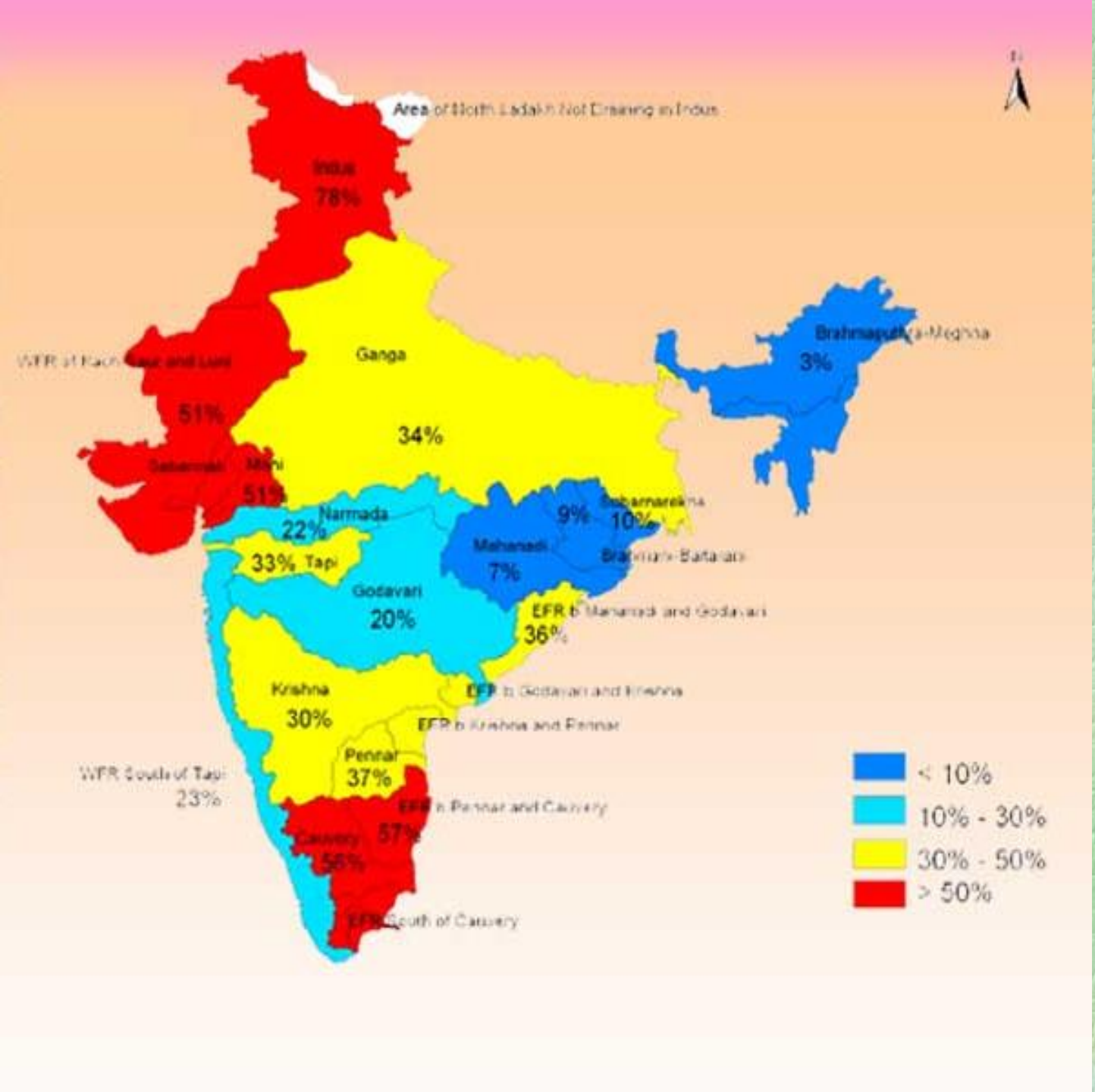
Annual potential ground water recharge augmentation from canal irrigation system is about 90.00 BCM.

Total replenishable groundwater resource is assessed as 433 BCM.

Major Aquifer Provinces in India

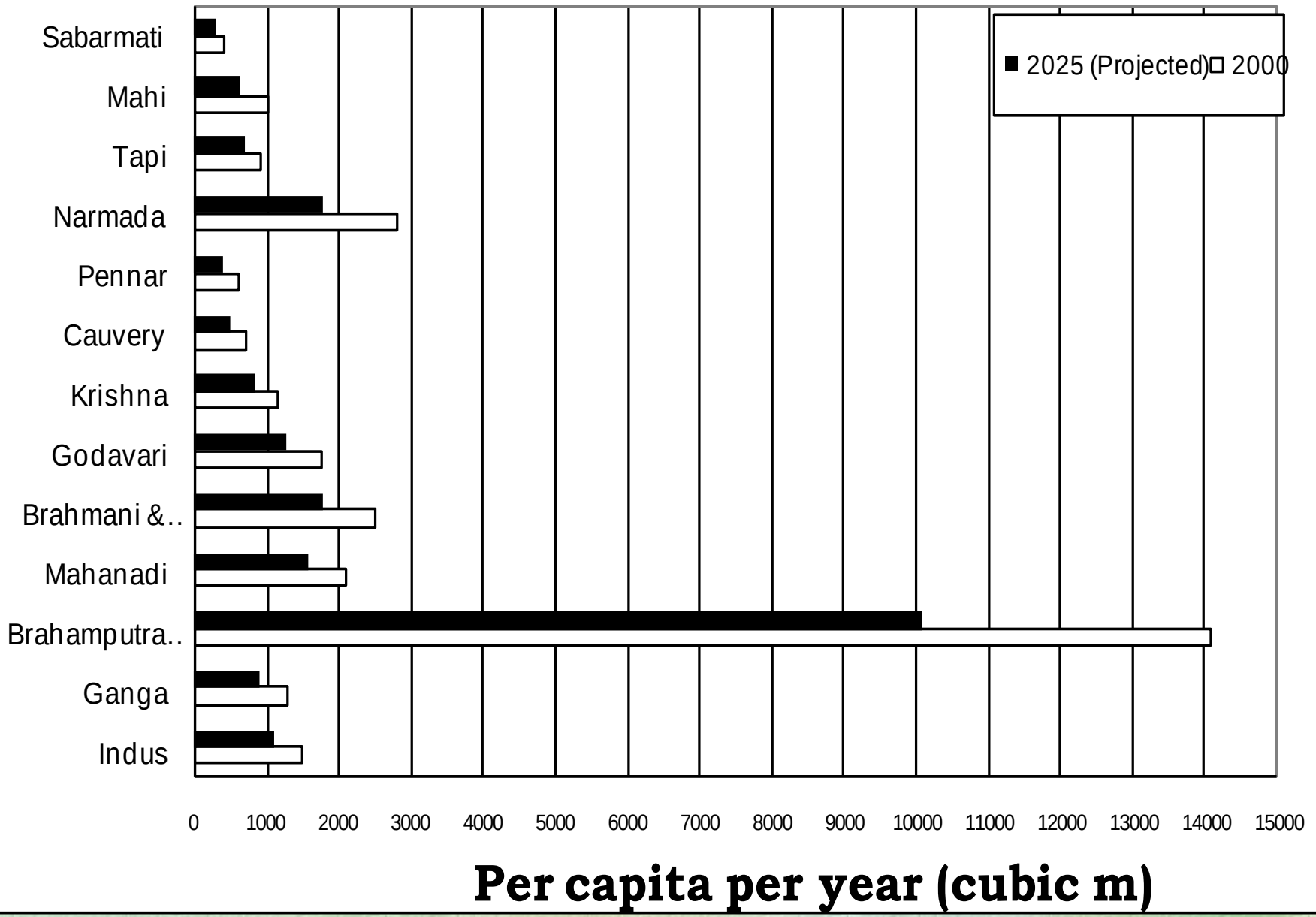
PROVINCE	AQUIFER MATERIAL (TYPE)	PARAMETERS
Indo-Gangetic alluvium	Alluvium with beds of sand, silt and clay with occasional beds of gravel (Shallow aquifers - unconfined, deeper ones confined or of leaky type)	T = 1000-5000 Sy = 10^{-4}-10^{-3} YP = 0.04-0.11
Cenozoic sedimentary basins	Unconsolidated to semi- Consolidated sandstone, shale and limestone (Deeper aquifers under confined condition; at places flowing wells)	T= 500-5000 Sy = 10^{-5}-10^{-3} YP = 0.01-0.04
Deccan Traps	Basaltic lava flows, generally flat lying, maximum thickness about 1,500 m in the western coast (Main source of groundwater are - Weathered and fractured horizon, Interflow spaces, Inter-trappeans, and Vesicular horizons)	T = 10 – 700 Sy = 10^{-3}-10^{-1} YP = 0.001 - 0.03
Gondwana Province	Semi- consolidated sandstone and shale with coal seams (Shallow aquifers unconfined, deeper ones confined)	T = 50-500 Sy = 10^{-3}-10^{-1} YP = 0.01-0.10
Precambrian sedimentary basins	Consolidated sandstone, shale and limestone (Intergranular porosity low; fractures are the main source of water in sandstone and shale; solution cavities in limestone)	T = 5-500 Sy = 10^{-3}-10^{-2} YP = 0.01-0.04
Precambrian crystalline province	Crystalline rocks, viz, granite, gneiss and schist (Weathered mantle is the main source of water supply, fractures and lineaments also facilitate groundwater movement)	T = 5 – 50 Sy = 10^{-3}-10^{-2} YP = 0.001-0.005

T = Transmissivity (m^2d^{-1})
Sy = Specific Yield
YP = Yield potential (m^3s^{-1})



Basin-wise Groundwater Development

Basinwise Per Capita Water Availability



Per Capita Water Availability with Time

Year	Population (in millions)	Per Capita water availability (in cubic meter)
1951	361	5177
2001	1027	1820
2025 (projected)	1394	1341
2050 (projected)	1640	1140

Irrigation Potential Created

Description	Major & Medium	Minor		Total
		Surface water	Ground water	
Ultimate irrigation potential (Mha)	58.47	17.38	64.05	139.90
Potential created up to March 2008 (Mha)	43.08	14.60	46.79	104.47
Balance potential (Mha)	15.39	2.78	17.26	35.43

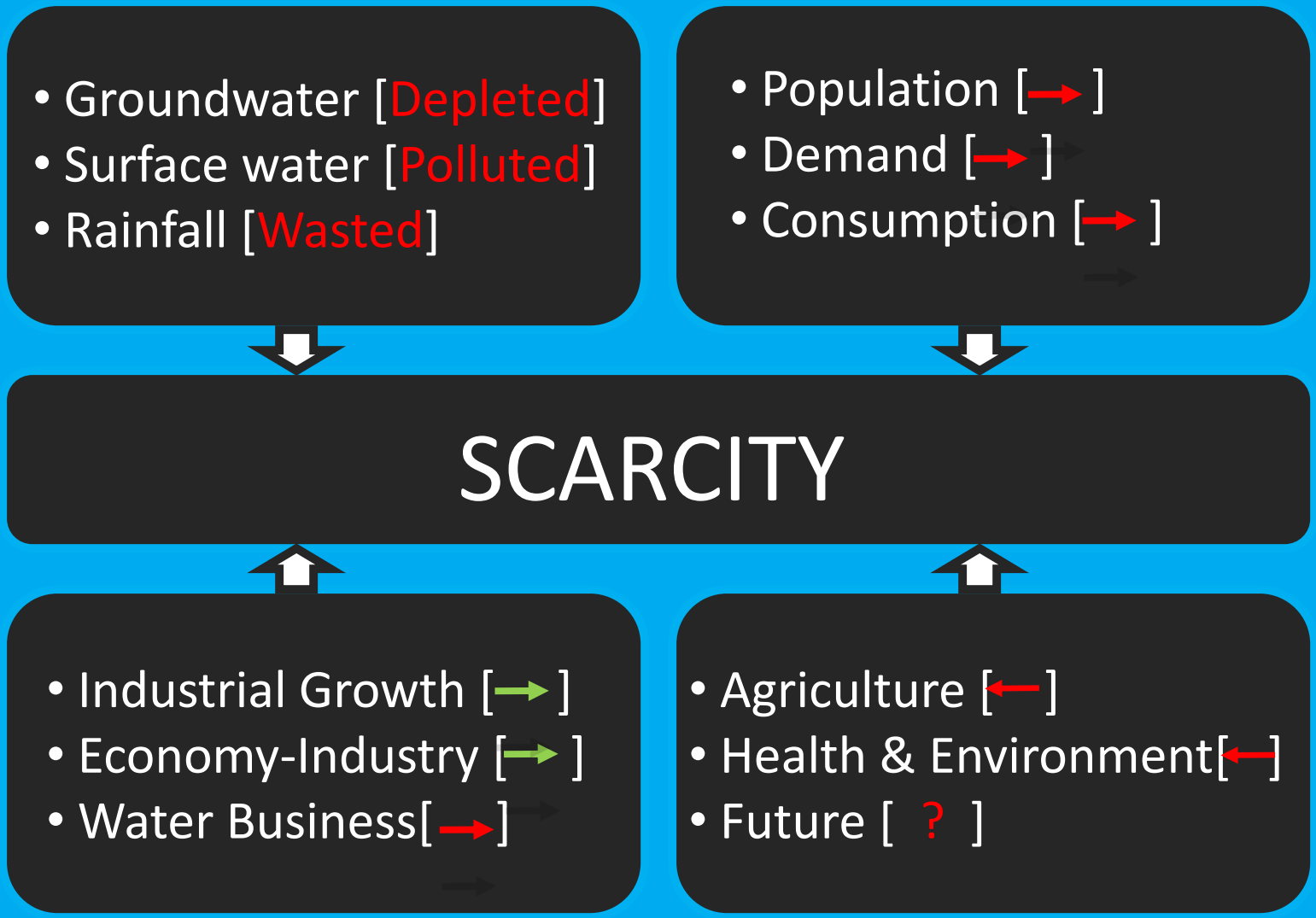
Storage Capacity Created

Storage already created	**225 BCM**
Storage in Projects under construction	**64 BCM**
Estimated storages through projects under consideration	**108 BCM**

India's Water Demands for Various Uses

Use	Year 2010		Year 2025		Year 2050	
	Water Demand (BCM)	% of total demand	Projected Demand (BCM)	% of total demand	Projected Demand (BCM)	% of total demand
Irrigation	557	78%	611	72%	807	69%
Domestic	43	6%	62	7%	111	9%
Industries	37	5%	67	8%	81	7%
Environment	5	1%	10	1%	20	2%
Others	68	10%	93	12%	161	13%
Total	710	100%	843	100%	1180	100%

The Indian situation



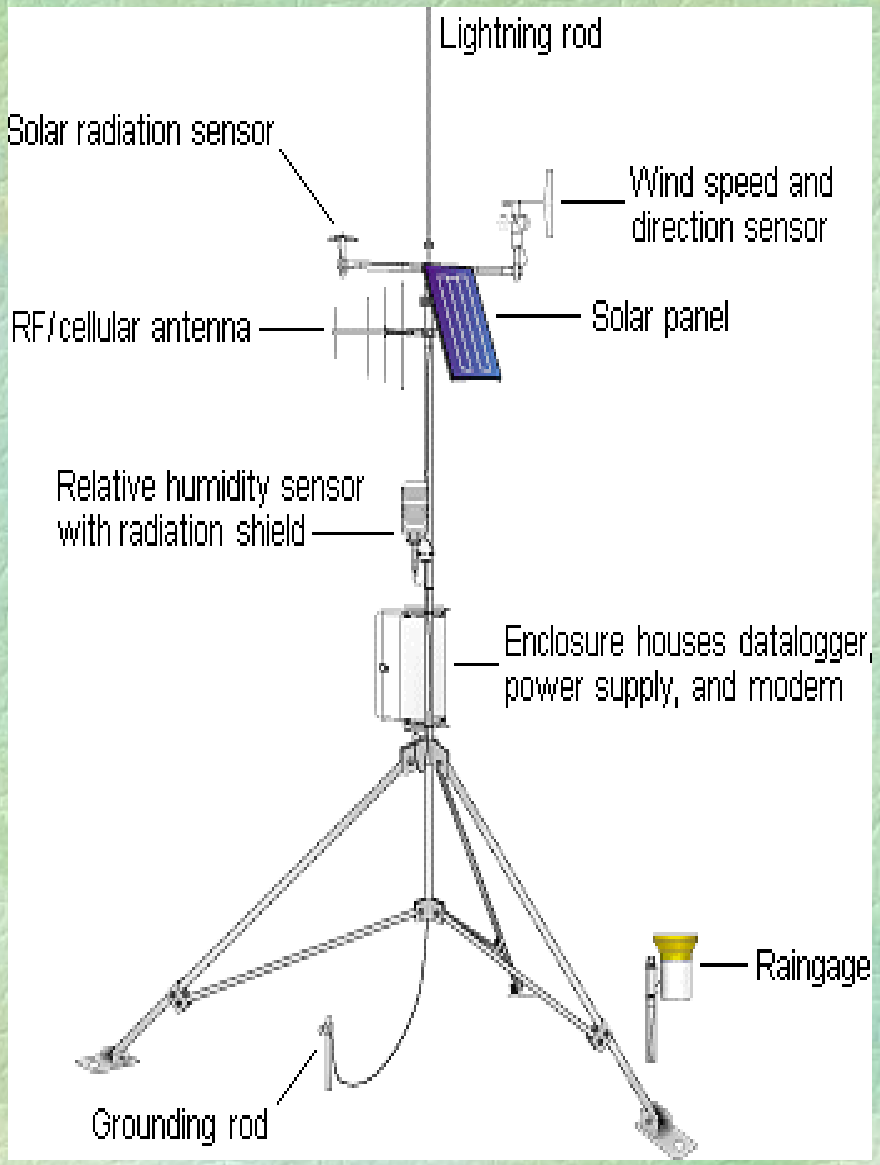
STRATEGIES FOR MANAGEMENT OF WATER RESOURCES

- Strengthening of Hydrological & Hydro-metereological network
- Establishment of additional sites
- Automation of Instruments
- Hydrological Information system (Temporal and Spatial data)
- O & M of water resources projects
- Equitable water distribution and water charges

Advances in Hydrological Instrumentation

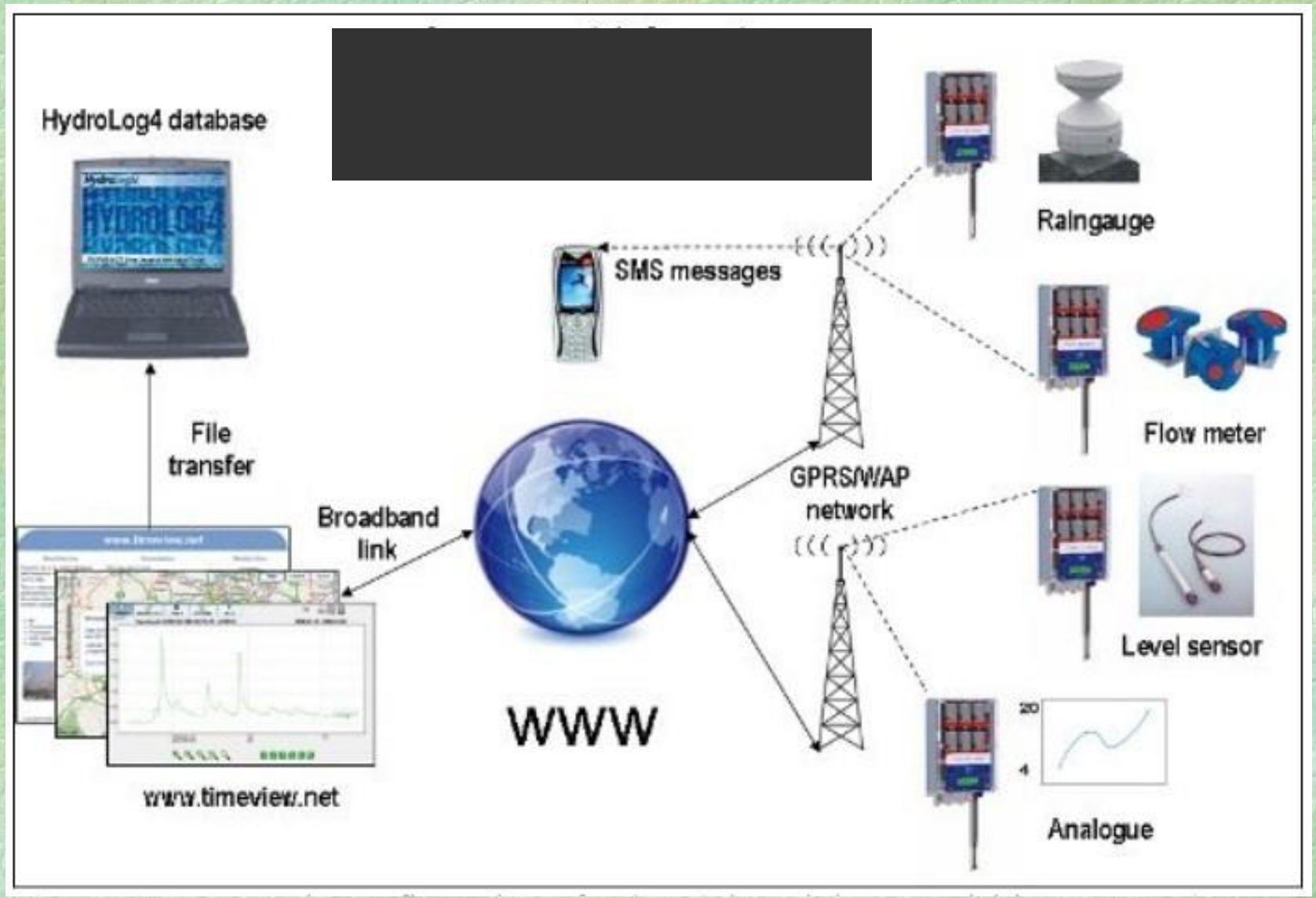
Automatic Weather Stations

- **Max. & min. temperature**
- **Humidity**
- **Wind speed & direction**
- **Sunshine & solar radiation**
- **Rainfall and snowfall**
- **Surface albedo**
- **Atmospheric pressure**



Advances in Hydrological Instrumentation

Low Cost Telemetry via GPRS



Advances in Hydrological Instrumentation

Radar water level recorder

Digital velocity meters

STRATEGIES FOR MANAGEMENT OF WATER RESOURCES ….

- Completion of command area development works
- Promote participatory Irrigation Management
- Timely completion of Multi-Purpose water resources projects
- Traditional System of water conservation
- Increasing water use efficiency and maintaining water quality

STRATEGIES FOR MANAGEMENT OF WATER RESOURCES ….

- R&D for increasing water use efficiency and maintaining quality
- Incentive for encouraging efficient irrigation practices
- Mandatory water auditing
- Integrated Water Resources planning, development and management
- Ground water Management to avoid over exploitation

STRATEGIES FOR MANAGEMENT OF WATER RESOURCES ….

- Sustainable development of water resources
- Systemic Approach for managing the flood & Drought
- Recycle and Reuse of water
- Rainwater Harvesting and Artificial Recharge
- Conjunctive use of surface water and ground water
- Watershed Management

STRATEGIES FOR MANAGEMENT OF WATER RESOURCES….

- Inter basin transfer
- Water Quality Monitoring
- Water Quality Conservation and Environment Restoration
- Vulnerability to Climate Change and adaptation strategies
- Water rights, ownership and pricing
- Desalination of water

Water Quality Issues

Common issues of Water Quality

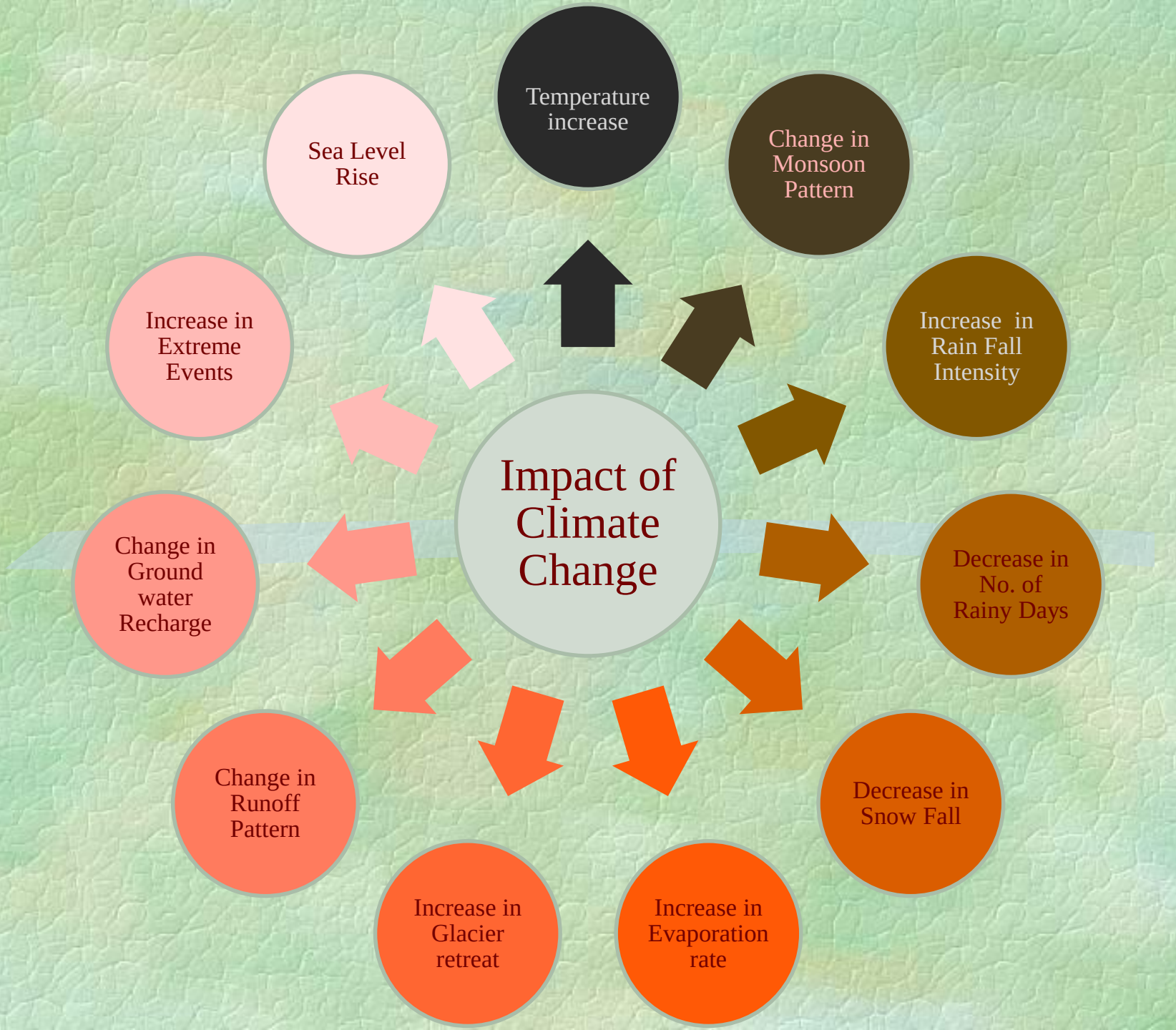
- Pathogenic (Bacteriological) Pollution
- Salinity
- Toxicity (micro-pollutants and other industrial pollutants)

Surface Water

- Eutrophication
- Oxygen depletion
- Ecological health

Ground Water

- Fluoride
- Nitrate
- Arsenic
- Iron
- Sea water intrusion


Impact of Climate Change
Temperature increase
Change in Monsoon Pattern
Increase in Rain Fall Intensity
Decrease in No. of Rainy Days
Decrease in Snow Fall
Increase in Evaporation rate
Increase in Glacier retreat
Change in Runoff Pattern
Change in Ground water Recharge
Increase in Extreme Events
Sea Level Rise

STRATEGIES FOR MANAGEMENT OF WATER RESOURCES….

- Legal restrictions on water use
- Decision support Systems in water resources
- Virtual Water Transfer
- People Participation and capacity Building
- Extensive R&D on all water related issues & challenges

Decision Support System

Computer based model together with their interactive interfaces are typically called decision support systems (DSSs)

Computer-based systems integrating tools and databases that assist a decision-maker in making informed decisions and analyse consequences

Major Initiatives in Water Resources Planning and Management

- Development of Water Resources Information System
- Hydrology Project
- Ground water Management and regulation
- Investigation of Water resources Development Schemes
- Dam safety studies and planning
- Flood management and flood Forecasting
- Repair, Renovation and Restoration of water bodies
- Research & Development

Major Initiatives in Water Resources Planning and Management

- Command Area development and water Management
- Technology Transfer Activities and training
- Information, Education and Communication

CONCLUDING REMARKS

The uneven spatial and temporal distribution of the precipitation in India leads to floods and drought affecting vast areas of the country.

Suitable models for forecasting the monsoon rainfall accurately.

The decision makers and farmers to adopt appropriate strategies for water resources management.

Adequate emphasis should be laid on management of floods and droughts.

CONCLUDING REMARKS…

Management of existing storages and creation of additional storages considering the economical, environmental and social aspects.

The movement of pollutants in the rivers, lakes and ground water aquifers needs to be regulated.

A regular monitoring programme needs to be initiated for identifying the areas likely to be affected because of the water quality problems.

For maintaining the quality of freshwater, sustainable water quality management strategies are required to be evolved and implemented.

Desalination as well as recycle and reuse of waste water should be encouraged.

CONCLUDING REMARKS…

Integrated and coordinated development of surface water and ground water resources and their conjunctive use should be envisaged right from the project planning stage and should form an integral part of the project implementation plan.

Optimal Reservoir Operation Policies should be evolved considering the Integrated System of Reservoirs for flood management and conservation purposes.

A comprehensive, reliable and easily accessible Information System for water resources data is a pre-requisite. Initiative of India-WRIS project with the aim of dissemination of data in public domain constitute the most important aspects of the water resources management.

CONCLUDING REMARKS…

Decision Support Systems are required to be developed for integrated planning, development and management of the water resources projects.

Development of DSS (Planning) for Integrated Water Resources Development and Management and DSS for Real Time Operation of Reservoir would be very useful for Water Resources Planning, Development and Management.

CONCLUDING REMARKS…

Studies are required to be taken up for assessment of water resources under changing climatic scenarios.

The concept of virtual water transfer requires to be introduced at policy level for food trade, agriculture and water management.

As most of the major rivers covering about 83% of geographical area in India are inter-state in nature; hence, there is a need for greater inter-state cooperation for integrated development and management of water resources.

The capacity building and awareness programmes should be organised for the users and public for encouraging their effective participation in water management practices and developing ethical concepts for making efficient use of water resources.

THANKS