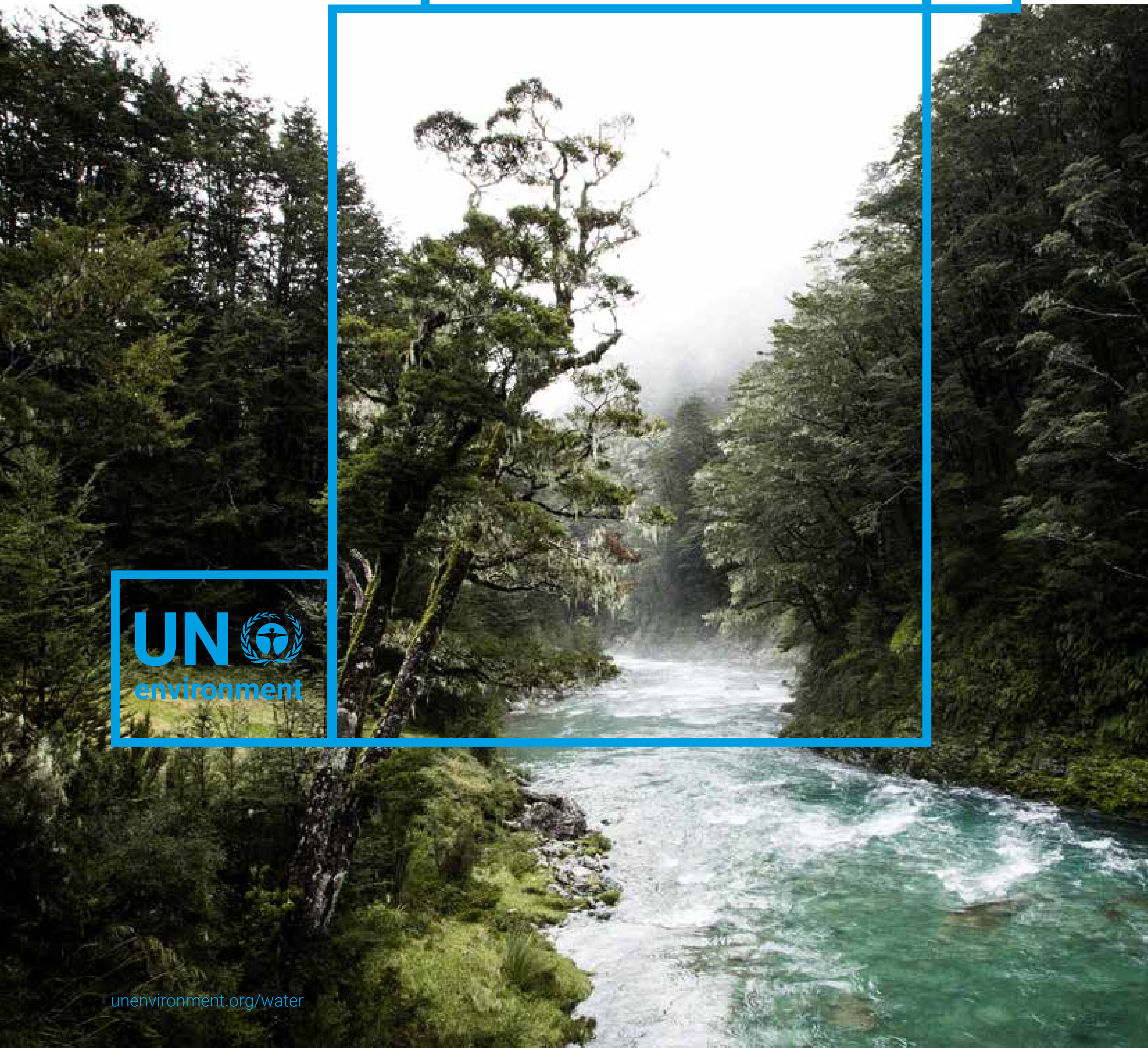
A Framework for Freshwater Ecosystem Management

Volume 3: Case Studies



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A Framework for Freshwater Ecosystem Management

Volume 3: Case Studies

Acknowledgement

We would like to acknowledge the contributors to this volume of the Framework for Freshwater Ecosystem Management series (formerly known as the International Water Quality Guidelines for Ecosystems).

The original versions of most of these case studies can be found in Volume 4 – Scientific Background. The versions presented in this volume have been adapted by UN Environment to illustrate revised steps in the Framework for Freshwater Ecosystem Management. The authors of the original versions were:

Case Study 1: Setting a Vision, Objectives and Targets: Eutrophication Management in Lake Balaton, Hungary (Budapest University of Technology and Economics, Hungary)

Case Study 2: A Look at the Full Framework: A Summary of the Development of a Freshwater Ecosystem Management Process in South Africa – Neels Kleynhans (formerly Department of Water Affairs, South Africa), reviewed by Mr. N. van Wyk (formerly Department of Water and Sanitation, South Africa) and Ms. Delana Louw (Rivers for Africa).

Case Study 3: An Ecosystem Health Report Card: Evaluating and Reporting on Mining Impacts on the Strickland River, Papua New Guinea - Stuart Bunn (Griffith University, Australia)

Case Study 4: Responding to a highly-degraded ecosystem: the Upper Tietê River Programme, Brazil - János Bogárdi (University of Bonn, Germany) based on material by Marcelo Pires da Costa (National Water Agenca, ANA, Brazil)

Case Study 5: Towards Water Quality Guidelines for Ecosystems, Indonesia - Ms Cynthia Henny (Indonesian Institute of Sciences, LIPI, Indonesia)

Case Study 6: A Desktop Study: The Use of National Data Sets to Assess Conditions of Freshwater Ecosystems in Mexico - Rebecca Tharme (Riverfutures, UK)

Case Study 7: Snapshots from 17 biological assessment programmes from across the United States - Joseph E. Flotemersch (US EPA, USA)

The original case studies, along with Volume 4 of the Framework series, was prepared on behalf of the United Nations Environmental Programme (UN Environment) by the Editorial Team of the United Nations University - Institute for Environment and Human Security (UNU-EHS). This team was composed of Mr Janos Bogardi, Mr Fabrice Renaud, Ms Zita Sebesvari, Ms Nike Sommerwerk and Ms Yvonne Walz supported by Ms Aarti Basnyat, Ms Susanne Haas, Ms Janine Kandel, Ms Aileen Orate, Ms Mariko Shimazu and Ms Sijia Yi.

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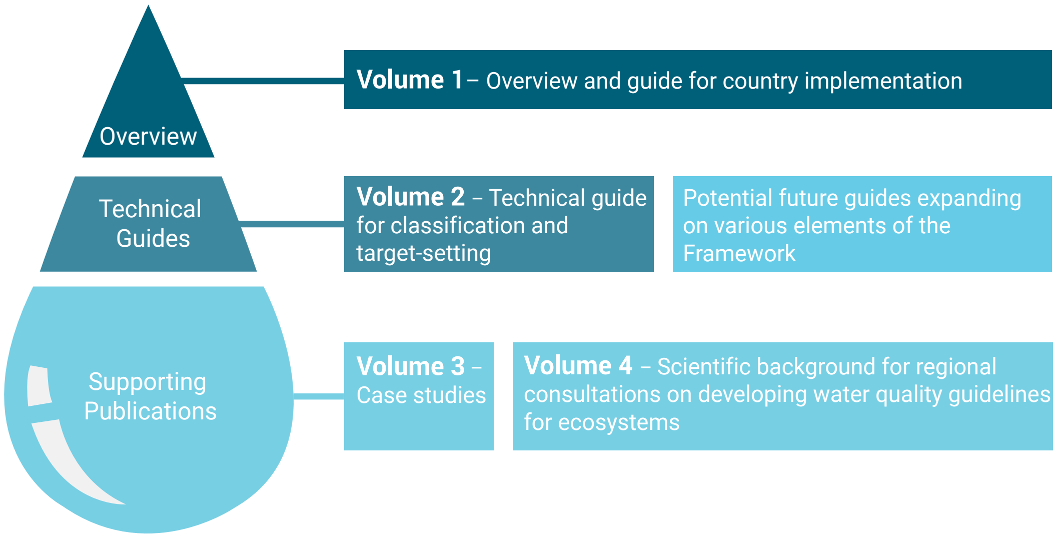
Preface

The UN Environment 'Framework for Freshwater Ecosystem Management' series presents a holistic management framework to guide country-level action to sustainably manage freshwater ecosystems. It builds on the decision by the UN Environment Programme (UNEP) Governing Council to develop water quality guidelines for ecosystems (Decision 27/3, 2013). UN Environment Assembly supports national and international goals related to freshwater ecosystems, such as relevant Aichi Biodiversity Targets and Sustainable Development Goal (SDG) targets. An overview of the series, which currently consists of four volumes, is provided below:



Volume 1 provides an overview of the Framework, and places it in the context of supporting Agenda 2030. It is intended for a wide audience, including decision makers, practitioners, scientists, non-governmental organizations and the general public.

Volume 2 describes aspects of the Framework in more technical detail: classification systems for freshwater ecosystem types, setting targets for ecological status, and monitoring progress against these targets. It is primarily aimed at government agency staff responsible for the sustainable management of freshwater ecosystems. These aspects have been selected for elaboration as they are likely to be the most useful for the largest number of countries in relation to Aichi Biodiversity Targets and the SDGs. Additional technical guides that expand on other parts of the Framework, such as the design and implementation of remediation actions, may be developed depending on demand from countries.

Volume 3 details case studies from around the world, illustrating how different aspects of the Framework are applied in freshwater ecosystem initiatives.

Volume 4 underpins the series with scientific background and includes a review of water quality guidelines for ecosystems from around the world.

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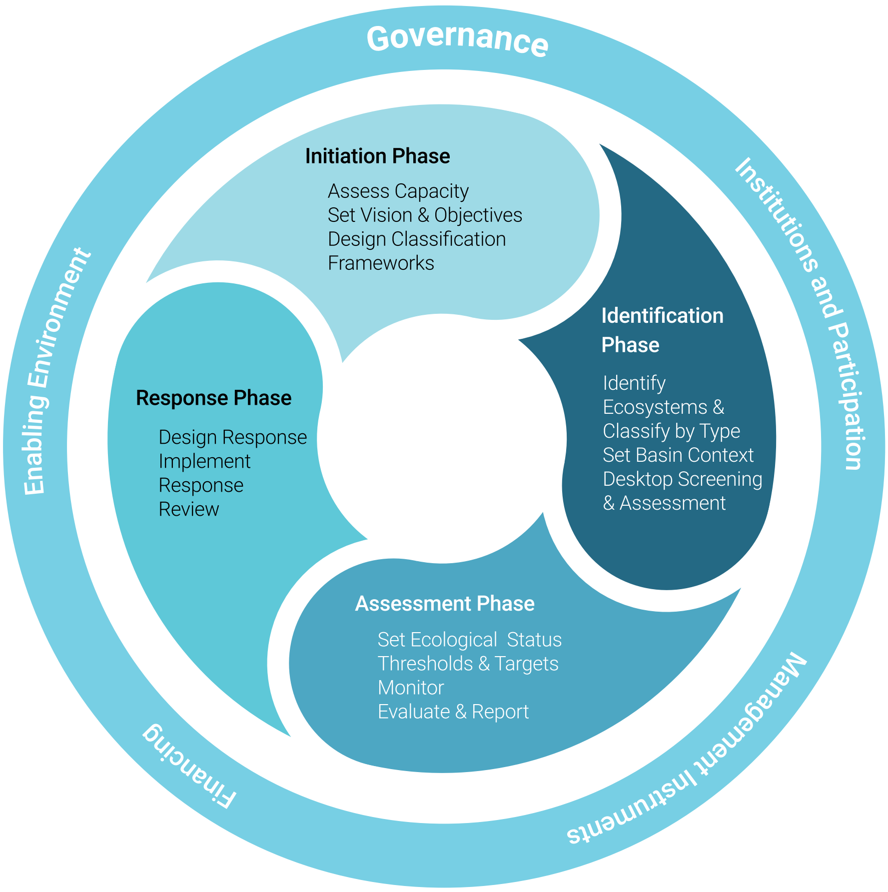
Krong Siem Reap, Cambodia
Photo credit: Fancycrave/ Unsplash

1 Introduction

This volume illustrates various case studies from around the world, detailing how steps from the Framework for Freshwater Ecosystem Management have been incorporated in freshwater ecosystem initiatives. It is intended to be a 'living document' that may be updated with new case studies.

The Framework for Freshwater Ecosystem Management



Many of the case studies illustrate how the phases and steps within the Framework overlap and may be undertaken concurrently. However, as demonstrated in Volume 1, these do not have to be followed in sequential order and may be taken in an order different to that shown in the figure above.

Overview of Case Studies

The case studies presented in this volume are as follows:

SECTION	NAME	STEPS FROM THE FRAMEWORK FOR FRESHWATER ECOSYSTEM MANAGEMENT	MORE DETAIL IN VOLUME 4 (Y/N)
1	Ecosystem restoration, Lake Balaton, Hungary	Agree on vision and set objectives; Set ecological status thresholds and targets	Y
2	National Framework for South Africa	All steps	N
3	Report card communication, Strickland River, Papua New Guinea	Assessment and reporting	Y
4	Restoration programme, Upper Tietê River, Brazil	Design, implement and review response	Y
5	Water Quality Guidelines, Indonesia	Classification systems for ecosystem types; Ecological status classes and targets	Y
6	Desktop Screening, Mexico	Desktop screening	Y
7	Comparative review, United States	All steps	Y

All information and reference sources can be found in Volume 4, Chapter 5, unless references are provided in the case studies in this volume. Additional case studies found in Volume 4 include:

- Application of South African Water Quality Guidelines for aquatic ecosystems in the context of the Reserve and Resource Quality Objectives (Section 5.7).[1]

Each case study in this volume contains:

- A summary box describing Framework steps, the scale of the initiative and the region
- A brief background
- A description of activities illustrating the Framework steps
- Lessons learned and replicability box

1 Section number refers to Volume 4.

Barvarian Forest, Haselbach, Germany
Photo credit: Pixabay

Yamzho Yumco, Shannan, China
Photo credit: Mèng Ji / Unsplash

2 Setting a Vision, Objectives and Targets: Eutrophication Management in Lake Balaton, Hungary

Many ecosystems suffer lasting impacts from various human activities, such as pollution. Reducing the causes of such impacts and successfully restoring ecosystems typically involves implementing long-term management plans with interim targets and the engagement of all stakeholders.

This case study illustrates the restoration of water quality in Lake Balaton, Hungary, which had deteriorated over several decades mainly due to nutrient runoff from agricultural activities. Lakes typically have long retention times, meaning it can often take years to see the positive effects of management interventions.

Although this case study focusses on a particular freshwater ecosystem rather than a national situation, many of the principles are still applicable. This demonstrates that the Framework can be adapted and applied successfully at both the national and individual ecosystem levels. Volume 4, Section 5.2 of this series discusses the Lake Balaton case study in more detail.

Case Study Summary

Illustrated Steps: 'Agree on vision and set objectives' (Initiation Phase) and 'Set ecological status thresholds and targets' (Assessment Phase).
Scale: Lake basin
Region: Europe

2.1 Background

Lake Balaton is a highly valued recreational area as well as a Ramsar site. It is a long, relatively narrow, shallow lake with a surface area approximately 600 km^2 with an average depth of 3 m. The water residence time of the lake is roughly two years.

There is significant agricultural activity in the Lake Balaton catchment. The first signs of man-made eutrophication were observed in the 1940s, with the water quality deteriorating even further in the 1960s and 1970s, due to fertilizer and pesticide usage and poorly treated wastewater. Public concern over deteriorating lake conditions increased following mass fish mortalities in 1965 and 1975. The water had also developed a greenish tone and in some areas decaying debris formed disgusting blankets. In 1982, there were massive algal blooms in the water and the lake became hypertrophic. After this, restoring the lake became a national concern.

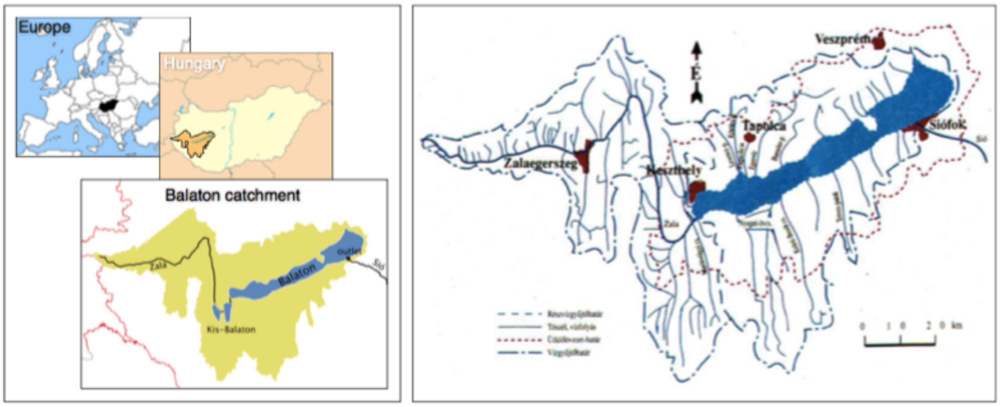


Figure 1 – Lake Balaton and its (entirely domestic) catchment and larger settlements. Zala River: main tributary; Sió: outlet; red line: Hungarian border. Source: Somlyódy and van Straten (1986).

2.2 Steps from the Framework for Freshwater Ecosystem Management

This case study primarily illustrates the ‘Set Vision and Objectives’ step in the Initiation Phase. However, it is also includes elements of the ‘Set Ecological Status Thresholds and Targets’ step in the Assessment Phase, namely ´Define ecological status classes´ and ´Set targets for ecological status´.

Set Vision and Objectives

Following significant public concern about the health of the lake, the government initiated procedures to develop a restoration strategy. This proved to be a learning curve for all involved.
Not unusually, Lake Balaton and its catchment are influenced by several factors which needed consideration, such as hydrology, land use management, sewage treatment, economics and tourism. In addition, the institutional make-up of the management of the lake and its catchment was rather complicated, comprising national government (involving several ministerial level institutions, such as housing and construction, agriculture, water, technology development, and science), three counties and three water district authorities, among others.

Furthermore, in the early 1980s in Hungary, there was limited experience with how to address environmental issues. Environmental impact assessment approaches were in their infancy. Water legislation existed, but was not adequately enforced. Public involvement and open planning were practically unknown, and non-governmental organizations (NGOs) had just started to come into existence. Until then, the Council of Ministers tended to make decisions of this nature.

However, given the physical and institutional complexity of the situation, several expert groups were formed which discussed key scientific aspects of eutrophication and its control. Between 30 and 40 technical reports were available and policy summaries were also under preparation, varying from 1–10 pages depending on which decision-making level was targeted. There was also a plan for various public hearings and consultations with leading decision makers.

It was decided that the overall aim was to attain and preserve water quality levels recorded in the early 1960s. It was recognized that this may take several decades to achieve, so three interim water quality targets were set. However, it quickly became apparent that a lack of clear communication was a major barrier to agreeing on a restoration strategy. Scientists had difficulties reaching a consensus on the key areas of the issue and appropriate management actions. Communication with the public and politicians was even more challenging. One of the main difficulties was the use of technical language, which was not well understood and instead led to confusion.

The Hungarian Academy of Sciences (a prestigious and well-trusted institution) became involved in developing the restoration strategy as a lead coordinator. Professionals were encouraged to avoid using technical language as far as possible and communication and publication content, including policy summaries, was significantly simplified.

The three interim water quality targets were recognized as a key part of the communication strategy and thus needed to be presented in a unique manner. As people still remembered the colour of the water as early as the 1960s and could compare it to the lake's current colour, the targets were set using a timeline approach and easy-to-understand descriptions:

- Level A (by 1990): Conservation of the water quality of the late 1970s and early 1980s, i.e. prevention of further deterioration. Exceptionally high algae production levels under adverse conditions – such as hot, rainy summers – may still be expected to occur.
- Level B (1995–2000): Gradual improvement of water quality. High probability of complete reduction in the appearance of high algae production levels.
- Level C (2005–2010): Restoration of the water quality of the early 1960s.

Politicians and the public reacted in the same way to the targets, which were now clear and easy to remember. Once the targets were finalized, the process became much smoother: proposed management measures were accepted (see Volume 4, Section 5.2) and an agreement was reached on setting priorities and allocating financial resources in the State budget.

The process of selecting indicators and defining indicator thresholds to measure target progress is described in Volume 4, Subsection 5.2.5. Further information on the other Framework steps involved in the Lake Balaton strategy can be found in Volume 4, Section 5.2.

Lessons Learned and Replicability: Set Vision and Objectives

1. The importance of the Lake Balaton ecosystem to the community as a recreational site and a national icon, clearly provided motivation for rehabilitation. In situations where communities do not explicitly recognize the ecosystem's importance, it becomes increasingly important for key stakeholders to demonstrate its significance.
2. A broad stakeholder engagement process was successfully developed, despite it being a relatively new and untested concept in the country at the time. Stakeholder engagement was an iterative process, with lessons learned along the way. Yet the most important aspect was stakeholders' willingness to engage and refine approaches.
3. Translating technical language into language that stakeholders could clearly understand led to the agreement of ecological status targets and management actions. Rehabilitation and monitoring funding is clearly dependent on political will and public support.
4. In restoration projects, setting water quality targets prior to significant pollution that is within the collective memory of stakeholders (e.g. within the last 30 years), can encourage stakeholders to support targets and management activities.

2.3 A Look at the Full Framework: A Summary of the Development of a Freshwater Ecosystem Management Process in South Africa Background: History and Development of the Process

Case Study Summary

Illustrated Steps: Brief overview of all phases and steps, providing a full illustration of the Framework.
Scale: National initiative, with implementation at the river basin level.
Region: South Africa

A countrywide structured approach to assess and manage the ecological condition of South African rivers originated in 1987, when the Department of Water Affairs and Forestry (DWAF) identified the need to quantify the ecological flow requirements of rivers.[1] Within the governance structure at that time, the monitoring of ecological conditions was most often related to protecting threatened aquatic species by provinces and the National Parks Board. In the 1950s, the National Water Act (NWA) was established, which focused on preventing pollution and providing water for agriculture, industries and formal human settlements as well as preventing pollution, failing to address ecological requirements for aquatic systems. Although provinces carried out extensive surveys of the distribution of fish species and were responsible for conserving threatened species, their mandate to protect aquatic habitats was limited.

Due to the international ecological importance of the Kruger National Park (KNP), the KNP Rivers Research Programme was established in 1989 to research and develop assessment methods for determining the instream flow requirements (IFRs) of rivers.[2] This initiative also resulted in increased attention of provincial governments in monitoring the condition of aquatic habitats and the distribution of aquatic biota in several South African rivers. These activities led to increased expertise in monitoring and assessment.

Following the establishment of a democratic government in South Africa in 1994, the DWAF continued investigating IFRs and ecological characteristics of rivers, often as part of environmental impact assessments for reservoir planning.

2.4 Steps from the Framework for Freshwater Ecosystem Management

Initiation Phase

- Set Vision and Objectives

A River Health Programme (RHP) to monitor and assess the ecological conditions in South African rivers was initiated in 1994. The aim of the RHP was primarily to establish coordinated efforts to determine and monitor the health of rivers and where possible, contribute to the protection and sustainable management of rivers.[3] To compliment the RHP, DWAF implemented IFR assessment methods in various areas of the country[4] and developed a desktop hydrological model to estimate the IFR of rivers.[5] Following this, the National Aquatic Ecosystem Health Monitoring Programme (NAEHMP) was developed as an umbrella programme for the RHP, wetlands, estuaries and aquatic ecosystems.[6]

1 Bruwer, C. 1991. Proceedings of a workshop on the Flow Requirements of Kruger National Park Rivers. Department of Water Affairs and Forestry, Pretoria. Report TR 149.
2 Breen, C. (Ed.). 1989. The Kruger National Park Rivers Research Programme. Water Research Commission, South Africa. Report No. TT 130/00.
3 http://www.dwa.gov.za/iwqs/rhp/rhp_background.aspx
4 King, J. and Louw, D. 1998. Instream flow assessments for regulated rivers in South Africa using the Building Block Methodology, Aquatic Ecosystem Health and Management, vol. 1, no. 2, pp. 109–124.
5 http://www.dwa.gov.za/iwqs/rhp/rhp_background.aspx
6 Ibid.

- Assess Capacity

The RHP initiative included national government departments and institutions, provincial governments, municipalities, universities and NGOs, all of which had their monitoring capacity and overall support for the programme assessed.[7]

The RHP significantly increased awareness of the importance and condition of rivers among the general public, resource managers, decision makers and politicians.[8]

- Design Classification Frameworks

In 1998, a new NWA was published,[9] providing for ecological requirements of freshwater systems (e.g. rivers, wetlands and estuaries as well as aquatic biota and habitats), with specific requirements for classifying aquatic resources, determining ecological reserves (i.e. ecological water requirements) and setting resource quality objectives. The act acknowledges the importance of protecting aquatic ecosystems and maintaining ecological services that people rely on for their livelihoods. In 1999, the DWAF developed the "Resource Directed Measures for Protection of Water Resources" to support the implementation of the NWA.[10] These guideline documents addressed the classification of aquatic resources.

- Set Vision and Objectives

As the RHP was designed prior to the NWA (1998) and did not directly address any cause and effect relationships for deterioration, it became necessary to harmonize the NAEHMP with the provisions set out in the NWA. This particularly applied to ecological water requirements and resource quality objectives, which establish targets that must be met. For river monitoring, this was achieved through developing the River Eco-status Monitoring Programme (REMP) in 2016,[11] which used the RHP information as its basis.

Identification Phase

- Identify Ecosystems and Classify by Type
- Set Basin Context

For hydrological modelling purposes, the river basins in South Africa are classified into 22 primary, 148 secondary, 288 tertiary and 1,946 quaternary catchments. Quaternary catchments are subdivided into approximately 9,400 sub-quaternary basins on a 1:500,000 scale.

Based on socio-economic considerations, South Africa is classified into nine Water Management Areas (WMAs) that extend across basin and provincial boundaries.

- Desktop Screening: Screen for Pressures and Estimate Ecological Status

To operationalize NWA ecological requirements, Present Ecological State and Ecological Importance and Sensitivity (PESEIS) assessments were carried out on primary rivers in 1,946 catchments in 1999. The Present Ecological State (PES) was based on an Index of Habitat Integrity (IHI) that considered human impacts on instream and riparian zone components of a river[13] according to a descriptive rating system.[14] Ecological Importance and Sensitivity (EIS) were assessed together and considered aspects such as the diversity of species and presence of threatened species. A simple spreadsheet programme was used to rate the EIS according to categories.[15] The aim of such assessments is to determine whether a PES rating is harmonized with the EIS rating (e.g. a 'Very high' EIS rating requires an 'A' PES rating;

7 Ibid.
8 http://www.dwa.gov.za/iwqs/rhp/state_of_rivers.aspx
9 Republic of South Africa, National Water Act: Act No. 36 of 1998.
10 http://www.dwa.gov.za/Documents/Policies/WRPP/default.htm
11 http://www.dwa.gov.za/iwqs/rhp/rhp_background.aspx
12 http://www.dwa.gov.za/iwqs/gis_data/river/rivs500k.aspx
13 Kleynhans, C.J. 1996. A qualitative procedure for the assessment of the habitat integrity status of the Luvuvhu River (Limpopo system, South Africa). Journal of Aquatic Ecosystem Health, vol. 5, no. 1, pp. 41–54.
14 According to: A = Natural, close to natural; B = Largely natural; C = Moderately modified; D = Largely modified; E = Seriously modified; F = Critically modified.
15 http://www.dwa.gov.za/Documents/Policies/WRPP/default.htm. EIS rated according to: Very high, High, Moderate, Low/Very Low.

a 'High' EIS rating requires 'B' PES rating; a 'Moderate' EIS rating requires a 'C' PES rating; and 'Low/Very low' EIS rating requires a 'D' PES rating). An 'E' or 'F' PES rating is considered unacceptable, regardless of the EIS rating.[16]

Due to a requirement for more detailed PESEIS information, previous PESEIS assessments were reviewed in 2014, leading to new assessments of approximately 9,400 sub-quaternary basins by local experts in various parts of the country using improved methods and supporting tools such as Google Earth. The instream component and riparian zone, including riparian wetlands, were assessed[17] within an ecoregion and geomorphological slope context.[18]

Information from these assessments is used to determine the condition and importance of freshwater ecosystems, evaluate water use requirements for planning purposes, provide classification ratings and determine NWA ecological water requirements.

Assessment Phase

- Set Ecological Status Thresholds and Targets

PESEIS assessments provide a desktop estimate of the PES and EIS on a national scale. However, in terms of specific water resource usage and development, PESEIS estimates need to be more accurate, which can be achieved with more thorough investigations. This involves determining the desired and attainable ecological state by assessing:

- hydrological, physicochemical and geomorphological conditions compared with reference conditions;
- the integrity of riparian and instream habitats compared with reference conditions using the IHI;
- biota and habitat EIS, including reference estimates and the present (baseline) conditions.

To attain a desired ecological state, ecological water requirements are determined according to what system drivers need to achieve a particular instream and riparian zone biological conditions. The best available ecological knowledge and information is used to define the habitat, physicochemical and flow conditions that biota require to attain the desired condition. The resulting desired class (e.g. A, B, C or D) is the target that needs to be achieved and is published in an NWA Government Gazette. These targets are quantified and specified for the overall condition of the system, as well as for flows, physicochemical conditions, habitat integrity, fish, aquatic macroinvertebrates and riparian vegetation.[19] In addition, thresholds are set in the supporting documentation on which the Government Gazette is based.

To support this process, an ecological classification (EcoClassification) process is followed that involves determining an ecological status (EcoStatus) according to a range of assessment methods and integrity indices for fish, aquatic macroinvertebrates, riparian vegetation and habitats.[20]

- Monitoring

For REMP, the desktop PESEIS information is used and the IHI, fish, aquatic macroinvertebrates, riparian vegetation and instream habitats are monitored. Sampling sites are selected based on sub-quaternary basins and on their representativeness according to ecoregions, geomorphic zones and various land uses. Sites used to determine ecological

16 http://www.dwa.gov.za/Documents/Policies/WRPP/default.htm
17 DWS. 2014. A Desktop Assessment of the Present Ecological State, Ecological Importance and Ecological Sensitivity per Sub Quaternary Reaches for Secondary Catchments in South Africa. Compiled by RQIS-RDM: https://www.dwa.gov.za/iwqs/rhp/eco/peseismodel.aspx
18 For more information on ecoregions, see: http://www.dwa.gov.za/iwqs/gis_data/ecoregions/get-ecoregions.aspx. For more information on river profiles,
see: http://www.dwa.gov.za/iwqs/gis_data/rivslopes/rivprofil.aspx
19 DWS. 2016. Government Gazette. National Water Act (36/1998). Classes and Resource Quality Objectives of Water Resources for the Olifants Catchment;
https://cer.org.za/wp-content/uploads/1999/12/Letaba.pdf; DWS. 2016. Government Gazette. National Water Act (36/1998). Classes of Water Resources and Resource Quality Objectives for the Catchments of the Inkomati.
20 For more information on EcoStatus, see: http://www.dwa.gov.za/iwqs/rhp/eco/ecostatus.aspx; DWS. 2017. Development of Procedures to Operationalise Resource Directed Measures; http://www.dwa.gov.za/rdm/wrcs/default.aspx

water requirements must be included. Flow and physicochemical information are usually obtained from numerous measuring stations.

- Evaluate and Report

REMP monitoring data are captured in spreadsheet data-retrieval models that allow for data to be analysed and compared with PESEIS assessments.[21]

The recommended ecological category as derived from PESEIS assessments for secondary catchments is used as a target for each of the components assessed. Monitoring results are compared with any ecological categories that have been published in a Government Gazette. REMP reporting has been completed for some catchments within the Inkomati River System, namely the Crocodile and Komati Rivers.[22]

Response Phase

- Design Response

Although the Department of Water and Sanitation (DWS) is responsible for maintaining and developing REMP methods and data, Catchment Management Agencies (CMAs) are responsible for monitoring, reporting and responding to results. However, CMAs have not yet been established in all nine WMAs in South Africa. Furthermore, the ecological water requirements (i.e. the ecological reserve) have not been fully implemented.

The Inkomati Usuthu Catchment Management Agency (IUCMA) has initiated the REMP in several catchments under their jurisdiction. Responses to monitoring results were expected following the publication of the resource quality objectives in December 2016.

Nevertheless, flows, water levels, physicochemical conditions, microbial contamination and eutrophication continue to be monitored at stations in rivers, reservoirs, wetlands, estuaries and at groundwater sites in various jurisdictions.[23]

NGOs often play an important role in reporting on and raising awareness of pollution and water resources mismanagement by water users and institutional water resource management authorities.

In the event that resource quality objectives are not achieved, an adaptive resource management and monitoring procedure will be followed, as shown in Figures 2 and 3.

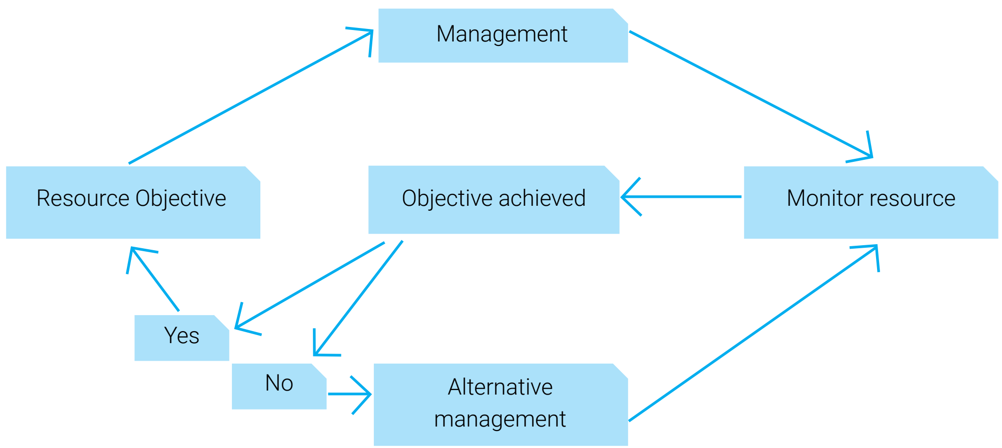


Figure 2 – The adaptive management cycle. Monitoring provides the critical link between objectives and adaptive management.[24]

21 http://www.dwa.gov.za/iwqs/rhp/rhp_background.aspx
22 https://www.iucma.co.za/reports-and-documents/
23 http://www.dwa.gov.za/iwqs/report.aspx
24 Elzinga, C.L., Salzer, D.W., John W. and Willoughby, J.W. 1998. Measuring & Monitoring Plant Populations. Bureau of Land Management. Denver, Colorado.

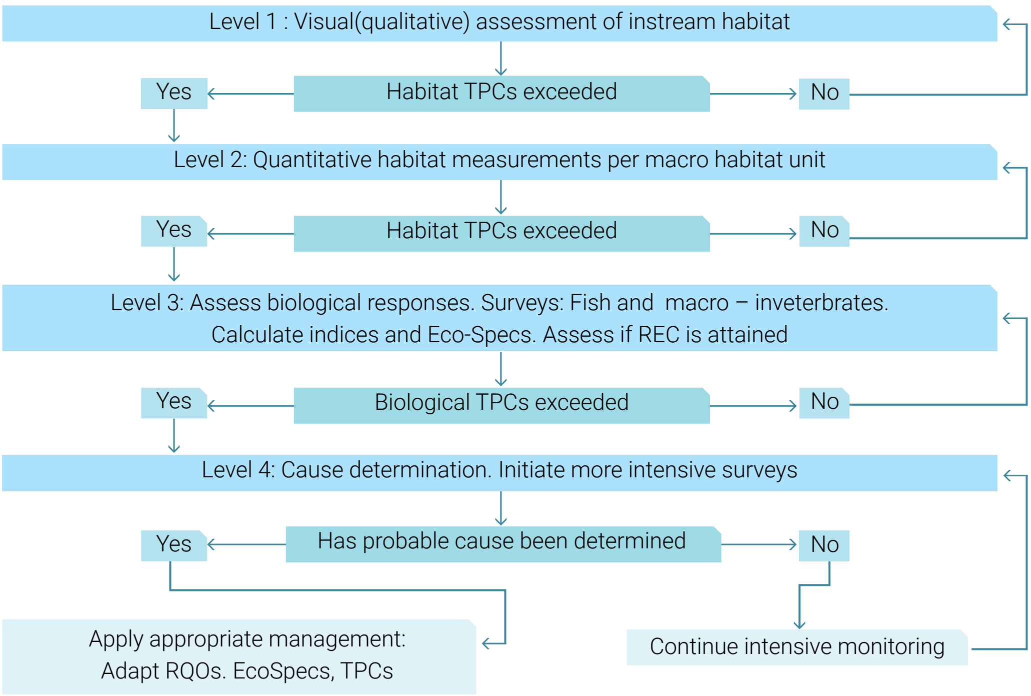


Figure 3 – Example of the elements of a Decision Support Framework (TPC = Threshold of Potential Concern, EcoSpecs = Ecological specifications, REC = Recommended Ecological Category, RQO = resource quality objectives).[25]

- Implement Response

No official response procedure based on REMP results has yet been implemented.

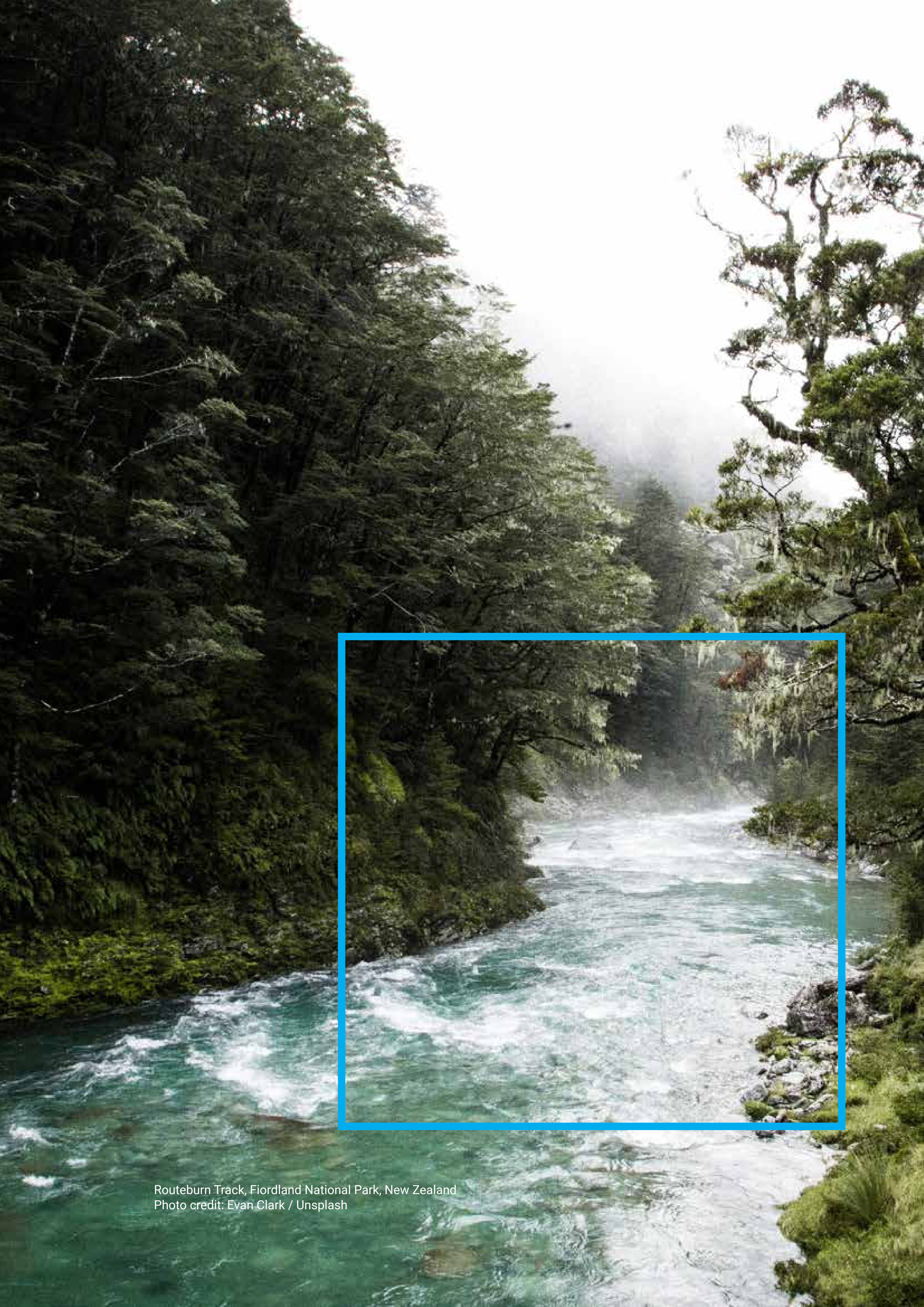
- Review Responses and Framework

A specific review process based on REMP results has not yet been developed. The REMP itself was developed following a review and was based on NWA requirements and developments, replacing the original RHP. However, a standardized and structured review process for a monitoring and management programme must still be established.

25 DWS. 2009. Development and Pilot Implementation of a Framework to Operationalise the Reserve. RDM/ Nat/00/CON/0907. Pretoria, South Africa.

Lessons Learned and Replicability

- During the establishment of an ecological resource management plan, detailed inventories of all available data and information must be gathered and collated.
- Support from different stakeholders (the government, research institutions, universities and NGOs, among others) is essential in developing and implementing a resource management plan. However, the focus must always be on managing resources, with support from appropriate scientific research and information.
- There must be the political and managerial will and support for the development and implementation of resource management plans.
- Similarly, there must be political and managerial understanding of the importance of monitoring programmes that are directed at managing natural resources and implementing resource management based on monitoring. This includes strengthening human resources and obtaining necessary financial support.
- The use of “citizen science” can be useful on a general scale, but should not replace ecological surveys and assessments (which is often the case due to their relatively lower costs and the level of human expertise required), since this may result in the neglect of scientifically based monitoring programmes.
- Although public awareness programmes are essential, resource management must be based on scientifically based monitoring and the production of scientific reports, rather than those created as public communications.
- Resource monitoring must result in a Decision Support Framework that will enable resource managers to understand the causes and sources of resource deterioration as well as the need for and implications of management actions to restore ecosystems.



Routeburn Track, Fiordland National Park, New Zealand
Photo credit: Evan Clark / Unsplash

3 An Ecosystem Health Report Card: Evaluating and Reporting on Mining Impacts on the Strickland River, Papua New Guinea

Many developing countries may not have comprehensive national freshwater ecosystem monitoring programmes in place. However, detailed monitoring information may be available at specific sites, often through private sector studies, typically in relation to development impacts, such as dams or mines. This case study focusses on the development of an ecosystem health report card for the Strickland River in Papua New Guinea, where a gold mine operates near one of the upstream tributaries. This case study is described in more detail in Volume 4, Section 5.4.

Case Study Summary

Illustrated Steps: Assessment Phase: define ecological status classes, select indicators, evaluate and report.
Scale: River basin
Region: Oceania

3.1 Background

Porgera Joint Venture (PJV) established a gold mine in the upper Porgera Valley in the late 1980s, and began gold production in 1990, initially processing 1,500 tonnes of ore per day and expanding to over 16,000 tonnes per day by 1996 (Commonwealth Scientific and Industrial Research Organisation (CSIRO), 1996). The mine was approved on the condition that an environmental management and monitoring programme was established and initial baseline sampling was carried out in 1989. PJV has undertaken an extensive environmental monitoring programme of the Strickland River system since 1990, with data on water quality, sediments and biota presented in the PJV Annual Environment Reports.[2] An independent

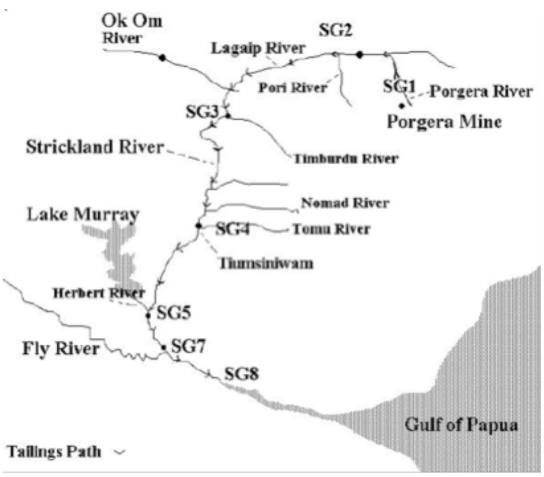


Figure 4 – Location of the Porgera Mine in the Strickland River basin.

2 See: http://www.barrick.com/files/porgera/2012-Porgera-Annual-Environmental-Report.pdf

committee was established to oversee the overall environmental and social sustainability of the mining operations.

3.2 Steps from the Framework for Freshwater Ecosystem Management

This case study focusses on the Assessment Phase, demonstrating how efficient reporting can condense large amounts of data into easy-to-understand information that is useful for various stakeholders, including government decision makers, private sector managers and the general public. The report card methodology was developed more than a decade after the management and monitoring programme was established in the river basin. While the steps described in this case study were mostly undertaken as part of the same programme, they can viewed both as examples of how the Framework steps can be designed and implemented at the beginning of a programme or project, or revisited and revised further along the process.

Set Threshold Values and Define Ecological Status Classes

Defining logical ecological status classes and thresholds for these classes facilitates clear communication and reporting at a later stage. In this case study, threshold values and ecological status classes were defined in the same exercise. Ecological status classes were framed as 'levels of concern' for ecosystem health. The threshold values of each class were based on a reference value, and two trigger levels of concern: an early trigger value and a 'true' trigger value.[3]

The reference value was based on long-term data from reference sites, using a conservative measure of reference site conditions within each region (e.g. the eightieth percentile of dissolved arsenic concentration in upper reference sites from the start of data collection to the present). Based on expert knowledge, this represented an acceptable health level, corresponding to a low level of concern. For most dissolved metals and other water quality parameters, trigger values and early trigger values were taken, respectively, as the ninetieth and ninety-fifth percentile of Australian and New Zealand guideline trigger values for ecosystem protection. For sediment metals, the Australian and New Zealand Interim Sediment Quality Guidelines (ISQG) were used to set the threshold values, with the trigger value set as 'Low' and the early trigger value as 'High'.

In the absence of any documented values of concern, trigger values for metals in fish tissue were set at three times the reference value. Similarly, trigger values for biotic measures were arbitrarily set at one third of the reference value.

Reporting was mostly based on median values for each indicator for a particular year. In the case of dissolved metals, sediment metals and fish tissue metals, the overall score for the indicator group reflected the worst-case score for any individual metal. For example, if a site received a green level of concern for dissolved arsenic, but an amber level for dissolved cadmium, the overall score for dissolved metals would be amber.

In summary, the 'levels of concern' and threshold values were determined as follows:

LEVELS OF CONCERN	MEDIAN ANNUAL VALUE
Low (Green)	less than or equal to the reference value or early trigger value
Moderate (Yellow)	between the early trigger value and trigger value
High (Amber)	greater than the trigger value

3 Bunn et al. 2010.

Evaluate and Report

The focus of the reporting was to develop a report card capable of condensing large amounts of data and information into an easily understandable format that could communicate ecosystem statuses to different stakeholders. Although various indices within each indicator group were combined as a single score, it was agreed that data for each of the groups would be presented in the report card, rather than combining them into a single site score. This avoided the concerns about relative weighting of indicator groups and provided more diagnostic information on specific problems at each site. Data were presented as a pentagon for the five indicator groups (Figure 5) and the report card was launched publicly and made available on the company website (Figure 6).[4] Although this type of highly condensed reporting is useful for communication purposes, it should not replace technical reports to inform and guide the design and implementation of management actions.

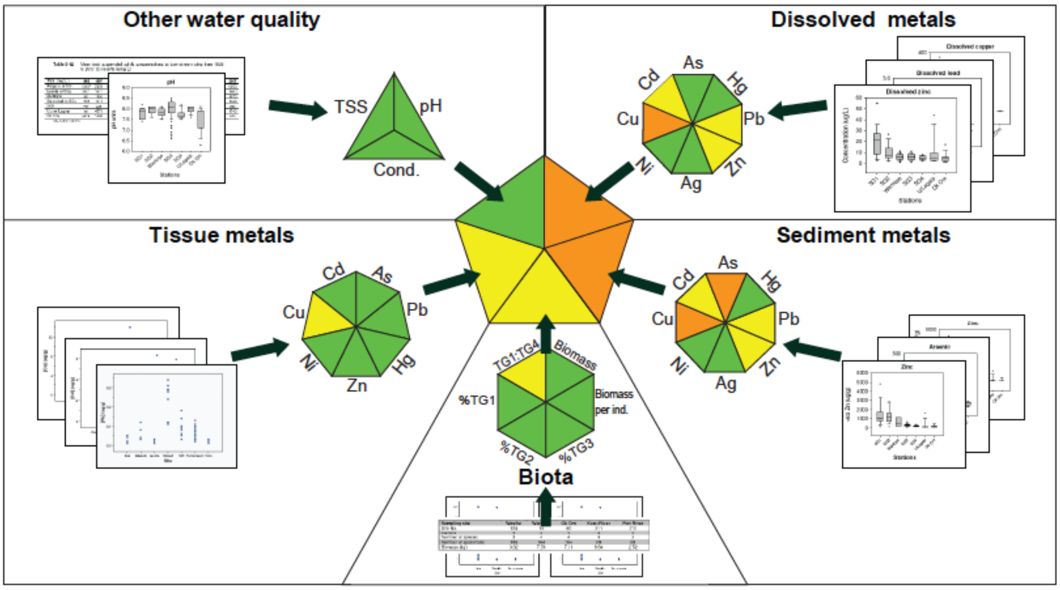


Figure 5 – Communicating large amounts of technical data in a simple report card format.

4 http://barrick.q4cdn.com/808035602/files/porgera/PEAK-Porgera-Report-Card-2010.pdf

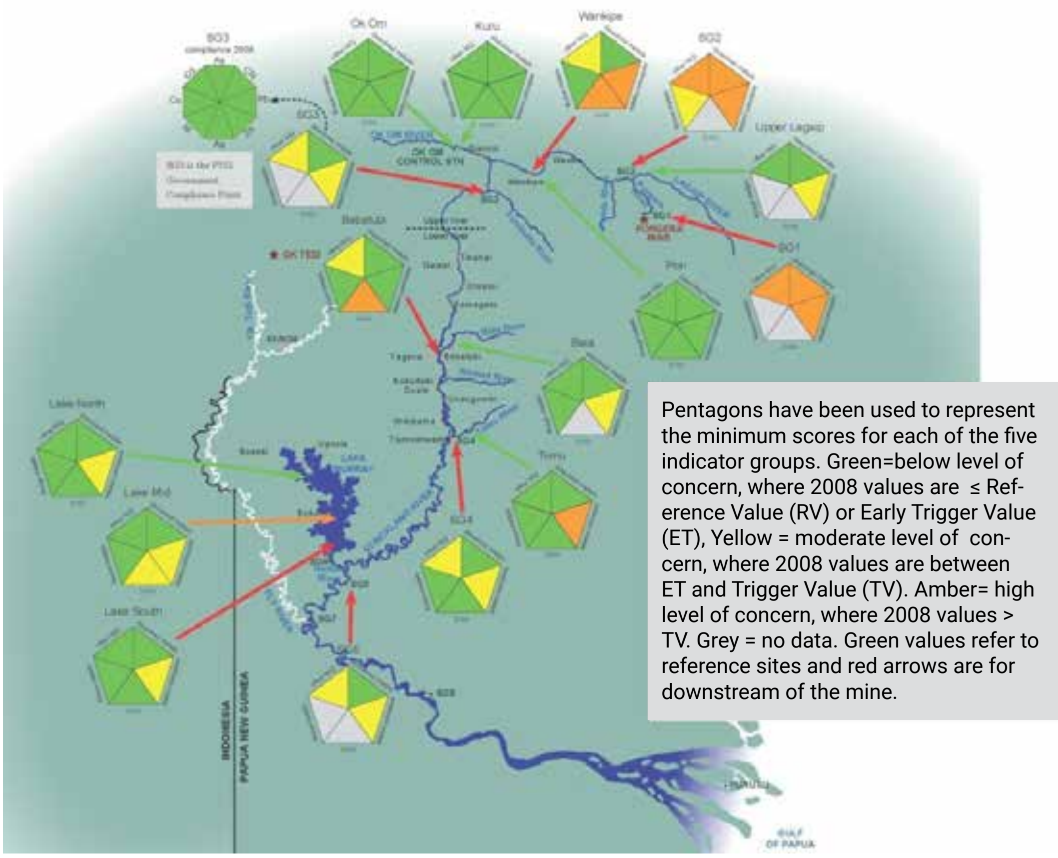
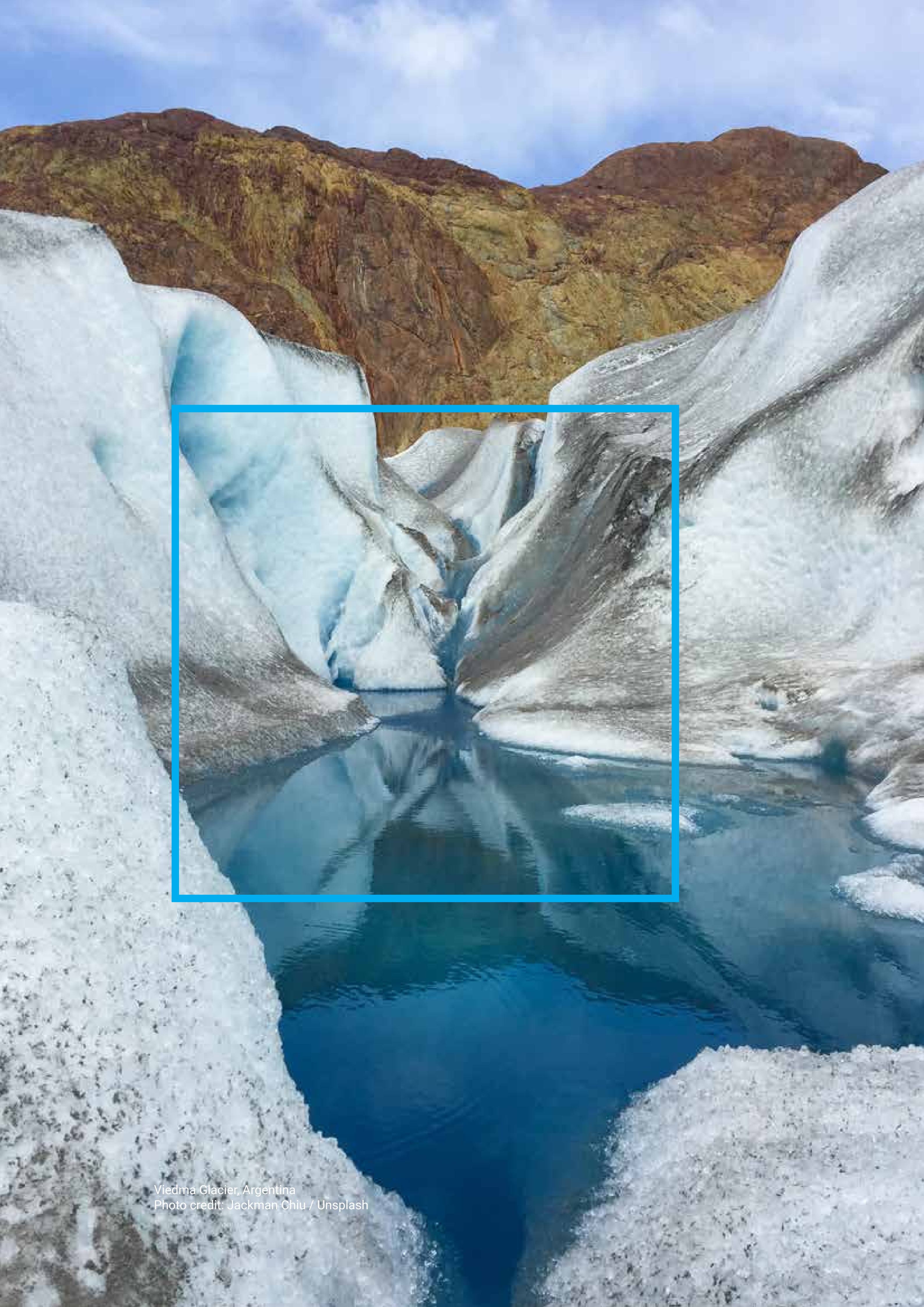


Figure 6 – Strickland River report card. Each pentagon represents results at a monitoring site.

Lessons Learned and Replicability: Strickland River

1. The ‘score card’ approach for reporting can be adapted and used in all situations, and at all levels (international, national and local).
2. The careful selection of a minimum number of priority indicators and easy-to-understand ecological status classes, coupled with innovative visual design, are critical elements of an effective reporting system.
3. Even in the absence of a comprehensive national monitoring programme, valuable data may be available at local levels which can be combined to contribute towards the development of a programme.
4. Private sector organizations leading development initiatives can be responsible for implementing and maintaining a monitoring programme within the catchment. The design and results of monitoring programmes should be subject to an independent review.

Stimpson Family Nature Reserve, Bellingham, United States
Photo credit: Justin Cron/ Unsplash



Viedma Glacier, Argentina
Photo credit: Jackman Chiu / Unsplash

4 Responding to a highly-degraded ecosystem: the Upper Tietê River Programme, Brazil

Many ecosystems have become heavily polluted from a complex array of sources. In most cases, significant recovery is possible, but restoration typically takes decades to implement and always requires adequate funding and prolonged engagement with relevant stakeholders for management actions to be sustainable.

This case study illustrates the design and implementation of a management programme to restore one of the most polluted watercourses in Brazil. More detail is provided in Volume 4, Section 5.3 of this series.

Case Study Summary

Illustrated Steps: Design, implement and review response
Scale: River basin
Region: South America

4.1 Background

The Upper Tietê River (a tributary of the Paraná River) in the state of São Paulo in Brazil, runs for 243 km and has a drainage area of 5,720 km². Urban areas occupy 37 percent of the basin, including the São Paulo Metropolitan Region. In 2010, the basin had 20 million inhabitants and a population density of approximately 3,500 inhabitants per km².

Both the water quantity and quality in the river basin is under significant pressure. Water is supplied by surface water from a series of reservoirs and around 7,000 groundwater wells. However, water demand is greater than availability in the basin, so demand is met by importing significant quantities from neighbouring basins.

Until the 1950s, the water quality was quite good in most of the river basin, supporting wildlife and recreational activities such as swimming and fishing. However, in the following decades, rapid population growth caused serious water quality issues caused by inadequate treatment of domestic and industrial wastewater, poor collection and disposal of solid waste, increased diffuse pollution (e.g. from pesticides and nutrients), toxic chemicals, heavy metals, petroleum gasoline seepage into groundwater and greater nutrient levels, causing significant algal blooms and eutrophication in reservoirs and very low levels of dissolved oxygen.

Figure 7 – Tietê River Basin. (adapted from FUSP, 2009)

4.2 Steps from the Framework for Freshwater Ecosystem Management

This case study describes the Response Phase of the Framework, which includes the design, implementation and review of the Upper Tietê River Basin Clean-up Programme.

Design Response

The development of this programme was largely due to public discontent on the condition of the river. In the late 1980s, NGOs and the media played an important role in a campaign to clean up the river. In 1991, a petition calling on the government to clean up the Tietê River was signed by 1.2 million people. Data from long-term water quality monitoring in the basin supported public opinion.[5] As a result, the São Paulo government launched the Upper Tietê River Basin Clean-up Programme in 1991.

There are several relevant agencies responsible for the sustainable management of the river basin. Water quality is monitored by the São Paulo Environmental Agency (CETESB), which is also responsible for water pollution control. Water quantity is monitored by the São Paulo Water Department (DAEE), which is also responsible for giving permissions for water use. In Brazil, municipalities are responsible for domestic sewage collection and treatment. In the Upper Tietê basin, most municipalities transferred sanitation services to the São Paulo State Sanitation Company (SABESP), although some decided to maintain their own municipal services. Thus, not all municipalities participated in the programme developed by SABESP the São Paulo Sanitation Agency, which caused delays in implementing measures to clean the Upper Tietê River in some municipalities.

Civil society, NGOs and the media also played an important role in developing and implementing the Upper Tietê River Basin Clean-up Programme.

To coordinate the various stakeholders, the Upper Tietê River Basin Committee was created in 1991, and was primarily also responsible for implementing the River Basin Plan.

The programme was initially divided into three phases, spanning 23 years at a cost of US$2.65 billion. Upon completion of the third phase, a fourth phase was designed, which included a review of progress to date (see Table 1).

5 Detailed in Volume 4, Section 5.3.

Table 1 – Upper Tietê River Basin Clean-up Programme phases

PHASE	PERIOD	INVESTMENT (US$)
First	1992–1998	1.1 billion
Second	2000–2008	500 million
Third	2009–2015	1.05 billion
Fourth (under negotiation in 2016)	2016–2025	1.9 billion
Total	1992–2025	4.55 billion

Source: SABESP

The programme included measures to reduce the pressures on the river basin, including the construction of new wastewater treatment facilities, expansion of existing plants and construction of sewage collection networks and control of industrial pollution.

The programme has been partly funded by the São Paulo State government and partly through loans from the Inter-American Development Bank and the Brazilian Development Bank (BNDES).

Implement Response

Once the programme was developed, the implementation phase began. In trying to increase sewage collection, the programme encountered a socio-economic problem whereby households in poor areas were unable to pay the connection fees. In these cases, the São Paulo government covered the connection costs.

In 1992, CETESB identified 1,250 industries that were responsible for 90 percent of the industrial pollution load to water bodies. Industries were requested to submit plans and a schedule for implementing treatment systems and were supported by loans from the World Bank and the BNDES. Fines were applied for lack of compliance with plans. The implementation of these plans and application of fines led to more than a 90 percent decrease of industrial organic and inorganic loads between 1992 and 2008.

Review Response

In addition to interim reviews, a major review was undertaken at the end of the third phase in 2015. The main improvements were:

- Between 1991 and 2015, wastewater collection increased from 70–87 percent, and treatment of domestic wastewater more than tripled from 24–84 percent.
- Between 1992 and 2008, industrial inorganic and organic loads were reduced by more than 90 percent.
- Between 1992 and 2014, the length of heavily polluted river was reduced from 260 km to 100 km.

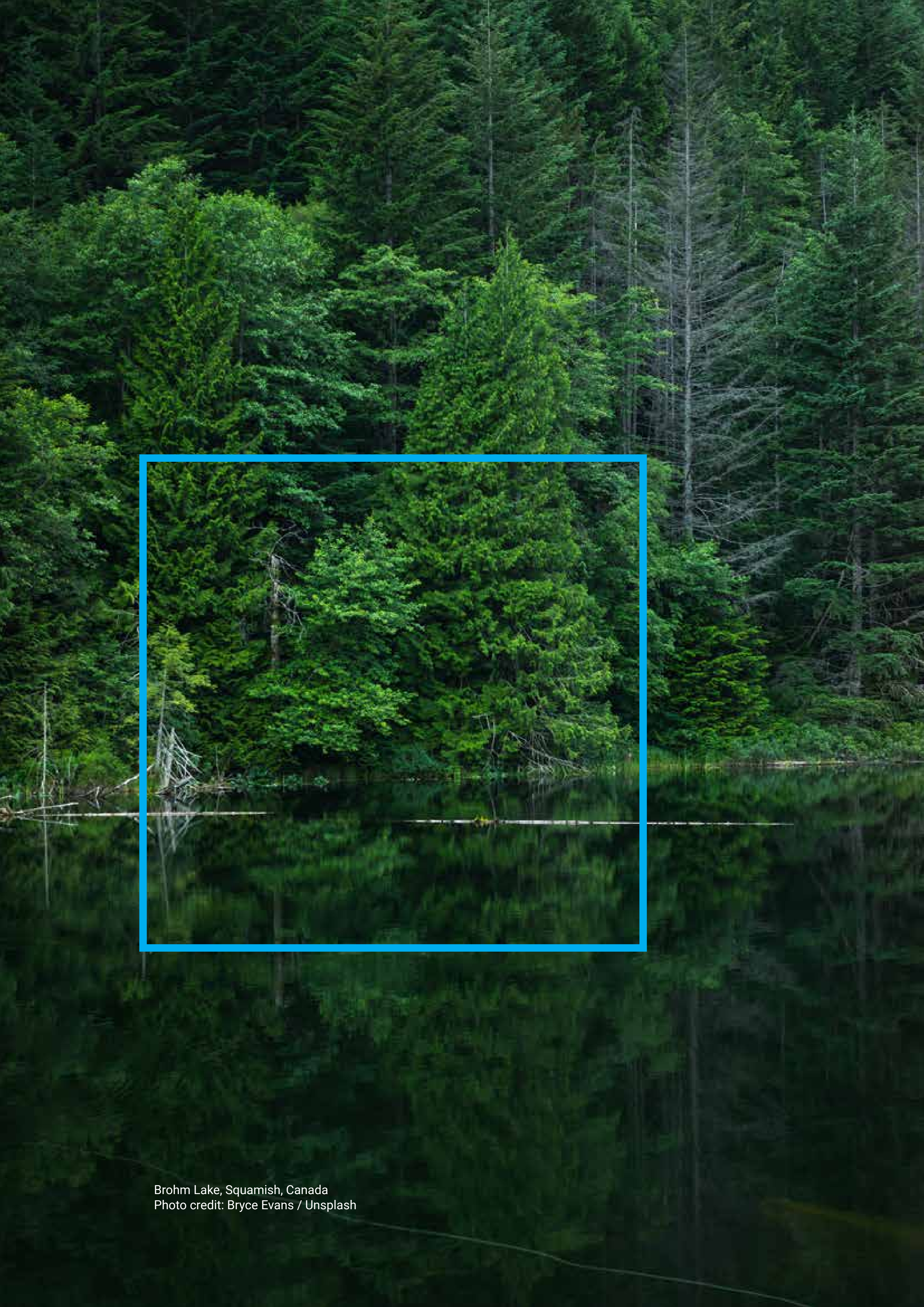
These improvements in wastewater collection and treatment resulted in fish returning to some locations downstream of the São Paulo Metropolitan Region and also reduced the level of unpleasant odours. However, despite significant progress, as of 2015 the river's water quality did not comply with human use standard, such as recreation and fisheries, and most city inhabitants have been unable to notice improvements in water quality in the urban stretch of the river in the São Paulo Metropolitan Region.

The review supported the design of a new fourth phase, to last from 2016 to 2025, demonstrating a cyclical adaptive management approach.

Lessons Learned and Replicability: Upper Tietê

1. The restoration of massively polluted water bodies can take decades to implement and potentially billions of US dollars. This highlights the need for:
   - continuity of public policy, good governance and sustainable financing;
   - multi-stakeholder participation, effective public communication, reporting and information sharing over a considerable timespan;
   - sustained water quality monitoring, supported by well-conceived guidelines and thresholds that are easy to communicate;
   - choosing sustainable development pathways that minimise impacts on freshwater ecosystems, rather than following the "impair and repair" approach which has overwhelmingly characterized industrial and urban development since the second half of the nineteenth century.
2. Civil society, NGOs and the media played an important role in developing and implementing the programme. Aiming to bring back a water quality and ecological status people can recall greatly helps to secure public support for policies.
3. The state government subsidised sewage connection fees in poor areas, highlighting the need for innovative and equitable financing.

Saksun, Faroe Islands
Photo credit: Hollie Harmsworth/ Unsplash



Brohm Lake, Squamish, Canada
Photo credit: Bryce Evans / Unsplash

5 Towards Water Quality Guidelines for Ecosystems, Indonesia

Countries often have water quality guidelines related to human use, but not specifically for ecosystems. This hampers adequate monitoring, reporting and communication of water quality for the protection and restoration of freshwater ecosystems.
This case study describes an attempt to develop national water quality guidelines for ecosystems in Indonesia, and relate them to existing water quality guidelines for human use. More detail is provided in Volume 4, Section 5.6.

Case Study Summary

Illustrated Steps: Define ecological status classes, select indicators, set threshold values.
Scale: National standards for lakes
Region: Asia

5.1 Background

More than 20 percent of the water resources in the Asia Pacific region are found in Indonesia. Most of Indonesia's 5,590 major rivers, 500 major lakes and thousands of small lakes have experienced ecosystem degradation due to pollution (e.g. from wastewater discharges, aquaculture and other stressors), eutrophication, invasive macrophytes and the loss of biodiversity. National water quality standards were published in government regulations in 2001, but they only related to direct human use. During the following decade, the Ministry of Environment undertook a process to develop water quality standards for ecosystems, building on the existing guidelines for human use.

5.2 Steps from the Framework for Freshwater Ecosystem Management

This case study focusses on setting ecological status classes and indicator threshold values for ecosystems, and describes the regulatory framework that supported this process.

Initiation Phase: Set Vision and Objectives

A primary objective of environmental management in Indonesia is to enable sustainable development. Water is recognized as having an important function in achieving sustainable development and maintaining the well-being of humans and other biota, and therefore needs to be wisely managed for the benefit of both present and future generations (Water Environment Partnership in Asia (WEPA), 2012).
Thus, the long-term vision in developing national water quality guidelines was to sustainably manage freshwater ecosystems. To achieve this, it was acknowledged that the guidelines needed to facilitate management decisions and actions. As the guidelines would be

dependent on the type of ecosystem, it was decided that they would initially focus on lakes. Two main long-term objectives for lake management were set: first, to restore degraded lakes to a good or moderate ecosystem health condition, where the ecosystem could function ecologically while supporting its ecosystem services; and second, to protect and maintain high ecosystem health condition of lakes that are habitats for endemic or potentially indigenous species.

Following a desktop study, the Ministry of Environment selected 15 priority lakes to be restored and protected.

Assessment Phase: Set Ecological Status Thresholds and Targets

- Define ecological status classes

In 2001, the Indonesian government issued regulation no. 82 on water quality management and water pollution control, which specified water quality classes, as well as threshold values for indicators in relation to human use (see Table 2).

Table 2 – Water quality classes based on human water use

CLASS	USE
Class I	Water can be used as raw water for drinking and/or other usage that requires the same water quality
Class II	Water can be used as raw water for recreation, fishery, livestock rearing, irrigation and/or other usage that requires the same water quality
Class III	Water that can be used for fishery, livestock rearing, irrigation, industry and/or other usage that requires the same water quality for such usage
Class IV	Water that can be used for irrigation, industry and/or other usage that requires the same water quality for such usage

In 2010, the Ministry of Environment developed draft lake management guidelines to evaluate the ecological status of the nation's lakes. In the guidelines, ecological status classes were divided into three categories:

1. Good
2. Moderate/slightly disturbed
3. Degraded/highly disturbed ecosystems (Figure 8).

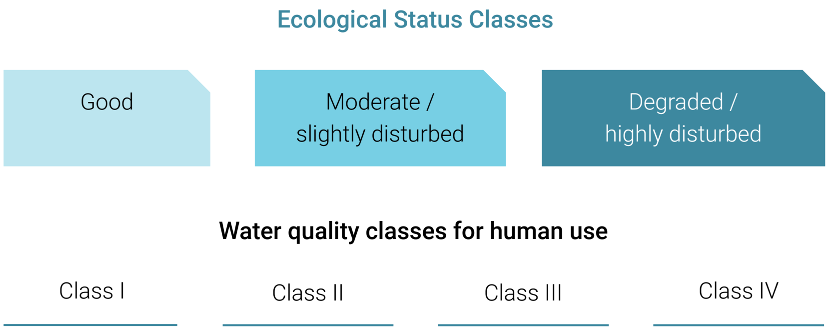


Figure 8 – Draft ecological status classes, linked to existing water quality classes for human use (see Table 2).

Comparing the ecological status classes with the human water use classes, the 'good' ecological status supports Class I water use, the 'moderate' ecological status supports Class II and Class III water use, and the 'degraded' ecological status only supports Class IV water use.

- Select indicators and set threshold values

The existing water quality guidelines for human use (2001) contained national threshold values for 46 physicochemical indicators, including the following:

- Physical parameters (temperature, total dissolved solids (TDS), total suspended solids (TSS));
- Inorganic pollutants, including toxic metals (pH, DO, BOD, COD, P-$PO_4$3–, N-NO_3, N-NH_3, As, Co, Ba, Bo, Se, Cd, Cr(VI), Cu, Fe, Pb, Mn, Hg, Zn, Cyanide, Chloride, Fluoride, N-NO_2, Sulphate, Free Chlorine, H_2S);
- Microbial pollutant (faecal coliform, total coliform) ;
- Radioactivity (gross alpha and gross beta);
- Organic pollutants (fat and grease, Phenol and six types of pesticides).

The Ministry of Environment established minimum threshold values with which local governments must comply (for values, see Table 5.7 in Volume 4, Subsection 5.6.6). Provincial governments can set tighter water quality guidelines than the national standards, as well as additional parameters according to the local characteristics and priorities of the area. However, lake ecological statuses could not be assessed using physicochemical indicators alone. Therefore, the draft water quality guidelines for lake management identified more key indicators for lake assessments, including:

- Hydromorphology;
- Trophic status (oligotrophic, mesotrophic and eutrophic/hypereutrophic);
- Water quality (physical and chemical parameters);
- Biodiversity (flora and fauna – endemic/local species, invasive species);
- Food web (balanced trophic level – primary, secondary productivity and consumers);
- Eutrophication (percentage of macrophyte coverage, blue green algae/microcystis);
- Carrying capacity (based on phosphorus and dissolved oxygen concentrations in lake water).

The threshold values for each indicator were set according to good, moderate and degraded ecological status classes. For example, based on a trophic status assessment of a lake, oligotrophic conditions indicate the ecosystem's health is good, mesotrophic conditions indicate it is moderate or slightly disturbed and eutrophic or hypereutrophic conditions indicate it is degraded or highly disturbed. These classes are not applied to physicochemical indicators, which follow the regular water quality guidelines for human use categories. In addition to the lake management guidelines, the Ministry of Health also proposed revising existing water quality guidelines to include several important indicators, such as water transparency (Secchi depth) and Chl-α.

Based on the assessment results of the 15 priority lakes, one lake had a good ecological status, nine lakes had a moderate ecological status but were a high risk of becoming highly disturbed, and five lakes had a highly disturbed ecological status.

Lessons Learned and Replicability: Water Quality Guidelines for Ecosystems, Indonesia

1. Water quality guidelines for human use, such as drinking water, recreation or irrigation, can be used as a starting point for developing water quality guidelines for ecosystems.
2. Water quality guidelines for ecosystems can be developed gradually, based on pilot studies on small groups of ecosystems.
3. It is important to develop indicators that are appropriate to the type of ecosystem, as well as being fit for purpose (e.g. fit for determining an ecological status).

Okavango River, Shakawe, Botswana
Photo credit: Wynand Uys / Unsplash

6 A Desktop Study: The Use of National Data Sets to Assess Conditions of Freshwater Ecosystems in Mexico

Countries often want to identify their most degraded, at-risk or valuable ecosystems in order to prioritize management actions. Most countries will have some data and information on ecosystems around the country, albeit with data gaps. This data can be assessed as part of a desktop study using a structured analysis to prioritize ecosystems. More detail is provided in Volume 4, Section 5.8.

Case Study Summary

Illustrated Steps: Desktop screening and assessment
Scale: National river basins
Region: Central America

6.1 Background

Pressure on Mexico's water resources is intensifying due to an increasing demand for water, food and energy as the population grows and the effects of climate change. The country's mega-biodiverse rivers are vital for supporting socio-economic growth, but are deteriorating under this stress.

6.2 Steps from the Framework for Freshwater Ecosystem Management

This case study focusses on desktop screening to make an initial assessment of the current situation of national river basins.

Identification Phase: Desktop Screening and Assessment

- Assess data availability by basin; Screen for pressures; Estimate ecological status of each ecosystem

The focus of the desktop assessment was to determine the extent of eco-hydrological alteration in Mexico's river basins. The assessment was conducted on three scales: (1) rivers, (2) riparian zones, and (3) basins. Existing national data was gathered for 393 river basins in the country. To make the assessment, indices were used as surrogate measures of the extent of eco-hydrological alteration in river systems, at each of the three scales (Figure 9). A total of 75 indices were developed. Although the data available for the indices had varying degrees of national coverage, from widespread to patchy, the indices could still be aggregated into sub-model clusters to address factors such as water quality, urbanization and groundwater exploitation.

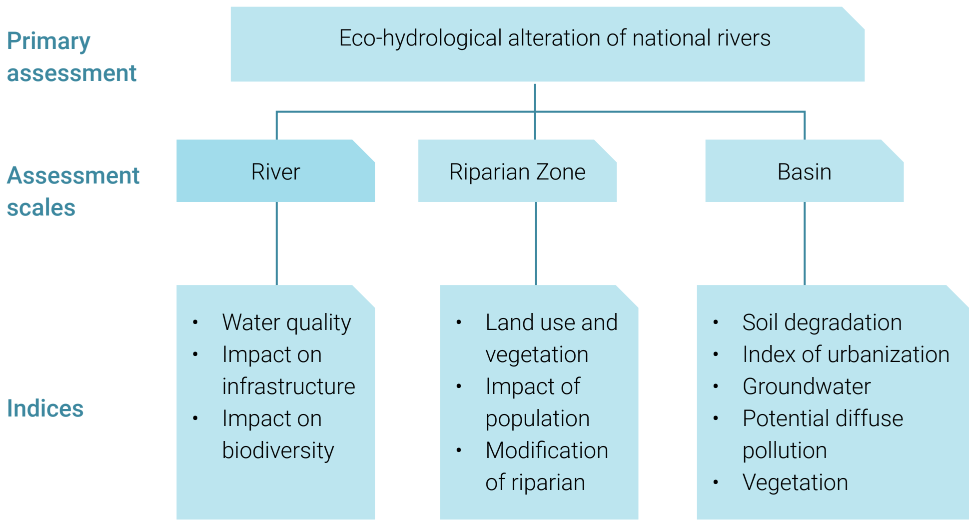


Figure 9 – Conceptual model for desktop assessment of eco-hydrological alteration.

A multi-criteria decision support model was developed to process the numerous indices and determine the overall eco-hydrological alteration of the each of the river systems. Alteration levels were classified into five categories: very high, high, moderate, low, and very low (Figure 10).

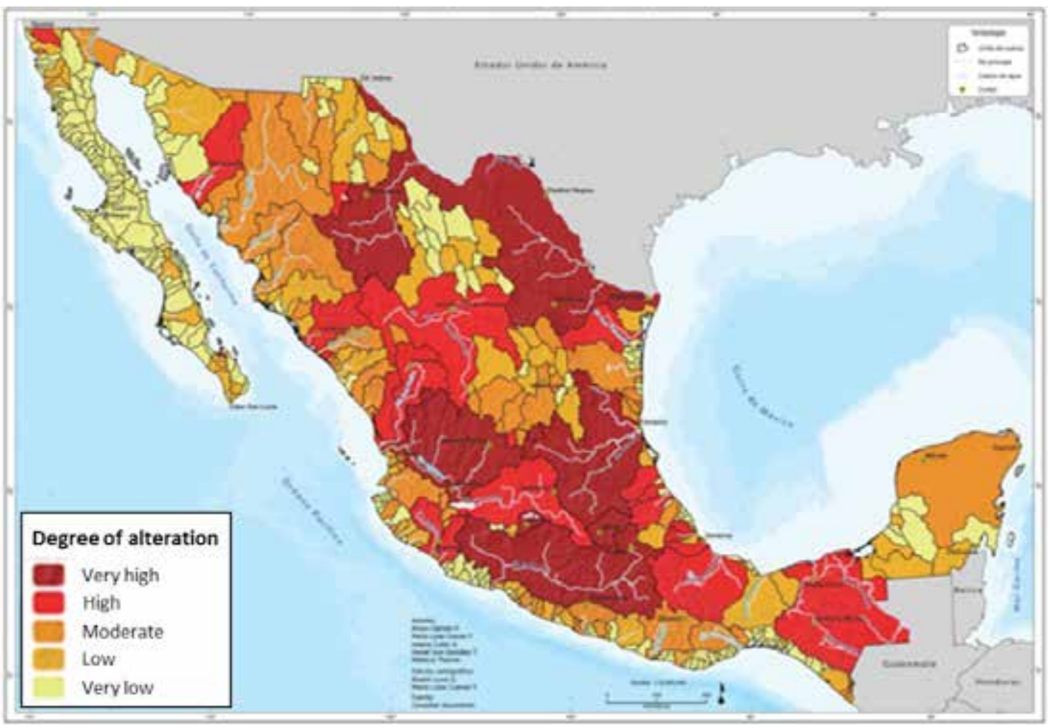


Figure 10 – Eco-hydrological alteration of river basins in Mexico based on a desktop study.

Approximately 55 percent of river systems were found to have a ‘very high’ or ‘high’ degree of alteration. These impacted rivers supported the well-being of almost 83 million people and cumulatively represent 313,000 km of river and 49 percent of national territory. Of these, seven basins, which represent significant water resources for more than half the country’s population, had a ‘very high’ degree of alteration. Encouragingly, 224 mostly first and second order river basins (though representing only 14 percent of national territory) remained relatively intact.

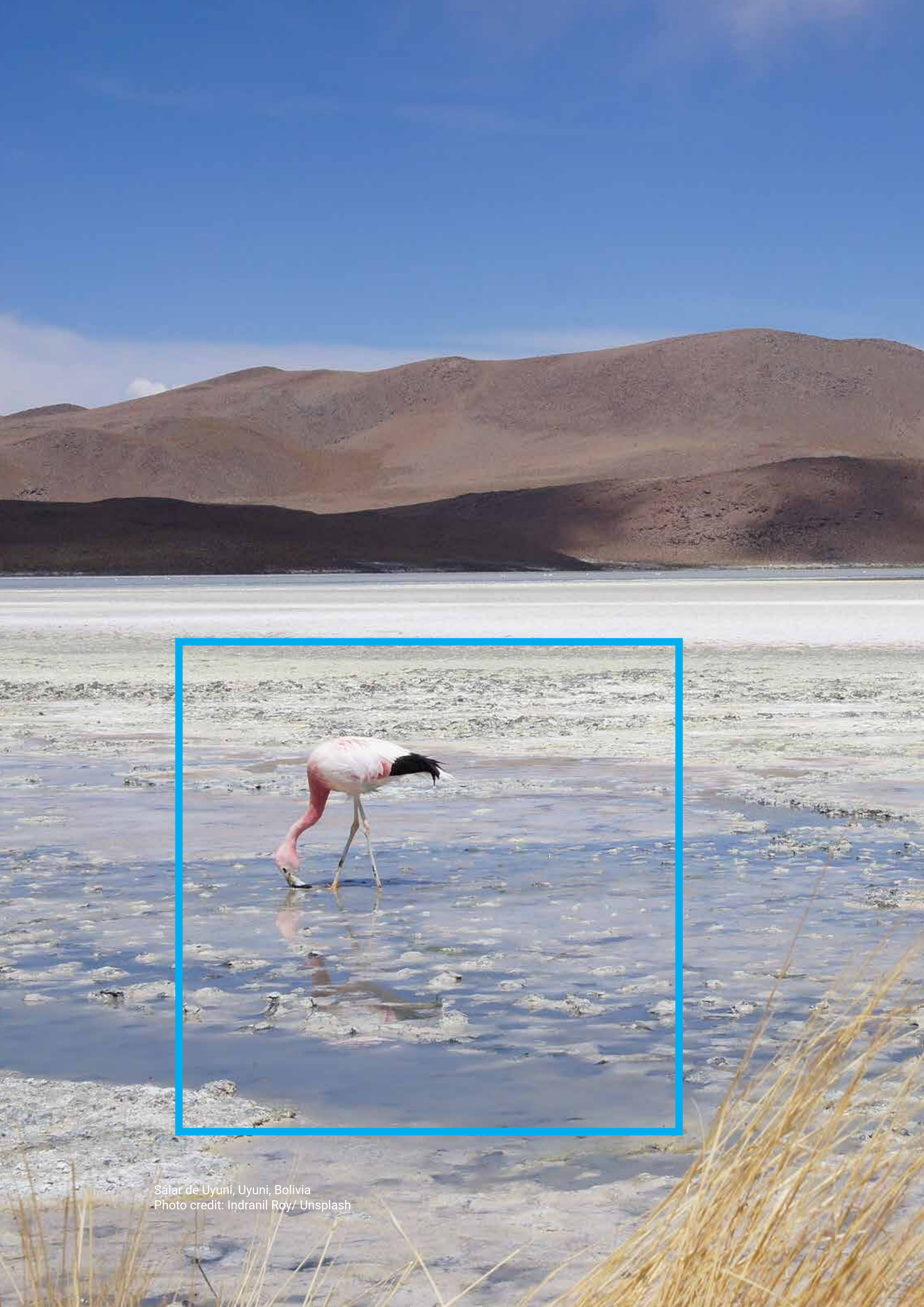
Some important drivers of ecosystem decline were found to be:

- flow regime alteration and system fragmentation by water resources infrastructure;
- basin conversion of natural vegetation to other land uses;
- water quality effects of diffuse agricultural pollution.

The results highlighted options for prioritizing national basin strategies for river conservation, improved flow management, including through the provision of environmental flows, and for better land management practices (e.g. reduction of nutrient and sediment loads in agricultural field runoffs).

Lessons Learned and Replicability: Desktop Studies for Initial Assessment

1. Readily available national data sets can be used to undertake a desktop assessment of current conditions, even if data gaps exist.
2. While a total of 75 indices were used in this rather comprehensive assessment, useful information can still be provided with much less data and fewer indices. The careful selection of a minimum number of priority indicators and easy-to-understand ecological status classes, coupled with innovative visual design, are critical elements of an effective reporting system.
3. Desktop study results should enable decision makers to prioritize the most highly degraded basins. In addition, identifying least degraded basins can provide useful information for determining indicator thresholds and targets for natural or almost natural ecosystems, as well as an opportunity to ensure that these basins have adequate protections in place to maintain their good ecosystem status.
4. Desktop study results should identify key issues that may need further assessment and that can lead to an initial determination of management options for addressing these issues.



Salar de Uyuni, Uyuni, Bolivia
Photo credit: Indranil Roy/ Unsplash

7 Snapshots from 17 biological assessment programmes from across the United States

National legislation can provide a strong foundation and framework for developing ecosystem management programmes and plans. For example, legislation can lay down the overall goal for ecosystem management, set the general structure to regulate pollutant discharges to waterways and specify a need for stakeholder engagement and inter-agency coordination.

Biological assessments, in conjunction with other data (chemical, toxicity, physical, landscape), provide water quality management programmes with data and information necessary to document the effectiveness of management actions that protect and restore water quality and clearly communicate that information to the public.

This case study provides brief examples of most steps in the Framework for Freshwater Ecosystem Management, from biological assessment programmes implemented throughout the United States. The original report on these case studies, "A Primer on Using Biological Assessments to Support Water Quality Management"[6] should be consulted to gain a complete overview of the examples included in this section.

Case Study Summary

Illustrated Steps: Brief examples of all phases and steps – the original case studies report should be referred to as required
Scale:
Region: North America

7.1 Background

In the United States, the sustainable management of freshwater ecosystems is based on the objectives of the Clean Water Act 1972 (CWA), namely to restore and maintain the chemical, physical and biological integrity of the country's waters.

The CWA provides the basic structure for regulating discharges of pollutants into national waters and regulates quality standards for surface waters. It requires public participation in developing, revising and enforcing any regulation, standard, effluent limitation, plan or programme. It also states that procedures to implement the CWA are to encourage inter-agency decision procedures and drastically reduce paperwork, to the maximum extent possible.

6 Environmental Protection Authority (EPA). 2011. A Primer on Using Biological Assessments to Support Water Quality Management. October 2011. Available at: https://www.epa.gov/nscep

Under the CWA, the United States Environmental Protection Agency (EPA) has implemented pollution control programmes, such as setting wastewater standards for industry. A set of nationally recommended water quality criteria for protecting aquatic life and human health in surface waters has been summarized for approximately 150 pollutants. Such standards provide guidelines for states and tribes to establish methods to measure water quality criteria (EPA, 2016a). States are required to compile lists of water bodies that do not fully support beneficial uses and are responsible for calculating a Total Maximum Daily Load (TMDL), which identifies the maximum amount of a pollutant that a body of water can receive while still meeting water quality standards.[7]

The EPA provides technical support for states on the development of biological criteria and biological assessment programmes. In 1985, a document was published providing guidelines for deriving numerical criteria for the protection of aquatic organisms.[8] In the early 1990s, documents were published providing guidance on developing and implementing narrative biological criteria as part of a new priority to develop biological water quality criteria.[9] Approaches for developing criteria have also been developed in more recent years[10] and a comprehensive Primer on Using Biological Assessments to Support Water Quality Management was published in 2011,[11] detailing three tools:

- Biological Assessment Program Review;
- Biological Condition Gradient (BCG);
- Stressor Identification (SI) and Causal Analysis/Diagnosis Decision System (CADDIS).

In 2013, a comprehensive Biological Assessment Program Review was published.[12]

These examples provide a comparative review of 17 selected case studies that addresses a particular aspect related to legislation on water quality, such as biological assessment programmes in various states. In 2011, the EPA released “A Primer on Using Biological Assessments to Support Water Quality Management”.[13] This document serves as guidance on the role of biological assessments in a variety of water quality management programme applications, including reporting on aquatic biota conditions, establishing biological criteria and assessing the effectiveness of pollutant source controls. The document also discusses how to successfully apply technical tools and approaches for developing strong biological assessment programmes.

7.2 Steps from the Framework for Freshwater Ecosystem Management

This case study provides snapshots of examples of most Framework steps, based on a review of 17 case studies originally published in “A Primer on Using Biological Assessments to Support Water Quality Management”. Further information on these case studies, as well as additional advice on and tools for incorporating biological assessments into water quality management, can be found in the original publication.

7 EPA, 2015c.
8 EPA, 1985.
9 EPA, 1990 and 1992.
10 EPA 2011b; Cormier and Suter, 2013; Cormier et al., 2013.
11 EPA, 2011b.
12 EPA, 2013b.
13 http://water.epa.gov/scitech/swguidance/standards/criteria/aqlife/biocriteria/upload/primer_update.pdf

Initiation Phase

- Set Vision and Objectives

In Virginia, a state department and a university are collaborating to develop and implement a state-wide Healthy Waters programme, which aims to identify and protect healthy streams. One of the programme objectives is effective stakeholder engagement, particularly in developing water quality goals and implementing strategies to achieve them. This has included developing and using a free online, interactive database that evaluates the ecological integrity of Virginia's streams. This is an example of extensive community engagement in establishing and achieving water quality guidelines and targets for freshwater ecosystems.

The Virginia approach integrates elements of the steps to set a vision and objectives, carry out desktop screening and implement a response, establishing and achieving water quality guidelines and targets for freshwater ecosystems.

Identification Phase

- Identify Ecosystems; Classify by type

The state of Arizona undertook a quantitative classification of stream biotic communities within a local biogeographical context and subsequently established condition criteria, summarized in lookup tables, for each of the stream categories.

This example indicates that water quality guidelines for freshwater ecosystems should be established within a natural biogeographical context.

- Set Basin Context

The state of Maryland has developed geographic information system (GIS) shapefiles that are available to local planners to assist them in locating high-quality waters within their jurisdiction.

This case study shows the importance of collating and providing existing spatial information to stakeholders, as it enables them to establish a basin context that can help to achieve water quality targets.

- Desktop Screening and Assessment

The Pennsylvania Department of Environmental Protection calibrated a quantitative BCG using pre-existing data to categorize streams according to their stress level.

This example demonstrates that an initial screening of conditions and stressors throughout a management area can help set water quality criteria and guidelines.

Assessment Phase

- Set Ecological Status Classes; Set Thresholds and Targets

The state of Maine has established detailed guidelines for multiple biological, habitat and water quality indicators to achieve aquatic life protection goals set out in the CWA.

A BCG is used to set criteria that must be achieved or exceeded for four classes of streams.

The assessed condition of any water body must not fall below its current class, with the broader goal being to improve the condition of a water body to a higher class level.

This case study shows that guidelines for measurable indicators can then successfully developed and used to prevent and improve the degradation of water quality.

- Select Indicators

The Oregon Department of Environmental Quality and the Oregon Department of Fish and Wildlife have used macroinvertebrate monitoring data to assess the condition of streams throughout the Oregon Coast Coho Evolutionary Significant Unit (ESU).

- Monitor

Monitoring was conducted in Oregon in four ESU areas. The monitoring data were used to determine the biological condition of streams based on comparisons with expected results based on a multivariate predictive model.

- Evaluate and Report

In Oregon, the monitoring data has been used to develop a stressor-response model and guide policy and management decisions. This is an example of how monitoring data can be used for various purposes within a water quality guidelines framework.

The Iowa Department of Natural Resources determined that a stretch of the North Fork Maquoketa River was not meeting its aquatic life targets. Monitoring data were used to evaluate the river's biological condition over several years, identifying significant stressors in the watershed. The reports were used to communicate the findings to stakeholders and the project specifically encouraged residents and businesses in the watershed to take action to improve water quality.

The Iowa study acts as an example of how reporting and communicating monitoring and assessment data to stakeholders is important in implementing and achieving water quality guidelines and targets for freshwater ecosystems.

Response Phase

- Design response

The state of Ohio uses the CWA within their governance framework to regulate activities removing dredged and fill materials from waterways. Dredged and fill material activities must not violate Ohio water quality standards and an index measuring habitat quality is used to set guidelines, assess impacts and identify required management actions.

Pls check the grammer as per Manglevis comment. Pls indicate the change.

This case study is an example of how legal frameworks, stakeholder responsibilities and future management actions can be incorporated into a governance framework to set and achieve water quality guidelines and targets.

- Implement Response

The Connecticut Department of Environmental Protection implemented TMDL criteria for Eagleville Brook.

Having identified impervious surface cover as a significant stressor on aquatic life, the programme investigated the most cost-effective management actions to reduce this.

This case study demonstrates the importance of considering the cost-effectiveness of management actions, given the funding issues that watershed managers often face.

- Review

The EPA Biological Assessment Program Review for 2013[14] provides a process for states and tribes to evaluate the technical rigour and capabilities of a biological assessment programme. Using the programme review process described in the document, states and tribes can identify the technical capabilities and limitations of their biological assessment programmes in order to develop a plan aimed at strengthening their programme.

14 EPA. 2013. Biological Assessment Program Review: Assessing Level of Technical Rigor to Support Water Quality Management.

Lessons Learned and Replicability: United States

- Evidently, reporting and communicating findings to stakeholders is important. Residents and businesses in the watersheds should be encouraged to take action to improve water quality.
- Research and development of guidelines and assessment methods by states and the EPA allowed ecosystem conditions to be determined, targets set and indicators identified within an adaptive management framework.
- The ultimate goal is a water quality management programme that integrates biological, physical and chemical data in order to create a more complete picture of resource conditions that support the effective implementation of management programmes.

Notes

Freshwater ecosystems such as wetlands, rivers, and lakes are indispensable for life on our planet and vital for directly ensuring a range of benefits and services fundamental to the environment, society and the economy.

However, they face serious pressures which affect their ability to provide those services, such as pollution, over-extraction and encroachment from urban and agricultural development.

One of the main challenges in managing freshwater ecosystems lies in finding the balance between short-term socioeconomic development objectives and the need to protect and restore freshwater ecosystems to support more sustainable, long-term socioeconomic wellbeing.

UN Environment has developed a publication series entitled 'A Framework for Freshwater Ecosystem Management'. The main aim of the series is to support countries to sustainably manage freshwater ecosystems. In doing so, it supports national and international goals related to freshwater ecosystems, such as certain Aichi Biodiversity Targets and Sustainable Development Goal (SDG) targets. The series currently consists of four volumes:

- *Volume 1: Overview and guide for country implementation*
- *Volume 2: Technical guide for classification and target-setting*
- *Volume 3: Case studies*
- *Volume 4: Scientific background for regional consultations on developing water quality guidelines for ecosystems*

This volume, 'Case studies, illustrates various case studies from around the world, detailing how steps from the Framework for Freshwater Ecosystem Management have been incorporated in freshwater ecosystem initiatives. It is intended to be a 'living document' that may be updated with new case studies.

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