中国水利水电科学研究院
China Institute of Water Resources and Hydropower Research

Towards a roadmap for River Restoration

——Introduction to research on the WB Program undertaken by ARRN

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2022.12

Contents

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1 Introduction

- Rivers are the arteries of the terrestrial ecosystem.
- River ecosystems face enormous challenges and issues.
- Approximately 30 percent of the global freshwater species are considered at risk of extinction – due to human development and anthropogenic impacts(IUCN).

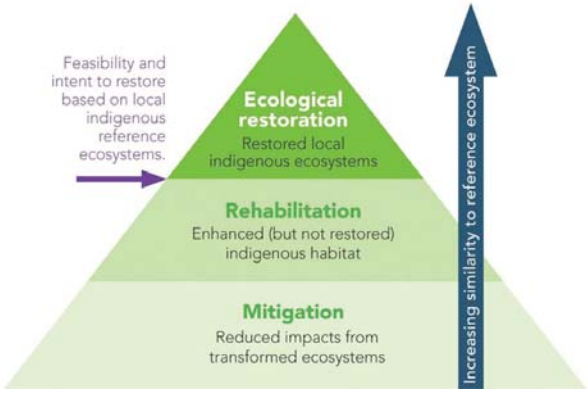
Pollution & eutrophication

Flow Cutoff

Species extinction

1 Introduction

River restoration: an ecological protection action that takes engineering and non engineering measures to restore the river ecosystem to a more natural state and improve its ecological integrity and sustainability on the basis of giving full play to the self restoration function of the ecosystem.

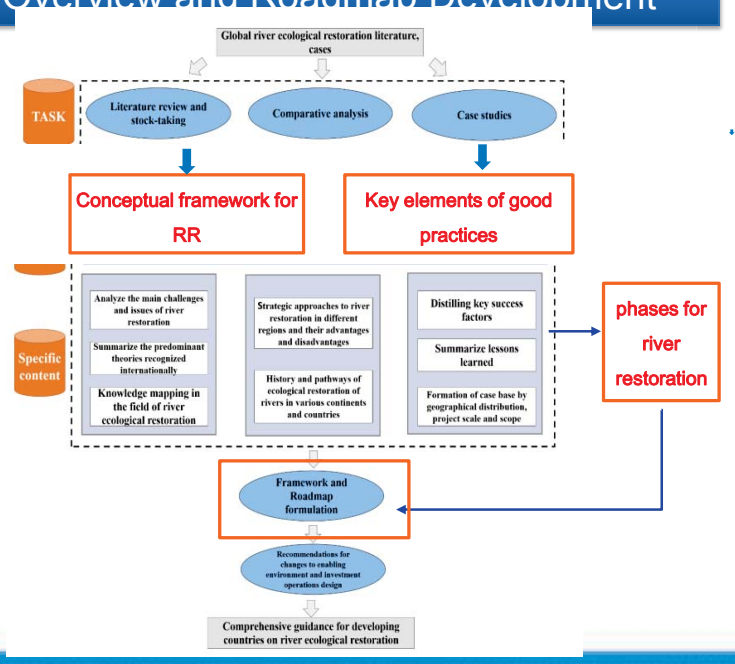


1 Introduction

River Restoration(RR) State-of-the-Art Overview and Roadmap Development

Objective

- Analyze and study the predominant theories and practices of river restoration in different countries and regions , and **formulate a river restoration roadmap applicable to developing countries**.
- With this roadmap, the World Bank task teams and clients can approach and design solutions a series of challenges.
- The World Bank can also use river restoration as instrument for evaluating the investment in regional transformationand high-quality development



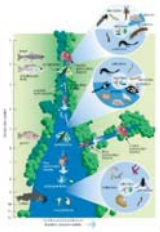
2 Conceptual framework for river restoration

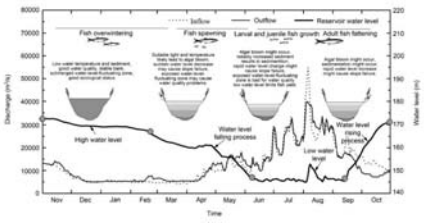
- **Predominant theories of river restoration**
- **River restoration policies, standards and practices around the world**
- **Strengths and weaknesses of different strategic approaches**
- **Conceptual framework for phased strategic approaches**

Predominant theories of river restoration

Paradigms and models

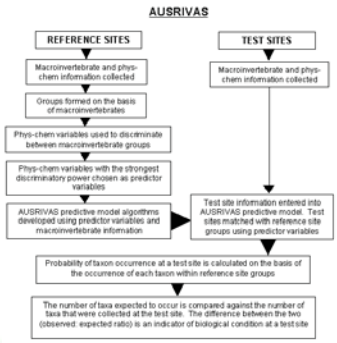
- River continuum concept
- Flood Pulse Concept
- Zonation concept
- Spiralling resource concept
- Serial discontinuity concept

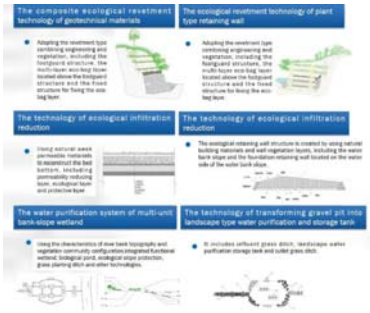




Concepts and theories

- River health assessment （RIVPACS , AUSRIVAS）
- Ecohydrology
- Eco-hydraulic engineering

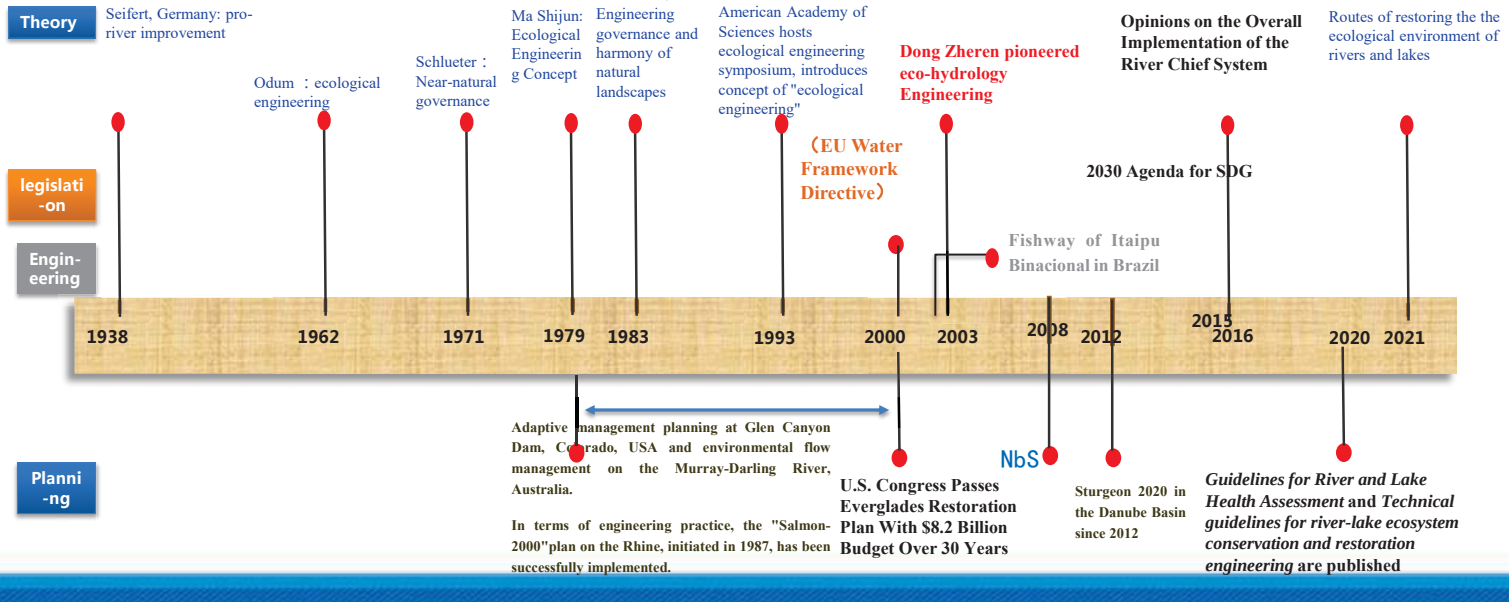




River restoration policies, standards and practices around the world

In 1962, Odum, famous ecologist, proposed the application of self-organizing behavior of ecosystems to engineering. He presented the term "ecological engineering" to promote the integration of ecology and engineering.

Ecological engineering：Design approaches that integrate human society with the natural environments to achieve the mutually beneficial and sustainable ecosystems



River restoration policies, standards and practices around the world

NbS

IUCN WCC Resolution 6.069

Definition of Nature-based Solutions
Nature-based solutions are actions to protect, sustainably manage and restore natural and modified ecosystems in ways that address societal challenges effectively and adaptively, to provide both human well-being and biodiversity benefits.

Principles	
Principle 1	NbS embrace nature conservation norms and principles.
Principle 2	NbS can be implemented alone or in an integrated manner with other solutions to societal challenges.
Principle 3	NbS are determined by site-specific natural and cultural contexts (incl. traditional, local and scientific knowledge).
Principle 4	NbS produce societal benefits in a fair and equitable way in a manner that promotes transparency and broad participation.
Principle 5	NbS maintain biological and cultural diversity and the ability of ecosystems to evolve over time.
Principle 6	NbS are applied at a landscape scale.
Principle 7	NbS recognize and address the trade-offs between the production of a few immediate economic benefits for development, and future options for the production of the full range of ecosystem services.
Principle 8	NbS are an integral part of the overall design of policies, and measures or actions, to address a specific challenge.

Global Standard fo

1. Societal challe
2. Design at scale
3. Biodiversity net-gain
4. Economic feasibility
5. Inclusive governance
6. Balance trade-offs
7. Adaptive management
8. Mainstreaming & Sustainability

River restoration policies, standards and practices around the world

The Sustainable Development Goals (SDGs), also known as the Global Goals, were adopted by the United Nations in 2015.

River restoration policies, standards and practices around the world

Related technical standards in developed countries

Table 1 Technical Standards on River Restoration in U.S.

Year	Technical Standards
1980	Habitant Evaluation Procedure（1980）
1985	Guidelines for deriving numerical national water quality criteria for the protection of aquatic organisms and their uses
1998	Stream Corridor Restoration: Principles, Processes, and Practices
1999	Rapid Bioassessment Protocol
2000	Nutrient criteria technical guidance manual lake and reservoirs: Nutrient criteria technical guidance manual rivers
2000	Guildelines for Landscape Planting and Vegetation Management at Floodwalls, Levees, and Embankment Dams
2008	Handbook for Developing Walershed Plans to Restore and Protect Our Waters
2010	habitat suitability inde
2017	2017 National Lakes Assessment Guide
2018	2018/2019 National Rivers and Streams Assessment Guide

Table 2 Technical Standards on River Restoration in U.K.

Year	Technical Standards
1984	River Invertebrate Prediction and Classification System
1992	River Habitat Survey
1998	SERCON
1998	National Biodiversity Policy
2001	Urban River Survey
2002	Traffic Guide
2005	Manual of river restoration techniques
2011	Practical river restoration assessment Guidance for monitoring options
2013	National Recovery Guide: Environmental Issues
2016	Citizen Science and Volunteer Monitoring
2019	Rivers: a natural and unnatural history

Table 3 Technical Standards on River Restoration in Australia

Year	Technical Standards
1993	State of the Rivers Survey (SRS)
1994	Australian River Evaluation System（AUSRIVAS）
1994	Geomorphic River Styles（GRS）
1999	Environmental flow guidelines
1999	Index Stream Condition
2000	River Ecological Restoration Handbook
2001	Guidance on the properties, protection, restoration and long-term management of Western Australian rivers
2004	Water Resources Sustainability Management Policy
2008	Characterization, measurement and significance of spatial hydrodiversity of plains rivers for fish
2010	Impacts of River Regulation, Drought and Exploitation on the Fish in a Degraded
2011	Draft Environmental Flow Guidelines
2016	National Standards for the Practice of Ecological Restoration in Australia
2019	National Standards for the Practice of Ecological Restoration in Australia（Second Edition）

Table 4 Technical Standards on River Restoration in Japan

Year	Technical Standards
1996	Construction method and key points of multi-natural type river construction
1997	River Law
2005	Guidelines for the construction of rivers suitable for fish survival
2006	Nature oriented RiverWorks Guide
2007	Essentials of Nature oriented River Works - River transformation tasks and considerations
2008	Small and medium-sized river restoration technical standards, small and medium-sized river restoration technical standards description
2018	Revised version of the basic policy guidelines for disaster recovery to protect beautiful mountains and rivers
2019	Nature-oriented river management in large rivers-deepening understanding in Q & A
2020	Guide for forming an ecosystem network based on rivers
2020	Guide for evaluation of ecosystem conservation in river projects (for practitioners)

Table 5 Technical Standards on River Restoration in Canada

Year	Technical Standards
1999	A guiding framework for the protection of freshwater aquatic life
2002	Ontario River Restoration Handbook
2011	Rivers and Lakes Improvement Act Administrative Guide
2015	Guidance manual for optimizing water quality monitoring program design
2016	Develop a comprehensive biosecurity plan
2016	Guidance manual for developing nutrient guidelines for rivers and streams

Table 6 Technical Standards on River Restoration in EU

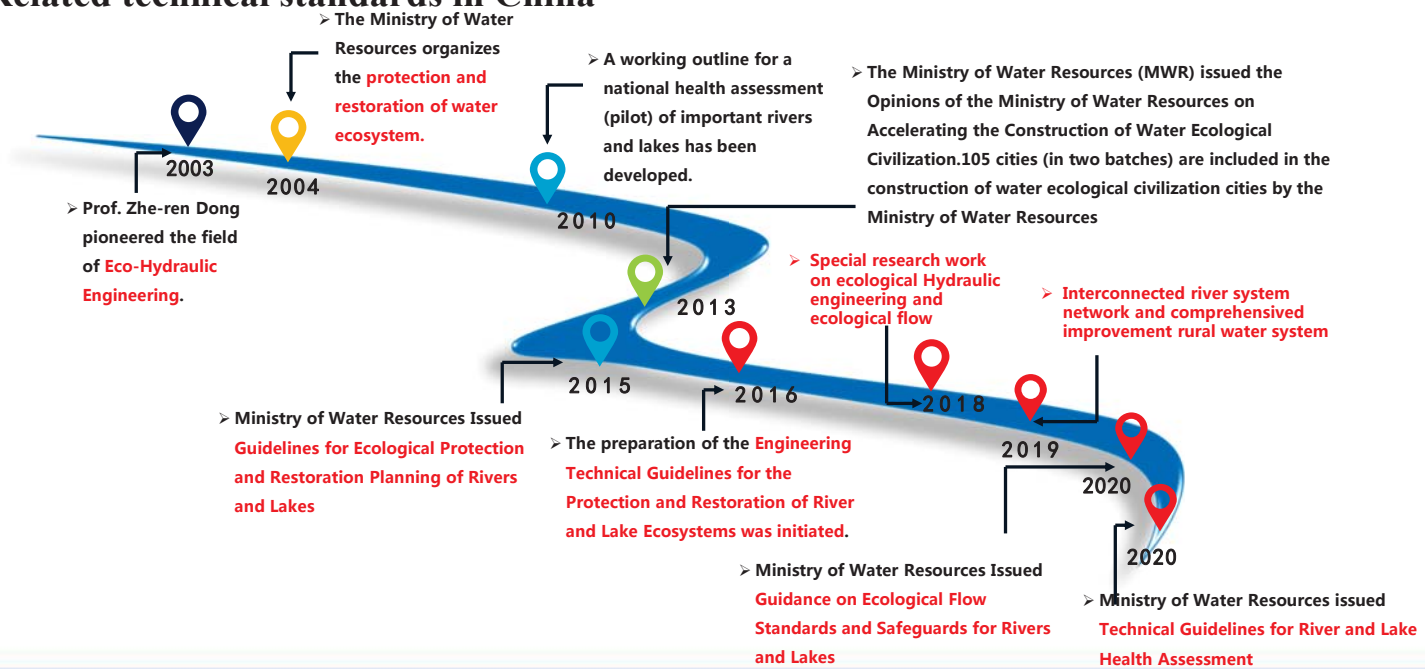
Year	Technical Standards
1975	Surface Water Directive
1976	Swimming Water Quality Standards Directive
1991	Municipal Wastewater Treatment Directive
1992	Habitat Directive
1998	Drinking Water Quality Standards Directive
2000	Water Framework Directive
2003	Risk evaluation technical guidance documents
2014	EIA Directive

Table 7 Other International Technical Standards on River Restoration

organization	Year	Technical Standards
Society for Ecological Restoration（SER）	2016	International principles and standards for the practice of ecological restoration（First Edition）
	2019	International principles and standards for the practice of ecological restoration（Second Edition）
the River Restoration Centre（RRC）	1997	Manual of River Restoration Techniques (1st Edition))
	2013	Manual of River Restoration Techniques (2nd Edition)
	2020	Manual of River Restoration Techniques (3rd Edition)
Asian River Ecological Restoration Network	2009	Guidelines for river restoration based on an ecologically appropriate approach to watersheds (1st edition)
	2012	Guidelines for river restoration based on an ecologically appropriate approach to watersheds (2nd edition)
Food and Agriculture Organization of the United Nations（FAO）	2008	FAO Fisheries Technical Manual Book 6, Supplement 1 Inland Waters Restoration Manual for Fisheries

River restoration policies, standards and practices around the world

Related technical standards in China



- 2003: Prof. Zhe-ren Dong pioneered the field of Eco-Hydraulic Engineering.
- 2004: The Ministry of Water Resources organizes the protection and restoration of water ecosystem.
- 2010: A working outline for a national health assessment (pilot) of important rivers and lakes has been developed.
- 2013: The Ministry of Water Resources (MWR) issued the Opinions of the Ministry of Water Resources on Accelerating the Construction of Water Ecological Civilization.105 cities (in two batches) are included in the construction of water ecological civilization cities by the Ministry of Water Resources
- 2015: Ministry of Water Resources Issued Guidelines for Ecological Protection and Restoration Planning of Rivers and Lakes
- 2016: The preparation of the Engineering Technical Guidelines for the Protection and Restoration of River and Lake Ecosystems was initiated.
- 2018: Special research work on ecological Hydraulic engineering and ecological flow
- 2019: Interconnected river system network and comprehensived improvement rural water system
- 2020: Ministry of Water Resources Issued Guidance on Ecological Flow Standards and Safeguards for Rivers and Lakes
- 2020: Ministry of Water Resources issued Technical Guidelines for River and Lake Health Assessment

Strengths and weaknesses of different strategic approaches

Developing strategic approaches

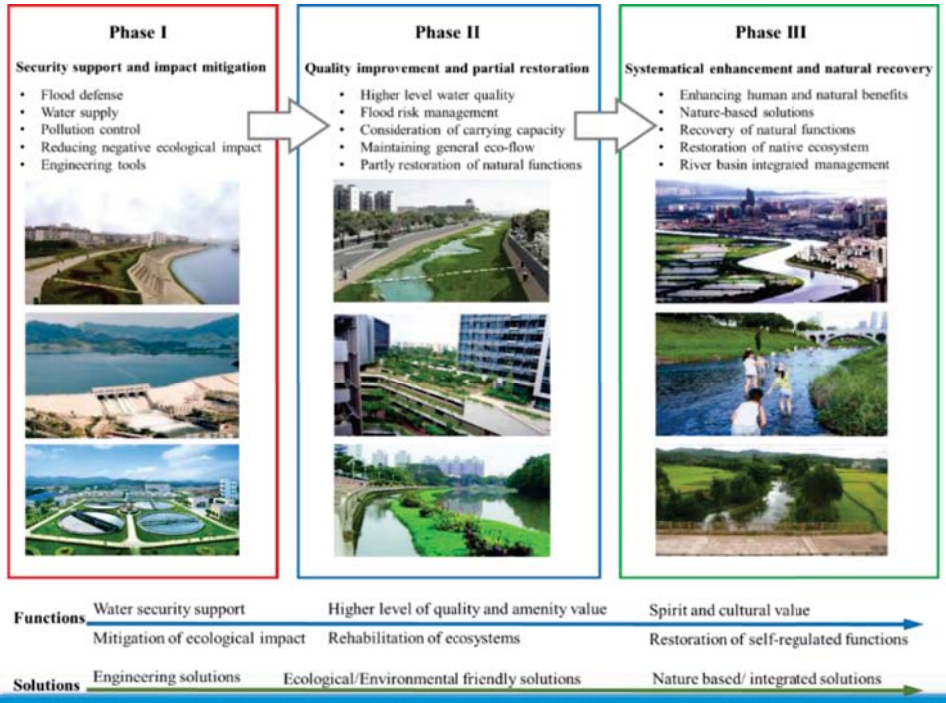
Strategic approaches		Strengths	Weakness
Typical approaches	Aspects		
• **Flood defence with concrete river works** • **Water resources exploitation for the increasing water demand** • **Pollution control by waste collection and treatment plants** • **Construction for recreation rather than ecological purposes**	Limited purposes (flood control / water supply / water quality, etc.)	Focus on solving the outstanding problem. Relatively easier for coordination and implementation, quick effect, lower investment	Lack of systematic thinking and solutions. Potential impacts of social / environmental / ecological / cultural issues
	River reach scope	Concentrating on higher pressure regions. Obtain obvious economic, social or recreational benefits, e.g., urban reaches	A lack of coherent strategy at the river basin or transboundary scope. Weakness when faced with the uncertainty of activities in related regions.
	Grey(engineering) solution	Effective in flood control and drainage. Easier regulation and maintenance. Relatively quick outcome	Potential impacts of environmental/ecological/cultural issues. Higher cost.
	Technical instruments	Effective in solving specific challenges and technical difficulties.	The actual effects would depend on financial and management capacity.

Strengths and weaknesses of different strategic approaches

Advanced strategic approaches

Strategic approaches		Strengths	Weakness
Typical approaches	Aspects		
• **Flood risk management with integrated measures**	Multiple purposes	Optimization of different goals based on multi-disciplinary solutions.	Higher cost. Longer duration to have the effect.
• **Pollution and erosion control by managing the entire process**	River basin scope	Holistic and coherent solutions from the watershed angle	Difficulty in the coordination of different regions. Longer duration to have the effect.
• **Maintaining ecological flow and river connectivity** • **Improvement of natural functions, native ecosystem and self-sustaining capacity**	Green (NBS) solution	Restore the natural capacity, e.g. self-purification. Lower cost. Positive impact on environment and ecosystems	Requirement of long-term to have the effect
• **Enhancement of natural landscape, amenity and cultural value**	Technical and institutional instruments	Effective in solving general challenges and implementation of restoration measures	Requirement of multi-dispensary collaboration, coordination of different governmental departments, and a higher-level enabling environment.

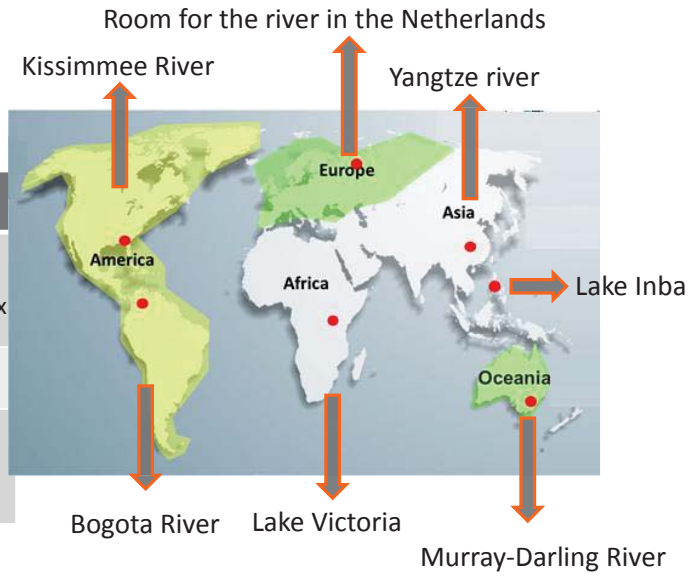
Conceptual framework for phased strategic approaches



3 Case studies and lessons learned

- Case studies focused on four main aspects: 1) pollution; 2) ecosystem degradation; 3) eutrophication; 4) flood.
- 7 cases was selected.

Conditions of the river	Developed country		Developing country	
	Complex/Trans boundary	Less Complex	Complex/Trans boundary	Less Complex
Predictable Flows	Kissimmee River	Lake Inba	Yangtze river	
Episodic	Murray-Darling River	Room for the river in the Netherlands	Lake Victoria	Bogota River



3 Case studies and lessons learned

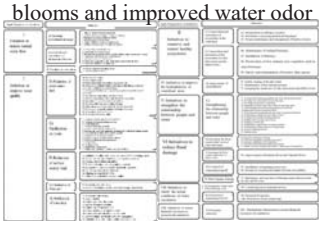
Kissimmee River

Develop complete assessment indicators
Recovery of hydrodynamic properties

Project area and construction of Kissimmee River Restoration Project

Lake Inba

Improved water quality, flood control and transparencyReduced algal blooms and improved water odor



Specific Measures in Inba-numa Watershed

Yangtze river

Coordination among provinces and components
Steady implementation of the river chief system
Improve the demonstration counties water pollution

Overview of Yangtze River Protection and Ecological Restoration Project

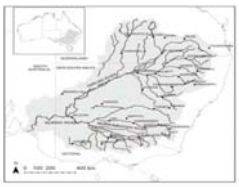
Victoria Lake

Improved collaborative management
Reduced environmental stress
Improved livelihoods of communities

Position of the Victoria Lake

Murray-Darling River

Increases river connectivity,
Manages environmental water use
Promotes the movement of native fish



The Murray-Darling Basin

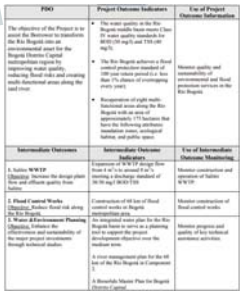
Room for the river in the Netherlands

Based on increasing the long-term vision
Crosses several disciplines
Established an integrated river basin management system

The Island in the river Waal project

Bogota River

1、Reduced flood risk
2、Incorporating Ecological Design into Flood Control Works
3、 Created a multifunctional and dynamic river.



Results Framework

3 Case studies and lessons learned

Menu of Interventions for River Restoration

- River ecological restoration measures can be classified into structural measures (14) and non-structural measures (17).

Type of measures		Restoration measures
Structural measures	Hydrological restoration	Ecological flow guarantee
		Ecological scheduling
		Ecological water replenishment
	Water quality improvement	Total Pollutant Control
		Prevention and control of eutrophication in lake reservoirs
		Governance of small watersheds
	River geomorphology restoration	Shore protection and restoration
		River connectivity restoration
		River basement ecological improvement
		Winding repair
	Biological diversity protection	Important Wetland Protection
		Migration channel protection
		Fish Habitat Conservation and Restoration
		Endangered, rare and endemic species protection

Type of measures		Restoration measures
Non-structural measures	Management system	Sustainable management of river basin
		Adaptive Management
		River ecological protection management system
		Protected area delineation and management
		Environmental law enforcement and supervision
	Institutional mechanism	Ecological compensation mechanism
		Public participation mechanism
		Cross-departmental and cross-industry coordination and cooperation mechanism
		Setting of management institutions
	Monitoring and evaluation	River health assessment
		Ecological value assessment
		Monitoring network construction and maintenance
		Assessment methods and data sharing
	Capacity building	Staff training
		Interdisciplinary scientific research
		Ecological conservation concepts and knowledge dissemination
		Informatization Construction

3 Case studies and lessons learned

Key elements for river restoration

- **Coordination of river restoration and socio-economic development**

River protection should be carried out in phases, specifically, pollution control followed by ecological restoration

- **Spatial and temporal scope of river restoration**

Planning should be conducted at the scale of river basins, and consider the relationships between the upper, middle and lower reaches of rivers.

- **Ecological integrity in river restoration**

River restoration must consider the ecological integrity of rivers, i.e. the structural and functional integrity of water ecosystems.

- **Negative feedback regulation-based design**

Negative feedback regulation-based planning is adapted to reflect the uncertainty of ecological processes in the design of ecological engineering based on monitoring, evaluations and adjustments.

- **Cost-benefit analysis**

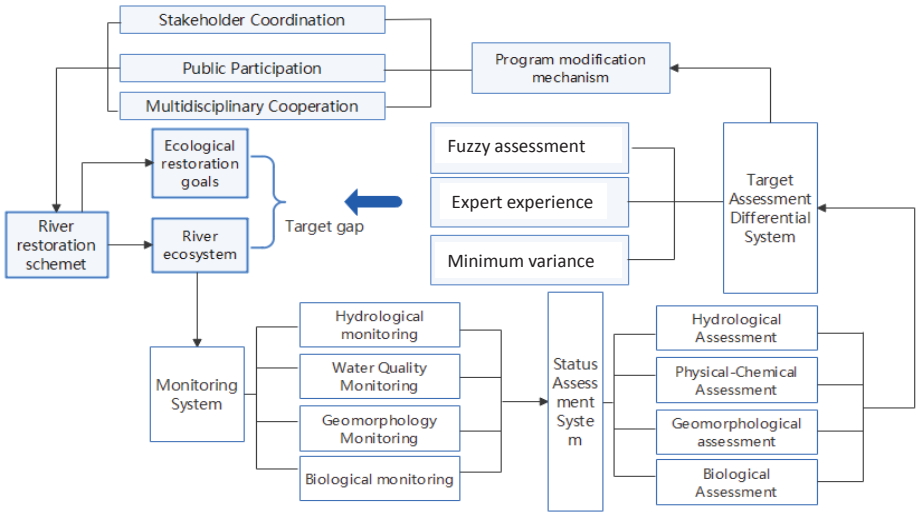
Cost-benefit analysis enables to showcase the economic rationale of river restoration projects.

4 Roadmap for River Restoration

- Great uncertainties in various natural processes and ecological elements of rivers bring huge risks.
  - ✓ Variability of river ecosystems
  - ✓ Limitations of people's knowledge

- New planning and design method: ***Negative Feedback Adjustment Planning And Design Method***

- Target gap: the degree of deviation between the status quo and restoration goals

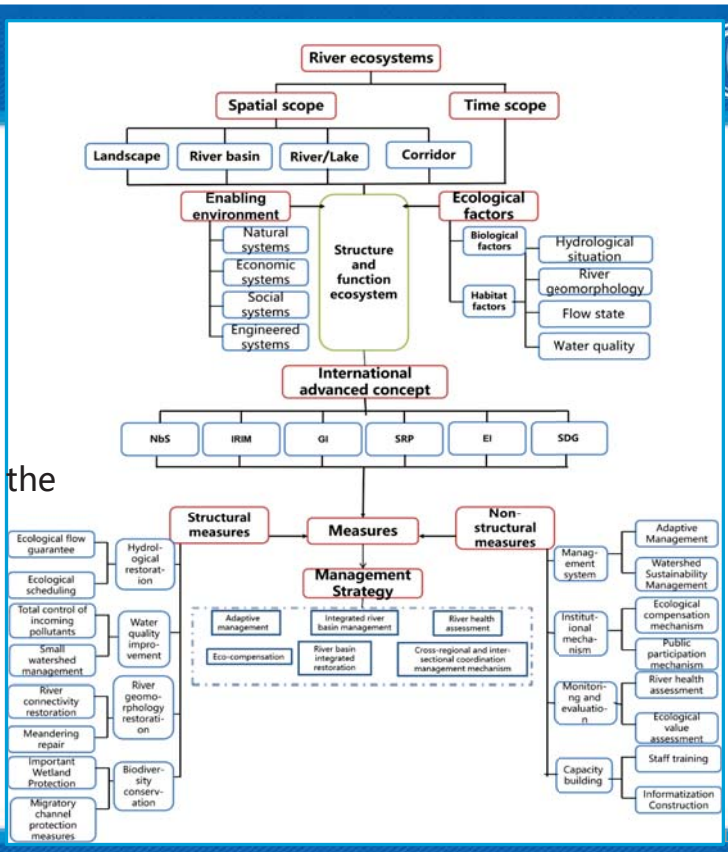


Negative feedback analytical for river restoration

4 Roadmap for River Restoration

A framework for a river restoration program based on the project cycle:

- based on investigation, monitoring and assessment,
- Consider the spatial and temporal scopes, the natural context, the economic and social context,
- Use the scientific paradigm and theories,
- Address technical measures: Structural measures, Nonstructural measures.



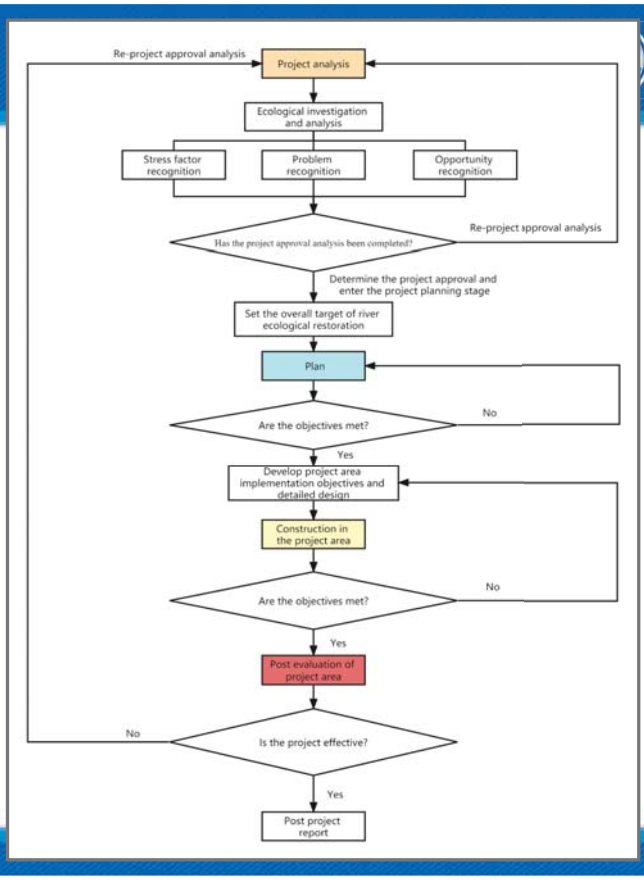
4 Roadmap for River Restoration

A roadmap for adaptive management for river restoration

The planning, design and implementation of river restoration follows the following processes:

- project analysis,
- formulation of overall objectives,
- project planning,
- formulation of implementation objectives,
- construction and monitoring,
- and post-evaluation of the project location.

Adaptive management is involved at the overall and intermediate stages of river restoration projects to achieve the objectives.




Thank You!