An Introduction to Environmental Flows

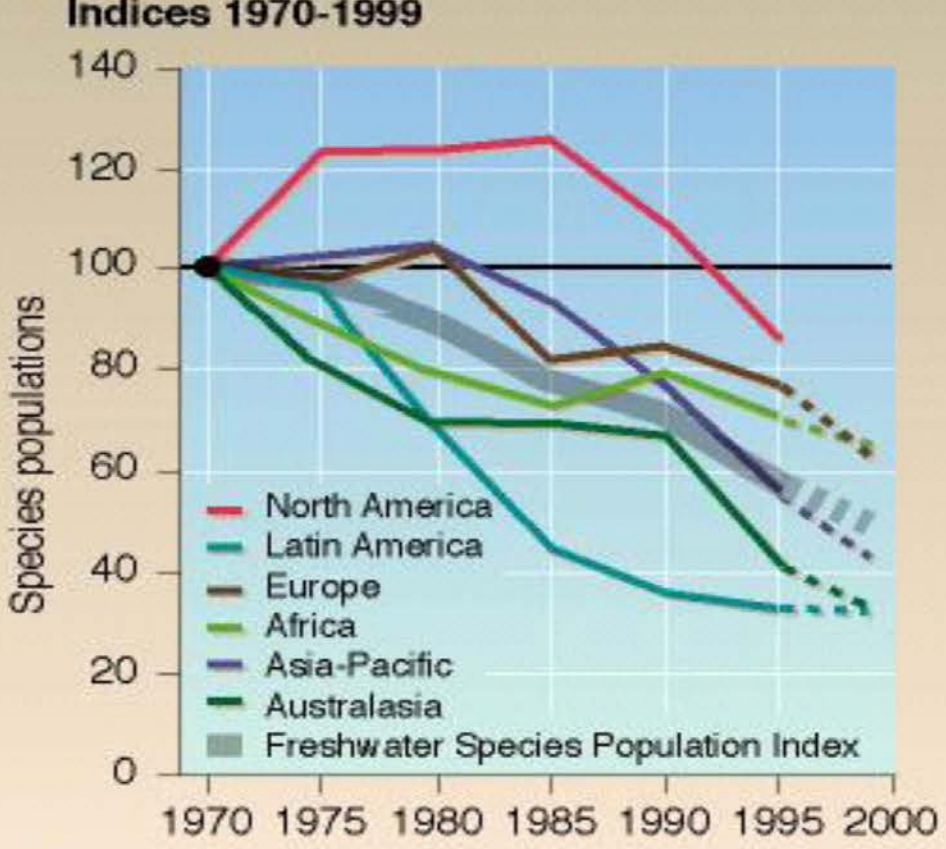
- The natural flow regime
- Flow alteration
- Environmental flows defined
- Scaling up

Eloise Kendy, Ph.D.
IUCN workshop
Kathmandu, Nepal
5 August 2011

The Nature Conservancy
SAVING THE LAST GREAT PLACES ON EARTH

Jefferson River, Montana
Eloise Kendy, photo

Changes in Freshwater Species Populations

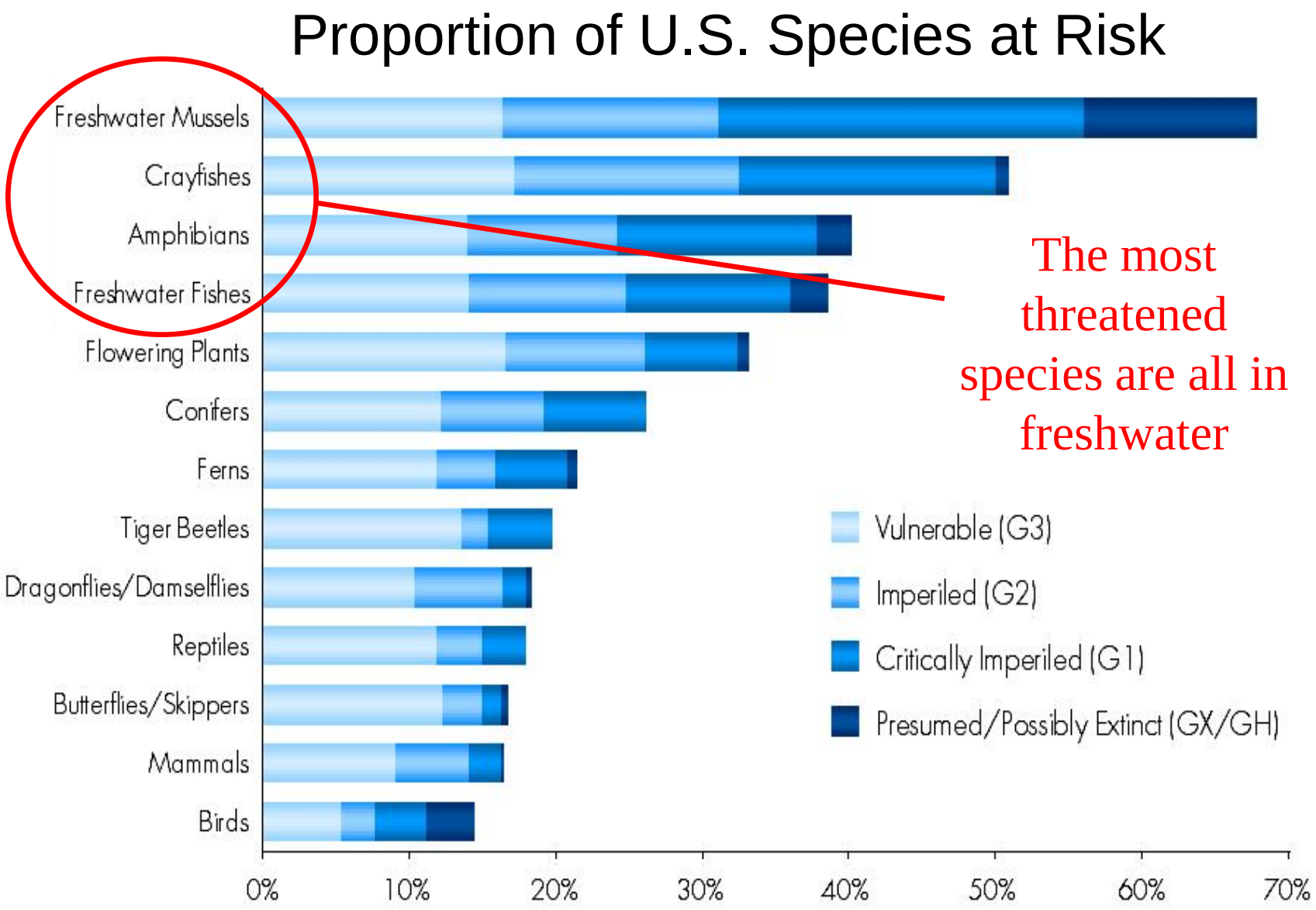


UNEP

DELPHINE DIGOUT
MAY 2002

Source: *Living Planet Report 2000*, World Wide Fund for Nature (WWF)

Status of freshwater species



Key Factors Affecting Aquatic Ecosystems

Hydrologic Regime

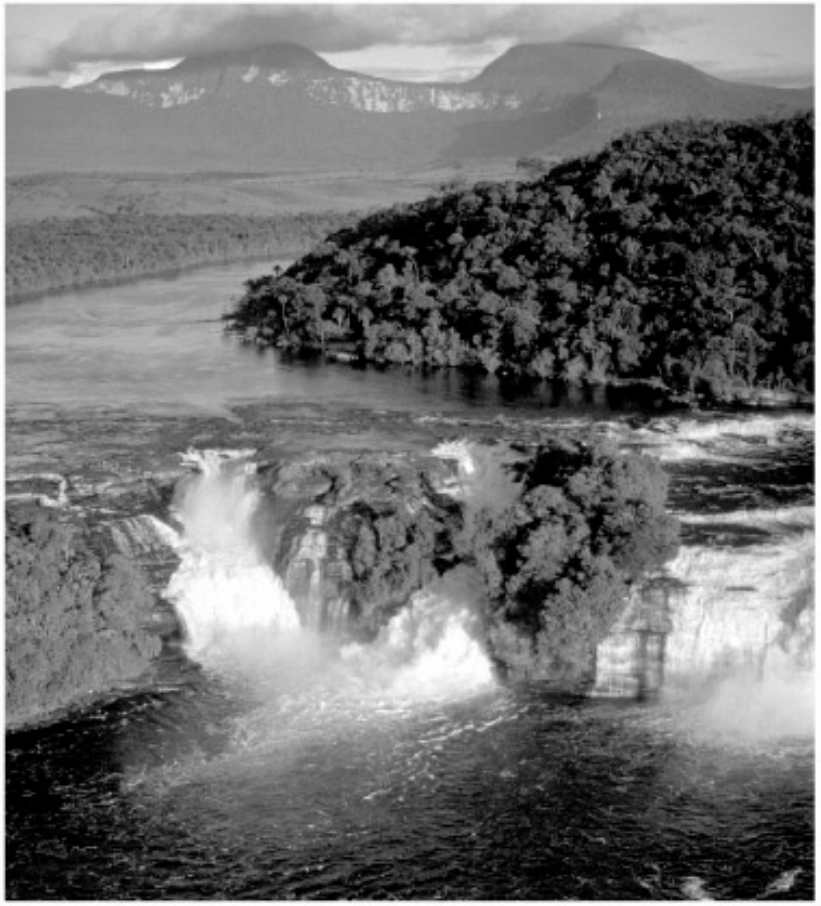
(surface flow, groundwater, surface inundation, and soil moisture regimes)

Physical Habitat Conditions

(woody debris, riparian canopy, geomorphology, sediment/soil regime)

Biological Composition & Interactions

(energy regime, feeding, 1· & 2· production, target structure & composition, competition & predation, reproduction, disease & parasitism, mutualism)



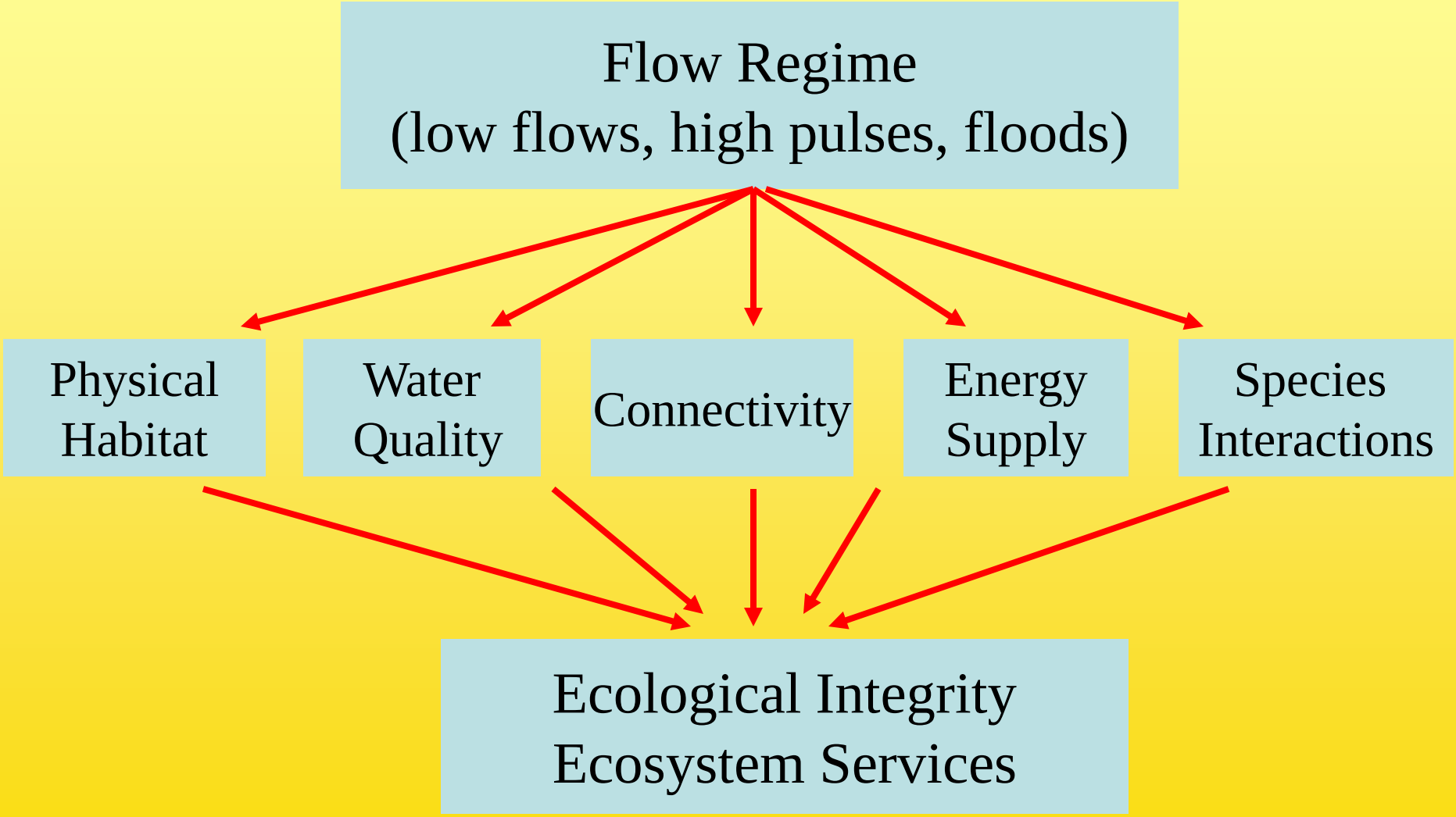
Connectivity

(up-down gradient continuity, water-wetland-land connectivity)

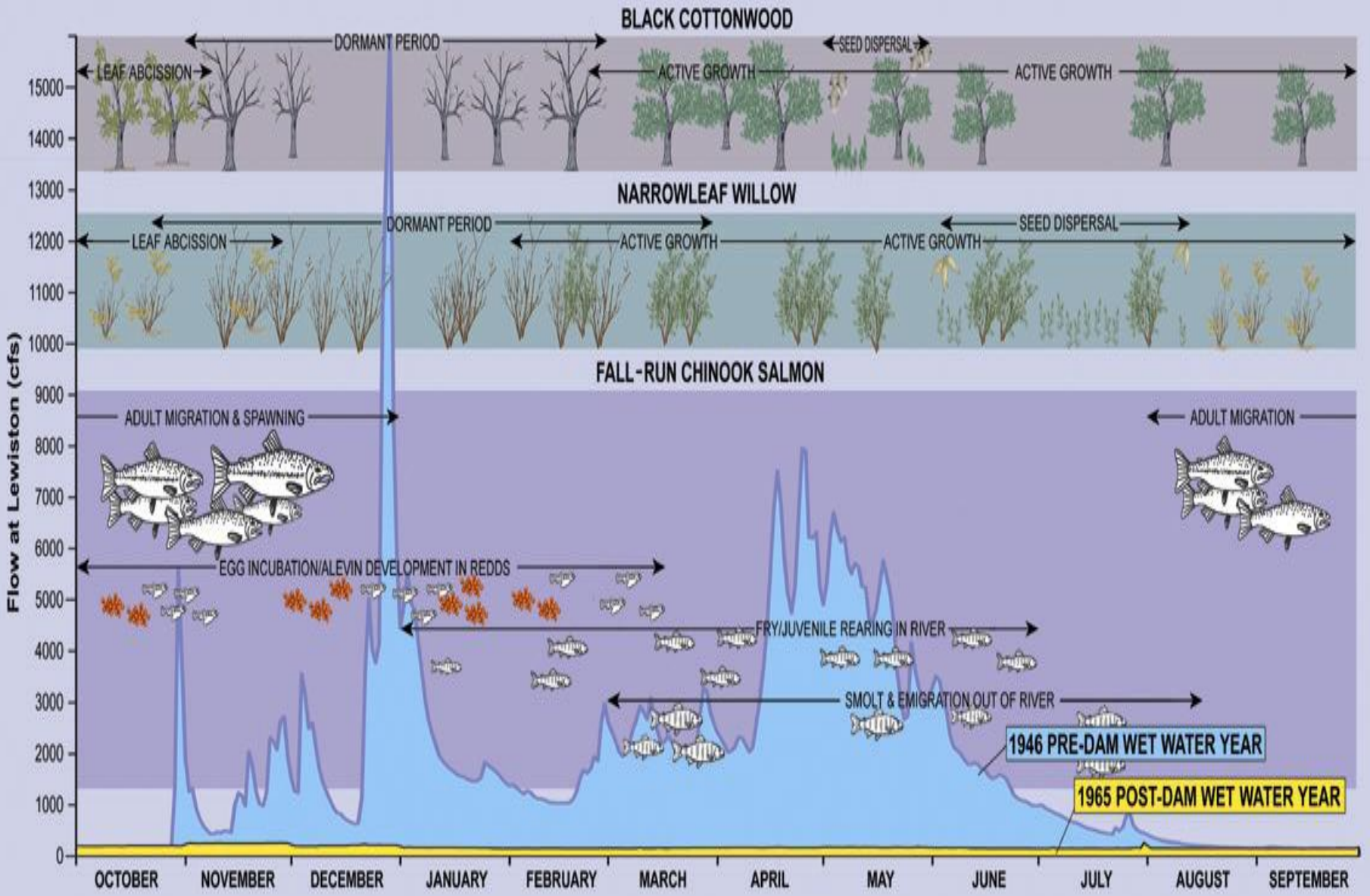
Water Chemistry Regime

(salinity, alkalinity, hardness, temperature, dissolved minerals, dissolved gases, turbidity, pH, ORP, radioactivity, organic compounds)

Flow is the Master Variable



Flow is the master variable.



The Natural Flow Paradigm

"The full range of natural intra- and inter-annual variation in hydrologic regimes, and associated characteristics of timing, duration, frequency, and rate of change, are critical in sustaining the full native biodiversity and integrity of aquatic ecosystems." (Poff *et al.* 1997)

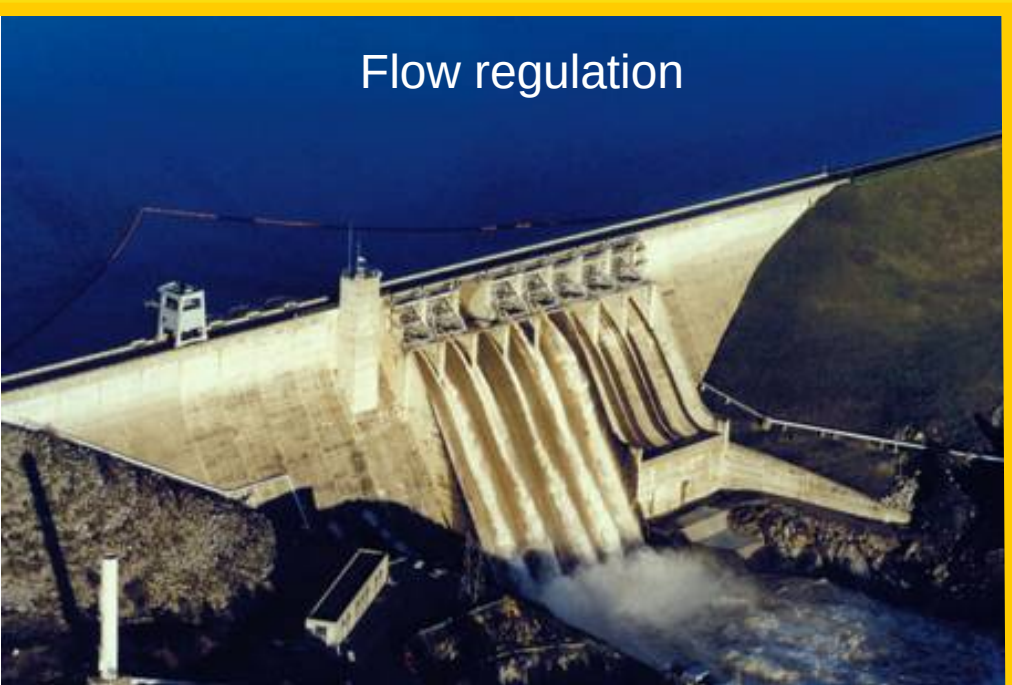



Hydrological Alteration:

Any anthropogenic disruption to the magnitude or timing of natural river flows

(Rosenberg *et al.* 2000)

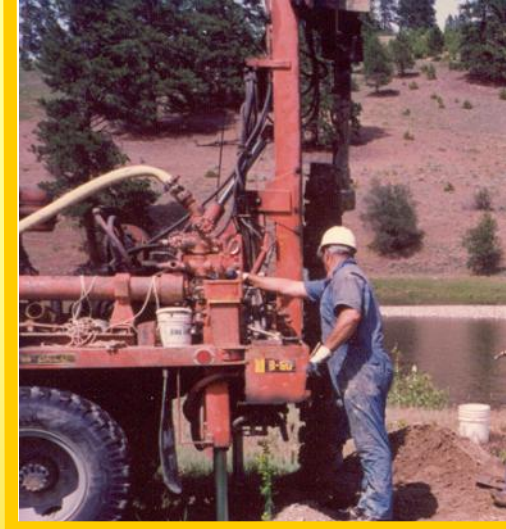
Flow regulation

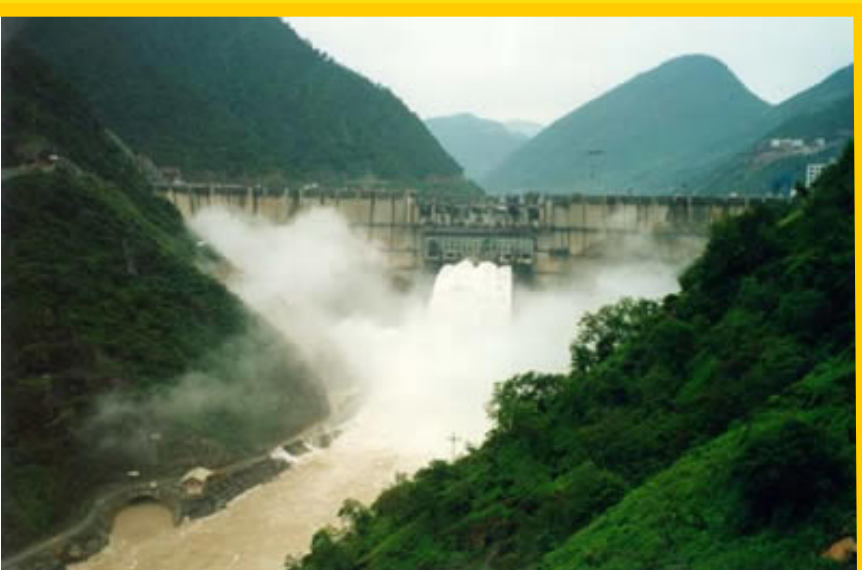


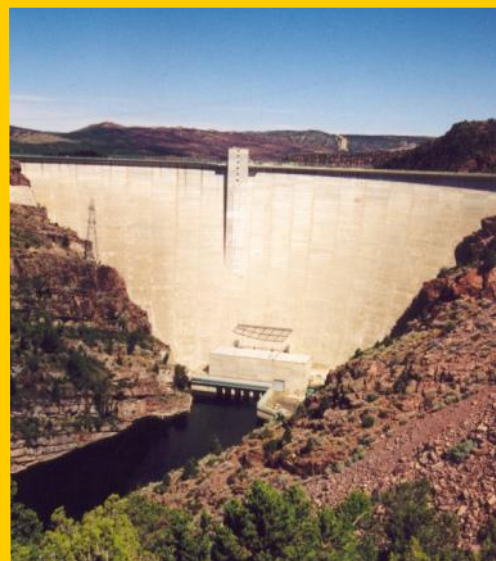
Loss of river-floodplain connectivity

What alters hydrology?

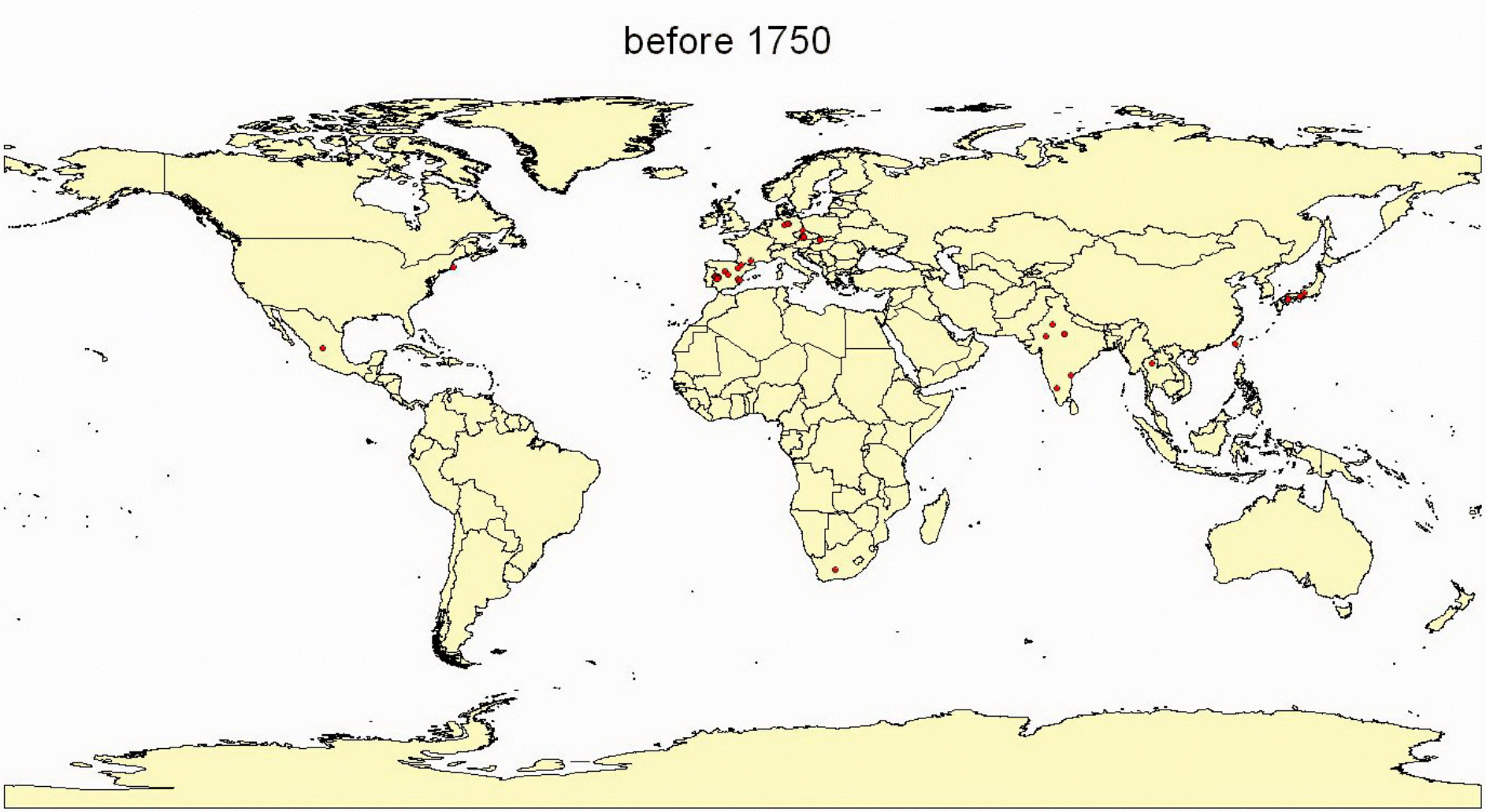
- Dams
- Withdrawals
- Land-Use Change
- Climate Change







The History of Global Dam Development



Map shows 23,427 large dams worldwide. Dam data are from Greifswald University, the ICOLD World Register of Dams, the FAO African Dams Database, the U.S. National Inventory of Dams, and The Nature Conservancy.

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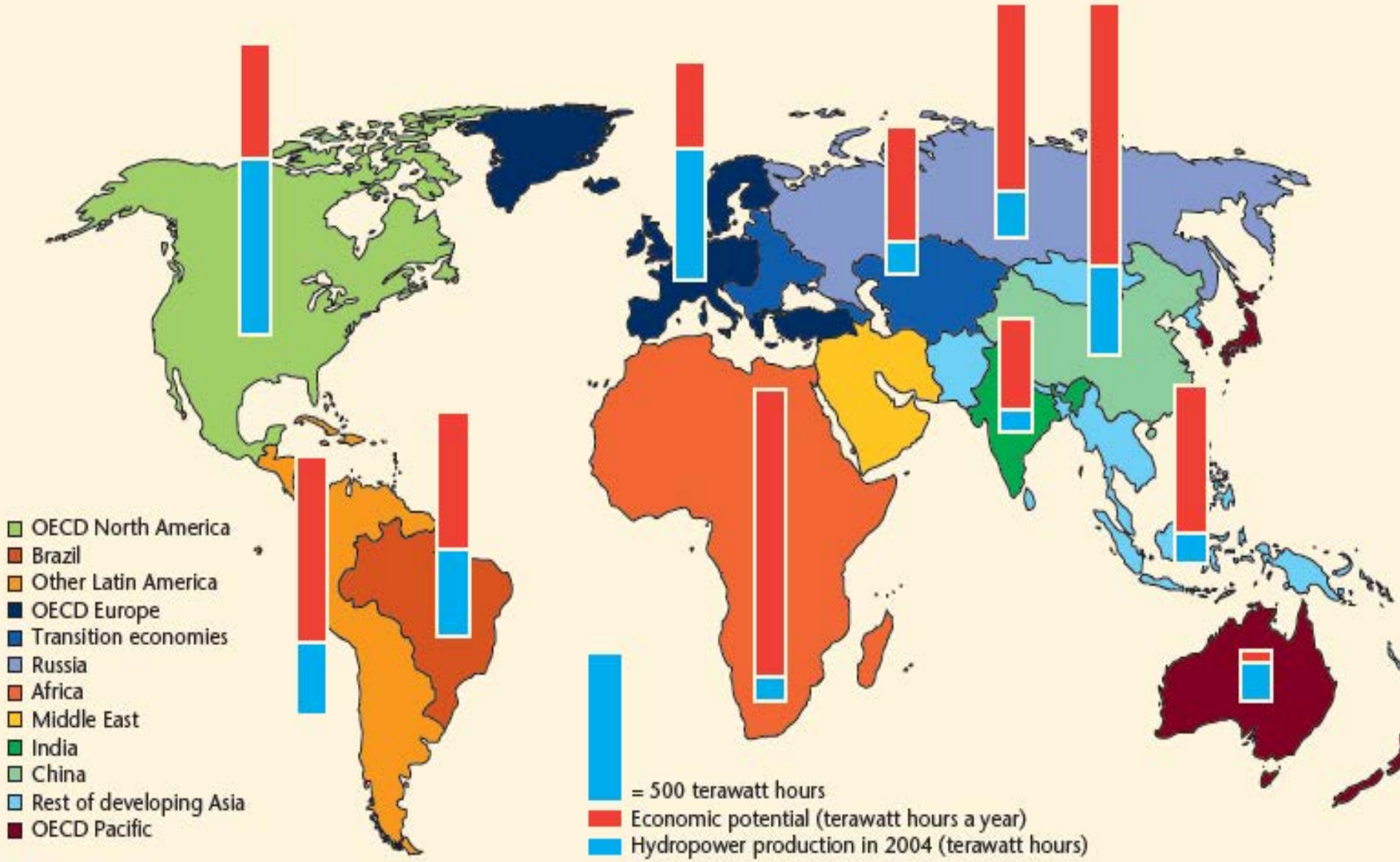
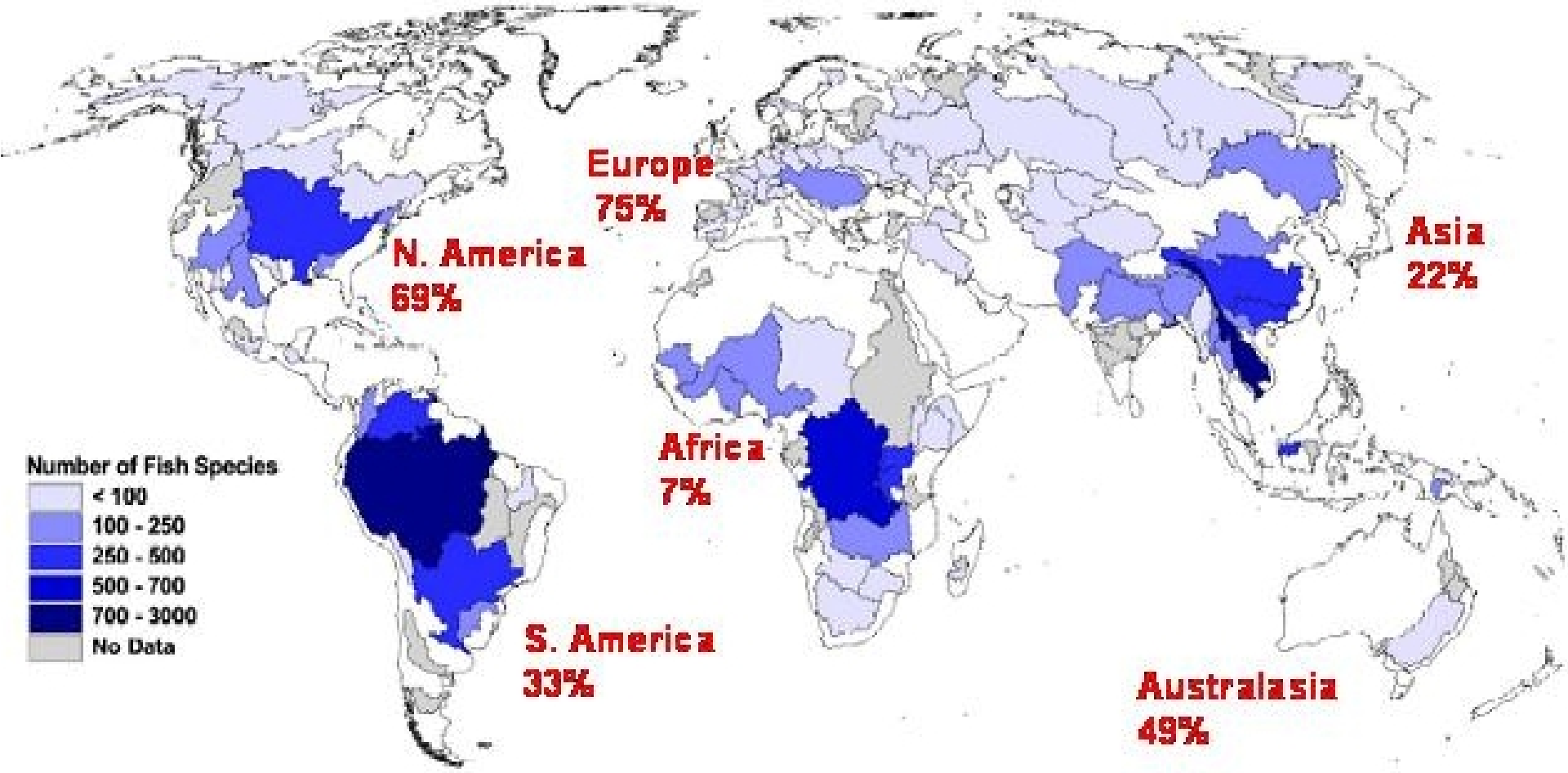
Map 7.6 **World potential and current hydropower production, 2004**



Source: IEA 2006.

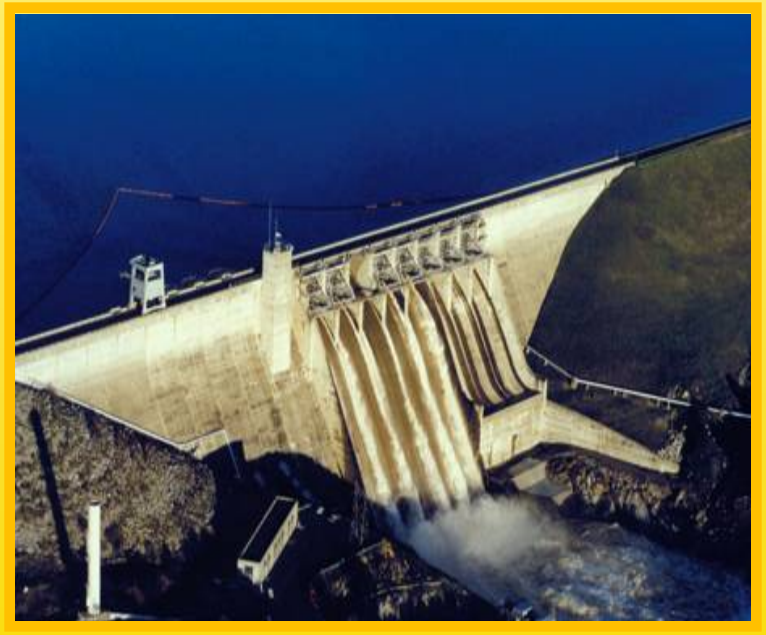
Proliferation of Future Dams



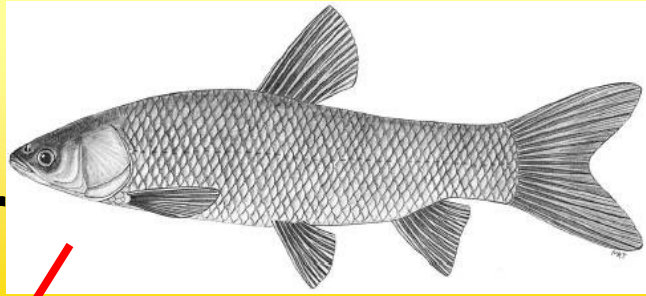
Percentage of economically feasible hydropower potential that has been developed (International Hydropower Association)

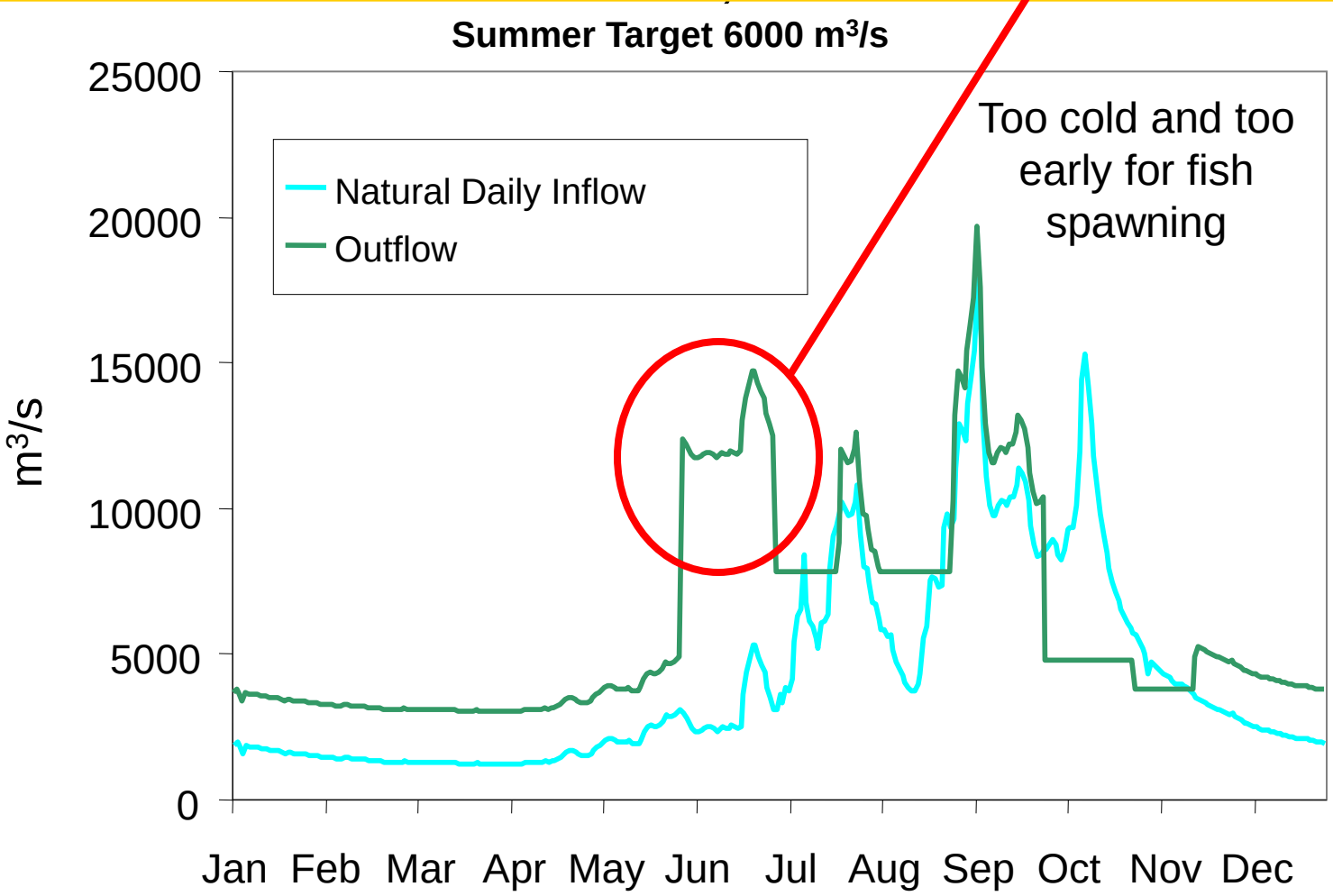
Dams

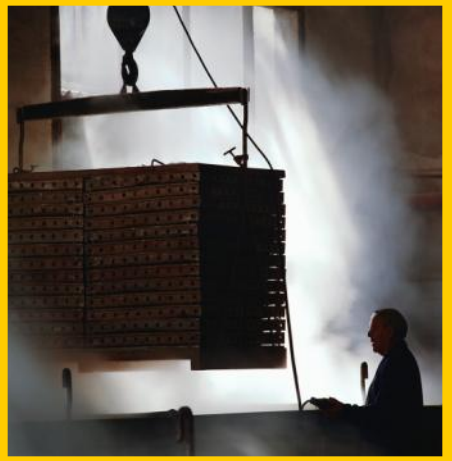
- Disconnect river reaches, preventing migration
- Pond water in reservoirs upstream
- Alter flow patterns downstream for:
  - Water supply
  - Hydropower production
  - Recreation
  - Flood control
- Downstream impacts:
  - Sediment
  - Water quality
  - Temperature
  - Flow

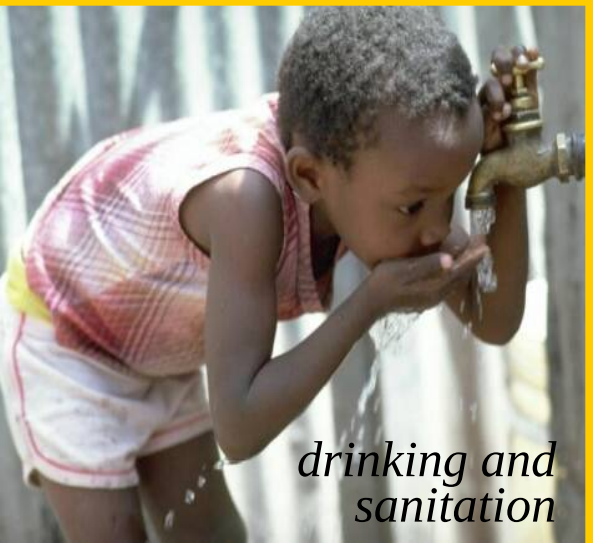


Impacts of reservoir operation for flood control, Yangtze River

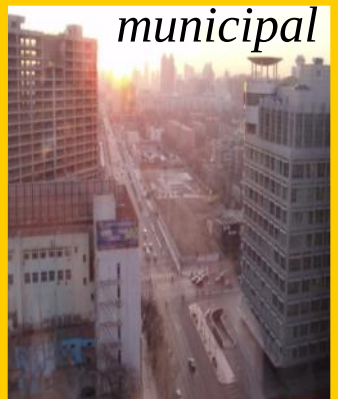




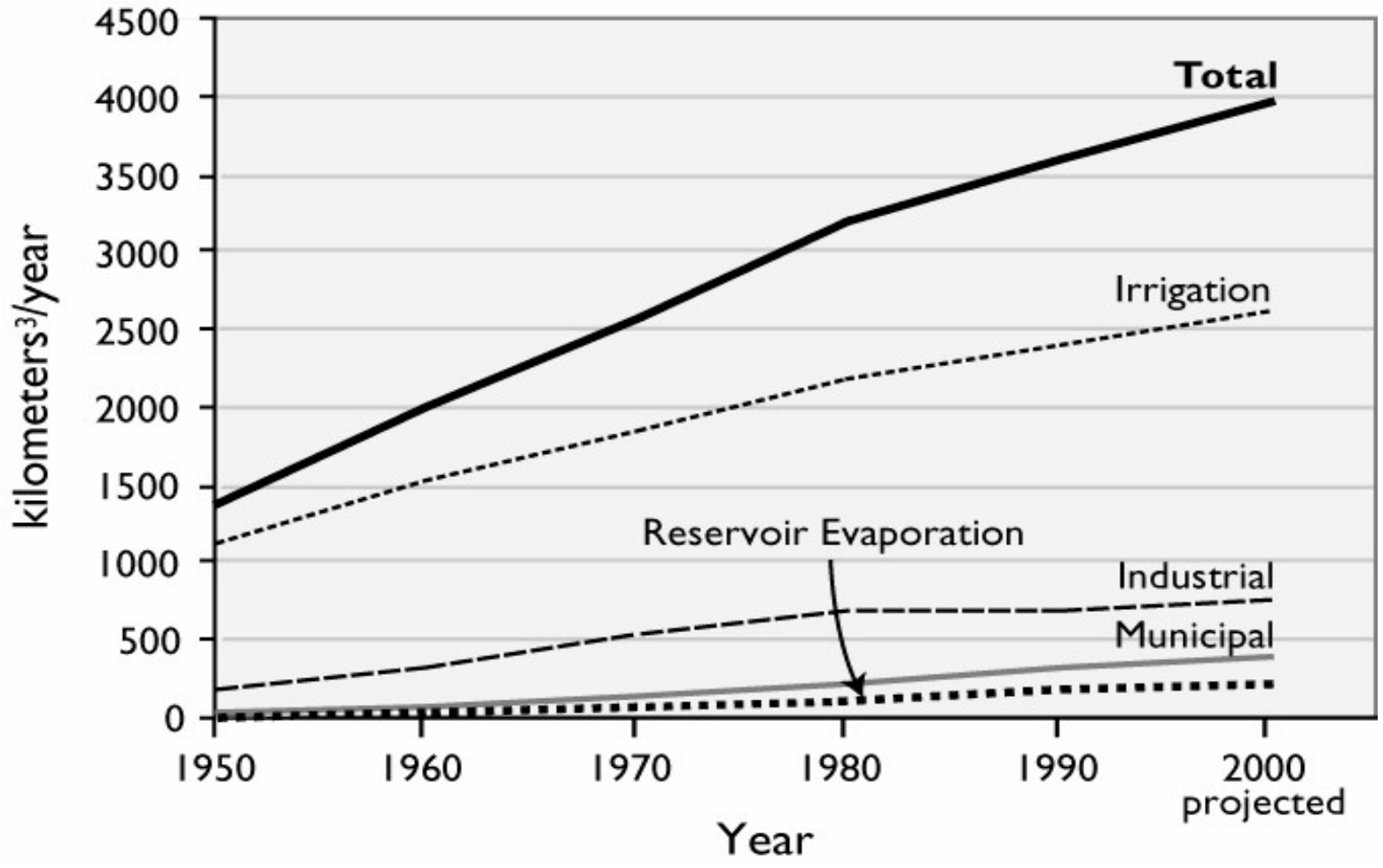




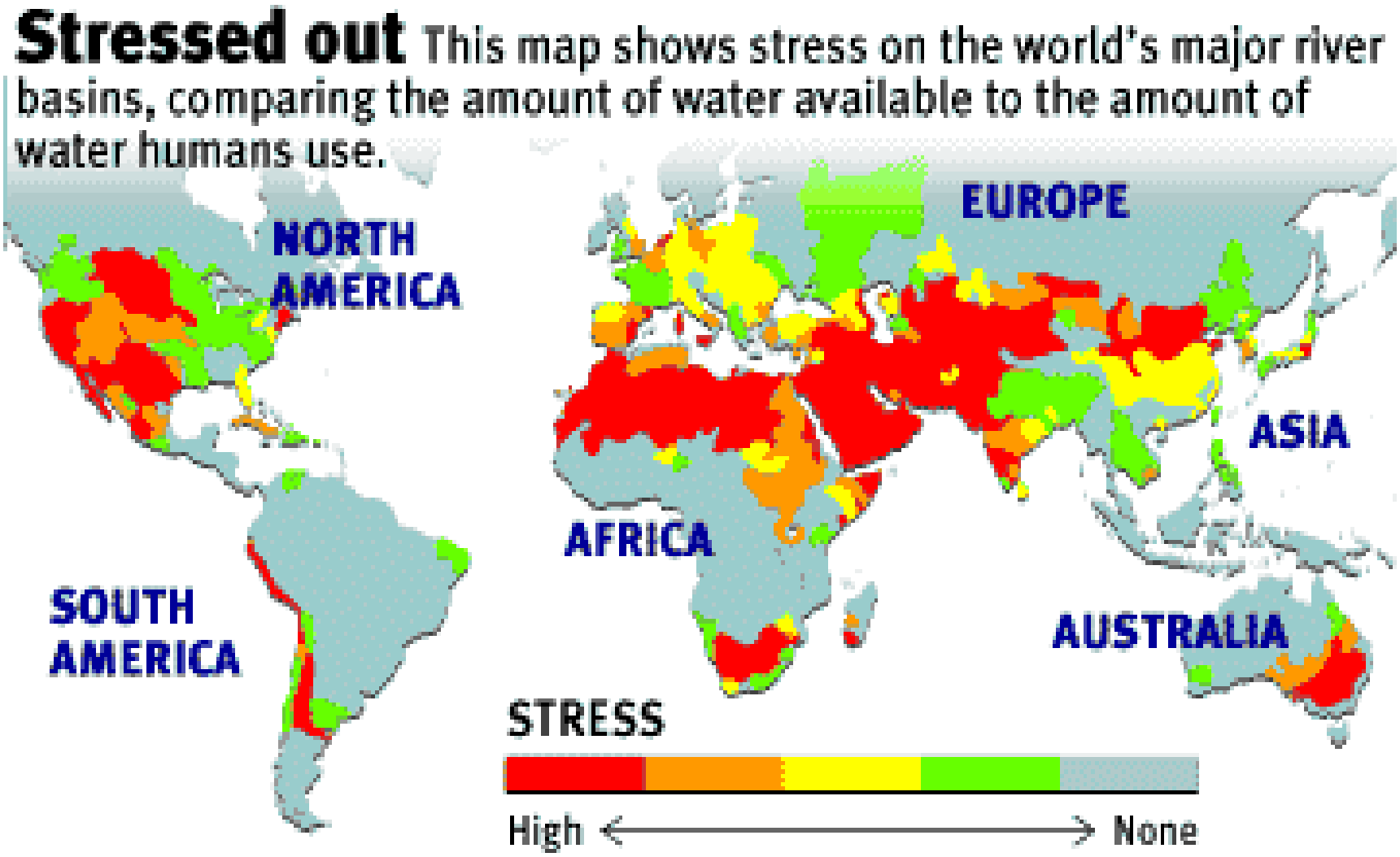
Withdrawals



Global Water Consumption

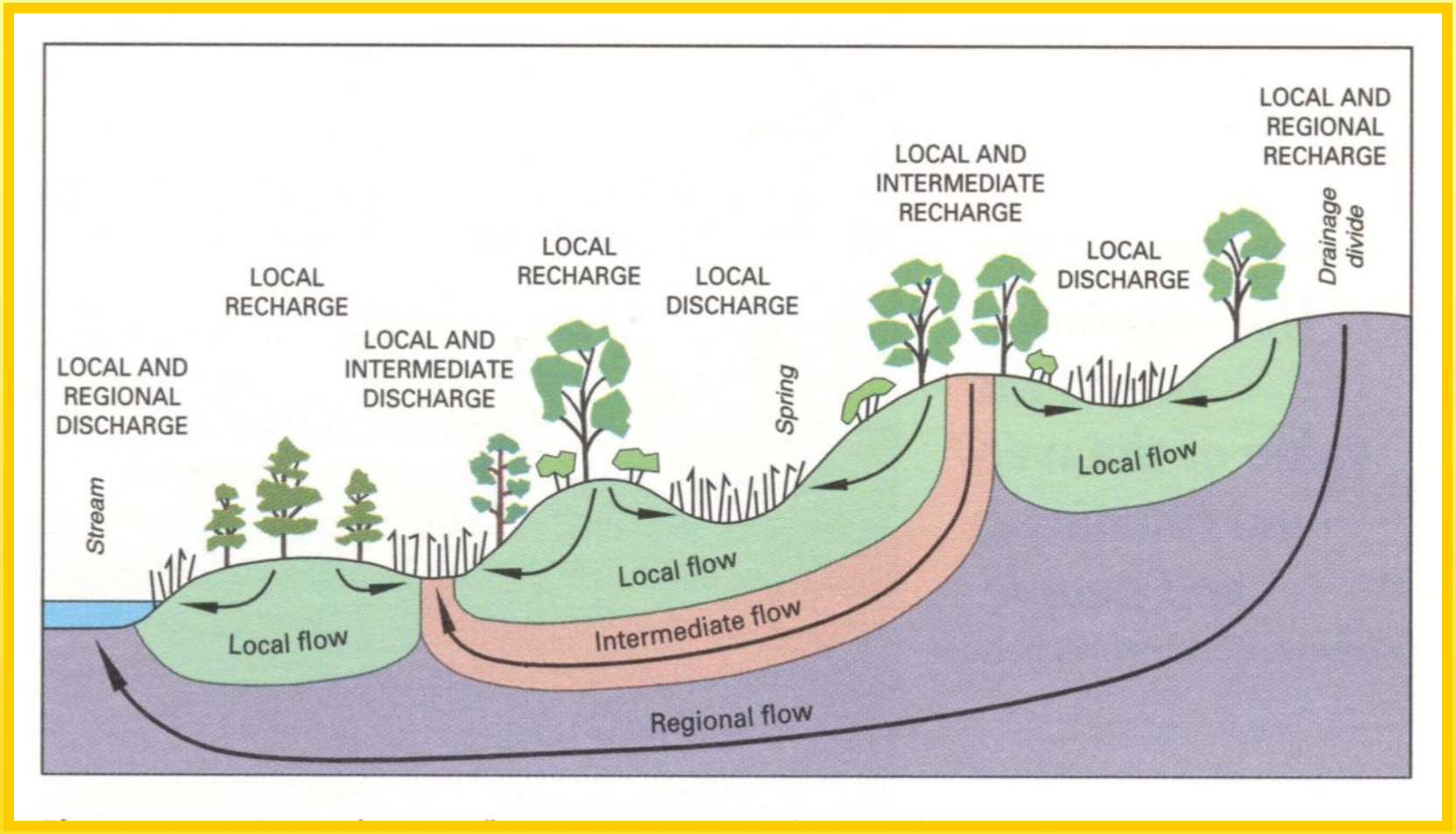


Global Water Stress



Source: World Commission on Water in the 21st Century

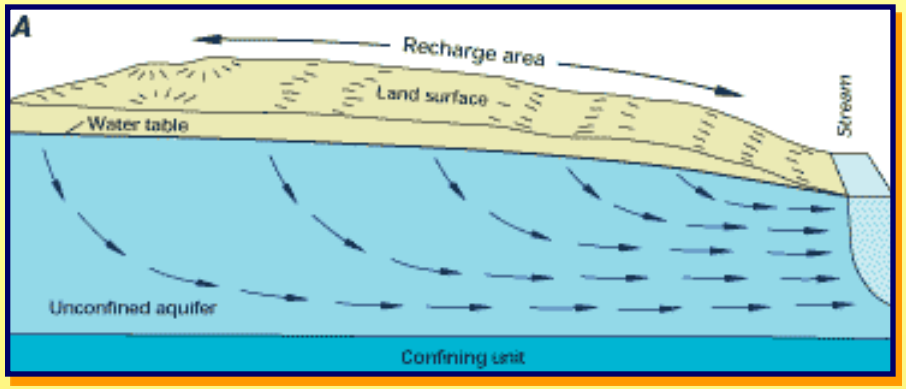
Ground-water discharge creates wetlands and contributes to surface flows.



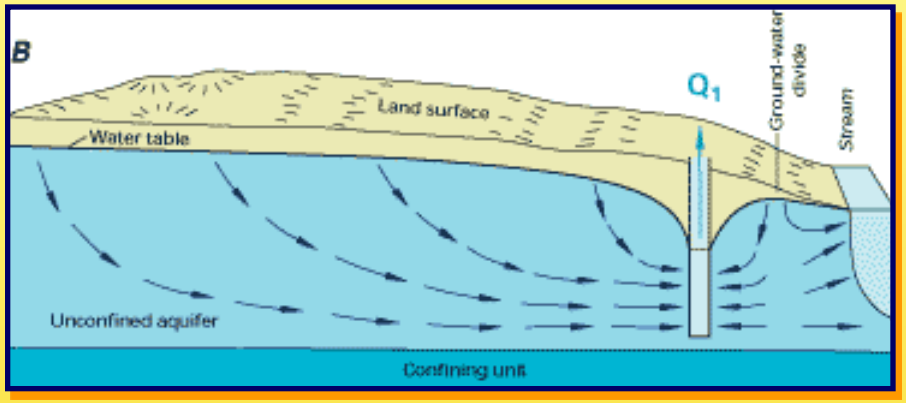
Carter 1996 (USGS WSP 2425)

Effects of ground-water pumping

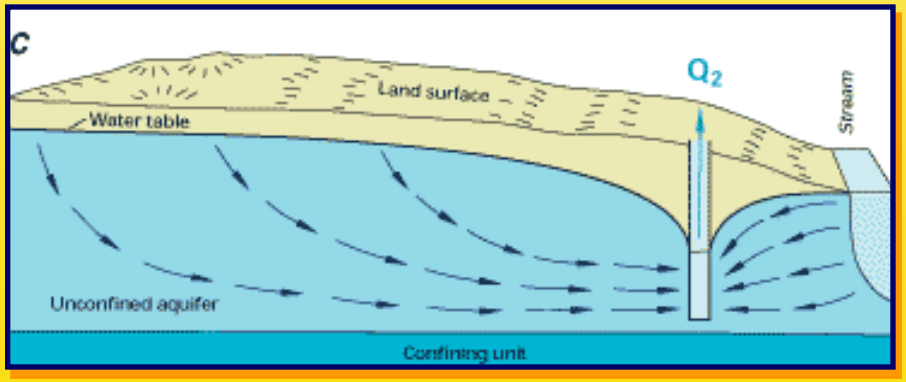
Pre-pumping



Well 1

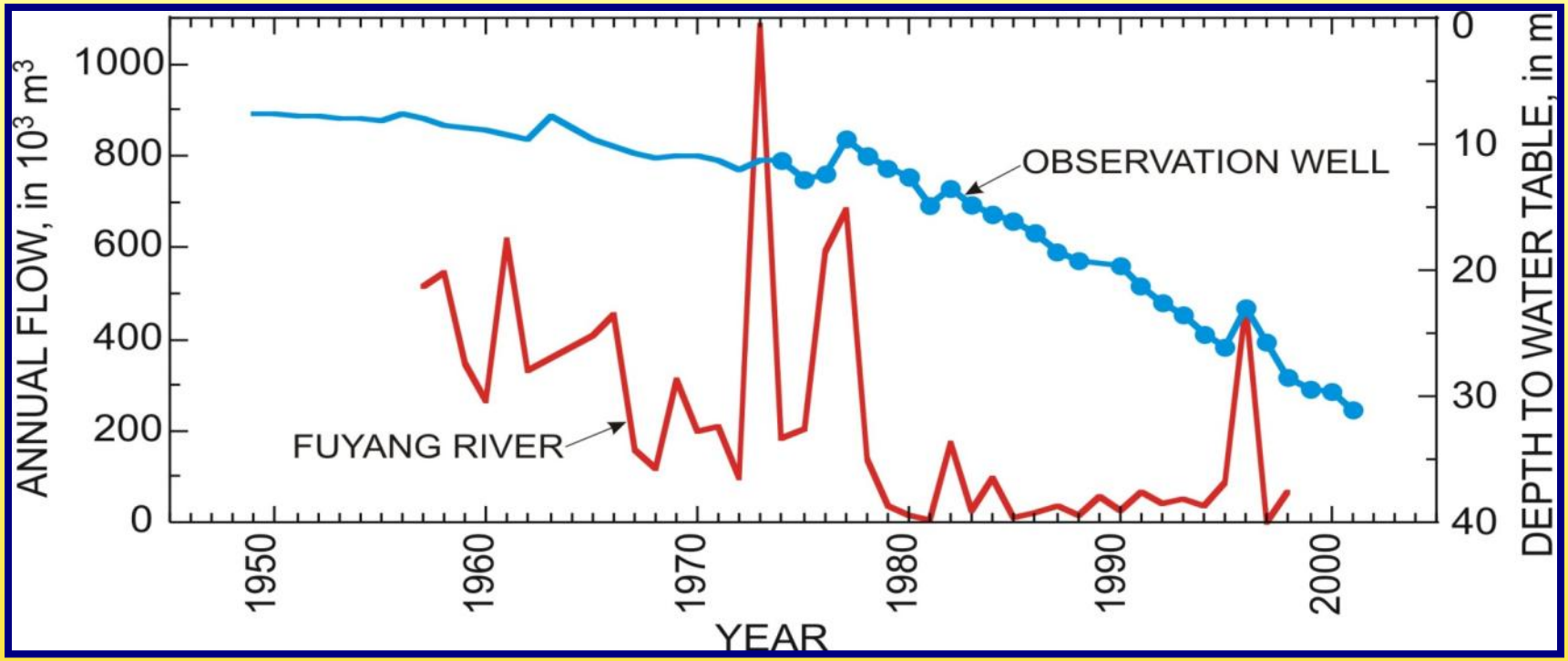


Well 2



Alley et al, 1999, USGS Circular 1186, fig. 13

Streamflow depletion: The inevitable consequence of ground-water withdrawal.

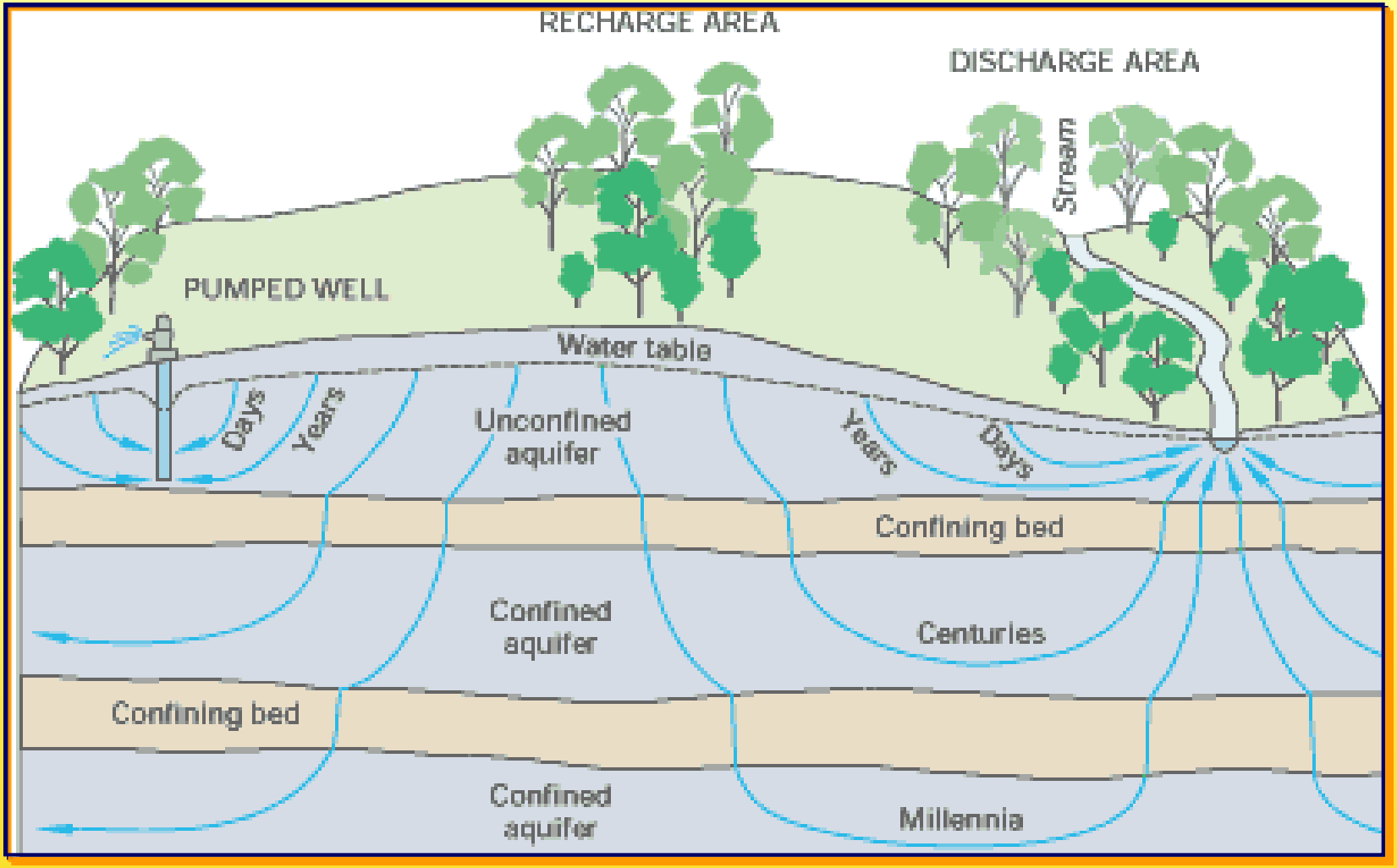


Fuyang Basin, North China Plain

(Kendy, 2002)

See also: WATER FOLLIES by R. Glennon

Land-Use Change



Ground-water flow paths

Winter et al, USGS Circular 1139, fig. 3

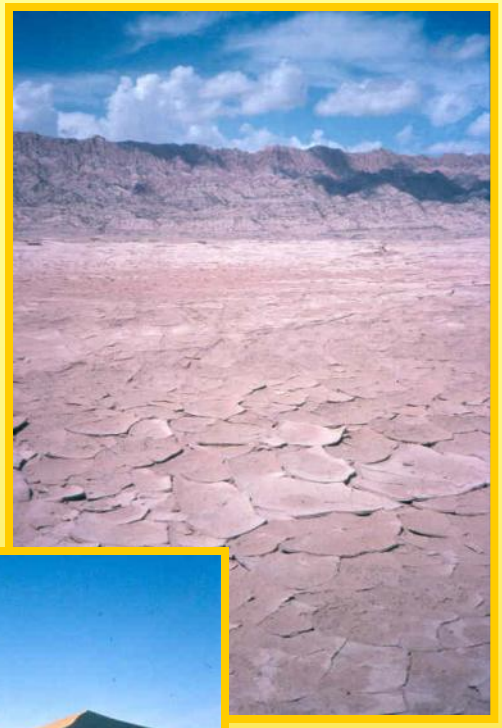
Climate Change

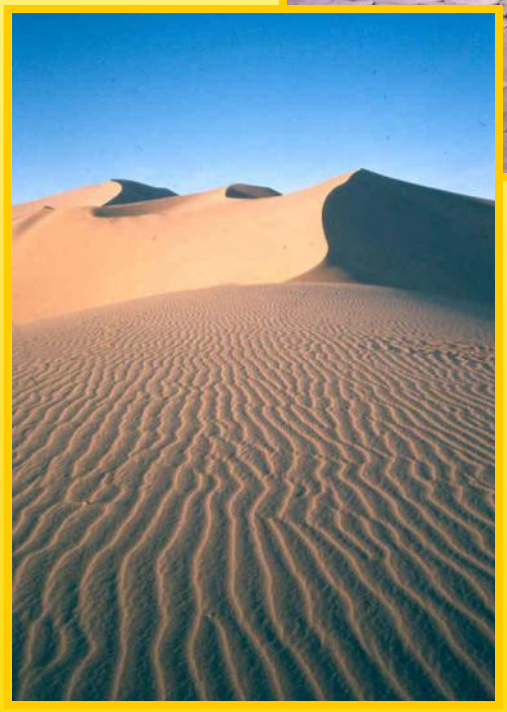
MORE FREQUENT DROUGHTS

MORE FREQUENT FLOODS

HIGHER TEMPERATURES

EARLIER SNOWMELT



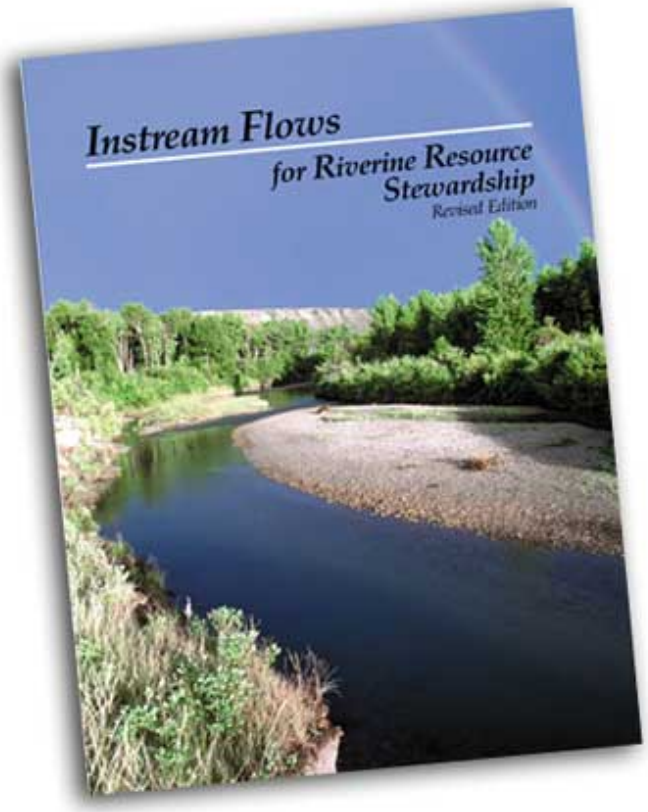


Eloise Kendy, photos

What are “environmental” flows?

…..*vs.* “minimum” flows?

…..*vs.* “instream” flows?



eFlowNet
Global Environmental Flows Network

The Brisbane Declaration

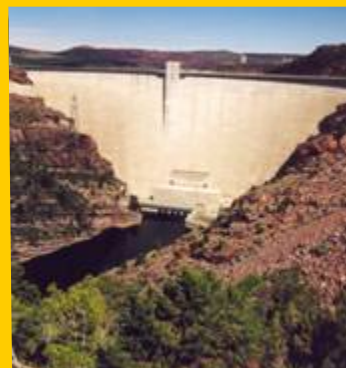
Environmental Flow:

Pattern of water flows through a natural river or lake that sustains healthy ecosystems and the goods and services that humans derive from them.





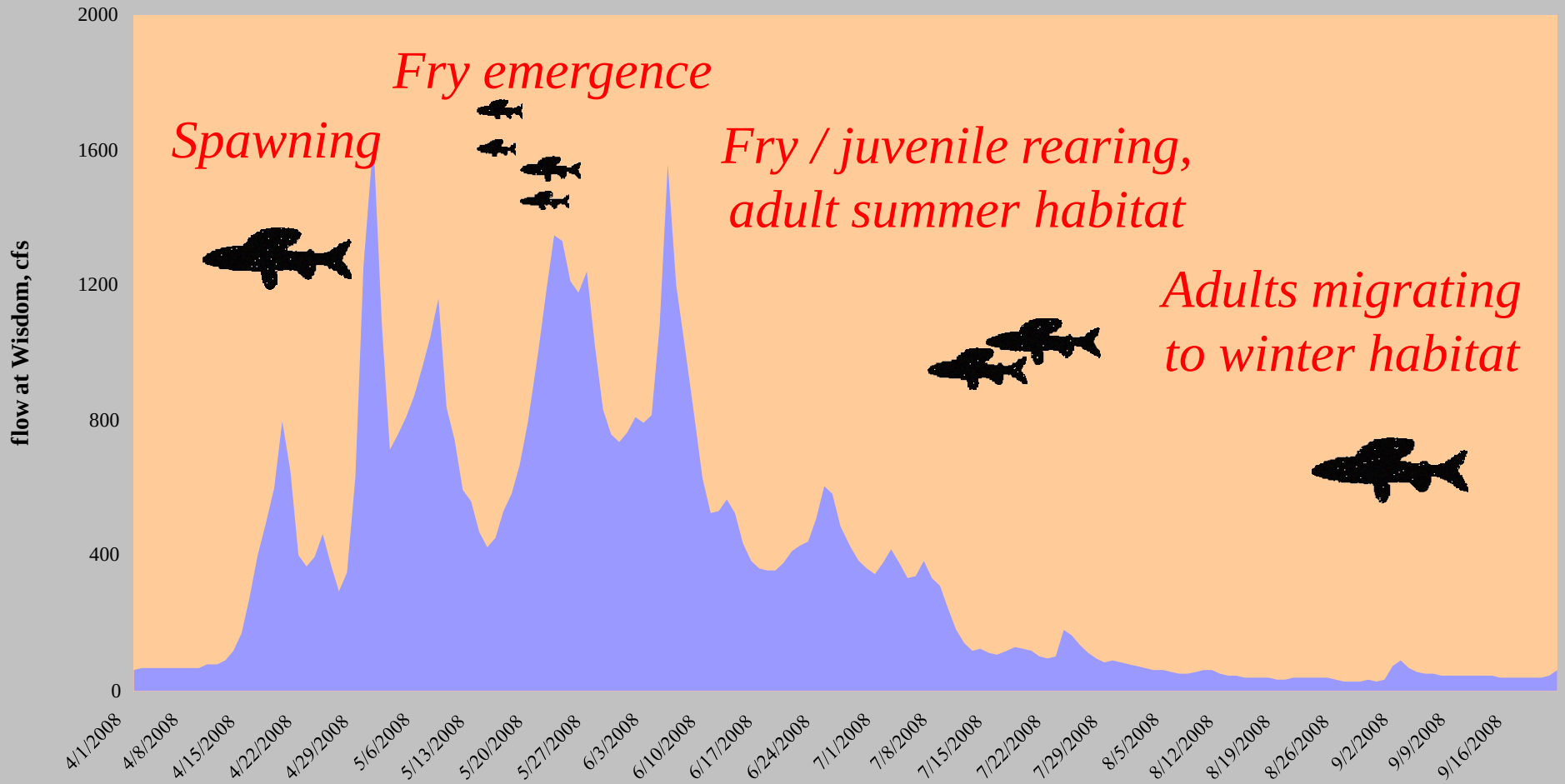


Not just “minimum” flows.

2008 USGS flow data is provisional

Flow requirements for endangered arctic grayling
Big Hole River at Wisdom, Montana (USA)



Source: Mike Roberts, Montana DNRC

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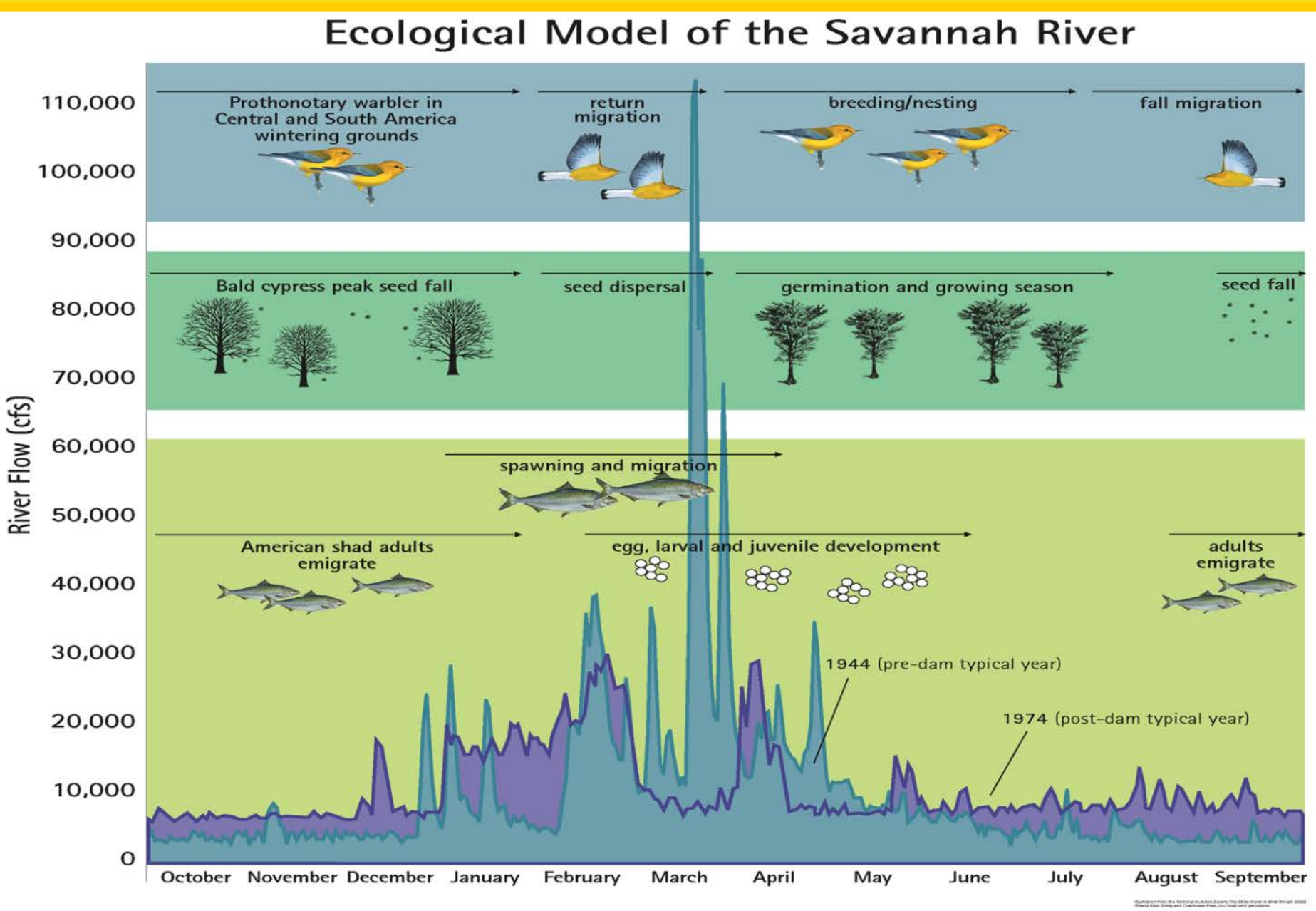
Not just fish.



Not just “instream” flows.

Savannah River, GA

Out-of-stream environmental flows in Australia

Murray-Darling, Australia: diversions from instream flows to floodplain to restore flood-dependent gum tree forests

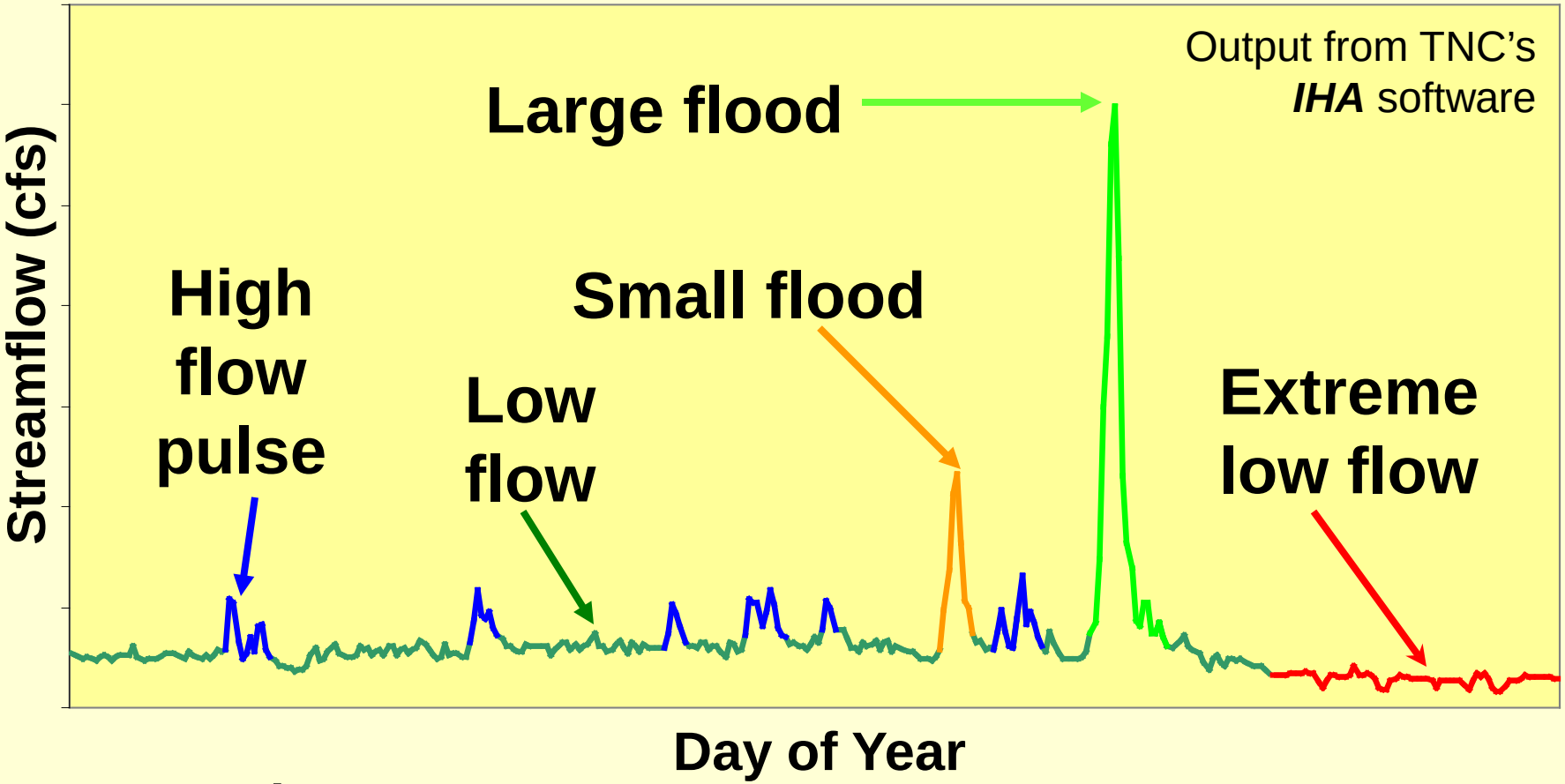
1992

2001

2006

Progressive deterioration of a red gum tree, Murray River, Australia

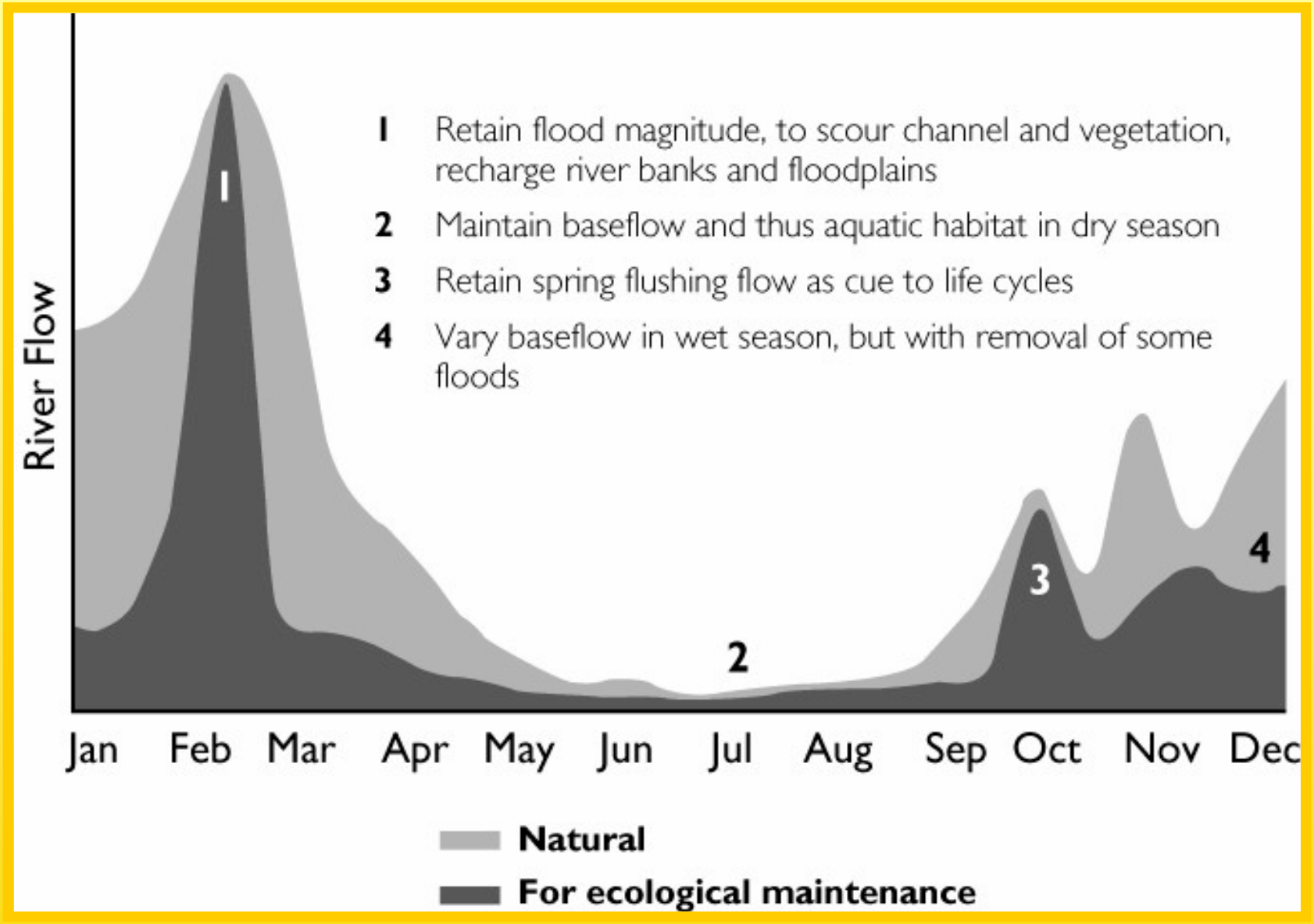
ENVIRONMENTAL FLOW COMPONENTS



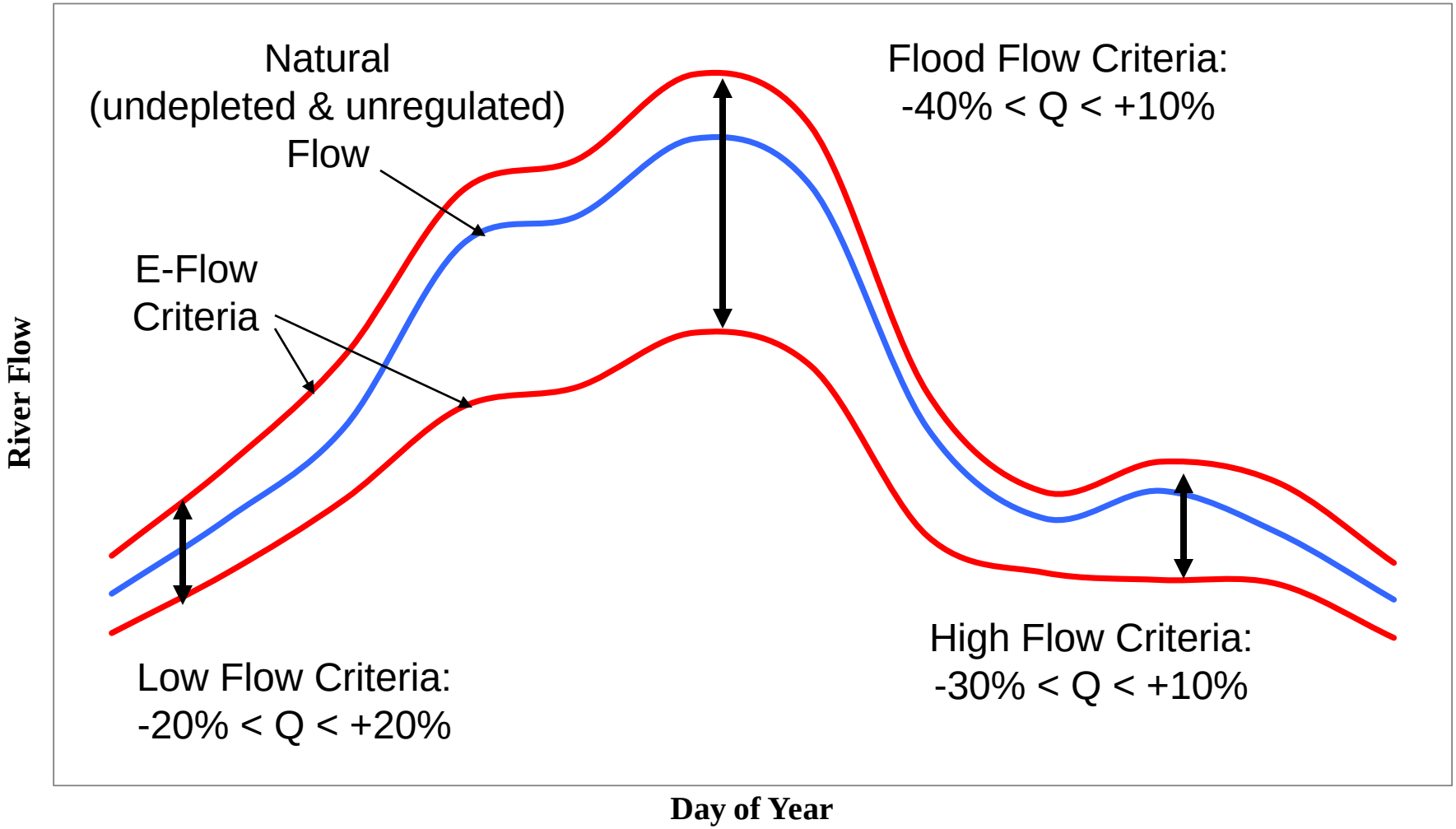
For each:

What are some ecological functions?

Environmental flow prescription



Postel and Richter, 2003



Sustainability boundaries

Richter, 2010

Implementing Environmental Flow Recommendations

(Discussion)

- Dams
- Withdrawals
- Land Use
- Climate Change

Scaling up: from dams to basins

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Mitigation at scale of a dam

Can potentially address:

- Seasonal patterns of flow and flow events
- Impacts from peaking operations

However, may be limited by operational constraints.

More difficult to address:

- Migratory fish and longitudinal connectivity
- Sediment
- Temperature and water quality
- Loss of free-flowing river

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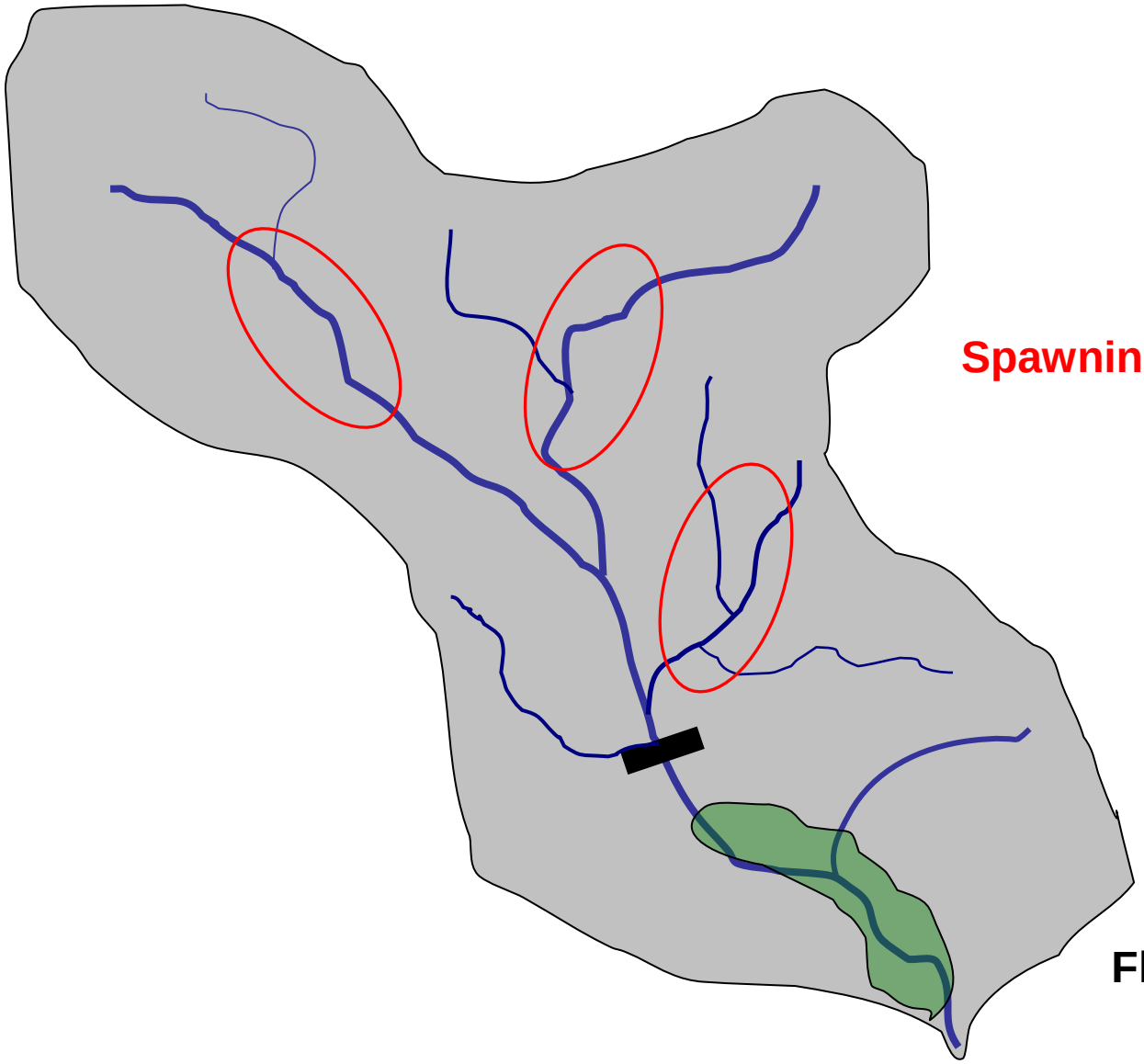
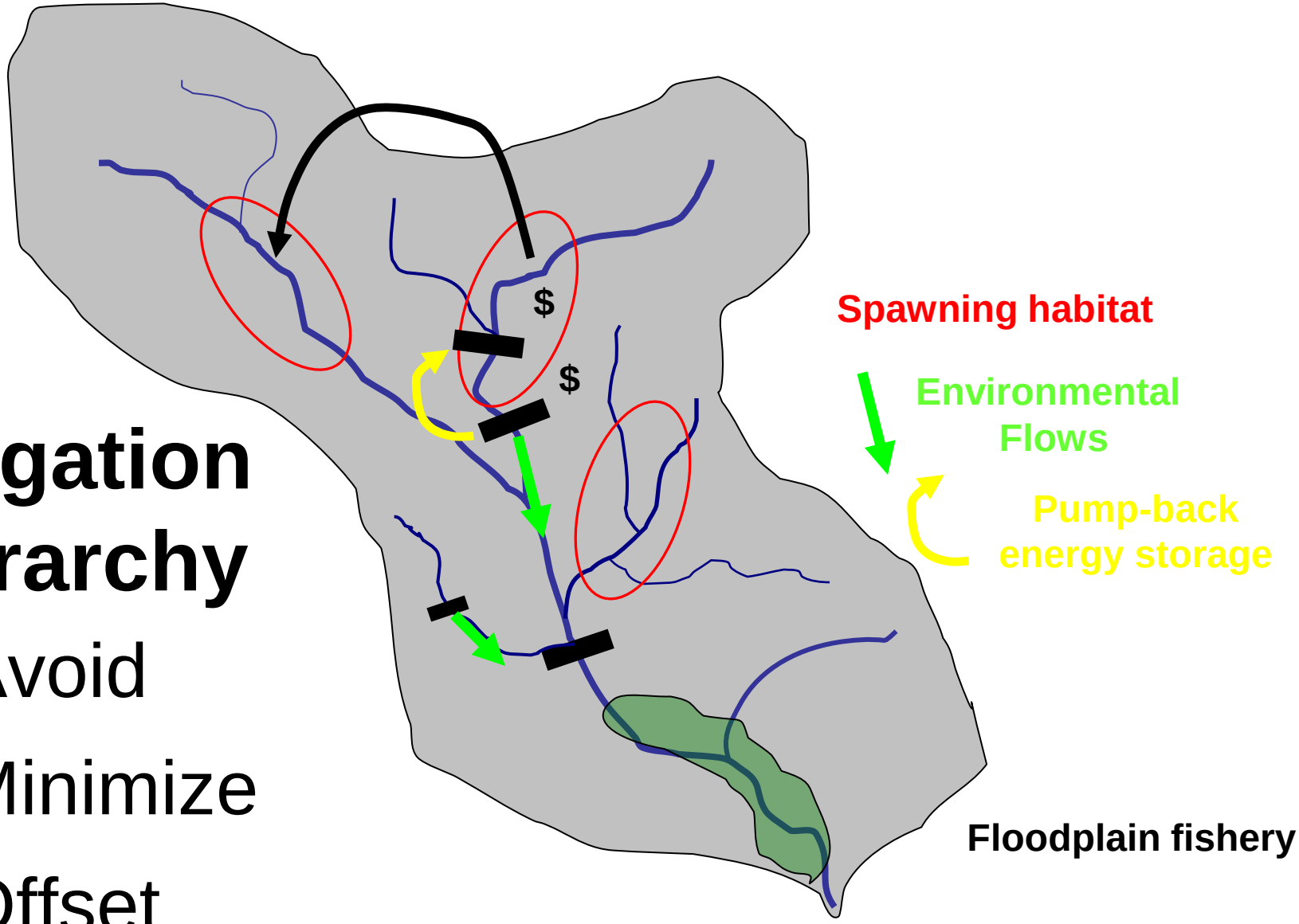
Limits to sustainability at scale of dam



System-scale design principles



Mitigation Hierarchy

1. Avoid
2. Minimize
3. Offset

Penobscot River Restoration

Energy

Medway Dam (expanded)

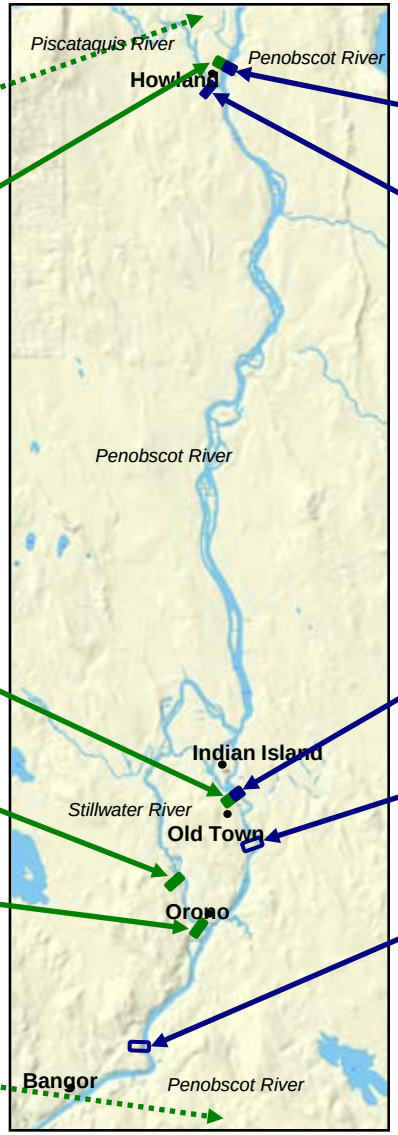
West Enfield Dam

Milford Dam

Stillwater Dam (expanded)

Orono Dam (added)

Ellsworth Dam (Union River)



Fisheries

West Enfield Dam
Existing Fish Passage

Howland Dam
Decommission / Innovative Fish Bypass

Milford Dam
New Upstream Fish Passage

Great Works Dam
Decommission / Removal

Veazie Dam
Decommission / Removal

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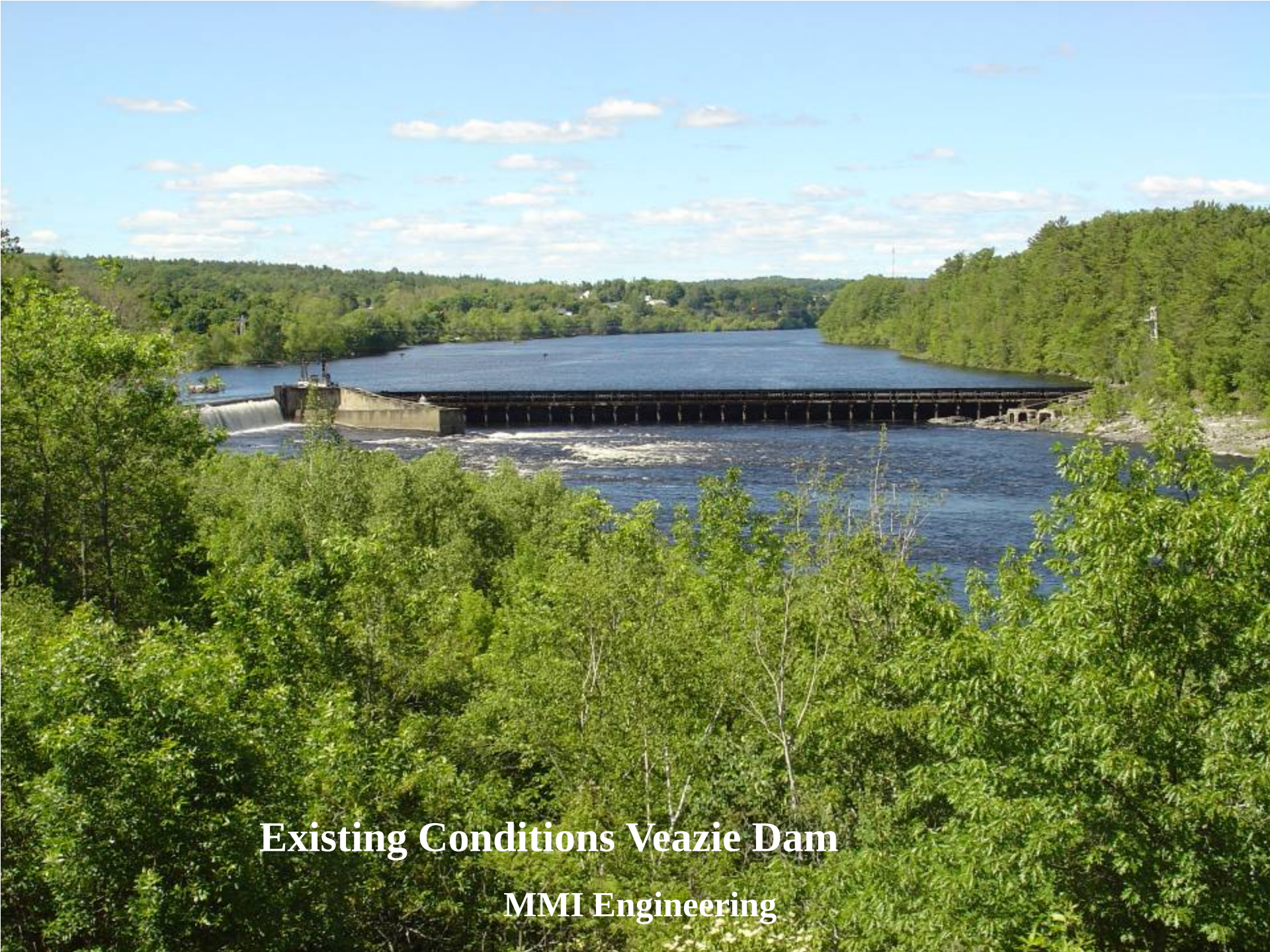


Existing Conditions Veazie Dam

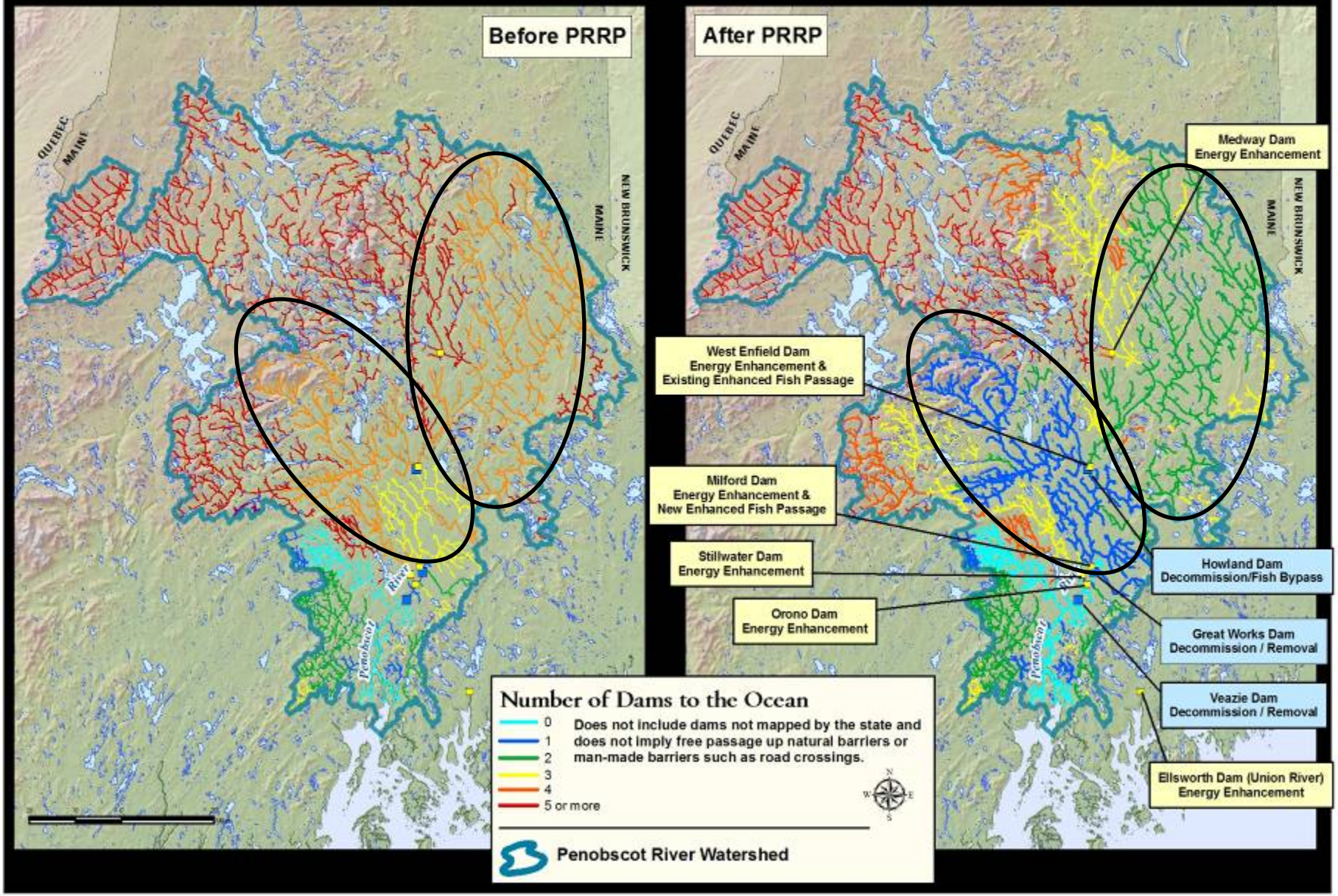
MMI Engineering

Projected Conditions Veazie Dam

MMI Engineering

Penobscot River and Tributaries

Number of Dams Downstream to get to or from the ocean after the PRRP is complete



Penobscot example: system planning

	Scenario A (the past)	Scenario B (the future)
Annual energy generation	~ 300,000 MWh	
Proportion of basin accessible to migratory fish	Minimal	
Annual shad run	Near zero	

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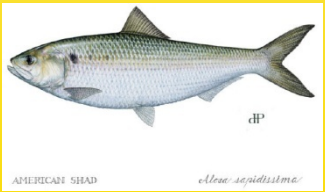
Penobscot example: system planning

	Scenario A (the past)	**Scenario B (the future)**
Annual energy generation	~ 300,000 MWh	~ 300,000 MWh
Proportion of basin accessible to migratory fish	Minimal	Majority of basin
Annual shad run	Near zero	1.5 million

If system planning had occurred in the Penobscot in 1880, which scenario would they have chosen?



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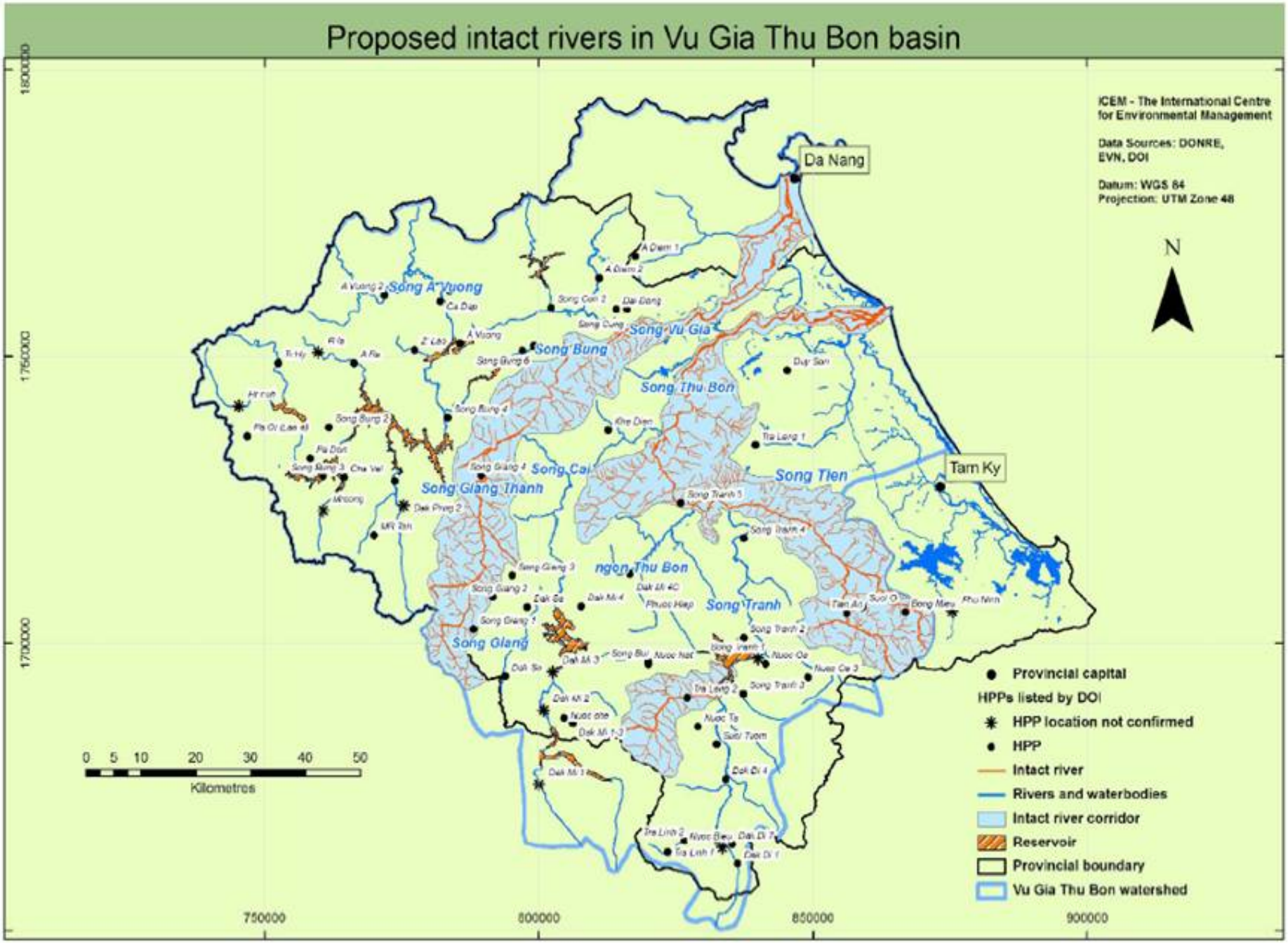
Proposed intact rivers in Vu Gia Thu Bon basin
ICEM - The International Centre for Environmental Management
Data Sources: DONRE, EVN, DOI
Datum: WGS 84
Projection: UTM Zone 48
N
Da Nang
Tam Ky
Song A Vuong
Song Vu Gia
Song Bung
Song Thu Bon
Song Cai
Song Giang Thanh
Song Tien
ngon Thu Bon
Song Tranh
Song Giang
0 5 10 20 30 40 50
Kilometres
750000
800000
850000
900000
Provincial capital
HPPs listed by DOI
HPP location not confirmed
HPP
Intact river
Rivers and waterbodies
Intact river corridor
Reservoir
Provincial boundary
Vu Gia Thu Bon watershed