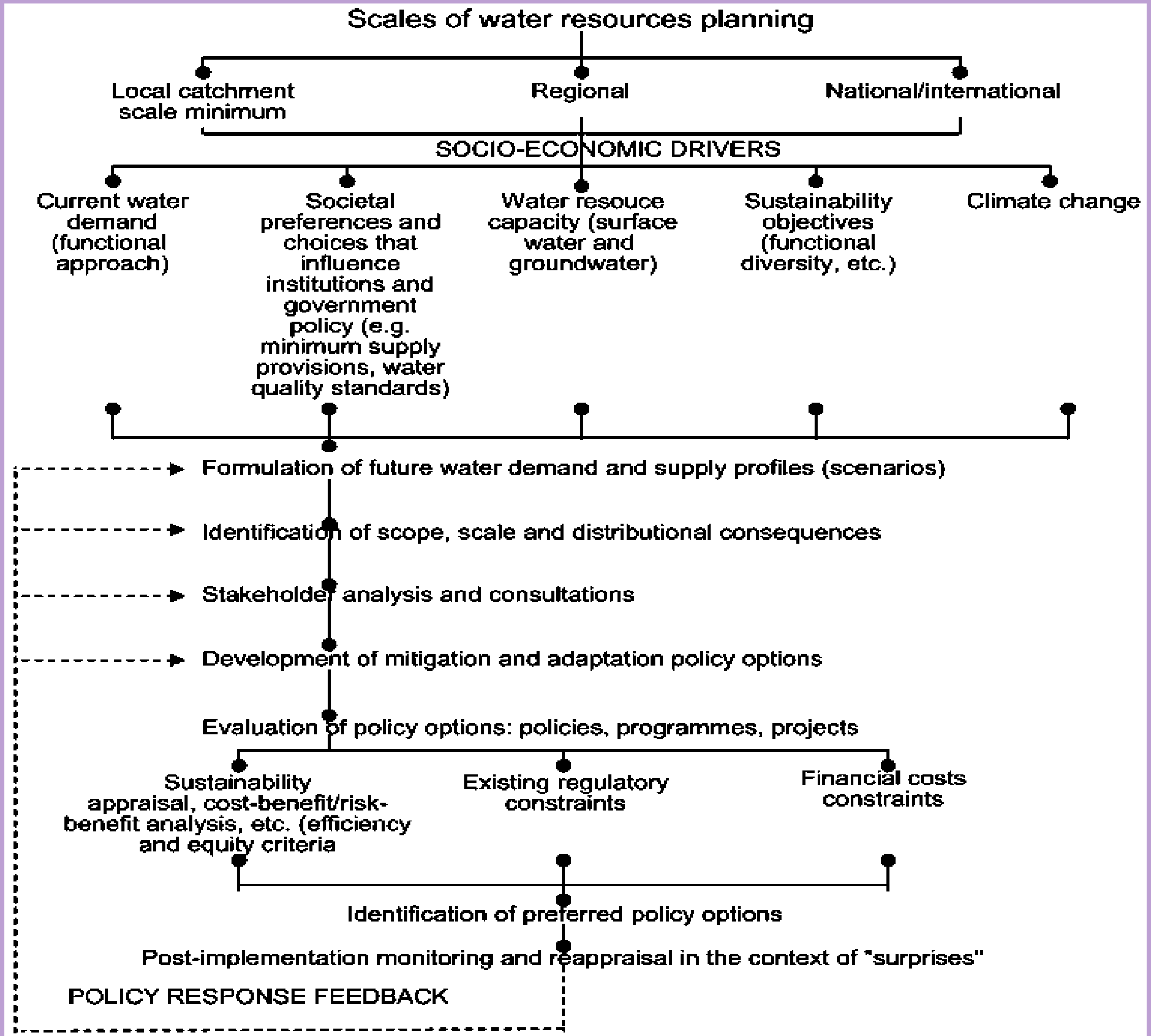
Lesson 7

River Health Assessment & e-flow


Scales of water resources planning
Local catchment scale minimum
Regional
National/international
SOCIO-ECONOMIC DRIVERS
Current water demand (functional approach)
Societal preferences and choices that influence institutions and government policy (e.g. minimum supply provisions, water quality standards)
Water resouce capacity (surface water and groundwater)
Sustainability objectives (functional diversity, etc.)
Climate change
Formulation of future water demand and supply profiles (scenarios)
Identification of scope, scale and distributional consequences
Stakeholder analysis and consultations
Development of mitigation and adaptation policy options
Evaluation of policy options: policies, programmes, projects
Sustainability appraisal, cost-benefit/risk-benefit analysis, etc. (efficiency and equity criteria
Existing regulatory constraints
Financial costs constraints
Identification of preferred policy options
Post-implementation monitoring and reappraisal in the context of "surprises"
POLICY RESPONSE FEEDBACK

Physical indicators of river system condition

Indicator	Components
Sediment sequence and composition	Rate of accumulation Sediment calibre Mineralogy Geochemistry
Soil and sediment erosion	Rate of erosion Source of sediment Mode of transport
Stream flow	Total annual flow Variability
Stream channel morphology	Slope Pattern Cross-sectional dimensions Stream sediment storage
Sediment flux and load	Mode of transport
Surface water quality	Turbidity Total suspended solids
Floodplains/wetlands	Wetting and drying *regimes*
Structure and hydrology	Connectivity with the river Area

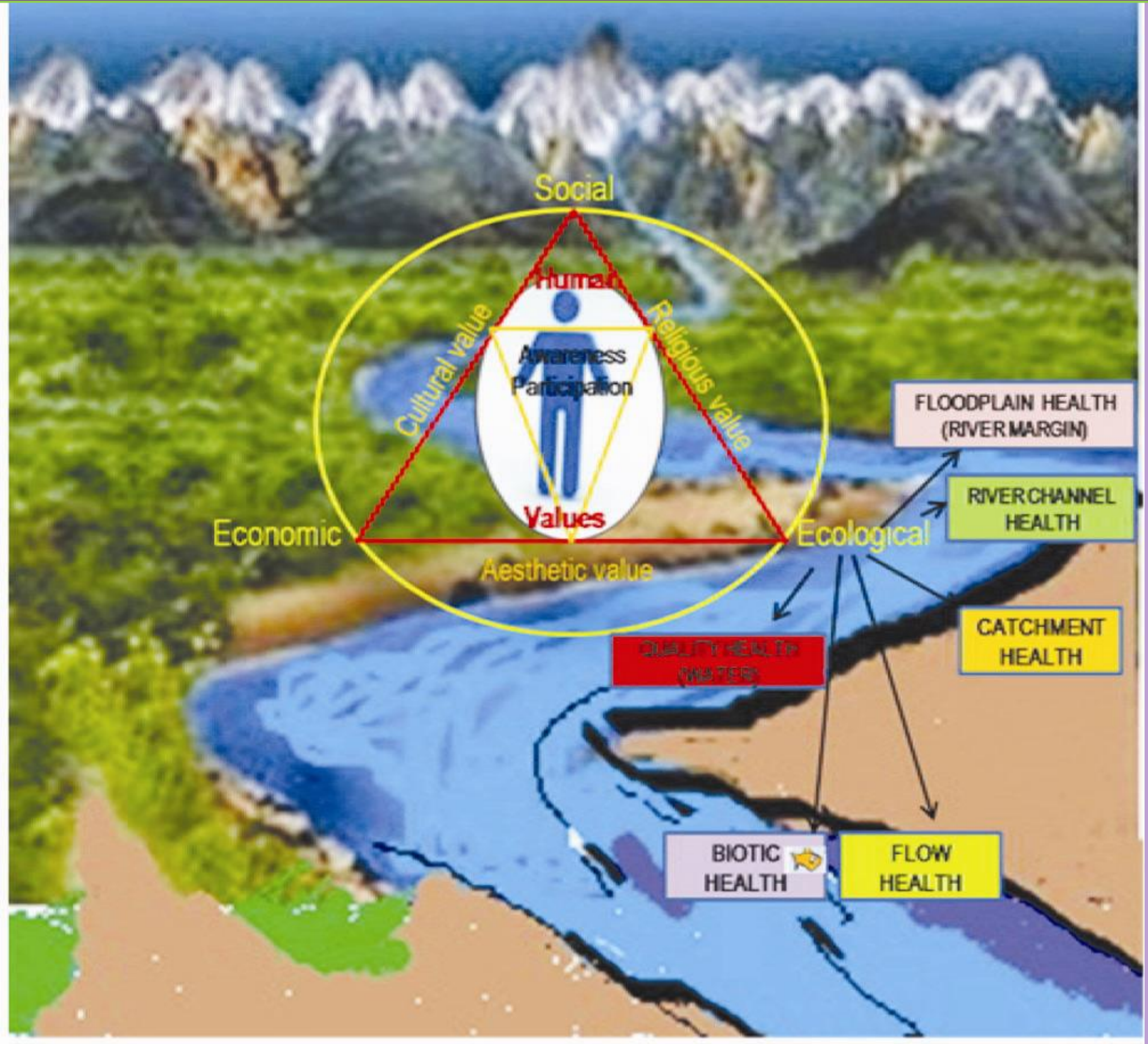
Appropriate indicators

- Ecological
- Water quality
- Hydrological
  - Flooding
  - Water shortage
  - Introduction of environmental flows
- Physical form
  - sediment
  - Channel sedimentation
  - Delta growth

- **River Delta Ramsar site**

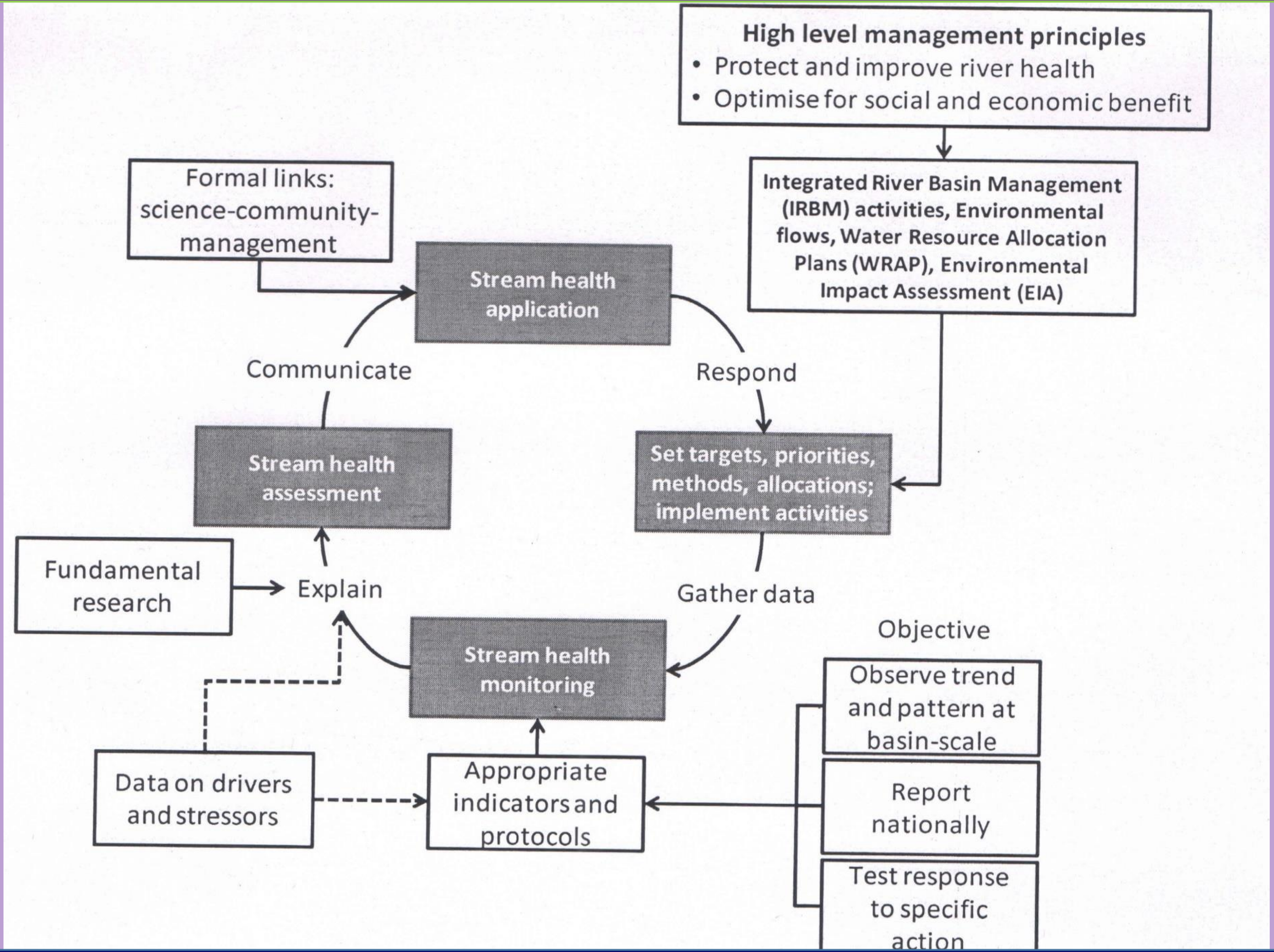
Hydrology into river health

- Need a simple measurement of hydrology that relates to ecology, and human disturbance
  - require a score for each year
- Hydrology can be directly controlled to improve/maintain health
  - Score should inform the appropriate response


Social
Human
Awareness
Participation
Cultural value
Religious value
Values
Economic
Ecological
Aesthetic value
FLOODPLAIN HEALTH (RIVER MARGIN)
RIVER CHANNEL HEALTH
CATCHMENT HEALTH
BIOTIC HEALTH
FLOW HEALTH

Potential impacts on water bodies

- Point source pollution - effluent discharges from sewage treatment works and industry;
- Diffuse source pollution - run-off from the land and acid rain;
- Water abstraction - removal of water for public supplies or manufacturing; and flow regulation, including the control of river flows for hydro-electric power, navigation, water supplies or other purposes;
- Physical or "morphological" alterations to water bodies, such as land claim for development, flood defence structures or channel modifications.


High level management principles
• Protect and improve river health
• Optimise for social and economic benefit
Integrated River Basin Management (IRBM) activities, Environmental flows, Water Resource Allocation Plans (WRAP), Environmental Impact Assessment (EIA)
Formal links: science-community-management
Stream health application
Communicate
Respond
Stream health assessment
Set targets, priorities, methods, allocations; implement activities
Fundamental research
Explain
Gather data
Objective
Stream health monitoring
Observe trend and pattern at basin-scale
Report nationally
Test response to specific action
Data on drivers and stressors
Appropriate indicators and protocols

River health assessment (RHA) is an evaluation tool for river management. It assesses the river health condition and offers scientific basis for monitoring and coordinating sustainable utilization of water function and sustainable development of economy.

Health of the river mainly refers to the river's water quantity, water quality, physical form and aquatic life.

It is the reflection of the river's contribution to human society and economy, and the significance of human maintaining river health in mind.

It is an important symbol of the river vitality, and ultimately affects the basin's sustainable development of society and economy.

River health monitoring programs can identify threats and the causes of poor health, help prioritise and guide management responses, and assess the effectiveness of those responses.

- Ecology: data on fish, macroinvertebrates and riparian plants were assessed against reach-specific reference values to provide a score on ecological condition. In addition, an index for riparian vegetation in the delta was developed, using satellite images to assess the composition of the vegetation in key wetlands and any loss of wetlands to agriculture.

- Water quality: based on the degree of achievement of a target grade.

- Physical form: based on channel capacity and the movement of sediment.

- Socio-economic factors: including indicators related to water supply, hydropower production, navigation, and flood risk

Hydrology

- **Index of Flow Deviation (IFD)** uses eight indicators to represent different aspects of flow regime that are of universal importance for river health. Monthly flow data was tested against a reference flow series to assess the extent of deviation from the natural range.
- **Index of Flow Health (IFH)** assesses the extent to which certain environmentally important flows are being achieved. This method requires that an environmental flow assessment first be undertaken

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Floodplains/wetlands structure and hydrology	Wetting and drying regimes Connectivity with the river Area

River health assessment indicators:

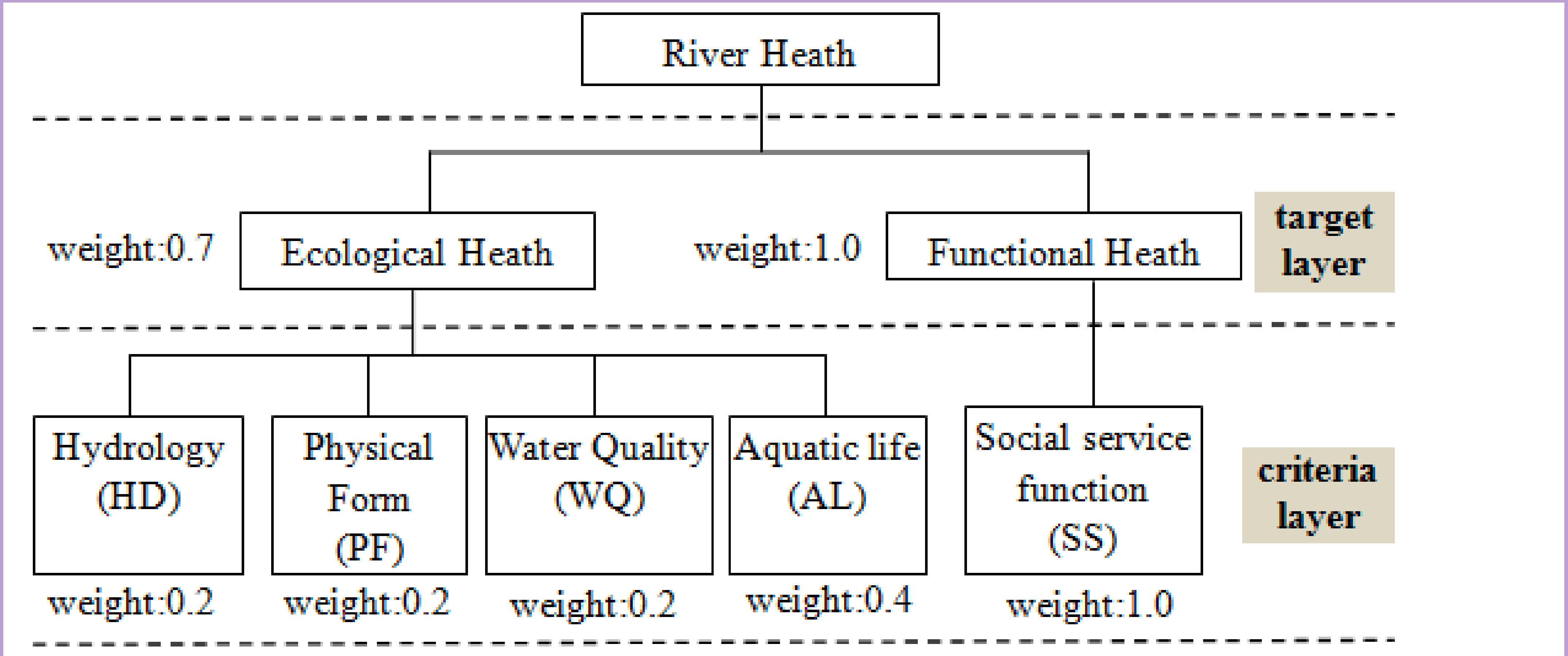
(1) the changing reasons of indicator can be basically identified;
(2) the indicator can be long-term monitored and assessed;
(3) the indicator can reflect the dual natural-artificial characteristics;
(4) the assessment results can provide a basis for horizontal comparison so that results of similar rivers in different regions can be compared.

Target layer reflects the holistic river health condition and includes the ecological health and functional health. It is calculated gradually from criteria layer and indicator layer.

Criteria layer assesses the health of the river from hydrology, physical form, water quality, aquatic life and social service function.

Ecological health consists of criteria layers on hydrology, physical form, water quality and aquatic life. Functional health is constituted by social service function.

Indicator layer uses quantitative or semi-quantitative indicators selected from every criteria layer to reflect the river health condition directly. It is unscientific and irrational to maintain the original state of the river realistically.


River Heath
weight:0.7
Ecological Heath
weight:1.0
Functional Heath
target layer
Hydrology (HD)
Physical Form (PF)
Water Quality (WQ)
Aquatic life (AL)
Social service function (SS)
criteria layer
weight:0.2
weight:0.2
weight:0.2
weight:0.4
weight:1.0

	Target	Criteria	Indicator	note
River health assessment system	Ecological health (0.65)	Hydrology (HD) 0.25	Flow process variability (0.30)	Indicates difference between actual and natural monthly runoff process
			Ecological flow satisfaction degree (0.45)	Flow process for maintaining ecosystem structure and function in different degree
			Groundwater exploitation co-efficient (0.25)	Ratio of actual exploitation to allowable exploitation of groundwater in certain region
		Physical form (PF) 0.25	Riparian condition (0.20)	Slope stability, riparian vegetation coverage and artificial disturbance
			River connectivity condition (0.15)	Whether construction of sluices and dams obstructs runoff and fish
			Retention rate of natural wetland(0.15)	Superiority of river eco-environment
			Flow capacity of main channel (0.25)	Cross sectional morphology, size and sidewall roughness of main channel
			Elevation difference between beach and channel (0.25)	Difference of average elevations between beach and channel
		Water quality (WQ) 0.25	Dissolved oxygen (DO)	Concentration of dissolved oxygen in water
			Oxygen consumption organics	Oxygen consumption indicators C)D, COD, BOD, NH4, N
		Aquatic life (AL) 0.25	Benthic index of biotic integrity (B-1B1)	Parameters –species number, richness, diversity indicator, resistance to fouling and resilience
			Fish loss exponent (FLE)	Ratio of fish species number surveyed in ten years period
	Functional health (0.35)	Social service function (SS) 1.00	Development and utilisation water resources (0.15)	Ratio of utilization to total volume of water resources in river
			Standard reaching rate of water function zones (0.15)	Scoring based on ratio of standard reaching number to total number of water function zone
			Flood control indicator (0,30)	Integrity of engineering measures and non-engineering measures in flood control
			Public satisfaction (0.20)	Public satisfaction on river landscape, aesthetic value and so on
			Safe condition of drinking water source (0,20)	Evaluating it from water quantity, quality, pollution sources in water source conservation zones

Indicator layer is constituted by **12 obligatory indicators and optional indicators** of the basin which are scored according to pre-set scoring standard.

Different rivers are different in natural conditions such as geographical location and climatic regime, even conditions such as climate, topography, biological systems and dominant ecological functions of different reaches of the same river are different greatly be-cause of different natural zones.

Socio-economic development and water resources utilization degree of different regions in our country are also quite different, so the characterizations of river health are different and using uniform weights can’t distinguish functional focuses of different partitions

River Health Index

Obligatory indicators are scored using calculation method and scoring standard in the document and optional indexes are calculated according to its characteristics and actual situation. River health assessment scores indicators in each layer and uses weighted sum to calculate health index comprehensively.

Indicator Assessment of Hydrology

Flow Process Variability Degree - According to the formula of flow process variability degree in the document (calculating with this formula hereinafter unless noted otherwise

Ecological Flow Satisfaction Degree is the minimum percentages of measured average daily flows from April to September and from October to March for average daily flow of many years, at rain gauge Station in 2010 is calculated with the recommended formula.

Groundwater Exploitation Coefficient is the ratio of actual exploitation to allowable exploitation of groundwater in certain region

Indicator Assessment of Physical Form

Riparian Condition is evaluated from the slope stability, riparian vegetation coverage and artificial disturbance. Artificial disturbance reflects the influence of 10 kinds of human activities in riparian and land area nearby, including riverbank hardening lining, sand excavation, buildings, roads, waste landfill sites, riverside park, pipelines, mining, agriculture farming and livestock breeding.

River Connectivity Condition reflects whether construction of sluices and dams obstructs runoff and fish.

Retention Rate of Natural Wetlands - The mainstream of the lower Yellow River wanders frequently. Floodplain develops well, and there are a large number of wetlands on both sides.

Flow Capacity of Main Channel - The flood and sediment discharge capacity of main channel is related mainly to channel width, depth, cross section area, slope and so on. Bank full discharge is the flow capacity of main channel when beach face is awash. It reflects cross section morphology, size and sidewall roughness comprehensively.

Elevation Difference Between Beach and Channel - The relationship between beach and channel of down-stream riverbed in the 1950s, based on historical data. Therefore, score of measured elevation difference between beach and channel in Gaocun reach is 70 according to scoring standard.

Indicator Assessment of Water Quality

Dissolved Oxygen (DO) is important to aquatic plants and animals, and too much or too little DO will harm aquatic life both. The average scores of DO in flood season and non-flood season are calculated respectively, and the minimum value between them is the final score of DO.

Oxygen-Consumption Organics include permanganate index (CODMn), chemical oxygen demand (CODCr), five-day biochemical oxygen demand (BOD5), ammonia-nitrogen (NH4+-N) and so on.

Indicator Assessment of Aquatic Life

Benthic Index of Biotic Integrity (B-IBI) B-IBI is evaluated according to recommended assessment standard. 95% quantile of reference point is 27.

Fish Loss Exponent (FLE) is compared with historical data, fish species i fish species number in the downstream surveyed in 1981

Indicator Assessment of Social Service Function

Scores of indicators such as standard-reaching rate of water function zones, development and utilization rate of water resources, flood control indicator, safe condition of drinking water source and public satisfaction

River health assessment

Data gathering programs already exist

Key drivers

- •Hydrology
- •Water quality
- •Physical form
- •Riparian vegetation

Key responses

- •Biological
  - Fish
  - Macroinvertebrates
  - Algae
- •Social
  - Production of goods
  - Recreation
  - Drinking water
  - etc.

Indicators help inform managers how to act

Indicators reflect management performance

All indicator groups are useful

国际水资源中心 | 中澳生态与环境发展伙伴 中国河流健康与生态流量

INTERNATIONAL WATERCENTRE | ACEDP: River Health and Environmental Flows in China

Thematic components as indicators of river health

Catchment health (CH): It is assessed through factors like land use change and physical characteristics of the catchment for planning and controlling the water quality and connectivity. Helps to evaluate the impact of human activities that can disturb the catchment area of the river.

Flood plain health (FPH): assessment of the impact of vegetation on the floodplains, the characteristics of the river bank and its stability or its susceptibility to erosion, other factors like the shape or the slope of the bank, its width and height, average run-off of the river, the impact of activities such as the use of chemicals and pesticides, mining, etc. It provides information about the changes and the impacts due to flood dynamics.

River channel health (RCH): regarding the ecology and the biotic condition of the river on the length and breadth of river channel, longitudinal connectivity and impact of dams and weirs, condition of plants and animals in the river.

Flow health (FH): information on the kind, frequency, magnitude and duration of the river flow and impact of water extraction structures such as tube wells and water pumps and barriers on the natural flow of the river.

River water quality health (QH): measured by assessing the water quality index of the river water.
Biotic health (BH): Includes aquatic organisms present in rivers that are affected by the changing condition of the river, the population of the flora and fauna, their habitats, linkages between the river and its catchment, the dynamics of water flow and the transport and transformation of nutrients.

River Health Assessment model need to:

- Have a good balance of social, economic and ecological factors.
- Include human values that are key to controlling anthropogenic activities, which when altered, can disturb the balance between the above factors.
- Consider cultural, aesthetic and religious values as important indicators that need to be measured.
- Presume that a balance between these three major human values can maintain socioeconomic and ecological health of the river.
- Emphasise participatory river management involving all stakeholders for establishing river health without compromising their livelihoods, social wellbeing, culture, tradition and environment.
- Encourage stakeholders’ participation in judicious use of water resources (agriculture, drinking, recreation, transport, industries), limited use of aquatic biodiversity (fishes, turtles, dolphins and others)
- Create awareness on river health through capacity building initiatives

Basic principles and benefits of using E-flows approach

- Although the concept of environmental flows has been in existence for a considerable time, the understanding and adoption of E-flows as critical public Policy by water managers is only very recent
- It requires establishing water flow regimes which recognize ecosystem needs to maintain the health of the river, while satisfying social and economic demands such as livelihoods
- It can be an important tool to assist diverse stakeholders in the process of negotiation and better understanding of water resources
- Negotiating E-flows is an essential part of river basin management
- The best E-flows solution for environmental health of the river is when the flow releases mimic natural flow conditions
- E-flows are not just about water but also need to include physical, biological and socioeconomic considerations
- There is definitely an economic cost for not addressing E-flows

Water resource developments such as impoundments, diversion weirs, inter basin water transfers, run-of-river abstraction and exploitation of aquifers for the primary uses of irrigated agriculture, hydropower generation, industry and domestic supply, are responsible worldwide for unprecedented impacts to riverine ecosystems, most of which emanate from alterations to the natural hydrological regime

Environmental Flow assessment
(EFA) for a river may be defined simply as an assessment of how much of the original flow regime of a river should

Environmental flow requirement (EFR)

- different flow regimes that would maintain a river ecosystem at various levels of health (condition)
- ways those different levels of river health will affect people.

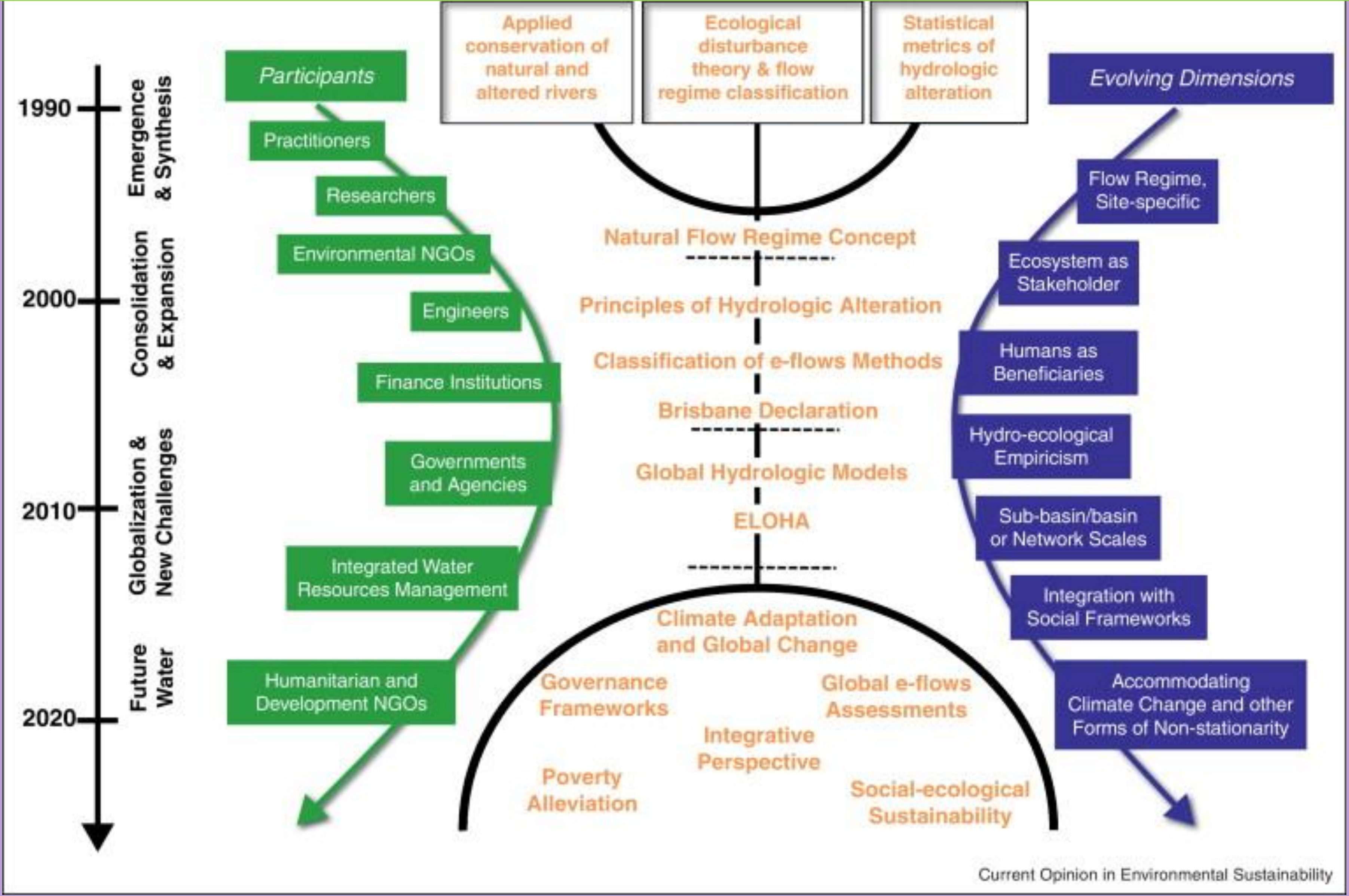
A flow assessment produces one or more descriptions of possible future flow regimes for a river, each linked to an objective which this achieves in terms of the condition or health of the riverine ecosystem.

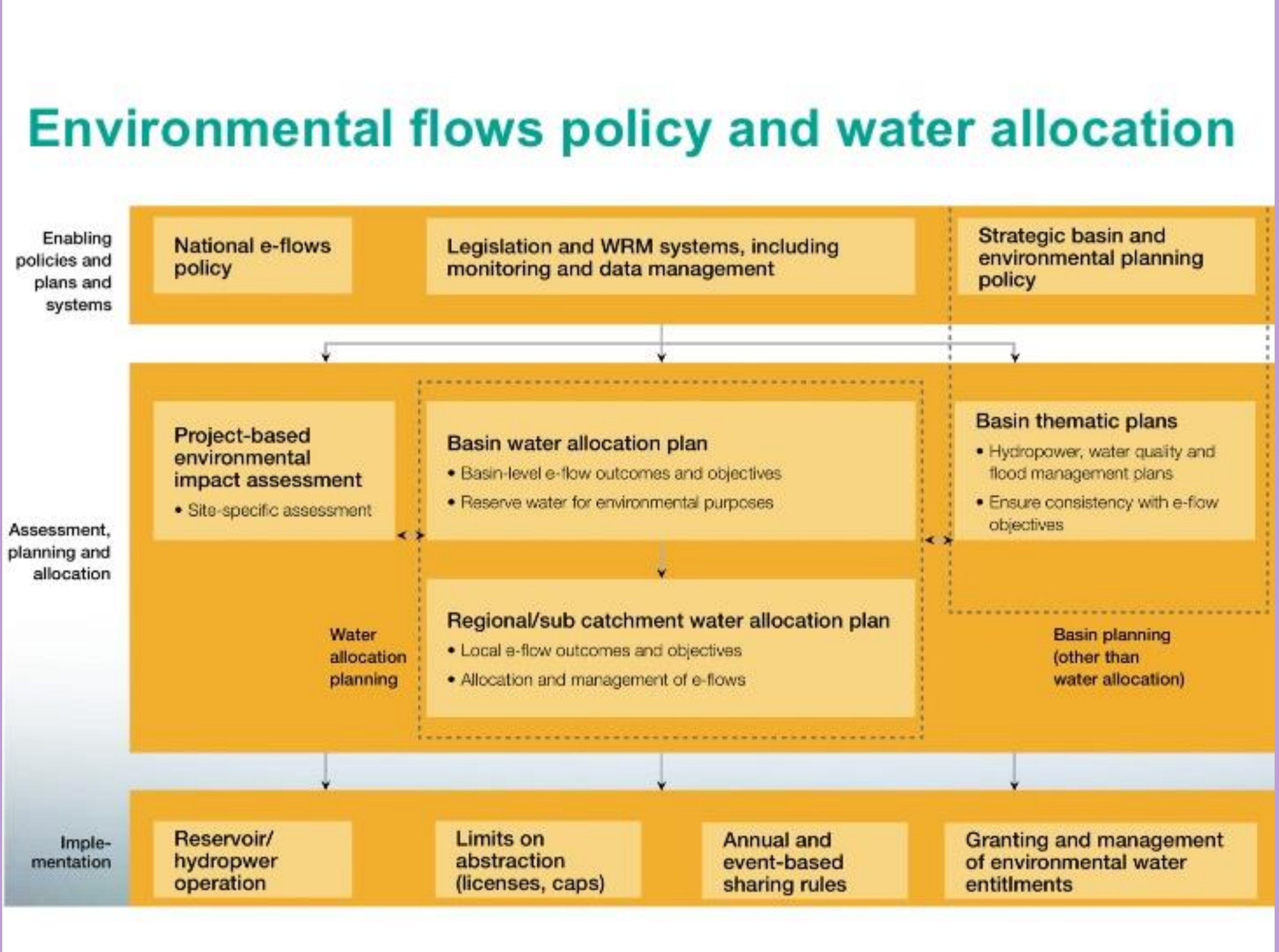
EFRs are widely recognised:

- Hydrological index methodologies;
- Hydraulic rating methodologies;
- Habitat simulation methodologies;
- Holistic methodologies.

River basin management is a mechanism not only for sediment control but also for cost-efficient and effective water management mechanism, if it is carried out in an integrated manner. Under the river basin management schemes, dam options can be compared with other options.

GNR 624 : Water Resources and River basin management




Environmental flows policy and water allocation
Enabling policies and plans and systems
National e-flows policy
Legislation and WRM systems, including monitoring and data management
Strategic basin and environmental planning policy
Assessment, planning and allocation
Project-based environmental impact assessment
• Site-specific assessment
Basin water allocation plan
• Basin-level e-flow outcomes and objectives
• Reserve water for environmental purposes
Basin thematic plans
• Hydropower, water quality and flood management plans
• Ensure consistency with e-flow objectives
Regional/sub catchment water allocation plan
• Local e-flow outcomes and objectives
• Allocation and management of e-flows
Water allocation planning
Basin planning (other than water allocation)
Imple-mentation
Reservoir/ hydropower operation
Limits on abstraction (licenses, caps)
Annual and event-based sharing rules
Granting and management of environmental water entitlments

Environmental flow compliance

1.Undertake an assessment of e-flow needs:

–Describe as flow components (frequency, duration, magnitude)

2.For each test year determine if the flow components occurred

3.Score the hydrology according to degree of compliance

Main steps in e-flow assessment

1.Define the ecological assets

2.Agree on the desired condition of the assets

3.Set ecological objectives (targets)

4.Scientific work to determine the flows needed to meet the objectives

5.Determine the impacts on other users

6.Undergo trade-off and negotiation

What do environmental flows protect? •"components, functions, processes, and resilience of aquatic ecosystems." (The Brisbane Declaration, 2007) Ecological assets

Using the results...

1.Prioritize pollution control/river management

2.Assess temporal trends in environmental condition

3.Raise awareness of ecosystem health and ecosystem values (goods and services)

Health and integrity of river systems ultimately depend on

- **Extreme low flows** occur during drought. During a period of natural extreme low flows, native species are likely to out-compete exotic species that have not adapted to these very low flows. Maintaining extreme low flows at their natural level can increase the abundance and survival rate of native species.

- **Low flows** maintain adequate habitat, temperature, dissolved oxygen, and chemistry for aquatic organisms; drinking water for terrestrial animals; and soil moisture for plants. Stable low flows support feeding and spawning activities of fish, offering both recreational and ecological benefits.

- **High flow pulses** occur after periods of precipitation and are contained within the natural banks of the river. High flows generally lead to decreased water temperature and increased dissolved oxygen. These events also prevent vegetation from invading river channels and can wash out plants, delivering large amounts of sediment and organic matter downstream in the process.

- **Small floods** occur every two to ten years. Small floods also aid the reproduction process of native riparian plants and can decrease the density of non-native species. Increases in native waterfowl, livestock grazing, rice cultivation, and fishery production have also been linked to small floods.

- **Large floods** take place infrequently. They can change the path of the river, form new habitat, and move large amounts of sediment and plant matter. Large floods also disperse plant seeds and provide seedlings with prolonged access to soil moisture. Importantly, large floods inundate connected floodplains, providing safe, warm, nutrient-rich nursery areas for juvenile fish.

Flow components, quantified in terms of its:

Magnitude: the volumetric flow rate or level; 100 cubic meters per second
Timing: the time of year during which a flow event occurs; for example, August
Duration: how long an event lasts; for example, 3 weeks
Frequency: how often the event occurs; for example, every 2–3 years
Rate of change: rate at which flows or levels increase or decrease in magnitude over time; (0.2 meter-per-day flood recession rate).

comprehensive approaches of e-flow include DRIFT (Downstream Response to Imposed Flow Transformation), BBM (Building Block Methodology), and the "Savannah Process" for site-specific environmental flow assessment, and ELOHA (Ecological Limits of Hydrologic Alteration) for regional-scale water resource planning and management.

Thank you